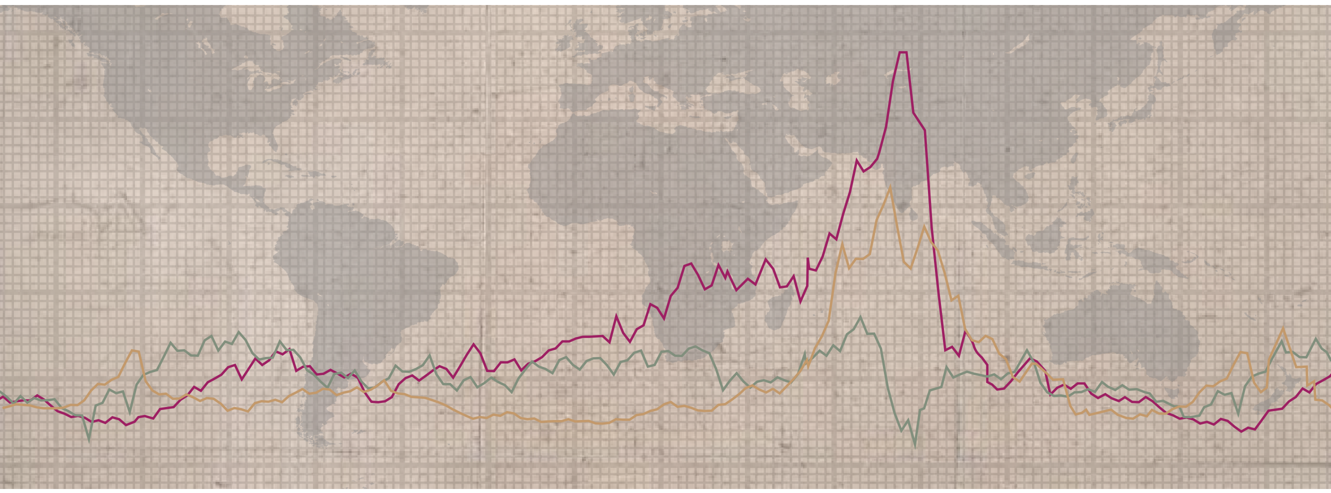
INFLATION IN AN ERA OF RELATIVE PRICE SHOCKS



RESERVE BANK
OF AUSTRALIA

THE AUSTRALIAN NATIONAL UNIVERSITY

CENTRE FOR APPLIED
MACROECONOMIC ANALYSIS

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INFLATION IN AN ERA OF RELATIVE PRICE SHOCKS

Editors:

Renée Fry
Callum Jones
Christopher Kent

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Introduction

Renée Fry, Callum Jones and Christopher Kent

Movements in commodity prices can have large effects on output and inflation. From both an academic and policy perspective, changes in commodity prices relative to the prices of services and manufactured goods pose a number of important questions. First, what are the fundamental processes or shocks that drive these changes and how persistent are they likely to be? Second, through what transmission mechanism do these shocks affect output and inflation and how does economic structure and the policy environment affect the transmission? And third, how should policy-makers respond to movements in relative prices?

The relevance of these issues has increased over the past decade, which has seen a large increase in the level of commodity prices. According to a broad-based measure constructed by the International Monetary Fund, commodity prices more than tripled between 2000 and mid 2008, with the increases widespread (Figure 1). They fell with the global economic downturn but have since rebounded substantially.

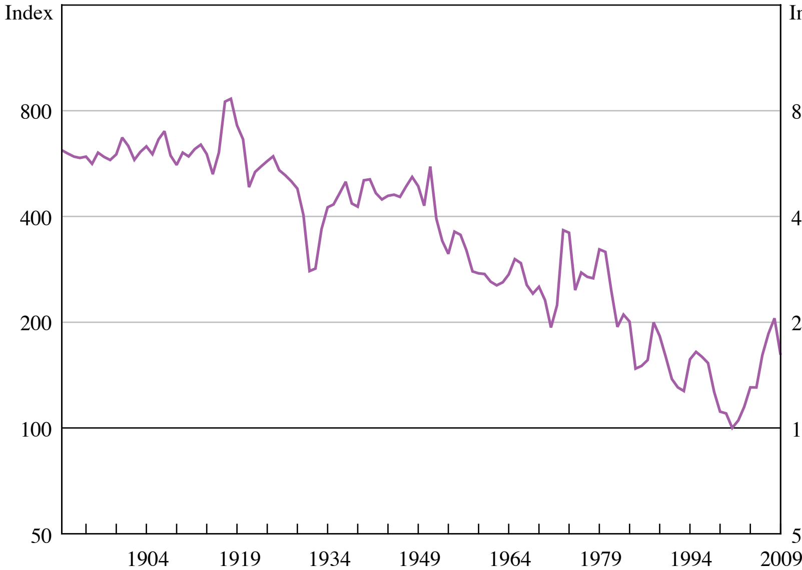
This general experience stands in contrast to the decline in commodity prices relative to the prices of other goods and services over much of the 20th century (Figure 2). Notably, the strength in commodity prices over the past decade has

Figure 1: Nominal Commodity Prices

SDRs, 2001 = 100

Sources: IMF; RBA

Figure 2: Real Commodity Prices
2001 = 100, log scale



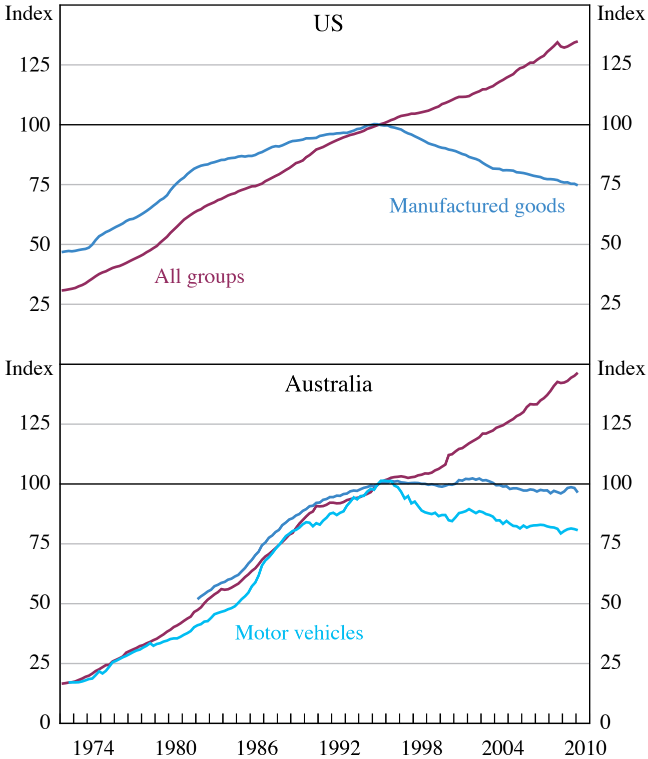
Notes: From 1983, the series is *The Economist*'s US$ 'All items' commodity price index, deflated by the US GDP deflator. Earlier observations have been spliced to this using *The Economist*'s US$ 'Industrial' commodity price index (also deflated by the US GDP deflator) from Cashin and McDermott (2002).

Sources: Cashin and McDermott (2002); Federal Reserve Bank of St. Louis; Thomson Reuters; authors' calculations

coincided with a decline in the nominal price of manufactured goods (Figure 3). This pronounced weakness in manufactured goods prices largely reflects the integration of low-cost developing economies into the global trading system. Of course, the rapid industrialisation of large developing economies has helped to drive up the demand for commodities, thereby linking these trends in commodity and manufactured goods prices.

This Conference – which was jointly organised by the Reserve Bank of Australia and the Centre for Applied Macroeconomic Analysis (CAMA) at the Australian National University – was designed to explore these issues. The Conference was preceded by a workshop in Münster, Germany – hosted by the local university Westfälische Wilhelms-Universität as well as the Canadian-based Viessmann European Research Centre of Wilfrid Laurier University – which provided an opportunity for the authors to present early drafts of their work. What follows is a brief summary of the proceedings of the Conference in Sydney.

Figure 3: Consumer Prices
1995 = 100



Notes: US consumer prices are given by Bureau of Economic Analysis (BEA) consumption deflators; the series for 'all groups' refers to the total personal consumption deflator, and that for 'manufactured goods' refers to the durable goods deflator. For Australian consumer prices, 'all groups' and 'motor vehicles' are as defined by the Australian Bureau of Statistics (ABS), while the series for 'manufactured goods' prices is constructed by the RBA.

Sources: ABS; BEA; RBA

Causes and Nature of Relative Price Shocks

A number of Conference papers and discussions examined the determinants of commodity prices and the causes and nature of shocks to commodity prices.

The Conference opened with a paper by Andrew Rose co-authored with Jeffrey Frankel looking at the macroeconomic and microeconomic determinants of commodity prices. Frankel and Rose discuss a range of possible explanations for the rise in commodity prices, focusing on the period 2003 to 2008. In particular, they explore the role of three factors that may have contributed to the rising demand for commodities. These are: first, the strong (actual and anticipated) economic growth of emerging China and India; second, the possibility of speculative factors fuelled by 'bandwagon expectations' (where forecasts of future commodity prices follow current trends); and third, easy monetary policy. In contrast, on the supply side, Frankel and Rose suggest that accommodative monetary policy in much of the world may have actually depressed the supply of commodities because lower real interest rates reduce the returns from investing the proceeds of commodity sales.

Their paper finds little support for the hypothesis that easy monetary policy contributed to higher real commodity prices, after account is taken of the effect of economic activity and inflation. Rather, they argue that there is evidence that commodity prices were affected by 'bandwagon expectations', consistent with the idea that speculative dynamics accounted for a significant share of the rise in commodity prices. This view was supported by Michael Dooley in his wrap-up discussion, in which he suggested that changes to the regulatory structure of commodity markets had facilitated speculation, driving commodity demand and prices. Further, he argued that greater speculative activity in commodity markets is likely to endure, implying less persistent and more volatile commodity prices. In discussions, parallels were drawn with the move to more flexible exchange rates following the breakdown of the Bretton Woods regime in the mid 1970s.

Frankel and Rose's conclusion that real economic activity has not had a significant influence on commodity prices was surprising to a number of participants, and stood in contrast to the assumptions and conclusions of other papers presented at the Conference. For example, the paper by Ine Van Robays, co-authored with Christiane Baumeister and Gert Peersman, assumes that oil demand shocks driven by economic activity raise the price of oil. Also, the paper by Lutz Kilian focuses on the potential for easy monetary policy to fuel the demand for commodities.

Kilian reviews the episode of stagflation during the 1970s and presents evidence that the stance of monetary policy led to a significant increase in global liquidity, demand for commodities and inflation. In particular, Kilian suggests that the relaxation of the constraints on monetary policy in the 1970s following the collapse of the Bretton Woods fixed exchange rate regime, and a period of experimentation with different policy regimes, drove this expansion in liquidity. This view contrasts with the more popular notion that the oil price rises of the 1970s were driven largely by supply shocks. Kilian argues that the recent boom in commodity prices was due to an unanticipated increase in global demand.

This point is picked up in the paper by Adam Cagliarini and Warwick McKibbin, who discuss the positive effect that the growth of developing economies has had on commodity prices. Their paper also highlights the other side of the 'relative-price-shock-coin', namely the fall in prices of manufactured goods globally. They examine these relative price dynamics using a large structural model of the world economy overlayed with three shocks: a large rise in manufacturing productivity growth relative to that of non-manufactures in developing economies; a fall in the global risk premia; and an easing of the stance of US monetary policy. With plausible calibrations for these three shocks, the model is able to replicate the observed direction of the shifts in relative prices – the decline in the prices of manufactured goods and the rise in commodity prices – but not to the extent seen over recent years. In particular, these three shocks do not explain the full extent of the rise in the relative prices of energy, mining and agricultural goods.

The Transmission of Relative Price Shocks through the Economy

An important issue explored at the Conference was the effect of large relative price shocks on different economies. Of particular interest are how the nature of the shock influences the way it is transmitted, whether or not there are important differences across countries based on differences in economic structure, and how the policy framework influences the transmission.

Van Robays and her co-authors examine the transmission of oil shocks in a sample of eight industrialised economies. Using a structural vector autoregression model they show how three types of shocks – oil demand shocks driven by global economic activity, demand shocks specific to the oil market, and oil supply shocks – have quite different economic effects and imply different monetary policy responses. Oil demand shocks driven by stronger economic activity initially increase real GDP and permanently increase consumer prices, with nominal interest rates generally rising, while positive oil-specific demand shocks generally lead to a transitory decline in real GDP, a mixed response of consumer prices and mostly falling nominal interest rates. For adverse oil supply shocks, economies that are net importers of energy experience a permanent fall in output, a rise in consumer prices and an initial increase in nominal interest rates. For net energy exporters the consequences of an adverse oil supply shock on GDP is mixed, while the effect on inflation is either negligible or negative, which appears to reflect the appreciation of the exchange rate; across these countries, nominal interest rates fall. In addition, Van Robays and her co-authors find that second-round inflationary effects coming from wage increases are important for some economies in Europe – the euro area and Switzerland – but not for other countries, including Japan and the United States.

Cagliarini and McKibbin's results suggest that the overall effect of rapid productivity growth in China on inflation globally has been ambiguous. In contrast, Robert Anderton and his co-authors Alessandro Galesi, Marco Lombardi and Filippo di Mauro find that competitive pressures from large developing economies have helped to exert downward pressure on inflation in the OECD over time – for example, via lower prices for manufactured imports – offset somewhat by higher commodity prices, particularly in oil markets. This issue is also touched on in the paper by Klaus Schmidt-Hebbel and his co-author César Calderón, who focus on the 'non-monetary' determinants of inflation across a large set of countries. They include a potential role for globalisation in explaining a general trend towards lower inflation (via disinflation 'imported' from new low-cost producers such as China) but find little evidence for such an effect.

A theme picked up by several participants was that, over time, policy frameworks have generally been better able to moderate the effect of relative price shocks on overall inflation. Kilian in particular devotes much attention to the anchoring of inflation expectations. Comparing the oil price shocks and stagflation of the 1970s and the oil price shocks of the 2003–2008 era, he attributes the absence of rising inflation over the past decade to be a result of the adoption of monetary policy regimes focusing on price stability. In a similar vein, Schmidt-Hebbel and

Calderón find that across a large sample of countries, inflation-targeting regimes are associated with lower inflation after controlling for macroeconomic and other determinants of inflation. They also find that countries with fixed exchanges rates have lower inflation, although this effect is more important for developing countries. Schmidt-Hebbel and Calderón suggest that these findings support the idea that a mechanism that imposes some discipline improves policy credibility and inflation results. Looking at differences over time, Anderton and his co-authors find that inflation expectations have become better anchored and that the effect of the output gap on inflation appears to have declined. Finally, in his wrap-up discussion, John Williams pointed out that inflation expectations have remained well anchored during the recent global downturn, notwithstanding unconventional quantitative easing policies of a number of central banks in major economies intended to stabilise financial markets and stimulate economic growth.

The Response of Policy

The Conference also considered how policies – both monetary and fiscal – respond to shocks that affect relative prices. Issues of measuring inflation and inflation expectations, as well as communication of central bank decisions to the public in the context of relative price shocks, were also considered.

Three papers have some focus on fiscal policy. First, Graciela Kaminsky sets out the arguments in favour of running fiscal policies such that savings are accumulated during terms of trade booms to deal more effectively with times when the terms of trade are weak. She then examines the relationship between fiscal policy and terms of trade cycles in a panel dataset of 74 developed and developing economies. She shows that the stance of fiscal policy differs according to the level of development across economies and the phase of the terms of trade cycle. Fiscal policy in the high-income (OECD) countries is countercyclical relative to GDP, but acyclical relative to the terms of trade. For upper-middle income countries that produce commodities, fiscal policy is typically countercyclical in the presence of terms of trade shocks, but less so during booms in the terms of trade. Second, the paper by Schmidt-Hebbel and Calderón found that fiscal restraint tends to reduce inflation for both developed and developing economies, particularly in the short run. Third, Cagliarini and McKibbin also discuss how fiscal authorities might respond to a commodity boom. They suggest that there may be cases where it is appropriate for countries to set up sovereign wealth funds to invest windfall tax revenues in economies that are not benefiting from the same commodity boom. This would help to reduce the amplitude of the business cycle and diversify risk.

The paper by Cagliarini and McKibbin also provides some insight into how monetary policy might respond to relative price shocks. They recognise that monetary policy, which is typically concerned with the overall rate of inflation, is also able to affect relative prices in the short run because a temporary change in real interest rates has differential effects across sectors. This implies that there might be a role for monetary policy to respond directly to relative price shocks to facilitate a more rapid adjustment to a new (and persistent) relative price equilibrium. They note, however, that the optimal response to persistent relative price shocks may be to keep policy unchanged so long as inflation expectations remain well anchored.

As a number of participants noted, in considering the response of policy it is important to have an accurate understanding of inflationary pressures abstracting from the near-term volatility associated with relative price shocks. To this end, Shaun Vahey in his paper co-authored with Francesco Ravazzolo constructs a measure of underlying inflation based on an overall probability distribution of inflation outcomes, by combining forecasts of inflation for different groups of goods and services. Vahey's paper provoked some debate about the usefulness of this type of underlying measure of inflation. Some participants saw such a measure as a useful tool for internal discussion among policy-makers, while others thought it could be a device for the public communication of policy, in part because it downweights some components of the basket of goods and services, but does not exclude them like some other measures of underlying inflation. The paper by Pierre Siklos also touches on this issue by looking at forecasts of inflation and the role that relative price changes have had in generating variation across different forecasters. He finds that relative price changes, particularly in commodity and asset prices, can move inflation forecasts relative to a benchmark forecast; this phenomenon has been particularly true over the past decade.

Conclusions

The large increase in commodity prices since the turn of the century and the steady decline in the prices of many manufactured goods have raised questions as to the causes and consequences of relative price movements, as well as how policy-makers might respond to these sorts of shocks.

While the Conference highlighted the role that demand has played in explaining commodity price movements, explanations differed about the cause of the rise in demand over the past decade, with some papers attributing it to strong global economic activity and others to speculative demand for commodities. A related issue is whether the much longer-term decline in real commodity prices – driven in large part by rapid productivity growth in resource production and mining exploration and extraction – will reassert itself in the coming decades.

The effects of relative price movements on economies were covered in some depth, with papers demonstrating that the consequences depend on the nature of the shock driving commodity prices and on the underlying structure of the economy, most notably whether countries are net resource importers or exporters.

On questions related to monetary policy, papers emphasise the importance of well-anchored inflation expectations in explaining the lack of sustained general price inflation over the course of the recent commodity price boom. However, there was some discussion among Conference participants about whether certain core-based measures of inflation that tended to exclude the effect of rapidly rising commodity prices but include the slower moving prices of many manufactured goods may have understated latent inflation pressures. Also, it may be that the global recession interceded to cut off what could have been emerging inflationary pressures in many parts of the world in 2008. The strength of commodity prices of late – even in the face of weak growth prospects in much of the developed world – highlights the value of further work to understand these issues better.

Reference

Cashin P and CJ McDermott (2002), 'The Long-Run Behavior of Commodity Prices: Small Trends and Big Variability', *IMF Staff Papers*, 49(2), pp 175–199.

Determinants of Agricultural and Mineral Commodity Prices

Jeffrey A Frankel and Andrew K Rose[1]

Abstract

Prices of most agricultural and mineral commodities rose strongly in the past decade, peaking sharply in 2008. Popular explanations included strong global growth (especially from China and India), easy monetary policy (as reflected in low real interest rates or expected inflation), a speculative bubble (resulting from bandwagon expectations) and risk (possibly resulting from geopolitical uncertainties). Motivated in part by this episode, this paper presents a theory that allows a role for macroeconomic determinants of real commodity prices, along the lines of the 'overshooting' model: the resulting model includes global GDP and the real interest rate as macroeconomic factors. Our model also includes microeconomic determinants: inventory levels, measures of uncertainty, and the spot-futures spread. We estimate the equation in a variety of different ways, for 11 individual commodities. Although two macroeconomic fundamentals – global output and inflation – both have positive effects on real commodity prices, the fundamentals that seem to have the most consistent and strongest effects are microeconomic variables: inventories, volatility and the spot-futures spread. There is also evidence of a bandwagon effect.

1. Macroeconomic Motivation

Questions related to the determination of prices for oil and other mineral and agricultural commodities have always fallen predominantly in the province of microeconomics. Nevertheless, there are times when so many commodity prices are moving so far in the same direction that it becomes difficult to ignore the influence of macroeconomic phenomena. The decade of the 1970s was one such time; recent history provides another. A rise in the price of oil might be explained by 'peak oil' fears, a risk premium related to instability in the Persian Gulf, or political

1. Jeffrey Frankel is Harpel Professor, Kennedy School of Government, Harvard University and Director of the NBER's International Finance and Macroeconomics Program. Andrew Rose is Rocca Professor, Economic Analysis and Policy, Haas School of Business, UC Berkeley, CEPR Research Fellow and NBER Research Associate. This is a substantial revision of a paper presented at a workshop on 16–17 June 2009 at Westfälishche Wilhelms University Münster, Münster, Germany. For research assistance we thank: Ellis Connolly, Marc Hinterschweiger, Imran Kahn and Frederico Meinberg. We thank Harry Bloch, Mike Dooley, Mardi Dungey, Renée Fry, Don Harding, Christopher Kent, Lutz Kilian, Mariano Kulish, Marco Lombardi, Philip Lowe, Warwick McKibbin, Simon Price, Tony Richards, Larry Schembri, Klaus Schmidt-Hebbel, Susan Thorp, Shaun Vahey, Ine Van Robays and RBA conference participants for suggestions and comments. The datasets, key output and a current version of this paper are available on Rose's website (http://faculty.haas.berkeley.edu/arose/).

developments in Russia, Nigeria or Venezuela. Spikes in certain agricultural prices might be explained by drought in Australia, shortages in China, or ethanol subsidies in the United States. But it cannot be a coincidence that almost all commodity prices rose together during much of the past decade, and peaked so abruptly and jointly in mid 2008. Indeed, from 2003–2008, three theories (at least) competed to explain the widespread ascent of commodity prices.

First, and perhaps most standard, was the *global demand growth explanation*. This argument stems from the unusually widespread growth in economic activity – particularly including the arrival of China, India and other entrants to the list of important economies, together with the prospects of continued high growth in those countries in the future. This growth has raised the demand for, and hence the price of, commodities. While reasonable, the size of this effect is uncertain.

The second explanation, also highly popular, at least outside of academia, was *destabilising speculation*. Many commodities are highly storable; a large number are actively traded on futures markets. We can define speculation as the purchases of the commodities – whether in physical form or via contracts traded on an exchange – in anticipation of financial gain at the time of resale. There is no question that speculation, so defined, is a major force in the market. However, the second explanation is more specific: that speculation was a major force that pushed commodity prices *up* during 2003–2008. In the absence of a fundamental reason to expect higher prices, this would be an instance of destabilising speculation or of a speculative bubble. But the role of speculators need not be pernicious; perhaps speculation was stabilising during this period. If speculators were short on average (in anticipation of a future reversion to more normal levels), they would have kept prices lower than they otherwise would have been.

Much evidence has been brought to bear on this argument. To check if speculators contributed to the price rises, one can examine whether futures prices lay above or below spot prices, and whether their net open positions were positive or negative.[2] A particularly convincing point against the destabilising speculation hypothesis is that commodities *without any futures markets* have experienced approximately as much volatility as commodities with active derivative markets. We also note that efforts to ban speculative futures markets have usually failed to reduce volatility in the past. Another relevant issue is the behaviour of inventories, which seems to undermine further the hypothesis that speculators contributed to the 2003–2008 run-up in prices. The premise is that inventories were not historically high, and in some cases were historically low. Thus speculators could not plausibly have been betting on price increases and could not, therefore, have added to the current demand.[3] One can also ask whether speculators seem to exhibit destabilising 'bandwagon expectations'. That is, do speculators seem to act on the basis of forecasts of future commodity

2. Expectations of future oil prices on the part of typical speculators, if anything, initially lagged behind contemporaneous spot prices. Furthermore, speculators have often been 'net short' (sellers) of commodities rather than 'long' (buyers). In other words, they may have delayed or moderated the price increases, rather than initiating or adding to them.

3. See Krugman (2008a, 2008b) and Wolf (2008).

prices that extrapolate recent trends? The case for destabilising speculative effects on commodity prices remains an open one.

The third explanation, somewhat less prominent than the first two, is that *easy monetary policy* was at least one of the factors contributing to either the high demand for, or low supply of, commodities. Easy monetary policy is often mediated through low real interest rates.[4] Some have argued that high prices for oil and other commodities in the 1970s were not exogenous, but rather a result of easy monetary policy.[5] Conversely, a substantial increase in real interest rates drove commodity prices down in the early 1980s, especially in the United States. High real interest rates raise the cost of holding inventories; lower demand for inventories then contributes to lower total demand for oil and other commodities. A second effect of higher interest rates is that they undermine the incentive for oil-producing countries to keep crude under the ground. By pumping oil instead of preserving it, OPEC countries could invest the proceeds at interest rates that were higher than the return from leaving it in the ground. Higher rates of pumping increase supply; both lower demand and higher supply contribute to a fall in oil prices. After 2000, the process went into reverse. The Federal Reserve cut real interest rates sharply in 2001–2004, and again in 2008. Each time, it lowered the cost of holding inventories, thereby contributing to an increase in demand and a decline in supply.

Critics of the interest rate theory as an explanation of the boom that peaked in 2008 point out that it implies that inventory levels should have been high, but argue that they were not. This is the same point that has been raised in objection to the destabilising speculation theory. For that matter, it can be applied to most theories. Explanation number one, the global boom theory, is often phrased in terms of expectations of China's future growth path, not just its currently high level of income; but this factor too, if operating in the market place, should in theory work to raise demand for inventories.[6]

How might high demand for commodities be reconciled with low observed inventories? One possibility is that researchers are looking at the wrong inventory data. Standard data inevitably exclude various components of inventories, such as those held by users or those in developing countries. They typically exclude deposits in the ground, uncut forests and crops and livestock in the fields. In other words, what is measured in inventory data is small compared to reserves. The decision by producers to pump oil today or to leave it underground for the future is more important than the decisions of oil companies or downstream users to hold higher or lower inventories. And the lower real interest rates of 2001–2005 and 2008 clearly reduced the incentive for oil producers to pump oil, relative to what it would otherwise have

4. See Frankel (2008a, 2008b), for example. A variant of the argument blaming the 2008 spike on easy monetary policy is that the mediating variable is expected inflation *per se*, rather than the real interest rate (Calvo 2008).

5. For example, Barsky and Kilian (2002, 2004).

6. We are indebted to Larry Summers for this point.

been.[7] We classify low extraction rates as low supply and high inventories as high demand; but either way the result is upward pressure on prices.

In 2008, enthusiasm for explanations number two and three, the speculation and interest rate theories, increased, at the expense of explanation number one, the global boom. Previously, rising demand from the global expansion, especially the boom in China, had seemed the obvious explanation for rising commodity prices. But the sub-prime mortgage crisis hit the United States around August 2007. Virtually every month thereafter, forecasts of growth were downgraded, not just for the United States but for the rest of the world as well, including China.[8] Meanwhile commodity prices, far from declining as one might expect from the global demand hypothesis, climbed at an accelerated rate. For the year following August 2007, at least, the global boom theory was clearly irrelevant. That left explanations number two and three.

In both cases – increased demand arising from either low interest rates or expectations of capital gains – detractors pointed out that the explanations implied that inventory holdings should be high and continued to argue that this was not the case.[9] To repeat a counter-argument, especially in the case of oil, what is measured in inventory data is small compared to reserves under the ground.

This paper presents a theoretical model of the determination of prices for storable commodities that gives full expression to such macroeconomic factors as economic activity and real interest rates. However, we do not ignore other fundamentals relevant for commodity price determination. To the contrary, our model includes a number of microeconomic factors including (but not limited to) inventories. We then estimate the equation using both macroeconomic and commodity-specific microeconomic determinants of commodity prices. To preview the results, most of the hypothesised determinants of real commodity prices receive support, when the data are aggregated across commodities: inventories, uncertainty, speculation, economic growth and expected inflation. The main disappointment is that the real interest rate does not appear to have a significant effect.

2. A Theory of Commodity Price Determination

Most agricultural and mineral products differ from other goods and services in that they are both storable and relatively homogeneous. As a result, they are hybrids of *assets* – where price is determined by supply of and demand for *stocks* – and *goods*, for which the *flows* of supply and demand matter.[10]

7. The King of Saudi Arabia said at this time that his country might as well leave the reserves in the ground for its grandchildren ('Saudi King Says Keeping Some Oil Finds for Future', Reuters, 13 April 2008).
8. For example, IMF (2007, 2008a, 2008b).
9. See among others, Kohn (2008) and Krugman (2008a, 2008b).
10. For example, Frankel (1984) and Calvo (2008).

The elements of an appropriate model have long been known.[11] The monetary aspect of the theory can be reduced to its simplest algebraic essence as a relationship between the real interest rate and the spot price of a commodity relative to its expected long-run equilibrium price. This relationship can be derived from two simple assumptions. The first governs expectations. Let:

$s \equiv$ the natural logarithm of the spot price,

$p \equiv$ the (log of the) economy-wide price index,

$q \equiv s–p$, the (log) real price of the commodity, and

$\overline{q} \equiv$ the long-run (log) equilibrium real price of the commodity.

Market participants who observe the real price of the commodity today lying either above or below its perceived long-run value expect it to regress back to equilibrium in the future over time, at an annual rate that is proportionate to the gap:

$$\mathrm{E}\left[\Delta(s-p)\right] \equiv \mathrm{E}\left[\Delta q\right] = -\theta\left(q-\overline{q}\right) \tag{1}$$

or

$$\mathrm{E}\left(\Delta s\right) = -\theta\left(q-\overline{q}\right) + \mathrm{E}\left(\Delta p\right). \tag{2}$$

Following the classic Dornbusch (1976) overshooting paper, which developed the model for the case of exchange rates, we begin by simply asserting the reasonableness of the form of expectations in these equations. It seems reasonable to expect a tendency for prices to regress back toward long-run equilibrium. But, as in that paper, it can be shown that regressive expectations are also rational expectations, under certain assumptions regarding the stickiness of prices of other goods (manufactures and services) and a certain restriction on the parameter value θ (Frankel 1986).

One alternative that we consider below is that expectations also have an extrapolative component to them. We model this as:

$$\mathrm{E}\left(\Delta s\right) = -\theta\left(q-\overline{q}\right) + \mathrm{E}\left(\Delta p\right) + \delta\left(\Delta s_{-1}\right). \tag{2'}$$

The next equation concerns the decision whether to hold the commodity for another period – leaving it in the ground, on the trees, or in inventory – or to sell it at today's price and use the proceeds to earn interest, an equation familiar from Hotelling's celebrated logic. The expected rate of return to these two alternatives must be the same:

$$\mathrm{E}\left(\Delta s\right) + c = i, \qquad \text{where: } c \equiv cy - sc - rp; \tag{3}$$

$cy \equiv$ convenience yield from holding the stock (for example, the insurance value of having an assured supply of some critical input in the event of a disruption, or in the case of a commodity like gold, the psychic pleasure of holding it);

$sc \equiv$ storage costs (for example, feed lot rates for cattle, silo rents and spoilage rates for grains, rental rates on oil tanks or oil tankers, costs of security to prevent plundering by others, etc);[12]

11. See Frankel (1986, 2008a, 2008b), among others.

12. Fama and French (1987) and Bopp and Lady (1991) emphasise storage costs.

$rp \equiv E(\Delta s) - (f - s) \equiv$ risk premium, where f is the log of the forward/futures rate at the same maturity as the interest rate. The risk premium is positive if being long in commodities is risky; and

$i \equiv$ the nominal interest rate.[13]

There is no reason why the convenience yield, storage costs or the risk premium should be constant over time. If one is interested in the derivatives markets, one often focuses on the forward discount or slope of the futures curve, $f-s$ in log terms (also sometimes called the 'spread' or the 'roll'). For example, the null hypothesis that the forward spread is an unbiased forecast of the future change in the spot price has been tested extensively.[14] This issue does not affect the questions addressed in this paper, however. Here we note only that one need not interpret the finding of bias in the futures rate as a rejection of rational expectations; it could be due to a risk premium. From Equation (3), the spread is given by:

$$f - s = i - cy + sc, \text{ or equivalently } f - s = E(\Delta s) - rp. \tag{4}$$

On average, $f-s$ tends to be negative. This phenomenon, 'normal backwardation', suggests that convenience yield on average outweighs the interest rate and storage costs.[15] To get our main result, we simply combine Equations (2) and (3):

$$-\theta(q - \bar{q}) + E(\Delta p) + c = i \Rightarrow q - \bar{q} = -(1/\theta)(i - E(\Delta p) - c). \tag{5}$$

Equation (5) says that the real price of the commodity, measured relative to its long-run equilibrium, is inversely proportional to the real interest rate (measured relative to the term c, which could be described as the net convenience yield – that is, the convenience yield after accounting for storage costs and any risk premium). When the real interest rate is high, as in the 1980s, money will flow out of commodities. This will continue until the prices of commodities are perceived to lie sufficiently below their future equilibria, generating expectations of future price *increases*, at which point the quasi-arbitrage condition will be met. Conversely, when the real interest rate is low, as in 2001–2005 and 2008–2009, money will flow into commodities. (This is the same phenomenon that also sends money flowing to foreign currencies (the 'carry trade'), emerging markets, and other securities.) This will continue until the prices of commodities (or the other alternative assets) are perceived to lie sufficiently above their future equilibria, generating expectations of future price *decreases*, so as to satisfy the speculative condition.

Under the alternative specification that leaves a possible role for bandwagon effects, we combine Equations (2') and (3) to get:

$$q - \bar{q} = -(1/\theta)(i - E(\Delta p) - c) + (\delta/\theta)(\Delta s_{-1}). \tag{5'}$$

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13. Working (1949) and Breeden (1980) are classic references on the roles of carrying costs and the risk premium, respectively, in commodity markets. Yang, Bessler and Leatham (2001) review the literature.

14. As in the (even more extensive) tests of the analogous unbiasedness propositions in the contexts of forward foreign exchange markets and the term structure of interest rates, the null hypothesis is usually rejected. Appendix A to this paper briefly reviews this literature.

15. For example, Kolb (1992).

As noted, there is no reason for the net convenience yield, c, in Equation (5) to be constant. Substituting from (3) into (5),

$$\begin{aligned} & c \equiv cy - sc - rp \Rightarrow \\ & q - \bar{q} = -(1/\theta)\left[i - \mathrm{E}(\Delta p) - cy + sc + rp\right] \\ & q = \bar{q} - (1/\theta)\left[i - \mathrm{E}(\Delta p)\right] + (1/\theta)cy - (1/\theta)sc - (1/\theta)rp. \end{aligned} \tag{6}$$

Thus, even if we continue to take the long-run equilibrium $\bar{q}$ as given, there are other variables in addition to the real interest rate that determine the real price: the convenience yield; storage costs; and the risk premium. But $\bar{q}$ need not necessarily be constant. Fluctuations in the convenience yield, storage costs, or the risk premium might also contain a permanent component; all such effects would then appear in the equation.

An additional hypothesis of interest is that storable commodities may serve as a hedge against inflation. Under this view, an increase in the expected long-run inflation rate would then raise the demand for commodities, thereby increasing real commodity prices today.[16] Adding the lagged inflation rate as a separate explanatory variable in the equation is thus another possible way of getting at the influence of monetary policy on commodity prices.

One way to isolate monetary effects on commodity prices is to look at jumps in financial markets that occur in immediate response to government announcements that change perceptions of the macroeconomic situation, as did Federal Reserve money supply announcements in the early 1980s. The experiment is interesting because news regarding disruptions to the supply of commodities and so forth is unlikely to have come out during the short time intervals in question. Frankel and Hardouvelis (1985) used Federal Reserve money supply announcements to test the monetary implications of this general theory of commodity price determination. Announcements that were interpreted as signalling tighter monetary policy indeed induced statistically significant decreases in commodity prices, and vice versa. As an alternative to the event study approach, in this paper we focus on estimating an equation for commodity price determination.

In translating Equation (6) into empirically usable form, there are several measurable determinants of the real commodity price for which we need to account. We discuss these in turn.

Inventories. Storage costs rise with the extent to which inventory holdings strain existing storage capacity: $sc = \Phi$ (*INVENTORIES*). If the level of inventories is observed to be at the high end historically, then storage costs must be high (absent any large recent increase in storage capacity), which has a negative effect on commodity prices.[17] Substituting into Equation (6),

16. This is the view of Calvo (2008).

17. Ye, Zyren and Shore (2002, 2005, 2006) emphasise the role of inventories in forecasting oil prices. Notice that, once we condition on the real interest rate (and convenience yield), inventories have a *negative* effect on commodity prices, rather than the positive relationship that has appeared in the arguments of Kohn (2008), Krugman (2008a, 2008b) and Wolf (2008).

$$q = \bar{q} - (1/\theta)\left[i - \mathrm{E}(\Delta p)\right] + (1/\theta)cy - (1/\theta)\Phi(INVENTORIES) - (1/\theta)rp. \quad (7)$$

There is no reason to think that the relationship $\Phi(\circ)$ is necessarily linear. We assume linearity in our estimation for simplicity, but allowing for non-linearity is a desirable extension of the analysis. Under the logic that inventories are bounded below by zero and above by some absolutely peak storage capacity, a logistic function might be appropriate.[18]

If one wished to estimate an equation for the determination of inventory holdings, one could use:

$$INVENTORIES = \Phi^{-1}(sc) = \Phi^{-1}\left(cy - i - (s - f)\right). \quad (8)$$

We see that low interest rates should predict not only high commodity prices but also high inventory holdings.

Economic activity (denoted Y) is a determinant of the convenience yield cy, since it drives the transactions demand for inventories. Higher economic activity should have a positive effect on the demand for inventory holdings and thus on prices; we usually proxy this with GDP. Let us designate the relationship $\gamma(Y)$. Again, the assumption of linearity is arbitrary.

Medium-term volatility (denoted σ), another determinant of convenience yield cy, should have a positive effect on the demand for inventories and therefore on prices. It may also be a determinant of the risk premium. Again, we assume linearity for convenience.

Risk (political, financial and economic), in the case of oil for example, is measured by a weighted average of political risk among 12 top oil producers. (In the measures we use, a rise in the index represents a decrease in risk.) The theoretical effect on price is ambiguous. Risk is another determinant of cy (especially to the extent that risk concerns fear of disruption of availability), whereby it should have a *positive* effect on inventory demand and therefore on commodity prices. But it is also a determinant of the risk premium rp, whereby it should have a *negative* effect on commodity prices.

The spot-futures spread. Intuitively the spot-futures spread reflects the speculative return to holding inventories.[19] It is one component of the risk premium, along with expected depreciation. A higher spot-futures spread (normal backwardation), or lower futures-spot spread, signifies a low speculative return and so should have a negative effect on inventory demand and on prices.[20]

18. We are implicitly assuming that the long-run commodity price can be modelled by a constant or trend term.

19. See, for example, the discussion of Figure 1.22 in IMF (2006, pp 57–58).

20. In theory, when estimating Equation (9), if inventories are already in the equation, the spread does not need to be added separately. But any available measure of inventories is likely to be incomplete, which might provide a reason to include the spread separately as a measure of speculative demand.

Substituting these extra effects into Equation (7), we get

$$q = C - (1/\theta)\left[i - \mathrm{E}(\Delta p)\right] + (1/\theta)\gamma(Y) - (1/\theta)\Phi(INVENTORIES) + (1/\theta)\Psi(\sigma) - \delta(s - f). \tag{9}$$

Finally, to allow for the possibility of bandwagon and bubble effects, and a separate effect of inflation on commodity prices, we can use the alternative expectations Equation (5') in place of (5). Equation (9) then becomes:

$$q = C - (1/\theta)\left[i - \mathrm{E}(\Delta p)\right] + (1/\theta)\gamma Y - (\Phi/\theta)(INVENTORIES) + (\Psi/\theta)\sigma - \delta(s - f) + \lambda \mathrm{E}(\Delta p) + (\delta/\theta)(\Delta s_{-1}). \tag{9'}$$

It is this equation – augmented by a hopefully well-behaved residual term – which we wish to investigate.

Each of the variables on the right-hand side of Equation (9) could easily be considered endogenous. This must be considered a limitation of our analysis. In future extensions, we would like to consider estimating three simultaneous equations: one for expectations formation, one for the inventory arbitrage condition and one for commodity price determination. However, we are short of plausibly exogenous variables with which to identify such equations. From the viewpoint of an individual commodity though, aggregate variables such as the real interest rate and GDP can reasonably be considered exogenous.[21]

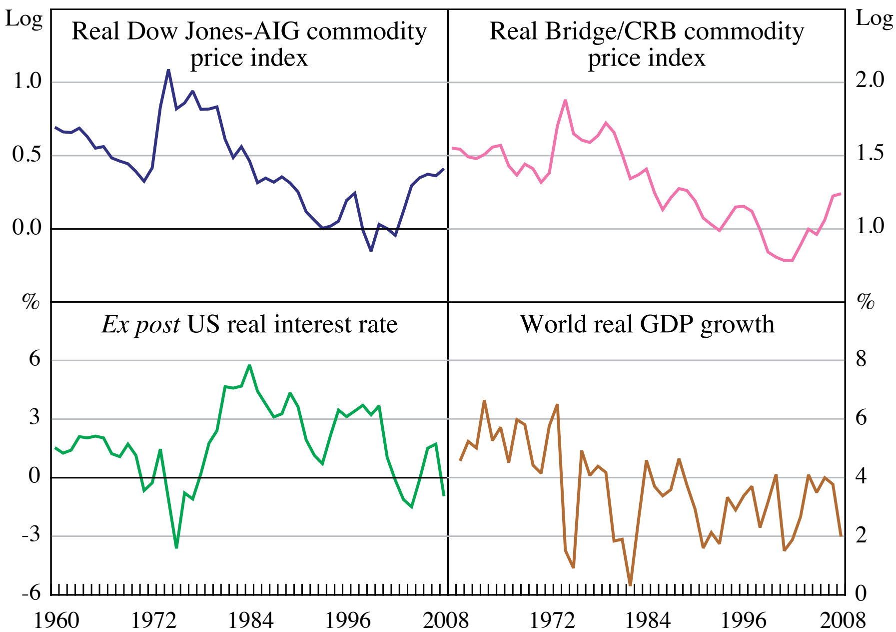
3. The Dataset

We begin with a preliminary examination of the data set, starting with the commodity price series and the macroeconomic determinants of commodity prices.

Figure 1 contains time-series plots for four variables of interest. The top pair portray the natural logarithms of two popular commodity price indices (the Dow Jones-AIG and the Bridge/CRB indices). Both series have been deflated by the US GDP chain price index to make them real. Below them are portrayed: the annualised realised US real interest rate (defined as the 3-month Treasury bill rate at auction less the percentage change in the US chain price index) and the growth rate of world real GDP (taken from the World Bank's *World Development Indicators*). All data are annual and span 1960 through 2008.

21. Also inventories could perhaps be considered predetermined in higher-frequency data, since it takes time to make big additions to, or subtractions from, inventories. But in this paper we use annual data.

Figure 1: Four Macro Variables of Interest



Sources: Executive Office of the President and the Council of Economic Advisers' 2009 *Economic Report of the President* (ERP); Global Financial Data (GFD); World Bank, *World Development Indicators*; authors' calculations

We follow the literature and measure commodity prices in US dollar terms and use US real interest rates. We think this is a reasonable way to proceed. If commodity markets are nationally segmented, by trade barriers and transport costs, then local commodity prices are determined by domestic real interest rates, domestic economic activity and so on. It is reasonable to assume, however, that world commodity markets are more integrated than they are segmented. Indeed, many assume that the law of one price holds closely for commodities.[22] In this case, the nominal price of wheat in Australian dollars is the nominal price in terms of US dollars multiplied by the nominal exchange rate.[23] Equivalently, the real price of wheat in Australia is the real price in the United States times the real exchange rate.[24]

22. For example, Protopapadakis and Stoll (1983, 1986) and Phillips and Pippenger (2005).

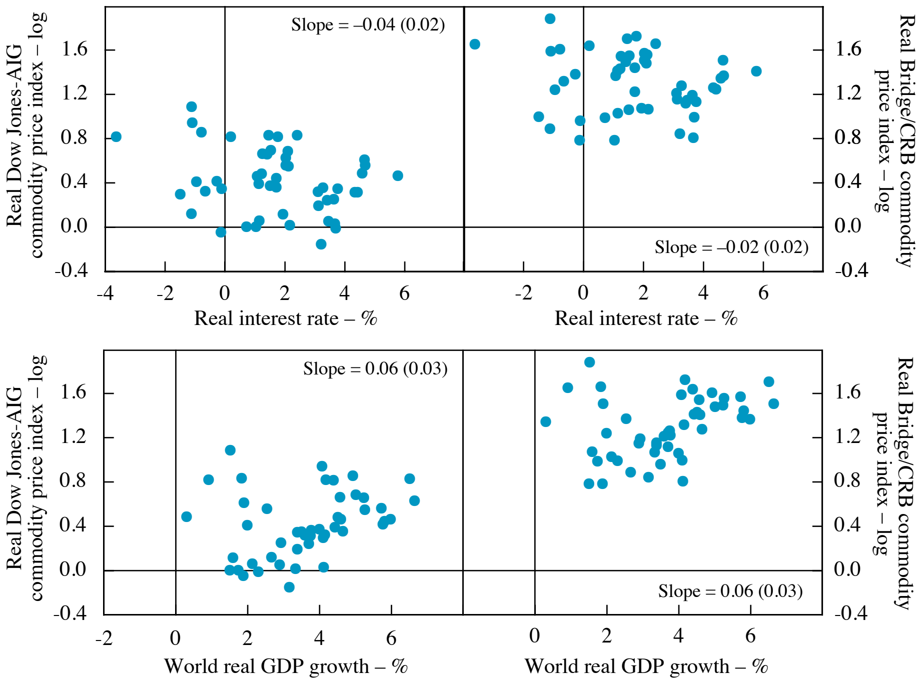
23. For example, Mundell (2002).

24. An application of the Dornbusch (1976) overshooting model can give us the prediction that the real exchange rate is proportionate to the real interest differential. It thus turns out that the real commodity price in local currency can be determined by the US real interest rate (and other determinants of the real US price) together with the differential in real interest rates between the domestic country and the United States. Equations along these lines are estimated in Frankel (2008a, Table 7.3, pp 307–310) for real commodity price indices in eight floating exchange rate countries: Australia, Brazil, Canada, Chile, Mexico, New Zealand, Switzerland and the United Kingdom. In almost every case, both the US real interest rate and the local–US real interest differential are found to have significant negative effects on local real commodity prices, just as hypothesised.

Figure 1 contains few surprises. The sharp run-up in real commodity prices in the early/mid 1970s is clearly visible, as is the most recent rise. Real interest rates were low during both periods of time, and high during the early 1980s, as expected. Global business cycle movements are also clearly present in the data.

Figure 2 provides simple scatter plots of both real commodity price series against the two key macroeconomic phenomena. The bivariate relationships seem weak; real commodity prices are slightly negatively linked to real interest rates and positively to world growth. We interpret this to mean that there is plenty of room for microeconomic determinants of real commodity prices, above and beyond macroeconomic phenomena.[25] Accordingly, we now turn from aggregate commodity price indices and explanatory variables to commodity-specific data.

Figure 2: Bivariate Macro Scatter Plots



Sources: 2009 ERP; GFD; World Bank, *World Development Indicators*; authors' calculations

25. Frankel (2008a) finds stronger evidence, especially for the relationship of commodity price indices and real interest rates.

We have collected data on prices and microeconomic fundamentals for 11 commodities of interest. Seven are agricultural, including a number of crops (corn, cotton, oats, soybeans and wheat), as well as two livestock variables (live cattle and hogs). We also have oil and three non-ferrous metals (copper, platinum and silver). We chose the span, frequency, and choice of commodities so as to maximise data availability. The series are annual, and typically run from some time after the early 1960s through 2008.[26]

Figure 3 provides time-series plots of the natural logarithm of commodity prices, each deflated by the US GDP chain price index. The log of the real price shows the boom of the 1970s in most commodities and the second boom that culminated in 2008 – especially in the minerals: copper, oil and platinum.

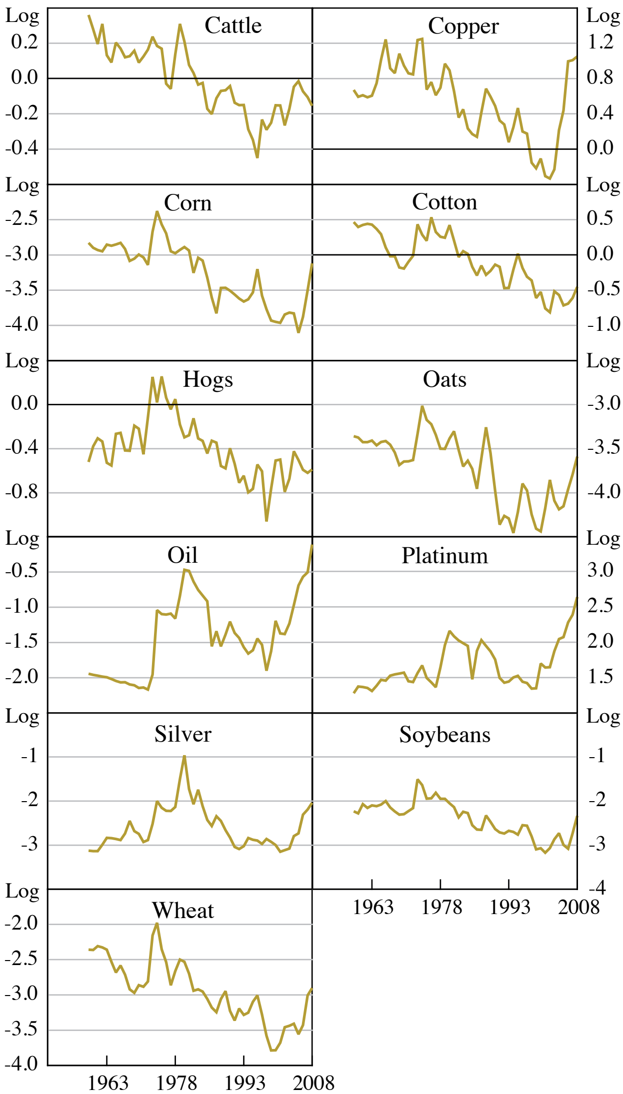
Figures 4 through 7 portray the commodity-specific fundamentals used as explanatory variables when we estimate Equation (9). We measure volatility as the standard deviation of the spot price over the past year.[27] According to our data, inventories for some commodities in 2008 were fairly high historically after all: corn, cotton, hogs, oil and soybeans.[28] The futures-spot spread alternates frequently between normal backwardation and contango. As one can see, the political risk variables are relatively limited in availability; accordingly, we do not include them in our basic equation for estimation, but use them for sensitivity analysis. Imaginative eyeballing can convince one that risks for the top oil-producing countries were high around the time of the 1973 Arab oil embargo and the aftermath of the 2001 attack on the World Trade Center.

26. Further details concerning the series, and the dataset itself, are available on Andrew Rose's website (http://faculty.haas.berkeley.edu/arose/).

27. Alternative measurements are possible; in the future, we hope to use the implicit forward-looking expected volatility that can be extracted from options prices.

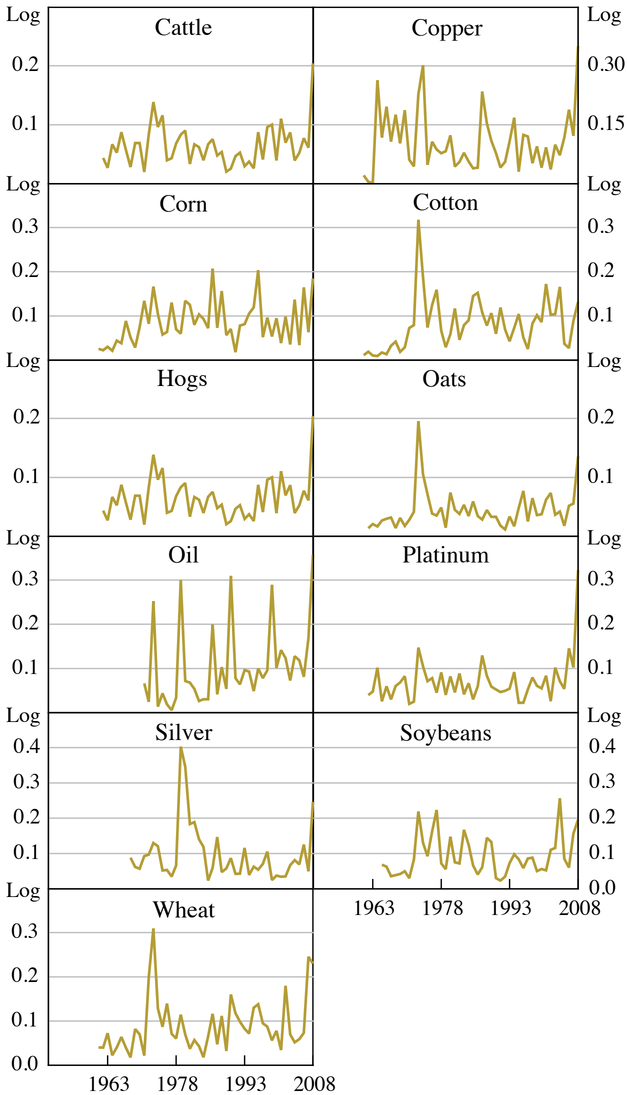
28. We use world inventories insofar as possible, but substitute US inventories when this is missing (specifically, in the cases of copper, live cattle and hogs, oats, platinum and silver).

Figure 3: Real Spot Commodity Prices



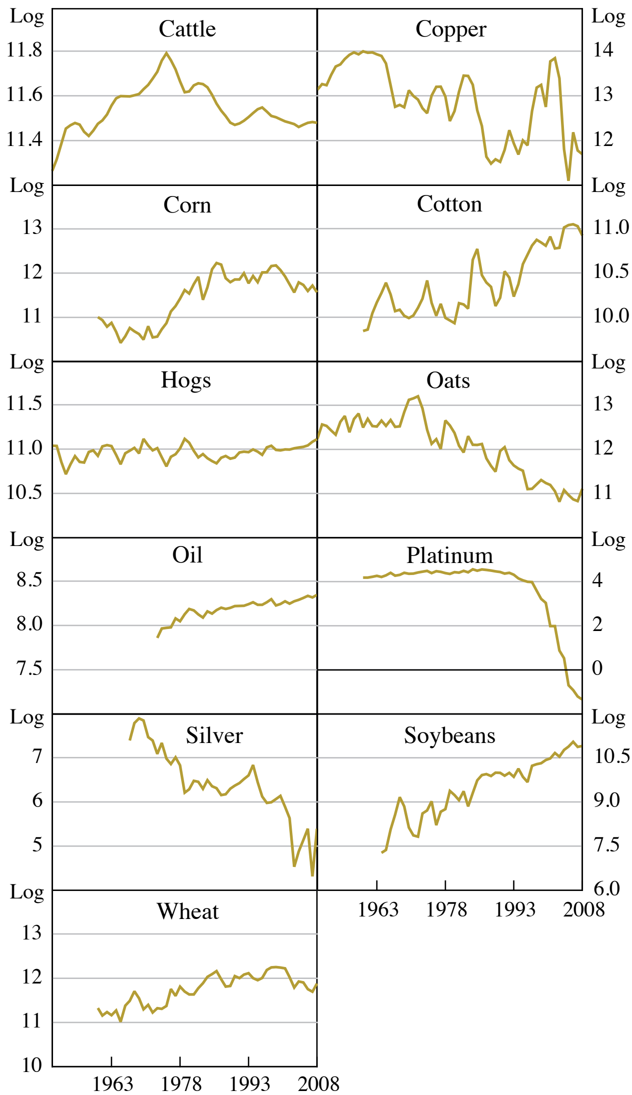
Note: Deflated by the US GDP chain price index
Sources: GFD; IMF; United States Geological Survey (USGS); authors' calculations

Figure 4: Volatility of Spot Commodity Prices



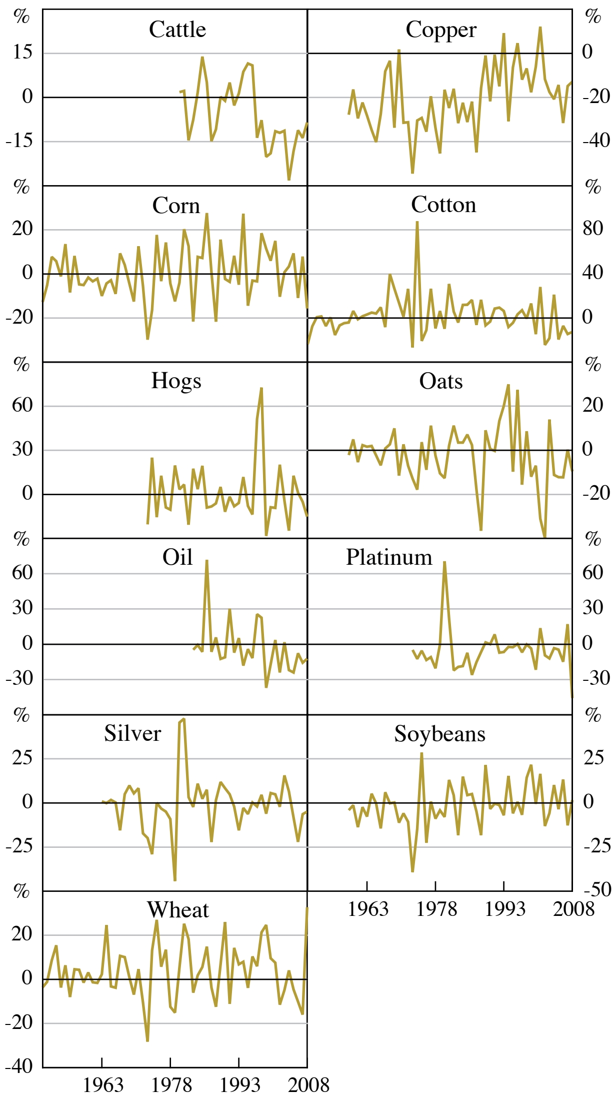
Note: Standard deviation of the spot price over the past year
Sources: GFD; IMF; USGS; authors' calculations

Figure 5: Commodity Log Inventory



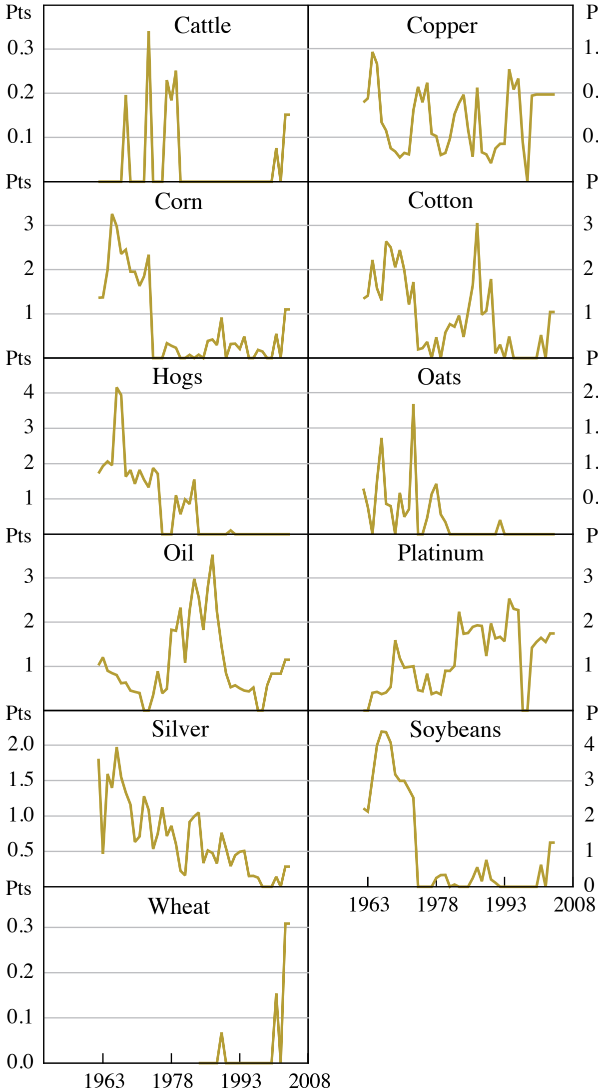
Sources: RBA; USGS; authors' calculations

Figure 6: Commodity Futures-Spot Spread



Sources: GFD; IMF; USGS; authors' calculations

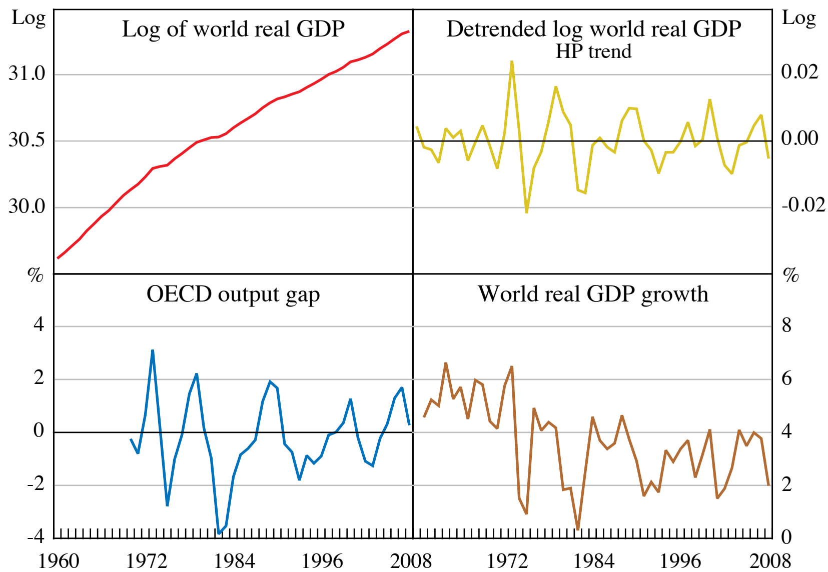
Figure 7: Commodity Risk



Source: The PRS Group

Finally, our preferred measure of real activity is plotted in Figure 8; (log) world real GDP. This has the advantage of including developing countries, including China and India. Of course all economic activity variables have positive trends. One must detrend them to be useful measures of the business cycle; we include a linear trend term in all our empirical work. (Another way to think of the trend term is as capturing the trend in supply or storage capacity, or perhaps the long-run equilibrium commodity price.) The growth rate of world GDP is also shown in Figure 8, as is world output detrended via the HP-filter. Finally, we also experiment with the output gap, which is available only for the OECD collectively, and only since 1970. In any of the measures of real economic activity one can see the recessions of 1975, 1982, 1991, 2001 and 2008.[29]

Figure 8: Real Activity



Sources: OECD; World Bank, *World Developments Indicators*; authors' calculations

29. In the past, we have also used US GDP, G7 GDP and industrial production (for the United States as well as for advanced countries in aggregate); the latter has the advantage of being available monthly.

4. Estimation of the Commodity Price Determination Equation

As a warm-up, Table 1 reports the results of bivariate regressions; we show coefficients along with robust standard errors. The correlation with real economic activity is reported in the first column. Surprisingly, real prices are not significantly correlated with global output for most commodities; the exceptions are corn, oats, silver and soybeans.[30] Volatility shows a positive bivariate correlation with all prices, significantly so for nine out of eleven commodities. The correlations with the spot-futures spread and inventories are also almost always of the hypothesised sign (negative), and significant for a few commodities. The real interest rate, too, shows the hypothesised negative correlation for eight out of eleven commodity prices, but is significantly different from zero for only one commodity, hogs. Political risk is significantly different from zero in just four cases: higher political risk (a fall in our index) appears to raise demand for corn, cotton and soybeans (a negative coefficient in the last column of Table 1), but to lower it for cattle. As with volatility, the theoretical prediction is ambiguous: the positive correlation is consistent with the convenience yield effect, and the negative correlation with the risk premium effect.[31]

The theory made it clear that prices depend on a variety of independent factors simultaneously, so these bivariate correlations may tell us little. Accordingly, Table 2a presents the multivariate estimation of Equation (9).[32] World output now shows the hypothesised positive coefficient in nine out of the eleven commodities, and is statistically significant in four of them: cattle, corn, oats and soybeans. That is, economic activity significantly raises demand for these commodities. The coefficient on volatility is statistically greater than zero for five commodities: copper, platinum, silver, soybeans and wheat. Evidently, at least for these five goods, volatility raises the demand to hold inventories, via the convenience yield. The spread and inventories are usually of the hypothesised negative sign (intuitively, backwardation signals expected future reduction in commodity values while high inventory levels imply that storage costs are high). However, the effects are significant only for a few commodities. The coefficient on the real interest rate is of the hypothesised negative sign in seven of the eleven commodities, but significantly so only for two: cattle and hogs. Overall, the macro variables work best for cattle. They work less well for the metals than for agricultural commodities, which would be surprising except that the same pattern appeared in Frankel (2008a).

30. When we substitute G7 real GDP, the three commodity prices that showed significant correlations – not reported here – were: corn, cotton and soybeans. We view global output as a better measure than G7 GDP or industrial production, because it is more comprehensive.

31. The results were a bit better when the same tests were run in terms of first differences (on data through 2007, not here reported but available in Table 1b of Frankel and Rose 2009, p 17). Correlation of price changes with G7 GDP growth was always positive, though again significant only for corn, cotton and soybeans. Correlations with volatility, the spread and inventories each show up as significant in five or six commodities out of eleven (and with the expected sign).

32. We exclude the political risk measure. It gives generally unclear results, perhaps in part because its coverage is incomplete and/or because of the possible theoretical ambiguity mentioned earlier. Volatility seems to be better at capturing risk. A useful extension would be to use implicit volatility from options prices, which might combine the virtues of both the volatility and political risk variables.

Table 1: Commodity by Commodity Bivariate Estimates – Levels

	World real GDP	Volatility	Spot-futures spread	Inventories	Real interest rate	Risk
Hypothesised sign on coefficient	+	+	–	–	–	+/–
Cattle	–1.77	0.10	–0.007**	0.11	–0.03	1.77**
	(1.27)	(0.68)	(0.002)	(0.41)	(0.02)	(0.50)
Copper	–1.36	2.74**	–0.008*	–0.28**	–0.04	–0.16
	(0.85)	(0.58)	(0.003)	(0.05)	(0.02)	(0.12)
Corn	–1.64**	2.08*	–0.005	–0.21	–0.03	–0.14**
	(0.59)	(0.96)	(0.003)	(0.12)	(0.02)	(0.05)
Cotton	–1.35*	1.11**	–0.002	–0.25	0.01	–0.14**
	(0.62)	(0.39)	(0.002)	(0.13)	(0.01)	(0.05)
Hogs	–1.66	1.72*	–0.004**	0.23	–0.05**	0.08
	(1.90)	(0.67)	(0.001)	(0.48)	(0.01)	(0.06)
Oats	1.51**	4.17*	–0.007*	–0.20	–0.03	–0.03
	(0.56)	(1.74)	(0.003)	(0.11)	(0.02)	(0.11)
Oil	–1.36	0.49	–0.004	–3.39	–0.01	0.16
	(6.18)	(1.26)	(0.003)	(4.03)	(0.06)	(0.08)
Platinum	3.79	3.24**	0.000	–0.17**	0.01	0.10
	(3.09)	(0.53)	(0.005)	(0.03)	(0.02)	(0.06)
Silver	6.69**	4.25**	0.003	–0.66**	0.03	–0.46
	(2.26)	(0.71)	(0.008)	(0.22)	(0.03)	(0.42)
Soybeans	2.48**	3.33**	–0.007	–0.07	–0.03	–0.10**
	(0.59)	(0.49)	(0.004)	(0.10)	(0.02)	(0.03)
Wheat	3.57	2.48**	–0.002	–1.03**	–0.01	0.63
	(3.57)	(0.84)	(0.006)	(0.22)	(0.04)	(0.43)

Notes: Annual data. Each cell contains a slope coefficient from a bivariate regression of the real price on the relevant regressor, allowing for an intercept and trend. ** (*) means significantly different from zero at the 1 and 5 per cent levels respectively. Robust standard errors in parentheses. Regressand: log real commodity price.

Table 2a: Multivariate Regressions, Commodity by Commodity Estimates – Levels

	World real GDP	Volatility	Spot-futures spread	Inventories	Real interest rate
Hypothesised sign on coefficient	+	+	–	–	–
Cattle	7.37**	–0.65	–0.007	2.37**	–0.06**
	(1.03)	(0.34)	(0.002)	(0.48)	(0.01)
Copper	0.03	1.92**	–0.005	–0.21**	–0.03
	(0.68)	(0.54)	(0.003)	(0.06)	(0.01)
Corn	1.53*	1.52	–0.003	–0.18	–0.01
	(0.69)	(0.89)	(0.003)	(0.17)	(0.02)
Cotton	0.66	1.07	–0.002	–0.12	0.01
	(0.85)	(0.57)	(0.002)	(0.14)	(0.01)
Hogs	–0.57	0.64	–0.004*	0.18	–0.03**
	(1.64)	(0.71)	(0.002)	(0.31)	(0.01)
Oats	2.66**	3.28	–0.006**	–0.59**	–0.02
	(0.71)	(1.69)	(0.002)	(0.11)	(0.01)
Oil	0.05	0.57	–0.003	–2.52	–0.01
	(8.60)	(1.69)	(0.003)	(5.02)	(0.07)
Platinum	1.22	1.78*	0.002	–0.21**	0.08**
	(2.17)	(0.87)	(0.002)	(0.03)	(0.01)
Silver	2.69	3.32**	0.003	–0.37*	0.01
	(2.13)	(0.73)	(0.003)	(0.18)	(0.03)
Soybeans	1.94**	2.68**	–0.001	–0.05	–0.01
	(0.70)	(0.55)	(0.002)	(0.07)	(0.01)
Wheat	–5.98*	1.90**	0.008*	–1.42**	0.03
	(2.79)	(0.47)	(0.003)	(0.27)	(0.02)

Notes: Annual data. OLS, commodity by commodity (so each row represents a different regression). ** (*) means significantly different from zero at the 1 and 5 per cent levels respectively. Robust standard errors in parentheses. Intercept and linear time trend included, not reported. Regressand: log real commodity price.

When the regressions are run in first differences, in Table 2b, the output coefficient is now always of the hypothesised positive sign. But the coefficient is smaller in magnitude and significant less often. Volatility is still significantly positive for five commodities, the spot-futures spread significantly negative for four, and inventories significantly negative for two. Any effect of the real interest rate has vanished.

Analysing commodities one at a time does not produce strong evidence overall. This may not be surprising. For one thing, because we are working with annual data here, each regression has relatively few observations. For another thing, we know that we have not captured idiosyncratic forces such as the weather events that lead to bad harvests in some regions or the political unrest that closes mines in other parts of the world. We hope to learn more when we combine data from different commodities together.

Tables 3a and 3b are probably our most important findings. They combine data from different commodities into one large panel data set.[33] In the panel setting, with all the data brought to bear, the theory is supported more strongly. The basic equation, with fixed effects for each commodity, is portrayed in the first row. The coefficients on world output and volatility have the expected positive effects; the latter is significantly different from zero at the 1 per cent level, while the former misses significance by a whisker (the significance level is 5.3 per cent). The coefficients on the spread and inventories are significantly different from zero with the hypothesised negative effects; and the coefficient on the real interest rate, though not significant, is of the hypothesised negative sign. Our basic equation also fits the data reasonably; the within-commodity $R^2 = 0.58$, though the between-commodity R^2 is a much lower 0.15 (as expected). The fitted values are graphed against the actual (log real) commodity prices in the top-left panel of Figure 9. (The panel immediately to the right shows the results when the fixed effects are removed from the fitted values.)

Table 3a also reports a variety of extensions and sensitivity tests in the lower rows. The second row of results *adds* year-specific effects to commodity-specific fixed effects. The two macroeconomic variables, world output and the real interest rate, necessarily drop out in the presence of these time-fixed effects; by definition they do not vary within a cross-section of commodities. But it is reassuring that the three remaining (microeconomic) variables – volatility, the spread, and inventories – retain their significant effects. The next row drops the spot-futures spread from the specification on the grounds that its role may already be played by inventories (see Equation (7)). The effects of inventories and the other variables remain essentially unchanged. Next, we add the political risk variable back in. It is statistically insignificant, but in its presence the world output variable becomes more significant than ever. We then try four alternative measures of global economic activity in place of the log of world real GDP: (1) the growth rate of world real GDP; (2) the OECD output gap; (3) Hodrick-Prescott filtered GDP; and (4) log world real GDP with a quadratic trend. None works as well as the level of real GDP, but the microeconomic effects are essentially unchanged.

33. Unless otherwise noted, in our panel estimation we always include a common trend and commodity-specific intercepts; we do not report these coefficients.

Table 2b: Commodity by Commodity Multivariate Results – First Differences

	World real GDP	Volatility	Spot-futures spread	Inventories	Real interest rate
Hypothesised sign on coefficient	+	+	–	–	–
Cattle	0.01	–0.46	–0.004**	–1.26	–0.00
	(0.02)	(0.50)	(0.001)	(0.96)	(0.01)
Copper	0.07**	0.44	–0.002	–0.08	0.03
	(0.02)	(0.27)	(0.001)	(0.07)	(0.02)
Corn	0.02	1.01	–0.001	–0.21	–0.01
	(0.02)	(0.53)	(0.001)	(0.12)	(0.02)
Cotton	0.01	1.05**	–0.001	–0.02	0.02
	(0.02)	(0.37)	(0.001)	(0.13)	(0.03)
Hogs	0.02	–0.76	–0.003**	–0.56	–0.02
	(0.03)	(0.85)	(0.001)	(0.50)	(0.02)
Oats	0.03	1.76*	–0.005**	–0.65**	–0.02
	(0.02)	(0.71)	(0.001)	(0.12)	(0.02)
Oil	0.10	–0.34	–0.003**	0.02	–0.04
	(0.06)	(0.49)	(0.001)	(1.24)	(0.04)
Platinum	0.03	1.28**	0.000	–0.02	0.02
	(0.03)	(0.44)	(0.001)	(0.07)	(0.03)
Silver	0.01	1.98**	0.003	–0.03	0.01
	(0.04)	(0.47)	(0.003)	(0.10)	(0.04)
Soybeans	0.05**	1.68**	–0.001	0.01	–0.02
	(0.02)	(0.37)	(0.001)	(0.08)	(0.02)
Wheat	0.03	0.90	0.004	–0.89**	–0.02
	(0.04)	(0.53)	(0.002)	(0.23)	(0.04)

Notes: Annual data. OLS, commodity by commodity (so each row represents a different regression). ** (*) means significantly different from zero at the 1 and 5 per cent levels respectively. Robust standard errors in parentheses. Intercept and linear time trend included, not reported. Regressand: first-difference in log real commodity price.

Table 3a: Panel Data Results – Levels

	World real GDP	Volatility	Spot-futures spread	Inventories	Real interest rate	Risk
Hypothesised sign on coefficient	+	+	–	–	–	+/–
Basic	0.60	2.29**	–0.003*	–0.15**	–0.01	
	(0.27)	(0.40)	(0.001)	(0.02)	(0.01)	
Add time-fixed effects	na	1.61**	–0.002*	–0.13**	na	
		(0.29)	(0.001)	(0.01)		
Drop spread	0.58	2.36**	na	–0.15**	–0.01	
	(0.30)	(0.38)		(0.02)	(0.01)	
Add risk	1.00**	1.67**	–0.003*	–0.15**	0.00	–0.05
	(0.23)	(0.57)	(0.001)	(0.03)	(0.01)	(0.04)
Growth (not log) of world real GDP	–0.01	2.36**	–0.003	–0.15**	–0.00	
	(0.01)	(0.40)	(0.001)	(0.02)	(0.01)	
OECD output gap	0.01	2.34**	–0.002*	–0.15**	–0.01	
	(0.01)	(0.44)	(0.001)	(0.02)	(0.01)	
HP-filtered GDP	2.35	2.32**	–0.003*	–0.14**	–0.01	
	(1.47)	(0.43)	(0.001)	(0.02)	(0.01)	
Add quadratic trend	0.48	2.30**	–0.003*	–0.15**	–0.01	
	(0.40)	(0.40)	(0.001)	(0.02)	(0.01)	

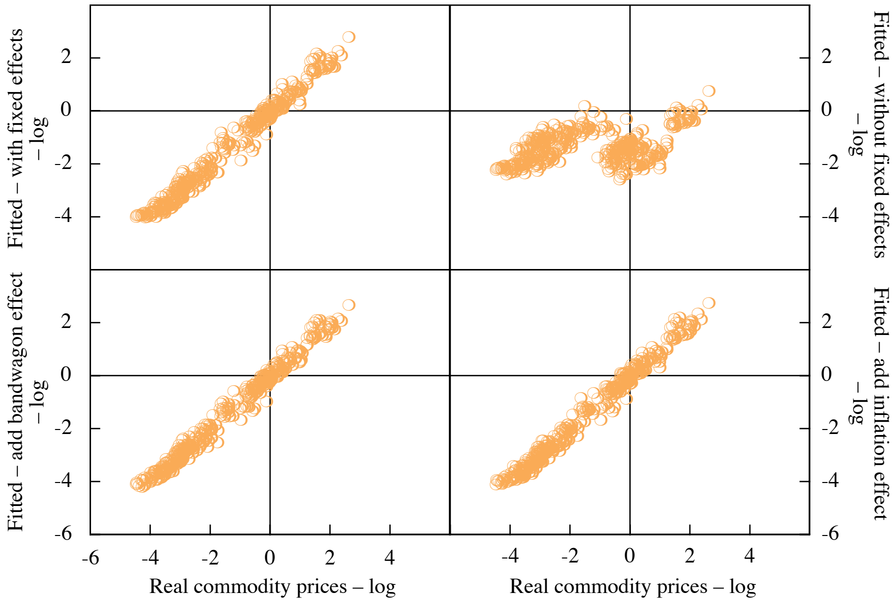
Notes: Annual data. ** (*) means significantly different from zero at the 1 and 5 per cent levels respectively. Robust standard errors in parentheses. Commodity-specific fixed intercepts and trend included, not reported. Regressand: log real commodity price.

Table 3b: Panel Data Results – First Differences

	World real GDP	Volatility	Spot-futures spread	Inventories	Real interest rate	Risk
Hypothesised sign on coefficient	+	+	–	–	–	+/–
Basic	0.03**	0.75**	–0.002**	–0.10*	0.00	
	(0.01)	(0.24)	(0.001)	(0.05)	(0.01)	
Add time-fixed effects	na	0.53**	–0.002**	–0.07	na	
		(0.18)	(0.001)	(0.04)		
Drop spread	0.04**	na	–0.0020**	–0.10	–0.00	
	(0.01)		(0.0005)	(0.05)	(0.01)	
Add risk	0.03**	0.65*	–0.0018**	–0.15*	0.01	–0.03
	(0.01)	(0.28)	(0.0005)	(0.07)	(0.01)	(0.02)
OECD output gap	0.03**	0.77*	–0.0018**	–0.12*	0.01	
	(0.01)	(0.25)	(0.0005)	(0.04)	(0.01)	
HP-filtered GDP	4.91**	0.78*	–0.002**	–0.12*	0.01	
	(0.97)	(0.23)	(0.001)	(0.04)	(0.01)	
Add quadratic trend	0.03**	0.75**	–0.002**	–0.10*	0.00	
	(0.01)	(0.24)	(0.001)	(0.05)	(0.01)	

Notes: Annual data. ** (*) means significantly different from zero at the 1 and 5 per cent levels respectively. Robust standard errors in parentheses. Commodity-specific fixed intercepts and trend included, not reported. Regressand: log real commodity price first-difference.

Figure 9: Fitted against Actual (Log Real) Commodity Prices



Sources: GFD; IMF; USGS; authors' calculations

Table 3b repeats the exercise of Table 3a, but using first differences rather than (log) levels, with similar results. In particular, the signs for the microeconomic determinants are almost always as hypothesised, as is the effect of economic activity. Most of the coefficients are also significantly different from zero, though the effect of activity on commodity prices is much smaller than in Table 3a. The estimated effects of real interest rates are often positive, although never significant.

Table 4 retains the panel estimation technique of Tables 3a and 3b, but reports the outcome of adding the rate of change of the spot commodity price over the *preceding* year to the standard list of determinants. The rationale is to test the theory of destabilising speculation by looking for evidence of bandwagon effects, as in Equation (9'). The lagged change in the spot price is indeed highly significant statistically, even if time-fixed effects are added, data after 2003 are dropped, or auto-correlated residuals are included in the estimation. It is also significant regardless of whether the spread or political risk variables are included or not, and regardless of the measure of economic activity. Evidently, alongside the regular mechanism of regressive expectations that is implicitly built into the basic model (a form of stabilising expectations), the results in Table 4 show that there is also a mechanism of extrapolative expectations (which is capable of producing self-confirming bubble effects).

Table 4: Testing for Bandwagon Effects

	World real GDP	Volatility	Spot-futures spread	Inventories	Real interest rate	Risk	Lagged nominal change
Hypothesised sign on coefficient	+	+	–	–	–	+/–	
Basic	0.50	1.84**	–0.004**	–0.13**	0.00		0.0061**
	(0.27)	(0.40)	(0.001)	(0.02)	(0.01)		(0.0005)
Add time-fixed effects	na	1.37**	–0.004**	–0.12**	na		0.0050**
		(0.28)	(0.001)	(0.01)			(0.0008)
Drop spread	0.48	2.01**	na	–0.14**	–0.00		0.0053**
	(0.32)	(0.37)		(0.02)	(0.01)		(0.0005)
Add risk	0.93**	1.25	–0.004**	–0.13**	0.01	–0.03	0.0050**
	(0.24)	(0.58)	(0.001)	(0.03)	(0.01)	(0.04)	(0.0005)
Growth (not log) of	–0.01	1.90**	–0.005**	–0.13**	0.01		0.0061**
world real GDP	(0.01)	(0.40)	(0.001)	(0.02)	(0.01)		(0.0005)
OECD output gap	–0.00	1.90**	–0.004**	–0.13**	0.01		0.0063**
	(0.01)	(0.43)	(0.001)	(0.02)	(0.01)		(0.0005)
HP-filtered GDP	–0.71	1.92**	–0.004**	–0.13**	0.01		0.0062**
	(1.58)	(0.42)	(0.001)	(0.02)	(0.01)		(0.0005)
Add quadratic trend	0.26	1.85**	–0.004**	–0.13**	0.01		0.0062**
	(0.37)	(0.41)	(0.001)	(0.02)	(0.01)		(0.0005)
Drop post-2003 data	1.21**	1.26	–0.004**	–0.11**	0.01		0.0049**
	(0.28)	(0.58)	(0.001)	(0.04)	(0.01)		(0.0005)
With AR(1) residuals	2.08*	0.89**	–0.0033**	–0.10**	0.00		0.0031**
	(0.81)	(0.13)	(0.00004)	(0.03)	(0.01)		(0.0004)

Notes: Annual data. ** (*) means significantly different from zero at the 1 and 5 per cent levels respectively. Robust standard errors in parentheses. Commodity-specific fixed intercepts and trend included, not reported. Regressand: log real commodity price. 'Lagged nominal change' is coefficient for lagged percentage change in nominal spot commodity price.

Table 5 reports the result of adding a separate coefficient for the US inflation rate, above and beyond the real interest rate (and the other standard commodity price determinants). Thus there are two separate measures of the monetary policy stance. Recall that the hypothesised role of the real interest rate is to pull the current real commodity price q away from its long-run equilibrium $\bar{q}$, while the role of the expected inflation rate is to raise $\bar{q}$ to the extent that commodities are considered useful as a hedge against inflation. In our default specification, and under almost all of the variations, the coefficient on inflation is greater than zero and highly significant. The result suggests that commodities are indeed valued as a hedge against inflation. The positive effect of inflation offers a third purely macroeconomic explanation for commodity price movements (alongside real interest rates, which do not work very well in our results, and growth, which does).[34,35]

Tables 6a and 6b report the results for a variety of aggregate commodity price indices that we have created. Prices and each of the relevant determinant variables have been aggregated using commodity-specific data and (time-invariant) weights from a particular index. We use weights from five popular indices (Dow Jones-AIG; S&P GSCI; Bridge/CRB; Grilli-Yang; and *The Economist*), and also create an equally weighted index. Since these rely on a number of commodities for which we do not have data, our constructed indices are by no means equal to the original indices (such as those portrayed in Figures 1 and 2). Further, the span of data available over time varies by commodity. Accordingly, we create three different indices for each weighting scheme; the narrowest (in that it relies on the fewest commodities) stretches back to 1964, while broader indices are available for shorter spans of time (we create indices that begin in 1973 and 1984). We use the same weights for prices and their fundamental determinants. The benefit from this aggregation is that some of the influences that are particular to individual commodities, such as weather, may wash out when we look at aggregate indices. The cost is that we are left with many fewer observations.

In the first column of Table 6a – which reports results in levels – the real GDP output coefficient always has the hypothesised positive sign. However, it is only significant in Table 6b, where the estimation is in terms of first differences. The volatility coefficient is almost always statistically greater than zero in both Tables 6a and 6b. The coefficient on the spot-futures spread is almost always negative, but not usually significantly different from zero. The inventory coefficient is also almost always negative, and sometimes significant. The real interest rate is never significant, though the sign is generally negative (and always negative in Table 6a). The lack of statistical significance probably arises because now that we are dealing with short time series of aggregate indices, the number of observations is smaller than in the panel analysis; this is especially true in the cases where we start the sample later.

34. For example, Calvo (2008).

35. Adding either a bandwagon or inflationary effect improves the fit of our equation: the within-commodity R^2 rises from 0.58 to 0.66 in both cases. Fitted values for both perturbations are graphed against actual prices in the bottom panels of Figure 9.

Table 5: Adding US Inflation to the Specification

	World real GDP	Volatility	Spot-futures spread	Inventories	Risk	Real interest rate	Inflation
Hypothesised sign on coefficient	+	+	–	–	+/–	–	+
Basic	–2.11**	2.12**	–0.0032**	–0.14**		0.019	0.082**
	(0.61)	(0.27)	(0.0007)	(0.02)		(0.012)	(0.015)
Drop spread	–2.04**	2.21**	na	–0.15**		0.015	0.079**
	(0.63)	(0.26)		(0.02)		(0.012)	(0.015)
Add risk	–1.25*	1.57**	–0.0031**	–0.14**	–0.02	0.020	0.067**
	(0.44)	(0.44)	(0.0006)	(0.02)	(0.04)	(0.014)	(0.015)
Growth (not log) of world real GDP	0.02	2.01**	–0.0027**	–0.15**		0.006	0.058**
	(0.01)	(0.32)	(0.0007)	(0.02)		(0.011)	(0.010)
OECD output gap	–0.00	2.09**	–0.0030**	–0.15**		0.014	0.083**
	(0.01)	(0.28)	(0.0007)	(0.02)		(0.012)	(0.014)
HP-filtered GDP	0.19	2.03**	–0.0031**	–0.15**		0.005	0.051**
	(1.64)	(0.33)	(0.0008)	(0.02)		(0.013)	(0.009)
Add quadratic trend	–2.47**	2.14**	–0.0032**	–0.14**		0.017	0.085**
	(0.76)	(0.27)	(0.0006)	(0.02)		(0.011)	(0.015)

Notes: Annual data. ** (*) means significantly different from zero at the 1 and 5 per cent levels respectively. Robust standard errors in parentheses. Commodity-specific fixed intercepts and trend included, not reported. Regressand: log real commodity price.

Table 6a: Commodity Price Index Results – Levels

	Period after	World real GDP	Volatility	Spot-futures spread	Inventories	Real interest rate
Hypothesised sign on coefficient		+	+	–	–	–
Dow Jones-AIG	1984	3.52	1.33**	–0.003	–0.21	–0.01
		(2.24)	(0.16)	(0.002)	(0.19)	(0.02)
	1973	2.11	1.32**	0.000	–0.30*	–0.01
		(1.13)	(0.11)	(0.002)	(0.13)	(0.01)
	1964	0.44	1.28**	–0.003	–0.11	–0.01
		(0.77)	(0.15)	(0.002)	(0.13)	(0.01)
S&P GSCI	1984	4.83	0.17	–0.004**	1.01**	–0.01
		(2.78)	(0.35)	(0.001)	(0.31)	(0.04)
	1973	2.18	1.29**	–0.000	–0.28*	–0.01
		(1.14)	(0.10)	(0.002)	(0.13)	(0.01)
	1964	0.42	1.31**	–0.003	–0.17	–0.01
		(0.75)	(0.15)	(0.002)	(0.13)	(0.01)
Bridge/CRB	1984	3.64	0.99**	–0.003	0.09	–0.01
		(2.58)	(0.23)	(0.002)	(0.25)	(0.03)
	1973	2.24	1.27**	–0.000	–0.25	–0.01
		(1.31)	(0.10)	(0.001)	(0.13)	(0.01)
	1964	0.47	1.32**	–0.003	–0.16	–0.01
		(0.71)	(0.15)	(0.002)	(0.13)	(0.01)
Grilli-Yang	1984	3.83	1.42**	–0.002	–0.25	–0.01
		(2.64)	(0.14)	(0.002)	(0.14)	(0.02)
	1973	2.61	1.18**	–0.001	–0.17	–0.01
		(1.76)	(0.13)	(0.002)	(0.16)	(0.01)
	1964	0.32	1.27**	–0.003	–0.18	–0.01
		(0.67)	(0.17)	(0.002)	(0.13)	(0.01)
The Economist	1984	3.76	1.39**	–0.002	–0.22	–0.01
		(2.55)	(0.11)	(0.002)	(0.12)	(0.02)
	1964	0.37	1.29**	–0.003	–0.14	–0.01
		(0.72)	(0.16)	(0.002)	(0.12)	(0.01)
Equally weighted	1984	3.26	1.64**	–0.003	–0.50**	–0.01
		(1.76)	(0.16)	(0.002)	(0.16)	(0.02)
	1973	2.09	1.36**	–0.000	–0.36*	–0.01
		(1.22)	(0.15)	(0.002)	(0.15)	(0.01)
	1964	0.43	1.40**	–0.003	–0.26	–0.01
		(0.61)	(0.17)	(0.002)	(0.13)	(0.01)

Notes: Annual data. ** (*) means significantly different from zero at the 1 and 5 per cent levels respectively. Robust standard errors in parentheses. Intercept and trend included, not reported. Price indices and micro-determinants are weighted averages (according to different schemes). Regressand: constructed log real commodity price index.

Table 6b: Commodity Price Index Results – First Differences

	Period after	World real GDP	Volatility	Spot-futures spread	Inventories	Real interest rate
Hypothesised sign on coefficient		+	+	–	–	–
Dow Jones-AIG	1984	0.07**	0.22	0.002	–0.35*	–0.02
		(0.02)	(0.48)	(0.001)	(0.14)	(0.02)
	1973	0.03*	1.55**	0.000	–0.29*	–0.00
		(0.01)	(0.39)	(0.002)	(0.12)	(0.02)
	1964	0.04**	1.98**	–0.002	–0.09	0.00
		(0.01)	(0.49)	(0.002)	(0.11)	(0.01)
S&P GSCI	1984	0.10*	–0.24	–0.002*	–0.66	–0.04
		(0.04)	(0.44)	(0.001)	(0.66)	(0.03)
	1973	0.03*	1.20*	0.000	–0.29*	–0.00
		(0.02)	(0.44)	(0.002)	(0.14)	(0.02)
	1964	0.04*	1.81**	–0.002	–0.13	0.00
		(0.02)	(0.50)	(0.002)	(0.11)	(0.01)
Bridge/CRB	1984	0.08**	–0.21	–0.002	–0.43*	–0.03
		(0.03)	(0.43)	(0.001)	(0.19)	(0.02)
	1973	0.03	1.35**	0.000	–0.25	0.00
		(0.02)	(0.42)	(0.002)	(0.13)	(0.02)
	1964	0.03**	1.87**	–0.002	–0.12	0.01
		(0.01)	(0.45)	(0.002)	(0.10)	(0.01)
Grilli-Yang	1984	0.03*	1.50*	–0.001	–0.22	0.02
		(0.02)	(0.61)	(0.002)	(0.13)	(0.02)
	1973	0.03	1.60**	–0.001	–0.17	0.02
		(0.02)	(0.42)	(0.002)	(0.14)	(0.02)
	1964	0.03	1.25**	–0.002	–0.12	0.02
		(0.02)	(0.39)	(0.002)	(0.12)	(0.01)
The Economist	1984	0.03*	2.13**	–0.001	–0.20*	0.02
		(0.02)	(0.66)	(0.001)	(0.10)	(0.02)
	1964	0.04**	1.79**	–0.002	–0.10	0.01
		(0.01)	(0.41)	(0.002)	(0.10)	(0.01)
Equally weighted	1984	0.06*	1.59**	–0.003	–0.35**	0.00
		(0.02)	(0.50)	(0.002)	(0.09)	(0.02)
	1973	0.03	1.84**	0.000	–0.35*	0.00
		(0.02)	(0.48)	(0.002)	(0.13)	(0.02)
	1964	0.03*	1.93**	–0.002	–0.22	0.00
		(0.01)	(0.46)	(0.002)	(0.11)	(0.01)

Notes: Annual data. ** (*) means significantly different from zero at the 1 and 5 per cent levels respectively. Robust standard errors in parentheses. Intercept and trend included, not reported. Price indices and micro-determinants are weighted averages (according to different schemes). Regressand: constructed first-difference log real commodity price index.

Although we have already reported results of regressions run in both levels and first differences, a complete analysis requires that we examine the stationarity or non-stationarity of the series more formally. Tables in Appendix A tabulate Phillips-Perron tests for unit roots in our individual variables; the aggregate series are handled in Table A1a, while the commodity-specific results are in Table A1b. Table A1c is the analogue that tests for common panel unit roots. The tests often fail to reject unit roots (though not for the spread and volatility). One school of thought would doubt, on *a priori* grounds, that variables such as the real interest rate could truly follow a random walk. The other school of thought says that one must go wherever the data instruct. Here we pursue the implication of unit roots to be safe, as a robustness check if nothing else. However, we are reluctant to over-interpret our results, especially given the limited number of time-series observations.[36]

Tables A2a–A2c report related tests of cointegration. We generally find cointegration in commodity-specific models, but have weaker results in our panel cointegration result. It is not clear to us whether this is the result of low power, the absence of fixed effects or some other misspecification. Still, Table A3 reports results from commodity-specific vector error correction models (VECMs). As in some of the previous tests, the three variables that are most consistently significant and of the hypothesised sign are the volatility, the spread and inventories. We view this as a reassuring corroboration of the panel estimation we have already documented.

5. Summary and Conclusion

This paper has presented a model that can accommodate each of the prominent explanations that were given for the run-up in prices of most agricultural and mineral commodities that culminated in the 2008 spike: global economic activity, easy monetary policy, and destabilising speculation. Our model includes both macroeconomic and microeconomic determinants of real commodity prices.

The theoretical model is built around the 'arbitrage' decision faced by any firm holding inventories. This is the trade-off between the cost of carrying the inventory on the one hand (the interest rate plus the cost of storage) versus the convenience yield and spot-futures spread (or, if unhedged, the expected capital gain adjusted for the risk premium) on the other hand. A second equation completes the picture; the real commodity price is expected to regress gradually back to its long-run equilibrium (at least absent bandwagon effects). The reduced-form equation expresses the real commodity price as a function of the real interest rate, storage costs, convenience yield and the risk premium. The level of inventories is a ready stand-in for storage costs. The empirical significance of the inventory variable suggests that the data and relationship are meaningful, notwithstanding fears that

36. Studies of the time-series properties of real commodity prices can find a negative trend, positive trend, random walk, or mean reversion, depending on the sample period available when the authors do their study. Examples include Cuddington and Urzúa (1989) and Reinhart and Wickham (1994).

the available measures of inventories are incomplete.[37] Global economic activity is an important determinant of the convenience yield. Measures of political risk and price uncertainty are other potentially important determinants of both convenience yield and the risk premium.

Our strongest results come about when we bring together as much data as possible, in the panel estimates of Tables 3a, 3b, 4 and 5. Our annual empirical results show support for the influence of economic activity, inventories, uncertainty, the spread and recent spot price changes. The significance of the inventories variable supports the legitimacy of arguments by others who have used observed inventory levels to gauge the roles of speculation or interest rates. There was little support in these new annual results for the hypothesis that easy monetary policy and low real interest rates are an important source of upward pressure on real commodity prices, beyond any effect they might have via real economic activity and inflation. (This result differs from more positive results of previous papers.) We also find evidence that commodity prices are driven in part by bandwagon effects and by inflation *per se*.

A number of possible extensions remain for future research. These include: (1) estimation at monthly or quarterly frequency (the big problem here is likely to be data availability, especially for any reasonably long span of time); (2) testing for nonlinearity in the effects of growth, uncertainty and (especially) inventories; (3) using implicit volatility inferred from commodity options prices as the measure of uncertainty; (4) using survey data to measure commodity price expectations explicitly; and (5) simultaneous estimation of the three equations: expectations formation (regressive versus bandwagon), the inventory arbitrage condition, and the equation for determination of the real commodity price. The future agenda remains large.

What caused the run-up in commodities prices in the 2000s? One explanation is the recent rapid global growth – as in the 1970s – aided now by China and India. Presumably, then the abrupt decline in the latter part of 2008, and even the partial recovery in the spring of 2009, could be explained by the rapidly evolving prospects for the real economy. But this story is still not able to explain the acceleration of commodity prices between mid 2007 and the peak around the second half of 2008, a time when growth prospects were already being downgraded in response to the US sub-prime mortgage crisis. Of the two candidate theories to explain that interval – low real interest rates and a speculative bubble – there is more support for the latter in this paper, in the form of bandwagon effects. But a more definitive judgment on both may have to await higher-frequency data.

37. We are implicitly considering inventories relative to full capacity, but explicit adjustment would improve the measurement, if the appropriate data on storage capacity could be found.

Appendix A: Predictive Bias in Commodity Futures Markets

This Appendix briefly reviews the literature on whether forward and futures prices are unbiased forecasts of future spot prices for commodities, and – where there is systematic bias – what the source might be.

Commodity futures can deliver both storage facilitation and a forward-pricing role in their price discovery function.[38] Accordingly, there are two main theories in commodity futures price determination:

1. The theory of storage or costs-of-carry models (Working 1949; Brennan 1958), which explain the difference in the contemporaneous spot price and futures price of commodities by the net costs of carrying stock. These are composed of: (1) interest foregone (had they been sold earlier); (2) warehousing costs; and (3) the convenience yield.
2. The view that the futures price has two components (Breeden 1980; Hazuka 1984): the expected risk premium (Keynes' 'normal backwardation theory') and the forecast of future spot price. Under this theory, the futures price is a biased estimate of future spot price because of the risk premium – insurance being sold by the speculators to the hedgers.

Is the Futures Price a Biased Predictor of the Future Spot Price?

Some studies address the question of the unbiasedness of futures prices (in forecasting spot prices) by examining the cointegration between futures and spot prices; this allows one to deal with problems of the non-stationary nature of commodities prices (for example, Covey and Bessler 1995; Brenner and Kroner 1995; Fortenbery and Zapata 1998; and Yang *et al* 2001). Moosa and Al-Loughani (1994) and Chernenko, Schwarz and Wright (2004) find bias. Similarly, Morana (2001) finds that forward rates for oil actually point in the wrong direction more often than not. Chinn, LeBlanc and Coibion (2005), however, do not find bias in energy futures, while Green and Mork (1991) have mixed results for oil.

Many studies are motivated by the presumed existence of a risk premium in the futures price. The evidence is mixed. For example, Bessembinder (1993) found evidence of non-trivial risk premia for live cattle, soybeans and cotton, but much smaller risk premia in non-agricultural assets such as T-bills. Gorton and Rouwenhorst (2006) and Gorton, Hayashi and Rouwenhorst (2007) find systematic components to commodity returns. On the other hand, Fama and French (1987) studied 21 commodities and found only weak evidence of time-varying risk premia. A study by Kolb (1992) did not find evidence of risk premia for most of the 29 commodities examined. Many of these studies, however, equated the risk premium to the extra returns earned by speculators during particular sample periods, in other words by defining the risk premium as observed bias in the futures price as a forecast of the

38. See Yang *et al* (2001) for a review of the literature.

future spot price. These studies tend to neglect the question of whether the bias in the futures price might come from systematic prediction errors in-sample, rather than from a time-varying risk premium.

Is the Bias a Risk Premium or Expectational Errors?

Choe (1990) attempted to bring an independent expectations measure to bear on the question of whether the predictive bias in commodity futures is due to a risk premium or to a failure of the rational expectations methodology, analogous to the approach taken by Froot and Frankel (1989) for the foreign exchange market. To test this for commodities (including cocoa, coffee, copper, cotton, maize, soybeans, sugar and wheat), Choe obtained the data on futures prices and then approximated expectations of the future spot price using the forecast conducted by the World Bank International Commodity Markets Division. He discovered that:

- using futures prices for short-term price forecasting is more bias-prone than relying on specialists' forecasts;
- in contrast to the results found by Froot and Frankel (1989), a major part of futures forecast bias comes from risk premia as well as expectational errors. For cocoa, copper, cotton and soybeans, the expectational errors seem to play a principal role, whereas the existence of risk premia is important for the other commodities;
- the size of the risk premia can be large compared to the expectational errors. However, the variance of risk premium is larger than that of the expected price change only for coffee and wheat; and
- the estimated bias from the risk premium is negative while that from expectational errors is mixed – negative for half of the commodities examined and positive for the others.

Literature Sources on Futures Bias

Authors	Sources
Dusak (1973)	United States Department of Agriculture
Fama and French (1987)	Chicago Board of Trade (CBOT) for broilers, corn, plywood, soy oil, soybeans, wheat
	Chicago Mercantile Exchange for cattle, hogs, lumber, pork bellies
	Commodity Exchange for copper, gold, and silver
	Coffee, Sugar and Cocoa Exchange for cocoa and coffee
	New York Cotton Exchange for cotton
	New York Mercantile Exchange for platinum
Choe (1990)	World Bank, International Economics Department and DRICOM commodity database of Data Resources Inc: cocoa, coffee, copper, cotton, maize, sugar, soybeans, wheat
Tomek (1997)	CBOT
Carter (1999)	Commodity Futures Trading Commission for both cash and futures prices
Yang *et al* (2001)	Datastream International: data on CBOT and Minneapolis Grain Exchange

Table A1a: Phillips-Perron Tests for Unit Root in Aggregate Time-series

	$Z(\rho)$	$Z(t)$ (MacKinnon p-value)
Log world real GDP	–0.81	–3.85** (0.00)
World growth rate	–20.8**	–3.59** (0.01)
OECD output gap	–19.1*	–3.34* (0.01)
Log world real GDP – HP trend	–31.9**	–4.84** (0.00)
Real interest rate	–10.00	–2.18 (0.21)

Notes: Annual data. ** (*) indicates rejection of null hypothesis of unit root at the 1 and 5 per cent significance levels respectively. Intercept included. Two lags as controls.

Table A1b: Phillips-Perron Tests for Unit Root in Commodity-specific Series

	Log real price	Spread	Log inventory	Volatility	Risk
Cattle	–7.0/–2.2	–12.3/–2.7	–7.5/–2.7	–39**/–4.5**	–34**/–5.1**
Copper	–7.4/–1.8	–40**/–5.5**	–8.6/–2.0	–39**/–5.2**	–22**/–3.7**
Corn	–5.8/–1.8	–61**/–8.6**	–2.6/–1.2	–53**/–6.7**	–6.2/–1.8
Cotton	–4.4/–1.6	–77**/–10**	–4.5/–1.5	–24**/–4.1**	–11.7/–2.6
Hogs	–8.3/–2.1	–34**/–6.2**	–23**/–3.5**	–39**/–4.5	–7.11/2.0
Oats	–7.7/–2.0	–46**/–6.2**	–2.1/–0.8	–30**/–4.2**	–29**/–4.7**
Oil	–2.6/–0.8	–27**/–5.1**	–5.0/–3.4*	–38**/–4.9**	–7.8/–2.0
Platinum	–3.2/–0.8	–29**/–4.6**	4.6/3.6	–40**/–3.6**	–13.4*/–2.9*
Silver	–7.3/–1.9	–35**/–5.4**	–3.1/–1.3	–19.7**/–3.3*	–14.7*/–3.3*
Soybeans	–5.4/–1.7	–56**/–8.1**	–4.2/–1.8	–24**/–4.0**	–3.9/–1.5
Wheat	–6.6/–2.0	–49**/–6.5**	–5.0/–1.7	–28**/–4.2**	–5.3/–1.1

Notes: $Z(\rho)/Z(t)$ statistics reported. Annual data. ** (*) indicates rejection of null hypothesis of unit root at the 1 and 5 per cent significance levels respectively. Intercept included. Two lags as controls.

Table A1c: Panel Unit Root Tests

	Im, Pesaran, Shin (*p*-value)	Levin, Lin	Dickey, Fuller	Maddala, Wu
Log real price	–1.79	–0.14	65	13.2
	(0.13)	(0.28)		(0.93)
Risk	–1.73	–0.34*	307	20.6
	(0.16)	(0.01)		(0.55)
Spread	–2.83**	–0.98*	136	83.6**
	(0.00)	(0.03)		(0.00)
Log inventory	–1.05	–0.06	85	27.4
	(0.94)	(0.95)		(0.20)
Volatility	–3.05**	–0.84	144	58.4**
	(0.00)	(0.09)		(0.00)

Notes: Annual data. ** (*) indicates rejection of null hypothesis of unit root at the 1 and 5 per cent significance levels respectively. Intercept included. Two lags as controls.

Table A2a: Johansen Tests for Cointegration in Commodity-specific Models

	Basic	1% level	3 lags	Add trend	Add risk	Drop spread
Cattle	4	3		5	6	2
Copper	0	0	1	0	1	1
Corn	2	1		2	5	2
Cotton	3	1	0		3	2
Hogs	2	1	4	3	4	2
Oats	2	1	1	2	2	2
Oil	3	3		4		2
Platinum	2	1	3	1	3	1
Silver	1	1	3	2	1	0
Soybeans	2	2	4	2	2	1
Wheat	3	2	5	2		2

Notes: Maximal rank from Johansen trace statistic at 5 per cent level unless noted. Annual data. Intercept included. Two lags included unless noted. Model of log real commodity price includes five controls (spread, log inventory, volatility, real interest rate, log world real GDP) unless noted.

Table A2b: Panel Cointegration Tests – Basic Equation

	G_t	G_a	P_t	P_a
Basic	–1.31	–2.47	–4.53	–2.70
	(1.00)	(1.00)	(0.92)	(0.99)
Only 1 lag	–1.88	–3.02	–4.97	–3.32
	(0.85)	(1.00)	(0.85)	(0.98)
Add constant	–1.41	–3.74	–4.28	–3.47
	(1.00)	(1.00)	(1.00)	(1.00)
Add constant, trend	–1.31	–3.32	–3.97	–3.08
	(1.00)	(1.00)	(1.00)	(1.00)
Add lead	–0.46	–0.57	–2.34	–0.87
	(1.00)	(1.00)	(1.00)	(1.00)

Notes: Basic: two lags. *p*-values (for null hypothesis of no cointegration) recorded in parentheses. Model of log real commodity price includes five controls (spread, log inventory, volatility, real interest rate, log world real GDP).

Table A2c: Panel Cointegration Tests – Including Risk

	G_t	G_a	P_t	P_a
Basic	–1.66	–2.70	–4.72	–3.07
	(0.85)	(1.00)	(0.69)	(0.92)
Only 1 lag	–1.87	–5.36	–5.14	–4.54
	(0.64)	(0.98)	(0.57)	(0.76)
Add constant	–1.51	–5.31	–4.00	–3.34
	(1.00)	(1.00)	(1.00)	(1.00)
Add constant, trend	–1.84	–6.88	–4.84	–4.22
	(1.00)	(1.00)	(1.00)	(1.00)
Add lead	–1.07	–2.33	–3.28	–1.79
	(1.00)	(1.00)	(0.95)	(0.98)

Notes: Basic: two lags. *p*-values (for null hypothesis of no cointegration) recorded in parentheses. Model of log real commodity price includes six controls (risk, spread, log inventory, volatility, real interest rate, log world real GDP).

Table A3: Cointegration Vector Estimates from Commodity-specific VECMs

	World real GDP	Volatility	Spot-futures spread	Inventories	Real interest rate
Hypothesised sign on coefficient	+	+	–	–	–
Cattle	6.20**	–72**	–0.095**	17.2**	0.08
	(1.76)	(10.0)	(0.023)	(6.6)	(0.17)
Copper	0.99**	–0.37	–0.076**	–0.40*	–0.04
	(0.27)	(1.54)	(0.007)	(0.16)	(0.05)
Corn	–0.28	3.65**	–0.056**	–0.47*	0.03
	(0.21)	(1.04)	(0.004)	(0.20)	(0.03)
Cotton	–0.92**	5.75**	–0.054**	–0.91**	0.01
	(0.19)	(0.95)	(0.003)	(0.24)	(0.03)
Hogs	–0.09	17.1**	–0.032**	–4.9**	0.02
	(0.27)	(2.7)	(0.004)	(1.2)	(0.03)
Oats	–0.54	9.6**	–0.035**	0.18	0.03
	(0.31)	(2.1)	(0.005)	(0.21)	(0.03)
Oil	–5.0	20.2**	–0.15**	18.0	–0.02
	(3.6)	(3.7)	(0.01)	(12.0)	(0.19)
Platinum	–1.9	10.0	0.081**	0.01	0.15
	(1.0)	(5.8)	(0.010)	(0.19)	(0.09)
Silver	–2.1**	4.6**	–0.043**	–0.89**	0.01
	(0.3)	(0.6)	(0.003)	(0.13)	(0.02)
Soybeans	1.54	0.64	–0.135	–0.39	0.07
	(0.79)	(2.15)	(0.009)	(0.34)	(0.06)
Wheat	–0.69**	4.44**	–0.039**	–0.39	0.03
	(0.14)	(0.64)	(0.003)	(0.20)	(0.02)

Notes: Annual data. ** (*) means significantly different from zero at 0.01 (0.05) level. Standard errors in parentheses. Intercept and linear time trend included, not reported. VEC estimation, commodity by commodity, one lag.

References

Barsky RB and L Kilian (2002), 'Do We Really Know that Oil Caused the Great Stagflation? A Monetary Alternative', in BS Bernanke and KS Rogoff (eds), *NBER Macroeconomics Annual 2001*, 16, MIT Press, Cambridge, pp 137–183.

Barsky RB and L Kilian (2004), 'Oil and the Macroeconomy since the 1970s', *Journal of Economic Perspectives*, 18(4), pp 115–134.

Bessembinder H (1993), 'An Empirical Analysis of Risk Premia in Futures Markets', *Journal of Futures Markets*, 13(6), pp 611–630.

Bopp AE and GM Lady (1991), 'A Comparison of Petroleum Futures versus Spot Prices as Predictors of Prices in the Future', *Energy Economics*, 13(4), pp 274–282.

Breeden DT (1980), 'Consumption Risks in Futures Markets', *Journal of Finance*, 35(2), pp 503–520.

Brennan MJ (1958), 'The Supply of Storage', *American Economic Review*, 48(1), pp 50–72.

Brenner RJ and KF Kroner (1995), 'Arbitrage, Cointegration, and Testing Unbiasedness Hypothesis in Financial Markets', *Journal of Financial and Quantitative Analysis*, 30(1), pp 23–42.

Calvo G (2008), 'Exploding Commodity Prices, Lax Monetary Policy, and Sovereign Wealth Funds', *Vox*, 20 June. Available at <http://www.voxeu.org/index.php?q=node/1244#fn5>.

Carter CA (1999), 'Commodity Futures Markets: A Survey', *Australian Journal of Agricultural and Resource Economics*, 43(2), pp 209–247.

Chernenko SV, KB Schwarz and JH Wright (2004), 'The Information Content of Forward and Futures Prices: Market Expectations and the Price of Risk', Board of Governors of the Federal Reserve System International Finance Discussion Paper No 808.

Chinn MD, M LeBlanc and O Coibion (2005), 'The Predictive Content of Energy Futures: An Update on Petroleum, Natural Gas, Heating Oil and Gasoline', NBER Working Paper No 11033.

Choe B-J (1990), 'Rational Expectations and Commodity Price Forecasts', World Bank Policy, Research, and External Affairs Working Paper No 435.

Covey T and DA Bessler (1995), 'Asset Storability and the Informational Content of Inter-Temporal Prices', *Journal of Empirical Finance*, 2(2), pp 103–115.

Cuddington JT and CM Urzúa (1989), 'Trends and Cycles in the Net Barter Terms of Trade: A New Approach', *Economic Journal*, 99(396), pp 426–442.

Dornbusch R (1976), 'Expectations and Exchange Rate Dynamics', *Journal of Political Economy*, 84(6), pp 1161–1176.

Dusak K (1973), 'Futures Trading and Investor Returns: An Investigation of Commodity Market Risk Premiums', *Journal of Political Economy*, 81(6), pp 1387–1406.

Fama EF and KR French (1987), 'Commodity Futures Prices: Some Evidence on Forecast Power, Premiums, and the Theory of Storage', *Journal of Business*, 60(1), pp 55–73.

Fortenbery TR and HO Zapata (1998), 'An Evaluation of Price Linkages between Futures and Cash Markets for Cheddar Cheese', *Journal of Futures Markets*, 17(3), pp 279–301.

Frankel JA (1984), 'Commodity Prices and Money: Lessons from International Finance', *American Journal of Agricultural Economics*, 66(5), pp 560–566.

Frankel JA (1986), 'Expectations and Commodity Price Dynamics: The Overshooting Model', *American Journal of Agricultural Economics,* 68(2), pp 344–348.

Frankel JA (2008a), 'The Effect of Monetary Policy on Real Commodity Prices', in JY Campbell (ed), *Asset Prices and Monetary Policy*, University of Chicago Press, Chicago, pp 291–327.

Frankel JA (2008b), 'An Explanation for Soaring Commodity Prices', *Vox*, 25 March. Available at <http://www.voxeu.org/index.php?q=node/1002>.

Frankel JA and GA Hardouvelis (1985), 'Commodity Prices, Money Surprises, and Fed Credibility', *Journal of Money, Credit and Banking*, 17(4, Part I), pp 427–438.

Frankel JA and AK Rose (2009), 'Macroeconomic Determination of Agricultural and Mineral Commodity Prices', paper presented at the workshop 'Challenges to Inflation in an Era of Relative Price Shocks', Westfälishche Wilhelms University Münster, Münster, 16–17 June.

Froot KA and JA Frankel (1989), 'Forward Discount Bias: Is It an Exchange Risk Premium?', *The Quarterly Journal of Economics*, 104(1), pp 139–161.

Gorton GB, F Hayashi and KG Rouwenhorst (2007), 'The Fundamentals of Commodity Futures Returns, NBER Working Paper No 13249.

Gorton GB and KG Rouwenhorst (2006), 'Facts and Fantasies about Commodity Futures', *Financial Analysts Journal*, 62(2), pp 47–68.

Green SL and KA Mork (1991), 'Toward Efficiency in the Crude-Oil Market', *Journal of Applied Econometrics*, 6(1), pp 45–66.

Hazuka TB (1984), 'Consumption Betas and Backwardation in Commodity Markets', *Journal of Finance*, 39(3), pp 647–655.

IMF (International Monetary Fund) (2006), *World Economic Outlook – Globalization and Inflation*, World Economic and Financial Surveys, IMF, Washington DC.

IMF (2007), *World Economic Outlook – Globalization and Inequality*, World Economic and Financial Surveys, IMF, Washington DC.

IMF (2008a), *World Economic Outlook – Financial Stress, Downturns, and Recoveries*, World Economic and Financial Surveys, IMF, Washington DC.

IMF (2008b), *World Economic Outlook – Housing and the Business Cycle*, World Economic and Financial Surveys, IMF, Washington DC.

Kohn D (2008), 'The Economic Outlook', speech at the National Conference on 'Public Employee Retirement Systems Annual Conference', New Orleans, 20 May.

Kolb RW (1992), 'Is Normal Backwardation Normal?', *Journal of Futures Markets*, 12(1), pp 75–91.

Krugman P (2008a), 'Commodity Prices (Wonkish)', *The New York Times*, 19 March. Available at <http://krugman.blogs.nytimes.com/2008/03/19/commodity-prices-wonkish/>.

Krugman P (2008b), 'The Oil Nonbubble', *The New York Times*, 12 May. Available at <http://www.nytimes.com/2008/05/12/opinion/12krugman.html>.

Moosa IA and NE Al-Loughani (1994), 'Unbiasedness and Time Varying Risk Premia in the Crude Oil Futures Market', *Energy Economics*, 16(2), pp 99–105.

Morana C (2001), 'A Semiparametric Approach to Short-Term Oil Price Forecasting', *Energy Economics*, 23(3), pp 325–338.

Mundell R (2002), 'Commodity Prices, Exchange Rates and the International Monetary System', in Food and Agriculture Organization of the United Nations (FAO) (ed), *Consultation on Agricultural Commodity Price Problems*, FAO, Rome, pp 21–26.

Phillips L and JE Pippenger (2005), 'Some Pitfalls in Testing the Law of One Price in Commodity Markets', University of California, Santa Barbara, Economics Working Paper No WP 4-05.

Protopapadakis A and HR Stoll (1983), 'Spot and Futures Prices and the Law of One Price', *Journal of Finance*, 38(5), pp 1431–1455.

Protopapadakis A and HR Stoll (1986), 'The Law of One Price in International Commodity Markets: A Reformulation and Some Formal Tests', *Journal of International Money and Finance*, 5(3), pp 335–360.

Reinhart C and P Wickham (1994), 'Commodity Prices: Cyclical Weakness or Secular Decline?', *IMF Staff Papers*, 41(2), pp 175–213.

Tomek WG (1997), 'Commodity Futures Prices as Forecasts', *Review of Agricultural Economics*, 19(1), pp 23–44.

Wolf M (2008), 'The Market Sets High Oil Prices to Tell Us What to Do', *Financial Times*, Asian edn, 14 May, p 11.

Working H (1949), 'The Theory of Price of Storage', *American Economic Review,* 39(6), pp 1254–1262.

Yang J, DA Bessler and DJ Leatham (2001), 'Asset Storability and Price Discovery in Commodity Futures Markets: A New Look', *Journal of Futures Markets*, 21(3), pp 279–300.

Ye M, J Zyren and J Shore (2002), 'Forecasting Crude Oil Spot Price Using OECD Petroleum Inventory Levels', *International Advances in Economic Research*, 8(4), pp 324–334.

Ye M, J Zyren and J Shore (2005), 'A Monthly Crude Oil Spot Price Forecasting Model Using Relative Inventories', *International Journal of Forecasting*, 21(3), pp 491–501.

Ye M, J Zyren and J Shore (2006), 'Forecasting Short-Run Crude Oil Price Using High- and Low-Inventory Variables', *Energy Policy*, 34(17), pp 2736–2743.

Discussion

1. Simon Price

It is a pleasure to be invited to discuss this rich paper by Jeffrey Frankel and Andrew Rose. After the events of the past few years, with a range of commodity prices exhibiting great volatility, it is not hard to motivate Frankel and Rose's choice of topic, seen from either a long- or medium-term perspective. The authors use annual data, mainly in a panel context, to examine the relationship between real commodity prices and a number of macro and microeconomic series. What they are trying to do, I believe, is to adopt an eclectic approach that combines a classic model of short-run dynamics (articulated in, for example, Frankel 1986) with other considerations that may affect both short- and medium-term movements. Meanwhile, the very long run is relegated to essentially un-modelled trends. The empirical analysis is conducted using a variety of methods that, it is argued, allow us to conclude that the results are relatively robust.

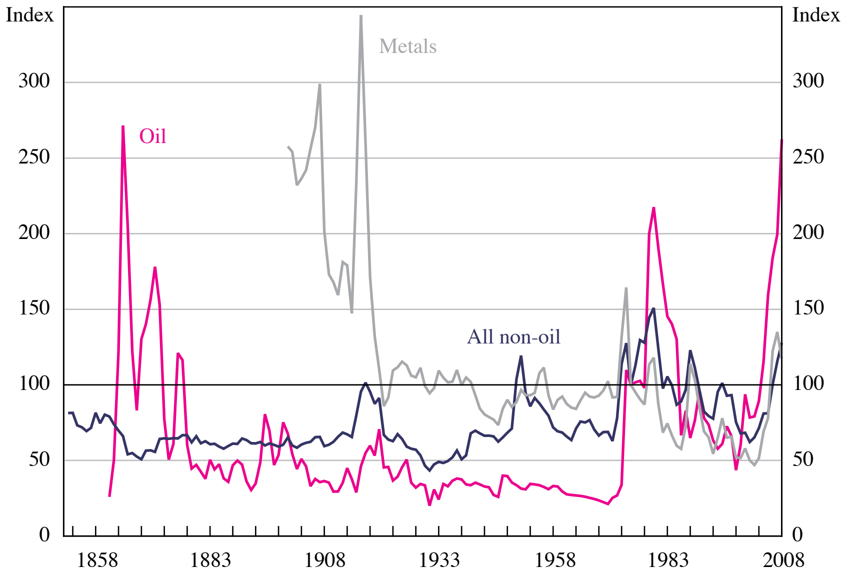
The results are certainly thoroughly explored. The aim of my remarks is to step to one side, so to speak, to consider other ways of thinking about the relationship between the long-run and short-run dynamics of commodity prices with the intention of encouraging some discussion. I hope the observations given may thereby complement the paper, where the long run is somewhat pushed into the background. My comments probably also reflect my intellectual upbringing by adopting a UK-based econometric approach. Unhappily, I am the first to admit that I do not have a fully articulated alternative to the authors' approach, but that is the privilege of a discussant.

I am old enough to remember that some of us became concerned about the environment and resources back in the 1970s, even before the first oil price shock. At the time, one view was that prices of commodities – the exhaustible ones anyway – would inevitably rise as they became increasingly scarce. Another view was that naïve Malthusian views, as embodied in the Club of Rome's approach, were absurdly ignorant of economics and history. These opposing views were neatly captured in the famous bet between Paul Ehrlich and Julian Simon. Simon argued that contrary to the views of Ehrlich, economic forces and technical progress would together ensure that commodity prices would not tend to rise in the long run, and proposed a bet based on the prices of raw materials. Ehrlich and two of his colleagues accepted the challenge (see Ehrlich 1981) on the basis of the change in the real price of a basket of five metals between 29 September 1980 and 29 September 1990.

Looking even further back, Hotelling (1931) argued that the rent due to owners of exhaustible resources would rise at the rate of interest. This essentially followed from an arbitrage condition, and would seem to imply that exhaustible commodity prices should rise inexorably.

What happened? Simon won his bet, and as Figure 1 shows, the real price of oil (deflated by the US GDP deflator) in 2003 was lower than its average in the second half of the 19th century. Although the chart also shows that this was not true in 2008, it seems likely at the time of writing in August 2009 that the eventual outcome for 2009 will be below the 2008 figure. Metals prices are lower than when the series started in the late 19th century; while in the 20th century they appear to be mean reverting. Similarly, the series for all non-oil commodities shows no obvious trend. So the question is, is this in any sense a puzzle?

Figure 1: Real Commodity Prices
1975 = 100



Note: Deflated using US GDP deflator
Sources: Bank of England; BP; *The Economist*; World Bank

Hotelling's (1931) proposal was that the rent due to the owner of an exhaustible resource would rise at the rate of interest:

$$s_{t+1} - c_{t+1} = (1+i)(s_t - c_t) \tag{1}$$

where: s is the spot price of the commodity; c is the marginal extraction cost; and i is the one-period nominal interest rate.

Equation (1) is an arbitrage condition as stated earlier. It applies under perfect competition. The question arises, why do the rents not get competed away? The answer is that the commodity is in fixed supply and no agent has an incentive to undercut.[1] But inspection of the data in Figure 1 does not suggest that exhaustible resources such as oil or metals rise at a rate determined solely by the real interest rate. The essential thing to grasp is that Equation (1) is a statement about the rent. So, in general, it is perfectly consistent with the data if c_t has fallen.

1. In passing, it is worth observing that this neatly explains why there should be no presumption that the price of oil should be anywhere near the marginal cost of extraction.

What is missing here is some consideration of general equilibrium issues. That will determine the initial condition that is consistent with the behaviour of all agents, and will also provide dynamics even in a flexible-price model. Peter Sinclair has a nice paper, sadly as yet unpublished although available in preliminary form (Sinclair 2006), tying Hotelling into a macroeconomic model of optimal Ramsey growth with exhaustible resources. I will sketch his argument here. Clearly, from the Hotelling rule in general equilibrium (with perfect competition) the marginal product of oil, for example, must be rising at the rate of interest along the steady state path. So in equilibrium the real quantities (both for production and consumption) must be such that this holds. Sinclair discusses what determines the steady state.[2] The steady state here relates to variables that in this non-stochastic model are stationary: the interest rate; the proportional rate at which 'oil' is extracted; output growth; and the ratio of consumption to capital. Output, capital and the price of 'oil' all grow. It is the constellation of deep parameters such as the rate of time preference, the rate of technical progress and population growth that determine the steady state. Only a shock to such fundamental parameters will perturb the steady state path. But other shocks may have an influence on the short-term path.

Suppose that there is an unexpected discovery of 'oil'. This would leave the steady state real interest rates and steady state rates of output growth and 'oil' extraction unaffected, although welfare would be higher and the paths for the levels of output and consumption would both jump. The 'oil' price would tumble on impact, and overshoot. It would jump to a point on the saddle path, along which the growth in the 'oil' price would differ from the long-run interest rate. Precise dynamics would depend on specific parametrisations. But my point is that there are real models that exhibit jumps in the 'oil' price and which may exhibit overshooting, but that overshoot need not be driven by sticky prices.

In the long run, what will determine the price of commodities? Although extraction costs are not in the formal model, a secular decline over time may well be a prime candidate for the long-run rise in prices to be less than implied by the interest rate. Higher impatience (the pure rate of time preference) will raise the real rate of interest so the spot price will jump down and the real oil price will rise faster in the long run. Eventually, the new level of prices will cross the previous path. Other deep parameters have other effects. As usual, it is hard to talk about the level of output or capital 'affecting' the price because they are endogenous; similarly, the rate of interest is endogenous. However, we might be able to say something about how output or interest rates co-move with 'oil' prices after a specific shock. If over time shocks tended to be of the same species, we would observe apparently stable, but essentially reduced-form, relationships between different endogenous and non-stationary variables (the real oil price and output, for example).

Taken literally, Hotelling suggests that the 'oil' price will be 'integrated of order 1' (I(1)) (unless the interest rate is a constant, in which case it will be trend stationary). Sinclair's (2006) Macro-Hotelling model also suggests that the 'oil' price will be I(1), and cointegrated or co-breaking with fundamental drivers. But

2. Sinclair (1994) has a similar structure.

those drivers are hard to measure. In a similar vein, Pindyck (1999) argues from a partial equilibrium perspective that such prices should revert to unobservable stochastic trends. However, from the co-movements of endogenous variables, we might observe cointegration with output, or indeed the long-run interest rate. Nevertheless, we should be aware this does not imply a structural relationship. This is a point that Lutz Killian has made repeatedly in a different way in his analysis of oil prices using structural decompositions, as is made clear, for example, in the title of Kilian (2009) 'Not All Oil Price Shocks Are Alike'.

Still on the subject of univariate time series properties, in an interesting paper, Lee, List and Strazicich (2005) look at the real prices of 11 natural resources from 1870 to 1990. They have a unit root test which allows for endogenously determined structural breaks with and without a quadratic trend. Contrary to some earlier research cited in their paper (for example, Berck and Roberts 1996), they find evidence against the unit root hypothesis for all price series. Natural resource prices are stationary around deterministic trends with structural breaks. So this is not strictly consistent with Hotelling unless the real interest rate is non-stochastic. But the message to take away is that breaks may matter.

It must be said that the commodities examined in Jeffrey and Andrew's paper are not exclusively exhaustible. Agricultural commodities are not usually thought of as such, although a read of Jared Diamond (2005, for example) provides plenty of examples where agricultural output has been (and often remains) unsustainable. Of course, there is an inventory arbitrage condition at work in any storable commodity, to which the authors appeal in their motivation.

So to return more specifically to the paper, in Frankel's formal model (Frankel 1986) we also have price jumps, where the mechanism is not capital accumulation but sticky prices *à la* Dornbusch (1976). But in both cases we have short-run dynamics that are converging on the long-run – $\overline{q}$ in terms of the paper. In the less formal model, we have a variety of mechanisms at work. On interest rates, to quote the related paper Frankel (2006, p 5):

> High interest rates reduce the demand for storable commodities, or increase the supply, through a variety of channels:
>
> - by increasing the incentive for extraction today rather than tomorrow (think of the rates at which oil is pumped, gold mined, forests logged, or livestock herds culled)
> - by decreasing firms' desire to carry inventories (think of oil inventories held in tanks)
> - by encouraging speculators to shift out of commodity contracts (especially spot contracts), and into treasury bills.

So I suppose my question is, what are we looking at – short-run dynamics or long-run determinants? I think the answer is that the authors take an eclectic approach and try to tease out what the data tell us. In which case we might ask how best to do that.

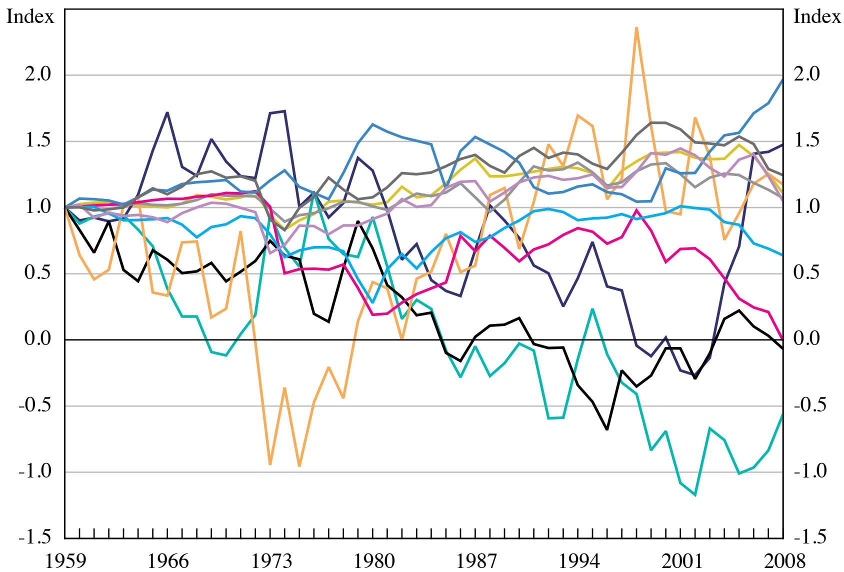
I was raised in what is sometimes called the Oxford-Copenhagen view of time series analysis, which takes the distinction between stationary and non-stationary data very seriously. This, and my discussion above, pushes me towards an analysis where there is a long-run relationship between commodity prices and their fundamentals, perturbed by shocks, with equilibration towards the long run that does not have to take place exclusively via prices: that is, a vector error correction mechanism (VECM). And it is not obvious, given the differences between commodities, that either the long-run relationships or short-run dynamics are common between the commodities.

While the authors report some cointegration tests and present results in an appendix, it strikes me as worthwhile to think more about these issues, particularly because several of the series included in their VECMs appear to be stationary. I have already suggested that prices may follow stochastic trends, and that things that move the steady state around will be cointegrated with prices. So one might expect to find cointegration with those long-run drivers, if one could work out what they are. However, that is a difficult task. I have also argued that we might observe a (non-structural) relationship between the level of output and the oil price. If technical progress were deterministic, we might also observe a linear trend, which is mainly what the authors use in their regressions. So these might be specifications worth exploring, with the stationary 'micro' series relegated to the dynamics. A lack of data might make this difficult, however, as the annual series mean that the number of data points is small.

One prominently exploited aspect of the paper is that the data constitute a panel. While I have argued that, in principle, long-run shocks are unlikely to be identical across the series, it may be true that there remains considerable co-movement in the price series. I took quarterly series of the real prices of cattle, copper, corn, hogs, soybeans, wheat and oil that I had to hand from 1977:Q1 to 2009:Q2. Two principal components explain 83 per cent of the variation of this data in levels terms. Similarly, in Jeffrey and Andrew's annual data set, two principal components explain 81.5 per cent (53.3 per cent) of the variance of the price levels (inflation rates). These are high proportions that by themselves support pooling, but inspection of the loadings on the two factors show that they vary markedly between series, indicating heterogeneity. So despite the common variance, this suggests that pooling the data will not necessarily be helpful. Another way to look at this is to simply compare the time series of the price series as shown in Figure 2 (these are normalised to unity at the start of the sample). I have not labelled the series, as the point of this exercise is to highlight the diversity in the data. The figure suggests to me that at least the long-run drivers do differ. Perhaps the panel approach is most helpful for assessing the short-run covariances and dynamics.

One way of modelling this short-run dependence might be to estimate a seemingly unrelated regression (SUR) on individual error correction mechanism (ECM) relationships. Pesaran, Shin and Smith (1999) suggest a related pooled mean group (PMG) approach. They argue that in dynamic panels there may be common long-run effects that may increase efficiency of estimation if they are exploited. I suspect those common effects are implausible in this case, but given we have a small system here we might be able to feasibly estimate a SUR without imposing long-run homogeneity, although higher-frequency data would probably be necessary. Alternatively, if the aim is to estimate the average long-run effects of the variables in the system, then the PMG method may be efficient even in the absence of homogeneity in the parameters; there is a Hausman test for this.

Figure 2: Real Log Levels of the Frankel and Rose Data
Normalised to unity at start of sample



Note: Deflated using US GDP deflator
Sources: Federal Reserve Bank of St. Louis; Frankel and Rose (this volume)

To conclude, both the authors' and a possible general equilibrium Ramsey growth theory suggest that there are long-run relations and short-run dynamics to model. Unfortunately, this may not best be captured in an essentially static framework. Exhaustible and agricultural products are likely to be driven very differently, again suggesting that pooling may not be the obvious approach to adopt. A VECM or system ECM approach might shed some different light on what drives commodity prices. Or perhaps an attempt to identify shocks, as in Lutz Killian's work, might be productive.

References

Berck P and M Roberts (1996), 'Natural Resource Prices: Will They Ever Turn Up?', *Journal of Environmental Economics and Management*, 31(1), pp 65–78.

Diamond JM (2005), *Collapse: How Societies Choose to Fail or Survive*, Allen Lane Science, London.

Dornbusch R (1976), 'Expectations and Exchange Rate Dynamics', *Journal of Political Economy*, 84(6), pp 1161–1176.

Ehrlich PR (1981), 'An Economist in Wonderland', *Social Science Quarterly*, 62, pp 44–49.

Frankel JA (1986), 'Expectations and Commodity Price Dynamics: The Overshooting Model', *American Journal of Agricultural Economics*, 68(2), pp 344–348.

Frankel JA (2006), 'The Effect of Monetary Policy on Real Commodity Prices', NBER Working Paper No 12713.

Hotelling H (1931), 'The Economics of Exhaustible Resources', *The Journal of Political Economy*, 39(2), pp 137–175.

Kilian L (2009), 'Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market', *American Economic Review*, 99(3), pp 1053–1069.

Lee J, JA List and MC Strazicich (2005), 'Nonrenewable Resource Prices: Deterministic or Stochastic Trends?', NBER Working Paper No 11487.

Pesaran MH, Y Shin and RP Smith (1999), 'Pooled Mean Group Estimation of Dynamic Heterogeneous Panels', *Journal of the American Statistical Association*, 94(446), pp 621–634.

Pindyck RS (1999), 'The Long-Run Evolution of Energy Prices', *The Energy Journal*, 20(2), pp 1–27.

Sinclair PJN (1994), 'On the Optimum Trend of Fossil Fuel Taxation', *Oxford Economic Papers*, 46, Special Issue on Environmental Economics, pp 869–877.

Sinclair PJN (2006), 'A Simple Guide to the Basic Macroeconomics of Oil', Centre for Dynamic Macroeconomic Analysis Conference Paper No 06/08. Available at <http://www.st-andrews.ac.uk/economics/CDMA/papers/cp0608.pdf>.

2. General Discussion

Much of the discussion surrounding Jeffrey Frankel and Andrew Rose's paper focused on the results related to the macroeconomic rather than the microeconomic determinants of commodity prices. A number of participants were concerned that measures of world economic activity did not have a more significant role in explaining commodity prices given their prior beliefs. Some participants wondered whether this was due to problems with constructing a measure of global activity relevant to commodity prices. One participant commented that world GDP was not the best measure of world output and that using other measures of industrial output may yield different results. Another suggested that the authors should experiment with some of the measures used by Lutz Kilian, or Ine Van Robay's measure of industrial production, which includes China. Andrew Rose responded by noting that their paper reports results based on a wide range of measures of global output, but that the findings were consistent across all of these. He thought that it might be worth trying some of the industrial production measures that had been suggested, but if they produced a different outcome to those of the other measures of output they had already examined, the overall conclusion would have to be that the results for global activity are not very robust. Other participants wondered whether some of the effects of stronger economic activity over recent years had been captured instead by the measure of inventories.

In response to Simon Price's questions about what drives the long-run evolution of commodity prices and how the long-run dynamics might be estimated, Andrew Rose suggested that the 48-year span of the dataset was insufficient for estimating the long-run relationship between commodity prices and macroeconomic factors, particularly given that the data were annual.

The discussion also touched on issues surrounding the nature of the supply side of commodity markets. In particular, given considerable differences in the elasticities of supply across commodities and differences in the long-term evolution of the prices of the commodities examined, there was some scepticism regarding the value of the paper's results based on pooled regressions. Andrew Rose emphasised that that is why they also had looked at unpooled results in the robustness checks, which were consistent with the pooled results. He again emphasised that much of the variation of the commodity prices over time could be accounted for by microeconomic factors. Even so, a participant suggested that more could be done to better understand the role of supply-side factors in determining commodity prices. In this regard, reference was made to previous episodes of significant commodity price movements where supply-side factors appeared to have played an important role, such as the oil price movements of the 1970s. Similarly, it was argued that the more recent run-up in commodity prices was partly a function of tight supply due to the lack of global exploration for commodities in the 1990s. Andrew Rose sympathised with the comments, but pointed to constraints on available data which precluded the use of supply-related variables.

Finally, the discussion turned to what the results, considered together with the framework of the paper, might imply for the level of commodity prices. There was particular interest in the question of whether commodity prices are indeed sustainable at the higher levels of late. Andrew Rose noted that their results had little to say on this question, but that it was an interesting area for future research. One participant noted that the rise of commodity prices over recent years had reversed a long downward trend associated with considerable productivity growth in the resources sector, and wondered if such trends will reassert themselves in time.

Oil Price Shocks, Monetary Policy and Stagflation

Lutz Kilian[1]

1. Introduction

One of the central questions in recent macroeconomic history is to what extent monetary policy, as opposed to oil price shocks, contributed to the stagflation of the 1970s. Understanding what went wrong in the 1970s is the key to learning from the past. One explanation explored in Barsky and Kilian (2002) is that worldwide shifts in monetary policy regimes not related to the oil market played a major role in causing both the subsequent oil price increases and stagflation in many economies. A competing view exemplified by Bernanke, Gertler and Watson (1997) is that the oil price shocks of the 1970s arose exogenously with respect to global macroeconomic conditions, but were propagated by the reaction of monetary policy-makers, causing stagflation in the process. The argument is that policy-makers responded to the inflationary pressures caused by oil price shocks by raising interest rates, thereby causing a deep recession that would not have occurred without the central bank's intervention. If policy-makers are only partially successful in controlling inflation, stagflation will ensue.

A challenge for macroeconomists is to explain why stagflation never occurred again after the 1970s and more generally why the economy has remained remarkably resilient to the sustained real oil price increases from 2003 to mid 2008. Although Hamilton (2009) documented that these oil price increases ultimately have contributed to the economic decline that followed the financial crisis of 2007–2008, without doubt this response has been far more muted, smaller in magnitude and more delayed than most economists would have imagined based on the historical precedent of the 1970s and early 1980s. Moreover, even granting that oil price increases contributed to the current recession, inflation has remained stable and there is no evidence of stagflation. The question is what makes recent events so different from the earlier episodes of oil price shocks in the 1970s.

The analysis of Barsky and Kilian (2002) implies that there is no reason to expect stagflation to occur again because there have been no more major monetary policy shifts since the early 1980s. Price stability has become universally accepted as the

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key objective of monetary policy. To the extent that the public views the central bank's commitment to price stability as credible, the pass-through from oil price shocks to the domestic price level is not associated with sustained inflation. This view fully explains the absence of stagflation in recent years, but necessitates an alternative explanation of the recent surge in the real price of oil. Kilian (2009b) and Kilian and Hicks (2009) have made the case that indeed this latest oil price shock was driven not by monetary policy shifts in OECD economies as in the 1970s, but by structural economic changes in emerging Asia.

If, in contrast, we believe that stagflation is caused by the endogenous monetary policy response to oil price shocks, we may try to explain the absence of stagflation as the result of improved monetary policy responses to oil price shocks. In that view, the central bank – by quenching completely the inflationary pressures associated with unexpectedly high oil prices – prevents stagflation from arising, but at the cost of a recession. The problem is that the data do not show a significant recession between 2003 and mid 2008, so this explanation seems implausible. An alternative explanation is that oil price shocks are no longer as inflationary as they used to be, allowing the central bank to respond less aggressively to a given oil price shock. For example, Blanchard and Galí (2010) recently made the case that the US economy has become much more flexible since the 1980s and that the real-wage rigidities that are thought to have characterised the US economy in the 1970s have been greatly reduced. Such a structural change could help explain the remarkable resilience of the US economy to the sustained oil price increases of 2003–2007.

In Sections 2 and 3 of the paper, I explore the evidence for these two main explanations and outline implications for monetary policy. In Section 4, I consider explanations for the diminished importance of oil price shocks, including the hypothesis that US real-wage rigidities have diminished. Section 5 investigates to what extent oil demand and oil supply shocks are inherently stagflationary. In Section 6, I highlight differences between the 2003–2008 oil price shock and earlier oil price shock episodes. Section 7 discusses how the central bank should respond to oil price shocks in the context of the 2003–2008 oil price shock. Further policy implications are discussed in Section 8.

2. Shifts in Monetary Policy Regimes

There has been much interest in the Great Moderation in recent years, but a longer historical perspective reveals that US macroeconomic performance in the 1990s was not so different from the early 1960s. The aberration appears to be the period of the 1970s and early 1980s. Barsky and Kilian (2002) suggest that the 1970s were different from the preceding and following decades because of the absence of effective constraints on monetary policy. They document that the beginning and end of the 1970s coincided with major shifts in monetary policy regimes. The initial shift toward a less restrictive monetary policy regime became apparent with the breakdown of Bretton Woods, which loosened the remaining constraints on national monetary policy. As a result, monetary policy lost its anchor. An anchor was re-established only under Paul Volcker after 1979. Similar shifts in monetary policy took place in many OECD countries at the same time.

As the world economy entered uncharted territory in the early 1970s with the emergence of flexible exchange rates and as the long post-war expansion appeared to come to an end, there was much uncertainty among policy-makers and the public about the rules of the game. Policy-making entered a stage of experimentation and learning. There was increased concern about the level of employment and central bankers felt the responsibility to stimulate employment by loosening monetary constraints, even if that perhaps meant some moderate inflation. There was a collective sense in industrialised countries that some action was required.[2]

Barsky and Kilian (2002) document a dramatic increase in worldwide liquidity in the early 1970s, representing a departure from historical precedent. If inflation is sluggish, as would be the case if the public is slow to catch on to the shift in monetary policy regime, it can be shown that an unexpected monetary expansion will create a temporary output boom. Inflation will rise only slowly initially, but will continue to rise even after output has peaked, resulting in stagflation. As inflation peaks, the economy goes into recession. In practice, this recession was deepened by the decision of the central bank to raise interest rates to combat the inflationary pressures it had itself unwittingly created, as discussed in Section 3.

If we accept this explanation, why were policy-makers so slow to realise their mistake? One reason is that the acceleration of inflation coincided with the oil price shock of late 1973 and early 1974, which seemed to provide a natural explanation of the inflationary pressures at the time. After all, monetary policy seemed to have worked just fine prior to the oil price shock. Indeed, following the recession of 1974–1975 central bankers reverted to the same go-and-stop monetary policies they had adopted in the early 1970s, causing another real output boom in the late 1970s. As the public increasingly caught up to the change in monetary policy regime, however, stimulatory policies became less effective and inflation a growing concern.

Only when Paul Volcker stepped in in 1979 and insisted on the primacy of the inflation objective to the detriment of the employment objective, was this cycle broken. The monetary tightening under Volcker represented a regime shift back toward a more stable regime. As in the case of the initial shift, the public was slow to accept the permanency of the shift and inflation was slow to come down, even as the economy went into a sharp recession in the early 1980s. In essence, the same model that explains the early 1970s also applies to the early 1980s, except in reverse. Given that central bankers worldwide have accepted the primacy of the inflation objective, it is not surprising that there have been no more outbreaks of stagflation since the 1970s. Although there have been several more oil price shocks since this time, they were not followed by stagflation, suggesting that such shocks are not inherently stagflationary.

2. With the benefit of hindsight we know that central bankers had misperceptions about the level of potential output and about the extent to which inflationary pressures would materialise. Nor was the risk of undermining the central bank's credibility fully appreciated.

The fact that both inflation surges in the early and late 1970s coincided with major increases in the real price of oil is no coincidence. Economic theory predicts that the real price of oil and other industrial commodities respond endogenously to fluctuations in global real activity, because the demand for industrial commodities is tied to the state of the global business cycle. To the extent that the increases in global liquidity in the early and mid 1970s fostered a global output boom, they also drove up the prices of oil and other industrial commodities. Much has been made of the quadrupling of nominal oil prices in the early 1970s, for example, but it is easy to forget that similar increases were common in other industrial commodity prices.[3] Recognising the endogeneity of the price of oil is important, because it means that a substantial part of the oil price increases of the 1970s was not a causal factor, but rather a symptom of deeper causes, namely the preceding monetary expansions. It also means that we cannot think of these oil price shocks as occurring in isolation, while holding everything else constant. Rather they are part of a broader pattern of price and quantity responses triggered by the earlier monetary policy regime shift.

The fact that the oil price increases of the 1970s were driven in substantial part by a shift in the monetary policy regime does not mean that *all* oil price shocks are due to monetary policy shifts. In fact, these were the only episodes in history in which monetary policy regime shifts caused major oil price increases. Not only are shifts in monetary policy regimes rare, but it takes concerted regime shifts in many countries to exert enough demand pressure to drive global commodity prices. This was the case both in the early 1970s and in the early 1980s, when most industrialised countries followed the US lead.

The key economic mechanism at play here is that unexpected fluctuations in the global business cycle drive oil and other industrial commodity prices. The cause of these global business cycle fluctuations is secondary. For example, unexpected productivity gains in industrialised countries or the emergence of newly industrialising economies in Asia, all else equal, will have effects on the demand for commodities and their prices similar to the effects of global shifts in monetary policy regimes. Kilian (2009b) and Kilian and Hicks (2009), using alternative methodologies, demonstrate, for example, that the rapid surge in the real price of oil between 2003 and mid 2008 can be explained on the basis of unexpected growth in emerging Asia in conjunction with strong growth in the OECD.

There are other potentially important determinants of the price of oil such as oil supply shocks or oil-market specific demand shocks. Kilian (2008c, 2009b) demonstrates that oil supply disruptions have had very limited effects historically on the real price of oil, not only since the mid 1980s, but even in the 1970s and early 1980s. There also is growing interest in the role of uncertainty (and more generally of shifts in expectations) on the demand for crude oil, notably during 1979, 1990–1991 and possibly after 2003 (see, for example, Kilian 2008c, 2009b; Dvir and Rogoff 2009; Alquist and Kilian

3. A comparison of the evolution of these prices is complicated by the fact that oil prices were kept artificially low by contractual agreements in the early 1970s, whereas industrial commodities were freely traded. For a detailed analysis of this and competing explanations of these historical episodes based on oil supply shocks see Barsky and Kilian (2002, 2004) and Kilian (2009a).

forthcoming). While there is no compelling evidence of such effects in recent data, there is considerable evidence that expectations-driven demand shifts mattered in 1979 and 1990–1991. While some of these shocks may be viewed as exogenous with respect to macroeconomic conditions, a key insight is that in general oil price shocks cannot be treated as exogenous.

3. Monetary Policy Reactions

Now consider the alternative view that stagflation is inexorably tied to the endogenous response of the central bank to exogenous oil price shocks. How should a monetary policy-maker in an oil-importing country respond to an oil price shock? For simplicity, suppose that a one-time oil price shock occurs, while everything else is held constant. There are two main channels of transmission. One is the increased cost of producing domestic output (which is akin to an adverse aggregate supply shock); the other is the reduced purchasing power of domestic households (which is akin to an adverse aggregate demand shock). The latter channel of transmission may be amplified by increased precautionary savings and by the increased cost of operating durables that use energy (see Edelstein and Kilian 2009).

Empirical evidence suggests that the supply channel of transmission is weak and that the demand channel of transmission dominates in practice (see Kilian 2008b). On that basis one would expect an oil price shock, if it occurs in isolation, to be recessionary and deflationary, suggesting that there is no reason for monetary policy-makers to raise interest rates. In fact, one could make the case that policy-makers should lower interest rates to cushion the recessionary impact. Moreover, if both the aggregate demand and the aggregate supply curves shift to the left, as seems plausible, the net effect on the domestic price level is likely to be small, so there is little need for central bankers to intervene.

This is, of course, not the interpretation favoured by economists ascribing recessions to the monetary policy reaction to oil price shocks. Bernanke *et al* (1997), for example, implicitly take the stand that exogenous oil price shocks are inherently adverse aggregate supply shocks that are both recessionary and inflationary. Their argument is that the recessionary impact in the absence of a monetary policy reaction is weak, but that the potential inflationary impact can be substantial, perhaps owing to wage-price setting dynamics. If it is correct that oil price shocks empirically are associated with significant recessions, then a natural conjecture is that the central bank, in combating the inflationary pressures emanating from oil price shocks, causes that recession. The reason that Bernanke *et al* were drawn to this interpretation is simply that conventional explanations of the link between oil price shocks and recessions based on the direct effects of oil price shocks had failed at explaining the recessions of 1974–1975 and 1982, yet the conventional wisdom at the time was that there must be a causal link.

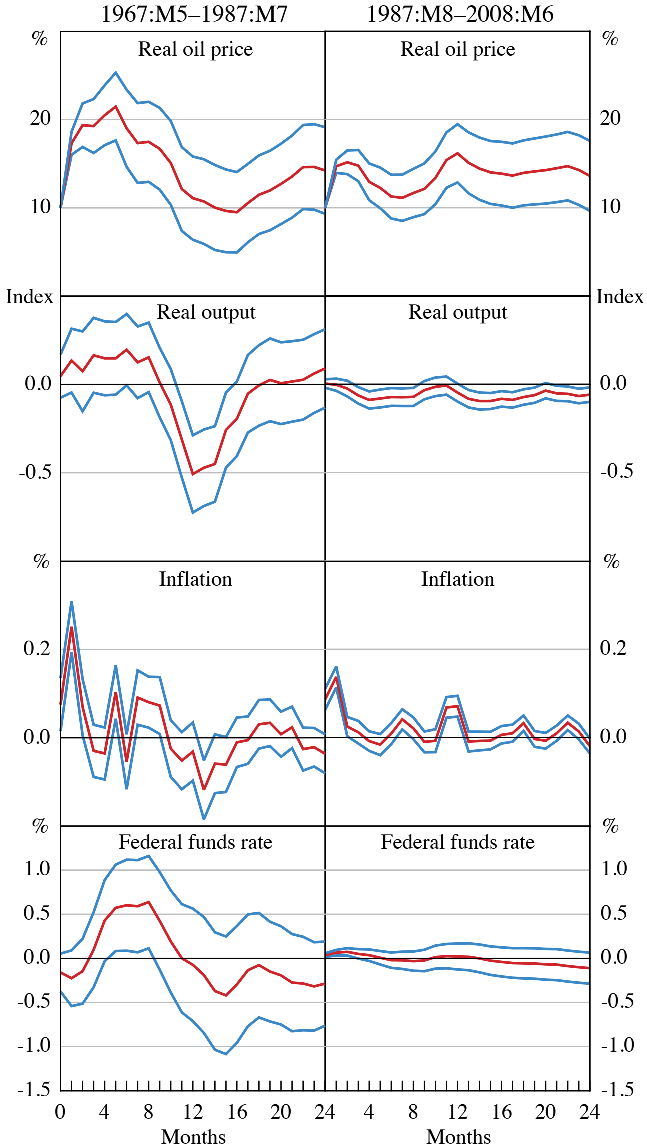
With the benefit of hindsight, the rationale for the type of monetary policy reaction described by Bernanke *et al* (1997) is weak. Unless a good case for the existence of a wage-price spiral can be made, oil price shocks would not be expected to cause sustained inflation. More importantly, the recent literature has established that oil price shocks do not take place in isolation, violating the premise of the analysis in Bernanke *et al*. This point matters. For example, Nakov and Pescatori (2010) demonstrate that a welfare-maximising central banker should not respond to innovations in the price of oil. More generally, Kilian (2008b) observes that policy-makers should respond not to the price of oil (which is merely a symptom rather than a cause), but directly to the underlying demand and supply shocks that drive the real price of oil along with other macroeconomic variables.

This does not mean that we should not take Bernanke *et al*'s (1997) explanation seriously. Even if there is no good justification for such a policy response in light of recent research, it may have seemed perfectly reasonable to policy-makers at the time. What then is the evidence that monetary policy reactions caused the recessions that followed earlier oil price shocks? Bernanke *et al* – and subsequent papers building on their analysis – utilised semi-structural vector autoregressions to support their interpretation. Their model included censored changes in nominal oil prices. Kilian and Vigfusson (2009) show that the impulse response estimates constructed from such censored vector autoregressive (VAR) models are inconsistent because the underlying structural model cannot be represented as a vector autoregression and because the impulse response functions were computed ignoring the nonlinearity of the model. Moreover, Kilian and Vigfusson formally show that there is no statistical evidence against the hypothesis of symmetric responses in positive and negative oil price shocks.

Following Kilian and Lewis (2009), I address this problem by fitting a recursively identified monthly linear VAR model for the percentage change in real commodity prices, the percentage change in the real price of oil, US real output expressed in deviations from trend, US CPI inflation, and the federal funds rate. The measure of real output is the monthly CFNAI principal components index constructed by the Federal Reserve Bank of Chicago. The sample period is May 1967 to June 2008 and the VAR contains 12 lags. How well does this model fit the data? Figure 1 shows selected impulse response estimates for the May 1967 to July 1987 and August 1987 to June 2008 sub-samples.[4] The start of the second sub-sample coincides with the beginning of Greenspan's tenure as Fed chairman. All responses have been normalised to represent the effects of an unanticipated 10 per cent real oil price shock. The estimated responses for the first sub-sample are similar to those in Bernanke *et al* (1997). An oil price shock causes a persistent increase in the real price of oil, a temporary increase in inflation, followed by a temporary increase in the federal funds rate, and ultimately a reduction in inflation and a temporary decline in real output about one year later, exactly as hypothesised in the literature. Interestingly, there is no evidence that these responses are stagflationary.

4. The full sample estimates are qualitatively similar to the first sub-sample, while somewhat smaller in magnitude, indicating that the experience of the 1970s and early 1980s dominates the empirical results for the full sample.

Figure 1: US Responses to Real Oil Price Shocks
With one-standard error bands



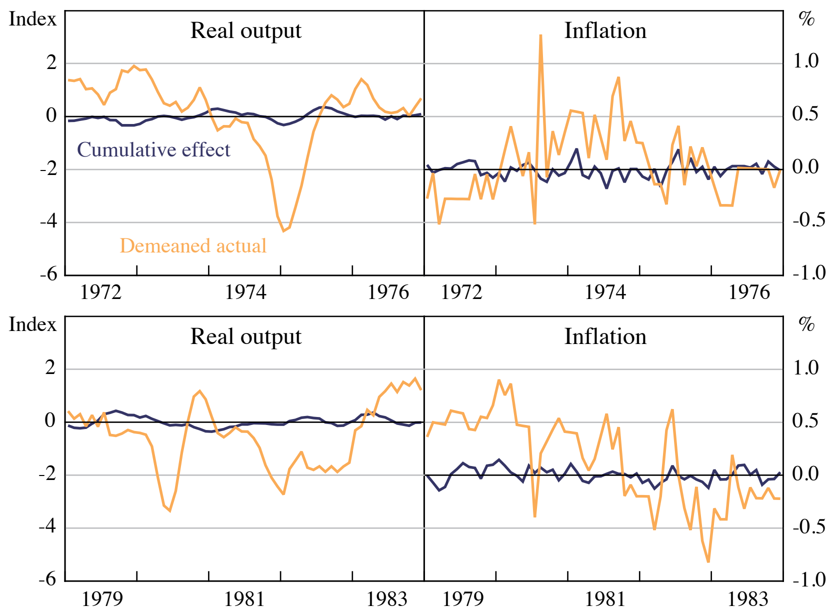
Notes: Real output refers to the Chicago Fed National Activity Index (CFNAI) principal components business cycle index. Estimates are based on a recursively identified VAR(12) model for the percentage change in real Commodity Research Bureau commodity prices, the percentage change in the real price of oil, CFNAI, CPI inflation and the federal funds rate.

Source: Kilian and Lewis (2009)

In sharp contrast, the same model applied to post-1987 data shows no evidence at all of an interest rate response or a substantial decline in real output. There is no indication that monetary policy reactions to oil price shocks played any role after the mid 1980s. This means that the evidence in favour of the policy reaction hypothesis is driven by the 1973–1974 and 1979–1980 oil price shocks. It is instructive to focus on the ability of this VAR model to explain the evolution of the US data during these two episodes. Figure 2 shows the cumulative effect of oil price shocks through time on US real output and inflation. It is evident that oil price shocks had little impact on observed real activity and inflation in the United States even in the first sub-sample. Based on this model, we conclude that there is no evidence that central bankers caused the recessions of the 1970s and early 1980s in an effort to stabilise inflation.

Figure 2: Cumulative Effect of Real Oil Price Shocks on US Real Output and Inflation

Selected episodes



Note: See Figure 1

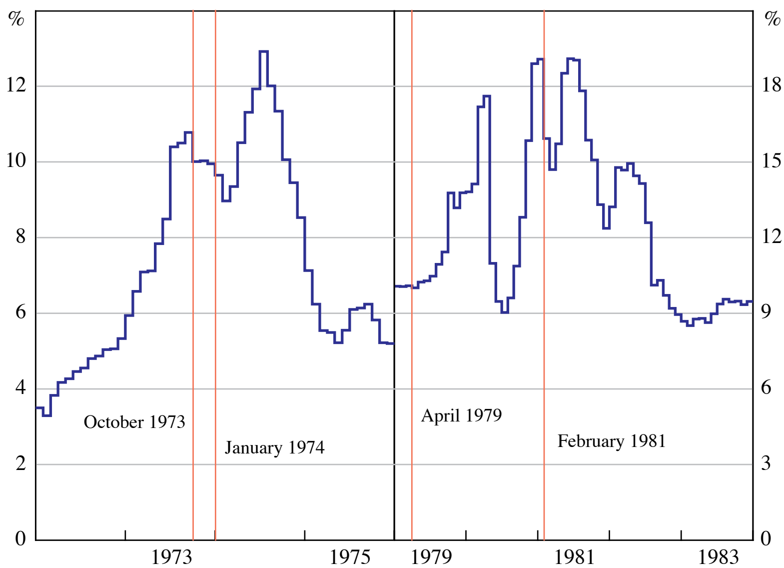
Source: Kilian and Lewis (2009)

It is noteworthy that even Bernanke *et al*'s (1997) original analysis, which we have to be sceptical of for the reasons discussed above, concluded that the 1974–1975 recession was not caused by the Federal Reserve's reaction to the oil price shock.[5] This result is consistent with evidence from Federal Reserve policy statements (see

5. Specifically, Bernanke *et al* (1997) concluded: '[T]he 1974–75 decline in output is generally not well explained by the oil price shock. The … major culprit was (non-oil) commodity prices. Commodity prices … rose very sharply before this recession and stimulated a sharp monetary policy response of their own' (p 121).

Barsky and Kilian 2002). The Fed, by its own account, was responding to rising industrial commodity prices when it continuously raised interest rates long before the oil price shock of late 1973. The observed rapid increases in global industrial commodity prices in 1972–1973 were an indication of an overheating global economy, consistent with the analysis in Barsky and Kilian. In fact, the Fed's initial reaction to the doubling of nominal oil prices in October 1973 was to lower the interest rate, consistent with the interpretation of oil price shocks as adverse aggregate demand shocks (see Figure 3). Only in the months after the second doubling in January 1974 were interest rates increased, reaching a peak in July 1974.

Figure 3: The Evolution of the Federal Funds Rate during the Oil Price Shocks of the 1970s and Early 1980s



Notes: In October 1973 and January 1974 the nominal price of oil doubled. April 1979 marks the beginning of the 1979 oil price surge; in February 1981 the price of imported crude oil peaks.

Source: Board of Governors of the Federal Reserve System

Equally noteworthy is that, regarding the 1979–1980 oil price shock, Bernanke *et al* (1997) found that at best part of the subsequent recession was attributable to the Fed's reaction to this oil price shock.[6] Given the erratic evolution of the federal funds rate between April 1979, when oil prices started their ascent, and the oil price peak of February 1981 (documented in Figure 3) it is not surprising

6. 'The decline in output through 1981 is well explained by the 1979 oil price shock and the subsequent response of monetary policy. After the beginning of 1982, the main source of output declines … was the lagged effect of the autonomous tightening of monetary policy in late 1980 and 1981' (Bernanke *et al* 1997, p 121).

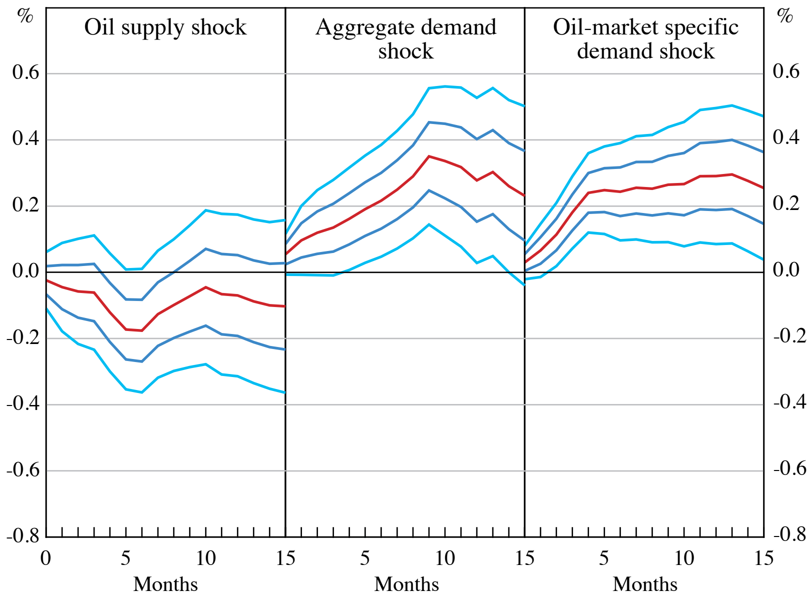
that simple policy rules about how the Federal Reserve responds to oil price shocks do not fit the data well.

The fact that Bernanke *et al*'s only evidence for monetary policy responses to oil price shocks comes from the 1979–1980 episode is troublesome because there is reason to suspect the existence of an identification problem for this episode. When Paul Volcker raised interest rates, did he do so in response to the oil price shock of 1979 or in response to rising inflation driven by domestic policies? Since both interest rates and oil prices moved at about the same time, it is difficult to separate correlation from causation. Given the additional evidence in Figure 2 that the empirical evidence for 1979–1980 is much weaker than suggested by Bernanke *et al*'s original results, even that concern seems moot. The linear symmetric model suggests that there is no evidence that the monetary policy reaction to the 1973–1974 and 1979–1980 oil price shocks was the primary cause of the subsequent recessions, nor does this policy reaction model appear to be a good representation of policy actions in the post-1987 period.

The lack of temporal stability in these VAR model results could be due to a number of reasons. Perhaps the most obvious reason, in light of the earlier discussion about the endogeneity of oil price innovations, is that one would expect the Federal Reserve to respond differently to oil price shocks associated with, say, unexpected booms in global demand, than oil supply disruptions. For example, an unexpected demand boom driven by the global business cycle will stimulate the US economy in the short run, whereas an oil supply disruption will not, calling for potentially different policy responses, depending on the underlying composition of oil price shocks. Figure 4 investigates this point by adding the federal funds rate as the fourth variable to the recursively identified VAR model utilised in Kilian (2009b).[7] I trace out the effects on the federal funds rate of unanticipated oil supply disruptions ('oil supply shocks'), unexpected positive innovations to the global business cycle ('aggregate demand shocks') and demand shocks that are specific to the oil market ('oil-market specific demand shocks'). Figure 4 shows that the Federal Reserve tends to respond to positive oil demand shocks by raising the interest rate, whereas it tends to lower the interest rate in response to oil supply disruptions. The former responses are statistically significant at the 5 per cent level, whereas the latter are not. The positive response to aggregate demand shocks in particular is consistent with the Fed's decision to raise interest rates long before the oil price shock of late 1973. The negative response to unanticipated oil supply disruptions is consistent with the view that the Federal Reserve views the resulting oil price increases as adverse aggregate demand shocks. Interpreting the positive response to demand shocks in this context is more difficult, as higher oil prices are but one of many consequences of such demand shocks.

7. This exercise is based on Kilian and Park (2009). The assumption that oil demand and supply shocks are predetermined with respect to the interest rate is consistent with evidence in Kilian and Vega (2008).

Figure 4: Response of the Effective Federal Funds Rate to Oil Supply and Oil Demand Shocks
With one- and two-standard error bands



Source: Kilian and Park (2009)

4. The Role of Real-wage Rigidities

To the extent that an unexpected one-time increase in the price of crude oil, all else equal, will be passed on to retail consumer prices, the question arises of how the central bank should respond to the resulting inflationary pressures. In the absence of real-wage rigidities, there is no reason for the central bank to be concerned with such a one-time event. As long as the monetary policy regime is credible, an inflation targeter may allow for drift in the price level without jeopardising the objective of stable medium-term inflation.[8] Only if the economy is subject to recurring oil price shocks for extended periods, as during 2003–2008, is there a risk that the public may begin to doubt the central bank's determination to contain inflation. This is more likely if the oil price shock occurs in an environment of monetary instability. If inflation expectations have become unhinged, there will be a tendency to respond to (or even anticipate) upward revisions in the price level. As consumption real wages drop in response to an oil price shock, workers will aim to offset these losses by insisting on higher nominal wages. This may give rise to a wage-price spiral. If workers are successful at preserving the real wage, unemployment will ensue. This

8. In contrast, a price-level targeter would have to tighten monetary policy to restore the initial price level.

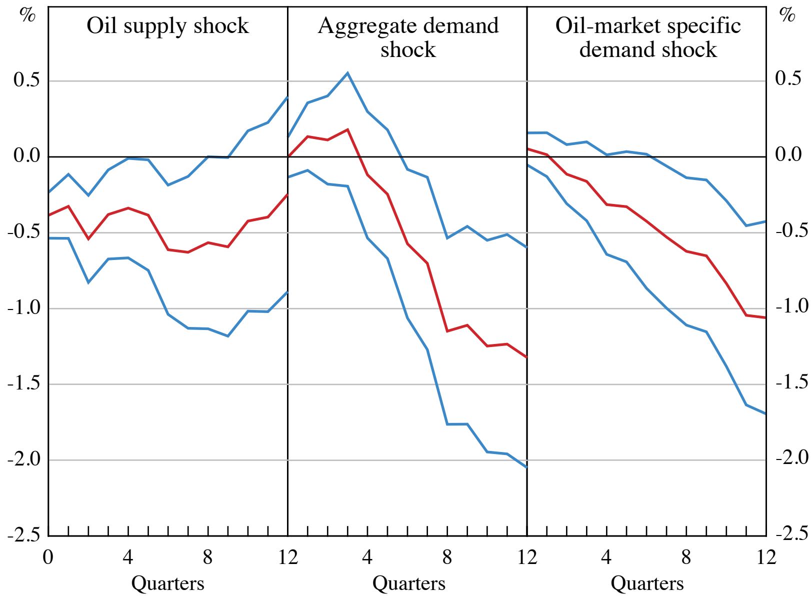
observation explains why a central bank has to be especially vigilant of inflation risks and move more aggressively to combat inflationary pressures, when inflation expectations are no longer anchored.

It is useful in its own right to investigate the hypothesis that reduced real-wage rigidities help explain the diminished importance of oil price shocks for US real output and inflation documented in Figure 1. The notion of real-wage rigidities was originally designed to explain high European unemployment (see Bruno and Sachs 1982). The idea was that strong unions tend to resist cuts in real wages associated with increases in the price level. To the extent that higher oil prices are passed on to consumers, unions insist on raising the nominal wage to preserve the real wage level. Excessively high real wages in turn cause unemployment. While this explanation may sound vaguely plausible for European economies, it seems less appealing for the United States. Clearly, US real wages fell in response to oil price shocks even in the 1970s and 1980s (see Rotemberg and Woodford 1996, for example). Although the real wage response shows some variability over time, there is no indication that it has systematically increased in magnitude since the mid 1980s. Recently, Blanchard and Galí (2010) therefore have refined the argument. Since the response of unemployment to the same shock has declined dramatically over time, they suggest that the decrease in real wages, which required a large increase in unemployment in the 1970s, today is achieved with barely any increase in unemployment, consistent with a reduction in real-wage rigidities.

It is not clear that this argument is valid, however, since the composition of oil demand and supply shocks underlying the innovations to the price of oil has changed over time. The structural VAR estimates in Kilian (2009b) suggest that each oil demand and oil supply shock involves different responses of US real output (see Figure 5) and unemployment. As a consequence, the estimated responses of these aggregates to oil price innovations will evolve with changes in the composition of oil demand and oil supply shocks. To the extent that global aggregate demand shocks have increased in importance in recent years, one naturally would expect precisely the diminished unemployment response documented by Blanchard and Galí (2010), even in the absence of structural changes in labour markets. In fact, this is one of the central implications of Kilian (2009b). Figure 6 shows that a structural model can fully account for the diminished importance of oil price shocks in 2002–2007 compared with 1979–1982, for example, even in the absence of structural change. This does not preclude that real wages may have become more flexible, as conjectured by Blanchard and Galí (2010), but it says that no direct evidence has been presented that supports that hypothesis.

Figure 5: Response of US Real GDP to Oil Supply and Oil Demand Shocks

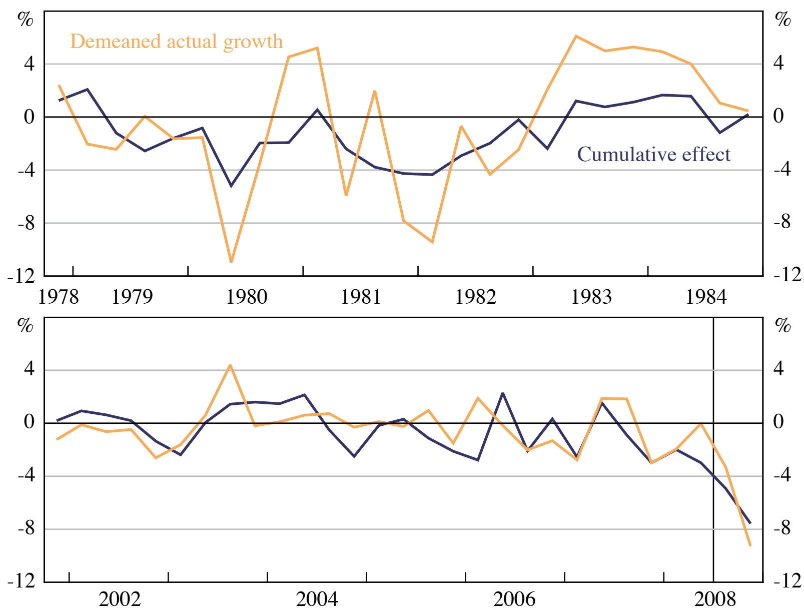
With one-standard error bands



Source: Kilian (2009b)

Figure 6: Explanatory Power of Oil Demand and Oil Supply Shocks Combined for US Real GDP Growth

Selected episodes



Note: The vertical line marks mid 2008 when global real economic activity peaked

Source: Based on Kilian (2009a)

We can, however, use cross-country evidence to assess the plausibility of the real-wage rigidity argument. For example, it is uncontroversial that real-wage rigidities in continental Europe (and in the United Kingdom prior to Margaret Thatcher) must have been higher than in the United States. If the degree of real-wage rigidities were the primary explanation of the severity of the real output response to oil price shocks, we would expect these countries to have performed worse than the United States during major oil price surges. Table 1 shows the economic performance of the G7 countries during selected oil price shock episodes. The data show that no G7 country experienced as steep a decline in real GDP growth (relative to average growth) following the 1973–1974 and 1979–1980 oil price shocks as the United States, contradicting the real-wage rigidity hypothesis.

Table 1: Real GDP Growth Rates Relative to Long-run Average in G7 Countries

Selected episodes of oil price shocks, per cent

	1973:Q4–1975:Q2	1978:Q4–1980:Q3	1980:Q4–1983:Q1	1990:Q3–1993:Q3
United States	–3.84	–2.64	–1.87	–1.30
Canada	–0.24	–0.41	–2.56	–2.71
France	–1.06	–0.24	–0.37	–1.72
Germany	–3.38	0.15	–2.01	2.33
Italy	–2.01	2.10	–1.66	–1.96
Japan	–1.75	1.00	0.17	–1.19
United Kindgom	–3.50	–2.45	–1.14	–2.02

Source: Kilian (2008a)

It may seem that perhaps differences in energy intensity across countries could also explain this pattern of results. If the United States were more energy-intensive than Europe and Japan, then, not controlling for energy intensity, US economic performance in Table 1 could look worse than that of other countries. While time series data on energy intensity by country are not readily available, an additional comparison suggests that this alternative explanation is unlikely. It seems reasonable to presume that the degree of real-wage rigidity in any one country was approximately constant between 1973–1974 and 1979–1980. Germany, Italy and Japan all experienced below-average real GDP growth following the first oil crisis, yet these same countries experienced above-average growth following the second oil crisis. Even granting some improvement in energy efficiency over this time period, this sign reversal cannot be explained by changes in energy intensity or changes in real-wage rigidities. It is consistent, however, with the view that Japan, for example, conducted very different monetary policies during the first and the second oil price shock (see Bohi 1989).

It is important to stress that not only are reduced real-wage rigidities not a plausible explanation of the diminished importance of oil price shocks since the mid 1980s, but neither are fluctuations in the energy share. Arguments that the declining US energy share in expenditures helps to explain the reduced importance of oil price shocks have been shown to be misleading (see Edelstein and Kilian 2007, 2009). One observation that is sometimes overlooked is that the US energy share is primarily driven by the price of oil and has rebounded sharply in recent years. Moreover, while it is true that fluctuations in the energy share have affected the transmission of energy price shocks, even controlling for the evolution of energy expenditures there is strong evidence for the reduced importance of oil price shocks. The latter phenomenon, as discussed above, is an artefact of changes in the composition of oil price shocks. It illustrates the dangers of thinking of oil price shocks as occurring in isolation from the state of the global economy.

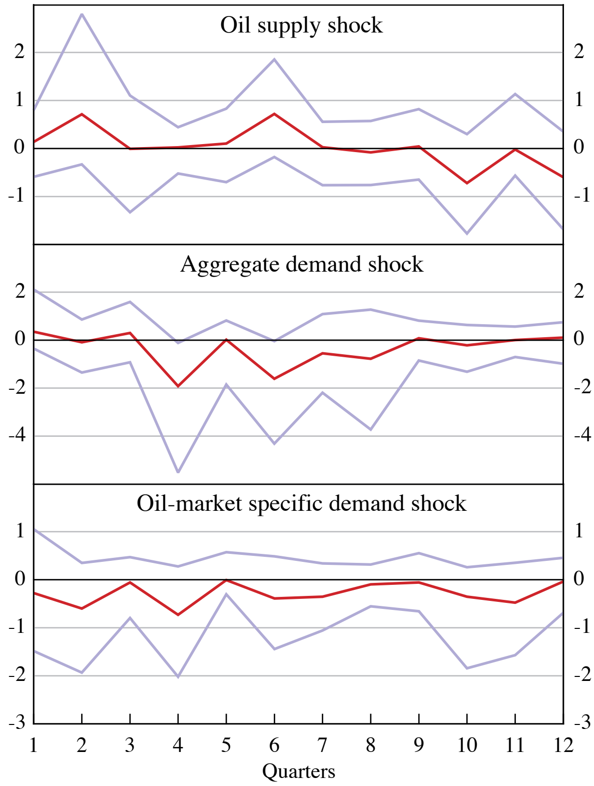
5. Are Oil Price Shocks Inherently Stagflationary?

The discussion in Section 2 stressed that stagflation may arise naturally following a shift toward a less restrictive monetary policy regime. The point was also made that oil price shocks are not necessarily stagflationary, given that none of the oil price shocks since the 1980s was associated with stagflation. Of course, that analysis is subject to the same caveat that oil price shocks in general do not represent causal determinants, but are merely symptoms of demand and supply shocks in oil markets that in turn may reflect broader global macroeconomic developments. We now take the analysis a step further and ask whether there is evidence that specific oil demand or oil supply shocks are associated with stagflationary responses. Figure 7 formally addresses this question based on a statistical measure of conditional co-movement developed by den Haan (2000). This measure is applied to the responses of US CPI inflation and US real GDP growth to each of the oil demand and oil supply shocks in the Kilian (2009b) model, allowing us to assess which – if any – of these shocks have stagflationary effects. Following den Haan and Sumner (2004, p 1340), the plot shows conditional covariances rather than conditional correlations. This normalisation facilitates a comparison of the statistic across horizons. The conditional covariance at horizon h is constructed as

$$C(h) = \Delta y_h^{imp} \pi_h^{imp} \tag{1}$$

where z_h^{imp} denotes the impulse response of variable z (either real output growth, Δy, or inflation, π) at horizon h to a given structural innovation (see den Haan 2000, p 8). Stagflation in the form of rising prices and falling output means that this measure will be negative. It is natural to conduct a one-sided test of the null of zero conditional covariance against the stagflationary alternative. Figure 7 plots 90 per cent bootstrap confidence intervals along with the point estimates. The coverage rates are chosen such that the rejection probability in the lower tail corresponds to 5 per cent. While it appears that oil demand shocks are more stagflationary than oil supply shocks, Figure 7 suggests that none of these covariances are significantly negative at conventional levels. Thus, stagflation is likely to have other causes, consistent with the analysis of Section 2.

Figure 7: Stagflationary Effects of Oil Supply and Oil Demand Shocks
With 90 per cent confidence bands



Notes: The figure shows the conditional covariance between US real GDP growth and CPI inflation, as defined by den Haan (2000). Stagflation in the form of rising prices and falling output means that this measure will be negative.

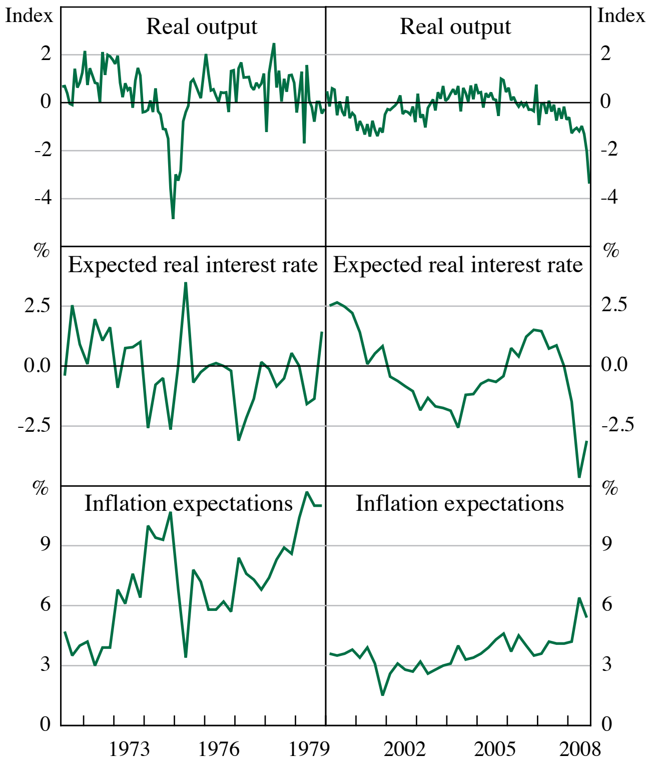
Source: Based on Kilian (2009b)

6. Did the Federal Reserve Contribute to the 2003–2008 Oil Price Shock?

Along many dimensions, the surge in the price of oil since 2003 is reminiscent of the 1970s. Given the sustained increase in both industrial commodity prices and oil prices between 2003 and mid 2008, it is natural to suspect another monetary policy regime shift in recent years. Indeed, Greenspan has been blamed with the benefit of hindsight for being too lenient in dealing with asset market bubbles, and both Greenspan and Bernanke occasionally have been criticised for being overly concerned with the employment objective. Nevertheless, as observed in Section 2, this explanation does not seem plausible. US monetary policy has been openly stimulatory only very recently in response to the mortgage and financial crisis. Given this timing, US monetary policy regime shifts are an unlikely candidate for explaining the oil price increases of 2003–2008.

Moreover, the effect of this recent monetary expansion was tempered by the credit crunch. How expansionary US monetary policy since 2001 has been may be gauged with the help of the following data. Figure 8 plots three indicators of the stance of monetary policy, allowing us to contrast the experience of the 1970s and 2000s. The first key difference is that the two monetary expansions of the early and mid 1970s coincided with real output in excess of potential output for extended periods, resulting in inflationary pressures. In contrast, the monetary expansions that have taken place since 2001 were never associated with an overheating domestic economy. One indication of the excessively easy stance of monetary policy in the early and mid 1970s was that *ex ante* real interest rates temporarily turned negative. The experience since 2001 at first sight may seem similar in that the expected real interest rate was negative between 2002 and 2006 and again in 2008. However, this superficial similarity is deceiving. Whereas the negative *ex ante* real interest rates of the 1970s were driven by rising inflation expectations, those since 2001 were driven by low nominal interest rates.

Figure 8: Indicators of the Stance of US Monetary Policy
Selected episodes



Notes: The figure shows 1-year-ahead inflation expectations from the 'Surveys of Consumers' and the corresponding *ex ante* 1-year real Treasury bill rate. Real output refers to the CFNAI principal components business cycle index.

Sources: Board of Governors of the Federal Reserve System; Federal Reserve Bank of Chicago, CFNAI; Reuters/University of Michigan, 'Surveys of Consumers'

Figure 8 shows that US inflation expectations remained remarkably stable as late as 2008:Q1.[9] Just when it appeared that inflation expectations might become unhinged after all in mid 2008, the oil and commodity price boom collapsed, along with the global economy, rendering concerns over inflation expectations moot.

Even if we grant that after 2000 the United States may have been somewhat more expansionary than called for, the degree of expansion prior to 2008 was not comparable to the 1970s. Moreover, unlike in the 1970s, there was no systematic monetary expansion elsewhere in the OECD, even granting that Japanese monetary policy during this period might be viewed as stimulatory. Without such reinforcement it is hard to see how a shift in US policy could have caused a global oil and commodity price boom. Even more to the point, Kilian (2009b) and Kilian and Hicks (2009) showed that this latest oil price boom was driven by unexpected growth in emerging Asia rather than in the OECD, as illustrated by the data on professional real GDP forecast errors shown in Table 2. What happened was not that OECD demand for oil and other industrial commodities increased substantially, as had happened in the 1970s, but that additional unexpected demand arose from emerging Asia, given continued high demand from OECD economies. This evidence on the geographic origins of demand leaves room for more subtle interpretations. One hypothesis is that the weak US dollar helped stimulate global demand for crude oil. Implicit in this argument is the assertion that the weakening US dollar was caused by US monetary policy actions. The extent to which this was the case, however, is unclear. Moreover, it has yet to be established that exchange rate fluctuations have predictive power for the real price of oil, casting doubt on the empirical content of this hypothesis.

Table 2: Average Forecast Surprises
Percentage points

	December 2000–May 2003	June 2003–June 2008	July 2008–December 2008
Germany	–0.12	0.00	–0.33
Japan	–0.10	0.08	–0.27
United States	–0.05	0.02	–0.08
Brazil	–0.10	0.03	0.07
China	–0.04	0.12	–0.17
India	–0.06	0.03	–0.17
Russia	0.06	0.12	–0.42

Note: Average forecast surprises computed based on successive annual forecasts of real GDP growth reported by the Economist Intelligence Unit
Source: Killian and Hicks (2009)

9. While the survey data used here only relate to 1-year horizons, alternative measures of inflation expectations paint a very similar picture. For example, the 2-year and 5–10-year inflation expectations reported by Consensus Economics are flat in early 2008, notwithstanding an increase in the 1-year expectation. Likewise, the TIPS breakeven inflation rate for 5–10 years ahead shows only a slight upward drift in early 2008.

This does not mean that there is no link between strong demand for oil from emerging Asia and the state of the US economy. As observed in Kilian (2009a), a key question is how much of that unexpected growth reflected an exogenous economic transformation in emerging Asia. Clearly, part of the economic growth in emerging Asia is self-sustained and would have occurred regardless of the global monetary environment. In addition, it is conceivable that China chose to stimulate domestic growth by overly expansionary monetary policies that were exogenous with respect to policy actions in the United States.

The alternative explanation is that the Federal Reserve sustained growth in the United States longer than appropriate by easing monetary policy too early and too much, enabling the export-based Chinese economy, and more generally the world economy, to thrive and fuelling the commodity and oil price boom that contributed to the current collapse of the real economy. This possibility of a policy mistake within a given regime (rather than a policy regime shift) deserves careful study, all the more so, as China's concern over a stable exchange rate (relative to the US dollar) resulted in a similar easing in China. In this context, it has also been conjectured that perhaps the Federal Reserve overestimated productivity gains and underestimated inflationary pressures during this episode, as cheap imports from China, all else equal, lowered the US CPI.

A third explanation is that the sustained prosperity in the United States between 2002 and mid 2008 was not directly linked to monetary policy, but to the failure of the Federal Reserve and other regulators to rein in financial and housing markets. To unravel the relative contribution of each of these complementary explanations would require the help of a fully specified multi-country open economy model. While it is conceivable that allowing the US economy to slow down earlier would have somewhat alleviated the commodity price boom of 2003–2008, it seems unlikely, however, that a slower easing of monetary policy would have made much of a difference, given the relatively small magnitudes involved.

7. How Should the Central Bank Respond to Oil Price Shocks?

The oil price shock of 2003–2008 raises the broader question of how the central bank of an oil-importing economy should respond to such events. This question remains topical, as there is every reason to believe that oil prices will rise again, as soon as the world economy recovers from the financial crisis.[10]

As the analysis in Kilian (2009b) makes clear, it would be a mistake for policy-makers to respond to oil price shocks as such because relative price shocks are often merely symptoms of broader global macroeconomic developments. Rather, central banks must identify the deeper causes of oil price shocks and respond to the underlying fundamental shocks. This requires a different class of structural models

10. It is understood that a similar analysis for oil or commodity exporters such as Australia, Canada, Norway or the United Kingdom would involve many further considerations and would require a fully specified model including multiple sectors and a detailed treatment of external accounts.

than are customarily used by policy-makers. Recent advances in the DSGE modelling of oil price shocks are a step in the right direction. For example, Bodenstein, Erceg and Guerrieri (2007) model oil-market-specific demand shocks, and Balke, Brown and Yücel (2009) model the dependence of oil demand on global macroeconomic conditions. In related work, Nakov and Pescatori (2010) explicitly model the endogeneity of oil production decisions. While none of these papers provides a comprehensive analysis of all relevant aspects of the relationship between oil prices and the macroeconomy, a new class of models is beginning to emerge. In addition, future work will have to incorporate in more detail the external transmission of oil demand and oil supply shocks (see Kilian, Rebucci and Spatafora 2009) as well as the nexus between crude oil prices and retail energy prices (see Edelstein and Kilian 2009). DSGE models may also allow us to distinguish between alternative causes of fluctuations in the global demand for industrial commodities, and to simulate the impact of alternative policy choices of the type discussed in Section 6.

In contrast, the traditional monetary policy reaction framework explored by Bernanke *et al* (1997) and incorporated in subsequent DSGE models has outlived its usefulness. In fact, it is not clear whether this framework ever was an adequate description of central bank behaviour. Nor is the textbook distinction between exogenous transitory (that is, white noise) and exogenous permanent (or, more precisely, random walk) oil price shocks useful. First, the persistence of the oil price response depends on the nature of the underlying shocks and on the policy reaction and is not exogenously given. Second, the degree of persistence of the responses to oil demand and oil supply shocks in general evolves along a continuum. Neither limiting case seems empirically relevant. Empirical evidence suggests that oil price responses are persistent, but ultimately transitory. Third, once we recognise that oil demand shocks may have direct effects on the economy not operating through the real price of oil, it becomes clear that the persistence of the responses may differ from one variable to the next and there is no particular interest in the oil price response.

The appropriate policy response to oil price shocks will depend on the composition of the underlying oil demand and oil supply shocks. In the specific case of the 2003–2008 oil price shock, the fundamental problem was one of oil demand growing faster than oil supplies. The extent to which global demand pressures translate into increases in industrial commodity prices depends on how elastically those commodities can be supplied. Although all industrial commodity prices increased substantially in recent years and metals prices, for example, more than tripled in real terms, the real price of crude oil more than quadrupled. This outcome reflects the evolution of the supply of crude oil. Table 3 shows that a substantial increase in global crude oil production took place between mid 2001 and mid 2008. Production of crude oil increased by 12.5 per cent compared with 14.5 per cent in the six years following January 1974. Growth in global oil production, however, all but ceased after 2005, which helps explain the steep rise in the price of oil in 2007–2008 in particular. A likely explanation of this pattern is not so much that the world is running out of oil in the foreseeable future, but that the threat of expropriation in many oil-producing countries has prevented the flow of much needed investments.

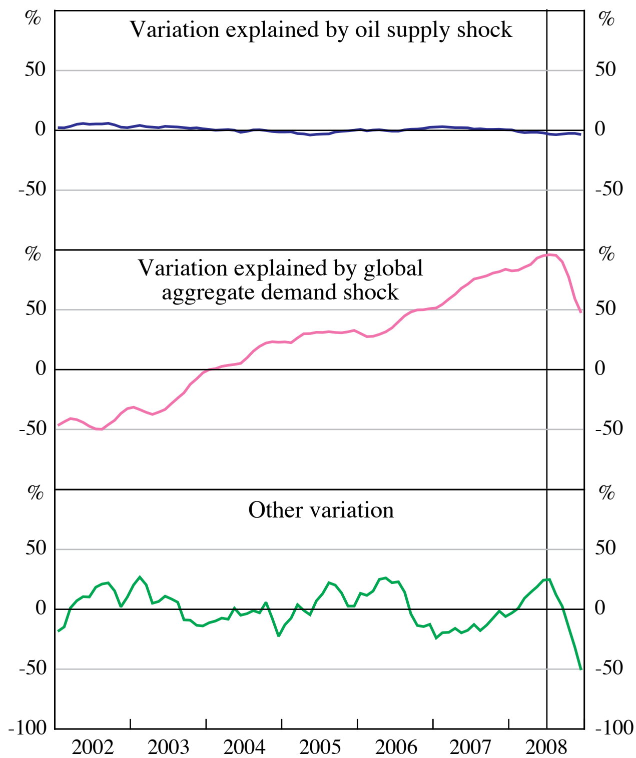
Table 3: Cumulative Growth Rates of Crude Oil Production
Selected periods, per cent

	January 1974–December 1979	June 2001–May 2008
World	14.5	12.5
Persian Gulf	4.0	23.7
OPEC	0.6	19.0
Non-OPEC, non-US	51.6	11.0
United States	–3.6	–10.4

Source: Based on data from *Monthly Energy Review*, Energy Information Administration

Figure 9 is based on the analysis in Kilian (2009a). It illustrates that the observed increase in the real price of oil since 2003 can be attributed almost exclusively to unanticipated positive global aggregate demand shocks.[11] In contrast, the sharp decline after mid 2008, while preceded by a slowing of world real activity,

Figure 9: Explanatory Power of Oil Supply and Oil Demand Shocks for the Real Oil Price



Note: The vertical line marks mid 2008 when global real economic activity peaked
Source: Kilian (2009a)

11. There is no empirical evidence to support the view that speculation was behind this oil price shock (see Kilian 2010).

also reflects historically unprecedented expectations shifts associated with the global financial crisis. Since the 2003–2008 oil price shock reflected a shift in the real scarcity of resources, there is nothing a central bank could or should have done in response, beyond making sure that inflation expectations remain anchored in the face of inflationary pressures arising from both oil and industrial commodity prices. In particular, a monetary easing would not have been appropriate, since the global demand pressures appeared highly persistent.

8. Conclusion

The analysis in this paper suggests that neither diminished real-wage rigidities nor improved monetary policy responses to oil price shocks are a plausible explanation of the increased resilience of the US economy to oil price shocks and of the absence of stagflationary responses since the mid 1980s. Rather, the increased resilience of the US economy can be traced to changes in the composition of the oil demand and oil supply shocks underlying the real price of oil. In particular, the surge in the real price of oil between 2003 and mid 2008 was driven almost entirely by a sequence of unexpected increases in the global demand for industrial commodities. These global aggregate demand pressures more than offset increases in the production of crude oil over the same time period. The resulting oil price increases reflected a persistent shift in the scarcity of oil, leaving little room for monetary policy-makers in oil-importing economies to cushion the impact of this shock. There is no evidence that oil supply shocks or speculation in oil markets played a significant role.

Since positive global aggregate demand shocks entail a stimulus for oil-importing economies, and since they raise oil prices and other industrial commodity prices only with a delay, their short-run effect on real GDP tends to be more benign than that of other oil demand or supply shocks. Only as that initial stimulus fades will the recessionary effects dominate. Thus, rising oil prices and a robust economy may coexist for several years, as long as the economy is sustained by repeated positive global aggregate demand shocks. The end of the demand boom, however, will be associated with a recession. The data indicate that global demand peaked in May 2008 and collapsed in the second half of 2008. Econometric models suggest that the drop in the real price of oil in the second half of 2008 reflected both sharply reduced global aggregate demand and the anticipation of a sustained global economic recession.

The 2003–2008 oil price shock episode has been different from the 1970s in that there is no sign that stagflation has made a comeback, although the surge in the real price of oil was larger than even in the 1970s. I have shown that the likely explanation of the absence of stagflation is the choice of a monetary policy regime that emphasises the price stability objective. Indeed, many central banks have been remarkably successful at keeping inflation expectations anchored and stable in an environment of high and rising oil prices. Central bankers are rightly proud that they have learned the lesson provided by the experience of the 1970s. This should not make us complacent, however. Armed with the insights of decades of research, it is easy to forget that central bankers in the 1970s had the best intentions and were fully aware of the potential dangers of inflation. When faced with major structural changes in the global economy, they did their best to sustain employment by an infusion of liquidity. Their perception was that for the time being inflation was the lesser risk compared with unemployment.

A common view at the time was that the economy did not work the way it used to. There was a need for experimentation. Given the complexity of the economy and the near-simultaneous occurrence of several different shocks, it proved difficult for policy-makers to determine the relative importance of alternative explanations of the macroeconomic data in real time. All these ingredients could be used to describe the current situation amidst the global financial crisis. There is the same urgency that something must be done, the same need to experiment, and the same uncertainty about the best approach. There also is a sense that for now the employment objective must have priority, and that moderate inflation seems like a small price to pay for avoiding a financial collapse. Finally, there is again great uncertainty about the level of potential output.

This is not to say that policy-makers have lost sight of the inflation objective. In fact, there is a consensus that the Federal Reserve must withdraw the liquidity (and capital infusions) currently needed to keep the financial system from collapsing, once the economy recovers. In practice, however, determining the right time for withdrawing this excess liquidity is about as difficult as guessing when the stock market will recover. In both cases, the right timing depends on business and consumer confidence. There will be a tendency to downplay the risks of inflation relative to those of high unemployment in the event of a financial collapse and to delay the removal of infusions of capital and liquidity, all the more so as business and consumer confidence are fragile. If the economy moves closer to potential than envisioned, one could easily imagine a situation that looks not so different from that faced by policy-makers after the breakdown of Bretton Woods. A situation that may require higher interest rates, higher taxes, and less spending to deal with the fiscal deficit could prove especially challenging. Thus, the real test of whether we have learned the lessons of the 1970s is yet to come.

References

Alquist R and L Kilian (forthcoming), 'What Do We Learn from the Price of Crude Oil Futures?', *Journal of Applied Econometrics*.

Balke NS, SPA Brown and MK Yücel (2009), 'Oil Price Shocks and U.S. Economic Activity: An International Perspective', mimeo, Federal Reserve Bank of Dallas.

Barsky RB and L Kilian (2002), 'Do We Really Know that Oil Caused the Great Stagflation? A Monetary Alternative', in BS Bernanke and KS Rogoff (eds), *NBER Macroeconomics Annual 2001*, 16, MIT Press, Cambridge, pp 137–183.

Barsky RB and L Kilian (2004), 'Oil and the Macroeconomy since the 1970s', *Journal of Economic Perspectives*, 18(4), pp 115–134.

Bernanke BS, M Gertler and M Watson (1997), 'Systematic Monetary Policy and the Effects of Oil Price Shocks', *Brookings Papers on Economic Activity*, 1, pp 91–142.

Blanchard OJ and J Galí (2010), 'The Macroeconomic Effects of Oil Price Shocks: Why Are the 2000s So Different from the 1970s?', in J Galí and M Gertler (eds), *International Dimensions of Monetary Policy*, University of Chicago Press, Chicago, pp 373–421.

Bodenstein M, Erceg CJ and L Guerrieri (2007), 'Oil Shocks and External Adjustment', Board of Governors of the Federal Reserve System International Finance Discussion Paper No 897.

Bohi DR (1989), *Energy Price Shocks and Macroeconomic Performance*, Resources for the Future, Washington DC.

Bruno M and J Sachs (1982), 'Input Price Shocks and the Slowdown in Economic Growth: The Case of U.K. Manufacturing', *Review of Economic Studies*, 49(5), pp 679–705.

den Haan WJ (2000), 'The Comovement between Output and Prices', *Journal of Monetary Economics*, 46(1), pp 3–30.

den Haan WJ and SW Sumner (2004), 'The Comovement between Real Activity and Prices in the G7', *European Economic Review*, 48(6), pp 1333–1347.

Dvir E and KS Rogoff (2009), 'The Three Epochs of Oil', Boston College Working Paper in Economics No 706.

Edelstein P and L Kilian (2007), 'The Response of Business Fixed Investment to Changes in Energy Prices: A Test of Some Hypotheses about the Transmission of Energy Price Shocks', *B.E. Journal of Macroeconomics*, 7(1) (Contributions), Article 35.

Edelstein P and L Kilian (2009), 'How Sensitive Are Consumer Expenditures to Retail Energy Prices?', *Journal of Monetary Economics*, 56(6), pp 766–779.

Hamilton JD (2009), 'Causes and Consequences of the Oil Shock of 2007–08', *Brookings Papers on Economic Activity*, 1, pp 215–261.

Kilian L (2008a), 'A Comparison of the Effects of Exogenous Oil Supply Shocks on Output and Inflation in the G7 Countries', *Journal of the European Economic Association*, 6(1), pp 78–121.

Kilian L (2008b), 'The Economic Effects of Energy Price Shocks', *Journal of Economic Literature*, 46(4), pp 871–909.

Kilian L (2008c), 'Exogenous Oil Supply Shocks: How Big Are They and How Much Do They Matter for the U.S. Economy?', *Review of Economics and Statistics*, 90(2), pp 216–240.

Kilian L (2009a), 'Comment on "Causes and Consequences of the Oil Shock of 2007–08" by JD Hamilton', *Brookings Papers on Economic Activity*, 1, pp 267–278.

Kilian L (2009b), 'Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market', *American Economic Review*, 99(3), pp 1053–1069.

Kilian L (2010), 'Explaining Fluctuations in Gasoline Prices: A Joint Model of the Global Crude Oil Market and the U.S. Retail Gasoline Market', *Energy Journal*, 31(2), pp 103–128.

Kilian L and B Hicks (2009), 'Did Unexpectedly Strong Economic Growth Cause the Oil Price Shock of 2003–2008?', CEPR Discussion Paper No 7265.

Kilian L and LT Lewis (2009), 'Does the Fed Respond to Oil Price Shocks?', mimeo, Department of Economics, University of Michigan.

Kilian L and C Park (2009), 'The Impact of Oil Price Shocks on the U.S. Stock Market', *International Economic Review*, 50(4), pp 1267–1287.

Kilian L, A Rebucci and N Spatafora (2009), 'Oil Shocks and External Balances', *Journal of International Economics*, 77(2), pp 181–194.

Kilian L and C Vega (2008), 'Do Energy Prices Respond to U.S. Macroeconomic News? A Test of the Hypothesis of Predetermined Energy Prices', CEPR Discussion Paper No 7015.

Kilian L and RJ Vigfusson (2009), 'Pitfalls in Estimating Asymmetric Effects of Energy Price Shocks', Board of Governors of the Federal Reserve System International Finance Discussion Paper No 970.

Nakov A and A Pescatori (2010), 'Monetary Policy Trade-Offs with a Dominant Oil Producer', *Journal of Money, Credit and Banking*, 42(1), pp 1–32.

Rotemberg JJ and M Woodford (1996), 'Imperfect Competition and the Effects of Energy Price Increases on Economic Activity', *Journal of Money, Credit and Banking*, 28(4), pp 549–577.

Discussion

1. Andrew Filardo[1]

Lutz Kilian offers a thought-provoking paper that contributes to our evolving understanding of the role of oil prices and the macroeconomy. What is truly remarkable about this paper is Lutz's ability to shed new light on this topic. This latest effort complements his impressive research in this area over the past decade, which has explored the monetary policy challenges that central banks face as oil prices swing high and low.

In this paper, Lutz provides compelling evidence that global demand developments have been the key factor behind the recent behaviour of oil prices. This conclusion is important for at least three reasons. First, since the 1970s, oil price shocks have generally been considered by economists to be a quintessential example of a macroeconomic supply shock. Lutz essentially tells us that such a view has been too simplistic and possibly misleading in current circumstances. Second, this demand-side interpretation suggests that the nature of the macroeconomic stabilisation policies for addressing movements in oil prices should be different from that of policies implemented when oil price movements represent supply shocks. Third, his conclusions run counter to the way many around the globe in the past few years have characterised the oil price developments buffeting their economies, especially in Asia and the Pacific. In this sense, his results should contribute significantly to the ongoing policy debate.

Lutz's paper also provides important insights into one of the questions that the organisers raised in their original call for papers: does the behaviour of relative price changes associated with commodity prices call for a new framework with which to think about policy trade-offs? In my commentary, I would like to draw some implications of his findings for monetary policy frameworks that emphasise the global perspective, rather than the more familiar country-centric one.

Admittedly, Lutz's focus in this paper is quite narrow, looking only at oil prices in the United States. Clearly, the relevance of his results goes well beyond this one commodity and this one country. Indeed, the recent behaviour of oil prices has largely been consistent with that of a wide range of other energy and non-energy commodities. This should not be a surprise; oil and other energy and non-energy commodities are traded globally and the prices are determined by a myriad of global demand and supply factors. Furthermore, the consequences of shocks to oil prices extend well beyond the territorial boundaries of the United States, to other developed and developing economies alike. It is in these two senses that Lutz's conclusions can be reasonably generalised and have implications for a wider range of central banks.

1. The views expressed are those of the author and not necessarily those of the Bank for International Settlements. The author extends his thanks to the Reserve Bank of Australia for the opportunity to participate in its annual research conference.

The role of global supply and demand factors is certainly not new but has received renewed attention in recent years. In part, it reflects the greater appreciation of the forces associated with economic and financial globalisation. Earlier in this decade, surprisingly low import prices underscored the development of more flexible and efficient global production centres, especially in emerging market economies. More recently, as Lutz highlights, the increased demand for, and prices of commodities reflect such factors too.

From a theoretical perspective, Woodford (2007) provides a stronger foundation for the monetary policy importance of global factors by showing how to extend the now canonical new Keynesian Phillips curve policy framework to an open economy setting. Even though his conclusions emphasised the continued effectiveness of country-centric monetary policies, he also showed the potential importance of global output gaps in determining inflation and output dynamics. The evidence in Lutz's paper provides valuable information about how one may calibrate these models and how to think about the evolving policy trade-offs as the nature of the shocks hitting economies has been changing.

Others have explored the empirical record to find evidence of the rising importance of global factors in macroeconomics. Borio and Filardo (2007), for example, find evidence that is consistent with that of Lutz's conclusion that global demand shocks have been playing a more dominant role since the 1970s. Namely, inflation dynamics in the past two decades have been less correlated with the big swings in oil prices once global demand factors are taken into account.

In this light, a key policy question is whether the apparent rise in the significance of global demand shocks calls for a change in the way we think about the monetary policy challenges facing central banks. Some argue that as long as exchange rates send the appropriate signals about nominal and real macroeconomic developments, a country-centric perspective is sufficiently applicable. However, exchange rates do not always behave in a way that is consistent with textbook models (see Engel 2009, for example).

An alternative view would emphasise the greater role of global demand shocks and their far-reaching implications for monetary policy frameworks. In particular, global shocks may require a more global policy perspective. At a minimum, this suggests that central banks need to better understand the evolving nature of the shocks hitting their economies – especially as economic and financial globalisation proceeds apace. Domestic authorities naturally have less detailed information about external shocks and, of course, will have much less ability to influence the underlying sources of the shocks. In the case of oil or other commodities, altering the size of the domestic output gap and influencing the exchange rate will at best only partially offset the forces.

The greater importance of external developments on the domestic macroeconomy also suggests big payoffs from international monitoring efforts. This would be particularly true if pressures were to arise abroad well before the spillovers reach one's national borders. Early policy reactions could naturally reduce the likelihood of policy-makers finding themselves behind the proverbial policy curve. And, it is possible that policy-makers across jurisdictions could forge an appropriate consensus about the global nature of the potential problems and hence take appropriate actions earlier than otherwise.

Of possible greater concern, the recent commodity price boom raises an issue about whether a country-centric (or, more appropriately, domestic economy-centric) perspective could lead central banks astray. In particular, if a boom in commodity prices for a (net) commodity-importing economy is perceived to be a supply shock rather than a global demand shock, the policy responses may lead to a procyclical policy bias. For example, consider the following thought experiment: a surge in commodity prices is driven by a *shift* in global demand (*along* a more steeply sloped aggregate supply curve). In this case, output would grow robustly even as prices of all types of commodity inputs rise. A hypothetical global monetary authority would therefore tighten monetary policy so as to counteract the shift in aggregate demand. And, if calibrated correctly, non-inflationary sustainable growth would be achieved. This thought experiment highlights a very stylised, and admittedly overly simplistic, policy trade-off and an unambiguous policy prescription.

But this stark prescription stands in sharp contrast to the way in which many central banks appeared to address the run-up in commodity prices in 2006–2008. In many economies, central banks kept nominal policy rates relatively low as real policy rates (based on headline CPI inflation) were close to zero and even negative in some cases. One explanation for the low policy rates could be that the economic prospects were seen to be much worse than what transpired prior to the bankruptcy of Lehman Brothers. Another possible explanation is that the financial headwinds from the global financial crisis were sufficiently worrisome that monetary policy countermeasures were necessary. There are certainly other possible conventional justifications. However, it is plausible in some jurisdictions that the commodity price boom was initially perceived to represent a supply shock, possibly driven by, amongst other things, speculative behaviour (see Dooley, this volume). If Lutz is right that the commodity price boom was primarily a global demand phenomenon rather than a supply phenomenon, it is not surprising that an accommodative policy stance (that is, a procyclicality bias) arose.

In addition, Lutz's focus on the role of global demand in driving oil market developments of late suggests that policy-makers need to be wary about applying the lessons from both the oil crisis in the 1970s and the subsequent conquest of the inflationary potential of oil price swings in the 1980s and 1990s. In a nutshell, the experience of the earlier periods illustrated that a monetary authority with a credible medium-term inflation anchor could follow a strategy consistent with constrained discretion, that is, the monetary authority could 'look through' transitory supply shocks when setting monetary policy. As long as inflation expectations are well anchored, relative price movements would lead to some volatility of headline inflation but underlying inflation would remain on target without unnecessary gyrations in nominal policy rates. While this is a reasonable perspective, the lessons do not necessarily extend to a situation where commodity prices are being driven by global demand shocks. Taken together, the possible misinterpretation of such lessons and the possible misinterpretation of the demand nature of the shock could account for a procyclicality bias that led to a pick-up in inflationary pressures through the middle of 2008 in many jurisdictions.

What does this all mean going forward? Lutz raises the spectre of stagflation. However, in August 2009, the threat of imminent stagflation in the near term seems minimal because the collapse of global demand has led to the marking down of expectations of inflation over the medium term around the world, and even the possibility of short-term deflation in some jurisdictions as lower commodity prices pass through to both headline and core inflation. Moreover, notwithstanding the prospect of a global recovery beginning to take hold, with ample spare productive capacity globally, the threat of an imminent rise in inflation seems low.

This reading of current conditions does not suggest that monetary policy challenges have become much simpler. On the contrary, while central banks around the world are still dealing with the waning forces associated with the global financial crisis, many central banks, especially those in Asia and the Pacific, are facing a different configuration of challenges. Instead of stagflation, the big risks ahead are more likely to be medium-term ones and to come from another round of boom-bust dynamics, in which commodity prices could figure prominently. If the predictions of Asia-Pacific leading the global recovery come true, it is not implausible to expect to see a resurgence of capital inflows (and carry trades) to the region as policy rates begin to normalise later this year and next. The extent of the flows this time around could be much greater in light of the huge amount of macroeconomic stimulus (especially the considerable liquidity expansion) in the pipeline in most jurisdictions. In conjunction with the region's strong inflation-fighting credibility (Filardo and Genberg 2009), these flows could stoke asset prices (including commodities) and raise concerns about the effectiveness of domestic monetary policies in the region, especially if monetary authorities were unconvinced of the wisdom of allowing a significant appreciation of their respective currencies.

In conclusion, the insights of Lutz are quite important. He reminds us that central bankers are best able to address their challenges if they truly understand the changing nature of the policy environment. My discussion has underscored the importance of not only assessing the nature of the shocks hitting the economy but also thinking about the monetary policy trade-offs from a less conventional global perspective when the key shocks are global in nature.

References

Borio C and A Filardo (2007), 'Globalisation and Inflation: New Cross-Country Evidence on the Global Determinants of Domestic Inflation', BIS Working Paper No 227.

Engel C (2009), 'Exchange Rate Policies', paper prepared for the Wrap-up Conference of the BIS Asian Research Programme 'The International Financial Crisis and Policy Challenges in Asia and the Pacific', Shanghai, 6–8 August.

Filardo A and H Genberg (2009), 'Targeting Inflation in Asia and the Pacific: Lessons from the Recent Past', paper presented at the 6th Norges Bank Monetary Policy Conference, Oslo, 11–12 June.

Woodford M (2007), 'Globalization and Monetary Control', NBER Working Paper No 13329.

2. General Discussion

There was a lot of debate about Lutz Kilian's conclusion that monetary policy played an important role in contributing to the stagflation of the 1970s. One participant commented that the run-up in inflation appeared to begin in the mid 1960s, rather than the 1970s, but that people took time to learn about both this and the fact that monetary authorities were not tightening policies sufficiently to counter rising inflation. Learning about these developments, however, helped to keep inflation high in the 1970s. Hence, models with gradual learning would imply less of a role for the oil price shock in causing high inflation in the 1970s. Other participants agreed that the policies implemented in the 1970s deviated from sound policy rules, contributing to the observed stagflation. Lutz Kilian concurred with these observations while cautioning that the implications of a model with learning may depend on the nature of the oil price shocks.

A number of participants agreed that the nature of the oil price shock in the 1970s was quite different from that which affected oil prices from 2003 to 2008. Lutz Kilian remarked that the general consensus is that the 1970s oil price rise was due to a supply shock, which has made oil price rises and supply shocks synonymous. However, he noted that if the data of that period are examined closely, there is little evidence that changes in supply led to significant movements in the price of oil. In addition, regarding the potential role of speculation in driving the recent rise in oil prices, he pointed to flat oil inventories over time as evidence against this view.

The rest of the discussion focused on the role of countries other than the United States in oil price shocks. One participant followed up on Andrew Filardo's comment that the paper was too focused on the results of the United States as compared to other areas of the world. It was suggested that any second-round effects of oil demand or supply shocks may be more significant in the euro area countries compared to the United States because of differences in their economic structures; if so, this would have implications for appropriate monetary policy responses. In reply, Lutz Kilian referenced theoretical research on the welfare implications of policy responses to oil price shocks and suggested that optimal monetary policy should not respond to the price of oil by itself, but rather the underlying demand and supply shocks driving the price of oil.

Following on from this comment, there was a suggestion that the paper was too quick to dismiss the results of previous studies. In particular, one participant noted that real wages have become more flexible in the United States since the 1970s and that when inflation expectations are anchored, people respond to shocks through flexible real wages. Lutz Kilian replied by reiterating his findings that there is little evidence for declining real wage rigidity in the United States, and that it does not constitute a first-order issue in problems of this kind.

It was noted that when discussing policy responses to shocks in the price of oil and other commodities, it was important not to ignore the role of positive supply shocks in developing countries, such as in China's manufacturing sector. It was suggested that positive supply shocks in developing countries had led policy-makers elsewhere to be less concerned about rising commodity prices because low manufacturing prices worked to offset commodity price increases, thereby reducing inflationary pressures. Subsequent discussion touched on the influence of exclusion-based measures of core inflation in guiding monetary policy decisions. It was suggested that exclusion-based measures of core inflation understate true inflationary pressures given that such measures discard rising energy and food prices, but capture the disinflationary effect of positive productivity shocks in developing nations working through the prices of manufactured goods.

On the contribution of loose monetary policy to the run-up in oil and other commodity prices from 2003 to 2008, one participant suggested that this effect may have been more prominent than implied by Lutz Kilian's paper. Over this period, both Japan and the United States had historically low interest rates, which, combined with the loose policy adopted by China by way of their currency peg to the US dollar, may have contributed to rising oil prices through increased global liquidity.

Finally, there was a suggestion that a helpful way to distinguish between oil demand and supply shocks would be to observe the lag between the change in the price of oil and the change in prices of other commodities. If the prices of energy products are observed to move together closely, this implies a general demand shock. On the other hand, a supply shock is more likely if the prices of other energy commodities lag the price rise of oil, reflecting the impact of sluggish substitution effects. Applying this idea to the period from 2003 to 2008, almost all energy products rose in price at the same time, which is consistent with a large demand shock, particularly from China.

The Economic Consequences of Oil Shocks: Differences across Countries and Time[1]

Christiane Baumeister, Gert Peersman and Ine Van Robays

Abstract

We examine the economic consequences of oil shocks across a set of industrialised economies over time. First, we show that knowing the underlying reason for a change in oil prices is crucial to determine the economic repercussions and the appropriate monetary policy reaction. For oil demand shocks driven by global economic activity, all economies experience a temporary increase in real GDP following an oil price increase, while for oil-specific demand shocks all economies experience a temporary decline in real GDP. The effects of exogenous oil supply shocks are, however, very different across countries when oil prices increase. Whereas net oil- and energy-importing economies all face a permanent fall in economic activity following an adverse supply shock, the impact is insignificant or even positive for net energy exporters. Second, the pass-through to inflation turns out to differ considerably across oil-importing economies and strongly depends on the existence of second-round effects via increasing wages. Third, we investigate how the dynamic effects have changed over time. We document a much less elastic oil demand curve since the mid 1980s, which seriously distorts intertemporal comparisons. However, we demonstrate that economies which improved their net energy position the most over time became relatively less vulnerable to oil shocks compared to other economies.

1. Introduction

The interaction between oil and macroeconomic performance has long attracted attention in the economic literature.[2] This interest dates back to the 1970s. As shown in Figure 1, the 1970s and early 1980s were characterised by large oil price spikes. Unfavourable oil supply shocks are frequently considered to have been the underlying source of worldwide macroeconomic volatility and stagflation during that period (see, for example, Blinder and Rudd 2008). The longstanding debate surrounding the relationship between oil and the macroeconomy has recently intensified in light of dramatic oil price fluctuations. Specifically, while the price

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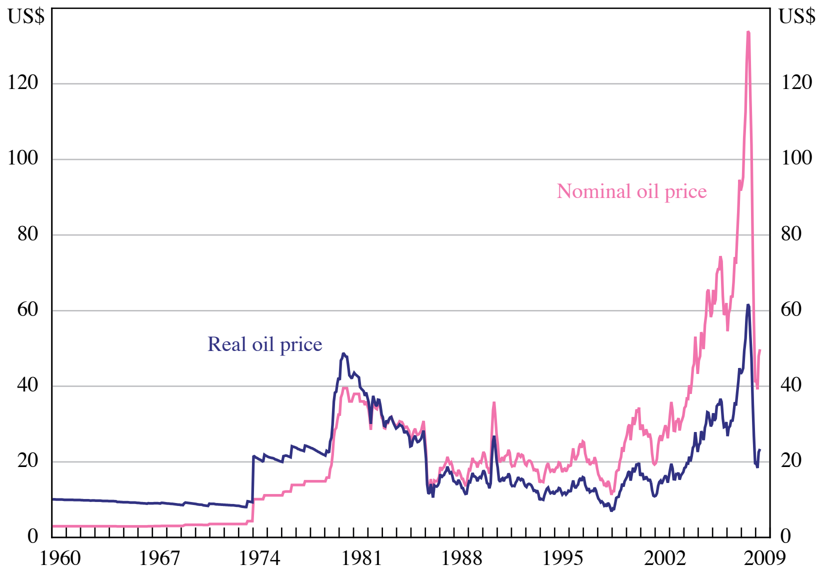
1. This paper was written for the workshop and conference on 'Inflation Challenges in an Era of Relative Price Shocks' held in Münster and Sydney in 2009. We thank Torben Hendricks and Mardi Dungey as well as the participants at both the Münster workshop and Sydney conference for their useful comments and suggestions. We acknowledge financial support from the Interuniversity Attraction Poles Programme – Belgian Science Policy [Contract No. P6/7] and the Belgian National Science Foundation. All remaining errors are ours.

2. Hamilton (1983) is the seminal academic contribution. For recent overviews, see Kilian (2008) and Hamilton (2009b).

of crude oil hovered around US$12 per barrel at the beginning of 1999, the price shot up to US$133 by the middle of 2008 and collapsed to US$39 in early 2009. In this paper, we examine the macroeconomic effects of oil shocks across a set of industrialised economies that are structurally diverse in terms of size, labour market characteristics, monetary policy regimes, and the role of oil and other forms of energy in the economy: Australia, Canada, the euro area, Japan, Norway, Switzerland, the United Kingdom and the United States. We analyse the interaction between oil and the macroeconomy from three different perspectives which can provide valuable insights for monetary policy.

Figure 1: Evolution of the Nominal and Real Price of Crude Oil



Notes: The oil price is the monthly average price of West Texas Intermediate in US dollars per barrel, real oil price (in 1982–1984 prices) deflated using monthly US CPI data

Sources: US Bureau of Labor Statistics; US Energy Information Administration; authors' calculations

First, we assess the economic repercussions of several types of oil shocks. Understanding the consequences of different oil shocks is important for formulating an appropriate policy response. It is likely that these consequences depend on the source of the oil price shift and differ across countries. Indeed, recent studies by Kilian (2009) and Peersman and Van Robays (2009b) have shown that the effects on the United States and the euro area economy vary considerably depending on the source of oil price movements. For example, exogenous disruptions in the supply of crude oil that lead to higher oil prices are expected to result in depressed economic activity and rising inflation in oil-importing economies. Alternatively, oil prices can rise because of increased demand for oil which could reflect worldwide economic expansion or precautionary motives, with potentially different effects on output.

The repercussions of oil shocks for oil-exporting economies are less clear, since rising oil prices imply higher oil export revenues in an inelastic market. Further, countries that export non-oil forms of energy could be affected by oil disturbances in a different way. Since the prices of alternative sources of energy typically rise with the price of crude oil due to substitution, oil-importing countries that produce and export other forms of energy could potentially benefit from soaring oil prices through an increased demand for their oil substitutes (Peersman and Van Robays 2009a).

In Section 2 of the paper, we investigate the extent to which the cause of the oil price increase matters for the dynamic effects across countries. Within a structural vector autoregression (SVAR) framework, a distinction is made between exogenous disruptions to oil supply, oil demand shocks driven by a thriving global economy, and oil-specific demand shocks, which could be the result of speculative activities or precautionary buying. We demonstrate different consequences depending on the underlying source of oil price shifts. After an unfavourable oil supply shock, oil- and energy-importing economies face a permanent fall in economic activity, while the impact is insignificant or even positive in net energy-exporting economies. Inflationary effects are also smaller in the latter group, which can be explained by an appreciation of their exchange rates. On the other hand, the dynamic effects of oil demand shocks driven by global economic activity and oil-specific demand shocks turn out to be much more similar across countries. In particular, for all countries, we find a transitory increase in real GDP after a global activity shock, whereas output temporarily declines following an oil-specific demand shock.

Second, we examine the transmission mechanism through which oil shocks affect inflation and economic activity. Direct effects on the general price level through rising energy prices are expected at short horizons because energy prices are a component of the consumer price index. However, additional inflationary effects may arise as higher energy input costs or higher wage demands feed through to consumer prices. These indirect effects are more delayed than the direct effects and can thus be influenced by the monetary policy reaction. For this reason, it is crucial for a forward-looking central bank to understand the transmission of oil shocks to inflation so that it can implement appropriate policy.

Following Peersman and Van Robays (2009b), we assess the quantitative importance of individual channels for all the oil-importing economies in Section 3. Consistent with the results of Peersman and Van Robays, we find that the direct effects of rising energy prices on consumer prices are significant for all economies, whereas additional indirect effects vary substantially, particularly the second-round effects. The latter are sizeable in the euro area and Switzerland, mild in Japan and absent in the United States. As a consequence, the speed and magnitude of the pass-through to consumer prices are also very different for these economies.

Finally, we investigate whether the dynamic effects of oil shocks have changed over time. On the one hand, the evolution of the monetary policy framework could explain the weaker effect of recent oil price changes. Other leading explanations for this resilience include a declining share of oil in the economy, more flexible labour markets, changes in the composition of automobile production and the overall importance of the automobile sector (see, for example, Bernanke 2006; Blanchard and Galí 2007; and Edelstein and Kilian 2009). On the other hand, the oil market itself has gone through a series of structural changes that could affect macroeconomic interactions. Lee, Ni and Ratti (1995) and Ferderer (1996) attribute the instability of the empirical relationship between oil prices and economic activity to the increased oil price volatility since the mid 1980s. Baumeister and Peersman (2008) provide evidence of a considerably less elastic global oil demand curve over time. Accordingly, more recent oil supply shocks are characterised by a much smaller impact on world oil production and a greater effect on oil prices compared to the 1970s and early 1980s, which can also bring about time-varying effects.

The steepening of the oil demand curve, as argued by Baumeister and Peersman (2008), distorts empirical comparisons of macroeconomic effects over time. By estimating the effect of exogenous oil supply shocks before and after the mid 1980s, we demonstrate that the choice of normalisation is crucial in concluding whether the economic consequences of oil shocks have changed in Section 4. In particular, when an oil supply shock is measured as a similar shift in oil prices (for example, a 10 per cent rise), the impact on real GDP and inflation becomes smaller over time, which is in line with the existing evidence comparing the impact of oil price shocks over time (for example, Blanchard and Galí 2007; Edelstein and Kilian 2009; and Herrera and Pesavento 2009). However, normalising on a similar oil price increase implicitly assumes a constant elasticity of oil demand over time, which is rejected by the data. In particular, the shift of the oil supply curve needed to generate for example a 10 per cent oil price increase is much smaller in more recent periods compared to the 1970s and early 1980s. When a typical one standard deviation oil supply shock is considered, the impact in many countries has not changed significantly over time. Whether the underlying magnitude of such an average oil shock has changed can unfortunately not be identified.

The cross-country dimension of our analysis, however, should allow us to explore the sources of time variation. Specifically, while all economies experienced a fall in oil intensity, the magnitudes have varied; some countries switched from being net oil-importers to net oil-exporters over time (for example, Canada and the United Kingdom). Accordingly, we can evaluate the relevance of the dependence on oil and other forms of energy by comparing the relative changes between countries across time. This exercise does not suffer from a normalisation problem, since the structural changes in the global oil market are the same for all countries. We show that modifications in the role of oil and other forms of energy across sub-periods are important in explaining time variation in the dynamic effects of oil shocks. In particular, countries that had the greatest improvement in their net oil and energy positions over time also became less vulnerable to oil supply shocks.

2. The Dynamic Effects of Different Types of Oil Shocks

2.1 Country characteristics

The first panel of Appendix Table B1 contains some country-specific structural indicators of the role of oil and other forms of energy. All entries are calculated as averages per unit of GDP. The role of oil is very different across the economies considered. Australia, the euro area, Japan, Switzerland and the United States are net oil-importing economies, whereas Canada, Norway and the United Kingdom are net oil-exporters. Imports of oil are considerably higher in the euro area, Japan and the United States compared to Australia and Switzerland. Australia and the United States also have a domestic oil-producing sector that cannot be ignored. On the other hand, average oil exports in Norway are about 35 times higher than in Canada and the United Kingdom.

The role of other forms of energy could also lead to cross-country differences in the dynamic effects of crude oil shocks. The prices of non-oil sources of energy, such as natural gas, typically move closely with oil prices. This is clearly the case when the oil price shift is driven by an expansion of worldwide economic activity which triggers a general surge in demand for commodities. For exogenous oil supply and oil-specific demand shocks, the magnitude of this effect will depend on the substitutability of oil with other sources of energy. Hence, an oil-importing economy that produces and exports other forms of energy could therefore still benefit from an adverse oil shock via increased demand for alternative sources of energy. Australia is a good example of this (see Table B1). Conversely, while being an oil-exporting economy, the United Kingdom is a net importer of non-oil energy. On the other hand, Canada and Norway are net exporters of both, and all other oil-importing economies (the euro area, Japan, Switzerland and the United States) also import other forms of energy. As shown in Peersman and Van Robays (2009a), the role of oil and energy can explain differences in the economic effects of oil shocks across countries. After discussing the model specification and identification in the following two sections, we reconsider their findings in light of the challenges they pose for monetary policy-makers in Section 2.5.

2.2 A benchmark SVAR model

Not every oil price increase is alike because the underlying source can differ. The oil price shocks of the 1970s, for instance, are typically attributed to exogenous shortfalls in oil production, whereas the prolonged build-up in oil prices that started in 1999 is commonly said to be mainly driven by shifts in the demand for crude oil (for example, Hamilton 2003, 2009b).[3] Knowing what drives an oil price increase is important for understanding the impact on the economy and for designing the appropriate monetary policy response. Indeed, Kilian (2009) and Peersman and

3. Barsky and Kilian (2004) argue that even the oil shocks of the 1970s were mostly demand-driven.

Van Robays (2009b) show that the economic effects of oil shocks in the United States and the euro area differ significantly depending on the cause of the oil price shift. In our analysis, we make an explicit distinction between oil supply shocks, oil-specific demand shocks, and oil demand shocks caused by global economic activity. Following Peersman and Van Robays (2009a), we rely on a SVAR framework that has the following general representation:

$$\begin{bmatrix} \boldsymbol{X}_t \\ \boldsymbol{Y}_{j,t} \end{bmatrix} = \boldsymbol{c} + A(L)\begin{bmatrix} \boldsymbol{X}_{t-1} \\ \boldsymbol{Y}_{j,t-1} \end{bmatrix} + \boldsymbol{B}\begin{bmatrix} \boldsymbol{\varepsilon}_t^X \\ \boldsymbol{\varepsilon}_{j,t}^Y \end{bmatrix}$$

The vector of endogenous variables can be divided into two groups. The first group, $\boldsymbol{X}_t$, captures the supply and demand conditions in the crude oil market and includes world oil production (Q_{oil}), the nominal refiner acquisition cost of imported crude oil expressed in US dollars (P_{oil}) and a measure of world economic activity (Y_w). The other block of variables, $\boldsymbol{Y}_{j,t}$, is country-specific and contains real GDP (Y_j), consumer prices (P_j), the nominal short-term interest rate (i_j) and the nominal effective exchange rate (S_j) of country *j*. $\boldsymbol{c}$ is a matrix of constants and linear trends, $A(L)$ is a matrix polynomial in the lag operator L, and $\boldsymbol{B}$ is the contemporaneous impact matrix of the vector of orthogonalised error terms $\boldsymbol{\varepsilon}_t^X$ and $\boldsymbol{\varepsilon}_{j,t}^Y$; $\boldsymbol{\varepsilon}_t^X$ captures the structural shocks in the oil market and $\boldsymbol{\varepsilon}_{j,t}^Y$ are shocks specific to country *j*. In this paper, we focus on shocks emanating from the crude oil market. This model is referred to as the benchmark SVAR model. A separate SVAR is estimated for each country *j*.

2.3 Identification of different types of oil shocks

Identification of the underlying structural shocks in an SVAR model requires a number of restrictions on the relationships between the endogenous variables. Kilian (2009) disentangles oil supply shocks from demand shocks by assuming a short-run vertical oil supply curve in a monthly SVAR, so shifts in the demand for oil do not have contemporaneous effects on the level of oil production. In addition, he postulates that economic activity is not immediately affected by oil-specific demand shocks. His recursive identification scheme is, however, less appropriate for estimations with quarterly data such as real GDP. He therefore averages the monthly structural disturbances over each quarter to estimate the impact on real GDP using a single-equation approach in a second step. Instead, we follow Peersman and Van Robays (2009b) and Baumeister and Peersman (2010) to recover the structural innovations by imposing the following more general sign restrictions:

Structural shocks	Q_{oil}	P_{oil}	Y_w	Y_j	P_j	i_j	S_j
1. Oil supply shock	<0	>0	≤ 0				
2. Oil demand shock driven by economic activity	>0	>0	>0				
3. Oil-specific demand shock	>0	>0	≤ 0				

The identification restrictions are derived from a simple supply and demand model of the oil market. First, an oil supply shock moves oil prices and oil production in opposite directions. Such shocks could, for instance, be the result of production disruptions caused by military conflicts or changes in the production quotas set by the Organization of the Petroleum Exporting Countries (OPEC). Following an unfavourable oil supply shock, world economic activity will either fall or not change.

Second, demand shocks result in a shift of oil production and oil prices in the same direction, as demand-driven rises in oil prices are typically accommodated by increasing oil production in oil-exporting countries. Demand for oil can increase because of changes in macroeconomic activity, which induces rising demand for commodities in general. Increasing demand from emerging economies like China is a good example. We define such a shock as an oil demand shock driven by economic activity. Accordingly, this shock is characterised by a positive co-movement between world economic activity, oil prices and oil production.

Finally, shifts in demand for oil that are not driven by economic activity are labelled oil-specific demand shocks. Fears concerning the availability of future supply of crude oil or an oil price increase based on speculative motives are obvious examples. In contrast to the demand shock driven by economic activity, oil-specific demand shocks do not have a positive effect on global economic activity since they emerge in a climate of uncertainty. Thus, the final impact on world activity could even be negative because of the associated oil price increase.

The sign conditions are imposed to hold for the first four quarters after the shocks to allow for sluggish responses. These conditions are sufficient to uniquely disentangle the three types of shocks, and no zero restrictions on the contemporaneous relationships among the oil market variables are needed. Since all individual country variables are left unconstrained in the estimations, the direction and magnitude of these responses are determined by the data. Except for the interest rate, all variables are transformed to quarterly growth rates by taking the first difference of the natural logarithm. A more detailed explanation of the data used and the estimation procedure is provided in Appendix A.

2.4 Relevance of different types of oil shocks

Variance decompositions of the benchmark SVARs indicate that disruptions in the supply of oil are the single most important driving force behind oil price fluctuations over the period 1986–2008. The two types of oil demand shocks in combination explain about the same extent of oil price volatility as the oil supply shocks.[4] The importance of exogenous oil supply disruptions is also reflected in the historical decomposition of the oil price. As shown in Figure B1, oil supply shocks drove sizeable fluctuations in the oil price, including: the considerable fall in the

4. More specifically, the contemporaneous contributions to oil price variability of an oil supply shock, an oil demand shock driven by global economic activity, and an oil-specific demand shock are 57, 27 and 16 per cent, respectively.

oil price in 1986 when Saudi Arabia decided to raise oil production; the increase in oil prices after Iraq's invasion of Kuwait in 1990; and the significant rise in the oil price in 1999 driven by the joint decision of OPEC and non-OPEC members to cut oil production. Although shocks to oil demand seem increasingly important in explaining the more recent run-up in oil prices since the early 2000s, oil production disruptions clearly remain a key factor for understanding fluctuations in the price of crude oil.

2.5 Economic consequences of oil shocks across countries

The results reported in this section are based on estimations of the benchmark SVAR model over the sample period 1986:Q1–2008:Q1 with three lags. The choice of starting date is motivated by Baumeister and Peersman (2008) who find a considerable break in the oil market dynamics in the first quarter of 1986 in a time-varying SVAR framework; the model remains relatively stable thereafter (see also Section 4). This date, which coincides with the collapse of the OPEC cartel and the start of the 'Great Moderation', is also often selected for sample splits in the oil literature.

Figures 2 to 4 summarise the estimated median impulse response functions of macroeconomic variables for each economy to the different types of oil shocks which are discussed in Sections 2.5.1–2.5.3.[5,6] Apart from the interest rate, the responses have been cumulated and are shown in levels to aid interpretation.[7] For reasons of comparability, each oil shock has been normalised in such a way that it leads to a 10 per cent long-run increase in the nominal price of oil, which is close to the observed quarterly volatility of oil prices over the estimation period. The responses for output and consumer prices are shown in Table B1 for horizons which vary depending on the type of shock.[8]

5. The responses of oil production and oil prices are shown in Section 4.1, which presents the changes in the dynamics of the oil market over time.

6. The presence of country-specific breaks in the data, for example because of changes in the monetary policy strategy, might affect some of the country-specific results. However, in order to not affect the cross-country comparability of the responses to oil shocks, no country-specific dummy variables are included in estimation.

7. Figures of impulse responses with 16th and 84th percentiles of the posterior are available from the authors on request. These bands are the 16th and 84th percentile responses of the joint draws that satisfy the imposed sign restrictions. Therefore, the error bands represent model uncertainty rather than sampling uncertainty (see Fry and Pagan 2007).

8. For the oil supply shock, the horizon for the response of GDP and the CPI is 20 quarters, to compare the permanent effects, or the long-run response of GDP and the CPI to the oil supply shock. For the global activity and oil-specific demand shocks, what is reported is the maximum response of GDP with the horizon that corresponds to the maximum response varying across countries. However, this horizon is usually within one year of the shock, which allows a comparison of the short-run effects of the demand shock on GDP. For the demand shocks, the horizon for the CPI is 20 quarters, in order to compare the permanent effects of the demand shock on the CPI.

2.5.1 Oil supply shocks

Figure 2 illustrates that the economic consequences of an oil supply shock are very different for oil-importing and oil-exporting economies. Consider real GDP in the top two panels. All net oil and non-oil energy-importing economies (the euro area, Japan, Switzerland and the United States) experience a permanent fall in real economic activity. The long-run magnitude is somewhat greater in Japan compared to the other three economies (see also Table B1). Moreover, output falls very slowly in the euro area and Switzerland, whereas we observe an immediate decline in Japan and the United States.[9] This difference in timing will be further discussed in Section 3 when we examine the oil transmission mechanism. On the other hand, output permanently increases in countries that export both oil and other forms of energy, that is, Canada and Norway. Despite being a net oil-importing country, real GDP only falls in Australia temporarily. However, Australia is a significant non-oil energy-exporting country, which probably compensates for the negative oil price effect. The United Kingdom, which is an oil-exporting but non-oil energy-importing country, also undergoes only a transitory decline in activity. Overall, not only the role of oil but also that of other forms of energy is likely to be important for the dynamic effects of oil supply shocks on the economy.

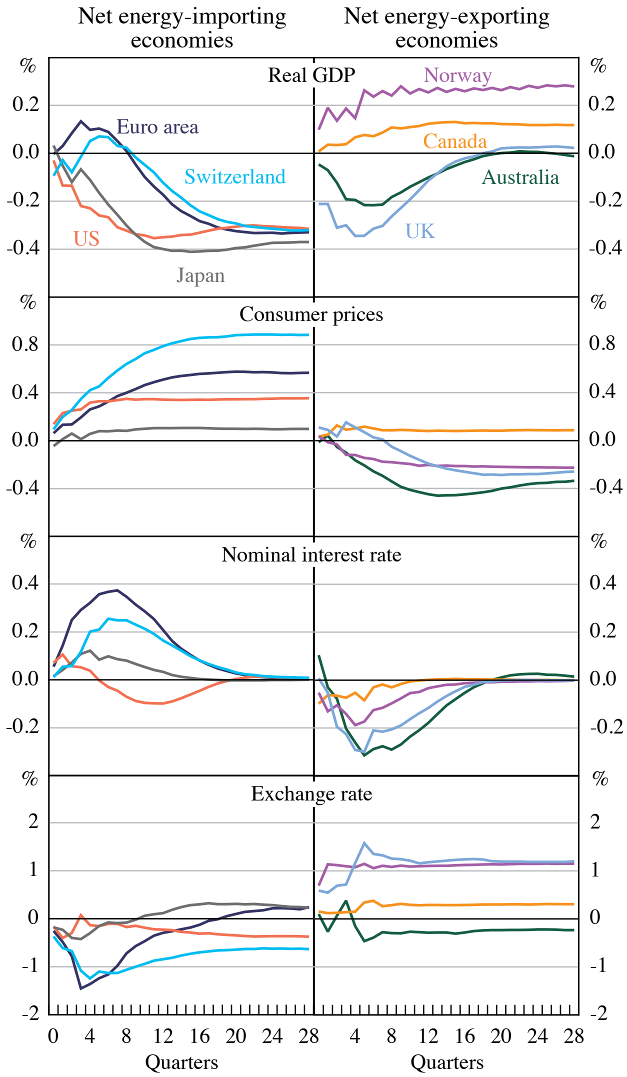
The dependence on oil and non-oil energy products also seems to matter for the inflationary consequences. The exact pass-through for net energy-importing countries will be analysed in Section 3, but the impulse responses reported in Figure 2 reveal a relatively strong impact on consumer prices for all of the net energy-importing economies (except for Japan) whereas inflationary pressures are negligible or even negative in energy-exporting countries. This different impact on consumer prices is probably driven by the response of exchange rates, which tend to appreciate in energy-exporting countries, exerting a downward effect on inflation.

As shown in Figure 2, all net energy-importing economies raise their interest rate substantially in order to fight the inflationary pressures the oil supply shock gives rise to. The tightening is much stronger in the euro area and Switzerland, compared to the slight increase in Japan and the United States. On the other hand, the monetary policy reaction is rather weaker in the net energy-exporting countries since the long-run effects on consumer prices are insignificant. In general, the reaction of monetary policy to an oil supply shock is thus consistent with the response of inflation.

9. Economic activity in the euro area and Switzerland rises temporarily, although these increases are not statistically different from zero.

Figure 2: Impact of Oil Supply Shock

Median impulse responses to a 10 per cent long-run rise in oil prices

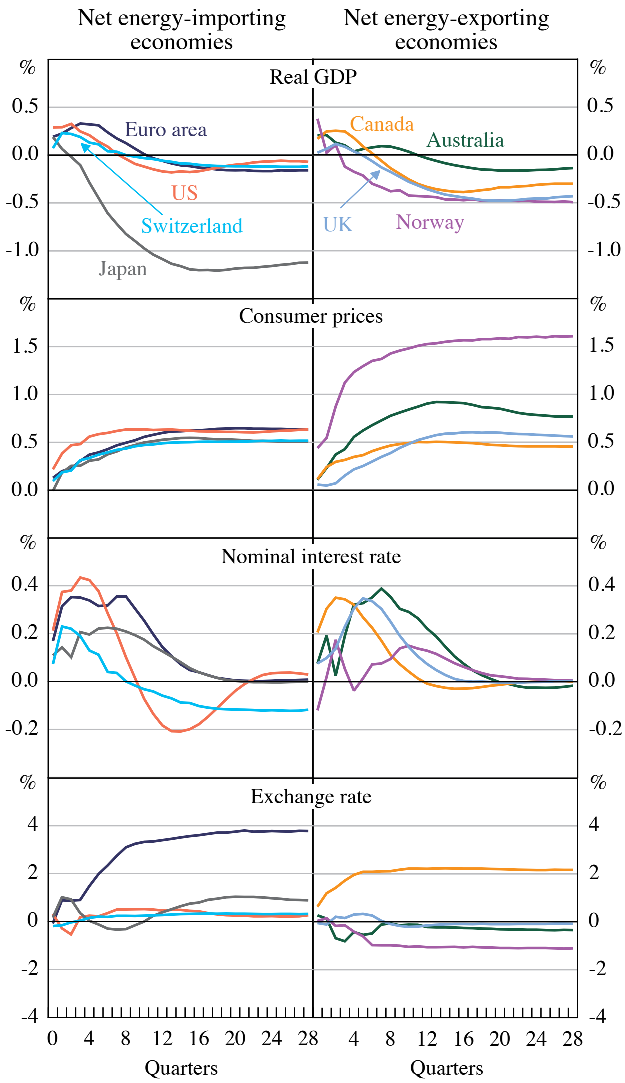


2.5.2 Oil demand shock driven by global economic activity shocks

The effects of an oil demand shock driven by rising global economic activity are substantially different from oil supply shocks. Figure 3 shows that all economies face significant long-run inflationary effects and a transitory increase in real GDP due to this shock. Somewhat surprising is the result that output in Canada, Japan and the United Kingdom declines in the long run. When we compare the magnitudes of the maximum impact across economies using Table B1, the temporary increase in output is rather similar, irrespective of the relevance of energy products. This is not a

Figure 3: Impact of Oil Demand Shock Driven by Economic Activity

Median impulse responses to a 10 per cent long-run rise in oil prices



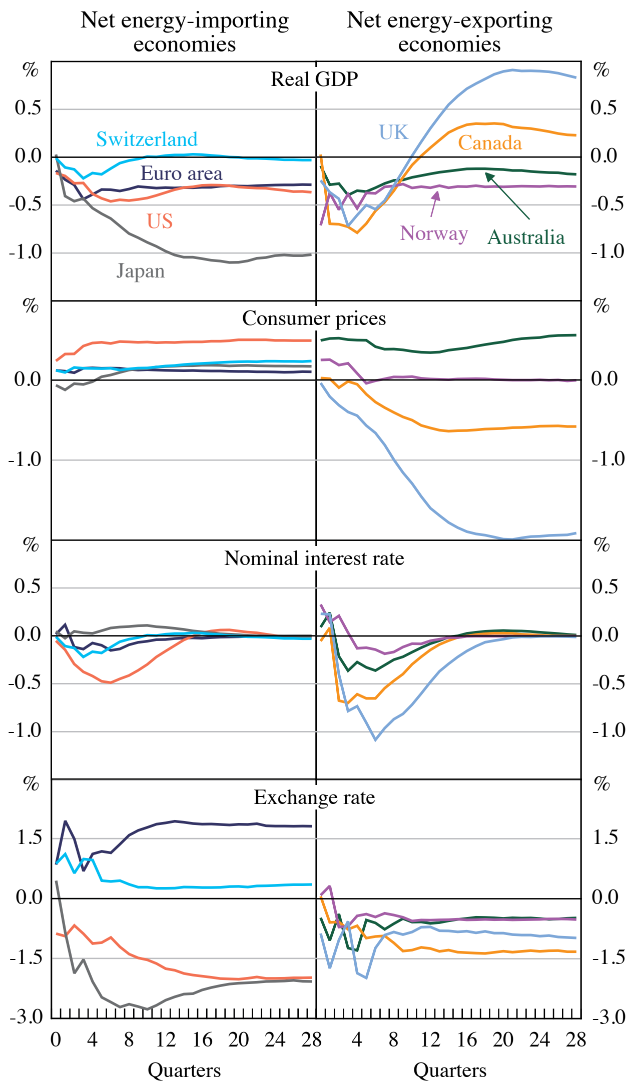
surprise since we are considering an oil price increase that is driven by an expansion of worldwide economic activity. Output can even rise in oil-importing economies because the country itself is in a boom, or because it indirectly gains from trade with the rest of the world. Accordingly, other structural features probably determine the size of the effects. In particular, shocks that affect global economic activity could, for instance, be technology or aggregate demand shocks. Also, the inflation differences are small between most economies. We only observe a stronger impact in Australia and Norway. Given the strong inflationary effects and the temporary increase in economic activity in all economies, no trade-off exists for monetary policy in the short run. Consequently, the interest rate is raised significantly in all countries with the exception of Norway.

2.5.3 Oil-specific demand shocks

The dynamic effects of oil-specific demand shocks are very different from the two other shocks, as shown in Figure 4. In all economies except Japan, this shock is followed by a temporary fall in real GDP with the peak mostly within the first year after the shock. The effects on consumer prices are, on average, much smaller compared to other types of oil shocks and only significantly positive in Australia

Figure 4: Impact of Oil-specific Demand Shock

Median impulse responses to a 10 per cent long-run rise in oil prices



and the United States. In the oil- and energy-exporting countries, the exchange rate does not respond significantly, in contrast to the appreciation after an oil supply shock. Comparing cross-country differences in the magnitudes of the effects of this shock on GDP indicates that oil-importing and oil-exporting economies react in a similar way (Table B1). That is, the role of oil and energy in the economy again seems not to matter much for this shock. Figure 4 also shows that no clear distinction can be made between the inflationary effects in the net energy-importing and exporting economies.

The temporary fall in economic activity in combination with the rise of consumer prices in most economies creates a trade-off for monetary policy-makers. The negligible reaction of consumer prices, however, should give more room to stabilise declines in output. Indeed, the interest rate tends to decrease in the aftermath of an oil-specific demand shock, although this response is mostly insignificant. In line with the other oil shocks, the monetary authorities generally change their interest rate in accordance with the effect on inflation. Only the United States accommodates the fall in economic activity despite the significant increase in consumer prices.

In summary, the economic effects of an oil price change critically depend on the cause of the price change. As a result, monetary policy implications differ depending on the nature of the oil shock. In addition, the role of oil and other forms of energy in the economy (that is, being an energy-importing or energy-exporting country) is only important for understanding cross-country differences in the case of conventional oil supply shocks.

3. The Pass-through to Inflation and Economic Activity

Knowledge of how oil market developments are transmitted to the macroeconomy is key to determining the appropriate policy reaction in response to oil shocks. First, the magnitude of the final effects on inflation and output depends on which channels are operative as well as on their relative strengths. Second, the timing of the impact is also important for policy decisions. Given that monetary policy actions affect headline inflation only with a lag, direct effects of rising energy prices are unavoidable. However, if the initial shock to relative energy prices also creates indirect effects by feeding into the price of non-energy goods and services over longer horizons, there is a stabilisation role for central banks. In what follows, we focus on the pass-through after oil supply shocks in oil-importing economies for two reasons.

First, as shown in the historical decompositions in Section 2.4, oil supply shocks are the single most important driving force behind oil price fluctuations. Furthermore, it is not straightforward to determine the precise transmission channels of oil price shifts driven by global economic activity since they could be correlated with domestic shocks, such as shocks to productivity or trade, which makes the interpretation difficult. This carries over to oil-specific demand shocks, after which the inflationary consequences are only significantly positive in Australia and the United States.

Second, as already documented in the previous section, there exist significant differences in the inflationary consequences between oil-importing and oil-exporting economies after an exogenous oil supply shock. The latter group is actually not confronted with rising consumer prices, which can be explained by an appreciation of the nominal and real effective exchange rates. Therefore, we investigate the relative importance of different transmission channels in oil-importing economies by applying a procedure proposed in Peersman and Van Robays (2009b). The idea is to examine the transmission of oil shocks by disentangling the effects on consumer prices and economic activity into several separate effects that are captured by the responses of different price measures and GDP components. This should help in understanding the cross-country differences of the monetary policy responses.

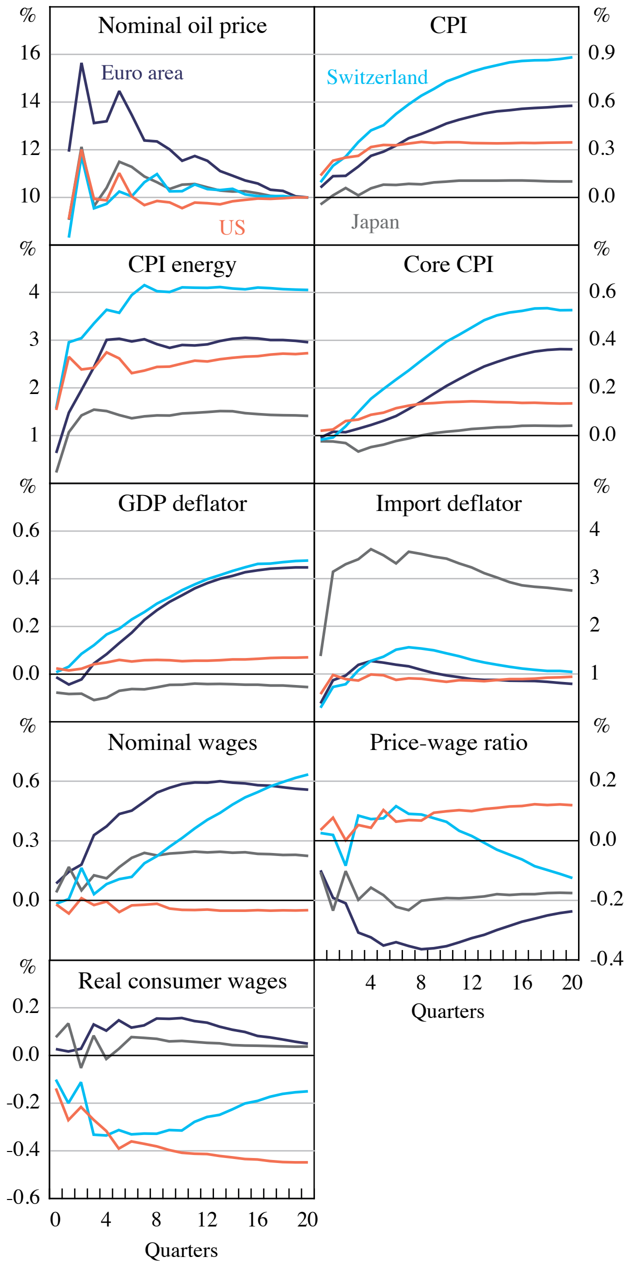
More specifically, we consider the direct effect of oil shocks on the energy component of consumer prices, the indirect effect via rising production costs of non-energy goods and services, second-round effects of rising wages, and an impact due to a fall in aggregate demand. The first three channels have a positive effect on inflation, whereas the latter channel should reduce inflationary pressures. Adverse aggregate demand effects are also reflected in the response of economic activity and its components. In order to evaluate the relevance of the individual transmission channels, we extend the analysis of Section 2.2 by re-estimating the benchmark SVARs for all economies by adding one additional variable at a time that captures a specific channel (see Appendix A for details). The results of the median estimates are summarised in Figures 5 and 6; the 16th and 84th percentile confidence bands are available from the authors on request.

The upper-right panel of Figure 5 shows that the ultimate effect on consumer prices and the speed of pass-through is very different across oil-importing economies. The upper-left panel displays the estimated median oil price responses, which are normalised to be 10 per cent increases over the long run.[10] The impact of this oil price increase on consumer prices is strong in the euro area (0.58 per cent), insignificant in Japan (0.10 per cent), very strong in Switzerland (0.88 per cent) and subdued in the United States (0.35 per cent); see also Table B1. Even more striking is the difference in the speed of adjustment. While pass-through is still less than half after one year in the euro area and Switzerland, it is almost complete in Japan and the United States over the same horizon. As already mentioned, the shapes of the output responses after an oil supply shock are different across countries (see Section 2.5.1). The response of economic activity is very sluggish in the euro area and Switzerland, compared to a much quicker decline in Japan and the United States. These remarkable differences are explained in the next sections.

10. The cross-country results are robust when the oil price increases are normalised to a short-run increase in oil prices. These results are available upon request from the authors.

Figure 5: Pass-through of Oil Supply Shocks to Consumer Prices in Oil- and Energy-importing Economies

Median impulse responses to a 10 per cent long-run rise in oil prices



3.1 Direct effects

To measure the direct effect of an oil price shock on inflation, we consider the impact of an oil supply disturbance on the energy component of the CPI. The impulse response functions for a rise of 10 per cent oil price over the long run are displayed in Figure 5. Not surprisingly, there is a significant reaction of the energy component of the CPI in all economies. The magnitude is 3.0, 1.4, 4.1 and 2.7 per cent for the euro area, Japan, Switzerland and the United States, respectively. The stronger response in Switzerland is partly driven by a significant exchange rate depreciation. For Japan and the United States, the impact on the energy component of the CPI is already complete after 1–2 quarters, while it takes about 1 year in the euro area and Switzerland.

If only direct effects are relevant, then prices of non-energy goods and services should not be influenced by the oil shock and the final effect on inflation is determined by the increase in relative prices. This can be examined by looking at the impact on core CPI, which explicitly excludes energy prices. These estimated responses (the second row of Figure 5) reveal that significant indirect inflationary effects are present in the euro area, Switzerland and the United States. The long-run magnitudes of these indirect effects are respectively, 0.36, 0.53 and 0.14 per cent. In addition, the speed of transmission to core inflation is very different. Core inflation starts to rise relatively quickly in the United States, while the pass-through is very sluggish in the euro area and Switzerland. These differences in speed and magnitude carry over to headline inflation. For Japan, we do not find additional indirect effects – the response of core CPI is insignificant. In turn, the magnitude and timing of the indirect inflationary effects depend on the presence and relative strength of its components: the cost effects, second-round effects and demand effects.

3.2 Cost effects

Increased oil prices imply higher production costs for firms, which will attempt to pass these onto consumers by raising their prices. In contrast to the direct effects, this cost effect has an influence on core inflation. To evaluate the role of cost pressures on core inflation, we estimate the effect on both the GDP deflator and the import deflator. Since only net oil-importing economies are considered, the cost effect should only affect the import deflator and not the GDP deflator, since the latter is the price of domestic value added that explicitly excludes foreign inputs. Both the direct and cost effects are thus only reflected in a shift of the import deflator, and the response of the GDP deflator captures the remaining indirect effects.[11] The import deflator not only incorporates the price of imports of crude oil, but also the price

11. This proposition relies on the standard assumption of separability between oil and other production factors in order to ensure the existence of a value-added production function (see Rotemberg and Woodford 1996 or Barsky and Kilian 2004 for a formal exposition of a production function with foreign commodity imports and domestic value added). The situation is slightly different for the United States, which is also a significant oil producer. In addition, the GDP deflator could also rise due to price increases of non-oil energy products that are produced within the country.

of imported final goods and other foreign commodities that could be directly or indirectly influenced by oil price shifts. For Switzerland, this effect is aggravated by an estimated significant depreciation of the exchange rate.

Impulse responses for the GDP and import deflators are presented in Figure 5. Whereas import prices increase significantly, there is no reaction of the US GDP deflator to an oil supply shock, despite being an oil-producing country. Consequently, the rise of US core inflation can be fully attributed to the cost effect. Similarly in Japan, an oil supply shock does not affect the GDP deflator in the long run. We even find a fall in the short run. Given the insignificant reaction of core inflation, the latter implies only a limited transitory cost effect in Japan.

The situation in the euro area and Switzerland is completely different. These economies experience a significant rise in the GDP deflator after an unfavourable oil supply shock. Given the reaction of the import deflator, which combines direct and cost effects, the existence of a cost effect in both economies cannot be excluded.[12] However, the speed and magnitude of the responses reveal that the bulk of the reaction of core inflation can be explained by the reaction of the GDP deflator. This striking contrast with Japan and the United States will be further examined in the next section.

3.3 Second-round effects

An unfavourable oil supply shock could increase the GDP deflator via positive second-round effects and decrease it via negative demand effects. The demand channel is analysed in the next section. Second-round effects are triggered if employees successfully raise nominal wages to maintain their purchasing power after a rise in energy prices. As a result, the costs to firms increase. If firms pass on higher wage costs to output prices, there is upward pressure on the prices of goods and services contained in the non-energy component of CPI. In contrast to direct and cost effects, rising wages also affect the GDP deflator. Moreover, while direct and cost effects only result in a permanent shift of the price level, second-round effects could lead to a self-sustaining spiral of increasing wages and prices which results in a more persistent impact on inflation. The existence of second-round effects could depend on the response of inflation expectations and the supply and demand conditions in the labour market. Note that second-round effects could also be triggered if price-setters increase their mark-ups because of higher inflation expectations.

The relevance of second-round effects in oil-importing economies can be evaluated by examining the reaction of (nominal) total labour costs per employee, real consumer wages and the producer price-wage ratio. The latter variable can be considered as the inverse of real producer wages or, alternatively, as the sum of

12. The response of the import deflator in the euro area should be interpreted with caution. This series, which is obtained from the Area-Wide Model dataset, is an aggregate of import prices of all individual member countries. As a result, higher export prices of one member country (due to second-round effects) will result in higher import prices for the other member countries and hence an increase in the aggregate import deflator.

profits and net indirect taxes. The median impulse responses of these variables can be found in the bottom rows of Figure 5. Strikingly, the existence of second-round effects is very different across countries and seems to be the key explanation of cross-country differences in the ultimate impact of an oil supply shock on inflation. For the United States, since nominal wages do not rise and the price-wage ratio remains constant, second-round effects are not present. Given the rise in overall consumer prices, this implies that the loss of purchasing power is entirely borne by employees, with a significant fall in the real consumer wage.

The situation is different in Japan. While the GDP deflator remains constant in the long run, nominal wages do rise slightly after an unfavourable oil supply shock and workers succeed more or less in maintaining their purchasing power. In contrast to the United States, producers suffer via a significant fall in the price-wage ratio, which offsets the wage increase and signals the presence of significant adverse demand effects.[13]

In the euro area, real consumer wages remain constant in the long run and there is a significant fall in the price-wage ratio. The latter indicates that demand effects are also present in the euro area, thereby limiting the transmission to headline inflation. However, in contrast to Japan, the fall in the price-wage ratio only partially offsets rising labour costs. Accordingly, rising labour costs and second-round effects also result in higher producer and consumer prices. The second-round effects are reflected in the significant rise of the GDP deflator. As is the case in the euro area, a significant increase in nominal wages in Switzerland triggers second-round effects that explain the rise in the GDP deflator. Although in the short run the loss in purchasing power is borne by the employees in Switzerland, they manage to keep their real wages constant in the long run.[14]

These cross-country differences in the pass-through to inflation have different implications for monetary policy. More specifically, the main channel through which an oil supply shock passes through to inflation in the euro area and Switzerland is via second-round effects. In order to stabilise inflation, a strong monetary policy response is needed since such a wage-price spiral could otherwise trigger persistent inflationary effects. Conversely, the final impact on consumer prices in the United States is mainly determined by direct and cost effects, and in Japan by direct effects, since nominal wage increases are not passed on to consumer prices. Accordingly, oil supply shocks in these latter two countries do not have a persistent effect on

13. The absence of a reaction of the GDP deflator to an oil supply shock in the United States does not imply that there are no (negative) demand effects. First, since the United States is also an oil-producing country, the constant price-wage ratio could imply that positive cost effects are offset by negative demand effects. Second, it is possible that a reduction in aggregate demand is transmitted to the labour market. A fall in labour demand and an accompanying rise in unemployment reduces the bargaining power of workers, helping to contain nominal wages. Peersman and Van Robays (2009b) show that this is what happens.

14. Since quarterly data on nominal total labour costs are not available for Switzerland, the data used are interpolated annual nominal wages based on variations in unit labour costs corrected for changes in GDP.

inflation, and a strong monetary policy response is not needed. This is exactly the monetary policy behaviour that we observe after an oil supply shock (Figure 2).

3.4 Demand effects

A reduction in aggregate demand is the final transmission channel of an adverse oil supply shock to inflation we need to consider, and is one that also influences the GDP deflator. On the one hand, an increase in costs and prices will lower demand and economic activity, with the aggregate supply curve shifting along a downward-sloping aggregate demand curve. To limit the fall in production, firms could react by decreasing profit margins or negotiating lower wages for their employees. The pass-through to inflation will depend, among other things, on the elasticity of aggregate demand. An oil shock could also trigger an independent reduction of aggregate demand – a shift of the aggregate demand curve. These additional demand-side effects further reduce economic activity but have a tempering impact on inflation.[15]

For oil-importing economies, an increase in oil and energy prices erodes disposable income. Given a relatively small elasticity of oil and energy demand, this income effect depresses the demand for other domestically produced goods. In addition, consumers may decide to increase their overall precautionary savings because of a greater perceived likelihood of future income loss, which also results in a reduction of private spending. Furthermore, if uncertainty increases about future availability of oil and its price, it may be optimal to postpone irreversible purchases of investment and consumption goods that are complementary to energy. Bernanke (1983) shows that increased uncertainty about the future price of irreversible investments raises the option value associated with waiting to invest, which will lead to less investment and durable consumption expenditure. Finally, aggregate demand could also fall if the central bank tightens policy in response to the inflation induced by the oil shock. These independent demand-side effects should reduce the ultimate pass-through of an oil supply shock to consumer prices.

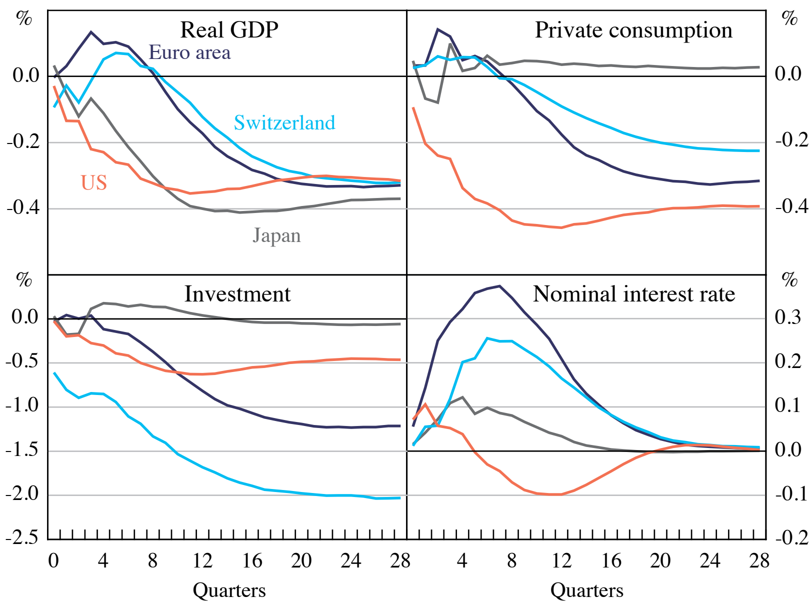
To learn more about the existence of demand effects, Figure 6 shows the median impulse responses of real GDP, private consumption, investment and the nominal interest rate. (The impulse response functions with confidence bands and the estimated reaction of exports and government consumption are available from the authors on request.) The results are again very different across economies. In the United States, there is an immediate fall in private consumption in line with the response of real

15. Oil shocks could also result in a changed composition of aggregate demand, for example a shift from energy-intensive to energy-efficient goods, which will also lower economic activity (Davis and Haltiwanger 2001). This change could cause a reallocation of capital and labour from energy-intensive to energy-efficient sectors. In the presence of frictions in capital and labour markets, these reallocations will be costly in the short run and can lead to a substantial reduction in economic activity. In contrast to the other demand effects, this allocative effect is not necessarily accompanied by a shift in the aggregate demand curve, and the impact on inflation is less clear. For a more detailed exposition of the demand-side effects and an overview of the empirical literature see Kilian (2008).

GDP. This pattern is consistent with the existence of an income and precautionary savings effect. It is not very likely that a monetary policy effect is present in the United States: we hardly find an increase in the nominal interest rate and certainly not in the real interest rate, and the investment reaction, which should capture the main channel of monetary transmission, is only marginally significant. The rather insignificant response of investment also indicates that the uncertainty effect, and the associated postponement of irreversible investment, is negligible.

Figure 6: Demand Effects and Pass-through to Economic Activity in Oil- and Energy-importing Economies

Median impulse responses to a 10 per cent long-run rise in oil prices



The nature of the demand-side effects in the euro area and Switzerland is completely different to that in Japan and the United States. Private consumption declines very sluggishly, which is not in line with an income or precautionary savings effect for which a relatively quick response is expected. For the euro area, this is not surprising given the insignificant reaction of real consumer wages. In Switzerland, purchasing power remains constant in the long run. In addition, there is a considerable decline of investment in the euro area and Switzerland that also only starts accelerating with a delay. This pattern of consumption and investment responses indicates that another effect is at play. The inflationary effects caused by the oil shock, and the existence of harmful second-round effects in these two economies, result in a monetary tightening as captured by the significant estimated interest rate increase in both economies. This monetary policy effect is likely to be responsible for the fall in economic activity and can also explain the different speed of pass-through to real GDP. Given lags in the monetary transmission mechanism, consumption, investment and real GDP only start to fall with a delay. The much stronger decline in investment is a feature that confirms the presence of monetary policy effects. The lack of an interest rate reaction in Japan, combined with the absence of a loss in purchasing power for consumers, results in an insignificant reaction of private consumption and investment. Hence, demand effects in Japan are only reflected in a significant fall of the price-wage ratio reported in Section 3.3.

4. Time-varying Effects of Oil Supply Shocks

There is reason to believe that the economic effects of oil shocks have changed fundamentally over time. The two large oil price shocks of the 1970s were associated with higher inflation and lower economic growth. In contrast, the latest, sustained run-up in oil prices appears to have had a relatively modest impact on real economic activity and consumer prices. Instabilities over time in the relationship between oil and the macroeconomy are widely documented in the literature.[16] On the one hand, the macroeconomic structure has evolved considerably over time. Prominent features of this change are improved monetary policy (Bernanke, Gertler and Watson 1997 and Blanchard and Galí 2007), more flexible labour markets (Blanchard and Galí 2007), changes in the composition of automobile production and the overall importance of the US automobile sector (Edelstein and Kilian 2009), and modifications in the role and share of oil in the economy (Bernanke 2006 and Blanchard and Galí 2007).[17] On the other hand, the oil market itself has undergone substantial changes. For instance, institutional transformations such as the transition from a regime of administered oil prices to direct trading in the spot market, and the collapse of the OPEC cartel in late 1985 were accompanied by a dramatic rise in oil price volatility. Lee *et al* (1995) and Ferderer (1996) make the case that this increased oil market volatility led to the breakdown of the relationship between oil prices and economic activity.

For the US economy, Blanchard and Galí (2007), Edelstein and Kilian (2009), and Herrera and Pesavento (2009) find a reduced impact of oil price shocks on real GDP and inflation over time. Baumeister and Peersman (2008), however, have shown that such intertemporal comparisons are seriously distorted since the global oil market has been characterised by further structural change since the mid 1980s. In what follows, we further document this structural change and the consequences for our analysis.

4.1 Structural change in the oil market

In order to explore how the interaction between oil shocks and the macroeconomy has evolved over time, Baumeister and Peersman (2008) estimate a multivariate Bayesian VAR that features time-varying coefficients and stochastic volatilities

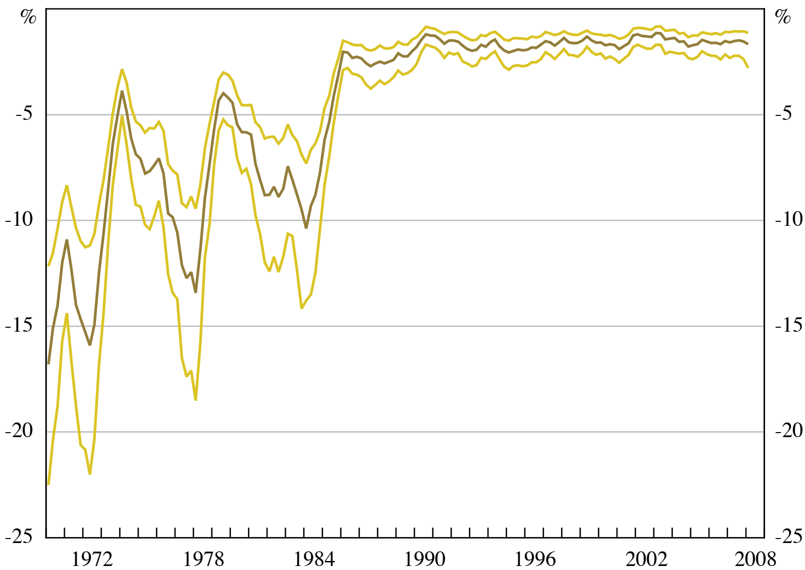
16. Structural breaks in the relationship between oil prices and the macroeconomy were first documented by Mork (1989) and Hooker (1996, 2002).

17. Other arguments for the changing (but not necessarily reduced) macroeconomic effects of oil shocks that have been put forward are time-varying mark-ups of firms (Rotemberg and Woodford 1996) and changes in firms' capacity utilisation (Finn 2000).

in the innovation processes for the period 1970:Q1–2008:Q1. The time-varying coefficients are meant to capture gradual transition in the propagation mechanism of oil shocks, while the stochastic volatility component models changes in the magnitude of structural shocks and their immediate impact.[18] Using this time-varying SVAR model, they document that the crude oil market is characterised by a considerably less elastic, hence steeper, oil demand curve since the mid 1980s. Figure 7 shows the estimated slope of the oil demand curve at each point in time with 16th and 84th percentiles of the posterior distribution.[19] While the price elasticity fluctuates between –5 per cent and –15 per cent during the 1970s and early 1980s, the contraction in oil demand after a 10 per cent increase in oil prices is as small as 1 to 2 per cent since the mid 1980s.

Figure 7: Estimated Elasticity of Oil Demand over Time

Median effect four quarters after the shock with 16th and 84th percentile confidence bands



Source: Baumeister and Peersman (2008)

This steepening of the oil demand curve seriously complicates comparisons of the dynamic effects of oil supply disturbances over time. For instance, a comparison that is based on a similar change in crude oil prices (for example, a 10 per cent rise) implicitly assumes a constant price elasticity of oil demand over time, which is

18. This approach has frequently been used in the so-called 'Great Moderation' literature; see, for example, Cogley and Sargent (2002) or Primiceri (2005).

19. The figure displays the elasticity of oil demand to a 10 per cent increase in the real price of crude oil $\left(\frac{\Delta Q}{Q} \Big/ \frac{\Delta P}{P}\right)$ measured four quarters after the initial shock. The exact horizon of the elasticity does not matter for the conclusions.

obviously rejected by the data. Consequently, this experiment compares the impact of a totally different underlying oil supply shock. Figure B2 illustrates that the shift of the oil supply curve needed to generate a similar oil price increase clearly differs for a steep, as opposed to a flat, oil demand curve. For exactly the same reason, measuring an exogenous oil supply shock as a similar shift in world oil production over time (for example, a drop in production of 1 per cent) is a biased experiment since the resulting oil price increase will be very different. However, the impact of a 'typical' (for example, one standard deviation) oil supply shock can be compared. Even so, the magnitude of a representative oil supply disturbance could have changed over time, which could also influence the outcome. Whether the size of a typical oil supply shock has changed unfortunately cannot be determined.[20] This problem of comparability also carries over to shocks originating on the demand side of the oil market. Baumeister and Peersman (2010) show that the short-run oil supply curve became highly inelastic over time. Accordingly, comparisons of normalised demand shocks are biased since a constant slope of the oil supply curve is assumed. In the next section, we demonstrate the consequences of this structural change for drawing conclusions about time variation.

4.2 Has the economic impact of oil shocks changed over time?

The results of Baumeister and Peersman (2008) presented in Figure 7 clearly show a break in the slope of the oil demand curve in the first quarter of 1986. To compare the dynamic effects of oil supply shocks, we use our benchmark SVAR model of Section 2.2 for the United States, estimated for two different sample periods: 1970:Q1–1985:Q4 (the '1970s') and 1986:Q1–2008:Q1 (the '1990s'). The latter period corresponds to the model reported in the previous sections. The top row of Figure B3 contains the impulse responses of world oil production and the oil price following a typical one standard deviation oil supply shock. An unfavourable oil supply shock in the 1990s is characterised by a much smaller fall in oil production in combination with a larger increase in the price of crude oil relative to the 1970s. The corresponding estimated slope of the oil demand curve, which is depicted in the top-right panel, confirms the considerable steepening over time.

The consequences of this structural change in the crude oil market for US real GDP and consumer prices is shown in the second and third rows of Figure B3.[21] Clearly, the choice of normalisation becomes very important. Consider, for instance, the effect of an oil supply shock which raises the price of crude oil by 10 per cent. Such a shock has a more muted impact on economic activity and inflation in more recent times compared to the 1970s. This finding complies with the general perception and

20. This is a standard problem when VAR results are compared across different sample periods. Only the contemporaneous impact of a shock on a number of variables can be measured. Consequently, it is not possible to know exactly whether the shock itself (volatility) has changed or if the immediate reaction to this shock has changed (economic structure).

21. Results for other countries and variables are available from the authors upon request. However, since the structural change in the oil market is the same for all countries, the general message of a distorted comparison over time is not altered.

the empirical evidence on time-varying effects of oil price shocks discussed above. This experiment, however, is biased since it implicitly assumes a constant slope of the oil demand curve across both sample periods, which is clearly not the case. More specifically, a 10 per cent rise in oil prices corresponds to an oil production shortfall of less than 1 per cent in the more recent sample period. To elicit the same oil price movement in the 1970s, a decline in oil supply of around 3 per cent was required. Despite the assertion by Blanchard and Galí (2007) that 'what matters … to any given country is not the level of global oil production, but the price at which firms and households can purchase oil' (p 17), it is the volume of oil which matters for the production process. For instance, the impact on revenues for oil-exporting countries and corresponding income-recycling effects via trade depend on both the amount of oil production and its price.[22]

Alternatively, we could consider a 1 per cent reduction in oil production. Oil supply shocks have often been associated with physical disruptions in the production of crude oil due to deliberate decisions by OPEC aimed at imposing a certain price level, or as a result of the destruction of oil facilities in the wake of military conflicts. Figure B3 shows that the accumulated loss in US real GDP growth is about twice as large in the 1990s compared to earlier times and the response of consumer prices is much more pronounced in the more recent period. This finding is not surprising, since a similar reduction in oil quantities triggers a substantially larger oil price increase in the recent period due to the much lower elasticity of the oil demand curve. More specifically, oil prices are estimated to have increased by 23.9 per cent in response to a 1 per cent shortfall in world oil production in the 1990s, while they only rose by 3.2 per cent in the 1970s. Normalising on the quantity variable to make intertemporal comparisons is therefore also problematic, because a typical (one standard deviation) shift of oil supply in the 1990s is characterised by a change in world oil production that is only one-fifth of an average shift in the 1970s. Given the inability to distinguish volatility and the immediate impact of a structural shock in an SVAR, it is not possible to identify whether these smaller variations in oil production are just the result of a steeper oil demand curve, or also the consequence of smaller shifts in the underlying supply curve over time.[23]

When we consider the dynamic effects of a typical one standard deviation oil supply shock, the middle and lower right-hand-side panels of Figure B3 show that the impact on US macroeconomic aggregates is rather similar across the two sample periods. This is consistent with the evidence provided in Baumeister and Peersman (2008).[24] If the effects of average oil supply disturbances on the US economy have not dramatically changed over time, it is surprising that the perceived

22. The issue of whether oil prices or quantities matter in a world production function can be compared with employment and wages. In this case, the amount of employment is more relevant for economic activity than the wage level, since the latter is only a transfer from employers to employees.

23. Note that, in the case of a vertical oil supply curve, the observed decline in oil production responses would be fully driven by decreased oil supply volatility.

24. However, this is not the case for all economies in our analysis, in particular the energy-exporting economies.

consequences of current oil shocks are so different now from those in the 1970s. To explain this, Baumeister and Peersman demonstrate that oil supply shocks made only a limited contribution to the 'Great Inflation'. Alternative factors, such as loose monetary policy, were much more important explanators of excessive inflation experienced during this period, in line with the propositions made by Barsky and Kilian (2004). Oil supply shocks contributed in varying degrees to the recessions of 1974–1975, the early 1980s and 1990s, but other shocks were also at play. Unfavourable oil supply disturbances substantially dampened real activity around 1999, which made the ongoing boom more subdued. As a consequence, the timing of oil shocks could have shaped the general perception that adverse oil supply shocks were more detrimental to the economy in the 1970s compared to more recent times.[25] Baumeister and Peersman (2008) show that the most recent oil price surges were more demand-driven, consistent with our findings concerning the historical decomposition of the oil price (see Section 2.4). Since economic consequences are very different for demand-side induced oil shocks, the fact that they currently dominate oil price movements could have altered the way that their effects are perceived.

4.3 Cross-country differences over time

The previous section documented that comparisons of the dynamic effects of oil supply shocks over time are problematic because of the problem of how to normalise the shocks. However, Peersman and Van Robays (2009a) show that the cross-country dimension of the analysis can be exploited to learn more about time variation while circumventing this normalisation problem.[26] Specifically, they argue that if reduced reliance on crude oil and other forms of energy is at the origin of a more subdued response to oil shocks, the change over time should be greater for countries that improved their net energy position or reduced the oil intensity of economic activity the most. Table B2 reports several indicators of the average shares of oil and energy for the economies in our sample for 1970–1985 and 1986–2008. While all economies experience a noticeable fall in total energy intensity and an improvement in net oil and energy dependence, the cross-country differences are substantial. Canada and the United Kingdom even switched from being oil importers in the 1970s to net exporters more recently. Even within the group of oil and energy-importing economies, the changes over time vary across economies. Unlike the euro area and Japan which significantly lowered their reliance on oil imports, Switzerland and the United States hardly improved their oil dependence.

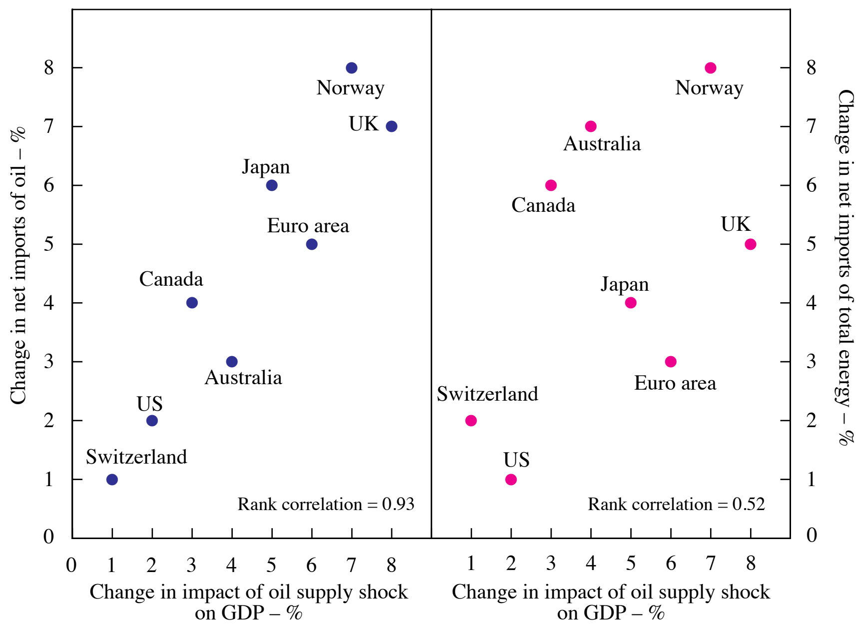
To evaluate whether a change in the importance of oil and other forms of energy in the economy is important in explaining time variation, we examine the impact of an oil supply shock, normalised to a 10 per cent long-run oil price rise, for all

25. Hamilton (2009a) argues, for instance, that oil price changes also made a significant contribution to the US recession between 2007:Q4 and 2008:Q3.

26. Since the structural changes in the global oil market are the same for all countries, comparing relative changes between countries does not suffer from a normalisation problem.

economies for the periods 1970–1985 and 1986–2008 (Figure B4).[27] The differences between both periods based on the maximum value of the median responses over the impulse response horizon are also reported in Table B2. Normalising on oil prices, the ultimate output consequences have indeed reduced over time for all economies, in line with the evidence for the United States reported above. However, the degree of improvement is very different across economies. Figure 8 provides a better sense of the link between oil and energy dependence and macroeconomic performance. It shows the rank correlations between changes in the net oil and energy imports per unit of GDP and changes in output effects measured by the difference in the maximum median impact of an oil supply shock on real GDP across sub-samples.

Figure 8: Rank Correlation of the Change in the Net Oil Energy Position (per Unit of GDP) and Impact on GDP over Time



Note: The rankings of the change in the oil and energy position over time are based on the results in Table B2 and the change in the impact on real GDP is calculated as the difference between the maximum negative median impact after an oil supply shock in the 1990s versus the 1970s.

The resulting scatter plots reveal a strongly positive relationship between improvements in the net oil and net energy positions and the moderation of consequences for economic activity. The relationship is more significant based on net oil imports. More specifically, economies that made the greatest advancements in either reducing their oil dependence, the euro area and Japan, or extending their net oil positions, Norway and the United Kingdom, experienced the greatest mitigation

27. Since we only compare the relative cross-country differences over time, it does not matter whether we normalise on oil prices or oil production.

of output effects. Switzerland and the United States, which made only little progress in lowering net oil imports, face smaller reductions in economic activity over time. With regard to changes in net energy imports, all countries that are currently net exporters of energy, Australia, Canada, Norway and the United Kingdom, made the largest improvement in their net energy position over time. While their output effects were more or less equally severe as in the other countries in the 1970s, the impact in these four countries became insignificant or even positive in more recent times. Both developments are reflected in the scatter plot, with these countries being concentrated in the upper-right corner of the right-hand panel of Figure 8. Even among the energy-importing economies, we notice a reduction in the output effects in combination with lower net imports of energy; again this is more modest in Switzerland and the United States since these economies hardly improved their net energy dependence over time.[28] Overall, these results support the hypothesis that the importance of oil and other forms of energy help to explain different output effects of oil supply shocks over time. For inflation, we also find a stronger reduction in the effects for economies that improved their net energy position the most over time (see Figure B4).

5. Conclusions

This paper investigates the dynamic effects of oil shocks on a set of industrialised economies that are very diverse with respect to the role of oil and energy in the economy. By approaching this cross-country analysis from three different perspectives, we can provide useful guidance regarding how monetary policy can best deal with oil price movements. Several results stand out.

First, the consequences of an oil price increase depend crucially on the underlying source of the oil price shift in all countries, in line with the results of Kilian (2009) and Peersman and Van Robays (2009b). More specifically, after an oil demand shock driven by a global economic upswing, output temporarily increases and consumer prices rise strongly. This is in contrast to an oil-specific demand shock, after which economic activity temporarily declines and inflationary effects are mostly insignificant. For both types of oil demand shocks, the degree of dependence on oil and energy is not important for explaining cross-country differences in the economic effects. Conversely, being a net oil- or energy-exporting country does matter for exogenous oil supply shocks. We find that all the net oil- and energy-importing economies (the euro area, Japan, Switzerland and the United States) experience a permanent contraction in economic activity and a significant boost in inflation, whereas the long-run output response in the oil- and energy-exporting countries (Australia, Canada, Norway and the United Kingdom) is insignificant or even positive. The inflationary consequences for these oil exporters are limited,

28. Note that, if we would only consider the long-run impact on economic activity, Japan is the country with the smallest improvement (see Figure B4). However, this result would be mainly driven by a changed speed of the effects. Considering the difference between the maximum impact on economic activity in both the 1970s and the 1990s takes this into account.

probably because of the appreciation of the effective exchange rates in the aftermath of an oil supply shock.

Second, the pass-through of an oil supply shock to consumer prices differs considerably among oil-importing economies. While the direct effects of oil supply disturbances to inflation are strong and significant in all of these economies, cross-country differences in inflationary pressures are due to indirect effects, which are mainly determined by the existence of second-round effects. In the euro area and Switzerland, the GDP deflator as well as nominal wages increase notably, which explains the relatively pronounced and sluggish responses of consumer prices. In contrast, in Japan and the United States the GDP deflator does not react in the long run. Second-round effects are not present in the United States since nominal wages and mark-ups do not adjust, whereas the slight increase in the wage rate in Japan is completely offset by a decrease in producers' profit margins. Also, demand and output effects are different across countries. In the United States, the income and precautionary savings effects help to account for the immediate fall in real GDP, while a delayed decrease in economic activity in the euro area and Switzerland can be attributed to monetary policy that tightens to halt second-round effects.

Finally, we find that countries that have improved their net energy position the most over time became relatively less susceptible to oil supply shocks. By exploring the cross-country dimension, we have avoided the normalisation problem that is inherent in comparing macroeconomic effects of oil supply shocks across time periods. This problem arises because the oil demand curve has become much less elastic since the mid 1980s. Accordingly, a similar oil price increase over time, or a similar oil production disruption, imply totally different underlying shifts of the oil supply curve.

It is likely that in addition to the dependence on oil and other energy products, changes in monetary policy credibility and labour market characteristics could play an important role in explaining time variation in the effect of oil supply shocks. Analysing the relative importance of these structural changes is left for future research. Another interesting question is whether the inflationary effects of oil shocks are symmetric.

Appendix A: SVAR Model and Identification

The economic consequences of oil shocks are analysed using a SVAR model, of which the general representation is given in Section 2.2. Since no significant cointegration relation is found, all variables are transformed to growth rates by taking the first difference of the natural logarithms, except for the interest rate which remains in levels. Based on standard likelihood ratio tests and the usual lag-length selection criteria, we include three lags of the endogenous variables. The model is estimated using quarterly data for the sample period 1986:Q1–2008:Q1. Data on all oil-related variables are obtained from the US Energy Information Administration (EIA) and the International Energy Agency (IEA). The oil price variable is the nominal refiner acquisition cost of imported crude oil, which is considered as the best proxy for the free market global price of imported crude oil in the literature. The indicator of global economic activity is obtained from the United Nations *Monthly Bulletin of Statistics* and is calculated as a weighted average of industrial production of a large set of individual countries, including, for instance, China and India. Refer to Baumeister and Peersman (2010) for further explanation of how this index is constructed. All euro area data are collected from an updated version of the Area-Wide Model (AWM) dataset; see Fagan, Henry and Mestre (2001). US data is from the Bureau of Labor Statistics (BLS), the Bureau of Economic Analysis (BEA) and the Federal Reserve Economic Data (FRED) database. For the remaining countries, GDP, consumer prices and nominal interest rates are obtained from the OECD 'Main Economic Indicators' database (OECD MEI), OECD 'Economic Outlook' database (OECD EO) or the IMF 'International Financial Statistics' database (IFS). Finally, the exchange rate data are the nominal effective exchange rate indices from the BIS. The results are robust to different choices of lag length, reasonable changes in the sample period, alternative oil price measures such as real crude oil prices (deflated by US GDP deflator) or the West Texas Intermediate spot oil price, and different indicators of worldwide economic activity such as the global industrial production index of the OECD.

The shocks in the SVAR model are identified by relying on a limited set of sign restrictions which are explained in Section 2.3. Since the structural shocks are mutually orthogonal, the variance-covariance matrix of a reduced-form estimation of the SVAR is $\boldsymbol{\Omega} = \boldsymbol{BB}'$, for an infinite number of possible $\boldsymbol{B}$ (see Equation (A1) below). We consider the set of possible $\boldsymbol{B}$ that fulfil the sign conditions imposed. Peersman (2005) shows how to generate all possible decompositions. To uniquely disentangle the three types of shocks in $\boldsymbol{\varepsilon}_t^X$, we implement the sign restrictions on the oil market variables. These are assumed to hold for the first four quarters after the shocks, which is standard in the literature. The responses of all country-specific variables are left unconstrained in the estimations and their responses are fully determined by the data. For more details on the implementation of sign restrictions for identification see Peersman (2005).

Similar to Peersman (2005) and Peersman and Van Robays (2009b), a Bayesian approach is used for estimation and inference, for which the prior and the posterior distribution belong to the Normal-Wishart family. In order to draw the 'candidate truths' from the posterior, a joint draw is taken from the unrestricted Normal-Wishart posterior for the SVAR parameters as well a draw of a possible contemporaneous impact matrix, which allows us to construct impulse response functions. If the imposed sign restrictions on the impulse response functions of the global oil market variables are satisfied, the draw is kept. Otherwise, the draw is rejected by giving it a zero prior weight. We require each draw to satisfy the restrictions of all three oil shocks simultaneously. A total of 1 000 'successful' joint draws are then used to generate the median responses, together with the 16th and 84th percentile error bands.

To evaluate the channels of transmission in Section 3, the benchmark SVAR model is extended as follows:

$$\begin{bmatrix} \boldsymbol{X}_t \\ \boldsymbol{Y}_{j,t} \\ \boldsymbol{Z}_{j,t} \end{bmatrix} = \boldsymbol{c} + A(L) \begin{bmatrix} \boldsymbol{X}_{t-1} \\ \boldsymbol{Y}_{j,t-1} \\ \boldsymbol{Z}_{j,t-1} \end{bmatrix} + \boldsymbol{B} \begin{bmatrix} \boldsymbol{\varepsilon}_t^X \\ \boldsymbol{\varepsilon}_{j,t}^Y \\ \boldsymbol{\varepsilon}_{j,t}^Z \end{bmatrix} \qquad \text{(A1)}$$

where: $\boldsymbol{X}_t$ and $\boldsymbol{Y}_{j,t}$ still contain the seven endogenous variables listed in Section 2.2, and the vector $\boldsymbol{Z}_{j,t}$ consists of one variable intended to capture a specific channel or effect. Estimation and inference are exactly the same as for the initial model. Note that feedback is allowed from the variable in $\boldsymbol{Z}_{j,t}$ to the benchmark variables in $\boldsymbol{X}_t$ and $\boldsymbol{Y}_{j,t}$. As a result, the estimated magnitude and dynamics of the oil shock might slightly change across different specifications, which could affect comparability. However, imposing strict exogeneity between the oil market and the country variables, by estimating a so-called near-VAR, does not affect the results. Therefore, comparisons can be made by normalising the oil shocks to a 10 per cent long-run oil price increase, which is done throughout the paper. The cross-country differences reported are also robust to normalising the oil shocks on a short-run oil price increase of 10 per cent. Data on the variables used to measure the pass-through are collected from the OECD MEI database, except for the euro area data which are from the AWM.

Appendix B

Figure B1: Historical Contribution of Different Types of Oil Shocks to Changes in the Nominal Oil Price

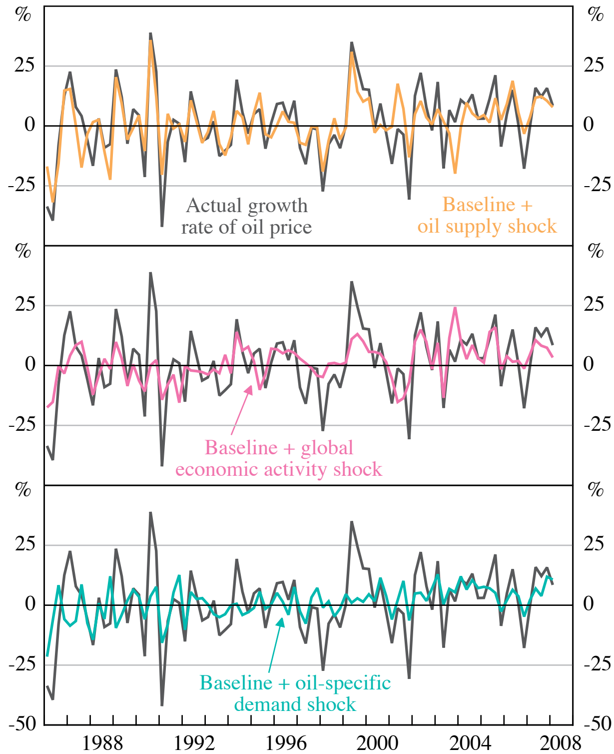


Figure B2: Oil Supply Shock with Same Oil Price Increase but Flat versus Steep Slope of Oil Demand Curve

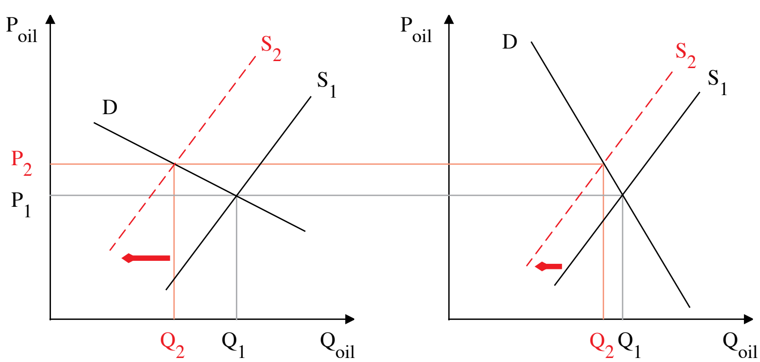


Figure B3: Impulse Response Functions after Oil Supply Shock over Time

Median impulse responses, together with 16th and 84th percentile confidence bands

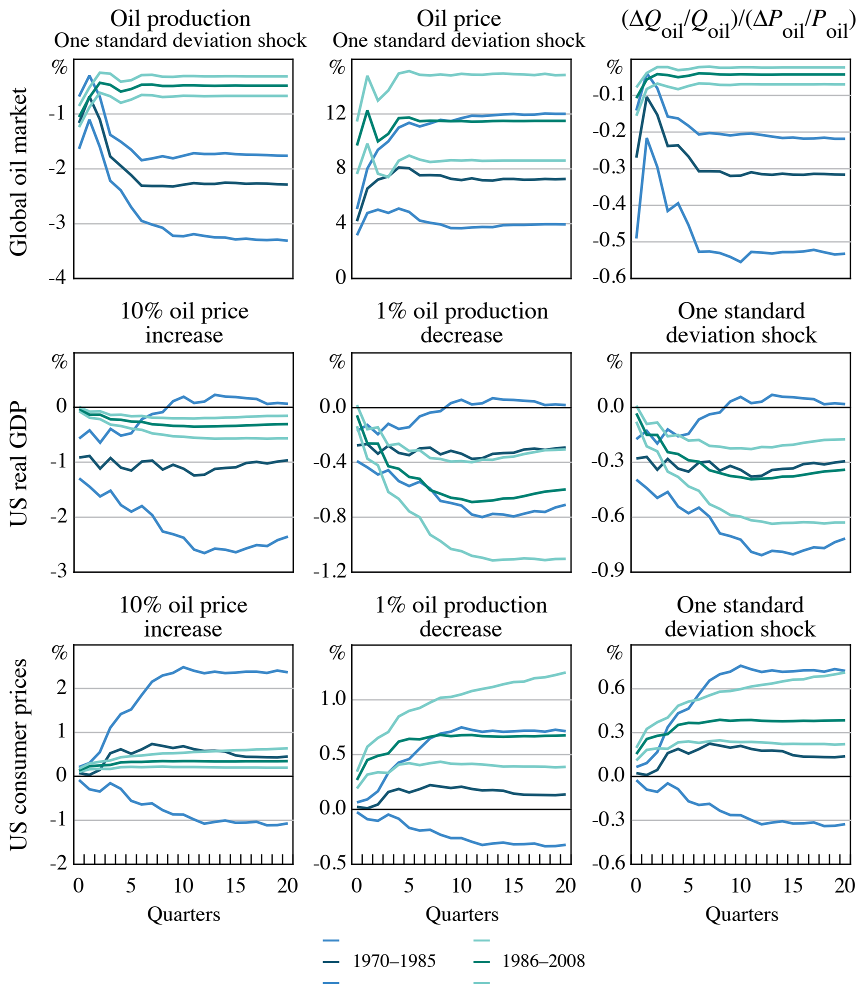


Figure B4: The Effects of Oil Supply Shock over Time
Median impulse responses to a 10 per cent long-run rise in oil prices, together with 16th and 84th percentile confidence bands
(*continued next page*)

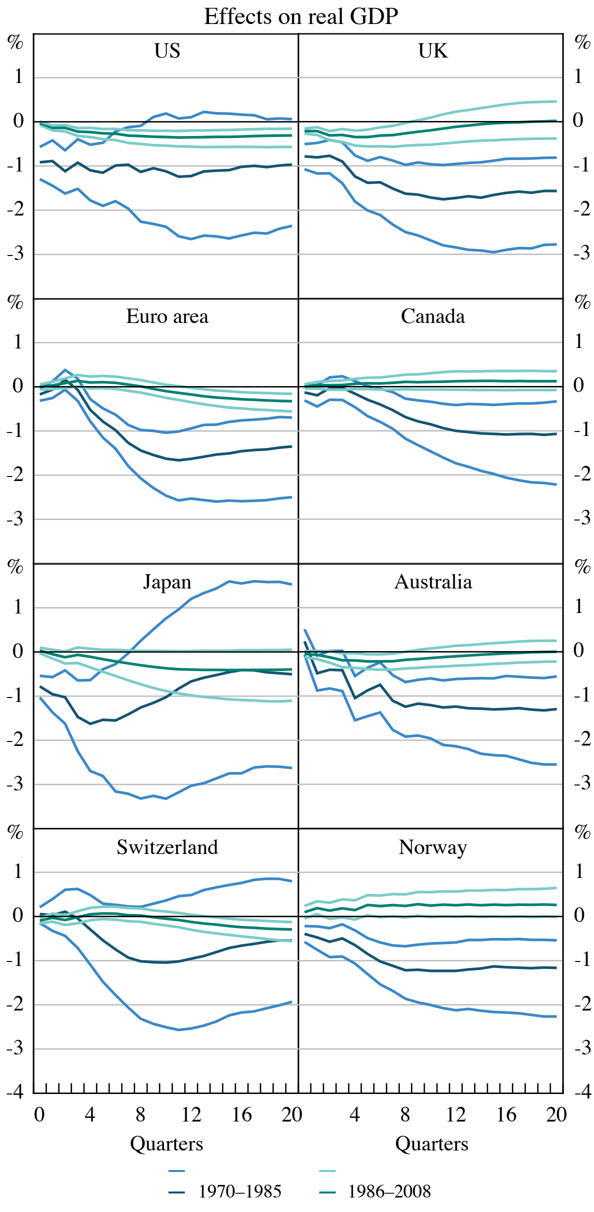


Figure B4: The Effects of Oil Supply Shock over Time

Median impulse responses to a 10 per cent long-run rise in oil prices, together with 16th and 84th percentile confidence bands

(*continued*)

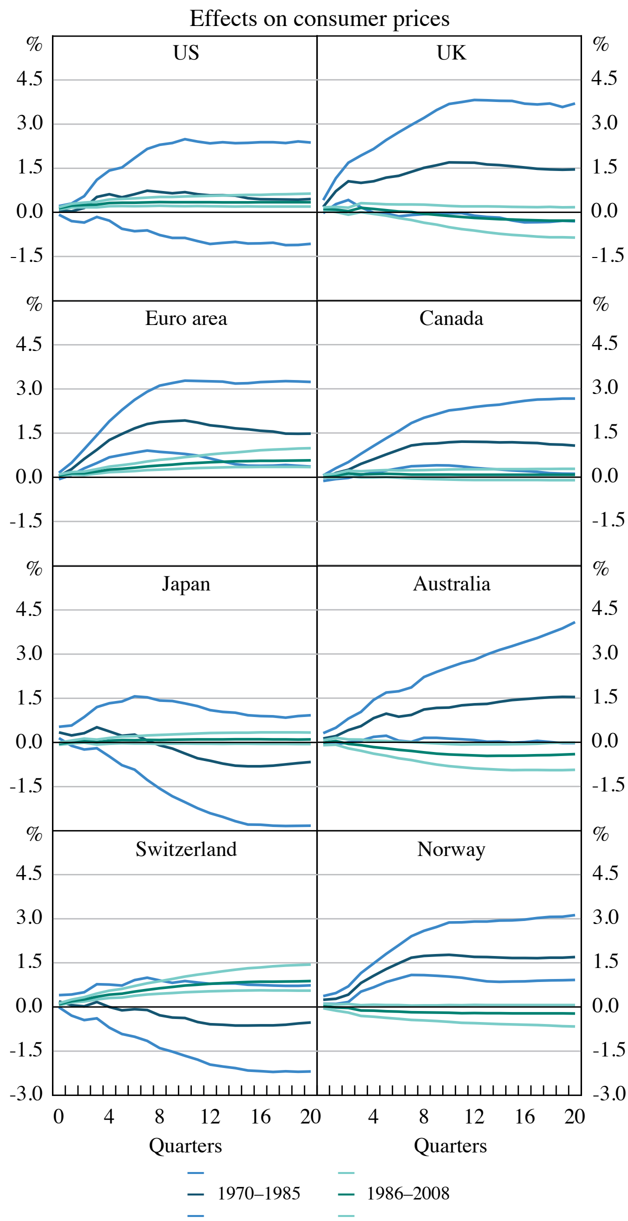


Table B1: Structural Differences across Economies and the Impact of Oil Shocks
1986–2008

	Oil[a]			Non-oil energy[a]			Total energy[a]			Oil supply[b]		Global activity[b]		Oil-specific demand[b]	
	Net import	Production	Total	Net import	Production	Total	Net import	Production	Total	GDP[c]	CPI[c]	GDP[d]	CPI[c]	GDP[d]	CPI[c]
United States	55	41	96	2	156	158	57	197	254	–0.31	0.35	0.33	0.61	–0.46	0.50
Euro area	71	2	73	30	65	95	101	67	168	–0.32	0.58	0.33	0.65	–0.44	0.11
Japan	67	0	67	62	29	91	129	29	158	–0.40	0.10	0.19	0.53	–1.10	0.18
Switzerland	22	0	22	47	50	97	69	50	119	–0.29	0.88	0.23	0.51	–0.22	0.23
United Kingdom	–21	79	58	11	95	106	–10	174	164	0.02	–0.29	0.12	0.60	–0.72	–1.99
Canada	–16	109	93	–116	329	213	–132	438	306	0.12	0.08	0.25	0.47	–0.79	–0.60
Australia	7	53	60	–220	375	155	–213	428	215	0.00	–0.40	0.21	0.85	–0.40	0.48
Norway	–704	815	111	–331	398	67	–1 035	1 213	178	0.26	–0.22	0.38	1.58	–0.71	0.00

(a) Averages for 1986–2008 based on IEA data measured as (tonnes of oil equivalent)/GDP (US$ million, PPP-weighted) of respectively crude oil, total energy excluding crude oil, and total energy
(b) Cumulated percentage change
(c) Estimated median impulse responses in the long run (20 quarters); comparison of permanent effects
(d) Estimated maximum median impulse responses; comparison of short-run effects
Sources: IEA; authors' calculations

Table B2: The Role of Oil and Energy and the Impact of Oil Supply Shocks over Time

	Net import of oil[(a)]			**Net import of energy**[(a)]			**Energy intensity**[(a)]			**Maximum impact on GDP**[(b)]			**Maximum impact on CPI**[(b)]		
	1970–1985	1986–2008	*Change*	1970–1985	1986–2008	*Change*	1970–1985	1986–2008	*Change*	1970–1985	1986–2008	*Change*	1970–1985	1986–2008	*Change*
United States	63	55	*–8*	59	57	*–2*	374	254	*–120*	–1.24	–0.35	*0.89*	0.74	0.35	*–0.38*
Euro area	112	71	*–41*	127	101	*–26*	210	168	*–42*	–1.66	–0.33	*1.33*	1.93	0.58	*–1.35*
Japan	122	67	*–55*	174	129	*–45*	197	158	*–39*	–1.63	–0.41	*1.22*	0.52	0.11	*–0.41*
Switzerland	28	22	*–6*	86	69	*–17*	122	119	*–3*	–1.04	–0.32	*0.72*	0.19	0.89	*0.70*
United Kingdom	44	–21	*–65*	59	–10	*–69*	239	164	*–75*	–1.75	–0.35	*1.40*	1.69	0.15	*–1.54*
Canada	12	–16	*–28*	–45	–132	*–87*	389	306	*–83*	–1.09	0.01	*1.10*	1.21	0.13	*–1.08*
Australia	31	7	*–24*	–56	–213	*–157*	260	215	*–45*	–1.37	–0.22	*1.15*	1.65	0.04	*–1.61*
Norway	–96	–704	*–608*	–178	–1 035	*–857*	219	178	*–41*	–1.23	0.10	*1.33*	1.77	0.04	*–1.74*

(a) Averages for period based on IEA data measured as (tonnes of oil equivalent)/GDP (US$ million, PPP-weighted) of respectively net imports of crude oil, net imports of total energy, and total domestic energy consumption.

(b) Cumulated percentage change. Estimated maximum median impulse response over the horizon to an oil supply shock that raises oil prices by 10 per cent; comparison of maximum responses over time.

Sources: IEA; authors' calculations

References

Barsky RB and L Kilian (2004), 'Oil and the Macroeconomy since the 1970s', *Journal of Economic Perspectives*, 18(4), pp 115–134.

Baumeister C and G Peersman (2008), 'Time-Varying Effects of Oil Supply Shocks on the US Economy', Ghent University Working Paper No 2008/515.

Baumeister C and G Peersman (2010), 'Sources of the Volatility Puzzle in the Crude Oil Market', Ghent University Working Paper No 2010/634.

Bernanke BS (1983), 'Irreversibility, Uncertainty, and Cyclical Investment', *Quarterly Journal of Economics*, 98(1), pp 85–106.

Bernanke BS (2006), 'Energy and the Economy', speech to the Economic Club of Chicago, Chicago, 15 June.

Bernanke BS, M Gertler and M Watson (1997), 'Systematic Monetary Policy and the Effects of Oil Price Shocks', *Brookings Papers on Economic Activity*, 1, pp 91–142.

Blanchard OJ and J Galí (2007), 'The Macroeconomic Effects of Oil Price Shocks: Why Are the 2000s so Different from the 1970s?', NBER Working Paper No 13368.

Blinder AS and JB Rudd (2008), 'The Supply-Shock Explanation of the Great Stagflation Revisited', NBER Working Paper No 14563.

Cogley T and TJ Sargent (2002), 'Evolving Post-WWII U.S. Inflation Dynamics', in BS Bernanke and KS Rogoff (eds), *NBER Macroeconomics Annual 2001*, 16, MIT Press, Cambridge, pp 331–373.

Davis SJ and J Haltiwanger (2001), 'Sectoral Job Creation and Destruction Responses to Oil Price Changes', *Journal of Monetary Economics*, 48(3), pp 465–512.

Edelstein P and L Kilian (2009), 'How Sensitive Are Consumer Expenditures to Retail Energy Prices?', *Journal of Monetary Economics*, 56(6), pp 766–779.

Fagan G, J Henry and R Mestre (2001), 'An Area-Wide Model (AWM) for the Euro Area', ECB Working Paper No 42.

Ferderer JP (1996), 'Oil Price Volatility and the Macroeconomy', *Journal of Macroeconomics*, 18(1), pp 1–26.

Finn MG (2000), 'Perfect Competition and the Effects of Energy Price Increases on Economic Activity', *Journal of Money, Credit and Banking*, 32(3), Part 1, pp 400–416.

Fry R and A Pagan (2007), 'Some Issues in Using Sign Restrictions for Identifying Structural VARs', National Centre for Econometric Research Working Paper No 14.

Hamilton JD (1983), 'Oil and the Macroeconomy since World War II', *Journal of Political Economy*, 91(2), pp 228–248.

Hamilton JD (2003), 'What Is an Oil Shock?', *Journal of Econometrics*, 113(2), pp 363–398.

Hamilton JD (2009a), 'Causes and Consequences of the Oil Shock of 2007–08', *Brookings Papers on Economic Activity*, 1, pp 215–261.

Hamilton JD (2009b), 'Understanding Crude Oil Prices', *Energy Journal*, 30(2), pp 179–206.

Herrera AM and E Pesavento (2009), 'Oil Price Shocks, Systematic Monetary Policy, and the "Great Moderation"', *Macroeconomic Dynamics*, 13(1), pp 107–137.

Hooker MA (1996), 'What Happened to the Oil Price–Macroeconomy Relationship?', *Journal of Monetary Economics*, 38(2), pp 195–213.

Hooker MA (2002), 'Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regime', *Journal of Money, Credit and Banking*, 34(2), pp 540–561.

Kilian L (2008), 'The Economic Effects of Energy Price Shocks', *Journal of Economic Literature*, 46(4), pp 871–909.

Kilian L (2009), 'Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market', *American Economic Review*, 99(3), pp 1053–1069.

Lee K, S Ni and RA Ratti (1995), 'Oil Shocks and the Macroeconomy: The Role of Price Variability', *Energy Journal*, 16(4), pp 39–56.

Mork KA (1989), 'Oil and the Macroeconomy when Prices Go Up and Down: An Extension of Hamilton's Results', *Journal of Political Economy*, 97(3), pp 740–744.

Peersman G (2005), 'What Caused the Early Millennium Slowdown? Evidence Based on Vector Autoregressions', *Journal of Applied Econometrics*, 20(2), pp 185–207.

Peersman G and I Van Robays (2009a), 'Cross-Country Differences in the Effects of Oil Shocks', Ghent University Working Paper No 2009/629.

Peersman G and I Van Robays (2009b), 'Oil and the Euro Area Economy', *Economic Policy*, 24(60), pp 603–651.

Primiceri GE (2005), 'Time Varying Structural Vector Autoregressions and Monetary Policy', *Review of Economic Studies*, 72(3), pp 821–852.

Rotemberg JJ and M Woodford (1996), 'Imperfect Competition and the Effects of Energy Price Increases on Economic Activity', *Journal of Money, Credit and Banking*, 28(4), Part 1, pp 549–577.

Discussion

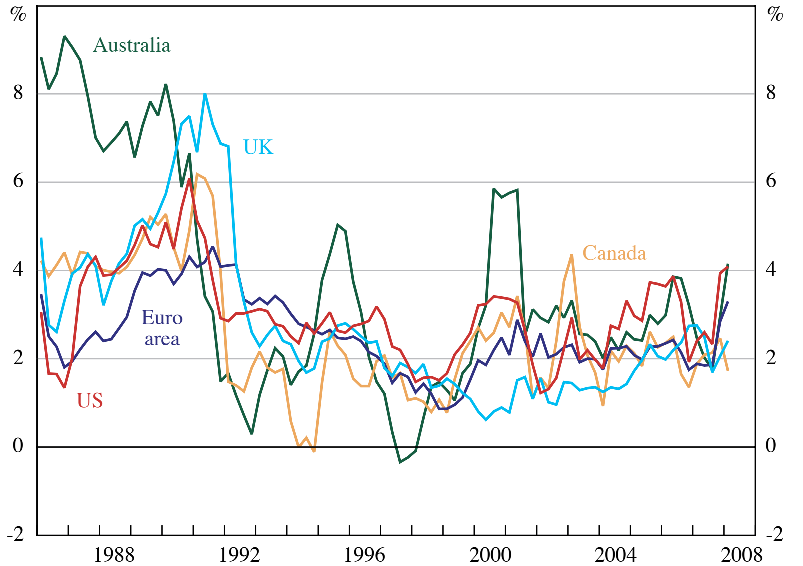
1. Mardi Dungey

This paper is one in a set of related papers recently put forward by Gert Peersman, in conjunction with the co-authors of this paper, Christiane Baumeister and Ine Van Robays. This body of work commendably attempts to more thoroughly explore the empirical linkages between oil price fluctuations and real economic outcomes for a variety of countries, in the hope of drawing together some general results about the impact of shocks to oil prices on the economy. Such generalisations are undoubtedly important for policy-makers. If it is possible to assess the expected response of an economy to a shock to oil prices based on the structure of the economy, then it will become somewhat easier to advocate appropriate policy responses.

What do we know?

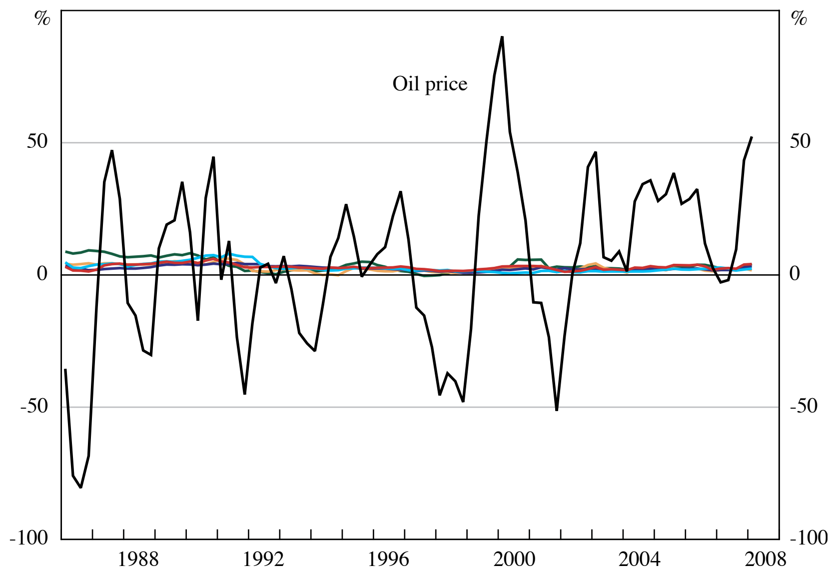
There is plenty of evidence that inflation behaviour in many countries is quite similar; see for example Figure 1, which compares the inflation rates for the economies in Christiane, Gert and Ine's sample. The figure shows the clear commonality in inflation rates, and there is a literature concerned with capturing the effects of global influences on inflation in individual countries, (for example, Binyamini and Razin 2008). The issue has also come to be associated with vector autoregression (VAR) estimates of individual country models as far back as Sims (1992), where he proposed that the price puzzle evident in many small VARs could be explained by capturing some measure of inflationary expectations, for which either commodity prices or oil prices could be useful proxies (an Australian example is provided by Brischetto and Voss 1999). Rather, Christiane, Gert and Ine attempt to use VAR estimates to distinguish the impact of oil market developments on economies. It is apparent that this link will be non-trivial to model by a simple comparison of the inflation rates of interest with changes in oil prices, shown in Figure 2. The volatility in oil prices swamps that in inflation rates, making its role as a proxy for a common factor unlikely. Christiane, Gert and Ine implicitly acknowledge this by attempting to disentangle the demand and supply shocks – if we examine the output profile of oil, through their quantity measure shown in Figure 3, it is apparent that this is also a relatively volatile series. As Christiane, Gert and Ine are at pains to point out, changes in oil output relate to both supply- and demand-side shocks, requiring appropriate identification technology.

Figure 1: Inflation Rates for Individual Economies
Year-ended percentage change



Source: Baumeister, Peersman and Van Robays (this volume)

Figure 2: Inflation Rates for Individual Economies and the Oil Price
Year-ended percentage change



Note: See Figure 1 for the inflation rates of individual economies
Source: Baumeister *et al* (this volume)

Figure 3: Quantity of Global Oil Output
Millions of barrels per day

Source: Baumeister *et al* (this volume)

Data selection

It is relatively well known that data intensive estimation methods such as VARs are sensitive to data choices. It then behoves me to make a number of comments on the selection of data for this paper, and the problems which may occur with cross-country comparisons. The first problem is that not all data sources are created equal. As we are all aware, the euro area did not exist prior to the official adoption of the euro in 1999, although some euro area data exist from the early 1990s courtesy of Eurostat. Even these data, however, are tainted by changing definitions of the countries in the euro area. The data used to represent the euro area in this paper are drawn from the Area-Wide Model (AWM) database of Fagan, Henry and Mestre (2001), a database conveniently available from the Euro Area Business Cycle Network (EABCN) for download. Euro area aggregates in this database are based on country data which are aggregated using PPP GDP-fixed weights for the entire pre-official euro area data. The weights are fixed in 2001. The back data for the euro area consumer price index are constructed using an entirely different set of weights based on household survey data, with back data constructed based on 1995 weights (see Anderson *et al* 2007 for a discussion). This may not be such a problem for the real data, but is a significant one for the financial data, particularly interest rates. Ehrmann and Fratzscher (2005) in fact find a significant break in the financial data at precisely the point at which this splicing would occur. The lack of real euro area data is likely to cause significant problems with sensitivity of the estimation, and the question of which data should be used is a lively area of debate with Brüggemann and Lütkepohl (2006) preferring German data, Beyer, Doornick and Hendry (2001) advocating nominal growth rate splicing and Anderson *et al* (2007) proposing sliding weights for financial market data based on distance from a measure of centrality in order to play down the effects of Italian and Portuguese financial markets. These issues should at least rate a mention in the paper – the AWM database was not designed to be a catch-all database for all applications.

The second problem is appropriate recognition of structural breaks and outliers in the data. A good example in the current context is the Australian CPI data. This is shown below in Figure 4. The impact of the introduction of the goods and services tax in 2000 is clearly evident as a short-lived increase in the inflation rate. Without controls for special features of the data such as this, significant distortions may arise. For example, using Christiane, Gert and Ine's data I estimated a very simple version of a linear Taylor rule for Australia with and without a dummy variable for the GST. The weights on inflation for these specifications are given in Table 1. Clearly, the dummy is significant, and its exclusion suggests that the Reserve Bank of Australia places a lower weight on domestic inflationary pressures than is the case when the appropriate control is in place.

Figure 4: Inflation Rate for Australia

Year-ended percentage change

Source: Baumeister *et al* (this volume)

Table 1: Inflation Coefficient in a Simple Taylor Rule Specification

	No dummy for GST	With dummy for GST
Coefficient on inflation	0.18	0.25
	(0.05)	(0.07)
Coefficient on dummy	na	–1.02
		(0.46)

Notes: With interest rate smoothing. Standard errors in parentheses.

Estimation methodology

This paper makes clever use of the sign restriction methodology to identify oil price shocks. By examining combinations of quantity and price responses to shocks in a VAR framework, the authors impose an identification which effectively supports demand from supply. This is very powerful. However, we need to be careful with this technology. Here three types of shocks are identified. One, when prices and quantities move in the same direction (a demand shock), a second when prices and quantities move in the opposite direction (a supply shock) and a third when prices and quantities move in the same direction but world output moves in the opposite direction (an oil-specific demand shock). These restrictions are imposed for four quarters. Although four quarters has become common in the literature, there is as yet no real methodology for determining the appropriate length of time which 'should' be applied. One of the criteria seems to be of reasonableness – and that we wish to find a sufficient number of identified draws in simulation. In this case, when the system is simulated the sign restrictions are satisfied some 25 per cent of the time – in effect this means that 75 per cent of the rotated draws are not satisfactory combinations. Again, we have no criteria to judge whether this is reasonable or not.

Peersman (2005) was one of the earlier papers to implement sign restrictions. Fry and Pagan (2007) show that the choice of point estimates for the sign-restricted impulse responses in that paper does not preserve the orthogonality of the shocks represented in the impulses. Without orthogonality, not only are the impulse response functions inconsistently generated but variance decompositions, such as given in Peersman, will be invalid. Simply, the Peersman proposal chose the median realisation of the acceptable simulated impulses at each point of time in the forecast horizon, which does not guarantee orthogonality. Fry and Pagan propose a simple distance estimator to overcome this problem in selecting the point estimate, and show that it can make a considerable difference to the impulse response function. In the current paper, it is not clear that such a correction has been applied to ensure the orthogonality of shocks at all points. If not, this should be undertaken to confirm the validity of the results.

Cross-country evidence

The novelty of this paper is the application of the identification methodology to a relatively wide range of economies, representing net oil importers and exporters, net importers and exporters of other energy sources, and large and small open economies. A potential problem is whether the shocks identified in each of the individual models for oil demand and supply are equivalent across the economies, validating the cross-country comparisons.

The authors present their model results for separate country groups defined according to these different economic structures. The first are energy importers, which import both oil and other energy substitutes: Japan, the euro area and Switzerland fall clearly into this category. The second are net oil importers, which largely import oil but export other energy substitutes: the United States, Australia and Canada are primary examples. The third are net oil exporters, which export oil but import other energy substitutes, such as the United Kingdom. And finally, there are oil-exporting countries who do not rely on other energy substitutes, such as Norway.

Overlaid on this distinction based on trade in energy, there are important differences in terms of the size and openness of the economies. Australia, Canada and Norway are all small open commodity-exporting economies. Japan and the euro area are typically classified as larger open economies, with the United Kingdom somewhere between these and the commodity exporters. Typically the United States is represented as a large closed economy.

The conclusions drawn by Christiane, Gert and Ine based on their categorisation of energy importers, and two categories of net energy importers and energy exporters, can be summarised as follows. An adverse oil supply shock results in permanently lower output for energy importers of all kinds, but is insignificant or occasionally positive for energy exporters. Inflationary effects may be offset by exchange rate movements, but are not always. Oil demand shocks are less able to be divided by the energy status of the individual economies.

Consider now whether the openness of the economies can also be related to the results. Small open economies seem to have smaller (and largely insignificant) impacts from an oil supply shock and their inflationary responses are also muted and insignificant. The shock does result in significant interest rate response in Australia, the euro area, the United Kingdom and Switzerland. Only in Japan, Canada and the United Kingdom are the output responses to oil demand shocks (from either source) significantly different from zero at a longer horizon. All countries experience significant inflation increases from an economic activity-driven oil demand shock. On the other hand, only the United Kingdom (and possibly the United States, it is not clear from the figure) have a significant inflationary impact from an oil-specific demand shock. In fact, it seems that it is difficult to make any generalisations regarding the effects of oil demand shocks based on either the classification of the energy import/export status or their openness.

Time-varying evidence

The authors present evidence drawn from a previous paper that the elasticity of demand for oil has changed within the sample period. Consequently, they re-estimate the VAR models and examine whether there are differences in impulses between the two sample periods. In general, they conclude that the responses in the later (1990s) period are muted compared with the earlier (1970s) period. This tallies with our understanding of economic relationships over the period. I would like to suggest that the authors consider an alternative representation of their results. By estimating the early period SVAR and projecting it forward into the later period, they can examine the different outcomes the early model predicts when encountering the later period shocks, and clearly examine the differences between them. This is in the spirit of the projections given in Dungey, Fry and Martin (2004). Another useful extension would be to decompose individual country inflation data into its components using an historical decomposition, where each component depends on the contribution of all previous shocks of a particular type – that is, the value of any variable in the VAR can be represented as a weighted sum of all previous shocks. This is a reorganisation of the information in the impulse responses, somewhat different to a forecast error variance decomposition, but it can be useful in obtaining a view of the relative importance of different shocks to domestic inflation over the period of interest. In this way it would be possible to say something about the relative importance of oil supply, oil demand and domestic shocks to the evolution of domestic inflation. With information about the sources of shocks it will be easier to assess the performance of monetary policy in response.

Concluding remarks

In summary, this paper is a contribution to better understanding of the effects of oil price shocks on economies, in light of the differences in the structure of the individual economies.

The identification of the oil price shocks in the paper is intelligent, but this is not the novelty of this paper. Rather, the authors concentrate on classifying the characteristics of economies in order to understand the way in which they respond to oil shocks. The paper is not quite in the vein of the global VAR (GVAR) papers of Dees *et al* (2007) and Dees *et al* (2009), but there are overlaps. In the GVAR, each country is treated as an individual module, where the structure of these modules is identical. The novelty of the GVAR modelling approach is that it uses a consistent means of interaction between countries, via a relationship with the rest of the world. In Christiane, Gert and Ine's paper we have a similar modular style of approach to the countries, with each linked to a rest-of-world activity variable, but we do not have interactions between all of the economies in a single model. It would be beneficial to take this one step further and take account of the structural idiosyncrasies of the data in these economies to further refine the results. Then we could be surer that the generalisations we desire are not being driven by outliers or anomalies, something which seems to be absolutely desirable from a policy-making perspective.

References

Anderson HM, M Dungey, DR Osborn and F Vahid (2007), 'Constructing Historical Euro Area Data', CAMA Working Paper No 18/2007.

Beyer A, JA Doornick and DF Hendry (2001), 'Constructing Historical Euro-Zone Data', *The Economic Journal*, 111(469), pp F102–F121.

Binyamini A and A Razin (2008), 'Inflation-Output Tradeoff as Equilibrium Outcome of Globalization', NBER Working Paper No 14379.

Brischetto A and G Voss (1999), 'A Structural Vector Autoregression Model of Monetary Policy in Australia', RBA Research Discussion Paper No 1999-11.

Brüggemann R and H Lütkepohl (2006), 'A Small Monetary System for the Euro Area Based on German Data', *Journal of Applied Econometrics*, 21(6), pp 683–702.

Dees S, P di Mauro, MH Pesaran and LV Smith (2007), 'Exploring the International Linkages of the Euro Area: A Global VAR Analysis', *Journal of Applied Econometrics*, 22(1), pp 1–38.

Dees S, MH Pesaran, LV Smith and RP Smith (2009), 'Identification of New Keynesian Phillips Curves from a Global Perspective', *Journal of Money, Credit and Banking*, 41(7), pp 1481–1502.

Dungey M, R Fry and VL Martin (2004), 'Identification of Common and Idiosyncratic Shocks in Real Equity Prices: Australia 1982–2002', *Global Finance Journal*, 15(1), pp 81–102.

Ehrmann M and M Fratzscher (2005), 'Equal Size, Equal Role? Interest Rate Interdependence between the Euro Area and the United States', *The Economic Journal*, 115(506), pp 928–948.

Fagan G, J Henry and R Mestre (2001) , 'An Area-Wide Model (AWM) for the Euro Area', ECB Working Paper No 42.

Fry R and A Pagan (2007), 'Some Issues in Using Sign Restrictions for Identifying Structural VARs', National Centre for Econometric Research Working Paper No 14.

Peersman G (2005), 'What Caused the Early Millennium Slowdown? Evidence Based on Vector Autoregressions', *Journal of Applied Econometrics*, 20(2), pp 185–207.

Sims CA (1992), 'Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy', *European Economic Review*, 36(5), pp 975–1000.

2. General Discussion

Three themes emerged from the discussion on the paper presented by Ine Van Robays examining the varying reactions to oil demand and oil supply shocks across economies, many following on from those raised in the first session of the conference.

There was some discussion of how best to measure real activity. A participant noted that the paper used a broad measure of output starting from 1986, but this came at the cost of a diminished sample length. This raised a concern that the parameter estimates of the VAR model may be compromised by the lack of sample data.

Another participant expanded on this point by noting that not only was it difficult to accurately estimate the coefficients of the model given the number of variables and available observations, but that extending the sample further back in time would encompass larger shocks specific to the oil market, namely those of the 1970s. It was suggested that incorporating these would better identify the VAR model, particularly in terms of the key oil supply and demand shocks of the model.

The second theme was introduced by a participant who wondered whether the nature of the impulse responses to oil shocks depends on where along the supply curve the economy is to begin with. If so, it was suggested that this might have important implications for monetary policy; if the economy is on the inelastic part of the supply curve, the response of prices to a general demand shock would be larger than if the economy was on a flatter portion of the curve. A related line of discussion arose regarding possible movements in the oil supply curve, with one participant conjecturing that the oil supply curve was becoming steeper. Another participant followed this up by raising the question of the consequences of a significant expansion of demand shifting the world economy up the supply curve. In response, a participant thought that the suggestion of moving up the global supply curve is not as severe as perhaps implied by the results of the paper because the world would find ways to adjust to short- and even medium-run supply constraints. They went on to claim that, but for the financial crisis, there would have been a significant amount of capital available to expand the supply of oil. It was noted, however, that while a rightward shift in the oil supply curve may be likely, it could take a long time and in the meantime, monetary policy-makers needed to consider the implications of a movement up the oil supply curve.

There was some debate about the assumptions used in the VAR model of the paper in relation to the supply of oil. One participant suggested that the supply of oil is a function of the decisions taken by swing producers, and that the VAR approach does not adequately model these decisions which will have an important influence on prices over the longer run. Another participant responded to this comment by explaining that the VAR approach used in the paper does not restrict the long-run response, but rather identifies shocks by making assumptions about the short-run responses of the economy to different types of shocks.

The third theme of the discussion was the importance of second-round effects on the inflation and monetary policy responses. One participant appreciated the precision with which the paper defined the direct and second-round effects. Another highlighted the paper's results regarding differences across economies in the impulse responses to oil supply shocks and suggested that they were potentially explained by differences in labour market flexibility.

What Drives Inflation in the World?

César Calderón and Klaus Schmidt-Hebbel[1]

Abstract

This paper evaluates the empirical role of non-monetary determinants of inflation in a world panel sample. We extend the previous literature by: (i) specifying a broad inflation model that encompasses existing partial models; (ii) assembling a dataset for 97 countries spanning 1975–2005; (iii) using a broad set of alternative estimation techniques; and (iv) testing the sensitivity of results to a non-linear inflation specification that allows for heterogeneity across different country groups and time periods. The findings show that, controlling for high-inflation and hyperinflation episodes, inflation-targeting (IT) regimes and fixed exchange rate regimes contribute to lower inflation. More financial openness, smaller fiscal deficits and more financial development also reduce inflation. The domestic output gap raises short-run inflation. Several of the latter effects are found to be larger in low- and middle-income economies than in high-income economies.

1. Introduction

The notion that inflation is ultimately a monetary phenomenon and that central banks are responsible for price stability is at the core of monetary economics. There is similar wide agreement about the output and welfare costs of high inflation (for example, Fischer, Sahay and Végh 2002). Why then do central banks inflate and why do many countries experience bouts of sustained high inflation? Among the answers to the latter questions found in the literature are exploitation of the short-term trade-off between unemployment and inflation, myopic bias toward short-term gains of inflation, fiscal deficit financing and alleviation of the burden of government debt. Such time-inconsistent policies are more likely to arise in countries where institutions are weak and governments prevent monetary authorities from focusing on longer-run price and output stability.[2] Here we use a broad meaning of the term 'institutions', encompassing the macroeconomic policy framework (regimes and

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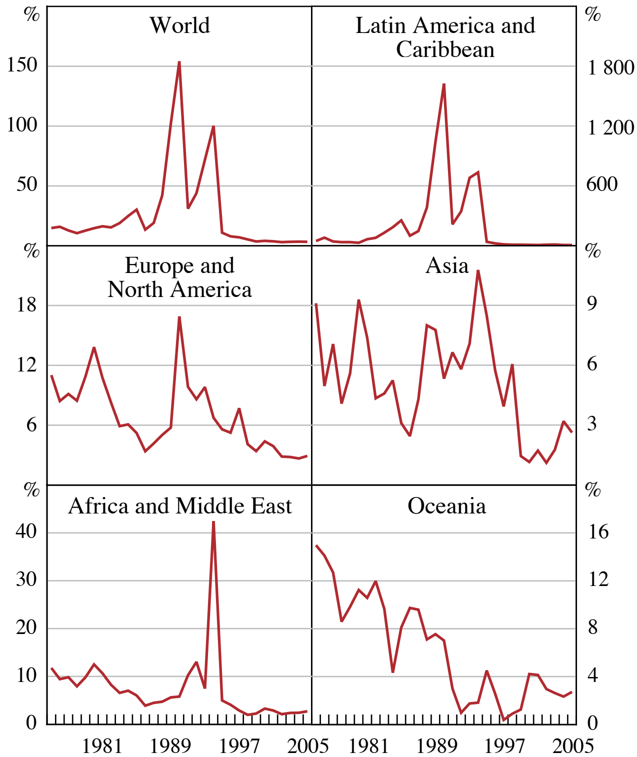
2. The question about the welfare preference between long- and short-term objectives of monetary policy and time inconsistency has been widely debated in the literature, starting with Kydland and Prescott (1977) and Barro and Gordon (1983).

policy rules), the quality of government bureaucracy and the sustainability of monetary and fiscal arrangements.

Inflation rates vary greatly across countries (and world regions) and over time, as depicted in Figure 1.[3] Yet a broad world trend is observed during the three decades spanning 1975–2005, as shown in Figures 1 and 2. Two periods are clearly apparent in the data. One is the *Great Inflation* period of the seventies and eighties, when industrial countries experienced abnormally persistent two-digit inflation rates and many developing countries lived through high-inflation and hyperinflation episodes.

Figure 1: World and Regional Inflation Rates



Note: Regional and world average rates are constructed as PPP GDP-weighted averages of countries' individual normalised inflation rates

Source: authors' calculations

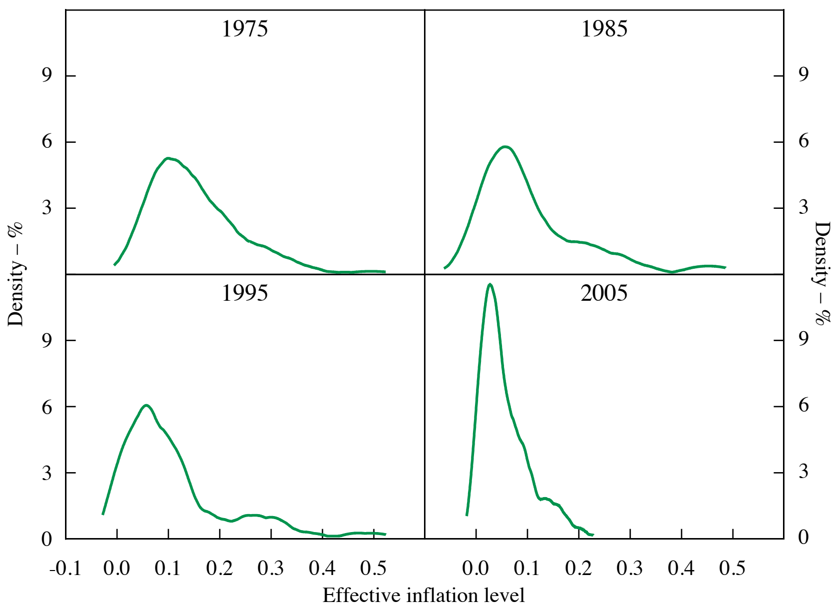
3. As discussed in Section 2, inflation is measured and represented here and throughout the paper in its normalised form.

A second period of persistent disinflation – the *Great Moderation*[4] – started in the eighties to early nineties and led most countries to converge to one-digit inflation rates at the start of the third millennium (Summers 2005; IMF 2007).[5]

The weak institutions and loose fiscal and monetary policy regimes that were behind the *Great Inflation* in industrial countries (and high inflation/hyperinflation in developing countries) led to worldwide reforms of macroeconomic institutions, regimes and policy rules. Inflation stabilisation began in industrial countries, including Switzerland, Germany, Japan and the United States, in the late seventies and early eighties. Developing economies followed by adopting successful stabilisation programs in the late eighties and early nineties. As a result of the latter changes, average world inflation fell below 3.5 per cent at the end of our sample period, in 2005 (Figure 2).

Figure 2: Distribution of Cross-country Inflation Rates

Kernel density plots for each period



Note: Inflation is defined on a decimal basis, thus 1% is equivalent to 0.01

Source: authors' calculations

4. Strictly speaking, the term *Great Moderation* refers to the decline in the volatility of inflation and output. Coined by James Stock, it was first documented by Blanchard and Simon (2001) and subsequently analysed by many authors, including Bernanke (2004), Summers (2005) and IMF (2007). In this paper we use it in the more narrow sense of a period of significant decline in inflation levels, which is highly correlated to the reduction in inflation volatility.
5. Our sample covers only through to 2005, therefore excluding the large swings in world inflation observed in the recent past, from higher inflation during the 2006–2008 commodity price boom to very low inflation during the 2008–2009 global financial crisis and recession.

The existing empirical literature that focuses on non-monetary determinants of inflation across countries is broad and diverse in its conclusions. Most studies address only a few determinants of inflation at a time and do so for a limited number of countries and/or time periods. Moreover, they rarely check for the robustness of results using alternative estimation techniques.

This paper extends the preceding literature in several dimensions. First, we consider a broad and comprehensive specification that encompasses previous partial specifications. In particular, we consider five types of explanatory variables: inflation-related variables; monetary and exchange rate regimes; measures of international openness; structural and institutional variables; and business-cycle variables. Second, we assemble a large dataset for 97 countries and 31 years (1975–2005), including both the *Great Inflation* and *Great Moderation* years. Third, we use a broad set of alternative estimation techniques, contrasting their results. Finally, we test for the robustness of our results to alternative specifications that allow for slope heterogeneity across country groups and over time.

The paper is divided into five sections. Section 2 discusses our set of potential inflation determinants classified according to the five categories of variables mentioned above, in the context of relevant literature. Section 3 introduces our inflation specification and the different econometric estimation models that we will apply for its estimation. Section 4 reports the statistical properties of the data sample and discusses our empirical results. Section 5 concludes.

2. Previous Literature and Inflation Specification

There is a large empirical literature on inflation determinants for individual countries. However, cross-country (panel data or cross-section) studies are scarce. Table 1 summarises the cross-country literature, highlighting its main findings and the fact that individual studies focus only exceptionally on more than two (out of our five) groups of potential inflation determinants.

Next, we introduce the arguments of the literature in support of our inclusion of inflation determinants in the subsequent empirical work. Our dependent variable – as opposed to most of the previous literature, which uses the simple inflation measure – is the rate of inflation for a country in its normalised form, defined as $\pi = (\Delta CPI/CPI)/(1+ \Delta CPI/CPI)$, where ΔCPI is the change in the consumer price index. We use the normalised form for two reasons. First, it is the correct way to represent the alternative cost of holding money when using discrete-time data. Second, this measure avoids attaching excessive weight to observations of high inflation. Our set of explanatory variables is divided into five categories: inflation-related variables; monetary and exchange rate regimes; international openness measures; structural and institutional variables; and business-cycle variables.

Table 1: Previous Empirical Results

Variable	Author	Effect on inflation	Panel data/ cross-section	Observations
Openness	Alfaro (2005)	(+/–)	Panel data	Imports and exports
	Campillo and Miron (1996)	(–)	Cross-section	Trade openness
	Catão and Terrones (2005)	nss	Panel data	
	Gruben and McLeod (2004)	(–)	Panel data	Trade openness
	Kamin, Marazzi and Schindler (2004)	(–)	Panel data	Trade openness
	Romer (1993)	(–)	Panel data	Trade openness (OECD)
	Temple (2002)	(–)	Panel data	Trade openness
	Terra (1998)	(+/–)	Panel data	Trade openness (OECD)
	Tytell and Wei (2004)	(–)	Panel data	Financial openness
Institutions	Aisen and Veiga (2006)	(–)	Panel data	Political instability
	Cottarelli, Griffiths and Moghadam (1998)	(–)	Panel data	Transition economies
Oil price inflation	Catão and Terrones (2005)	(+)	Panel data	
Exchange rate regime	Alfaro (2005)	(–)	Panel data	Unflexibility of exchange rate regime
	Catão and Terrones (2005)	nss	Panel data	
	Cottarelli *et al* (1998)	(–)	Panel data	Transition economies
Fiscal variables	Alfaro (2005)	(–)	Panel data	
	Catão and Terrones (2005)	(–)	Panel data	
	Cottarelli *et al* (1998)	(–)	Cross-section	Transition economies
	Fischer *et al* (2002)	(–)	Both	Focus on hyperinflation episodes

Notes: Restricted to panel data or cross-section estimations; nss = no statistically significant effect found

Source: authors' elaboration

2.1 Inflation-related variables

We include three variables in this category. We control for episodes of high inflation and hyperinflation using binary variables. Following Dornbusch and Fischer (1993), hyperinflation episodes are defined when non-normalised annual inflation exceeds 1 000 per cent and high-inflation episodes are those when non-normalised annual inflation exceeds 50 per cent.[6] Fischer *et al* (2002) point out that there are several

6. Cagan (1956) defined hyperinflation episodes as beginning in the month when monthly inflation first exceeds 50 per cent and ending in the month before monthly inflation declines below 50 per cent for at least one year. Note that a (non-normalised) monthly inflation rate of 50 per cent is equivalent to a (non-normalised) annual inflation rate of 12 875 per cent.

reasons to isolate these extreme but infrequent episodes. Hyperinflations are very costly and countries are not willing to tolerate them for more than a few years or even some months. Hence, some hyperinflation episodes may not be accounted for by annual datasets. Also, linear estimation models tend to severely overestimate the impact of inflation on macroeconomic performance when based on samples that include hyperinflations in comparison to estimations based on samples without hyperinflations.[7]

We also account for inflation inertia by including the lagged dependent variable. There are several reasons why inflation is time-dependent. First, if prices are set in a forward-looking manner under conditions of nominal rigidity, it is optimal for firms to set higher prices in advance when they rationally expect the aggregate price level to rise. Second, inflation inertia arises under conditions of indexation. This is observed when wages and prices of goods and services (most frequently, but not exclusively, prices of non-tradables like public utilities, home rents and other services) are indexed to past inflation.

2.2 Monetary and exchange rate regimes

We control for two types of monetary and exchange rate arrangements that have been the focus of previous literature. First, we construct a binary variable that takes the value of 1 for countries with an inflation-targeting (IT) regime, and 0 otherwise. IT is an operational framework for monetary policy aimed at achieving an explicit numerical target value or range for the rate of inflation. Hence, having IT in place could contribute to stabilising inflation expectations and reducing average inflation rates, compared to alternative monetary regimes. Empirical evidence on the effect of adopting an IT regime tends to show that it lowers inflation and inflation expectations and reduces its volatility (Truman 2003; Hyvonen 2004; and Vega and Winkelried 2005, among others). Ball and Sheridan (2004) present contradictory evidence, showing that IT does not make any difference for the latter variables in industrial countries. In contrast, Mishkin and Schmidt-Hebbel (2007) find that the largest benefits of inflation reduction among inflation targeters is experienced in emerging market economies and converging-to-stationary-target inflation targeters, showing that the choice of control group is the key for documenting any effect of IT on inflation. In our large dataset the control group will be comprised of the large majority of countries that have not adopted IT.

Second, we account for the effects of different exchange rate (ER) regimes on inflation performance. Evidence on the negative association between inflation and fixed ER regime pegs can be found in Cottarelli *et al* (1998), Husain, Mody and Rogoff (2005) and Levy-Yeyati and Sturzenegger (2005). Following the latter, we expect inflation to be lower in countries with fixed ER regimes – with the impact larger in countries with hard pegs (Levy-Yeyati and Sturzenegger 2001) – for several reasons. First, countries that adopt a pegged ER are often those which have suffered

7. In our sample, hyperinflation episodes have occurred in Argentina, Bolivia, Brazil, Bulgaria, Croatia, the Democratic Republic of Congo, Nicaragua and Peru.

previously from high inflation and use the nominal ER as an anchor to lower inflation. Second, ER pegs operate as a disciplinary tool for monetary authorities, limiting their ability to raise the money supply at the risk of causing a balance of payments crisis. Third, fixed ER regimes also signal a commitment to lower future inflation, which may help anchor inflation expectations and thus lower actual inflation. While the latter factors may explain why many countries adopted ER pegs in the past, they are also behind the more widespread adoption of IT today, a regime that nowadays dominates the choice of ER pegs.

2.3 International openness

Borio and Filardo (2007) argue that global factors are becoming predominant in the inflation dynamics of globally integrated economies. We account for the impact of openness on domestic inflation across three different dimensions: trade openness; financial openness; and global inflation. Regarding trade openness, increased competition and integration to world markets fosters productivity growth, therefore reducing costs and domestic prices (Grossman and Helpman 1991). Romer (1993) documents that OECD countries with a more open trade regime have lower inflation. Lane (1997) argues that the mechanism that links openness to incentives to inflate does not rely on a large country terms-of-trade effect, as Romer (1993) suggested, but instead is based on imperfect competition and nominal price rigidity in the non-traded goods sector. Terra (1998) finds that the negative association between trade openness and inflation is stronger among severely indebted countries since they exhibit weak pre-commitment in their conduct of monetary policy. Another possibility is that openness induces higher competition and market flexibility, forcing local firms to reduce domestic prices (Rogoff 2003; Sbordone 2007). Several recent papers have documented a negative relation between trade openness and inflation (Temple 2002; Gruben and McLeod 2004; Borio and Filardo 2007).

Capital account openness affects inflation through different channels. First, financial integration lowers the cost of foreign financing of temporary fiscal deficits, making it less likely that governments resort to using seigniorage and creating inflation (Phelps 1973; Aizenman 1992). Second, capital account opening (and hence openness) is one component of the package of reforms that aim at macroeconomic stability, reinforcing fiscal discipline, central bank independence and sound monetary policy. Finally, capital account openness by itself exerts disciplinary effects against monetary expansion by neutralising it under fixed ER regimes or inducing currency substitution and currency depreciation under floating ER regimes. Hence financial openness, by raising the costs of inflation and enhancing monetary policy credibility, lowers inflation (Tytell and Wei 2004).

The third dimension of openness is the impact of external inflation on domestic inflation. Recent developments in the world economy have brought to the fore the likely influence of globalisation on domestic inflation (Helbling, Jaumotte and Sommer 2006). In particular, it has been argued that China and India have exported deflation by swamping world markets with low-cost manufactured goods.[8] Therefore we test for the influence of country-specific external inflation for domestic inflation.

2.4 Structural and institutional variables

Low and stable inflation can be a difficult objective for central banks because it may entail sacrificing alternative short-run objectives. Many central banks have sacrificed the goal of low and stable inflation by using expansionary monetary policies to achieve lower short-term unemployment (exploiting the short-term Phillips curve), financing public deficits (through the inflation tax) or lowering the real value of public debt. High-quality institutional arrangements would prevent such time-inconsistent policies and thus contribute to lower inflation (Cukierman 1992; Aisen and Veiga 2006). Due to the dearth of sufficient panel data on central bank independence (for example, see Cukierman, Webb and Neyapti 1992), we are not able to include this direct measure of central bank institutional strength in our specification. Instead, we include four more widely available measures of institutional and structural strength. The first is a measure of democratic accountability, which reflects the strength of governments and central banks to resist short-run populist demands, strengthening their pursuit of long-run stabilisation objectives. The second measure is a proxy for overall institutional development: per capita income.[9] The fiscal theory of inflation predicts that the weaker is the revenue system or the more excessive is public spending, the more likely is the use of seigniorage to finance public spending beyond tax revenue (Phelps 1973; Sargent and Wallace 1981; Végh 1989; Cukierman, Edwards and Tabellini 1992). To test directly for the fiscal theory of inflation, we include the ratio of the fiscal surplus to GDP in our specification. Although theoretically appealing, there has not been much empirical success supporting this theory. Most of the literature attempting to study this relation finds no significance of fiscal indicators on inflation. An exception is Catão and Terrones (2005), who report a positive association between fiscal deficits and inflation.

Our final institutional variable is financial depth, for which we use a standard measure, the ratio of domestic private sector credit to GDP. To our knowledge there is no cross-country study that tests for the possible influence of financial depth on inflation. However, financial development is likely to reduce inflation for three reasons. First, like democratic accountability and income per capita, it is a proxy for overall institutional development. Second, the more developed financial markets are, the easier it is for governments to finance temporary (and sustainable) deficits by borrowing from national residents, reducing the likelihood of inflation-

8. Ball (2006) has counter-argued that China and India's increased exports change relative prices but not long-run world inflation. Furthermore, at least part of the latter effect would be offset by higher imports of China and India due to their income gains, again causing changes in world relative prices.

9. Dollar and Kraay (2003) report that cross-country differences in institutions are highly correlated to differences in per capita GDP levels.

tax financing. Finally, Posen (1993, 1995) has argued that opposition to inflation from the financial sector is a significant factor in reducing inflation.

2.5 Cyclical variables

When using annual data, it is important to account for cyclical variables that reflect short-term aggregate demand and supply pressures on inflation. We account for aggregate demand pressures by including measures for both the domestic and foreign output gap. In this, we follow the New Keynesian literature on the short-run Phillips curve to account for the influence of a measure of domestic economic activity (relative to productive capacity) on inflation (for example, Clark and McCracken 2006; Galí, Gertler and López-Salido 2007; Galí 2008). We add a country-specific measure of the foreign output gap to account for the possible additional effect of the world business cycle on domestic inflation. Regarding supply shocks, we include the most standard measure for the latter in the form of the cyclical component of the international oil price.

3. Specification and Econometric Approach

In this section of the paper we describe our general specification and the econometric techniques applied for estimation and robustness testing. Our general linear specification for inflation is:

$$\pi_{i,t} = \alpha_0 + \mathbf{B}_1'\mathbf{INFR}_{i,t} + \mathbf{B}_2'\mathbf{MERR}_{i,t} + \mathbf{B}_3'\mathbf{OPN}_{i,t} + \mathbf{B}_4'\mathbf{STIN}_{i,t} + \mathbf{B}_5'\mathbf{CYC}_{i,t} + \mu_i + \varepsilon_{i,t} \quad (1)$$

where variables are defined as above: π is normalised inflation; the bold-letter matrices correspond to the five groups of inflation determinants discussed in Section 2; μ is a country-specific fixed effect; ε is a stochastic error term; and i and t are country and time sub-indices, respectively. α_0 is a fixed scalar and the $\mathbf{B}_j$ (for $j = 1, ..., 5$) are coefficient vectors in this linear specification.

We estimate Equation (1) using different econometric techniques. We first assume slope homogeneity across countries and estimate fixed-effects (FE) and random-effects (RE) panel data models using instrumental variables (IV) to account for likely endogeneity of explanatory variables. We instrument the lagged dependent variable, the IT regime, the fiscal surplus[10], per capita income, and the domestic output gap, using the first lag of the corresponding variable as instruments. We perform IV estimations using fixed and random effects and test the validity of the latter *vis-à-vis* the former.

Second, we distinguish between long- and short-term determinants of inflation dynamics. We impose slope homogeneity across countries on long-term coefficients and allow full slope heterogeneity across countries for short-term coefficients. For

10. If nominal interest rate payments of public debt are contingent on inflation, the fiscal surplus is correlated with the residual term $\varepsilon_{i,t}$.

this purpose we use the pooled mean group (PMG) estimator proposed by Pesaran, Shin and Smith (1999).[11] We run our Equation (1) as an auto-regressive distributed lag (ARDL) model where dependent and independent variables enter the right-hand-side with lags of order *p* and *q* respectively:[12]

$$\pi_{i,t} = \sum_{j=1}^{p} \lambda_{i,j}\pi_{i,t-j} + \sum_{1=0}^{q} \mathbf{\Gamma}'_{i,j}\mathbf{X}_{i,t-1} + \mu_i + \varepsilon_{i,t} \tag{2}$$

where **X** is the matrix comprised by all five matrices of inflation determinants that were introduced above and all other variables are defined as in Equation (1). The λ_j ($j = 1, \ldots, p$) are the coefficients for the lagged dependent variable terms and the $\mathbf{\Gamma}_l$ ($l = 0, \ldots, q$) are the coefficient vectors for contemporaneous and lagged independent variables.

As discussed by Calderón, Loayza and Servén (2003), in order to derive a long-run relationship between $\pi_{i,t}$ and $\mathbf{X}_{i,t}$, the corresponding dynamic regression should satisfy two conditions. First, the regression residuals should be serially uncorrelated and, second, $\mathbf{X}_{i,t}$ should be strictly exogenous, that is, it should be independent of the residuals at all leads and lags. One strength of the ARDL representation is that all right-hand-side variables enter the equation with sufficiently long lags to ensure the second exogeneity condition. Another advantage of the method is that standard estimation and inference can be performed regardless of the order of integration of the variables in $\mathbf{X}_{i,t}$ and $\pi_{i,t}$. We just need to assume that there exists a single long-run relationship and that the error vector behaves properly. Then Equation (2) can be re-parameterised using simple algebra (as shown by Pesaran *et al* 1999), yielding the following specification[13]:

$$\Delta\pi_{i,t} = \mu_i - \mathbf{\Gamma}'_{i,1}\Delta\mathbf{X}_{i,t} - \left(1-\lambda_{i,1}\right)\left(\pi_{i,t-1} - \frac{\mathbf{\Gamma}'_{i,0} + \mathbf{\Gamma}'_{i,1}}{1-\lambda_{i,1}}\mathbf{X}_{i,t}\right) + \varepsilon_{i,t} \tag{3}$$

Equation (3) is the final form we use in our estimations. We will focus on the long-run relationship for which we impose coefficient homogeneity. All other coefficients on the right-hand-side of Equation (3) are allowed to vary freely across countries.

PMG estimation of long-term coefficients is performed jointly across all countries by a (concentrated) maximum likelihood procedure. Then the estimation of short-run coefficients (including the speed of adjustment, $1-\lambda_{i,1}$), country-specific intercepts,

11. As discussed in Section 3, one must choose between different assumptions when deciding which econometric technique to use. On the one hand one can fully neglect slope heterogeneity by using FE panel models or one can accept complete heterogeneity by estimating any model on a country-by-country basis. The latter approach, however, takes no advantage of the richness of a panel dataset. Thus the choice among these estimators faces a general trade-off between consistency and efficiency. Estimators that impose homogeneity dominate heterogeneous estimators in terms of efficiency but are inconsistent if the null hypothesis of slope homogeneity is not true (Pesaran *et al* 1999). In between such extreme choices is the PMG estimator which assumes that there exists heterogeneity in short-run dynamics but homogeneity in long-run dynamics.

12. For a detailed discussion of this estimator and its asymptotic properties see Pesaran *et al* (1999). Here we provide only a summary discussion of its application to our model.

13. Assuming a general ARDL $p = q = 1$.

and country-specific error variances is performed on a country-by-country basis, also by maximum likelihood and using the estimates of the long-run coefficients obtained before.[14] We also report estimation results based on the mean group (MG) estimator, which is the average of country estimates. MG is also consistent but less efficient than the PMG estimator under the null hypothesis of long-run slope homogeneity. Finally, we engage in dynamic fixed-effects (DFE) estimation, which assumes perfect homogeneity in long-run and short-run coefficients. We discriminate between the PMG and MG models by applying a Hausman test to assess the null of long-run slope homogeneity.

At the final stage we extend our general linear specification in Equation (1) to allow for possible slope heterogeneity for different country groups and time clusters. By introducing interactions between structural inflation determinants and different country groups and time periods, we test for heterogeneity across countries and over time. Equation (1) is widened to encompass interaction matrices, as reflected in the following equation:

$$\begin{aligned}\pi_{i,t} = \alpha_0 &+ \mathbf{B}_1'\mathbf{INFR}_{i,t} + \mathbf{B}_2'\mathbf{MERR}_{i,t} + \mathbf{B}_3'\mathbf{OPN}_{i,t} + \mathbf{B}_4'\mathbf{STIN}_{i,t} + \mathbf{B}_5'\mathbf{CYC}_{i,t} \\ &+ \boldsymbol{\psi}_1'\mathbf{INFR}_{i,t} \otimes \mathbf{Dc}_{i,t} + \boldsymbol{\psi}_2'\mathbf{MERR}_{i,t} \otimes \mathbf{Dc}_{i,t} + \boldsymbol{\psi}_3'\mathbf{OPN}_{i,t} \otimes \mathbf{Dc}_{i,t} \\ &+ \boldsymbol{\psi}_4'\mathbf{STIN}_{i,t} \otimes \mathbf{Dc}_{i,t} + \boldsymbol{\psi}_5'\mathbf{CYC}_{i,t} \otimes \mathbf{Dc}_{i,t} + \mu_i + \varepsilon_{i,t}\end{aligned} \quad (4)$$

where **Dc** are matrices of group dummy variables that interact potentially with each of the five groups of inflation determinants, and ⊗ is the corresponding Kronecker product. The $\boldsymbol{\Psi}_j$ (for $j = 1, ..., 5$) are coefficient vectors for the non-linear interaction terms.

We use alternative measures of interactive **Dc** matrices that cluster observations in three different ways: two for introducing country heterogeneity and one for time-period heterogeneity. Country heterogeneity by income levels is tested, first, by separating low- and middle-income economies from high-income economies, and, alternatively, by separating low-income economies from middle- and high-income economies. Finally, we separate observations according to two different time periods to test for structural change after 1995.

4. Empirical Assessment

The data definitions, sources and transformations are described in Table A1. Descriptive statistics of our world sample are summarised in Table A2. Figure 2 depicts the cross-country kernel density plot of the distribution of actual (non-normalised) inflation rates in the world for four select years across the 1975 to 2005 sample. The value of the density function is measured on the vertical axis and actual (non-normalised) inflation is measured on the horizontal axis. The first, second and third moments of the distribution of inflation in the world were larger in the 1980s

14. We also allow for time-specific effects in the estimated regression in order to obtain independence of residuals across countries and, therefore, to ensure consistency of our PMG estimates. This is attained by defining each variable as a deviation with respect to the cross-section mean.

and early 1990s than after 1995. As noted above, this is consistent with the *Great Moderation* observed worldwide.

We report our results clustered by models and estimation techniques. Our linear model in Equation (1) is estimated for annual data by FE and RE instrumental variables (IV) estimation (results in Table 2) and by PMG, MG and DFE estimation (Table 3). Subsequently, we report results for our non-linear interaction model in Equation (4), restricting our estimation technique to FE IV[15], applied to alternative country and time dummy interactions (Tables 4–6).

In Tables 2 and 3 we report different estimations, starting with general specifications and ending up with more parsimonious results. In Tables 4–6 we report results for only one parsimonious specification.

4.1 FE and RE instrumental variables (IV) estimations

Table 2 reports our main results for Equation (1). Columns (1a) and (1b) report IV results for the same specification using FE IV and RE IV estimators, respectively. We perform a standard Hausman test to verify the validity of such assumptions; the results at the bottom of the table favour the FE estimator. The same tests yielding the same results are performed for the subsequent regressions reported in columns (2)–(4), where we limit reporting of results to our FE IV estimations.

To control for possible endogeneity of inflation regressors we use IV estimation, using the first lag of each instrumented variable as instruments. As an alternative to instrumenting some variables, we use directly the lagged variable instead of the instrumented contemporaneous variable.[16] Columns (2)–(4) report regression results where we gradually replace the direct use of lagged variables (instead of their contemporaneous values) by formally instrumenting contemporaneous values (using their first lags as instruments). In addition, we drop many regressors that are not significant in columns (1)–(3) from the more parsimonious specification in column (4).

Next we discuss the results presented in columns (3) and (4). We focus on the individual variables that comprise each group of inflation determinants, starting with inflation-related variables. There is weak evidence of inflation persistence, reflected by the non-significant lagged inflation term. Controlling for high-inflation and hyperinflation episodes is very important to avoid exclusion bias of coefficient estimates for all other inflation determinants. This is reflected in the large and

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15. We choose not to apply the PMG estimator to the non-linear model due to the small (yet largest available) size of our sample. This estimator requires large N and large T, as well as a semi-balanced panel, to be asymptotically consistent (see Pesaran *et al* 1999 for a detailed discussion). These two requirements, combined with the large specification of the non-linear model and the constraints imposed by the grouping dummies, result in the dropping of several countries and the consequent possibility of bias.

16. For example, lagged inflation is instrumented across all five columns by using its own lag (the second lag of inflation) as its instrument. In contrast, for the IT variable we replace it by its lagged value in columns (1a) and (1b), while instrumenting it by using its lagged value as a formal instrument in columns (2)–(4).

Table 2: Determinants of Inflation – FE and RE IV Estimates
(*continued next page*)

	(1)		(2)	(3)	(4)
	FE IV	RE IV	FE IV	FE IV	FE IV
Inflation-related variables					
Lagged inflation	0.160***	–0.033	0.196*	0.141	0.139
Normalised and instrumented value	(1.97)	(0.22)	(1.87)	(1.42)	(1.39)
Hyperinflation	0.348***	0.488***	0.357***	0.363***	0.364***
	(9.29)	(6.54)	(8.24)	(8.83)	(8.82)
High inflation	0.232***	0.308***	0.226***	0.230***	0.232***
	(14.02)	(8.29)	(11.14)	(11.85)	(11.72)
Monetary and exchange rate regime					
Inflation targeting	–0.051***	–0.045***	–0.051***(a)	–0.054***(a)	–0.055***(a)
Lagged	(5.41)	(4.25)	(3.80)	(4.16)	(4.27)
Exchange rate regime	–0.029***	–0.037***	–0.031***	–0.033***	–0.033***
Lagged	(7.70)	(5.97)	(6.77)	(7.70)	(7.82)
Openness					
Trade openness	–0.009	–0.012**	–0.019	–0.010	
Lagged	(0.81)	(2.15)	(1.43)	(0.73)	
Capital openness	–0.013***	–0.011***	–0.013***	–0.013***	–0.013***
Lagged	(5.94)	(4.90)	(4.79)	(5.09)	(5.06)
Relevant external inflation	0.210***	0.412***	0.169**	0.080	0.127
Normalised	(3.11)	(4.77)	(2.10)	(0.96)	(1.57)
Structural and institutional variables					
Fiscal surplus	–0.204***	–0.179***	–0.251***	–0.459***(a)	–0.427***(a)
Lagged	(5.30)	(4.46)	(5.17)	(5.15)	(5.00)
Income per capita	–0.040***	0.012***	–0.045***	–0.051***(a)	–0.047***(a)
Lagged	(3.67)	(3.09)	(3.46)	(4.06)	(4.20)
Domestic private credit	0.018*	0.059***	0.028**	0.025**	0.024**
Lagged	(1.87)	(4.65)	(2.37)	(2.26)	(2.29)
Democratic accountability	–0.002	–0.003	–0.002	–0.002	
	(1.22)	(1.65)	(1.05)	(0.74)	

Table 2: Determinants of Inflation – FE and RE IV Estimates
(*continued*)

	(1)		(2)	(3)	(4)
	FE IV	RE IV	FE IV	FE IV	FE IV
Cyclical domestic and foreign variables					
Cyclical component of oil prices	0.019** (2.01)	0.017 (1.48)	0.013 (1.14)	0.026** (2.34)	0.021** (2.05)
Domestic output gap *Lagged*	0.238*** (3.60)	0.057 (0.55)	1.182***(a) (3.06)	0.724**(a) (2.07)	0.709**(a) (2.02)
Foreign output gap (weighted by GDP)	–0.204 (0.93)	–0.406 (1.40)	–0.565** (2.11)	–0.366 (1.45)	
Constant	0.467*** (4.80)	0.086*** (3.68)	0.504*** (4.47)	0.557** (5.09)	0.512*** (5.22)
Hausman test (RE vs FE) *p*-value	0.00		0.00	0.00	0.00
Observations	1 574	1 574	1 574	1 570	1 619
Number of countries	65	65	65	65	65
R^2 overall	0.75	0.79	0.71	0.68	0.69

Notes: Dependent variable: normalised inflation
Estimation: fixed effects with instrumental variables
Sample: 1975–2005 (annual data)
Absolute value of *t*-statistics in parentheses; *, ** and *** denote significance at the 10, 5 and 1 per cent levels respectively
The Hausman test favours FE regressions in all cases; thus RE, being inconsistent, is not reported from Equation (2)
(a) Not lagged but instrumented
Source: authors' calculations

significant coefficient values on high-inflation and hyperinflation variables. Conditional to other variables, normalised inflation is on average 23 per cent higher in periods of high inflation and 59 per cent (the sum of both high-inflation and hyperinflation coefficients) higher during hyperinflations.

Turning to monetary and ER regimes, the results show that IT is associated with significantly lower inflation rates: inflation targeters exhibit inflation that is 5–6 per cent lower than for all other country-years, including their own pre-IT past. Similarly, countries with *de facto* fixed ER regimes show significantly lower inflation rates, by 3 per cent. These results suggest that either IT (normally associated with a flexible ER) or *de facto* pegs (normally associated with the lack of a national currency or, at least, lack of an independent monetary policy) foster monetary discipline, enhance monetary policy credibility and lower inflation.[17]

17. Note that the simple correlation between IT and a pegged ER is –0.15 and significant at the 1 per cent level in our panel sample (Table 2). Notwithstanding the expected negative correlation, its size is low – it differs significantly from –1.0. This reflects the fact that most countries in our sample with non-pegged (that is, intermediate and floating) ER regimes have in place monetary regimes other than IT.

Now we turn to international openness measures. Trade openness does not seem to affect inflation at standard significance levels, in contrast to the negative association found in some previous studies. However, capital account openness is significant and robust in lowering inflation, although its economic effect is very small. Relevant international inflation – that of the monetary policy reference country – exerts a positive influence on domestic inflation, although the significance of this is not robust.

Democratic accountability is one of our four structural and institutional variables that may affect inflation; but it does not. However, income per capita, our general proxy for overall economic development – which, as noted above, is highly correlated with institutional variables like democratic accountability – is associated robustly and significantly, both in statistical and economic terms, with lower inflation. A 10 per cent increase in per capita GDP reduces inflation by 0.5 per cent.

As expected, fiscal surpluses are significantly and robustly associated with lower inflation. We note that the coefficient estimated when instrumenting the fiscal surplus by its own lag (in columns (3) and (4)) is close to –0.44, roughly twice its size when replacing the contemporaneous fiscal surplus directly by its own lag (in columns (1) and (2)). Hence stronger (that is, larger) support for the fiscal theory of inflation is found by using the contemporaneous instrumented measure of the fiscal balance instead of using its lagged measure directly. Considering the latter coefficient estimate, a rise in the fiscal balance from the panel sample mean of –3.5 per cent to 0 would reduce inflation by 1.5 per cent. In contrast to our prior, our measure of financial depth – the ratio of domestic private credit to GDP – contributes positively and significantly to inflation, even though its economic significance is small.

Lastly, there is the influence of cyclical factors on inflation to consider. The domestic output gap has a significant positive influence on inflation. As in the case of the fiscal surplus, the magnitude of its coefficient estimate rises significantly when going from a regression based on its own lag (column (1)) to instrumenting it by its own lag (columns (2)–(4)). A 1 per cent rise in the domestic output gap increases domestic inflation by 0.7 per cent. In contrast, our measure of the country-specific relevant foreign output gap does not affect inflation significantly. Finally, the cyclical component of the international oil price has a positive and statistically significant effect on domestic inflation, but its economic significance is negligible.

4.2 PMG, MG and DFE estimations

Table 3 reports the results for Equation (1) using the PMG estimator (first four columns), the MG estimator (second set of four columns) and the DFE estimator (third set of four columns). The last four columns in Table 3 report the Hausman test results that assess the null hypothesis of long-run slope homogeneity. A large enough p-value would imply a failure to reject the null, in which case the PMG results would dominate the MG results.

We report four specifications – from general to particular models – for each estimation technique. Specifications under the same column are identical and hence

Table 3: Determinants of Inflation – ARDL-based Estimates (*continued next page*)

	PMG				MG			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
LONG-RUN PARAMETERS								
Inflation-related variables								
High inflation	0.307***	0.324***	0.300***	0.295***	0.400***	0.258***	0.342***	0.451***
	(22.77)	(22.40)	(22.13)	(21.09)	(4.69)	(4.08)	(6.77)	(7.45)
Monetary and exchange rate regime								
Inflation targeting	–0.053***	–0.038***	–0.054***	–0.063***	–0.120	–0.045	–0.031	–0.02
	(8.17)	(5.86)	(8.30)	(8.67)	(1.63)	(0.80)	(0.59)	(0.42)
Exchange rate regime	–0.025***	–0.028***	–0.024***	–0.035***	–0.029***	–0.025***	–0.029***	–0.036***
	(10.26)	(10.51)	(9.84)	(13.07)	(3.11)	(2.81)	(4.12)	(5.83)
Openness								
Trade openness	0.022**	0.016*	0.021**	0.019***	0.153**	0.131***	0.103**	0.081**
	(2.51)	(1.86)	(2.45)	(2.67)	(2.45)	(3.20)	(2.23)	(2.03)
Capital openness	–0.013***	–0.013***	–0.013***	–0.012***	0.008	–0.001	–0.02*	–0.016**
	(8.32)	(8.44)	(8.37)	(8.02)	(0.48)	(0.19)	(1.75)	(2.03)
Relevant external inflation	0.015	0.051			–0.241	0.159		
Normalised	(0.23)	(0.68)			(0.84)	(0.74)		
Foreign output gap		–0.17				–1.107		
Trade-weighted average		(0.86)				(1.54)		
Structural and institutional variables								
Fiscal surplus	–0.122***	–0.139***	–0.143***	–0.201***	–0.489*	–0.246*	–0.31	–0.363*
Per cent to GDP	(3.09)	(3.29)	(3.78)	(4.81)	(1.87)	(1.72)	(1.63)	(1.85)
Income per capita	–0.007	0.002	–0.006		–0.056	–0.121	–0.046	
Logarithm	(0.64)	(0.26)	(0.61)		(0.49)	(1.76)	(0.63)	
Domestic private credit	0.001				0.025			
	(0.41)				(0.87)			

Table 3: Determinants of Inflation – ARDL-based Estimates (*continued next page*)

	PMG				MG			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Cyclical domestic and foreign variables								
Domestic output gap	0.394***	0.432***	0.409***	0.399[a]	–0.18	0.242	–0.083	0.009
Pooling	(5.09)	(4.64)	(5.18)	(0.68)	(0.88)	(1.33)	(0.46)	(0.06)
ERROR CORRECTION								
Adjustment velocity	–0.513***	–0.462***	–0.511***	–0.451***	–0.681***	–0.877***	–0.83***	–0.708***
	(18.52)	(17.62)	(18.05)	(14.74)	(21.60)	(18.06)	(21.99)	(23.31)
SHORT-RUN PARAMETERS								
Oil price gap	–0.009	–0.001	–0.005		–0.015	–0.002	–0.011*	
Deviation (%) from trend	(1.25)	(0.23)	(0.94)		(1.62)	(0.38)	(1.69)	
Δ capital openness	0.006*	0.005	0.007**	0.005	0.015	–0.009	0.003	–0.001
	(1.72)	(1.52)	(2.08)	(1.39)	(1.12)	(1.47)	(0.49)	(0.22)
Δ income per capita	–0.069		–0.102		–0.364*		–0.279	
In logarithms	(0.57)		(0.84)		(1.91)		(1.54)	
Δ fiscal surplus	0.203***	0.234***	0.225***	0.217***	0.499***	0.283***	0.364***	0.318***
	(3.42)	(3.91)	(3.96)	(4.13)	(5.18)	(2.88)	(4.24)	(3.96)
Δ domestic output gap	–0.331**	–0.444***	–0.34**	–0.455***	0.195	–0.211**	0.105	–0.247***
	(2.46)	(8.48)	(2.47)	(5.81)	(0.92)	(2.47)	(0.50)	(3.12)
Δ foreign output gap		–0.37*				–0.187		
		(1.90)				(0.56)		
Constant	–0.001	0.001	–0.001	0.001	0.107	–0.001	0.055	0.004
	(0.27)	(0.36)	(0.48)	(0.44)	(1.39)	(0.02)	(0.84)	(0.32)

Table 3: Determinants of Inflation – ARDL-based Estimates (*continued next page*)

	DFE				Hausman test			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
LONG-RUN PARAMETERS								
Inflation-related variables								
High inflation	0.346***	0.3483***	0.3467***	0.3483***	1.21	1.15	0.73	7.06
	(29.63)	(29.79)	(29.85)	(29.76)	(0.27)	(0.28)	(0.39)	(0.01)
Monetary and exchange rate regime								
Inflation targeting	–0.0455***	–0.0451***	–0.0442***	–0.046***	0.83	0.002	0.2	0.78
	(4.28)	(4.29)	(4.22)	(4.38)	(0.36)	(0.90)	(0.66)	(0.38)
Exchange rate regime	–0.0362***	–0.0368***	–0.0362***	–0.0369***	0.18	0.09	0.56	0.02
	(9.70)	(9.85)	(9.78)	(9.91)	(0.67)	(0.76)	(0.45)	(0.88)
Openness								
Trade openness	0.0502***	0.0437***	0.0515***	0.0431***	4.49	8.21	3.24	2.5
	(2.95)	(2.60)	(3.04)	(2.61)	(0.03)	(0.00)	(0.07)	(0.11)
Capital openness	–0.0113***	–0.0114***	–0.0112***	–0.0115***	1.62	2.48	0.4	0.22
	(4.05)	(4.09)	(4.08)	(4.14)	(0.20)	(0.11)	(0.53)	(0.64)
Relevant external inflation	0.1103	0.1004			0.84	0.29		
Normalised	(0.89)	(0.80)			(0.36)	(0.59)		
Foreign output gap		–0.0212				1.83		
Trade-weighted average		(0.07)				(0.18)		
Structural and institutional variables								
Fiscal surplus	–0.3216***	–0.3269***	–0.3119***	–0.334***	2.02	0.6	0.8	0.72
Per cent to GDP	(4.45)	(4.56)	(4.37)	(4.67)	(0.15)	(0.44)	(0.37)	(0.40)
Income per capita	–0.018	–0.0104	–0.0182		0.19	3.28	0.29	
Logarithm	(1.09)	(0.65)	(1.12)		(0.66)	(0.07)	(0.59)	
Domestic private credit	0.0024				0.72			
	(0.77)				(0.40)			

Table 3: Determinants of Inflation – ARDL-based Estimates (*continued*)

	DFE				Hausman test			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Cyclical domestic and foreign variables								
Domestic output gap	0.2261*	0.2349*	0.2254*	0.218*	9.22	1.49	8.97	(a)
Pooling	(1.77)	(1.83)	(1.78)	(1.74)	(0.00)	(0.22)	(0.00)	
ERROR CORRECTION								
Adjustment velocity	–0.507***	–0.5038***	–0.5068***	–0.5027***				
	(34.53)	(34.59)	(34.73)	(34.77)				
SHORT-RUN PARAMETERS								
Oil price gap	–0.0055	–0.0036	–0.0037					
Deviation (%) from trend	(0.83)	(0.56)	(0.57)					
Δ capital openness	0.0036	0.0031	0.0032	0.0032				
	(1.34)	(1.13)	(1.18)	(1.18)				
Δ income per capita	–0.1088*		–0.1265**					
In logarithms	(1.92)		(2.22)					
Δ fiscal surplus	0.2213***	0.2153***	0.2203***	0.2172***				
	(5.45)	(5.35)	(5.49)	(5.42)				
Δ domestic output gap	–0.2866***	–0.4187***	–0.2707***	–0.4182***				
	(3.43)	(8.28)	(3.25)	(8.29)				
Δ foreign output gap		–0.0375						
		(0.28)						

Notes: Absolute value of *t*-statistics in parentheses. *, ** and *** denote significance at the 10, 5 and 1 per cent levels respectively. Hausman test's null hypothesis: parameter homogeneity
(a) Denotes that parameter homogeneity is not imposed
Source: authors' calculations

comparable across different estimators. The regressions in columns (1) and (2) reflect our general specifications. The regression reported in column (3) shows a particular estimation dropping most non-significant variables. Column (4) differs from (3) by allowing for slope heterogeneity under PMG estimation. The Hausman test rejects slope homogeneity for the domestic output gap, implying that countries differ in the slope coefficient of their Phillips Curve. Thus the specification underlying the results reported in column (4) imposes long-run homogeneity of coefficients for all parameters in the long-run vector but not for the domestic output gap. After allowing for such heterogeneity, we can be certain that the PMG estimator is consistent.

Across our sets of regression results obtained by using the three different econometric techniques, most coefficient estimates of key inflation determinants are similar and therefore robustly estimated. Given the statistical dominance of the PMG results over those obtained by MG and DFE estimations, we focus the subsequent discussion on the former, and, in particular, on the PMG results in column (4).

The short-run behaviour of the change in inflation is significantly influenced by changes in the fiscal surplus and the domestic output gap. No other changes in variables affect short-term changes in inflation. Turning to long-run determinants of inflation, the aggregate error correction coefficient is very significant and large – close to half – justifying our focus on the long-term inflation process.

Many individual variable results are similar to those found with the FE IV estimator. In high-inflation episodes, normalised inflation is on average 30 per cent higher.[18] IT lowers inflation by 6 per cent and fixed ER regimes reduce inflation by about 4 per cent. Capital account openness reduces inflation. Yet, in contrast to our prior, trade openness has a positive and statistically significant effect on inflation, although the economic significance of this is small. The fiscal surplus lowers inflation significantly and the domestic output gap raises inflation significantly, although the size of both coefficient estimates falls well below those found under FE IV. But per capita income, private credit and the cyclical component of oil prices are not significant now.

4.3 Sensitivity analysis: FE IV estimations for non-linear interactions

We test the robustness of our linear model (Equation (1)) by introducing, in a nested way, heterogeneous country groups and time periods. We use Equation (4) that adds interactions between structural inflation determinants and different country groups and time periods. In the context of our nested regressions – see Equation (4) – point estimates for the parameters in the $\boldsymbol{\psi}_j{}'$ coefficient matrix that are statistically different from zero imply heterogeneity across different country groups and time

18. Note that our specification does not match exactly the one used in the FE and RE IV models. Here we were forced to drop the hyperinflation dummy variable due to our sample properties. The ARDL estimator requires a panel that features a large T and a large N, in contrast to FE or RE that require a moderate T. For the ARDL estimator T should be large enough for every variable, which is not the case for our few hyperinflation episodes.

periods. We test for heterogeneity, restricting our focus to the more parsimonious regression results obtained above in order to facilitate comparison across different non-linear results below as well as those of the linear models reported above. We restrict our use of estimation techniques to FE IV.

4.3.1 Heterogeneity across country groups

We test if the parameters of our inflation equation are equal between high-income economies (hereafter developed countries) and non-high income economies (hereafter developing countries), with the latter group including middle- and low-income economies. Hence the group dummy variable **Dc** in Equation (4) takes a value of 1 for developing countries and 0 for developed countries. These results are shown in Table 4.

We also test for heterogeneity in an alternative binary country grouping, separating between low-income economies (hereafter poor countries) and middle- and high-income economies (hereafter non-poor countries). Now **Dc** takes a value of 1 for poor countries and 0 otherwise. These results are shown in Table 5.

We estimate and report the nested regression of our non-linear model using the specification of our preferred results obtained in our linear model: (i) columns (3) and (4) of Table 2. In Tables 4 to 6, we present two columns for each equation: the first column – labelled as *baseline* – shows the parameter estimates for the $\mathbf{B}_j'$ matrix, while the second column – labelled as *differential* – shows the estimates for the $\boldsymbol{\psi}_j'$ matrix associated with the variable in the same row. In other words, this *differential* column shows the incremental effect of belonging to the group for which the dummy variable is set to 1.

While the results for the non-linear model reported in Table 4 (developed versus developing countries) are not too different from those for the linear model in Table 2, some relevant differences across country groups are apparent. The results for which there are significant differences across both country groups are as follows. Inflation is significantly less persistent in developing countries, compared to developed economies. Adopting IT reduces inflation by 6–8 per cent in developing countries, while it does not lower inflation in developed countries. This is very much in line with previous findings by Mishkin and Schmidt-Hebbel (2007) for a world panel sample. The same differential effect is found for adopting a fixed ER, which lowers inflation by 2–3 per cent in developing countries and by nil in developed countries.

There is evidence that capital account openness reduces inflation in developing countries but not in developed countries. Finally, the coefficient of the output gap for developing countries is positive but significantly smaller than that of developed countries. This may suggest that the inflation effect of the output gap in developed countries is primarily determined by aggregate demand, while that of developing countries is significantly offset by more intense and/or more frequent supply shocks.

Table 4: Determinants of Inflation – Country Heterogeneity
Developed versus developing countries (*continued next page*)

	FE and RE IV estimates			
	(1)		(2)	
	Baseline	Differential	Baseline	Differential
Inflation-related variables				
Lagged inflation	0.512***	–0.413**	0.496***	–0.402**
Normalised and instrumented value	(4.16)	(2.50)	(4.32)	(2.55)
Hyperinflation	0.372***		0.371***	
	(8.32)		(8.47)	
High inflation	0.150***	–0.086**	0.176***	0.061
	(4.15)	(2.06)	(5.27)	(1.56)
Monetary and exchange rate regime				
Inflation targeting	0.003[(a)]	–0.080***[(a)]	–0.009[(a)]	–0.070***[(a)]
Lagged	(0.17)	(3.02)	(0.54)	(2.86)
Exchange rate regime	–0.014	–0.020	–0.006	–0.028**
Lagged	(1.11)	(1.45)	(0.57)	(2.33)
Openness				
Trade openness	–0.069	0.068		
Lagged	(1.27)	(1.21)		
Capital openness	–0.003	–0.011*	–0.004	–0.010*
Lagged	(0.51)	(1.81)	(0.71)	(1.72)
Relevant external inflation	0.154	–0.103	0.078	0.032
Normalised	(0.67)	(0.42)	(0.37)	(0.14)
Structural and institutional variables				
Fiscal surplus	–0.701***[(a)]	0.207[(a)]	–0.435**[(a)]	–0.048[(a)]
Lagged	(3.19)	(0.85)	(2.56)	(0.24)
Income per capita	–0.002[(a)]	–0.050	–0.015	–0.033
Lagged	(0.04)	(1.30)	(0.65)	(1.23)
Domestic private credit	0.020	–0.010	0.012	0.001
Lagged	(0.98)	(0.36)	(0.68)	(0.03)
Democratic accountability	–0.011	0.009		
	(1.31)	(1.01)		

Table 4: Determinants of Inflation – Country Heterogeneity
Developed versus developing countries (*continued*)

	FE and RE IV estimates			
	(1)		(2)	
	Baseline	Differential	Baseline	Differential
Cyclical domestic and foreign variables				
Cyclical component of oil prices	–0.009 (0.36)	0.042 (1.48)	–0.010 (0.39)	0.037 (1.28)
Domestic output gap *Lagged*	3.041***[(a)] (2.74)	–2.586**[(a)] (2.20)	2.148**[(a)] (2.54)	–1.706*[(a)] (1.83)
Foreign output gap (weighted by GDP)	–0.472 (0.62)	–0.055 (0.07)		
Constant	0.473*** (4.07)		0.444*** (4.57)	
Observations	1 570		1 619	
Number of countries	65		65	
R^2 overall	0.17		0.24	

Notes: Dependent variable: normalised inflation
Estimation: fixed effects with instrumental variables
Sample: 1975–2005 (annual data)
Absolute value of *t*-statistics in parentheses; *, ** and *** denote significance at the 10, 5 and 1 per cent levels respectively
The Hausman test favours FE regressions in all cases
Country heterogeneity is accomplished through the inclusion of an interactive dummy variable which is set equal to 0 for high-income economies and equal to 1 for middle- and low-income economies
(a) Not lagged but instrumented
Source: authors' calculations

Now let's turn to the results for low-income economies and middle- and high-income economies, reported in Table 5. In contrast to the latter results for developed versus developing country groups in Table 4, we find larger heterogeneity of inflation behaviour between poor and non-poor countries (Table 5). While inflation persistence is similar in poor and non-poor countries, it has a much larger role in driving inflation in poor countries. IT contributes significantly to reduced inflation in both country groups but the contribution is much larger in poor countries (–8.5 per cent) than in non-poor countries (–4 per cent). Overall, these results suggest that IT has a large (moderate, nil) role in reducing inflation in low- (middle-, high-) income economies. Regarding the influence of a fixed ER regime, the results point toward no country heterogeneity. Finally, capital account openness has no additional effect for the poor relative to the non-poor, and the same holds true for the domestic output gap.

Table 5: Determinants of Inflation – Country Heterogeneity
Non-poor versus poor countries (*continued next page*)

	FE and RE IV estimates			
	(1)		(2)	
	Baseline	Differential	Baseline	Differential
Inflation-related variables				
Lagged inflation	0.251***	–0.148	0.262***	–0.158
Normalised and instrumented value	(4.48)	(1.07)	(4.80)	(1.16)
Hyperinflation	0.422***	–0.071	0.415***	–0.063
	(7.30)	(0.91)	(7.42)	(0.81)
High inflation	0.194***	0.049*	0.194***	0.050*
	(12.29)	(1.76)	(12.53)	(1.79)
Monetary and exchange rate regime				
Inflation targeting	–0.035***(a)	–0.050*(a)	–0.038***(a)	0.048*(a)
Lagged	(2.95)	(1.70)	(3.37)	(1.73)
Exchange rate regime	–0.032***	0.001	–0.031***	–0.000
Lagged	(6.33)	(0.07)	(6.33)	(0.07)
Openness				
Trade openness	–0.017	0.014		
Lagged	(0.87)	(0.48)		
Capital openness	–0.011***	–0.002	–0.011***	–0.002
Lagged	(3.58)	(0.48)	(3.62)	(0.45)
Relevant external inflation	0.172	–0.244	0.169	–0.151
Normalised	(1.34)	(1.41)	(1.37)	(0.93)
Structural and institutional variables				
Fiscal surplus	–0.435***(a)	–0.175(a)	–0.398***(a)	–0.166(a)
Lagged	(3.70)	(0.94)	(3.71)	(0.94)
Income per capita	–0.054***(a)	0.015(a)	–0.051***(a)	0.016(a)
Lagged	(2.67)	(0.57)	(3.06)	(0.68)
Domestic private credit	0.037***	–0.043*	0.034***	–0.038
Lagged	(2.68)	(1.65)	(2.67)	(1.50)
Democratic accountability	–0.003	0.002		
	(0.83)	(0.42)		

Table 5: Determinants of Inflation – Country Heterogeneity
Non-poor versus poor countries (*continued*)

	FE and RE IV estimates			
	(1)		(2)	
	Baseline	Differential	Baseline	Differential
Cyclical domestic and foreign variables				
Cyclical component of oil prices	0.013 (0.74)	0.027 (1.17)	0.008 (0.49)	0.023 (1.09)
Domestic output gap *Lagged*	1.275***[(a)] (3.64)	–0.912[(a)] (1.48)	1.260***[(a)] (3.64)	–0.892[(a)] (1.45)
Foreign output gap (weighted by GDP)	–0.383 (0.90)	–0.107 (0.20)		
Constant	0.511*** (4.57)		0.467*** (4.76)	
Observations	1 570		1 619	
Number of countries	65		65	
R^2 overall	0.51		0.54	

Notes: Dependent variable: normalised inflation
Estimation: fixed effects with instrumental variables
Sample: 1975–2005 (annual data)
Absolute value of *t*-statistics in parentheses; *, ** and *** denote significance at the 10, 5 and 1 per cent levels respectively
The Hausman test favours FE regressions in all cases
Country heterogeneity is accomplished through the inclusion of an interactive dummy variable which is set equal to 0 for middle- and high-income economies and equal to 1 for low-income economies
(a) Not lagged but instrumented

Source: authors' calculations

4.3.2 Heterogeneity over time

The final test is whether regression coefficients of the inflation equation remain constant over time. For this test the group dummy variable **Dc** in Equation (4) takes a value of 1 for annual observations after 1995 and 0 otherwise. Table 6 shows the results of the inflation equation that includes interaction terms between the time dummy and all explanatory variables. The surprising findings point toward uniform homogeneity across both periods, implying zero evidence of structural break in the behaviour of inflation after 1995.

Table 6: Determinants of Inflation – Country Heterogeneity
1975–1994 versus 1995–2005 (*continued next page*)

	FE and RE IV estimates			
	(1)		(2)	
	Baseline	Differential	Baseline	Differential
Inflation-related variables				
Lagged inflation	0.219**	–0.305***	0.193**	–0.212***
Normalised and instrumented value	(2.44)	(3.43)	(2.25)	(3.47)
Hyperinflation	0.327***		0.337***	
	(8.28)		(8.91)	
High inflation	0.222***	0.002	0.229***	–0.009
	(12.42)	(0.10)	(12.84)	(0.39)
Monetary and exchange rate regime				
Inflation targeting	–0.063[(a)]	–0.004[(a)]	–0.063*[(a)]	–0.004[(a)]
Lagged	(1.53)	(0.14)	(1.83)	(0.16)
Exchange rate regime	–0.029***	–0.006	–0.032***	0.002
Lagged	(6.12)	(1.23)	(5.53)	(0.18)
Openness				
Trade openness	–0.008	0.036		
Lagged	(0.40)	(1.31)		
Capital openness	–0.012***	–0.002	–0.011***	–0.004
Lagged	(3.79)	(0.41)	(3.66)	(0.58)
Relevant external inflation	0.093	0.190	0.025	0.344
Normalised	(0.40)	(0.55)	(0.23)	(0.93)
Structural and institutional variables				
Fiscal surplus	–0.316[(a)]	–0.509[(a)]	–0.326**[(a)]	–0.448[(a)]
Lagged	(1.35)	(0.78)	(2.14)	(0.96)
Income per capita	–0.073*[(a)]	0.060[(a)]	–0.060*[(a)]	0.042[(a)]
Lagged	(1.75)	(0.74)	(1.91)	(0.86)
Domestic private credit	0.038	–0.063	0.030	–0.046
Lagged	(1.47)	(0.91)	(1.72)	(0.95)
Democratic accountability	0.009	–0.017		
	(0.60)	(0.68)		

Table 6: Determinants of Inflation – Country Heterogeneity
1975–1994 versus 1995–2005 (*continued*)

	FE and RE IV estimates			
	(1)		(2)	
	Baseline	Differential	Baseline	Differential
Cyclical domestic and foreign variables				
Cyclical component of oil prices	0.033**	–0.030	0.035**	–0.019
	(2.01)	(1.10)	(2.49)	(0.76)
Domestic output gap	0.791**[(a)]	–0.208[(a)]	0.728*[(a)]	–0.002[(a)]
Lagged	(2.08)	(0.29)	(1.95)	(0.00)
Foreign output gap (weighted by GDP)	–0.179	1.104		
	(0.59)	(1.25)		
Constant	0.692***	–0.418	0.620***	–0.348
	(2.29)	(0.73)	(2.34)	(0.85)
Observations	1 570		1 619	
Number of countries	65		65	
R^2 overall	0.67		0.69	

Notes: Dependent variable: normalised inflation
Estimation: fixed effects with instrumental variables
Sample: 1975–2005 (annual data)
Absolute value of *t*-statistics in parentheses; *, ** and *** denote significance at the 10, 5 and 1 per cent levels respectively
The Hausman test favours FE regressions in all cases
Country heterogeneity is accomplished through the inclusion of an interactive dummy variable which is set equal to 1 for the period comprising years 1995 to 2005 and equal to 0 for the rest
(a) Not lagged but instrumented

Source: authors' calculations

5. Conclusions

In this paper we have assessed the empirical contribution of non-monetary determinants of inflation in a world panel sample. We have extended the preceding literature in four ways. First, we consider a broad and comprehensive specification of inflation that encompasses partial models found in the previous theoretical and empirical literature on inflation. Second, we assemble and use a large dataset for 97 countries spanning 31 years (1975–2005), including both the *Great Inflation* and the *Great Moderation* periods. Third, we have examined the robustness of our results to the use of a broad set of alternative estimation techniques. Finally, we have tested for the sensitivity of our findings to a non-linear inflation specification that allows for slope heterogeneity across different country groups and time periods.

Our broad inflation specification encompasses five groups of potential inflation determinants suggested by different strands of the theoretical and empirical inflation literature: inflation persistence and high-inflation as well as hyperinflation episodes;

monetary and exchange rate regimes; external openness measures; structural variables and institutions; and business-cycle-related variables.

We start by summarising our main findings for variables that are robustly significant in driving inflation in the world sample. Our results show that it is essential to control for high-inflation and hyperinflation experiences in the world sample in order to avoid specification bias in identifying the role of fundamental inflation determinants. Two monetary and exchange rate regimes are shown to contribute to lower inflation: countries that adopt IT attain lower inflation rates that range from 3 to 6 per cent, in comparison to other countries in the world sample; while economies with pegged exchange rate (ER) regimes achieve 3 to 4 per cent lower inflation rates compared with economies with intermediate or flexible ER regimes. This suggests that either IT (normally associated with a flexible ER) or ER pegs are more effective than their alternatives in strengthening monetary discipline and policy credibility, a result that is consistent with the *two-corner hypothesis* on the choice of ER regimes.

Capital account or financial openness is found to contribute robustly to lower inflation. The fiscal theory of inflation is confirmed by our estimates, which show that raising the fiscal surplus ratio to GDP by 3.5 per cent contributes to lower inflation in the range of 0.7 to 1.5 per cent. Among cyclical variables affecting inflation in the short run, the domestic output gap contributes robustly and positively to inflation. This is consistent with the view that aggregate demand shocks drive inflation to a larger extent than supply shocks, as reflected by a conventional short-term Phillips curve. Our quantitative finding is that a 1 per cent increase in the domestic output gap raises short-term inflation by between 0.4 to 0.7 per cent.

We do not obtain robust results for other variables across different specifications, samples or econometric techniques. For economic development (proxied by per capita income) and domestic financial development (proxied by the ratio of domestic private credit to GDP), we find evidence that both reduce inflation only in some cases. We also find only weak evidence that international oil prices contribute to short-term inflation. To our surprise, we have not found support for the hypothesis that trade openness helps to reduce inflation, contradicting some of the previous literature. Democratic accountability and the relevant foreign output gap do not influence domestic inflation either.

The results for our non-linear specification – which allows for nested testing of slope heterogeneity across different country groups and time periods – are broadly in line with those from our linear model. We find that IT adoption lowers inflation in low- and middle-income economies – by between 7 to 8.5 per cent – while their contribution to inflation in high-income economies is not statistically different from zero. This finding largely confirms previous results of Mishkin and Schmidt-Hebbel (2007). Similarly, we also find that ER pegs lower inflation in low-income and middle-income economies – by between 2 to 3 per cent – while their contribution to inflation in high-income countries is nil, like that of IT. We also find some evidence that capital account openness reduces inflation in low- and middle-income economies, but not in high-income economies. Contrary to existing results in the literature, the slope of the Phillips curve (that is, the size of the domestic output coefficient) is larger in high-income than in low- and middle-income economies. Finally, our results for slope heterogeneity over time – that is, structural breaks after 1995 – show no evidence of structural change in the behaviour of inflation after 1995.

Appendix A

Table A1: Data Definitions, Sources and Transformations

Variable	Description	Source
Inflation rate (normalised)	CPI inflation rate/(1 + CPI inflation)	WDI
Inflation targeting	Dummy variable	Corbo, Landerretche and Schmidt-Hebbel (2002); Truman (2003); Mishkin and Schmidt-Hebbel (2007)
Exchange rate regime	Discrete variable	AREAER; Reinhart and Rogoff (2004)
Trade openness	(Exports + imports)/GDP	WDI
Capital openness	Four dummy variables reported in IMF's AREAER	Chinn and Ito (2002, 2005)
Relevant external inflation	Own elaboration based on Di Giovanni and Shambaugh (2007)	See Table A2
Fiscal surplus	Overall government budget balance (surplus)/GDP	EIU; GFS
Income per capita	GDP per capita (2000 US$)	WDI
Domestic private credit	Domestic credit to private sector/GDP	WDI
Democratic accountability	International Country Risk Guide	The PRS Group
Oil price	Simple average of international current nominal oil prices (in US$ per barrel): UK Brent, West Texas Intermediate, Dubai	IFS
Domestic output gap	Cyclical component (HP-filtered) of real GDP as per cent deviation from trend	WDI
Foreign output gap	GDP-weighted average of foreign output gaps (excludes national output gap)	WDI

Notes: AREAER = *Annual Report on Exchange Arrangements and Exchange Restrictions*, IMF, various issues
EIU = Economist Intelligence Unit
GFS = *Government Finance Statistics*, IMF, various issues
IFS = *International Financial Statistics*, IMF, various issues
WDI = *World Development Indicators*, World Bank, 2007

Table A2: Descriptive Statistics

Variable	Observations	Mean	Standard deviation	Min	Max
Inflation rate (normalised)	3 044	0.119	0.153	–0.150	0.996
Trade openness	3 175	0.685	0.418	0.063	4.561
Capital openness	3 114	0.146	1.557	–1.767	2.603
Relevant external inflation	3 379	0.041	0.029	–0.001	0.143
Fiscal surplus (% GDP)	2 420	–0.035	0.049	–0.451	0.206
Income per capita (in logs)	3 243	8.510	1.157	6.130	10.889
Domestic private credit	3 152	0.630	5.242	0.000	152.318
Democratic accountability	3 119	3.708	1.647	0.000	6.000
Cyclical component of oil prices	3 379	–0.004	0.166	–0.384	0.296
Domestic output gap	3 243	0.000	0.028	–0.368	0.270
Foreign output gap (GDP-weighted average)	3 379	–0.001	0.008	–0.021	0.017

Source: authors' calculations

References

Aisen A and FJ Veiga (2006), 'Does Political Instability Lead to Higher Inflation? A Panel Data Analysis', *Journal of Money, Credit and Banking*, 38(5), pp 1379–1389.

Aizenman J (1992), 'Competitive Externalities and the Optimal Seigniorage', *Journal of Money, Credit and Banking*, 24(1), pp 61–71.

Alfaro L (2005), 'Inflation, Openness, and Exchange-Rate Regimes: The Quest for Short-Term Commitment', *Journal of Development Economics*, 77(1), pp 229–249.

Ball LM (2006), 'Has Globalization Changed Inflation?', NBER Working Paper No 12687.

Ball LM and N Sheridan (2004), 'Does Inflation Targeting Matter?', in BS Bernanke and M Woodford (eds), *The Inflation-Targeting Debate*, University of Chicago Press, Chicago, pp 249–282.

Barro RJ and DB Gordon (1983), 'Rules, Discretion and Reputation in a Model of Monetary Policy', *Journal of Monetary Economics*, 12(1), pp 101–121.

Bernanke BS (2004), 'The Great Moderation', Remarks at the meetings of the Eastern Economic Association, Washington DC, 20 February. Available at <http://www.federalreserve.gov/boarddocs/speeches/2004/20040220/default.htm>.

Blanchard O and J Simon (2001), 'The Long and Large Decline in U.S. Output Volatility', *Brookings Papers on Economic Activity*, 1, pp 135–174.

Borio C and A Filardo (2007), 'Globalisation and Inflation: New Cross-Country Evidence on the Global Determinants of Domestic Inflation', BIS Working Paper No 227.

Cagan P (1956), 'The Monetary Dynamics of Hyperinflation', in M Friedman (ed), *Studies in The Quantity Theory of Money*, Chicago University Press, Chicago, pp 25–117.

Calderón CA, N Loayza and L Servén (2003), 'Do Capital Flows Respond to Risk and Return?', World Bank Policy Research Working Paper No 3059.

Campillo M and JA Miron (1996), 'Why Does Inflation Differ across Countries?', NBER Working Paper No 5540.

Catão LAV and ME Terrones (2005), 'Fiscal Deficits and Inflation', *Journal of Monetary Economics*, 52(3), pp 529–554.

Chinn MD and H Ito (2002), 'Capital Account Liberalization, Institutions and Financial Development: Cross Country Evidence', NBER Working Paper No 8967.

Chinn MD and H Ito (2005), 'What Matters for Financial Development? Capital Controls, Institutions, and Interactions', La Follette School Working Paper No 2005-007.

Clark TE and MW McCracken (2006), 'The Predictive Content of the Output Gap for Inflation: Resolving In-Sample and Out-of-Sample Evidence', *Journal of Money, Credit and Banking*, 38(5), pp 1127–1148.

Corbo V, O Landerretche and K Schmidt-Hebbel (2002), 'Does Inflation Targeting Make a Difference?', in N Loayza and R Soto (eds), *Inflation Targeting: Design, Performance, Challenges*, Central Bank of Chile, Santiago, pp 221–269.

Cottarelli C, M Griffiths and R Moghadam (1998), 'The Nonmonetary Determinants of Inflation: A Panel Data Study', IMF Working Paper No 98/23.

Cukierman A (1992), *Central Bank Strategy, Credibility, and Independence: Theory and Evidence*, MIT Press, Cambridge.

Cukierman A, S Edwards and G Tabellini (1992), 'Seigniorage and Political Instability', *American Economic Review*, 82(3), pp 537–555.

Cukierman A, SB Webb and B Neyapti (1992), 'Measuring the Independence of Central Banks and Its Effect on Policy Outcomes', *World Bank Economic Review*, 6(3), pp 353–398.

Di Giovanni J and JC Shambaugh (2007), 'The Impact of Foreign Interest Rates on the Economy: The Role of the Exchange Rate Regime', NBER Working Paper No 13467.

Dollar D and A Kraay (2003), 'Institutions, Trade, and Growth: Revisiting the Evidence', World Bank Policy Research Working Paper No 3004.

Dornbusch R and S Fischer (1993), 'Moderate Inflation', World Bank *Economic Review*, 7(1), pp 1–44.

Fischer S, R Sahay and CA Végh (2002), 'Modern Hyper- and High Inflations', *Journal of Economic Literature*, 40(3), pp 837–880.

Galí J (2008), *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*, Princeton University Press, Princeton.

Galí J, M Gertler and JD López-Salido (2007), 'Markups, Gaps, and the Welfare Costs of Business Fluctuations', *The Review of Economics and Statistics*, 89(1), p 44–59.

Grossman GM and E Helpman (1991), 'Trade, Knowledge Spillovers, and Growth', NBER Working Paper No 3485.

Gruben WC and D McLeod (2004), 'The Openness-Inflation Puzzle Revisited', *Applied Economic Letters*, 11(8), pp 465–468.

Helbling T, F Jaumotte and M Sommer (2006), 'How Has Globalization Affected Inflation?', *World Economic Outlook – Globalization and Inflation*, World Economic and Financial Surveys, IMF, Washington DC, pp 97–134.

Husain AM, A Mody and KS Rogoff (2005), 'Exchange Rate Durability and Performance in Developing versus Advanced Economies', *Journal of Monetary Economics*, 52(1), pp 35–64.

Hyvonen M (2004), 'Inflation Convergence across Countries', RBA Research Discussion Paper No 2004-04.

IMF (International Monetary Fund) (2007), *World Economic Outlook – Globalization and Inequality*, World Economic and Financial Surveys, IMF, Washington DC.

Kamin S, M Marazzi and JW Schindler (2004), 'Is China "Exporting Deflation"?', Board of Governors of the Federal Reserve System International Finance Discussion Paper No 791.

Kydland FE and EC Prescott (1977), 'Rules rather than Discretion: The Inconsistency of Optimal Plans', *Journal of Political Economy*, 85(3), pp 473–491.

Lane PR (1997), 'Inflation in Open Economies', *Journal of International Economics*, 42(3–4), pp 327–347.

Levy-Yeyati E and F Sturzenegger (2005), 'Classifying Exchange Rate Regimes: Deeds vs. Words', *European Economic Review*, 49(6), pp 1603–1635.

Mishkin FS and K Schmidt-Hebbel (2007), 'Does Inflation Targeting Make a Difference?', in FS Mishkin and K Schmidt-Hebbel (eds), *Monetary Policy under Inflation Targeting*, Central Bank of Chile, Santiago, pp 291–372.

Pesaran MH, Y Shin and RP Smith (1999), 'Pooled Mean Group Estimation of Dynamic Heterogeneous Panels', *Journal of the American Statistical Association*, 94(446), pp 621–634.

Phelps E (1973), 'Inflation in the Theory of Public Finance', *Swedish Journal of Economics*, 75(1), pp 67–82.

Posen AS (1993), 'Why Central Bank Independence Does Not Cause Low Inflation: The Politics behind the Institutional Fix', manuscript, Harvard University.

Posen AS (1995), 'Declarations Are Not Enough: Financial Sector Sources of Central Bank Independence', in BS Bernanke and JJ Rotemberg (eds), *NBER Macroeconomics Annual 1995*, 10, MIT Press, Cambridge, pp 253–274.

Reinhart CM and KS Rogoff (2004), 'The Modern History of Exchange Rate Arrangements: A Reinterpretation', *Quarterly Journal of Economics*, 119(1), pp 1–48.

Rogoff KS (2003), 'Disinflation: An Unsung Benefit of Globalization?', *Finance and Development*, 40(4), pp 54–55.

Romer D (1993), 'Openness and Inflation: Theory and Evidence', *The Quarterly Journal of Economics*, 108(4), pp 869–903.

Sargent TJ and N Wallace (1981), 'Some Unpleasant Monetarist Arithmetic', Federal Reserve Bank of Minneapolis *Quarterly Review*, 5(3), pp 1–17.

Sbordone AM (2007), 'Globalization and Inflation Dynamics: The Impact of Increased Competition', NBER Working Paper No 13556.

Summers PM (2005), 'What Caused the Great Moderation? Some Cross-Country Evidence', Federal Reserve Bank of Kansas City *Economic Review*, 90(3), pp 5–32.

Temple J (2002), 'Openness, Inflation, and the Phillips Curve: A Puzzle', *Journal of Money, Credit and Banking*, 34(2), pp 450–468.

Terra CT (1998), 'Openness and Inflation: A New Assessment', *The Quarterly Journal of Economics*, 113(2), pp 641–648.

Truman EM (2003), *Inflation Targeting in the World Economy*, Institute for International Economics, Washington DC.

Tytell I and S-J Wei (2004), 'Does Financial Globalization Induce Better Macroeconomic Policies?', IMF Working Paper No 04/84.

Vega M and D Winkelried (2005), 'Inflation Targeting and Inflation Behavior: A Successful Story?', *International Journal of Central Banking*, 1(3), pp 153–175.

Végh CA (1989), 'Government Spending and Inflationary Finance: A Public Finance Approach', *IMF Staff Papers*, 36(3), pp 657–677.

Discussion

1. John McDermott

It is a pleasure to comment on the paper by César Calderón and Klaus Schmidt-Hebbel. Typically, when economists ask the question 'what drives inflation?', explanations turn to monetary factors. The problem of inflation control is naturally encapsulated in the new Keynesian models such as that described in Woodford (2003) and Galí (2008). An important contribution of César and Klaus's paper is that it highlights that just focusing on monetary factors to understand inflation is insufficient.

The objective of César and Klaus's paper is to evaluate the importance of non-monetary factors for inflation. They classify their candidate factors into five groups – high inflation and persistence, monetary and exchange rate regimes, openness, structural variables and institutions, and business-cycle-related variables.

In their study, César and Klaus use an impressive large panel dataset that consists of 97 countries over thirty years and a range of econometric approaches. They find that a disciplined monetary regime, sensible fiscal policy, and financial openness are crucial to low-inflation outcomes. They also show that globalisation – as proxied by a foreign output gap – has no significant effect on domestic inflation.

My discussion will use the empirical findings of César and Klaus as a springboard to address three topics of importance when thinking about monetary policy and the control of inflation: the role of nominal anchors, fiscal policy and commodity prices.

The first issue to address is the role of nominal anchors. There has been growing agreement among economists that credibly adhering to a nominal anchor is essential to controlling expected and actual inflation. César and Klaus evaluate two main nominal anchors: inflation targeting and an exchange rate peg. The findings are consistent with a large body of literature demonstrating that inflation targeting generally improves economic performance. For example, Mishkin and Schmidt-Hebbel (2007) provide extensive empirical evidence that inflation targeting improves monetary performance.[1] In addition, the results in César and Klaus's paper are also consistent with the findings of Ghosh *et al* (1997) who find evidence that fixed exchange rate regimes reduce inflation.[2]

The second issue to address is fiscal policy. There has long been a view among economists that fiscal policy can significantly influence inflation outcomes.

1. The conclusion that inflation targeting is beneficial is not universally held. Ball and Sheridan (2004) find that inflation targeting does not make a difference to economic performance in advanced countries. That said, Ball and Sheridan use control countries such as Germany and the United States, which, it has been argued, have strong implicit nominal anchors (Mishkin 2007).

2. There are limits to this empirical finding. Mishkin (1999) notes that there are substantial risks with using fixed exchange rate regimes as a nominal anchor if the regimes are not supported by appropriate policies.

Mishkin (2007) argues that sensible fiscal policy is a prerequisite for an inflation-targeting regime. Recent global developments have only re-ignited such views. For an example of these current concerns see Sims (2009). There are two ideas on how fiscal policy can influence inflation worth exploring: aggregate demand pressure and the fiscal theory of the price level.

Fiscal deficits can create excessive aggregate demand pressure. An often-used strategy of governments unable to address fiscal imbalances is to turn to the central bank to print money in order to finance these deficits (see Sargent 1982 for a discussion of some particular case studies). Nevertheless, formal econometric evidence of the relationship between fiscal deficits and inflation tends to be elusive.

The advantage of César and Klaus's panel econometric approach is that they examine evidence across a variety of countries, including many countries that have suffered persistent fiscal imbalances. Consequentially these results can be considered more robust than individual case studies and thus provide an important contribution to the literature in this area.

The notion that poor fiscal policy can undermine monetary policy also appears in the literature on the theory of the price level. Many models used to analyse monetary policy often ignore the government budget constraint. However, even if the government budget constraint is not explicitly stated in our models, it is always present. The standard government budget constraint can be solved for the price level to highlight the fact that, at least in the long run, the price level is determined by fiscal policy. That is, we have

$$P_t = \frac{B_t}{\frac{y_t}{1+R}\sum_{s=0}^{\infty}\left(\frac{1+\pi+\gamma}{1+R}\right)^s\left(\frac{-d_{t+s}}{y_{t+s}}\right)}$$

where: B is the stock of bonds; R is the nominal interest rate; π is the inflation rate; γ is the rate of GDP growth; y is the level of GDP; P is the price level; and d is the primary deficit. While the fiscal theory of the price level is often difficult to verify empirically, it serves as a useful reminder that central banks should pay close attention to fiscal developments.

The third issue to address is commodity prices. The huge run-up in oil prices from around US$55 per barrel at the start of 2007 to more than US$140 in July 2008 highlights the significance of commodity prices on the inflation process. In fact there is a relatively old literature that argues that the fall in inflation in OECD countries in the early 1980s was mostly due to the fall in commodity prices, as opposed to the more traditional view of excessive slack in the economy, particularly in the labour market (Beckerman and Jenkinson 1986).[3] While it is clear that commodity prices have a strong association with headline inflation, it is less clear that they have a strong influence on the persistence element of inflation, or core inflation.

3. While Gilbert (1990) argues that Beckerman and Jenkinson attributed too much importance to commodity prices in the determination of inflation, he does find it to be a significant driver.

Since large jumps in commodity prices are generally temporary, commodity price movements tend not to feed into inflationary expectations and, therefore, tend not to feed into inflationary pressure over the medium term. Moreover, increases in the price of commodities that are typically imported reduce consumers' real incomes in a way that tends to offset the direct price effects on headline inflation. Conversely, increases in the price of commodities that are typically exported tend to be matched by an appreciating exchange rate (Chen and Rogoff 2003). The direct effect on prices from an appreciating currency tends to offset the indirect effect of higher incomes. The implication is that large but temporary shifts in commodity prices need not have a long-run impact on inflation if there is a credible nominal anchor.

The paper by César and Klaus provides a valuable contribution to the empirical literature of inflation determination. Three key lessons from the paper are: (i) that nominal anchors, such as inflation targeting and fixed exchange rates, are essential for inflation control; (ii) good fiscal policy is a prerequisite for inflation control; and (iii) relative price changes can, and do, change the cyclical nature of inflation, but they are unlikely to affect inflation over the medium term.

Finally, I have some questions on the results with regard to the effects of globalisation on inflation. The proxy for globalisation used in the paper is the foreign output gap, which is found to have no significant effect on domestic inflation. This result is contrary to some other recent findings where important 'international/global' dimensions to the country-level inflation have been found (Monacelli and Sala 2009).

Moreover, I believe that using the foreign output gap is too narrow a concept for globalisation. First, globalisation in trade reduces barriers to market access by foreign producers, thereby increasing price competition in domestic markets, especially with the integration of rapidly industrialising economies into the global trading system. I believe this has had significant effects on the prices of both manufactures and commodities. This competition in turn forces a reallocation of productive resources to more cost-efficient firms, thus keeping a lid on inflation. Karagedikli, Mumtaz and Tanaka (2010) find evidence in support of this idea. In particular, they find that the relative price movements across developed economies are, to a significant extent, driven by global factors affecting different products, which is probably due to trade and product market integration. Second, globalisation in financial markets can increase the fear of a reduction in foreign investment flows, which in turn provides the discipline for the central bank to conduct monetary policy in a manner that keeps inflation under control.

References

Ball L and N Sheridan (2004), 'Does Inflation Targeting Matter?', in BS Bernanke and M Woodford (eds), *The Inflation-Targeting Debate*, University of Chicago Press, Chicago, pp 249–282.

Beckerman W and T Jenkinson (1986), 'What Stopped the Inflation? Unemployment or Commodity Prices?', *Economic Journal*, 96(381), pp 39–54.

Chen Y and K Rogoff (2003), 'Commodity Currencies', *Journal of International Economics*, 60(1), pp 133–160.

Galí J (2008), *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*, Princeton University Press, Princeton.

Ghosh AR, A-M Gulde, JD Ostry and HC Wolf (1997), 'Does the Nominal Exchange Rate Regime Matter?', NBER Working Paper No 5874.

Gilbert CL (1990), 'Primary Commodity Prices and Inflation', *Oxford Review of Economic Policy*, 6(4), pp 77–99.

Karagedikli Ö, H Mumtaz and M Tanaka (2010), 'Altogether Now: Do International Factors Explain Relative Price Co-Movements?', Bank of England Working Paper No 381.

Mishkin FS (1999), 'International Experiences with Different Monetary Policy Regimes', *Journal of Monetary Economics*, 43(3), pp 579–605.

Mishkin FS (2007), *Monetary Policy Strategy*, MIT Press, Cambridge.

Mishkin FS and K Schmidt-Hebbel (2007), 'Does Inflation Targeting Make a Difference?', in FS Mishkin and K Schmidt-Hebbel (eds), *Monetary Policy under Inflation Targeting*, Central Bank of Chile, Santiago, pp 291–372.

Monacelli T and L Sala (2009), 'The International Dimension of Inflation: Evidence from Disaggregated Consumer Price Data', *Journal of Money, Credit and Banking*, 41(s1), pp 101–120.

Sargent TJ (1982), 'The Ends of Four Big Inflations', in RE Hall (ed), *Inflation: Causes and Effects*, University of Chicago Press, Chicago, pp 41–97.

Sims CA (2009), 'Fiscal/Monetary Coordination when the Anchor Cable Has Snapped', paper presented at the Conference on 'Monetary-Fiscal Policy Interactions, Expectations, and Dynamics in the Current Economic Crisis', Princeton University, Princeton, 22–23 May.

Woodford M (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press, Princeton.

2. General Discussion

The discussion opened with a participant noting that there were two main changes in inflation over the period from 1975 to 2005 covered by the paper by César Calderón and Klaus Schmidt-Hebbel; the great moderation of inflation, and a change in the cyclical behaviour of inflation. This led them to question whether the results of the paper explained more the disinflationary story or the cyclical story. Similarly, others asked how well the regression models dealt with common, global inflationary shocks; were the time-fixed effects sufficient to soak this up and what did they look like? Klaus Schmidt-Hebbel's response was that the paper explained the observed disinflation, and that while there was less observed inflation persistence after 1996, the cyclical-related variables showed little deviation across the sample period.

Much of the debate related to the model specification. The discussion was varied and covered issues surrounding variable selection and the way in which they were included in the models. There was some concern expressed about possible collinearity amongst the explanatory variables. For instance, measures of both capital account and trade openness were included in the paper. Another participant wondered about the potential for a non-linear relationship between the output gap and inflation. There was also some discussion of the specification of the monetary policy regimes of the countries in the sample, with one participant noting that the paper did not include a variable to capture countries that had formed a currency union in order to lower inflation, instead of explicitly targeting inflation or fixing exchange rates outside of a currency union. Further suggestions touched on the inclusion of interaction terms in the paper's regressions, such as having a variable for the volatility of the terms of trade interacting with an indicator of inflation targeting and/or flexible exchange rate regimes. A participant thought that it would be worth looking at the effect of the duration of an inflation-targeting regime, while another suggested there should be interactions between fixed exchange rates and measures of openness. Klaus Schmidt-Hebbel welcomed these suggestions and said that the inclusion of interaction terms was something he would consider in future versions of the work.

The conversation turned to issues of fiscal policy, with extensive discussion on the appropriate measures to assess the effect of fiscal positions on inflation. The paper used a fiscal surplus-to-GDP variable to model the fiscal theory of inflation, which proposes that the smaller a country's tax base or the greater the pressure on government spending, the greater incentive a country has to resort to an inflation tax. One participant suggested that it might be more appropriate to use a measure that would gauge fiscal sustainability instead of the fiscal surplus – the debt-to-GDP ratio, for example. A subsequent comment focused on the political economy implications of high stocks of government debt. It was suggested that if an economy has a high level of debt, there are potential implications for the independence of monetary authorities, which do not manifest themselves in a linear fashion as implied by the inclusion of a fiscal surplus variable in a regression. One participant noted that the fiscal experience of Latin American countries is quite distinct from that of countries in the rest of the world and suggested the paper investigate whether the overall results on the fiscal theory of inflation are driven by the Latin American observations. Later in the discussion, a comment was made on the implications of high inflation for the fiscal surplus variable. It was suggested that, if a country uses an inflation tax to finance its expenditures, the fiscal surplus variable would be less effective at capturing spending pressures leading to inflation. Klaus Schmidt-Hebbel noted that to better capture fiscal conditions required more data, which were not readily available for all the countries in the sample.

Measuring Core Inflation in Australia with Disaggregate Ensembles

Francesco Ravazzolo and Shaun P Vahey[1]

Abstract

We construct ensemble predictives for inflation in Australia based on the out-of-sample forecast performance of many component models, where each component model uses a particular disaggregate inflation series. Following Ravazzolo and Vahey (2009), the disaggregate ensemble can be interpreted as a forecast-based measure of core inflation. We demonstrate that the ensemble forecast densities for measured inflation using disaggregate information by city and by sector are well calibrated. The resulting forecast densities outperform considerably those from a benchmark autoregressive model. And the point forecasts are competitive. We show that the traditional weighted median and trimmed mean measures of core inflation sometimes differ substantially from the median of the forecast density.

1. Introduction

Since the introduction of inflation targeting, many central banks have focused greater attention on the behaviour of measured inflation. Unfortunately, the theoretical concept of inflation is conceptually mismatched with the headline consumer price index (CPI) measure; see, for example, the arguments in Quah and Vahey (2005). In particular, relative price movements are confounded with general price movements. For example, should we think of recent increases in commodity prices as part of inflation or as movements in relative prices?

A number of central banks regularly examine disaggregate inflation series for less volatile and leading evidence of the inflationary process. The aim in using a 'core' or 'underlying' measure to communicate inflationary pressures is that the influence of relative prices can be removed, or at least moderated. (Hereafter, we use the terms core and underlying interchangeably.) One popular approach truncates (and averages) the disaggregate inflation (or price) cross-sectional distribution to provide a 'core' measure. A second approach excludes particular disaggregates, that is, they receive zero weight; the resulting measure is commonly referred to as an 'ex' core measure. In practice, which series are discarded varies across central banks and through time. Although theoretical considerations are often advanced as

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a justification for both of these approaches, there is considerable uncertainty over which disaggregates or what proportion of the cross-section should be discarded.

Faced with these and other ambiguities in defining core inflation, practitioners often evaluate candidate core inflation measures based on forecasting performance; see, for example, Roger (1998), Wynne (1999) and Smith (2004). The jury is still out on whether core measures offer any advantage over a simple autoregressive benchmark for measured inflation in terms of the out-of-sample accuracy of point forecasts.

In this paper, we reformulate the measuring underlying inflation issue. We start by focusing directly on the forecasting problem, limiting our attention to candidate disaggregate series as forecasting variables. In contrast to the earlier literature on core inflation, we assess forecasting performance based on the complete density for inflation. Tests of point forecast accuracy provide no guidance on the usefulness of core measures for general (but unknown) loss functions.

Our ensemble methodology follows the analysis of inflation in the United States by Ravazzolo and Vahey (2009). We construct ensemble predictive densities based on the out-of-sample forecast performance of many component models, where each model uses a particular disaggregate series. This approach provides well-calibrated forecast densities for measured inflation in Australia. Combining the evidence from two sources of disaggregation, by city and by sector, yields considerable improvement in density performance. The resulting forecast densities are preferable to those from a benchmark autoregressive model, with competitive point forecast performance. The traditional weighted median and trimmed mean measures of core inflation sometimes differ considerably from the median of the forecast density. For example, the probability of inflation being overstated by the (subsequently published) trimmed mean measure was more than 75 per cent for 2008:Q1.

In our application, we focus entirely on one-quarter-ahead forecasts. Within the underlying inflation literature, the horizon of interest varies, typically between one and eight quarters ahead. Although longer horizon ensemble forecasts are possible with our methodology, we concentrate on horizons much shorter than typically focused on by many inflation-targeting central banks. Our hope is that the disaggregate ensemble core measure picks up the inflation already in the pricing pipeline, and does not respond to future changes in policy stance. For further discussion of the choice of forecasting horizon in the core inflation literature, see Brischetto and Richards (2006).

The remainder of this paper is as follows. We provide a brief review of the core inflation literature in Section 2. The ensemble modelling strategy is discussed in Section 3. We describe our component models and our ensemble predictives in Section 4. The Australian dataset is summarised in Section 5, and results are presented in Section 6. Some conclusions are drawn in Section 7.

2. A Brief Review of the Core Inflation Literature

It is widely recognised by the public and central bankers that movements in the CPI do not always capture true 'inflationary' pressures. The weights on the disaggregates in the cost of living index reflect the preferences and budget constraint of the representative consumer. But those weights can lead to a misleading assessment of inflationary pressures because relative price changes are confounded with sustained general price movements.

In the core inflation literature, the aim is to measure the general increase in prices. Most central banks consider a variety of measures of underlying inflation. Many of these are derived by removing an 'unwanted' component, which is often treated as 'noise'; for further discussion see Brischetto and Richards (2006).

Traditional methods for measuring core inflation include smoothing and structural time-series modelling. The first of these takes a moving average of measured inflation and labels this as the core. The second makes specific assumptions about the functional form for underlying inflation (such as taking it to be a Gaussian random walk) and produces an estimate with the Kalman filter.

Partly as a result of dissatisfaction with the ability of these models to forecast inflation, many central banks consider measures of core inflation obtained by applying zero weights to particular components. Bryan and Cecchetti (1994) extend this exclusion-based methodology by zero-weighting the disaggregates in the tails of the cross-section. Although Bryan and Cecchetti offer a menu cost model as a rationale for truncating the distribution, that theory does not imply any particular truncation factor for the disaggregate distribution.

A related problem blights the less complex 'ex' core measures that always exclude particular components. The argument for using 'ex' measures is that: if you know that one or two (or more) disaggregate series contain a great deal of 'noise', then they should be dropped from measured inflation to form the core measure. This is the argument, for example, regarding the personal consumption expenditures chain-type price index excluding food and energy in the United States (Ravazzolo and Vahey 2009).

Unfortunately, zero-weighting disaggregate components rarely produces a core measure that beats simple autoregressive benchmarks in out-of-sample forecast evaluations. Moreover, the uncertainties involved in the selection of truncation factors, or the series to be excluded, affect the usefulness of the candidate core measures as communication tools. The public often suspect that the central bank exploiting these communication devices prefers to ignore inconvenient data. For example, the December 1997 Reserve Bank of New Zealand background briefing for the Policy Targets Agreement explicitly draws attention to this difficulty.[2]

In our ensemble approach described below, we avoid using strong off-model or prior information about which disaggregates are likely to provide useful signals regarding future values of measured inflation. Instead, we formulate the problem

2. See <http://www.rbnz.govt.nz/monpol/pta/0055243.html>.

of measuring core inflation as one of combining component forecast densities of measured inflation, where each component is based on a particular disaggregate series. In this sense, we let the data speak clearly about which disaggregates are important for density forecasts of measured inflation. If particular disaggregates do not matter for inflation in the next quarter, they receive a small weight (bounded at zero). In so doing, we formally account for the uncertainty regarding which disaggregates should be included, and also over the type of disaggregation.

3. Modelling Strategy

Garratt, Mitchell and Vahey (2009) drew attention to the antecedents of ensemble macro modelling in statistics and weather forecasting. Outside of the econometrics literature, the benefits of the ensemble approach to forecasting have been recognised for around 15 years. Meteorologists and statisticians have focused a great deal of attention on analysing statistical ensembles. The idea behind the ensemble approach is to consider a large number of models, each of which is a variant or component of the 'preferred' specification. Each component could be viewed as an approximation of the current state of the 'true' but unknown specification, and when considered together, the ensemble approximates the truth.

In the meteorological forecasting literature, the ensemble methodology is a response to what macro-econometricians sometimes call 'uncertain instabilities' (see Clark and McCracken 2007, for example). Individual empirical specifications tend to exhibit instabilities, which can be difficult to isolate with short runs of real-time macroeconomic data.

Bache *et al* (2009) list four common characteristics of an ensemble strategy for macro modelling:

i. generation of forecasting densities, rather than point forecasts;

ii. predictive density construction from a large number of component macroeconometric models;

iii. forecast density evaluation and combination based on out-of-sample performance, rather than in-sample analysis; and

iv. component model weights vary through evaluation – ensemble densities have time-varying weights.

Papers in the economics literature that satisfy these criteria include: Jore, Mitchell and Vahey (2008), Garratt *et al* (2009) and Kascha and Ravazzolo (2010). Smith *et al* (2009) consider the performance of the Norges Bank 'nowcasting' system, which also adopts the ensemble methodology. In these cases, the out-of-sample densities from many macroeconometric component models are directly combined into the ensemble using an 'opinion pool'.[3] These papers differ in the

3. Wallis (2005) uses opinion pools to average (model free) survey forecasts, rather than those from macroeconometric models. Mitchell and Hall (2005) use opinion pools to combine forecasts from two institutions. Gerard and Nimark (2008) consider opinion pool combinations with three macro models.

design of the model space and the number of components considered, as well as the applied problem of interest.

Another strand of the economics literature uses informative priors for the combination step to produce ensembles. Maheu and Gordon (2008) and Geweke (2010) use mixture models to give non-Gaussian predictives. Andersson and Karlsson (2007) take a predictive likelihood approach to combining vector autoregressions (VARs).

Geweke (2010) discusses the relationships between density pooling and mixture modelling, and argues that the former presents a more coherent approach for incomplete model spaces. Clearly, both variants can be effective methods for combining densities in forecasting applications. In a related literature, Patton (2004), Maheu and McCurdy (2009) and Amisano and Geweke (2010) consider ensembles in various financial applications.

Before we move on to discuss the model space and ensembles for our application, it is worth considering whether we want to forecast the entire density of measured inflation. In our view, restricting attention to point forecast accuracy makes no sense. There is no reason to believe that the inflation process is Gaussian; and there is nothing particularly compelling about the quadratic loss function. In the absence of either assumption, the root mean squared forecast error (RMSFE) metric has no justification. If we want to forecast inflation, the whole forecast density seems a natural starting point.

4. Component Model Space and Ensembles

For each observation in the policy-maker's out-of-sample 'evaluation period', we use density forecast performance to compute the weight on each component model. The component models use a common time-series structure, namely an autoregressive specification with four lags, AR(4).[4] Each component model uses a particular disaggregate inflation measure. The weights on the individual components are based on the 'fit' of the component predictive densities for measured inflation. Given these weights, we construct ensemble forecast densities for measured inflation.

More formally, consider a policy-maker aggregating *N* forecasts from different 'sources', each using a unique component forecasting model. Given $i = 1, ..., N$ components (where *N* could be a large number), we define the ensemble measure of core inflation by the convex combination also known as a linear opinion pool:

$$DE_\tau = p\left(\pi_{\tau,h}\right) = \sum_{i=1}^{N} w_{i,\tau,h} g\left(\pi_{\tau,h} \middle| I_{i,\tau}\right), \quad \tau = \underline{\tau},\ldots,\overline{\tau}, \tag{1}$$

where $g\left(\pi_{\tau,h} \middle| I_{i,\tau}\right)$ are the *h*-step-ahead forecast densities from component model i, $i = 1, ..., N$, conditional on the information set I_τ.

4. Ravazzolo and Vahey (2009) consider time-varying parameter components but find that simple autoregressive components result in a relatively small drop in forecast performance.

Each component model forecasts disaggregate inflation. Then in each recursion, we centre the component forecasts on measured inflation. In effect, this step restricts the ensemble forecast density to be uni-modal but not symmetric. Bao *et al* (2007) discuss the common practice of centring ensemble forecast densities prior to combination.

After this centring procedure, each component model produces h-step-ahead forecast densities for measured inflation, g(•). Each component model uses data, dated $\tau - h$ or earlier, to produce a h-step-ahead forecast density for τ. The non-negative weights, $w_{i,\tau,h}$, in this finite mixture sum to unity, are positive, and vary by recursion in the evaluation period $\tau = \underline{\tau},\ldots,\overline{\tau}$.

We emphasise that the ensemble forecast density has the scope to be non-Gaussian even if the component models produce Gaussian predictives. The linear opinion pool ensemble (Equation (1)) accommodates skewness and kurtosis. The flexible structure resulting from linear pooling allows the data to reveal whether, for example, the ensemble should have fat tails, or asymmetries.[5]

We construct the ensemble forecast density for measured inflation using Equation (1). Implementation of the density combination requires a measure of component density fit to provide the weights. A number of recent applications in the economics literature have used density scoring rules. In this application, we utilise the continuous ranked probability score (CRPS), which as (among others) Gneiting and Raftery (2007), Panagiotelis and Smith (2008) and Ravazzolo and Vahey (2009) note, rewards predictive densities from components with high probabilities near (and at) the actual outcome.[6]

The weights for the h-step-ahead disaggregate ensemble (DE) CPI densities are:

$$w_{i,\tau,h} = \frac{\left[\sum_{\underline{\tau}}^{\tau-1-h} X\left(g\left(\pi_{\tau,h} \middle| I_{i,\tau}\right)\right)\right]}{\sum_{i=1}^{N}\left[\sum_{\underline{\tau}}^{\tau-1-h} X\left(g\left(\pi_{\tau,h} \middle| I_{i,\tau}\right)\right)\right]}, \qquad \tau = \underline{\tau},\ldots,\overline{\tau}. \qquad (2)$$

where $g\left(\pi_{\tau,h} \middle| I_{i,\tau}\right)$ is the centred predictive density for measured aggregate inflation $\pi_{\tau,h}$ given by model i; and X is the CRPS-based measure of density performance as in Ravazzolo and Vahey (2009).

Using Equations (1) and (2), we construct two disaggregate ensembles that combine predictive densities from cities, and sectors, respectively. The city DE, denoted DE_c, contains eight components (city disaggregates); the sector DE, DE_s, contains 10 components (sector disaggregates). We also use the 'grand ensemble' technique proposed by Garratt *et al* (2009) to combine the two ensembles based on different types of disaggregation. Given the short sample in our application,

5. Kascha and Ravazzolo (2010) compare and contrast logarithmic and linear pooling. Logarithmic opinion pools force the ensemble predictives to be symmetric, but accommodate fat tails; see also Smith *et al* (2009).

6. See Panagiotelis and Smith (2008) for an explanation of how CRPS is calculated in practice.

we give equal weight to the ensembles, DE_c and DE_s in constructing the grand ensemble, denoted, DE_cs.[7]

As a benchmark for our forecast evaluations, we use an AR(4) model for measured inflation. (We experimented with various lag orders for the benchmark and found the results to be qualitatively similar.) Our choice of an autoregressive benchmark was motivated by the Stock-Watson observation that similar specifications are 'hard to beat' in out-of-sample forecast evaluations. We use non-informative priors for the AR(4) parameters, with an expanding window for estimation – so that forecasts are recursive. The predictive densities follow the *t*-distribution, with mean and variance equal to OLS estimates (see Koop 2003 for details).

To assess the calibration properties of the ensemble densities we follow Diebold, Gunther and Tay (1998) and compute probability integral transforms, *PITS*. We apply the Berkowitz (2001) likelihood ratio test for independence, zero mean and unit variance of the *PITS*. The test statistic is distributed $\chi^2(3)$ under the null hypothesis of no calibration failure, with a maintained hypothesis of normality. We also report the average (over the evaluation period $T = \overline{\tau} - \underline{\tau}$) logarithmic score. The logarithmic score of the *i*-th density forecast, ln $g\left(\pi_{\tau,h} \middle| I_{i,\tau}\right)$, is the logarithm of the probability density function $g\left(. \middle| I_{i,\tau}\right)$, evaluated at the outcome $\pi_{\tau,h}$. Hence, the log score evaluates the predictives at the outcome only. We investigate relative predictive accuracy by considering a test based on the Kullback-Leibler information criterion (KLIC), derived from the expected difference in the log scores of the two models; see Mitchell and Hall (2005), Amisano and Giacomini (2007) and Bao, Lee and Saltoglu (2007). Suppose that there are two ensemble forecast densities, $g\left(\pi_{\tau,h} \middle| I_{1,\tau}\right)$ and $g\left(\pi_{\tau,h} \middle| I_{2,\tau}\right)$, so that the KLIC differential between them is the expected difference in their log scores: $d_{\tau,h} = \ln g\left(\pi_{\tau,h} \middle| I_{1,\tau}\right) - \ln g\left(\pi_{\tau,h} \middle| I_{2,\tau}\right)$. The null hypothesis of equal density forecast accuracy is $H_0 : E\left(d_{\tau,h}\right) = 0$. A test can then be constructed since the mean of $d_{\tau,h}$ over the evaluation period, $d_{\tau,h}$, under appropriate assumptions, has the limiting distribution: $\sqrt{T}\overline{d}_{\tau,h} \rightarrow N\left(0,\Omega\right)$, where Ω is a consistent estimator of the asymptotic variance of $d_{\tau,h}$.[8] Mitchell and Wallis (2008) explain the importance and practical difficulties of using information-based methods to discriminate between competing forecast densities.

7. Garratt *et al* (2009) explore the use of recursively estimated weights to construct their grand ensembles.

8. When evaluating the ensemble forecast densities we treat them as primitives, and abstract from the ensemble combination methodology. Giacomini and White (2006) and Amisano and Giacomini (2007) discuss more generally the limiting distribution of related test statistics.

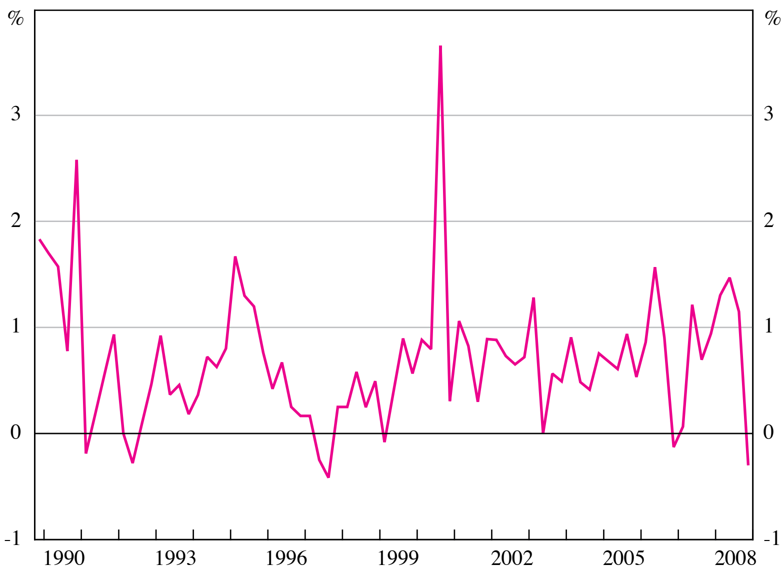
5. Data

We apply our ensemble methodology to combine Australian disaggregate inflation forecasts for quarter-on-quarter growth of the CPI. We assess the performance of the disaggregate ensembles, and other core measures, using an evaluation period from 1997:Q1 to 2008:Q4 (48 observations). The period 1994:Q4 to 1996:Q4 is used as a 'training period' to initialise the ensemble weights.[9]

As mentioned above, the Australian CPI can be broken down by sectors and cities. The first breakdown decomposes the CPI into 10 disaggregates representing sectors. In our empirical analysis, we exclude the sector 'financial and insurance services' for which there are data from 2005:Q3 only. The second form of disaggregation decomposes the CPI according to data on prices from eight cities.

Figures 1, 2 and 3 plot respectively the CPI, its sector disaggregates and its city disaggregates over the sample 1989:Q4–2008:Q4. One striking feature is the high degree of contemporaneous dependence across cities. In contrast, the sectors display more heterogeneity, with differences in means and volatility.

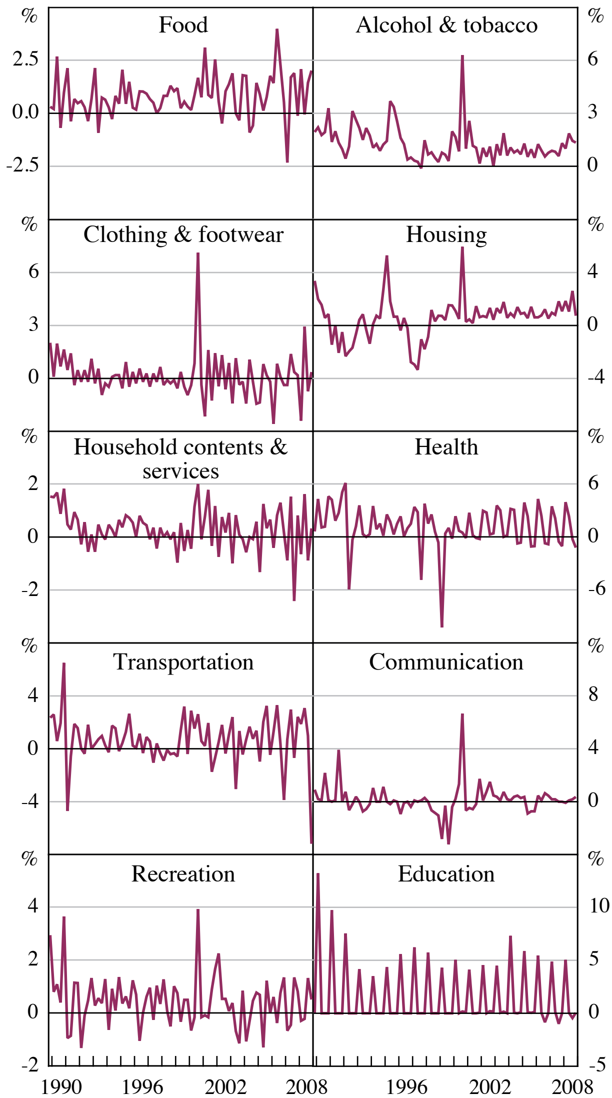
Figure 1: Australian CPI Inflation
Quarterly



Source: ABS

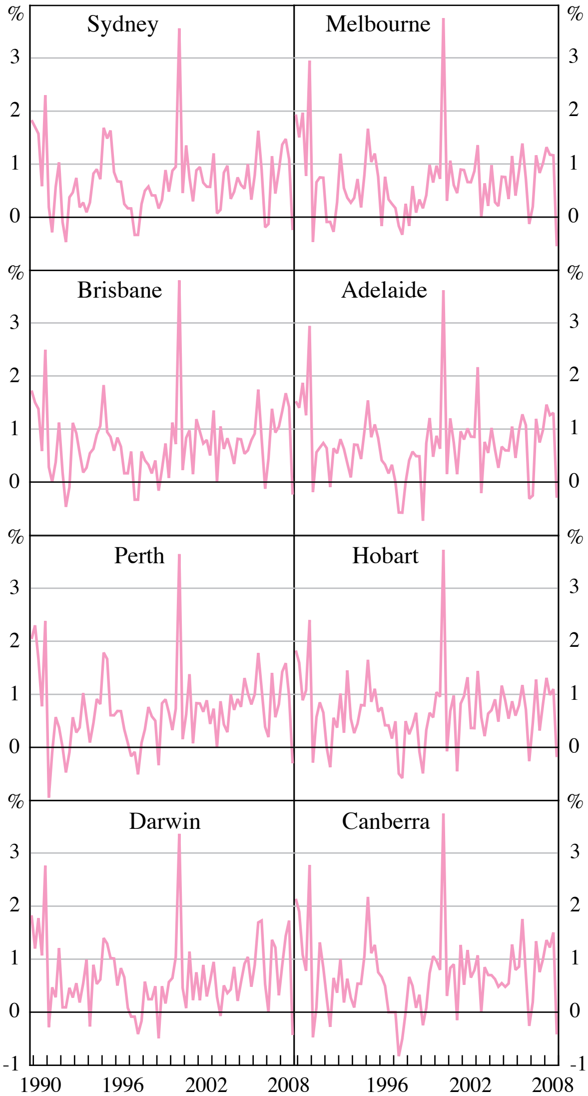
9. Data are available from the Australian Bureau of Statistics at <http://www.abs.gov.au> (ABS Cat No 6401.0).

Figure 2: Disaggregate Inflation by Sector
Quarterly



Source: ABS

Figure 3: Disaggregate Inflation by City
Quarterly



Source: ABS

6. Results

Recall that we construct the core inflation measure, DE, by combining the predictive densities from the disaggregate component models. We compare and contrast the ensembles using disaggregation by sector DE_s, by city DE_c, and the grand ensemble of the two, DE_cs. Below we report evaluations for the one-step- (one-quarter-) ahead horizon.[10]

Before turning to the density evaluations for our various ensembles, we summarise point forecast performance. The RMSFE of DE_s, DE_c, DE_cs, and the benchmark AR(4) are 0.558, 0.424, 0.473 and 0.378, respectively. The Clark and West (2006) test for superior predictive accuracy (against the null of equal accuracy) indicates that the ensembles are competitive with the AR(4) benchmark with test statistics of 1.592, 1.556, 1.574 for the DE_s, DE_c, and DE_cs, respectively. The critical value for rejection of the null for a 95 per cent interval is 1.645. Smith (2004) and Kiley (2008) discuss the properties of various point forecasts for core inflation measures. Most fail to outperform simple autoregressive benchmarks.

We turn now to the *ex post* (end of period) evaluation of the forecast densities from the ensemble forecasts and the benchmark. Table 1 has four rows; one for each ensemble and the benchmark. The columns report (reading from left to right) the Berkowitz likelihood ratio test (based on the *PITS*), the log scores (averaged over the evaluation period) and the p-values for the equal predictive density accuracy test (based on the log scores), respectively. Whereas DE_s, DE_c and DE_cs appear to be well-calibrated on the basis of the Berkowitz likelihood ratio, the final column shows that the AR(4) is rejected in favour of DE_cs only in the case of the KLIC-based test. The ensemble DE_cs delivers a statistically significant improvement in the log score (reported in the second column) based on a 95 per cent confidence interval.

The weights in DE_s and DE_c display some variation through time. Tables 2 and 3 report the weights on the sector and city disaggregates, respectively, for three

Table 1: Forecast Performance

	LR	LS	LS-test
AR(4)	0.185	–1.078	
DE_s	0.222	–0.940	0.148
DE_c	0.184	–1.062	0.383
DE_cs	0.215	–0.864	0.037

Notes: The column LR is the likelihood ratio p-value of the test of zero mean, unit variance and independence of the inverse normal cumulative distribution function-transformed *PITS*, with a maintained assumption of normality for transformed *PITS*. LS is the average logarithmic score, averaged over the evaluation period. LS-test is the p-value of the KLIC-based test for equal density forecasting performance of AR(4) and DE12 over the sample 1997:Q1 to 2008:Q4.

10. We also computed, but do not report, forecasts for two-, three- and four-step-ahead horizons. Results are qualitatively similar and available upon request from the authors.

Table 2: Disaggregate Weights – DE_s

	1997:Q1	2002:Q4	2008:Q4
Food	0.166	0.178	0.156
Alcohol & tobacco	0.100	0.098	0.110
Clothing & footwear	0.095	0.068	0.080
Housing	0.077	0.086	0.100
Household contents & services	0.150	0.159	0.128
Health	0.066	0.068	0.070
Transportation	0.094	0.112	0.104
Communication	0.122	0.095	0.111
Recreation	0.085	0.093	0.101
Education	0.046	0.044	0.041

Table 3: Disaggregate Weights – DE_c

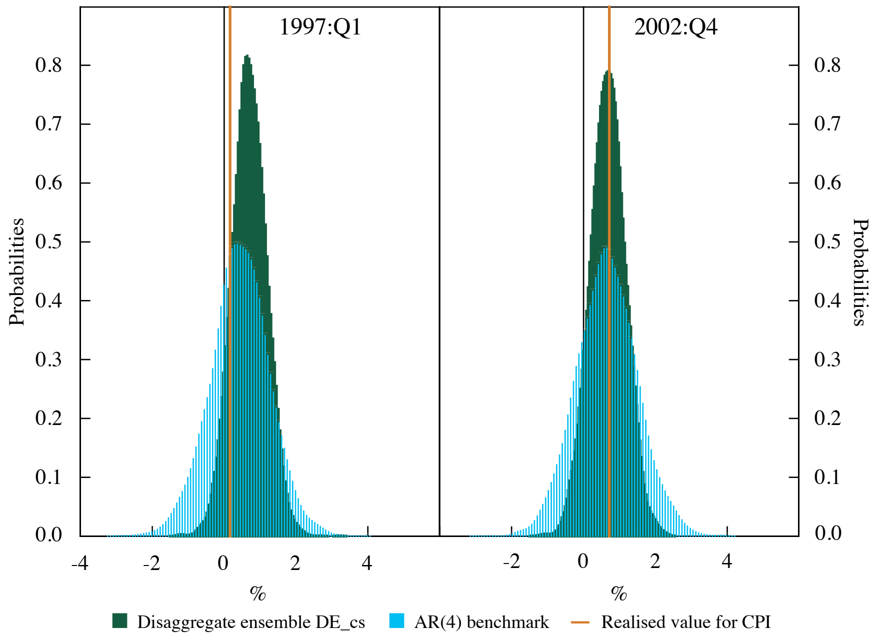
	1997:Q1	2002:Q4	2008:Q4
Sydney	0.087	0.073	0.084
Melbourne	0.123	0.150	0.146
Brisbane	0.138	0.126	0.116
Adelaide	0.098	0.122	0.117
Perth	0.076	0.117	0.110
Hobart	0.110	0.142	0.157
Darwin	0.205	0.138	0.137
Canberra	0.162	0.132	0.133

specific observations. It can be seen from both tables that generally all disaggregate components have a non-zero weight. There does not seem to be a case for excluding the information on individual disaggregates, or groups of particular disaggregates, on the basis of these weights.[11]

To provide insight into the probability of inflation events, Figure 4 provides the ensemble forecast densities from DE_cs at particular observations, namely 1997:Q1 and 2002:Q4 (the first and the middle observations in our evaluation period), together with the benchmark densities. We see that the AR(4) benchmark produces density forecasts that are too wide, with a high probability mass attributed to (quarterly) inflation in excess of 2 per cent in absolute value for both observations. The core predictives contain more mass in the regions around the actual outcomes than the AR(4) benchmark, with minor departures from symmetry.

11. Geweke (2010) argues that even a zero weight is not sufficient to conclude that a component model has zero value for the linear opinion pool.

Figure 4: AR(4) and DE_cs Density Forecasts
Quarterly growth



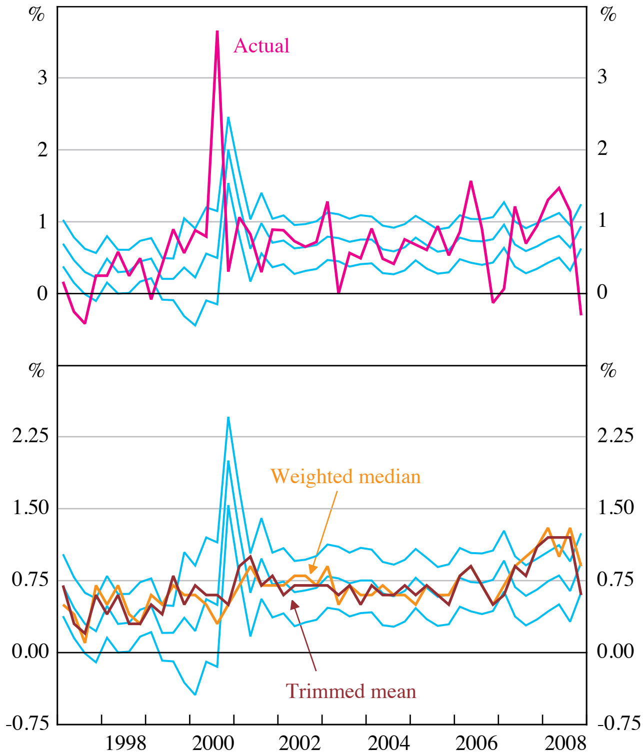
Sources: ABS; authors' calculations

Returning to the issue of measuring core inflation, recall that, in this paper, we reformulate the problem of measuring underlying inflation. We focus on constructing complete forecast densities for measured inflation and limit our set of candidate forecasting variables to disaggregate series. We describe our disaggregate ensemble forecast density for measured inflation as the measure of core inflation. How should we interpret the traditional weighted median and trimmed mean measures of core inflation conditional on our density forecast? In Figure 5, we plot the median from our grand ensemble core, DE_cs, together with the 25th and 75th percentiles, through the evaluation period. The DE_cs core ignores several extreme values in the actual measured inflation series – the forecast median of this measure is fairly smooth.[12] This figure also plots the trimmed mean and weighted median measures of core inflation used by the Reserve Bank of Australia; see Appendix A for details. The DE core inflation measure suggests that both of these periodically give assessments of inflationary pressures that are low-probability. The year 2008 saw several outcomes above the 75th percentile for both of these underlying measures. The DE core implies that inflationary pressures were more moderate. For example, according to

12. Following the suggestion of our discussant, we also experimented with a CPI series, and disaggregate series, with tax effects removed. For most of the evaluation period, the forecast densities for measured inflation were almost identical to those reported in this paper. The exception is the spike at the start of this decade, which does not appear in the forecasts with tax-adjusted data.

the DE core measure, the probability of inflation being overstated by the trimmed mean measure was more than 75 per cent for 2008:Q1. We should note also that the traditional measures of underlying inflation plotted here are less timely than the DE core, which is a well-calibrated one-step-ahead forecast density.

Figure 5: Inflation Interval Forecasts

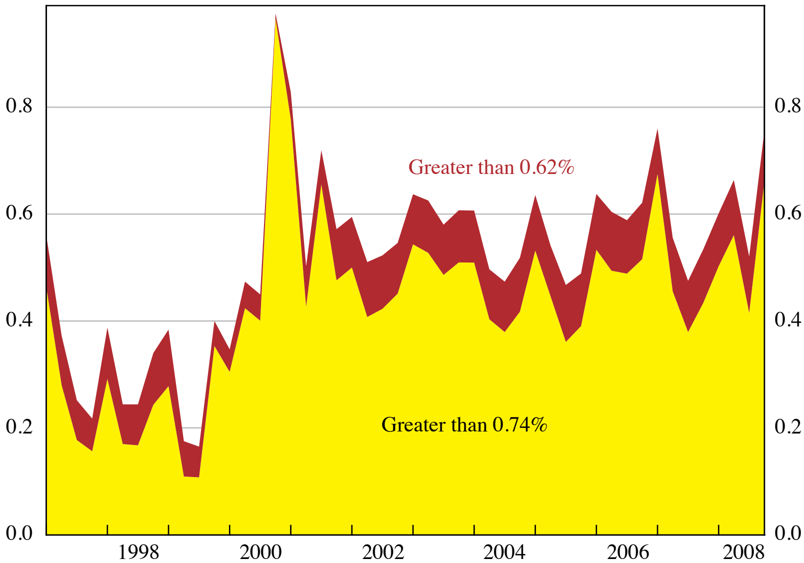


Note: Figure shows the posterior median, the 25th and 75th percentiles of the predictive density given by disaggregate ensemble DE_cs using unadjusted data

Sources: ABS; RBA; authors' calculations

One advantage of our probabilistic approach to measuring core inflation is that we can calculate the probability of specific events for measured inflation of interest to policy-makers. As an example, we calculate the (one-step-ahead) probability that measured inflation exceeds the upper range and midpoint of the inflation target. The target for monetary policy in Australia is to achieve an inflation rate of 2–3 per cent, on average, over the cycle (in annualised terms). We work with analogous thresholds for the one-step-ahead horizon, interpreted at a quarterly frequency. The events of interest are: (1) measured inflation greater than 0.74 per cent (upper range of the target); and (2) measured inflation greater than 0.62 per cent (midpoint of the target). The time series for the probabilities of these two events are plotted in Figure 6. As a visual aid, we label the 'upper range' event yellow, and the 'midpoint' event red, and shade the plot appropriately. The figure suggests that the probability of exceeding the upper threshold has generally been around 50 per cent in recent years. The probability of measured inflation exceeding the midpoint of the band is typically greater than 50 per cent.

Figure 6: Measured Inflation Probabilities



Source: authors' calculations

7. Conclusions

Instead of gauging core inflation by traditional methods, we have focused on the problem of constructing an ensemble forecast density. We conclude from our analysis that the ensemble approach provides well-calibrated forecast densities for Australian measured inflation from disaggregate information. Our forecast densities use information from disaggregation both by city and by sector, and indicate that more traditional core measures at times fail to strip out the impact of relative prices in measured inflation.

Appendix A: Traditional Core Measures

Extract from 'Notes to Tables', Reserve Bank of Australia *Bulletin*, December 2009 (Table G.1 Measures of Consumer Price Inflation, pp S118–S119):

> The 'Weighted median' and 'Trimmed mean' are calculated using the component level data of the consumer price index. Both measures exclude interest charges prior to the September quarter 1998 and are adjusted for the tax changes of 1999–2000. The 'Trimmed mean' is calculated by ordering all the CPI components by their price change in the quarter and taking the expenditure-weighted average of the middle 70 per cent of these price changes. The 'Weighted median' is the price change in the middle of this ordered distribution, taking also expenditure weights into account. Annual rates of 'Weighted median' and 'Trimmed mean' inflation are calculated based on compounded quarterly rates. For calculating the 'Weighted median' and 'Trimmed mean', where CPI components are identified as having a seasonal pattern, quarterly price changes are estimated on a seasonally adjusted basis. Seasonal adjustment factors are calculated as concurrent factors, that is using the history of price changes up to and including the current CPI release. There is a series break at September 2002 due to the ABS publishing the 'Weighted median' and 'Trimmed mean' on behalf of the RBA from that point forward, using data to a higher level of precision than is publicly available.
>
> For further information on the various measures of underlying consumer price inflation, refer to 'Box D: Underlying Inflation', *Statement on Monetary Policy*, May 2002; 'Box D: Measures of Underlying Inflation', *Statement on Monetary Policy*, August 2005; and Roberts (2005), 'Underlying Inflation: Concepts, Measurement and Performance', Reserve Bank of Australia Research Discussion Paper No 2005-05.

References

Amisano G and J Geweke (2010), 'Comparing and Evaluating Bayesian Predictive Distributions of Asset Returns', *International Journal of Forecasting*, 26(2), pp 216–230.

Amisano G and R Giacomini (2007), 'Comparing Density Forecasts via Weighted Likelihood Ratio Tests', *Journal of Business & Economic Statistic*s, 25(2), pp 177–190.

Andersson MK and S Karlsson (2007), 'Bayesian Forecast Combination for VAR Models', Sveriges Riksbank Working Paper No 216.

Bache IW, J Mitchell, F Ravazzolo and SP Vahey (2009), 'Macro Modelling with Many Models', National Institute of Economic and Social Research Discussion Paper No 337.

Bao L, T Gneiting, EP Grimit, P Guttop and AE Raftery (2007), 'Bias Correction and Bayesian Model Averaging for Ensemble Forecasts of Surface Wind Direction', University of Washington, Department of Statistics, Technical Report No 557.

Bao Y, T-H Lee and B Saltoglu (2007), 'Comparing Density Forecast Models', *Journal of Forecasting*, 26(3), pp 203–225.

Berkowitz J (2001), 'Testing Density Forecasts, with Applications to Risk Management', *Journal of Business & Economic Statistics*, 19(4), pp 465–474.

Brischetto A and A Richards (2006), 'The Performance of Trimmed Mean Measures of Underlying Inflation', RBA Research Discussion Paper No 2006-10.

Bryan MF and SG Cecchetti (1994), 'Measuring Core Inflation', in NG Mankiw (ed), *Monetary Policy*, University of Chicago Press, Chicago, pp 195–219.

Clark TE and MW McCracken (2007), 'Averaging Forecasts from VARs with Uncertain Instabilities', Federal Reserve Bank of Kansas City Working Paper No 06-12.

Clark TE and KD West (2006), 'Approximately Normal Tests for Equal Predictive Accuracy in Nested Models', *Journal of Econometrics*, 138(1), pp 291–311.

Diebold FX, TA Gunther and AS Tay (1998), 'Evaluating Density Forecasts with Applications to Financial Risk Management', *International Economic Review*, 39(4), pp 863–883.

Garratt A, J Mitchell and SP Vahey (2009), 'Measuring Output Gap Uncertainty', unpublished manuscript, Birkbeck College, University of London.

Gerard H and K Nimark (2008), 'Combining Multivariate Density Forecasts Using Predictive Criteria', RBA Research Discussion Paper No 2008-02.

Geweke J (2010), *Complete and Incomplete Econometric Models*, Princeton University Press, Princeton.

Giacomini R and H White (2006), 'Tests of Conditional Predictive Ability', *Econometrica*, 74(6), pp 1545–1578.

Gneiting T and AE Raftery (2007), 'Strictly Proper Scoring Rules, Prediction, and Estimation', *Journal of the American Statistical Association*, 102(477), pp 359–378.

Jore AS, J Mitchell and SP Vahey (2008), 'Combining Forecast Densities from VARs with Uncertain Instabilities', National Institute of Economic and Social Research Discussion Paper No 303.

Kascha C and F Ravazzolo (2010), 'Combining Inflation Density Forecasts', J*ournal of Forecasting*, 29(1), pp 231–250.

Kiley MT (2008), 'Estimating the Common Trend Rate of Inflation for Consumer Prices and Consumer Prices Excluding Food and Energy Prices', Board of Governors of the Federal Reserve System Finance and Economics Discussion Series No 2008-38.

Koop G (2003), *Bayesian Econometrics*, John Wiley and Sons, Hoboken.

Maheu JM and S Gordon (2008), 'Learning, Forecasting and Structural Breaks', *Journal of Applied Econometrics*, 23(5), pp 553–583.

Maheu JM and TH McCurdy (2009), 'How Useful are Historical Data for Forecasting the Long-Run Equity Return Distribution?', *Journal of Business & Economic Statistics*, 27(1), pp 95–112.

Mitchell J and SG Hall (2005), 'Evaluating, Comparing and Combining Density Forecasts Using the KLIC with an Application to the Bank of England and NIESR "Fan" Charts of Inflation', *Oxford Bulletin of Economics and Statistics*, 67(S1), pp 995–1033.

Mitchell J and KF Wallis (2008), 'Evaluating Density Forecasts: Forecast Combinations, Model Mixtures, Calibration and Sharpness', National Institute of Economic and Social Research Discussion Paper No 320.

Panagiotelis A and M Smith (2008), 'Bayesian Density Forecasting of Intraday Electricity Prices using Multivariate Skew *t* Distributions', *International Journal of Forecasting*, 24(4), pp 710–727.

Patton AJ (2004), 'On the Out-of-Sample Importance of Skewness and Asymmetric Dependence for Asset Allocation', *Journal of Financial Econometrics*, 2(1), pp 130–168.

Quah DT and SP Vahey (2005), 'Measuring Core Inflation', *Economic Journal*, 105(432), pp 1130–1144.

Ravazzolo F and SP Vahey (2009), 'Ditch the Ex! Measure Core Inflation with a Disaggregate Ensemble', unpublished manuscript, Norges Bank.

Roger S (1998), 'Core Inflation: Concepts, Uses and Measurement', Reserve Bank of New Zealand Discussion Paper No G98/9.

Smith C, K Gerdrup, AS Jore and LA Thorsrud (2009), 'There Is More than One Weight to Skin a Cat: Combining Densities at Norges Bank', unpublished manuscript, Norges Bank.

Smith JK (2004), 'Weighted Median Inflation: Is This Core inflation?', *Journal of Money, Credit and Banking*, 36(2), pp 253–263.

Wallis KF (2005), 'Combining Density and Interval Forecasts: A Modest Proposal', *Oxford Bulletin of Economics and Statistics*, 67(S1), pp 983–994.

Wynne MA (1999), 'Core Inflation: A Review of Some Conceptual Issues', ECB Working Paper Series No 5.

Discussion

1. Anthony Richards

In these comments I will begin with a discussion of how central banks typically use measures of core or underlying inflation[1], and then discuss the specific methodology that Francesco Ravazzolo and Shaun Vahey propose.[2]

How do central banks use measures of underlying inflation?

There is significant 'noise' in headline inflation. Good measures of underlying inflation are ones that help to abstract from this noise and give a better read of the 'signal'. Understanding the current pace of inflation is important for central banks as a starting point for forecasts. In Brischetto and Richards (2006), we argue that good measures of underlying inflation are likely to have some short-term predictive power for inflation. I would stress that this is not about the predictability of inflation in two or three years: central banks use their economic models to forecast inflation at that horizon. Rather, tests of near-term predictability provide an indication of which measures of inflation have less noise and relatively more signal.

At the RBA, we look at a wide range of measures of inflation in addition to headline inflation. These include the following:

- A number of 'exclusion measures', such as those that exclude automotive fuel and fruit & vegetables, as well as items that may be significantly affected by policy (for example, deposit & loan facilities, the prices of which have been affected both by measurement issues and by the large movements in the cash rate over the past year).
- A number of trimmed-mean and weighted-median measures calculated using both quarterly and annual price changes. In addition to the standard measures calculated by the ABS, we also calculate measures using price data disaggregated by both expenditure item and capital city, reflecting the innovation proposed for the United States in Brischetto and Richards (2006).
- Given that there is strong evidence of seasonality in some individual CPI components and some evidence of seasonality in the overall CPI, we calculate a seasonally adjusted CPI, as well as seasonally adjusted exclusion measures.
- Finally, we also look at some more technical methods, such as factor and time-series models.

Based on this, we reach a judgment about the trend in inflation over the past quarter or year, attempting to abstract from noise from individual items, and thinking

1. The terms core and underlying inflation are often used fairly interchangeably. However, many use the term 'core' to refer to a specific exclusion measure of underlying inflation (typically the CPI excluding automotive fuel and some food items). I will use the term 'underlying' to refer to a general concept, rather than any specific measure.
2. Many of the ideas in these comments are borrowed from Brischetto and Richards (2006).

about the particular factors influencing the data. As part of this process, we often do some (mental) time-series filtering or smoothing.

We then prepare forecasts of inflation, both underlying and headline, based on a suite of models, with the current pace of underlying inflation an important input into these forecasts. We recognise that any forecast has a distribution, and spend a fair bit of time thinking about how the world could be different (although, relative to Francesco and Shaun, we spend relatively more time thinking about the central forecast than thinking about the width of the distribution).

This paper

Francesco and Shaun start with the premise, consistent with the comments above, that measures of core inflation should be informative about inflation probabilities.

In simple terms, their methodology is as follows. They begin with quarterly inflation in CPI components (either 10 expenditure classes or 8 capital cities) up to time t. They then fit autoregressive models with four lags (AR(4)) explaining each component, and take the fitted values and densities for each component in period $t+1$. Then they mean-adjust (or re-centre) each fitted value and density to match mean CPI inflation. The re-centred AR(4) predictions and densities are then combined. This combined forecast is called ‘core inflation’ in period $t+1$, with an accompanying density. For some of these steps, the authors use some fairly advanced techniques to which my brief description does not do justice. Of course, this highly technical approach will be a two-edged sword and might hinder any attempt to use the proposed measure in a central bank’s communication with the public.

Although the paper is titled ‘Measuring Core Inflation in Australia with Disaggregate Ensembles’, it is more about modelling and forecasting than about measuring in the conventional sense: indeed the authors can give us period $t+1$ underlying inflation before the statistical office has published even the headline inflation data for that period.[3]

Nevertheless, it is worth asking how it relates to existing measures of underlying inflation. Most measures of underlying inflation can be viewed as providing some degree of noise reduction through either time-series smoothing or through cross-sectional reweighting. This paper can be thought of as having elements of both time-series smoothing (the AR(4) modelling to generate forecasts) and reweighting (the combination of different forecasts).

Regarding the reweighting, it is worth comparing how the weights in this proposed measure compare with the conventional CPI and with a measure like the RBA’s 15 per cent trimmed mean. Table 3 in their paper indicates that the city-based ensemble significantly down-weights Sydney and Melbourne, and significantly up-weights Darwin, Canberra and Hobart. Similarly, one can compare the weights

3. This seems odd: the authors should consider changing their date/naming convention: although the forecast may be for inflation in period $t+1$, it uses period t data and might be better called underlying inflation for period t.

on the expenditure groups with the CPI weights: their Table 2 shows that the expenditure-weighted ensemble significantly down-weights housing, and up-weights education relative to the CPI. In addition, one might consider how the weights in the proposed methodology compare with weights in trimmed-mean measures. This is not, of course, straightforward because the weights in the trimmed mean are highly time-varying. However, we might get an approximation from the average frequency with which CPI items are inside the central 70 per cent of the price-change distribution, over time. Such a calculation shows that the departures from CPI weights are much larger for the proposed methodology than for the trimmed mean.

Such large deviations from CPI weights are risky in the computation of measures of underlying inflation, because over long periods of time there may be persistent differences in the average inflation rates of different types of items in the CPI. If so, a significant reweighting of CPI components may yield a measure that is biased relative to the CPI, which is an undesirable feature of a measure of underlying inflation. Of course, it is possible that Francesco and Shaun's step of re-centring the mean growth rates reduces this risk.

Regarding the time-series smoothing, it is possible that the AR(4) modelling gives more smoothing than is appropriate. And the use of raw, rather than seasonally adjusted, data might exacerbate this given that price increases for some expenditure groups are highly seasonal. For example, there are four of the ten expenditure groups for which seasonally unadjusted data suggest that AR(4) models are appropriate, whereas seasonally adjusted data suggest that AR(1) or AR(2) models are appropriate. Hence it seems that the AR(4) modelling using seasonally unadjusted data places excessive weight on quite lagged data and insufficient weight on the more recent data.

Regarding the results, Francesco and Shaun's methodology provides a distribution of core inflation, but I will focus on the centre of the distribution.[4] A first point to note is that the central estimate for core inflation does not show all that much medium-term variation.[5] The authors suggest that the RBA trimmed-mean and weighted-median measures may have overstated core inflation in 2008. But an alternative reading of their results would be that their estimates might not show enough movement to be good estimates of underlying inflation.

As noted above, the central estimate for 'core inflation' is the central forecast for next period's CPI inflation. So one might ask how good their central forecasts are. As a benchmark for their forecast evaluations, Francesco and Shaun use an AR(4) model for headline inflation, and they find that their point forecasts 'are competitive with the AR(4) benchmark' (p 188). But it turns out that an AR(4) model of headline

4. I leave open the broader question of whether it would be desirable for a published measure of core inflation to have a wide confidence interval around it. However, I think one could make a good case that central banks should always give the sense that the future is uncertain and sometimes even that the current data are uncertain, but they should not overdo this.

5. And, much of the short-term variation in the measure appears to be seasonal. This highlights the need to deal with seasonality anytime one is working with disaggregated CPI data. Another data issue to be dealt with when working with Australian data is the one-off price jump due to the tax changes of 1999–2000.

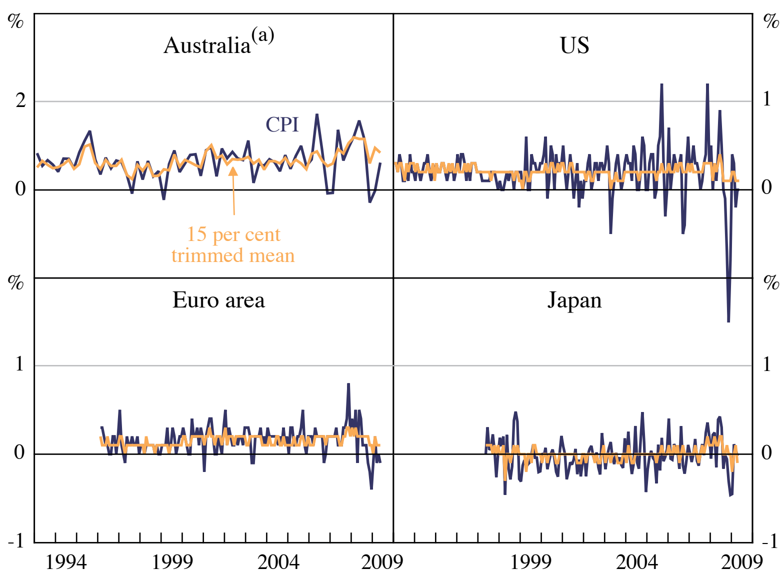
CPI inflation has an adjusted R-squared, in-sample, of essentially zero. So when the authors say their model is competitive with an AR(4), we should not take that as a particularly high hurdle.

A natural question, assuming one is using this approach, is whether one can come up with simple one-step-ahead forecasts of headline inflation that do better than either the AR(4) model or Francesco and Shaun's disaggregate ensembles. One obvious candidate in my mind was lagged trimmed-mean inflation. Indeed, when one adds lagged trimmed-mean inflation to an AR(4) model (or to my own simple attempted replication of Francesco and Shaun's methodology) it is clearly significant, although the adjusted R-squared is less than 0.10. So if one is trying to forecast the next period's headline inflation, one can indeed do better than an AR(4) model or the core measures proposed in this paper.

So does this mean that short-term inflation is close to unpredictable? Actually, it is somewhat predictable, you just have to be predicting something which has less noise than headline inflation. Again, one might consider trimmed-mean inflation. For example, I have used data for Australia, the euro area, Japan and the United States to run a regression explaining quarterly or three-month-ended trimmed-mean inflation by (non-overlapping) lagged headline and lagged trimmed-mean inflation. For all four economies, there is a reasonably high adjusted R-squared, with lagged trimmed-mean inflation highly significant, but lagged CPI inflation either insignificant or the 'wrong' sign.

These results stem from the fact that trimmed-mean inflation, unlike CPI inflation, is relatively smooth. As we can see in Figure 1, trimmed-mean inflation appears to

Figure 1: Measures of Inflation



Note: (a) Quarterly
Sources: RBA; author's calculations

abstract from much of the noise in CPI inflation, raising the possibility that we may actually be able to see some signal in monthly or quarterly inflation data.

None of this is to suggest that the RBA or other central banks should necessarily be targeting trimmed-mean inflation or any other underlying measure. In Australia, the target is CPI inflation, but we have found that underlying measures can help us understand the trend in inflation, which should help us meet our broader goals for monetary policy.

Summary and suggestions

Overall, I agree with the premise of the paper that measures of underlying inflation should be judged in part on what information they provide about near-term inflation outcomes. While the paper's analysis of density functions is new, I suspect most readers will be more interested in its point estimates of underlying inflation. Here, my sense is that the suggested methodology, as currently implemented, has not yet made a strong case that it is an improvement over traditional underlying measures (including trimmed means) that use the cross-section of the data to remove some of the noise in headline inflation.

If the authors expand on their work, I would suggest that they should consider focusing on three aspects. First, it is important to deal with seasonality, especially when dealing with component-level data. Second, they should consider the possibility of adding other predictors to the ensembles, the obvious one being trimmed-mean inflation, but there are no doubt others. Finally, I think they should take more seriously the idea that the headline CPI is very noisy in the short term. If they find they really cannot predict quarter-on-quarter movements in the CPI, then their one-step-ahead prediction will always look like something close to a straight line and may not be informative about swings in underlying inflation. So they should also look at the short-term predictability of other inflation measures.

Reference

Brischetto A and A Richards (2006), 'The Performance of Trimmed Mean Measures of Underlying Inflation', RBA Research Discussion Paper No 2006-10.

2. General Discussion

Francesco Ravazzolo and Shaun Vahey's paper generated debate on the possible uses of core inflation measures, including: as modelling tools; for internal bank discussion; or to communicate inflation outcomes to the public. One participant noted that an argument against using core inflation as a device for communication is that it requires convincing explanations about what is being excluded. For instance, it is difficult to justify excluding energy prices from a measure of inflation when expenditure on energy is often foremost in consumers' minds. Some other participants were of the same opinion, questioning the value of core inflation measures and suggesting that they are best suited to internal deliberations. Someone thought that it would be helpful for inflation measures to differentiate between those prices that are relatively flexible and those that are 'sticky', with the latter of greater concern to policy-makers. Shaun Vahey replied by suggesting that the measure of core inflation constructed in the paper was useful both for internal discussions and communication with the public. On the latter, he emphasised the ability of the approach presented in the paper to offer probabilistic forecasts of core inflation, which he argued are reasonably easy to understand.

The rest of the discussion considered modelling choices made by the authors. A participant suggested that the model should use more disaggregated CPI components, and avoid using the city disaggregated components. In response, Shaun Vahey noted that the ensemble methodology proposed has the capacity to handle any form of disaggregation. He cited the example of weather forecasting, from which the ensemble methodology was derived, which uses up to 50 components of disaggregation. He indicated that including the city components helps improve the model's predictive performance, so he was satisfied with this choice.

The one-period forecasting horizon considered in the paper was queried, with the suggestion that longer horizons should be considered. However, if the latter approach was taken, some people thought that a more appropriate predictive model, which also incorporates the responses of interest rates and output, should be considered. Shaun Vahey agreed with the sentiments expressed, and suggested that they justified the paper's focus on one-quarter-ahead forecasts.

One participant suggested that the model presented in the paper would not pick up any second-round effects following, say, a relative price shock because the autoregressive model with four lags imposed too much persistence on the inflation process. Shaun Vahey reiterated that a key feature of the model is its use of time-varying weights on the components, which gives the model the ability to adapt relatively quickly to shocks.

Key Elements of Global Inflation[1]

Robert Anderton, Alessandro Galesi, Marco Lombardi and Filippo di Mauro

Abstract

Against the background of large fluctuations in world commodity prices and global growth, combined with ongoing structural changes relating to globalisation, this paper examines some of the key factors affecting global inflation. The paper investigates the effects of shocks affecting relative prices and structural changes on global inflation by: estimating a global vector autoregression (GVAR) to examine how oil price shocks feed through to core and headline inflation; calculating the impact of increased imports from low-cost countries on manufacturing import prices; and estimating Phillips curves in order to shed light on whether the inflationary process in OECD countries has changed over time, particularly with respect to the roles of import prices, unit labour costs and the output gap. Overall, the paper finds that there seem to be various significant pressures on global trade prices and labour markets associated with structural factors. These are possibly partly due to globalisation which, in addition to changes in monetary policy, seem to be behind some of the changes in the inflation process over the period examined in this paper.

1. Introduction

This paper considers the various factors affecting global inflation, with a focus on shocks affecting relative prices and longer-term structural changes. It is split into two main parts. The first part provides the relevant background to the analysis by looking at longer-term trends as well as current developments in global inflation. We document how OECD inflation has fallen dramatically since the 1970s and consider the possible reasons behind this decline, as well as looking at more recent inflation developments – particularly in the context of the rise in oil and other commodity prices since the turn of the century. Some stylised facts regarding the linkages between global inflation and output gaps and how this might be changing over time are also examined.

The second part of the paper investigates the role of ongoing structural factors and relative price shocks in the global inflationary process. Globalisation has been accompanied in developed economies by a higher share of imports of

1. The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Central Bank. We are greatly indebted to Tadios Tewolde for excellent assistance with the econometric estimation. We also extend our thanks as well to U Baumann, P Hiebert, J Hutchinson, B Landau, A Patarau, R Pereira and D Taglioni for their valuable help, input and comments. We are also grateful to Hans-Joachim Klockers for comments. We are also extremely grateful to the discussants of the paper (Heather Anderson – Monash University and CAMA; David Sondermann – University of Münster), as well as the other participants – particularly Lutz Kilian – at the Münster workshop and RBA/CAMA Conference for their very useful comments.

manufactured goods from low-cost countries, which may put downward pressure on both manufacturing import prices and inflation, while increased global demand (particularly in the non-OECD countries) may have exerted upward pressure on commodity prices, particularly oil prices. At the same time, globalisation seems to be affecting labour markets and unit labour costs in the OECD economies. Even so, monetary policy ultimately determines inflation, and regime changes in monetary policy over past decades may have also changed the inflationary process.

The investigation of the role of these relative price shocks and structural factors for global inflation proceeds in various steps. First, the impact and persistence of changes in oil prices on headline and core inflation is quantified for the euro area and US economies using a GVAR model of the world economy.[2] This provides up-to-date parameter estimates of how changes in oil prices might feed into the inflationary process.

Second, the impact of increased import penetration from low-cost countries on euro area import prices of manufactures is estimated. This impact is decomposed into two components: the first due to changes in the import share (the 'share effect') capturing the impact of the relatively lower price level of countries that are low-cost suppliers; and the second due to differences in import price inflation differentials between countries that are low- and high-cost suppliers.

Third, Phillips curves are estimated to shed light on whether the inflationary process in the OECD economies has changed over time, particularly with respect to the roles of import prices, unit labour costs, the output gap and monetary policy.

The overall structure of the paper proceeds as follows. Section 2 provides the relevant background to the analysis referred to above. Section 3 examines and explains the various relative price and structural aspects of global inflation in more detail by: estimating a GVAR model to assess the quantitative impact and persistence of changes in oil and food prices on headline and core inflation for the United States and the euro area; estimating the impact of increased imports from low-cost countries on euro area import prices of manufactures; and estimating Phillips curves for OECD economies to examine the roles of import prices, unit labour costs, output gaps and monetary policy in the inflationary process in the OECD. Section 4 concludes.

2. Past and Current Trends in Global Inflation and Activity

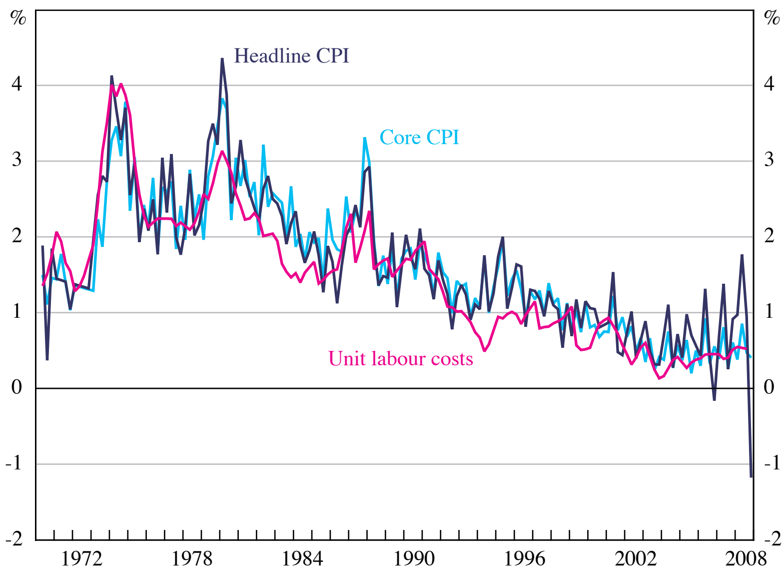
We begin with an overview of past and current trends in OECD inflation. Figure 1 shows quarterly growth since the start of the 1970s of core and headline CPI measures as well as unit labour costs for the OECD as a whole. The series are characterised by longer-term trend declines which tend to flatten out in the 2000s. Some of the major reasons given in the literature for the longer-term declines in inflation and

2. For a description of the GVAR approach, see Pesaran, Schuermann and Weiner (2004) and Dees *et al* (2007).

unit labour costs include: improvements in the credibility of monetary policy and the associated movement to low and well-anchored inflation expectations; changes in import prices and increased competitive pressures in goods and labour markets due to globalisation; and various reforms aimed at making labour and product markets more flexible.

Figure 1: Consumer Price Index and Total Unit Labour Costs for the OECD Aggregate

Quarterly growth



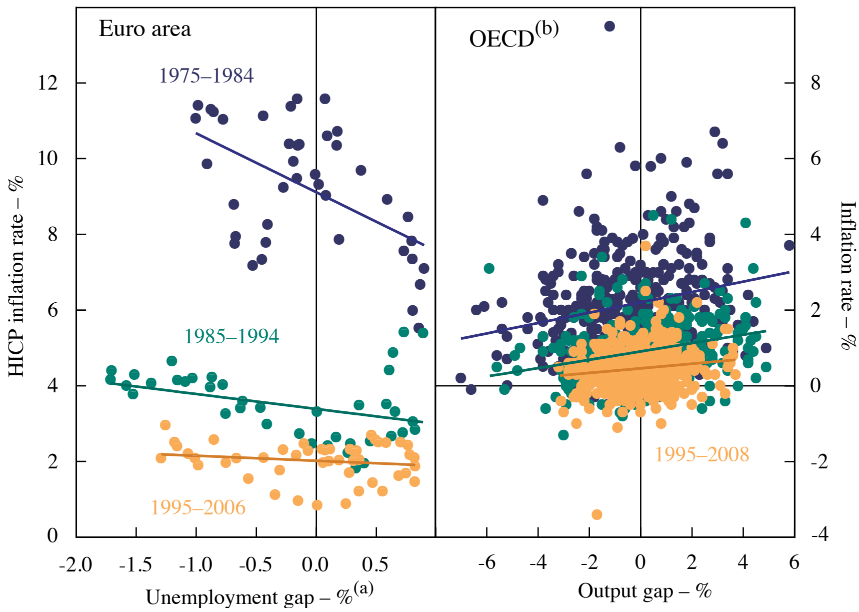
Sources: OECD; authors' calculations

Turning to more recent developments, headline inflation started rising again in the mid 2000s, following continual and persistent increases in food and oil prices, while core inflation and growth in unit labour costs remained fairly stable (partly due to strong growth in global productivity). Of course, the sharp decline in oil prices in the second half of 2008 resulted in a strong fall in headline inflation. Overall, the message is that inflation – particularly core inflation which excludes energy and food – seems to have remained fairly stable in the 2000s despite the strong rise in oil prices over most of the period. This implies that inflationary expectations remain well anchored.

In addition to the impact of commodity prices and unit labour costs, global economic activity and output gaps should also influence world inflation. However, more recent downturns in global GDP may not have such strong downward impacts on global inflation in comparison to previous recessions, as there may have been a flattening of Phillips curves over recent decades. For example, in the euro area, a flattening in the relationship between inflation and the unemployment gap may have occurred over the past few decades, while a similar story holds for some of the key OECD countries for inflation and the output gap (Figure 2).[3] Nevertheless, it is not clear whether this reflects: a growing influence of global or foreign measures of economic slack on domestic inflation (as implied by Borio and Filardo 2007, for example); greater credibility of monetary policy associated with lower and well-anchored inflation expectations; 'good luck' (fewer adverse macroeconomic or other shocks); or structural reforms. In contrast, theoretical arguments imply a steepening of the Phillips curve in response to globalisation, as competitive forces make prices more flexible in response to changing costs or measures of economic slack (see Ball 2006 or Rogoff 2006, for example).

Following on from various other papers including Kamin, Marazzi and Schindler (2004); Pain *et al* (2006); Borio and Filardo (2007); Mody and Ohnsorge (2007); Eickmeier and Moll (2009); and Sekine (2009), the next section of this paper aims to shed light on the above developments and stylised facts.

Figure 2: Inflation and the Unemployment/Output Gap



Notes: (a) Defined as the deviation of unemployment from trend unemployment measured by an HP filter

(b) Based on data for nine countries (see Section 3.3 for further details, including definitiion for the output gap)

Sources: ECB; OECD; authors' calculations

3. This possible flattening of Phillips curves is discussed in further detail in IMF (2006, Chapter 3), Pain, Koske and Sollie (2006), Bean (2007) and Anderton and Hiebert (2009).

3. Structural Aspects of Global Inflation

There seem to be a number of relative price shocks at the global level which appear to be related to globalisation. In the case of import prices (for OECD economies), there are two opposing effects: on the one hand, strong growth in the non-OECD economies in recent years seems to explain at least part of the significant rise in the prices of oil and non-energy commodities since 1999 (up to the first half of 2008); on the other hand, rising imports from low-cost countries are putting downward pressure on manufacturing import prices. Turning to the labour market, recent decades have seen wage moderation which may also be related to globalisation. In particular, the massive increase in the global supply of labour associated with China, India and the former Soviet bloc joining the global economy, and the associated 'offshoring' or threat of offshoring (the practice of outsourcing business activities to foreign providers), may have reduced the bargaining power of workers in more developed economies. There may also have been downward pressure on unit labour costs via an increase in productivity related to greater competition, offshoring and the rise in globalisation.

In this section we investigate the role of these relative price shocks and structural changes in various steps. First, we quantify the impact and persistence of changes in oil prices on headline and core inflation for the euro area and US economies using a GVAR model. This provides up-to-date parameter estimates of how recent changes in oil prices might feed into the inflationary process. Second, we estimate the impact of increased import penetration from low-cost countries on euro area import prices of manufactures. This impact is decomposed into two components: that which is due to changes in the import share (the 'share effect') capturing the impact of the lower price level of low-cost import suppliers; and that due to import price inflation differentials between low- and high-cost country suppliers. Third, Phillips curves are estimated to shed light on whether the inflationary process in the OECD countries has changed over time, particularly with respect to the roles of import prices, unit labour costs, the output gap and monetary policy.

3.1 Impacts of oil price shocks using a GVAR

In this section, a GVAR is constructed to examine the impacts of oil price increases on output and inflation, showing separate results for headline and core inflation. This will provide a greater understanding of the contribution to inflation of rising oil prices over most of the 2000s, particularly as the GVAR will be estimated over the period January 1999 to December 2007 and, therefore, provide results for the impact of oil price increases over the most recent period. In summary, our results for the euro area and the United States show that the effects of oil prices on inflation seem to be weaker than in the past and do not tend to feed into core inflation. This seems to be partly the result of counter-inflationary monetary policy, which has kept inflation expectations well anchored. One caveat is that the simulations implicitly assume both linear and symmetric responses to the oil price regardless of the magnitude and sign of oil price shocks, which may not be the case.

3.1.1 The GVAR model[4]

A GVAR model is estimated based on the specification of Pesaran *et al* (2004) which was further developed by Dees *et al* (2007). The GVAR consists of a number of economies, each modelled individually as a VARX* (that is, a VAR model augmented by weakly exogenous variables), with each country model comprising domestic and foreign variables. For example, consider a VARX*(p_i, q_i) for a generic country i:

$$\Phi_i\left(L,p_i\right)x_{it} = \alpha_{i0} + \alpha_{i1}t + \Lambda_i\left(L,q_i\right)x_{it}^* + \Psi_i\left(L,q_i\right)d_t + u_{it}, \quad \text{for } t = 1,\ldots,T, \quad (1)$$

where x_{it}, x_{it}^* and d_t are the sets of country-specific (domestic), foreign-specific and global variables, respectively.

The country-specific variables, x_{it}, are: monthly core inflation π_{it}^c based on the CPI excluding energy and food price components, expressed as an annualised rate; the monthly headline inflation π_{it}^h expressed as an annualised rate; the industrial production index (y_{it}) deflated by the producer price index; the nominal short-term interest rate (i_{it}); and the nominal effective exchange rate (e_{it}). The foreign variables for country i, x_{it}^* , are computed as weighted averages of the corresponding variables of the other countries, using cross-country bilateral trade flows as weights.[5] The global variables, d_t, are oil p_t^o and food p_t^f prices denominated in US dollars.

Each country model is estimated by assuming weak exogeneity for both domestic and foreign variables (this assumption allows the individual estimation of each country model, thereby avoiding the estimation of the whole GVAR, which would be too onerous).

The GVAR model covers 33 economies, including both developed and developing economies.[6] The data are monthly.

After estimating each of the country models, the results are connected through link matrices and then stacked together to build the GVAR model. We then investigate the dynamic properties of our GVAR by means of the generalised impulse response functions (GIRFs), proposed in Koop, Pesaran and Potter (1996) and further developed in Pesaran and Shin (1998).[7]

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4. The specification of the GVAR model, as well as the reported empirical results, are provided in Galesi and Lombardi (2009).

5. The weights are fixed over time, and computed in the usual way for GVAR models as averages of exports and imports for the period 1999–2007. However, given the key role of imports in transmitting inflationary pressures, the GVAR model using import-based weights was also estimated. As there was no significant change in the results, we only report the results using the weights based on the averages of exports and imports.

6. These are either individual countries, such as the United States or the United Kingdom, or regional aggregates. The euro area is modelled as a single entity based on the GDP-weighted average of the following countries: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Slovenia and Spain.

7. In the GVAR framework, the GIRFs are more appealing than the traditional Sims' (1980) orthogonalised impulse response functions, since they are invariant to the ordering of the variables and the countries. Given that there is no clear economic *a priori* knowledge to establish a reasonable ordering of the countries, it is preferable to employ the GIRFs. Moreover, even if the GIRFs assess the effects of observable-specific rather than identified shocks, the typical (and atheoretical) GVAR analysis is based on the investigation of the geographical transmission of country-specific or global shocks, thus this limitation is not material.

3.1.2 GVAR generalised impulse response functions of an oil price shock

A positive one standard error shock to the nominal oil prices is simulated and the impulse response functions are presented in Figure 3.[8] The simulations are provided for the euro area and the United States (results for other parts of the world are documented in Galesi and Lombardi 2009). (Galesi and Lombardi also present simulations of responses to food price shocks.) The key issues to be addressed are: whether there is significant pass-through of oil price shocks to core inflation; and are the inflationary effects persistent? We examine the extent to which oil price shocks result in second-round effects by comparing the responses of headline and core inflation.

Each impulse response shows the dynamic response of each domestic variable to standard error unit shocks to oil prices over two years. Confidence intervals are presented at the 90 per cent significance level, although it is anticipated that for a number of reasons some of the responses may not be statistically significant, including the use of volatile monthly data.[9] The positive standard error unit shock to nominal oil prices corresponds to an increase of about 6 per cent in the oil price index in one month. The impact on other key commodities – such as food prices – is not significant.[10]

The impulse responses for headline inflation indicate the direct inflationary effects due to oil price increases. US headline inflation rises on impact by 1.1 per cent, then returns to baseline after three months. The observed effect on euro area inflation is roughly half of the magnitude of the effects for the United States; euro area headline inflation increases by about 0.6 per cent on impact, then declines and returns to the baseline after approximately two months. The differences in results between the euro area and the United States are consistent with Anderton and di Mauro (2007), who show that the oil intensity of production in the euro area is about 75 per cent of that of the United States (when the oil intensity of production is proxied by oil demand divided by GDP in real terms).[11]

The impact of the oil price shock on *core inflation* is not statistically significant for the United States, implying that oil price shocks did not result in second-round effects from January 1999 to December 2007 (consistent with the findings

8. Setting the shock equal to one standard error is common practice in the empirical literature. Given that the GVAR is a linear model, resizing the shock is straightforward.

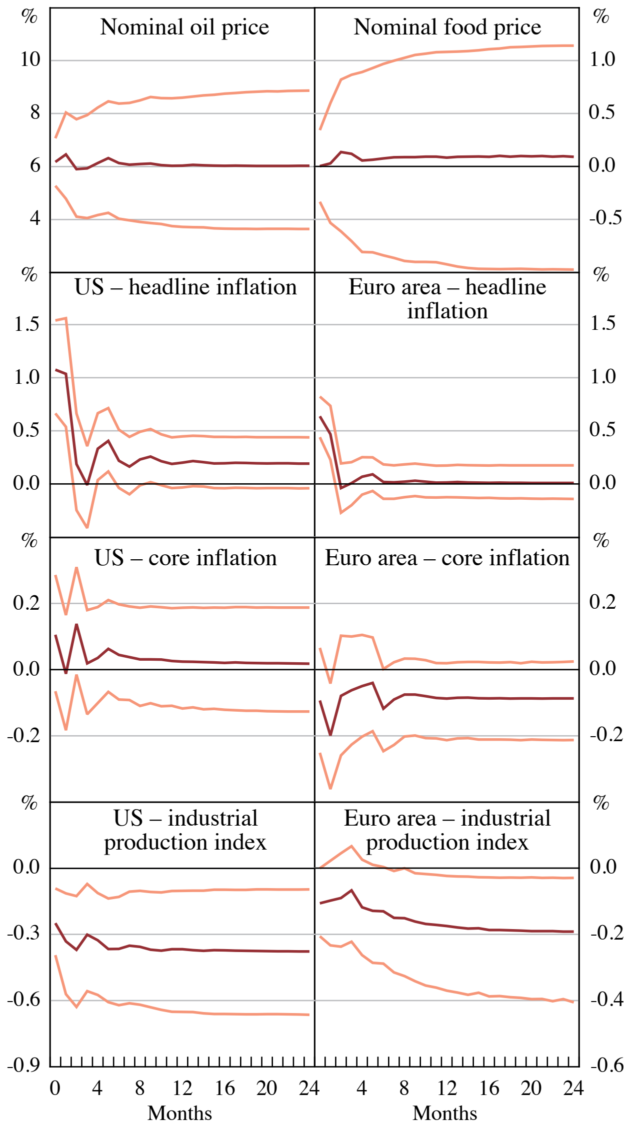
9. The estimation of the GVAR model using monthly data necessarily implies the presence of high volatility in our estimates. The country-specific parameter estimates are derived from unrestricted estimations: in the context of a short-run analysis such as in this section, we prefer not to impose economic-based restrictions in the cointegrating space of each country's vector error correction (VECMX*) model, which are likely to be rejected by the appropriate tests.

10. We had expected to observe a significant positive dynamic correlation between oil and food prices. This counterintuitive finding could be due to the fact that the global variables in the GVAR model are endogenous, so that the effect on food prices of an oil price shock is dampened by the response of other variables in the system.

11. In addition, higher energy taxes in the euro area compared to the United States may also partly explain these differences, since they dampen the effect of oil price hikes in the euro area.

Figure 3: Generalised Impulse Responses of a Positive Unit (Standard Error) Shock to Oil Prices

Percentage change



Source: Galesi and Lombardi (2009)

of Hooker 2002). Similarly, no second-round effects are found for the euro area. These results are in line with the policies of the United States and the euro area's monetary authorities to limit the nominal consequences of oil shocks, in line with maintaining low and well-anchored inflation expectations.[12]

Turning to the real side, US industrial production falls on impact by 0.25 per cent in response to the rise in oil prices, declining by almost 0.4 per cent below baseline after two years. Smaller effects are observed for the euro area, where the oil price increase is associated with an initial decline of industrial output of 0.1 per cent, and further falls to 0.2 per cent below the baseline after two years. Again, the impact on industrial production in the euro area may be smaller than in the United States due to the lower oil intensity of production in the euro area.

Overall, the impact of an oil price shock on inflation and output seem to be in line with the results of Blanchard and Galí (2007), who find that oil price shocks now have smaller effects compared to the past on prices and wages as well as output and employment, primarily due to: a decrease in real wage rigidities; an increase in the credibility of monetary policy resulting in smaller impacts of oil price shocks on expected inflation; and the decrease in the share of oil in consumption and production.

The GVAR model is also used to simulate a positive standard error unit shock to nominal food prices (not shown), but overall the results for the United States and euro area are much the same. The effects are mainly limited to headline while core inflation is unresponsive. However, the detailed results do show a small positive impact on US core inflation from the rise in food prices.

In summary, our results for the euro area and the United States show that oil price impacts temporarily affect headline inflation but that the impacts may be weaker than in the past and do not tend to feed into core inflation.[13] The latter may be partly the result of monetary policy which has kept inflation expectations low and well anchored. However, the simulations implicitly assume both linear and asymmetric responses to increases and decreases in oil prices, which may not be the case.[14] Nevertheless, these results are consistent with the regression analysis of Cecchetti and Moessner (2008) regarding the impact of the rise in food and energy prices on inflation. They find that in recent years core inflation has not tended to follow headline inflation in response to oil and food price shocks, implying that commodity

12. Other evidence supporting the assertion that inflation expectations are well anchored is provided by ECB (2009), which reports that various measures of longer-term inflation expectations for both the United States and euro area fluctuate in a fairly narrow band consistent with monetary policy objectives and price stability.

13. Other models for the euro area and the United States may find impacts on core inflation from oil price shocks – see, for example, the results for the euro area by Landau and Skudelny (2009). Hence, the reported GVAR should be interpreted with caution and as indicating qualitative results – that is, the impact on core inflation is small, but not necessarily nonexistent.

14. In addition, the GVAR results capture statistical/econometric relationships based on the data, and should be contrasted with the results obtained from more structural models such as Kilian (this volume) and Baumeister, Peersman and Van Robays (this volume).

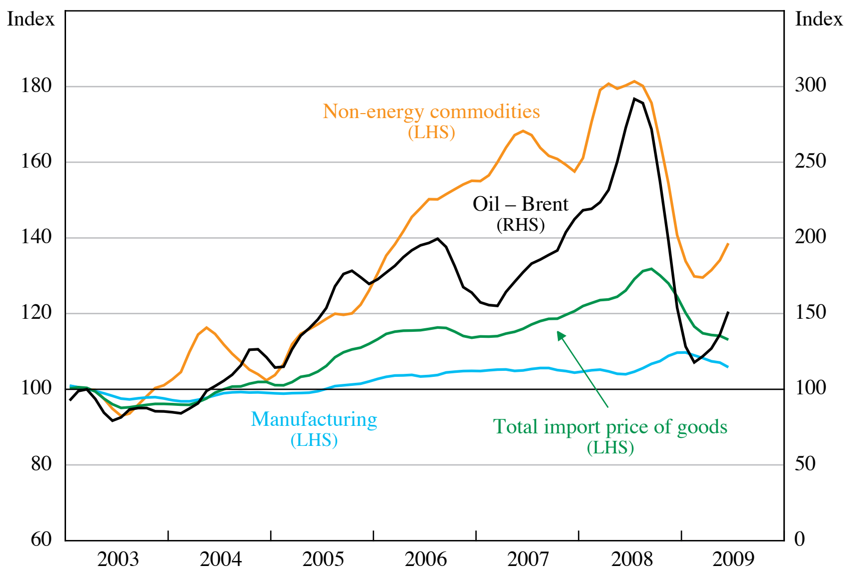
prices do not now generally lead to second-round effects on inflation. These findings are also consistent with the work of Furlong and Ingenito (1996), who show that, as for oil prices, commodity prices also fail to predict core inflation.

3.2 Euro area evidence on import prices, labour markets and inflationary pressures

There are various structural factors that may be associated with downward pressure on inflation. Globalisation has been accompanied in the euro area by a higher share of imports of manufactured goods from low-cost countries, which may be the main reason why import prices for manufactures have been stagnant in recent years (Figure 4).

Figure 4: Extra-euro Area Import Prices by Commodity

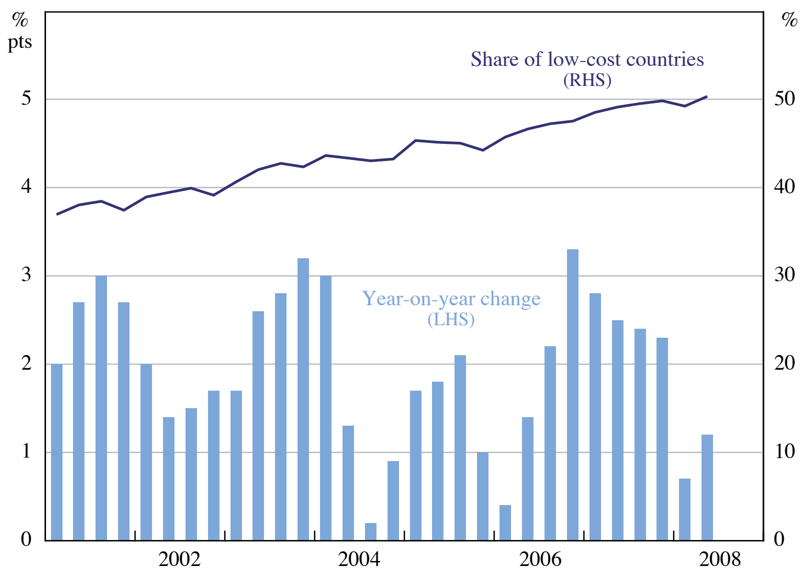
Three-month moving average, 2003:Q1 = 100, seasonally adjusted



Sources: Eurostat; authors' calculations

Overall, it is estimated that the increase in euro area import penetration from low-cost countries, whose share increased from over one-third to more than a half since the start of the 2000s (Figure 5), may have dampened euro area import prices of manufactures by about 2 percentage points each year between 1996–2007. This is mostly due to the 'share effect' of China and the new EU member countries – that is, the downward impact on import prices of the rising import share of low-cost countries combined with the relatively lower price level of low-cost import suppliers. Meanwhile, the 'price effect' – which captures the impact of export price inflation differentials between low- and high-cost countries – makes a much smaller contribution to these downward pressures (Table 1). The methodology used to decompose manufacturing imports into the share and price effect is described in detail in Appendix A. It is similar to that of Kamin *et al* (2004) who calculate the impact of the higher import share of China on US import price inflation. They find an average direct impact of China on US import inflation of around 1 percentage point per annum.

Figure 5: Share of Extra-euro Area Manufacturing Imports from Low-cost Countries



Sources: Eurostat; authors' calculations

Table 1: Decomposition of Euro Area Manufacturing Import Prices
Per cent per annum

	1996–2007
Manufacturing import price inflation	**0.09**
High-cost countries effect	2.08
Low-cost countries effect	–1.99
China	–0.75
Share effect	*–0.81*
Price effect	*0.06*
New EU Member States	–0.26
Share effect	*–0.66*
Price effect	*0.40*
Rest of low-cost countries	–0.99
Share effect	*–0.10*
Price effect	*–0.89*

Source: Taglioni and Vergote (2009)

The low level of inflation of imported manufactured goods is one side of the *relative price effect* of globalisation. The other side is the higher prices of commodity imports, which at least in part reflects global demand pressures from those emerging economies that export manufactured goods (Figure 4 highlights the strong rise in import prices of commodities, at least up to mid 2008). However, such changes in relative prices need not have any enduring effect on aggregate inflation.

Apart from these direct relative price effects, globalisation may also put downward pressure on prices via increased competition in the labour and goods markets (see Anderton, Brenton and Whalley (2006) for a comprehensive analysis of how globalisation has affected labour markets). Turning to recent wage developments in the euro area, globalisation may have been one contributing factor to an extended period of wage moderation (for instance, offshoring or the threat of offshoring may reduce the wage demands of workers). Euro area real wage growth has been weaker than that of productivity, both in aggregate and within the manufacturing and services sectors (see Anderton and Hiebert (2009) for an extensive analysis of this issue). At the same time, there has been a long-term decline in the wage share of gross national income in the euro area, which since the mid 1980s has been even more severe than the fall in the United States, bringing this measure in both regions to historical lows (Figure 6). While this might be taken to indicate that the bargaining power of workers may have declined in the context of globalisation, extreme

Figure 6: Long-term Developments in Labour Shares
Per cent of gross national income

Notes: Self-employment-adjusted labour shares – total domestic economy. The labour share is defined as the ratio of total compensation of employees to gross national income at current market prices.

Sources: Anderton and Hiebert (2009); EUROPA, 'AMECO' database; authors' calculations caution should be made in drawing such conclusions given several caveats related to measurement issues[15] and the fact that much of this decline took place well before the recent phase of globalisation.[16] As for the impact of globalisation on prices, Pula and Skudelny (forthcoming), using calculations based on several methodologies, find a direct dampening effect of import openness on euro area producer price inflation of 0.1–1.0 percentage points per annum for the manufacturing sector over the period 1996 to 2004. These authors report a dampening impact on euro area consumer price inflation of 0.05–0.2 percentage points per annum based on aggregate data over the same period. Pain *et al* (2006) find a combined effect on consumer price inflation from lower non-commodity import price inflation and higher commodity import price inflation of up to 0.3 percentage points per annum over the period 2000 to 2005. Using similar methodologies, Glatzer, Gnan and Valderrama (2006) and Helbling, Jaumotte and Sommer (2006) report findings of a similar magnitude for other countries and regional groupings.

3.3 Phillips curves for the OECD economies

In this section, the roles of unit labour costs, import prices, the output gap and monetary policy in the inflation process for the OECD economies are examined in more detail. We are particularly interested to see if the impact of the output gap on inflation has changed over time as suggested in Section 2, whether the relative roles of import prices and unit labour costs have changed, and to evaluate how the inflation process might have changed due to changes in monetary policy.

Phillips curves are estimated based on quarterly data over the period 1970:Q1 to 2008:Q3, where we proxy the OECD by using data from nine individual OECD countries – Australia, France, Germany, Italy, Japan, the Netherlands, Sweden, the United Kingdom and the United States. The specification is based on the following traditional backward-looking Phillips curve, along the lines of previous work (such as Pain *et al* 2006 and Eickmeier and Moll 2009):[17]

$$\Delta p_{i,t} = c + \sum_{j=1}^{4} \alpha_j \Delta p_{i,t-j} + \beta ygap_{i,t} + \sum_{j=0}^{4} \gamma_j \Delta ulc_{i,t-j} + \sum_{j=0}^{4} \varphi_j \Delta mp_{i,t-j} + \text{seas} + \varepsilon_t \quad (2)$$

where: $\Delta p_{i,t}$ is the quarterly change in the log of the CPI for country i, with the explanatory variables comprising the log of past inflation; the output gap ($ygap_{i,t}$); log differences of quarterly total economy unit labour costs ($\Delta ulc_{i,t}$) and import prices of

15. Several measurement problems limit the reliability of the wage share, including the growing importance of non-wage remuneration (particularly for the increasing number of self-employed), which implies that this measure cannot be interpreted reliably as the share of income accruing to capital or labour.

16. See Anderton and Hiebert (2009) for more details of globalisation's possible impacts on the euro area labour market.

17. Although forward-looking New-Keynesian Phillips Curve models have many advantages, it seems that backward-looking models may be more stable in some respects (Stock and Watson 2007), hence we prefer to estimate a backward-looking Phillips curve.

goods and services ($\Delta mp_{i,t}$); a constant (c); and quarterly seasonal dummies (seas).[18] As in previous papers, the output gap only enters the model contemporaneously without any lagged terms. *A priori*, positive signs are expected for the sum of the parameters corresponding to each of the explanatory variables.

This eclectic framework is a reduced-form model similar to specifications estimated in various other empirical papers.[19] The lagged inflation terms can be interpreted as representing the (backward-looking) inflation expectations of economic agents, but they also capture the dynamics of price adjustment and the degree of persistence of the inflation process. These, in turn, are related to wage and price rigidities, institutional factors and monetary policy. Excess aggregate demand is captured by the output gap, while other factors are captured by changes in import prices and unit labour costs, which could also be interpreted as supply-side influences.

Panel estimates of Equation (2) are obtained by pooling the data across nine major OECD countries, thereby providing an approximation of the parameters for the OECD as a whole. In effect, the same slope parameters are imposed across the different countries, but fixed effects allow each country to have a different intercept. The estimators could be biased as the lagged dependent variable is correlated with the fixed effects.[20] Consequently, the Arellano and Bond (1991) estimator based on the generalised method of moments (GMM) is frequently used in these circumstances. However, it is still correct to estimate the equation by least squares dummy variables (LSDV), which will still provide reasonable results in the present case as the time dimension is relatively large compared to the number of variables.[21]

Another econometric issue is whether the same slope parameters should be imposed across the different countries. A simple F-test shows that the restriction of equal slope parameters for each country is rejected.[22] However, we note that Baltagi and Griffin (1983) argue that the empirical test of equal slope parameters in panel estimation is frequently rejected despite the fact that there may be a strong economic rationale for imposing common slope parameters.

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18. All data including the output gaps, unless otherwise stated, are obtained from the OECD 'Economic Outlook' database.

19. See, for example, Lown and Rich (1997), Batini, Jackson and Nickell (2005), Borio and Filardo (2007), Mody and Ohnsorge (2007) and Sekine (2009).

20. The bias results from the correlation between the lagged dependent variable and the transformed residuals. Nickell (1981) shows that the lagged dependent variable is biased towards zero, but that the bias decreases as the sample period lengthens and disappears when it becomes infinitely long.

21. For example, Judson and Owen (1999) compare the bias of six different estimators of dynamic panel data models: the OLS estimator; the LSDV estimator; a corrected LSDV estimator as proposed by Kiviet (1995); two GMM estimators suggested by Arellano and Bond (1991); and the IV techniques used by Anderson and Hsiao (1982). Their findings are that the LSDV estimator performs just as well, or better than, the majority of the alternatives as T increases and is larger than N. In addition, Kiviet (1995) notes that although the LSDV estimator is biased, its standard deviations are very small compared to different IV estimators. Therefore, on the basis of the mean-square-error (MSE) criterion (efficiency versus bias), Kiviet argues that LSDV may be preferable to alternative estimators.

22. The F-test of equal slope parameters is $F[126, 1\ 206] = 3.4558$.

Our estimation strategy is to estimate a basic Phillips curve using different techniques and compare the results in the following way. First, the LSDV estimator is used. These results are then checked for robustness by estimating the same equation by GMM. Given the rejection of the common slope restriction, we also estimate the equation using the mean group (MG) estimator, which is the simple arithmetic average of the individual countries' coefficients. Four lags of each of the variables are included in Equation (2) (with the exception that the output gap is included contemporaneously as discussed above, but with its own lagged values used as instruments to avoid simultaneity problems). The results are shown in Table 2, which reports the sum of the coefficients for each variable for which lags are included, as well as an F-test and p-value of a Wald test of the hypothesis that the parameters are equal to zero.

The full sample results show that the signs of the variables are positive as expected, while the key variables are statistically significant across the three estimation techniques.[23] Hence, past inflation, unit labour costs, import prices and the output gap are all significant determinants of inflation. The long-run parameters for *ulc*, *mp* and *ygap* are respectively:

$$\sum_{j=0}^{4}\gamma_j \Big/ \left(1-\sum_{j=1}^{4}\alpha_j\right), \sum_{j=0}^{4}\varphi_j \Big/ \left(1-\sum_{j=1}^{4}\alpha_j\right) \text{and } \beta \Big/ \left(1-\sum_{j=1}^{4}\alpha_j\right). \quad (3)$$

Overall, the results tend to be similar across the three techniques, with the LSDV and GMM results particularly close. The exception with the MG estimator results is that the sum of the lagged inflation parameters tend to be somewhat smaller, and the sum of the unit labour cost parameters are larger, in comparison to the results for the other two estimators. In addition, the output gap term is less significant when using the MG estimator. In terms of the long-run parameters, the LSDV results imply that the *relative weights* of *ulc* and *mp* are around two-thirds and one-third respectively (that is, long-run parameters of about 0.54 and 0.21 respectively). These parameters are very similar in magnitude to those of Pain *et al* (2006) as well as Eickmeier and Moll (2009).

Our next step is to see if there is any indication of a change in the parameters over time – which may be due to factors such as globalisation – by estimating the equations over different sample periods. Based on rolling-window parameter estimates and other information, two possible points for structural breaks are chosen: 1985 or 1995.[24] The results are reported in Table 3. Given the similarity of the full sample period results across the three different techniques, we only report the results for

23. The F-tests decisively reject the null hypothesis that the sum of the coefficients are zero for lagged inflation, unit labour costs and import prices.

24. The break in 1985 is consistent with the relationship between euro area inflation and the unemployment gap shown in Figure 2, while the break in 1995 corresponds to the period of increased globalisation when countries such as China and those from previously communist eastern Europe started to become more integrated in the world economy. The 1995 break is also found to be statistically significant by Pain *et al* (2006).

Table 2: OECD Phillips Curves – LSDV, GMM and MG Estimator Panel Estimation Results
1971:Q2–2008:Q3

Variable	LSDV			GMM			MG		
	Coefficient	*F*-stat	*t*-stat	Coefficient	*F*-stat	*t*-stat	Coefficient	*F*-stat	*t*-stat
$\Delta P_{t-1,\ldots,t-4}$	0.61	250.78 [0.000]		0.649	145.08 [0.000]		0.47		8.31 [0.000]
$\Delta ulc_{t,\ldots,t-4}$	0.209	44.40 [0.000]		0.16	14.74 [0.000]		0.299		4.72 [0.000]
$\Delta mp_{t,\ldots,t-4}$	0.079	62.75 [0.000]		0.079	45.40 [0.000]		0.1		6.77 [0.000]
$ygap_t$	0.000359		3.41 [0.000]	0.000373		3.31 [0.000]	0.000308		1.82 [0.000]
c	0.0014		3.54 [0.000]	0.0013		2.95 [0.003]	0.0011		4.13 [0.000]
Adjusted R^2		0.762			0.759			0.6	
Standard error of regression		0.0058			0.0058			0.004	

Notes: LSDV = least squares dummy variables estimated by instrumental variables (*ygap* instrumented by own lagged values); GMM = Arellano and Bond generalised method of moments; MG = mean group estimator; *F*-tests relate to exclusion tests of the parameters (*p*-values in square brackets); unbalanced panel based on nine OECD countries; country-specific fixed effects and seasonal dummies included

Sources: OECD; authors' calculations

Table 3: OECD Phillips Curves – LSDV Panel Estimation Results over Different Sample Periods

Variable	Full sample			1971:Q2–1984:Q4			1985:Q1–2008:Q3			1971:Q2–1994:Q4			1995:Q1–2008:Q3		
	Coeff	*F*-stat	*t*-stat	Coeff	*F*-stat	*t*-stat	Coeff	*F*-stat	*t*-stat	Coeff	*F*-stat	*t*-stat	Coeff	*F*-stat	*t*-stat
$\Delta P_{t-1,\dots,t-4}$	0.61	250.78 [0.000]		0.499	53.188 [0.000]		0.613	143.66 [0.000]		0.56	125.39 [0.000]		0.439	20.86 [0.000]	
$\Delta ulc_{t,\dots,t-4}$	0.209	44.39 [0.000]		0.217	16.37 [0.000]		0.199	17.58 [0.000]		0.223	32.29 [0.039]		0.1	1.87 [0.1712]	
Long-run	0.537			0.434			0.516			0.51			0.178		
$\Delta mp_{t,\dots,t-4}$	0.079	62.76 [0.000]		0.078	16.87 [0.000]		0.088	56.51 [0.000]		0.083	42.04 [0.000]		0.101	25.86 [0.000]	
Long-run	0.204			0.156			0.226			0.187			0.179		
$ygap_t$	0.000359		3.41 [0.000]	0.000624		2.81 [0.005]	0.000245		2.07 [0.039]	0.000378		2.79 [0.005]	0.000342		1.96 [0.619]
Long-run	0.000921			0.001248			0.00063			0.000857			0.000609		
c	0.00139		3.54 [0.000]	0.0046		3.92 [0.001]	0.0006		1.64 [0.101]	0.0027		4.29 [0.000]	0.0009		1.65 [0.098]
Adjusted R^2		0.757			0.658			0.605			0.725			0.511	
Standard error of regression		0.0058			0.0078			0.004			0.0067			0.0036	

Notes: Panel estimates based on least squares dummy variables (LSDV) estimated by instrumental variables (*ygap* instrumented by own lagged values); *F*-tests relate to exclusion tests of the parameters (*p*-values in square brackets); unbalanced panel based on nine OECD countries; country-specific fixed effects and seasonal dummies included

Sources: OECD; authors' calculations

the LSDV estimator; we discuss the results of the other techniques only when they differ from the LSDV estimator.

A key result of this analysis is that the long-run output gap parameter is currently about half the size of that estimated for the earlier period when the sample is broken at 1985, and about two-thirds the magnitude of the earlier period when the sample is broken at 1995. This is even stronger for the MG estimator, which implies that the output gap parameter is not statistically significant in the most recent period.[25] The finding of a weaker impact of the output gap on inflation in the most recent period is in line with the anecdotal evidence as well as some hypotheses related to globalisation as discussed in Section 2.

Two other results stand out. First, there is a decline in the persistence of inflation (that is, the estimated sum of lagged dependent variable parameters declines from 0.56 for the pre-1995 sample to 0.44 for the post-1995 sample). This corresponds with other studies that find that the degree of inflation persistence has declined over time and may be related to changes in the credibility of monetary policy.[26] Second, there is an increase in the long-run parameter for import prices relative to unit labour costs.[27] This is consistent with the increase in the degree of import penetration over time – as measured by imports as a percentage of GDP – and therefore an increasing role for import prices in the determination of inflation.[28]

3.4 Global components of inflation

A related aspect of the relationships discussed above is that the importance of global factors for inflation seems to have increased relative to domestic factors (see Neely and Rapach 2008; Eickmeier and Moll 2009). Although further analysis on this issue is beyond the scope of this paper, it is worth summarising the contrasting evidence on this issue.[29] On the one hand, Borio and Filardo (2007) find a significant role for measures of global economic slack in Phillips curves of advanced economies (albeit with mixed results for the euro area), while studies such as Paloviita (2008) and Rumler (2007) find euro area inflation dynamics are better captured by an open economy specification. In a similar vein, Ciccarelli and Mojon (2005) find that for

25. The t-statistics for the output gap (*ygap*) parameter using the MG estimator for the periods 1985:Q1–2008:Q3 and 1995:Q1–2008:Q3 are 0.801 and 0.256 respectively.

26. See, for example, Alogoskoufis (1992) and Anderton (1997). These results are also consistent with the GVAR simulation results in Section 3.1, which show that oil price shocks do not feed through to core inflation, possibly due to well-anchored inflation expectations following improvements in the credibility of monetary policy.

27. The size of the import price parameter increases relative to the unit labour costs parameter for both break points.

28. However, the increase in magnitude of the import price parameter may also be due to an increase in international competition – particularly due to rising imports from low-cost countries – which can put downward pressure on inflation.

29. Globalisation may have weakened the link of domestic liquidity on domestic prices or, alternatively, implied a higher role for foreign liquidity in domestic prices; Rüffer and Stracca (2006) find evidence of a significant spillover of global liquidity to the euro area economy.

several OECD countries, the global inflation rate moves largely in response to global real variables over short horizons and global monetary variables at longer horizons. In looking at inflation dynamics of highly disaggregated consumer price data, Monacelli and Sala (2007) find that a sizeable fraction of the variance of inflation is explained by macroeconomic factors attributable to 'international' factors for both Germany and France, but that such factors are more relevant in the goods/manufacturing sector than in the services sector. For the United Kingdom, Batini *et al* (2005) find external competitive pressures also seem to affect UK inflation via their impact on the equilibrium mark-up of domestic firms.

On the other hand, many other studies have failed to identify a significant role for measures of global economic slack in Phillips curves of advanced economies. Specifically for the euro area, Calza (2008) finds limited evidence in support of the 'global output gap hypothesis'. Indeed, Musso, Stracca and van Dijk (2007) find that a flattening of the slope of the euro area Phillips curve occurred mainly in the 1980s, before the current globalisation phase. Ball (2006), Ihrig *et al* (2007), Woodford (2007) and Wynne and Kersting (2007) argue that measures of global economic slack have a negligible effect on inflation dynamics, while Pain *et al* (2006) link the heightened sensitivity of domestic inflation in OECD economies to foreign economic conditions to an import price channel alone. On the basis of a New-Keynesian Phillips Curve model, Sbordone (2008) finds it difficult to argue that an increase in trade could have generated a large enough increase in market competition in the United States to reduce the slope of the inflation-marginal cost relationship.

4. Conclusions

Against the background of large fluctuations in world commodity prices and world growth, combined with ongoing structural changes relating to globalisation, this paper assesses some of the key determinants of global inflation. The paper considers various relative price and structural impacts on global inflation by examining three sources of evidence: a GVAR that examines how oil price shocks feed through to core and headline inflation; estimates of the impact of increased imports from low-cost countries on manufacturing import prices; and estimates of Phillips curves to shed light on whether the inflationary process in the OECD countries had changed over time, particularly with respect to the role of import prices, unit labour costs and output gaps.

The GVAR simulations – focusing on behaviour since around the turn of the century – suggest that oil price shocks have non-significant (or very limited) impacts on core inflation in the euro area and the United States. This may reflect a reduction in second-round effects due to well-anchored inflation expectations. Looking at import prices suggests that globalisation had a dampening effect on OECD inflation until the mid 2000s. This was associated with low prices of imports of manufactured goods through increased global supply of goods and labour from low-cost countries. More recently, this effect may have been offset by strong increases in the prices of commodities such as oil (at least until the first half of 2008) resulting from heightened global demand pressures. At the same time, international competitive pressures have also contributed to reducing inflationary pressures in the OECD economies via wage moderation and lower growth of unit labour costs. Finally, over a somewhat longer sample period, estimated Phillips curves provide tentative evidence that the impact of the output gap on the inflation of OECD economies may be becoming weaker over time, possibly due to the effects of globalisation and/or changes in monetary policy. By contrast, import prices have grown in importance in the inflation process – in line with their increasing weight in the CPI – while the persistence of inflation has declined, perhaps due to changes in monetary policy that have contributed to low and well-anchored inflation expectations.

Appendix A: Estimating the Impact of Low-cost Countries on the Euro Area's Manufacturing Import Price

To decompose the changes in the euro area manufacturing import unit value (which is a proxy for the import price) into the effects arising from a change in the geographical distribution of imports between low- and high-cost countries (and among them, China, new EU Member States and the remaining low-cost countries, hereafter referred to as CN, NMS and ROLC, respectively) two factors have to be considered separately. A *share effect* (what would have been observed if only the geographical import shares had changed), and a *price effect* (what would have been observed if only the import price from low-cost countries had changed relative to that of the high-cost countries).

The methodology used to decompose import price inflation

The euro area absolute import unit value is a weighted average of the import unit values from various countries of provenance. Hence, the percentage change in the euro area import unit value from period *t–n* to period *t* can be deduced from Equation (A1), which takes into consideration the fact that the sum of the weights adds to 1, and sets the group of high-cost countries as the reference point:

$$\frac{\Delta p_t}{p_{t-n}} = \sum_j \left[\frac{p_{j,t} - p_{HC,t}}{p_{t-n}} \Delta\alpha_{j,t} \right] + \sum_j \alpha_{j,t-n} \left[\frac{\Delta p_{j,t}}{p_{j,t-n}} \frac{p_{j,t-n}}{p_{t-n}} - \frac{\Delta p_{HC,t}}{p_{HC,t-n}} \frac{p_{HC,t-n}}{p_{t-n}} \right] + \frac{\Delta p_{HC,t}}{p_{HC,t-n}} \frac{p_{HC,t-n}}{p_{t-n}} \tag{A1}$$

where: $j = \{CN, NMS, ROLC\}$; HC are the high-cost countries; p is the import price; and Δp is the change in the price.

In Equation (A1), for each low-cost country *j*, the first and second terms capture the direct effect of imports from that country on the change in the euro area import price:

- The first term is the share effect – that is, the effect of a change in the import share from a particular country given its price differential against the reference (high-cost) group of countries. If the country's import price is lower than that of the reference country, then an increase in its import share will change the composition of imports towards cheaper goods and will therefore have a negative effect on the overall import price. The size of the share effect depends on both the magnitude of the change in the share, and the import price differential of country *j* against the reference country.
- The second term in the equation represents the price effect. It captures the change in the euro area import price due to different export price inflation rates of country *j* and the reference country. If the export price of country *j* increases by more (decreases by less) than that of the reference country, then given the geographical composition of imports, country *j* will have a positive (negative) impact on the

overall euro area import price. The impact increases with the import share of country *j*.

- Finally, the third term in the decomposition represents the residual effect due to price developments in the high-cost countries.

This methodology is subject to four main caveats:

- First, the aggregate euro area import unit value series computed is slightly different from the unit value series officially published by Eurostat. The differences arise mainly due to methodological differences in the aggregation. In contrast to the computed unit value series, the Eurostat series is based on the Fischer index.
- Second, the results of the magnitude of the share and price effects depend on the grouping of the countries, and therefore on the reference country. This paper focuses on the effect of imports from the low-cost countries – CN, NMS and ROLC – so the reference country in this case is the aggregate of high-cost countries. However, it should be noted that if the aim were to analyse the effects of imports from just one country *vis-à-vis* all other import partners, the results would be different. For example, if the focus were purely on Chinese imports, the share effect of China against the rest of the import partners would be lower than that against just the high-cost countries. The price effect would also be affected, although *a priori* it is not possible to know in which direction.
- Third, when setting the high-cost countries as the reference, it is implicitly assumed that the low-cost countries (countries with linearly independent weights in the aggregation) are competing against the high-cost countries, but not among themselves. So by construction, an increase in country *j*'s import share is thus always a substitution for imports from the high-cost countries, but not for imports from any other low-cost country or country group.
- Fourth, import shares in value terms are used for the aggregation of the import unit value, thus in addition to structural developments this also captures valuation effects. The alternative would be to use import share in volume terms. However, the Eurostat Comext database reports volumes measured in weight units (multiples of kilograms) that are difficult to interpret at an aggregate level.

References

Alogoskoufis GS (1992), 'Monetary Accommodation, Exchange Rate Regimes and Inflation Persistence', *Economic Journal*, 102 (412), pp 461–480.

Anderson TW and C Hsiao (1982), 'Formulation and Estimation of Dynamic Models Using Panel Data, *Journal of Econometrics*, 18(1), pp 47–82.

Anderton R (1997), 'Did the Underlying Behaviour of Inflation Change in the 1980s? A Study of 17 Countries', *Weltwirtschaftliches Archiv*, 133(1), pp 22–38.

Anderton R, P Brenton and J Whalley (eds) (2006), *Globalisation and the Labour Market: Trade, Technology and Less-Skilled Workers in Europe and the United States*, Routledge, London.

Anderton R and F di Mauro (2007), 'The External Dimension of the Euro Area: Stylised Facts and Initial Findings', in F di Mauro and R Anderton (eds), *The External Dimension of the Euro Area: Assessing the Linkages*, Cambridge University Press, London, pp 8–51.

Anderton R and P Hiebert (2009), 'The Impact of Globalisation on the Euro Area Macroeconomy', University of Nottingham Globalisation and Economic Policy Research Paper No 09/14.

Arellano M and SR Bond (1991), 'Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations', *Review of Economic Studies*, 58(2), pp 277–297.

Ball LM (2006), 'Has Globalization Changed Inflation?', NBER Working Paper No 12687.

Baltagi BH and JM Griffin (1983), 'Gasoline Demand in the OECD: An Application of Pooling and Testing Procedures', *European Economic Review*, 22(2), pp 117–137.

Batini N, B Jackson and S Nickell (2005), 'An Open-Economy New Keynesian Phillips Curve for the UK', *Journal of Monetary Economics*, 52(6), pp 1061–1071.

Bean C (2007), 'Globalisation and Inflation', Bank of England *Quarterly Bulletin,* 46(4), pp 468–475.

Blanchard OJ and J Galí (2007), 'The Macroeconomic Effects of Oil Price Shocks: Why Are the 2000s so Different from the 1970s?', NBER Working Paper No 13368.

Borio C and A Filardo (2007), 'Globalisation and Inflation: New Cross-Country Evidence on the Global Determinants of Domestic Inflation', BIS Working Paper No 227.

Calza A (2008), 'Globalisation, Domestic Inflation and Global Output Gaps: Evidence from the Euro Area', ECB Working Paper No 890.

Cecchetti SG and R Moessner (2008), 'Commodity Prices and Inflation Dynamics', *BIS Quarterly Review*, December, pp 55–66.

Ciccarelli M and B Mojon (2005), 'Global inflation', ECB Working Paper No 537.

Dees S, F di Mauro, MH Pesaran and LV Smith (2007), 'Exploring the International Linkages of the Euro Area: A Global VAR Analysis', *Journal of Applied Econometrics*, 22(1), pp 1–38.

ECB (European Central Bank) (2009), 'Expectations and the Conduct of Monetary Policy', *Monthly Bulletin*, May, pp 75–90.

Eickmeier S and K Moll (2009), 'The Global Dimension of Inflation – Evidence from Factor-Augmented Phillips Curves', ECB Working Paper No 1011.

Furlong F and R Ingenito (1996), 'Commodity Prices and Inflation', Federal Reserve Bank of San Francisco *Economic Review*, 2, pp 27–47.

Galesi A and M Lombardi (2009), 'External Shocks and International Inflation Linkages: A Global VAR Analysis', ECB Working Paper No 1062.

Glatzer E, E Gnan and MT Valderrama (2006), 'Globalization, Import Prices and Producer Prices in Austria', Oesterreichische Nationalbank *Monetary Policy & the Economy*, Q3/06, pp 24–43.

Helbling T, F Jaumotte and M Sommer (2006), 'How Has Globalization Affected Inflation?', *World Economic Outlook – Globalization and Inflation*, World Economic and Financial Surveys, IMF, Washington DC, pp 97–134.

Hooker MA (2002), 'Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regime', *Journal of Money, Credit and Banking*, 34(2), pp 540–561.

Ihrig J, SB Kamin, D Lindner and J Marquez (2007), 'Some Simple Tests of the Globalization and Inflation Hypothesis', Board of Governors of the Federal Reserve System International Finance Discussion Paper No 891.

IMF (International Monetary Fund) (2006), *World Economic Outlook – Globalization and Inflation*, World Economic and Financial Surveys, IMF, Washington DC.

Jaumotte F and I Tytell (2007), 'The Globalization of Labor', in *World Economic Outlook – Spillovers and Cycles in the Global Economy,* World Economic and Financial Surveys, IMF, Washington DC, pp 161–192.

Judson RA and AL Owen (1999), 'Estimating Dynamic Panel Data Models: A Guide for Macroeconomists', *Economics Letters*, 65(1), pp 9–15.

Kamin SB, M Marazzi and JW Schindler (2004), 'Is China "Exporting Deflation"?', Board of Governors of the Federal Reserve System International Finance Discussion Paper No 791.

Kiviet JF (1995), 'On Bias, Inconsistency, and Efficiency of Various Estimators in Dynamic Panel Data Models', *Journal of Econometrics*, 68(1), pp 53–78.

Koop G, MH Pesaran and SM Potter (1996), 'Impulse Response Analysis in Nonlinear Multivariate Models', *Journal of Econometrics*, 74(1), pp 119–147.

Landau B and F Skudelny (2009), 'Pass-Through of External Shocks along the Pricing Chain: A Panel Estimation Approach for the Euro Area', ECB Working Paper No 1104.

Lown CS and RW Rich (1997), 'Is There an Inflation Puzzle?', *Economic Policy Review*, 3(4), pp 51–77.

Mody A and F Ohnsorge (2007), 'Can Domestic Policies Influence Inflation?', IMF Working Paper No 07/257.

Monacelli T and L Sala (2007), 'The International Dimension of Inflation: Evidence from Disaggregated Consumer Price Data', paper prepared for the *Journal of Money, Credit and Banking* (JMCB)-Federal Reserve Board Conference on 'Domestic Prices in an Integrated World Economy', Washington DC, 27–28 September.

Musso A, L Stracca and D van Dijk (2007), 'Instability and Nonlinearity in the Euro Area Phillips Curve', ECB Working Paper No 811.

Neely CJ and DE Rapach (2008), 'Is Inflation an International Phenomenon?', Federal Reserve Bank of St. Louis Working Paper No 2008-025C.

Nickell SJ (1981), 'Biases in Dynamic Models with Fixed Effects', *Econometrica*, 49(6), pp 1417–1426.

Pain N, I Koske and M Sollie (2006), 'Globalisation and Inflation in the OECD Economies', OECD Economics Department Working Paper No 524.

Paloviita M (2008), 'Estimating Open Economy Phillips Curves for the Euro Area with Directly Measured Expectations', Bank of Finland Research Discussion Paper No 16/2008.

Pesaran MH, T Schuermann and SM Weiner (2004), 'Modeling Regional Interdependencies Using a Global Error-Correcting Macroeconometric Model', *Journal of Business & Economic Statistics*, 22(2), pp 129–162.

Pesaran MH and Y Shin (1998), 'Generalized Impulse Response Analysis in Linear Multivariate Models', *Economics Letters*, 58(1), pp 17–29.

Pula G and F Skudelny (forthcoming), 'Globalisation and Euro Area Prices and Labour Markets – Some Evidence on the Impact of Low-Cost Countries', in R Anderton and G Kenny (eds) (forthcoming), *Globalisation and Macroeconomic Performance*, Cambridge University Press, Cambridge.

Rogoff KS (2006), 'Impact of Globalization on Monetary Policy', in *The new Economic Geography: Effects and Policy Implications*, a Symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, pp 265–305.

Rüffer R and L Stracca (2006), 'What Is Global Excess Liquidity, and Does It Matter?', ECB Working Paper No 696.

Rumler F (2007), 'Estimates of the Open Economy New Keynesian Phillips Curve for Euro Area Countries', *Open Economies Review*, 18(4), pp 427–451.

Sbordone AM (2008), 'Globalization and Inflation Dynamics: The Impact of Increased Competition', Federal Reserve Bank of New York Staff Report No 324.

Sekine T (2009), 'Another Look at Global Disinflation', BIS Working Paper No 283.

Sims CA (1980), 'Macroeconomics and Reality', *Econometrica*, 48(1), pp 1–48.

Stock JH and MW Watson (2007), 'Why Has U.S. Inflation Become Harder to Forecast?', *Journal of Money, Credit and Banking*, 39(s1), pp 3–33.

Taglioni D and O Vergote (2009), 'Impacts of Low-Cost Countries on Extra-Euro Area Import Prices', internal mimeo, ECB.

Woodford M (2007), 'Globalization and Monetary Control', paper prepared for the NBER Conference on 'International Dimensions of Monetary Policy', Girona, 11–13 June.

Wynne MA and EK Kersting (2007), 'Openness and Inflation', Federal Reserve Bank of Dallas Staff Papers No 2.

Discussion

1. Heather M Anderson[1]

This paper studies recent trends in global inflation, with the broad aim of assessing the relative influences of phenomena associated with globalisation on European inflation. The authors' approach is very broad, inviting the reader to look at many characteristics of inflation through a variety of windows. These windows provide glimpses on the conflicting pressures on prices that Europeans face. From one vantage point we see downward pressure on prices arising from an increase in the supply of imported goods manufactured in low-cost countries, but from another we see upward pressure on prices arising from increased worldwide demand for oil and commodities. Further, although we see increases in the marginal product of labour and hence in real wages, we also see downward pressure on wages arising from increases in the global supply of labour. Surprisingly, overall inflation has changed very little in recent years, despite the many relative price changes that have followed globalisation. This overall stability might be due to counteracting forces, but the authors also put forward the view that inflationary expectations are well-anchored, and that this has contributed towards stability in global inflation.

The broadness of the authors' approach is appealing, because it allows the reader to consider many possible determinants of inflation separately. However, this broadness also imposes a heavy burden on the reader, who needs to focus on different aspects of inflation at different points in the analysis, yet draw a coherent set of conclusions. At first pass, the study is quite *ad hoc*, using different definitions of inflation at different points in the paper, and studying inflation in different sets of countries over horizons that are sometimes short-run, sometimes medium-run and sometimes long-run. The paper also includes many different forms of data analysis, each of which uses or implies different definitions of trend and concepts of persistence. The different sections of the paper are quite loosely linked, perhaps leaving it up to the reader to formulate his/her own set of 'take home' messages. My discussion below focuses on various problems that this sort of piece-wise analysis can entail, but it also tries to offer a second pass that might help to build up and sell some of the paper's main messages.

Each of the trends in global inflation noted above are supported by empirical evidence, with techniques used for data analysis ranging from simple time-series figures, to the estimation of Phillips curves and the presentation of generalised impulse response functions (GIRFs) derived from global vector autoregressions (GVARs). The figures are mainly used to illustrate some historical trends, while the empirical Phillips curves are used to show that in addition to a decline in the persistence of inflation, the effects of output gaps and labour costs on inflation have declined over time, whereas import prices have had an increasing influence. The GIRFs predict that (global) oil price shocks will have little effect on either US or European inflation. In my view, the Phillips curves offer the most potential for

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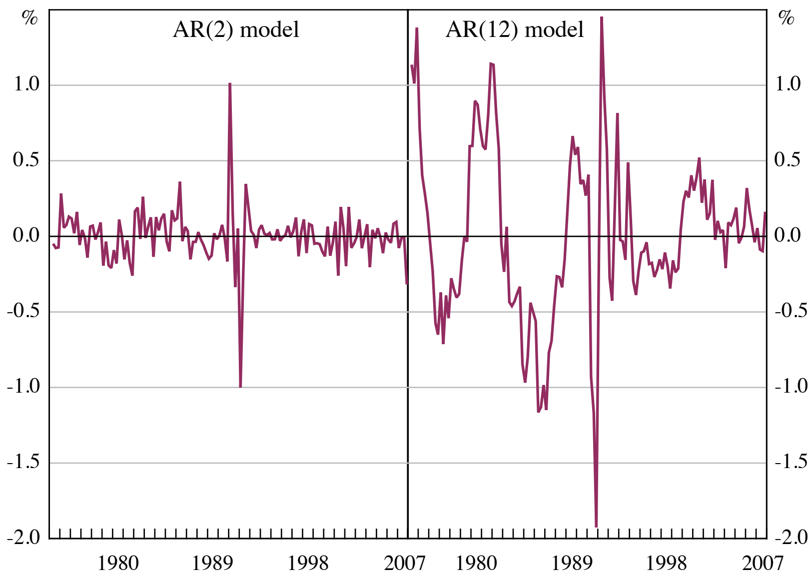
learning about the evolution of inflation, although as detailed below, I have some issues with the specification of these (and the GVAR) models.

My sensitivity to the different definitions of inflation has its basis in the sensitivity of the data to different definitions of trends and cycles. A simple example of the sensitivity of Beveridge-Nelson (1981; BN) cycles to lag structure is illustrated in Figure 1 below, and although this example might not seem relevant here, it is, because the authors have imposed a (short) lag structure on their GVAR, even though a longer structure would have been better aligned with economists' views on cyclical behaviour in inflation. In a multivariate setting, the lag and cointegration structure in a GVAR (or in any vector error correction model) implicitly define the BN trends (the 'integrated of order 1' factors) and the cycles (stationary components), and these, in turn, influence the properties of the GIRFs. Of particular importance is the modelling of the forcing variable – in this case, the world oil price. Given these considerations, and the paper's focus on trends in inflation, I feel that the authors' 'black-box' treatment of their GVAR may have led to results that are not particularly informative, especially since empirical results are rarely robust to modelling choices. Extra details about the modelling choices, or some provision of caveats about the reliability of the results might have better informed the debate about how oil shocks influence inflation.

Figure 1: Beveridge-Nelson Cycles of Euro Area Inflation Based on AR Models



Sources: Anderson *et al* (2007); Eurostat; author's calculations

The findings based on the estimated Phillips curves are more compelling, because the modelling process is more transparent. There are difficulties aligning these findings with those from the GVAR, because the set-up with respect to modelling trends and thinking about persistence is now quite different, but the results themselves appear to be reproducible, as well as relatively robust to the mode of estimation. The individual country graphs suggest that care should be taken in modelling seasonality in inflation, and I note that the authors have taken steps to deal with this. The imposition of common coefficients across the panel may have introduced some bias (which is addressed only in the paper's Table 2), and the full sample estimates indicate that inflation is positively related to the output gap, unit labour costs and import prices, as standard economic considerations would suggest.

Separate sub-sample analysis suggests that the effects of output gaps and labour costs on inflation have declined over time, whereas import prices have had an increasing influence. Further, the persistence in inflation seems to have declined. The latter finding is attributed to more effective monetary policy in an environment in which inflationary expectations are quite stable, while the lower output gap effect is attributed to a declining influence on domestic prices of pressures in the domestic economy, given that global developments might now be a relatively more important determinant of domestic demand. The increasing effect of import prices is attributed to greater penetration of imports into the countries under study, while the authors are somewhat silent about the declining influence of labour costs. The latter results might be due to lower labour shares in (domestic) production.

One could tie some of the loose ends of the paper together by considering how the effects of increasing prices for oil and other commodities might affect inflation, conditional on other variables (such as import and labour prices) remaining constant, and an obvious way to do this would be to include oil (or energy) prices in the Phillips curves in Section 3.3. Perhaps the authors did not do this because their GVAR indicated that oil prices have little effect on inflation, but it would have been nice to see if this result held up in a setting that explicitly tried to account for changes in relevant structural factors. Given the observed changes in import shares, it is not clear that the GVAR provides an appropriate tool for studying the joint effects of commodity prices and changes in structural factors on inflation (unless the trade-based weighting matrices are varied to account for increased import penetration), so the suggested alternative of augmenting the Phillips curve with oil prices and then testing for structural change seems preferable. Regardless of whether one wants to develop the Phillips curves or the GVAR further to tease out some joint effects, it might also be useful to study some of the individual country results, because these can potentially highlight issues that may be hidden in the aggregate analysis.

References

Anderson HM, M Dungey, DR Osborn and F Vahid (2007), 'Constructing Historical Euro Area Data', CAMA Working Paper No 18/2007.

Beveridge S and CR Nelson (1981), 'A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the "Business Cycle"', *Journal of Monetary Economics*, 7(2), pp 151–174.

2. General Discussion

Much of the discussion centred on questions of policy. To start, one participant asked what an inflation-targeting central bank should do in response to an expected decline in the prices of manufactured goods associated with the emergence of China and other developing economies. Should policy-makers: (i) allow the aggregate price level to shift, that is, have inflation fall below the target temporarily if they are careful to ensure that inflation expectations remain anchored and that there will be no second-round effects; (ii) attempt to hit the target, allowing other prices to increase to offset the lower manufactured goods prices; or (iii) recognise that lower manufactured goods prices are likely to be matched also by rising commodity prices, thereby requiring little if any policy response? In response, Robert Anderton thought that it was important for policy to maintain the target and to focus decisions around the forecast for aggregate inflation. On this same theme, another participant remarked that strong output growth from 2003 to 2007 was not accompanied by inflation, and that this was possibly attributable to the expansion of supply out of China. It was suggested that focusing on standard exclusion-based measures of core inflation may have provided a false sense of comfort, given that these often exclude rapidly rising prices of energy and food. Robert Anderton replied by noting the difficulty in formulating policy in the context of sharp changes in relative prices.

On the Phillips curve analysis in the paper, it was suggested that instead of comparing different sub-samples, there may be a better way to account directly for the rising share of manufactured imports from low-cost countries. It was also suggested that it would help to perform various tests of the robustness of the Phillips curve results, including use of instrumental variables. Robert Anderton said that this would be something he would like to include in future research.

There was considerable discussion of the GVAR model used in the paper and the results of that model. There was concern that the impulse response results needed to be clarified. In particular, the results suggested that a shock to the nominal price of oil is eroded over time by a rise in the inflation rate such that the real price of oil eventually falls, which was puzzling in light of the sustained decline in industrial production. Arising out of the general discussion of this point, one idea was that the result might reflect the modelling peculiarities of the GVAR system. On these impulse responses, a comment was made that they were statistically insignificant, leading to questions regarding the reliability of interpretation of the results. It was suggested that the paper implement a range of statistical techniques to check the robustness of the results. Another participant suggested that the model assumes a small open economy framework, which may be inappropriate for the euro area and US economies, and that an assumption of exogeneity of the domestic and foreign variables is incorrect, given the expected interactions between those variables.

Terms of Trade Shocks and Fiscal Cycles

Graciela L Kaminsky[1]

Abstract

The latest boom in commodity prices fuelled concerns about fiscal policies in commodity-exporting countries, with evidence suggesting that it triggered loose fiscal policy and left no funds for a rainy day. This paper examines the links between fiscal policy and terms of trade fluctuations using a sample of 74 countries, both developed and developing. It finds evidence that booms in the terms of trade do not necessarily lead to larger government surpluses in developing countries, particularly in emerging markets and especially during capital flow bonanzas. This is not the case in OECD countries, where fiscal policy is of an acyclical nature.

1. Introduction

After several years of relatively stable commodity prices, volatility has returned, fuelling, as always, worries about its effects on overall economic stability around the world. This time around, the debate is also focused on fiscal policy. During the boom that started in 2003, concerns were raised that commodity price increases were encouraging excessive government spending in resource-abundant countries, leaving no funds for a rainy day. For example, an Inter-American Development Bank report is entitled 'All that Glitters May Not Be Gold', partly in reference to the fiscal positions of Latin American countries during the latest boom in commodity prices (Izquierdo and Talvi 2008). This report concludes that the fiscal surpluses observed during this period are far from reassuring since they are based on inflated and unsustainable fiscal revenues due to transitory increases in the price of commodities. In fact, the report concludes that when government revenues are estimated at the 'long-run' prices of commodities, the average fiscal position of these countries has deteriorated with deficits averaging 4 per cent of GDP.

This concern is not limited to Latin America. Both in academic and policy circles the debate regarding what governments in commodity-exporting countries should do when their terms of trade improve has intensified. A new proposal based on neoclassical models of fiscal policy supports the creation of commodity sovereign wealth funds. According to this proposal, fiscal policy should be acyclical, with government consumption smoothed over the business cycle and savings accumulating

1. George Washington University and NBER, Washington DC. This paper was written for the Conference on 'Inflation in an Era of Relative Price Shocks', Sydney, 17–18 August 2009, jointly hosted by the Reserve Bank of Australia and the Centre for Applied Macroeconomic Analysis (CAMA) (Australian National University, Canberra, Australia). I thank Renée Fry, Christopher Kent, Larry Schembri, and participants at the Conference in Sydney for helpful comments.

in boom times to provide funding for a rainy day. In fact, this policy has been at the core of the IMF recommendations for countries dependent on commodity exports.[2] This paper does not examine the role of these funds but rather pays particular attention to the effects of terms of trade cycles on fiscal positions around the world.

Relying on data for 74 countries for the period 1960–2008, this paper examines the evidence on the cycles in the terms of trade and those of fiscal policy. In particular, it studies the behaviour of government expenditure, revenues and primary balances, as well as inflation. The paper examines separately the evidence on countries grouped by income levels. It also disaggregates the sample along a variety of dimensions, by (i) differentiating episodes of capital flow bonanzas from those when international capital flows are at their historical lows; (ii) differentiating episodes of terms of trade booms from those of terms of trade crashes; (iii) separating the responses of countries with persistent terms of trade shocks from those with transitory terms of trade shocks; (iv) comparing responses during periods of more rigid exchange rate regimes separately from more flexible arrangements; and (v) examining separately the fiscal responses in commodity-exporting countries.

The paper proceeds as follows. The next section briefly discusses the theoretical literature on fiscal policy used to interpret the results on terms of trade and fiscal policy cycles. Section 3 provides a visual representation of alternative fiscal policies and terms of trade cycles around the world by focusing on the evidence of just two countries: Argentina and Norway. Section 4 extends the analysis of fiscal responses to the whole sample of 74 countries using panel data estimation techniques. Section 5 contains concluding remarks.

2. Models of Fiscal Policy

A number of models have been proposed to explain the cyclical behaviour of fiscal policies. Keynesian models provide the rationale for countercyclical fiscal policy. In these models, the fiscal authority has an objective function that penalises deviations of output from trend. Since an increase in government spending and/or a reduction in tax rates would expand output (and *vice versa*), fiscal policy will be countercyclical. In contrast, neoclassical models rationalise acyclical fiscal policy since roughly constant tax rates over the business cycle reduce distortions (see Chari and Kehoe 1999). Moreover, if government spending is endogeneised (by, say, providing direct utility), neoclassical models predict that it would be optimal for it to behave in a similar way to private consumption and hence would be acyclical in the presence of complete markets (Riascos and Végh 2003).

In contrast to Keynesian and neoclassical recommendations, recent empirical literature has noted that while fiscal policy is acyclical or countercyclical in developed countries, it is procyclical in most developing countries, with fiscal policy probably exacerbating the business cycle in those countries. This begs the question of why these countries follow policies that tend to create macroeconomic instability. Theoretical

2. See, for example, Davis *et al* (2001) and Barnett and Ossowski (2003).

models suggest two possible explanations. The first one relies on the presence of distortions in international capital markets. For example, Gavin and Perotti (1997), Caballero and Krishnamurthy (2004) and Guerson (2004) argue that developing countries face credit constraints that prevent them from borrowing in bad times. Hence, they are 'forced' to repay in bad times, which requires a contractionary fiscal policy. In the same vein, Riascos and Végh (2003) show that incomplete markets could explain procyclical fiscal policy as the outcome of a Ramsey problem without having to impose any additional frictions.

The second strand of the literature relies on a political economy explanation. For example, Tornell and Lane (1999) develop a model in which competition for a common pool of funds among different units (ministries, provinces) leads to the so-called 'voracity effect', whereby expenditure could actually exceed a given windfall. Taking as given such a political distortion, Talvi and Végh (2005) show how policy-makers would find it optimal to run smaller primary surpluses in good times by increasing government spending and reducing tax rates.[3]

While political distortions can be present in all countries, a number of authors have concluded that these distortions can be more widespread in resource-rich countries where non-resource taxes are low and resource rents are high. For example, Lane and Tornell (1996) argue that resource-rich economies are subject to more extreme rent-seeking behaviour than resource-poor economies because national politics is oriented to appropriating the rents earned by the natural resource endowments. In their model, a windfall coming from a terms of trade improvement can lead to sharp increases in spending, a distorted allocation of spending over time, dissipated revenues and a collapse in growth.

There is also an important literature that links fiscal policy with exchange rate regimes. Conventional wisdom indicates that fixed exchange rates provide more fiscal discipline than flexible exchange rates (see, for example, Giavazzi and Pagano 1988; Aghevli, Khan and Montiel 1991; and Frenkel, Goldstein and Masson 1991). The claim is that fixed rates induce more discipline because the sustained adoption of lax fiscal policies must eventually lead to a depletion of foreign exchange reserves and thus to a politically costly collapse of the peg. In contrast, Tornell and Velasco (2000) argue that flexible exchange rate regimes trigger more austere fiscal policies. They examine the role of exchange rate regimes using an intertemporal model with endogenous optimal fiscal policy. In this model, loose fiscal policies are costly under both fixed and flexible exchange rates. While under fixed exchange rates bad behaviour today leads to punishment tomorrow (when reserves are depleted and a costly currency crisis starts), under flexible exchange rates unsound fiscal policy manifests itself immediately through movements in the exchange rate. The difference is in the intertemporal distribution of these costs. They show that if fiscal authorities are impatient, flexible rates – by forcing the costs to be paid up-front – provide more fiscal discipline and higher welfare for the representative agent.

3. See also, Calderón and Schmidt-Hebbel (2003); Alesina and Tabellini (2005); and Ilzetzki (2009).

Finally, the last strand of the literature on sub-optimal macro policies concludes that distortionary macroeconomic policies are likely to be symptoms of underlying institutional problems, such as lack of enforcement of property rights and repudiation of contracts. As Acemoglu *et al* (2003) conclude, in societies with institutional problems, politicians may be forced to pursue unsustainable policies in order to satisfy various groups and remain in power.

3. Fiscal Stance and Terms of Trade Cycles: A Tale of Two Countries

To grasp the distinct characteristics of cycles in the terms of trade and the fiscal stance around the world, visual evidence from two commodity-exporting countries is presented. The first country is a developing economy, Argentina; the second one is a developed economy, Norway. On average, the share of commodity exports in total exports for both countries oscillates around 70 per cent. Figure 1 shows the cycles in the terms of trade as well as those in government expenditure, government revenues and the primary balance. In this figure, and also in the panel estimations in Section 4, I identify cycles by using the ubiquitous Hodrick-Prescott (HP) filter. Figure 1 also reports pair-wise correlations between the cyclical components of the terms of trade and the fiscal stance for the two economies. While these correlations only provide a metric of contemporaneous co-movements, Section 4 explores potential temporal causal patterns.[4]

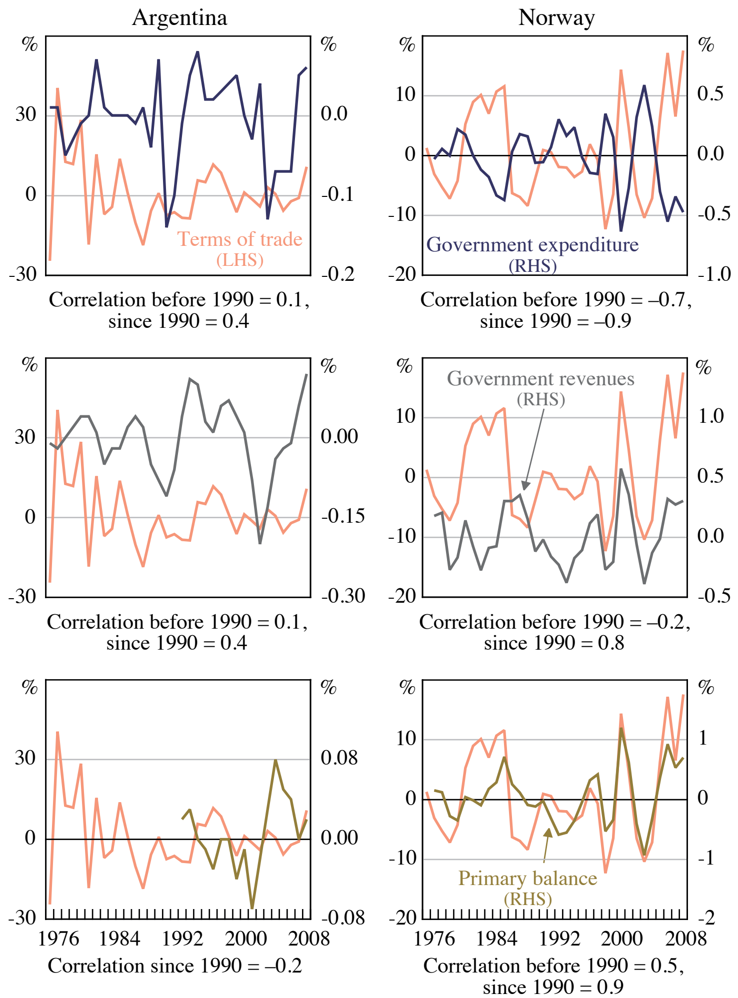
It should also be noted that only government expenditure provides a measure of discretionary fiscal policy. As discussed extensively in Kaminsky, Reinhart and Végh (2005), government revenues and the primary balance depend on the tax base (output or, in this case, the terms of trade), with the correlations between these two indicators and output (or terms of trade) providing, in most cases, ambiguous information on the cyclicality of fiscal policy.[5] Still, in order to examine whether the fiscal stance tends to be loose when the terms of trade improve, this paper is also concerned with the cycles in government revenues and primary balance.

As shown in the top panels of Figure 1, while government expenditure is highly countercyclical in Norway, this is not the case in Argentina where government expenditure has become increasingly procyclical since the early 1990s. Again, the evidence from the middle and lower panels indicates that booms in the terms of trade in Argentina did not trigger higher public savings; in fact, the primary balance is below trend when Argentina's terms of trade improve. The evidence from Norway is in stark contrast, with the fiscal stance improving with booms in the terms of trade.

4. Both fiscal and terms of trade indicators are obtained from the World Economic Outlook (WEO) database of the IMF and are described in Table A1.

5. For example, tax revenues = tax rate × tax base. Suppose the government follows a procyclical fiscal policy. Since, by definition, the tax rate goes down in good times (and *vice versa*) but the tax base moves in the opposite direction, the correlation of tax revenues with the business (or terms of trade) cycle is ambiguous.

Figure 1: Fiscal Policy and Terms of Trade Cycles



Notes: The cycles are estimated using the Hodrick-Prescott filter. The correlation statistics in each panel show the pair-wise correlation between each indicator of fiscal policy cycles and the terms of trade cycles.

4. Panel Estimation

Kaminsky *et al* (2005) examine the cyclical characteristics of fiscal and monetary policies around the world and find that developing countries (in particular, middle-income countries) follow procyclical policies while developed countries implement acyclical or countercyclical policies. In a similar vein, this paper documents the relationship between booms and busts in the terms of trade and government expenditure and revenues, primary balances and inflation. The purpose of this paper is not to examine the cyclical characteristics of fiscal policy but to evaluate whether fiscal positions of countries around the world deteriorate or improve with terms of trade cycles.

As discussed in Section 2, political and institutional distortions are at the core of models of sub-optimal fiscal policy. Since these distortions are more widespread in developing countries, I examine separately the evidence on countries grouped by income levels. The World Bank classification in 2008 is used to divide the sample into groups of low-income, lower-middle-income, upper-middle-income and high-income (OECD) countries (see Appendix A for details).

Even within the panel estimation by income groups, I also examine the possibility of non-linear relationships between the various measures of the fiscal stance and fluctuations in the terms of trade as suggested by the various models of fiscal policy.

First, as discussed in Gavin and Perotti (1997), I examine whether the relationship between the fiscal stance and the terms of trade depends on the degree of liquidity in international capital markets, that is, on the ability of countries to tap international capital markets. To identify liquidity in international capital markets, I follow Reinhart and Reinhart (2008) who identify capital flow bonanza episodes country by country[6] using a sample of 181 countries and then tally, year by year, the number of countries with capital flow bonanzas. An index of worldwide bonanzas is then constructed. This index indicates the proportion of countries with an episode of capital flow bonanza in any given year. I identify episodes of worldwide capital flow bonanzas when the Reinhart and Reinhart index indicates that at least 20 per cent of the countries are found to be having a capital flow bonanza. This metric identifies 1978–1983, 1991–1993, 1998, and 2005–2008 as periods of worldwide capital flow bonanza.

Second, models with liquidity constraints and overall imperfections in capital markets also suggest that fiscal responses in bad times (when, for example, terms of trade deteriorate) may be more procyclical than those in good times, with government introducing draconian reforms in response to a collapse in the terms of trade due to lack of access to credit. Thus, I also examine whether the fiscal stance responds asymmetrically to booms and busts in the terms of trade. I identify good times (terms of trade booms) as those years when the terms of trade are above their trend and bad times (terms of trade busts) as those years when they are below their trend, with the trend estimated with the HP filter.

Third, the response of the fiscal stance to terms of trade fluctuations may depend on the exchange rate regime. To test for this, episodes of fixed and floating exchange rate regimes are identified by using the Reinhart and Rogoff (2004) *de facto* exchange rate regime classification. For this paper, it is enough to define two exchange rate regimes: fixed or predetermined exchange rates, and flexible exchange rates (which are defined as including any regime in which the exchange rate is allowed some flexibility). Flexible exchange rate regimes include clean floats (which are rare) and dirty floats (which are more common).

Fourth, many have argued that fiscal authorities tend to believe that good times are more permanent than they really are, leading to too much spending or a reduction in tax rates in times of terms of trade booms. According to this hypothesis, the fiscal

6. For each country, a capital flow bonanza year is one with a large current account deficit, defined as a current account balance in the 20th percentile.

stance responds equally to transitory and persistent terms of trade shocks. To examine this hypothesis, I classify shocks into transitory and persistent following the analysis in Kent and Cashin (2003). These authors estimate equations of the form:

$$\Delta tot_{i,t} = c_i + \phi_i \Delta tot_{i,t-1} + \mu_{i,t} \quad (1)$$

where Δtot is the growth rate of the terms of trade. The coefficient ϕ captures the degree of persistence of the shocks, with shocks becoming more persistent as ϕ approaches 1 in absolute value. Again, following Kent and Cashin, transitory and permanent terms of trade shocks are separated by first estimating the half-life of a shock (*HLS*):

$$HLS = \text{abs}\left(\log\left(1/2\right) / \log\left(\phi\right)\right) \quad (2)$$

For each income group, countries with persistent terms of trade shocks are identified as those countries with shocks that have a half-life larger than the median value of the half-life of shocks in the group. The rest of the countries are identified as countries with transitory terms of trade shocks.[7]

Finally, I also examine whether responses to terms of trade shocks are different in resource-abundant economies. The IMF (WEO) classification scheme is used to identify resource-abundant countries as those where commodity-related export earnings account for more than half of total export earnings. Using United Nations COMTRADE data, for each country and for every year of the sample, the share of non-fuel primary products commodity exports (Standard International Trade Classification (SITC) 0, 1 2, 4, and 68) plus fuel exports (SITC 3) in total exports is calculated. For each country, a dummy variable is created that is equal to one when commodity export shares are above 50 per cent and zero otherwise.

As in Section 3, cycles in the fiscal stance, economic activity, and the terms of trade are identified using the HP filter. The indicators are obtained from the IMF (WEO) database and are listed in Table A1.

To examine the links between the fiscal stance and the terms of trade the following regression using fixed-effects panel techniques is estimated. Each regression takes the form:

$$cY_{i,t} = \alpha_i + \beta ctot_{i,t} + \gamma ctot_{i,t} \times I^j_{i,t} + \delta X_{i,t} + \varepsilon_{i,t} \quad (3)$$

where *cY* represents alternatively the cycle in government expenditure, government revenue, the primary balance and inflation; *ctot* is the cycle in the terms of trade; *I* is a variable used to examine the presence of non-linearities; and *X* captures the state of the business cycle, that is, the output cycle of each country.

The simplest strategy is to estimate the model in Equation (3) using ordinary least squares (OLS) regressions. However, cycles in economic activity as captured by cycles in GDP are endogenous, so we may be capturing reverse causality. In this case, OLS regressions will give results that do not correspond to the causal effect

7. The classification of countries into those with persistent terms of trade shocks and those with transitory terms of trade shocks is done using all sample data. Governments do not have all of this information when deciding on spending and taxes and thus may not respond optimally to shocks with different degrees of persistence.

of economic activity on the fiscal stance. Thus, Equation (3) is estimated using two-stage least squares (2SLS), with lagged values of GDP cycles as instruments for current values of GDP cycles.

In the regressions, I test sequentially each possible non-linearity between the fiscal stance and the terms of trade. More precisely, when examining for the effect of liquid international capital markets, the index I is equal to one during episodes of worldwide capital flow bonanzas and zero otherwise. When examining the presence of asymmetric responses to booms and busts in the terms of trade, the index I is equal to one when the country experiences a terms of trade boom and zero otherwise. When studying whether countries respond differently to transitory and permanent terms of trade shocks, I is equal to one for countries with permanent shocks and zero otherwise. When evaluating whether the exchange rate regime matters, the indicator I is equal to one when the country adopts a flexible exchange rate regime and zero otherwise. Finally, when studying whether resource-abundant countries respond differently to terms of trade shocks, I is equal to one for resource-abundant countries and zero otherwise. That is, the coefficient β will capture, respectively, the response of the fiscal indicator to terms of trade fluctuations in times of illiquidity in world capital markets, in times when the terms of trade are not booming, in countries with transitory terms of trade shocks, in years of fixed exchange rate regimes, and in countries which are not resource-abundant. $\beta + \gamma$ will capture, respectively, the response of the fiscal indicators to terms of trade shocks at times of capital flow bonanzas, in times of booms in the terms of trade, in countries with permanent terms of trade shocks, in years with flexible exchange rates, and in resource-abundant countries.

Tables 1–4 show the panel regressions for cycles in government primary balances, government revenues, government spending and inflation, respectively. Four panel models are estimated separately according to income groups: high-income (OECD), upper-middle-income, lower-middle-income, and low-income countries.

For each fiscal indicator, there are six regressions. The top regression provides the benchmark. The other five regressions allow for non-linearities in the responses to terms of trade shocks. Each regression includes the terms of trade cycle; the coefficient of this variable is β (from Equation (3)). The next variable captures the possible non-linear effects. The coefficient on this variable is γ (from Equation (3)). The final variable is the GDP cycle. The coefficient of this variable is δ (from Equation (3)).

Table 1 shows the relationship between cycles in fiscal primary balances and cycles in the terms of trade and overall GDP. It is important to highlight the varied responses across the different income groups. First, fiscal balances in OECD countries increase with output, suggesting the presence of countercyclical or acyclical fiscal policies.[8] This is not the case in developing countries. In middle-income countries, fiscal balances tend to decline with output, suggesting more procyclical policies, while in low-income countries, fiscal balances are uncorrelated with GDP cycles. To examine whether the responses are economically significant, I estimate the elasticity

8. Even if government expenditure and tax rates do not change (acyclical policy), primary balances improve with increases in output.

Table 1: Cycles in Government Primary Balance and Terms of Trade

$$cY_{i,t} = \alpha_i + \beta ctot_{i,t} + \gamma ctot_{i,t} \times I^j_{i,t} + \delta X_{i,t} + \varepsilon_{i,t}$$

Regressions	Explanatory variables	Countries							
		High-income (OECD)		Upper-middle-income		Lower-middle-income		Low-income	
		Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Benchmark	Constant	–0.03	(0.93)	0.003	(0.87)	0.07	(0.97)	0.01	(0.99)
	Terms of trade	0.06	(0.13)	0.31	(0.00)	0.16	(0.25)	0.001	(0.98)
	GDP	0.01	(0.00)	–0.003	(0.00)	–0.001	(0.00)	1×10^{-4}	(0.77)
1	Terms of trade	0.04	(0.53)	0.40	(0.00)	0.59	(0.01)	–0.02	(0.65)
	Terms of trade x capital flow bonanzas	–0.15	(0.10)	–0.17	(0.01)	–0.75	(0.02)	0.06	(0.46)
	GDP	0.01	(0.00)	–0.003	(0.00)	–0.001	(0.00)	2×10^{-4}	(0.76)
2	Terms of trade	0.06	(0.29)	0.44	(0.00)	0.43	(0.06)	0.04	(0.53)
	Terms of trade x terms of trade booms	–0.00	(0.98)	–0.23	(0.00)	–0.57	(0.14)	–0.08	(0.46)
	GDP	0.01	(0.00)	–0.002	(0.00)	–0.001	(0.00)	2×10^{-4}	(0.76)
3	Terms of trade	0.02	(0.61)	0.10	(0.03)	–0.12	(0.68)	0.02	(0.68)
	Terms of trade x flexible exchange rates	0.27	(0.11)	0.20	(0.00)	0.27	(0.41)	–0.01	(0.92)
	GDP	0.01	(0.00)	–0.002	(0.00)	–0.001	(0.00)	-2×10^{-4}	(0.76)
4	Terms of trade	0.07	(0.11)	–0.01	(0.87)	0.09	(0.75)	–0.03	(0.56)
	Terms of trade x persistent terms of trade shocks	–0.08	(0.57)	0.48	(0.00)	0.08	(0.80)	0.06	(0.41)
	GDP	0.01	(0.00)	–0.003	(0.00)	–0.001	(0.00)	1×10^{-4}	(0.79)
5	Terms of trade	0.06	(0.12)	0.002	(0.98)	0.04	(0.86)	–0.03	(0.58)
	Terms of trade x commodity-producing countries	–0.05	(0.70)	0.38	(0.00)	0.18	(0.53)	0.10	(0.27)
	GDP	0.01	(0.00)	–0.003	(0.00)	–0.001	(0.00)	2×10^{-4}	(0.78)

Source: author's calculations

of fiscal balances to GDP cycles (evaluated at the mean value of primary balance and GDP cycles).[9] The elasticities of primary balances with respect to GDP cycles are: 2.00 for OECD countries, –0.60 for upper-middle-income countries, and –0.04 for lower-middle-income countries, indicating strong responses in both high-income and upper-middle-income countries. Second, fiscal balances in OECD and low-income countries are not affected by terms of trade cycles. Third, the response of primary balances to terms of trade cycles in middle-income countries are affected by the extent of liquidity in international capital markets, episodes of terms of trade booms or busts, and exchange rate regimes. As shown in Regression (1), in times of international capital market liquidity, the response of fiscal balances to terms of trade cycles in lower-middle-income countries is negative, with the fiscal balance deteriorating when the terms of trade are rising and improving when the terms of trade are falling, suggesting procyclical responses to terms of trade fluctuations. In the case of upper-middle-income countries, the response of fiscal balances to terms of trade cycles, while still positive in episodes of capital flow bonanza, is significantly smaller, indicating a less countercyclical policy than during episodes of illiquidity in international capital markets. For upper-middle-income countries, the elasticity of fiscal balances to terms of trade cycles is equal to 2.00 in times of illiquid international capital markets and 1.00 in episodes of capital flow bonanza. The corresponding elasticity for lower-middle-income countries is respectively 0.40 and –0.10. Also, as shown in Regression (2), there is evidence of asymmetric responses to terms of trade booms and busts. The fiscal balance of upper- and lower-middle-income countries responds less countercyclically in times of terms of trade booms. Again in this case, responses in upper-middle-income countries are stronger in terms of elasticities (2.00 and 1.00 for upper-middle-income countries and 0.30 and –0.10 for lower-middle-income countries, respectively for times of terms of trade busts and booms). Furthermore, as shown in Regression (3), responses to terms of trade cycles in middle-income countries depend on the exchange rate regime. Flexible exchange rate regimes seem to fuel more countercyclical fiscal policies in both upper-middle- and lower-middle-income countries, providing some support to the model in Tornell and Velasco (2000). Third, as shown in Regression (4), for most income groups, the degree of persistence of terms of trade shocks does not seem to matter. Surprisingly, primary balances of upper-middle-income countries tend to improve more in countries with more persistent terms of trade.[10] Fourth, responses to terms of trade cycles in commodity-producing countries are significantly different from those in non-commodity-producing countries only in the upper-middle-income group.

Table 2 shows the responses of government revenues to fluctuations in the terms of trade. As in the previous table, all the regressions control for cycles in GDP and allow for non-linear responses to terms of trade shocks. While the results in this

9. I use the mean of the absolute value of the primary balance and GDP cycles since, by construction, these cycles have zero mean.

10. These results should be interpreted with caution since the degree of persistence of terms of trade shocks is estimated by using information on the evolution of terms of trade for all of the sample period. Governments, in contrast, may underestimate or overestimate the degree of persistence of shocks by using available past information.

Table 2: Cycles in Government Revenues and Terms of Trade

$$cY_{i,t} = \alpha_i + \beta ctot_{i,t} + \gamma ctot_{i,t} \times I^j_{i,t} + \delta X_{i,t} + \varepsilon_{i,t}$$

Regressions	Explanatory variables	Countries							
		High-income (OECD)		Upper-middle-income		Lower-middle-income		Low-income	
		Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Benchmark	Constant	0.05	(0.90)	0.003	(0.99)	–0.12	(0.95)	–0.01	(0.99)
	Terms of trade	–0.01	(0.71)	0.08	(0.00)	0.26	(0.02)	–0.03	(0.25)
	GDP	0.004	(0.00)	0.001	(0.24)	0.001	(0.00)	0.003	(0.00)
1	Terms of trade	–0.07	(0.24)	0.11	(0.00)	0.42	(0.02)	–0.03	(0.50)
	Terms of trade x capital flow bonanzas	–0.10	(0.29)	0.01	(0.93)	–0.49	(0.09)	–0.03	(0.72)
	GDP	0.004	(0.00)	0.001	(0.23)	0.001	(0.01)	0.003	(0.00)
2	Terms of trade	0.01	(0.82)	0.15	(0.00)	0.69	(0.00)	–0.02	(0.71)
	Terms of trade x terms of trade booms	–0.06	(0.52)	–0.12	(0.01)	–0.77	(0.02)	–0.02	(0.81)
	GDP	0.004	(0.00)	0.001	(0.21)	0.001	(0.00)	0.003	(0.00)
3	Terms of trade	–0.02	(0.68)	0.03	(0.22)	0.60	(0.00)	–0.01	(0.64)
	Terms of trade x flexible exchange rates	–0.23	(0.17)	0.06	(0.06)	–0.63	(0.01)	0.01	(0.68)
	GDP	0.004	(0.00)	0.001	(0.11)	0.001	(0.00)	0.006	(0.00)
4	Terms of trade	0.04	(0.36)	–0.01	(0.80)	0.03	(0.90)	–0.04	(0.19)
	Terms of trade x persistent terms of trade shocks	–0.33	(0.00)	0.14	(0.00)	0.29	(0.29)	0.03	(0.51)
	GDP	0.004	(0.00)	0.0004	(0.41)	0.001	(0.00)	0.003	(0.00)
5	Terms of trade	–0.02	(0.69)	–0.01	(0.45)	–0.02	(0.90)	–0.04	(0.19)
	Terms of trade x commodity-producing countries	0.02	(0.89)	0.18	(0.00)	0.56	(0.02)	0.05	(0.50)
	GDP	0.004	(0.00)	0.001	(0.14)	0.001	(0.00)	0.003	(0.00)

Source: author’s calculations

table indicate that fiscal revenues increase with output across all groups of countries, these responses are far stronger in OECD countries. For the high-income group, the elasticity is equal to 0.80. In contrast, the elasticities of government revenues with respect to the cycles in GDP vary from 0.03 for lower-middle-income countries and 0.32 in low-income countries, with the elasticity of upper-middle-income countries equal to 0.12. Again, the responses to terms of trade cycles in middle-income countries are different from those in OECD and low-income countries. In OECD and low-income countries, government revenues are uncorrelated with terms of trade cycles. For middle-income countries, Table 2 indicates that while there is an overall positive link between government revenues and terms of trade cycles (a sign of either countercyclical or acyclical responses to terms of trade shocks), this link is weaker or even reversed in times of international capital flow bonanzas and in episodes of terms of trade booms (evidence of more procyclical responses to terms of trade cycles). Table 2 also shows that the exchange rate regime affects the responses of government revenues to terms of trade cycles. Again, for upper-middle-income countries, responses of government revenues to terms of trade cycles tend to be more countercyclical during floating exchange rates, with elasticities of 0.60 and 0.20 under flexible exchange rate and fixed exchange rate regimes, respectively. In contrast, for lower-middle-income countries, fiscal revenues seem to become more procyclical during flexible exchange rate regimes. Lastly, as shown in Regression (5), government revenues in middle-income countries are only positively related to terms of trade cycles in resource-abundant countries.

Table 3 shows the responses of government spending to terms of trade cycles and the overall business cycle. Supporting previous results in the literature, Table 3 shows that responses to GDP cycles in OECD countries are countercyclical, while they are procyclical in all developing countries (as captured by the positive and statistically significant coefficient of the GDP cycle). Responses to terms of trade cycles are also different across countries in different income groups. Overall, terms of trade cycles do not affect government spending in OECD and low-income countries. Interestingly, responses of government spending to terms of trade fluctuations are countercyclical in upper-middle-income countries but procyclical in lower-middle-income countries. Importantly, when examining the role of the exchange rate regime in the responses to terms of trade shocks, the evidence suggests that government spending in middle-income countries is countercyclical only when exchange rates are floating.

Table 4 links inflation to fluctuations in the terms of trade. The experience in low- and middle-income countries with bouts of hyperinflation and overall chronic inflation during most of the years of the sample examined suggests that terms of trade fluctuations are not the main drivers of inflation. The results in Table 4 confirm this expectation. The evidence for OECD countries indicates that overall inflation increases when economic activity is strong. Interestingly, inflation declines with increases in the terms of trade, suggesting perhaps the effects of lower commodity prices since most of the OECD countries are commodity importers.[11]

11. It may also reflect the effect of an appreciation of the exchange rate when the terms of trade are high. This is also consistent with the stronger effect for flexible exchange rate regimes.

Table 3: Cycles in Government Expenditure and Terms of Trade

$$cY_{i,t} = \alpha_i + \beta ctot_{i,t} + \gamma ctot_{i,t} \times I^j_{i,t} + \delta X_{i,t} + \varepsilon_{i,t}$$

Regressions	Explanatory variables	Countries							
		High-income (OECD)		Upper-middle-income		Lower-middle-income		Low-income	
		Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Benchmark	Constant	–0.07	(0.88)	0.003	(0.94)	–0.10	(0.96)	0.02	(0.97)
	Terms of trade	0.02	(0.62)	–0.05	(0.00)	0.14	(0.19)	–0.03	(0.19)
	GDP	–0.001	(0.00)	0.002	(0.00)	0.001	(0.00)	0.003	(0.00)
1	Terms of trade	0.03	(0.69)	–0.08	(0.00)	0.17	(0.34)	–0.01	(0.77)
	Terms of trade x capital flow bonanzas	0.01	(0.92)	0.02	(0.56)	–0.16	(0.54)	–0.08	(0.20)
	GDP	–0.001	(0.01)	0.002	(0.00)	0.001	(0.09)	0.003	(0.00)
2	Terms of trade	0.06	(0.32)	–0.11	(0.00)	0.39	(0.06)	–0.08	(0.12)
	Terms of trade x terms of trade booms	–0.10	(0.37)	–0.08	(0.05)	–0.44	(0.16)	0.07	(0.30)
	GDP	–0.001	(0.00)	0.002	(0.00)	0.001	(0.00)	0.003	(0.00)
3	Terms of trade	0.03	(0.57)	–0.01	(0.79)	0.54	(0.02)	–0.03	(0.15)
	Terms of trade x flexible exchange rates	–0.08	(0.69)	–0.08	(0.03)	–0.72	(0.01)	0.02	(0.43)
	GDP	–0.001	(0.00)	0.002	(0.00)	0.001	(0.00)	0.006	(0.00)
4	Terms of trade	0.03	(0.50)	–0.01	(0.58)	–0.02	(0.93)	–0.03	(0.34)
	Terms of trade x persistent terms of trade shocks	–0.08	(0.52)	–0.06	(0.05)	0.20	(0.44)	–0.01	(0.91)
	GDP	–0.001	(0.00)	0.002	(0.00)	1×10^{-4}	(0.00)	0.003	(0.00)
5	Terms of trade	0.02	(0.60)	–0.01	(0.60)	–0.02	(0.91)	–0.03	(0.33)
	Terms of trade x commodity-producing countries	–0.03	(0.82)	–0.08	(0.01)	0.32	(0.16)	–0.03	(0.68)
	GDP	–0.001	(0.00)	0.002	(0.00)	0.001	(0.00)	0.003	(0.00)

Source: author's calculations

Table 4: Cycles in Inflation and Terms of Trade

$$cY_{i,t} = \alpha_i + \beta ctot_{i,t} + \gamma ctot_{i,t} \times I^j_{i,t} + \delta X_{i,t} + \varepsilon_{i,t}$$

Regressions	Explanatory variables	Countries							
		High-income (OECD)		Upper-middle-income		Lower-middle-income		Low-income	
		Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Benchmark	Constant	0.01	(0.91)	–1.03	(0.89)	–3.03	(0.75)	–0.8	(0.94)
	Terms of trade	–0.04	(0.00)	0.02	(0.97)	0.13	(0.83)	-2×10^{-4}	(0.99)
	GDP	1×10^{-4}	(0.10)	0.002	(0.90)	5×10^{-5}	(0.96)	-7×10^{-4}	(0.43)
1	Terms of trade	–0.04	(0.01)	–0.80	(0.42)	0.16	(0.89)	–0.03	(0.96)
	Terms of trade x capital flow bonanzas	–0.05	(0.01)	1.43	(0.33)	0.002	(0.99)	0.02	(0.86)
	GDP	1×10^{-4}	(0.19)	0.003	(0.85)	5×10^{-5}	(0.97)	–0.001	(0.47)
2	Terms of trade	–0.06	(0.00)	1.04	(0.36)	0.55	(0.63)	–0.12	(0.13)
	Terms of trade x terms of trade booms	0.04	(0.05)	–1.64	(0.30)	–0.74	(0.66)	0.20	(0.08)
	GDP	1×10^{-4}	(0.11)	0.003	(0.87)	5×10^{-5}	(0.96)	-1×10^{-4}	(0.43)
3	Terms of trade	–0.03	(0.00)	–0.08	(0.93)	–0.16	(0.87)	0.27	(0.00)
	Terms of trade x flexible exchange rates	–0.07	(0.13)	0.39	(0.76)	0.73	(0.59)	–0.23	(0.00)
	GDP	1×10^{-4}	(0.02)	2×10^{-4}	(0.99)	1×10^{-4}	(0.93)	-1×10^{-4}	(0.27)
4	Terms of trade	–0.04	(0.00)	–0.67	(0.45)	–0.01	(0.99)	–0.01	(0.86)
	Terms of trade x persistent terms of trade shocks	–0.01	(0.89)	1.09	(0.33)	0.19	(0.88)	0.03	(0.75)
	GDP	1×10^{-4}	(0.10)	8×10^{-4}	(0.95)	5×10^{-5}	(0.96)	–0.001	(0.43)
5	Terms of trade	–0.04	(0.00)	–0.30	(0.72)	–0.14	(0.87)	–0.01	(0.81)
	Terms of trade x commodity-producing countries	–0.03	(0.89)	0.52	(0.62)	0.51	(0.67)	0.03	(0.80)
	GDP	1×10^{-4}	(0.10)	0.002	(0.89)	9×10^{-5}	(0.94)	-1×10^{-4}	(0.41)

Source: author's calculations

Table 5 examines in more detail the responses of the fiscal stance to terms of trade cycles in resource-abundant countries. This table only reports the responses in upper-middle-income countries because the results in Tables 1–3 indicate that it is in this group of countries where the fiscal stance is significantly different in commodity-producing countries. In particular, Table 5 explores whether responses to terms of trade cycles in resource-abundant countries are affected by episodes of capital flow bonanzas, terms of trade booms and busts, and fixed and flexible exchange rate regimes. The estimated regression in Table 5 is

$$cY_{i,t} = \alpha_i + \beta ctot_{i,t} + \gamma ctot_{i,t} \times I_{i,t}^{com} + \rho ctot_{i,t} \times I_{i,t}^{com} \times I_{i,t}^{j} + \delta X_{i,t} + \varepsilon_{i,t} \quad (4)$$

where: I^{com} captures whether the country is a commodity-producing country; and I^{j} captures alternately the episodes of capital flow bonanzas, booms in the terms of trade, and episodes of flexible exchange rate regimes.

As in Tables 1–3, the results in Table 5 indicate that terms of trade cycles in the upper-middle-income group only affect the fiscal stance in commodity-producing countries. While fiscal policy in upper-middle-income countries is procyclical with respect to fluctuations in GDP, it is countercyclical with respect to terms of trade fluctuations. However, the degree of countercyclicality declines sharply in episodes of capital flow bonanza and in times of booms in the terms of trade, suggesting that the claim that 'all that glitters may not be gold' may in fact have some support. In particular, the combination of booms in the terms of trade and the increase in liquidity in international capital markets from 2003 to 2008 may have fueled an easy fiscal policy in commodity-producing countries with access to international capital markets. In contrast, the results in Table 5 suggest that the degree of countercyclicality increases during episodes of flexible exchange rates. The results on the links between exchange rate regimes and fiscal policy are preliminary and need to be examined in a larger sample of commodity-producing countries, but the possibility that flexible exchange rates may contribute to less distortionary fiscal policies merits our full attention.

5. Conclusions

This paper has examined the links between the fiscal stance and terms of trade cycles. While still much more analysis needs to be undertaken to refine our understanding of the links between the terms of trade fluctuations and fiscal policies, the main findings of the paper can be summarised as follows:

(i) Confirming the results in the empirical literature, the results in this paper indicate that fiscal policy is countercyclical in OECD countries (*vis à vis* GDP). In contrast, fiscal policy is procyclical (*vis à vis* GDP) for developing countries.

(ii) In OECD and low-income countries, fiscal policy is acyclical with regards to the terms of trade. Moreover, the responses of the fiscal stance to terms of trade cycles are not affected by international capital liquidity, exchange rate regimes or the degree of persistence of the shocks.

Table 5: Cycles in Fiscal Policy and Terms of Trade for Upper-middle-income, Commodity-producing Countries

$$cY_{i,t} = \alpha_i + \beta ctot_{i,t} + \gamma ctot_{i,t} \times I_{i,t}^{com} + \rho ctot_{i,t} \times I_{i,t}^{com} \times I_{i,t}^{j} + \delta X_{i,t} + \varepsilon_{i,t}$$

Explanatory variables	Government primary balance			Government revenues			Government expenditure		
Terms of trade	0.002 (0.97)	0.004 (0.95)	0.003 (0.96)	–0.02 (0.49)	–0.02 (0.44)	–0.02 (0.31)	–0.02 (0.61)	–0.01 (0.61)	–0.02 (0.52)
Terms of trade x commodity-producing countries	0.46 (0.00)	0.57 (0.00)	0.11 (0.15)	0.30 (0.00)	0.24 (0.00)	0.08 (0.03)	–0.17 (0.00)	–0.13 (0.00)	0.01 (0.81)
Terms of trade x commodity-producing countries x capital flow bonanzas	–0.17 (0.02)			–0.11 (0.03)			0.11 (0.04)		
Terms of trade x commodity-producing countries x terms of trade booms		–0.35 (0.01)			–0.10 (0.05)			0.08 (0.15)	
Terms of trade x commodity-producing countries x flexible exchange rates			0.37 (0.00)			0.15 (0.00)			–0.13 (0.01)
GDP	–0.002 (0.00)	–0.002 (0.00)	–0.003 (0.00)	0.001 (0.12)	0.001 (0.10)	0.001 (0.07)	0.002 (0.00)	0.002 (0.00)	0.002 (0.00)
Adjusted R^2	0.22	0.24	0.17	0.23	0.18	0.14	0.09	0.09	0.11
Number of observations	360	360	324	426	498	454	426	498	454
F-statistic	7.87	8.47	5.51	5.71	4.72	2.90	1.60	1.70	1.37
Prob(*F*-statistic)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.06)	(0.04)	(0.13)

Note: *p*-values in parentheses
Source: author's calculations

(iii) For upper-middle-income countries, there is evidence of fiscal policy countercyclicality with respect to the terms of trade. But the degree of countercyclicality declines in episodes of capital flow bonanzas or during episodes of terms of trade booms, suggesting that in those episodes these countries may not be saving enough for a rainy day. Importantly, flexible exchange rate regimes seem to contribute to a more countercyclical fiscal policy.

(iv) For lower-middle-income countries, there is even evidence suggesting that fiscal policy responds procyclically to terms of trade fluctuations; that is, there is evidence that fiscal policy contributes to reinforce the terms of trade cycle. Again, as in upper-middle-income countries, episodes of capital flow bonanza and terms of trade boom fuel even more procyclicality while flexible exchange rate regimes enhance countercyclicality.[12]

These findings suggest that the boom in commodity prices during the latest episode of capital flow bonanza may have fueled a procyclical policy in middle-income countries that reinforced the terms of trade cycle. While a variety of models explain why countries follow these sub-optimal fiscal policies, we need to find mechanisms that would enable macro policies to be conducted in a neutral or stabilising way. In this regard, the suggestive results on flexible exchange rates for upper-middle-income countries deserve our full attention.

12. I should note that in lower-middle-income countries, flexible exchange rates seem to contribute to lower government revenues when the terms of trade increase. However, this effect is not significant from an economic point of view. The elasticity of the government revenues with respect to terms of trade cycles in these countries is quite small: 0.04 for fixed exchange rates and 0 for flexible exchange rates.

Appendix A: Data

Table A1: Data Sources

Indicator	Source
1. External	
Terms of trade	IMF, WEO
2. Fiscal – general or consolidated government:	
Expenditure	IMF, WEO
Primary balance	IMF, WEO
Revenues	IMF, WEO
4. Other	
Real GDP	IMF, WEO
GDP deflator	IMF, WEO
Consumer price index	IMF, 'International Financial Statistics'

Table A2: Countries in the Sample

Low-income countries (14)	Lower-middle-income countries (21)	Upper-middle-income countries (17)	High-income OECD countries (22)
Cambodia	Albania	Argentina	Australia
Côte d'Ivoire	Angola	Brazil	Austria
Ethiopia	Cameroon	Bulgaria	Belgium
Kenya	China	Chile	Canada
Lao, People's Dem Rep	Colombia	Costa Rica	Denmark
Malawi	Congo, Republic of	Latvia	Finland
Mozambique	Egypt	Lebanon	France
Nigeria	El Salvador	Lithuania	Germany
Pakistan	Honduras	Malaysia	Greece
Senegal	India	Mexico	Hungary
Tanzania	Indonesia	Panama	Iceland
Uganda	Iran	Poland	Ireland
Vietnam	Jordan	Russia	Italy
Yemen	Morocco	South Africa	Japan
	Paraguay	Turkey	Netherlands
	Peru	Uruguay	New Zealand
	Philippines	Venezuela	Norway
	Syrian Arab Republic		South Korea
	Thailand		Spain
	Tunisia		Sweden
	Ukraine		United Kingdom
			United States

References

Acemoglu D, S Johnson, J Robinson and Y Thaicharoen (2003), 'Institutional Causes, Macroeconomic Symptoms: Volatility, Crises and Growth', *Journal of Monetary Economics*, 50(1), pp 49–123.

Aghevli BB, MS Khan and PJ Montiel (1991), 'Exchange Rate Policies in Developing Countries: Some Analytical Issues', IMF Occasional Paper No 78.

Alesina A and G Tabellini (2005), 'Why Is Fiscal Policy Often Procyclical?', NBER Working Paper No 11600.

Barnett S and R Ossowski (2003), 'Operational Aspects of Fiscal Policy in Oil-Producing Countries', in J Davis, R Ossowski and A Fedelino (eds), *Fiscal Policy Formulation and Implementation in Oil-Producing Countries*, IMF, Washington DC, pp 45–81.

Caballero RJ and A Krishnamurthy (2004), 'Fiscal Policy and Financial Depth', NBER Working Paper No 10532.

Calderón C and K Schmidt-Hebbel (2003), 'Macroeconomic Policies and Performance in Latin America', *Journal of International Money and Finance*, 22(7), pp 895–923.

Chari VV and PJ Kehoe (1999), 'Optimal Fiscal and Monetary Policy', NBER Working Paper No 6891.

Davis J, R Ossowski, J Daniel and S Barnett (2001), 'Stabilization and Savings Funds for Nonrenewable Resources: Experience and Fiscal Policy Implications', IMF Occasional Paper No 205.

Frenkel JA, M Goldstein and PR Masson (1991), 'Characteristics of a Successful Exchange Rate System', IMF Occasional Paper No 82.

Gavin M and R Perotti (1997), 'Fiscal Policy in Latin America', in BS Bernanke and JJ Rotemberg (eds), *NBER Macroeconomics Annual 1997*, 12, MIT Press, Cambridge, pp 11–61.

Giavazzi F and M Pagano (1988), 'The Advantage of Tying One's Hands: EMS Discipline and Central Bank Credibility', *European Economic Review*, 32(5), pp 1055–1075.

Guerson A (2004), 'On the Optimality of Procyclical Fiscal Policy when Governments Are Not Credible', unpublished PhD dissertation, George Washington University.

Ilzetzki E (2009), 'Rent-Seeking Distortions and Fiscal Procyclicality', mimeo, University of Maryland.

Izquierdo JA and E Talvi (2008), 'All That Glitters May Not Be Gold: Asessing Latin America's Recent Macroeconomic Performance', Inter-American Development Bank Research Department Report.

Kaminsky GL, CM Reinhart and CA Végh (2005), 'When It Rains, It Pours: Procyclical Capital Flows and Macroeconomic Policies', in M Gertler and KS Rogoff (eds), *NBER Macroeconomics Annual 2004*, 19, MIT Press, Cambridge, pp 11–53.

Kent C and P Cashin (2003), 'The Response of the Current Account to Terms of Trade Shocks: Persistence Matters', IMF Working Paper No 03/143.

Lane PR and A Tornell (1996), 'Power, Growth, and the Voracity Effect', *Journal of Economic Growth*, 1(2), pp 213–241.

Reinhart CM and VR Reinhart (2008), 'Capital Flow Bonanzas: An Encompassing View of the Past and Present', NBER Working Paper No 14321.

Reinhart CM and KS Rogoff (2004), 'The Modern History of Exchange Rate Arrangements: A Reinterpretation', *Quarterly Journal of Economics*, 119(1), pp 1–48.

Riascos A and CA Végh (2003), 'Procyclical Government Spending in Developing Countries: The Role of Capital Market Imperfections', Banco de la República and UCLA (University of California, Los Angeles), mimeo.

Talvi E and CA Végh (2005), 'Tax Base Variability and Procyclical Fiscal Policy in Developing Countries', *Journal of Development Economics*, 78(1), pp 156–190.

Tornell A and PR Lane (1999), 'The Voracity Effect', *American Economic Review*, 89(1), pp 22–46.

Tornell A and A Velasco (2000), 'Fixed Versus Flexible Exchange Rates: Which Provides More Fiscal Discipline?', *Journal of Monetary Economics*, 45(2), pp 399–436.

Discussion

1. Lawrence L Schembri[1]

Overall impression and key findings

This paper investigates the impact of terms of trade movements on the stance of fiscal policy. This analysis is timely and important because the volatility of the terms of trade has increased in recent years, largely due to significant fluctuations in commodity prices. Moreover, the prominence of fiscal policy has increased as countries have adopted aggressive discretionary actions to combat the global recession. Although the paper includes a selected review of the related theoretical literature, its primary purpose is empirical: that is, to determine what can be learned about this relationship from the data.

Like much of Graciela Kaminsky's well-known research, this investigation uses a comprehensive and carefully collected dataset, consisting of observations on 74 countries over the period 1960 to 2008, and adopts a rigorous, yet robust, approach to analysing these data.[2] In particular, three fiscal variables – primary government balance, government expenditure and government revenue – as well as inflation, are regressed on the terms of trade, on the deviation of output from trend (to control for the business cycle), and on nonlinear interaction variables between the terms of trade and global capital flow bonanzas, terms of trade booms (to capture asymmetric effects), large terms of trade movements and the exchange rate regime. She also divides the sample of countries into four groups according to level of per capita income to control for differences in behaviour due to differences in level of development.

From this empirical exercise, Graciela obtains some useful inferences that highlight the key differences in the fiscal policy reactions to terms of trade movements across countries. In particular, she finds that developing countries typically run procyclical fiscal policies; that is, government expenditures rise, for example, with an increase in the terms of trade. She also finds that this procyclical effect is magnified by sizable capital flow bonanzas, which typically occur at the same time as the terms of trade increase. In contrast, she finds that OECD countries can effectively smooth the economic impact of transitory terms of trade movements by running countercyclical fiscal policies.

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2. Much of the data, including the terms of trade series, are filtered with a Hodrick-Prescott filter.

All terms of trade shocks are not created equal

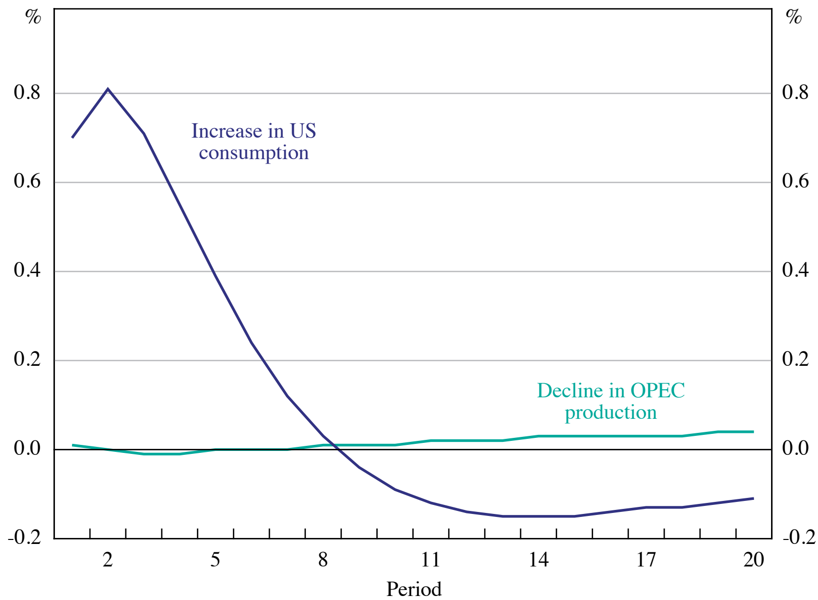
The regression analysis treats all terms of trade shocks as being equal and exogenous, although an effort is made to control for nonlinear effects of terms of trade shocks due to the magnitude (larger shocks could have a bigger impact) and to asymmetry (positive and negative shocks could have different effects). In theory and in practice, the underlying causes of the terms of trade shock matter. For example, a terms of trade improvement can occur because of an increase in export prices (due to a commodity price increase for a commodity exporter) or because of a reduction in import prices (due to increased imports from a lower-priced source country such as China). These two underlying changes are unlikely to have the same impact on the fiscal policy stance, despite the fact that they both cause a terms of trade increase, especially because the production and sale of commodities are taxed differently from that of other goods and services to ensure that a portion of the natural resource rents accrue to the government. To address this potential problem, the empirical analysis should focus on one source of terms of trade shocks, namely, commodity price variations, by dividing the sample of countries into commodity price exporters and importers and by constructing country-specific exporter or importer commodity price indices.

Even for commodity price movements, the macroeconomic impact of the movement depends on the underlying fundamental shock. For example, an oil price increase could be the result of a demand shock or a supply shock and the impact on output and the fiscal stance would be very different. Consider Figure 1: it shows the simulated impacts of a 10 per cent increase in oil prices on Canadian GDP generated by a temporary reduction in supply and by a temporary increase in US demand.[3] Despite the fact that the increase in oil prices is the same, the effects on Canadian GDP and thus the fiscal stance are radically different because stronger US demand is a large positive shock to the Canadian economy, whereas an oil supply shock has a much smaller impact because it slows down US economic activity. The empirical work in this paper does not control for the sources of the terms of trade movements nor is it able to take into account the general equilibrium effects. To address this issue would require a more structural estimation approach that can uncover the underlying fundamental shocks.

3. This simulation was conducted by Stephen Snudden using the Bank of Canada's global DSGE model, BoC-GEM. For more details on BoC-GEM, consult Lalonde and Muir (2007).

Figure 1: Canada's GDP Response to a Positive 10 Per Cent Oil Price Shock

Per cent deviation from control



Source: Bank of Canada

The econometric approach also assumes that all terms of trade movements are exogenous. Although this is a useful first approximation, it is not generally true. There are many examples in which the economic activity of the home economy has affected its terms of trade. In particular, the US high-tech boom of the 1990s drove down the relative price of information technology and communications equipment through rapid technology improvements and supply increases. Other things being equal, this had the effect of reducing the US terms of trade. A similar story can be told for China regarding its production and export of semi-durables and durables after it joined the World Trade Organization in 2002. Consequently, the estimation techniques should also include instrumental variables estimation to control for the potential endogeneity of the terms of trade.

Although the advantage of using the terms of trade is that this data series is available for each country, the terms of trade variable is subject to measurement problems that represent important caveats to the empirical results.[4] Central bankers, especially those that are inflation targeters, spend a lot of time worrying about measurement issues surrounding the consumer price index (CPI) and also how to measure the 'underlying' rate of inflation.[5] Since the terms of trade represents the ratio of two

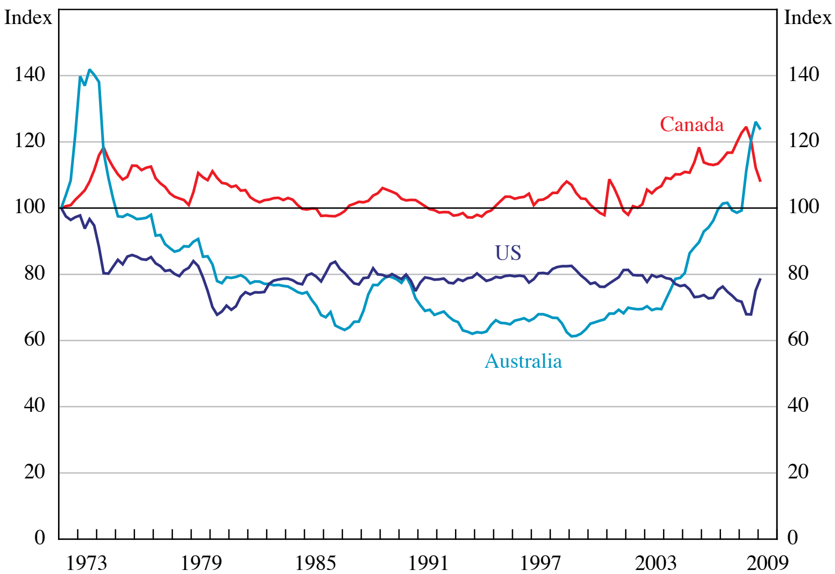
4. Silver (2007) provides a useful recent discussion of the measurement problems surrounding import and export price indices which are used to construct the terms of trade.

5. The paper by Francesco Ravazzolo and Shaun Vahey in this volume addresses the issue of measuring the underlying rate of inflation.

baskets of goods, as opposed to one in the case of the CPI, the potential measurement issues are compounded. Figure 2 shows the terms of trade measures for Canada, the United States and Australia. I am most familiar with the first two measures and what I find most striking about them is how smooth they are, despite the significant movements in the structure of global trade and in relative prices witnessed over the past 25 years. Indeed, I question how meaningful the variation would be in these two series after applying a Hodrick-Prescott filter to them. Figure 3 compares the Canadian terms of trade to the Bank of Canada's commodity price index. The difference between the two series is striking, especially since commodity-based products represent roughly 40 per cent of Canadian exports. Therefore, given the potential measurement errors with the terms of trade, using an index of commodity prices, as suggested earlier, may generate more efficient and more economically meaningful results.

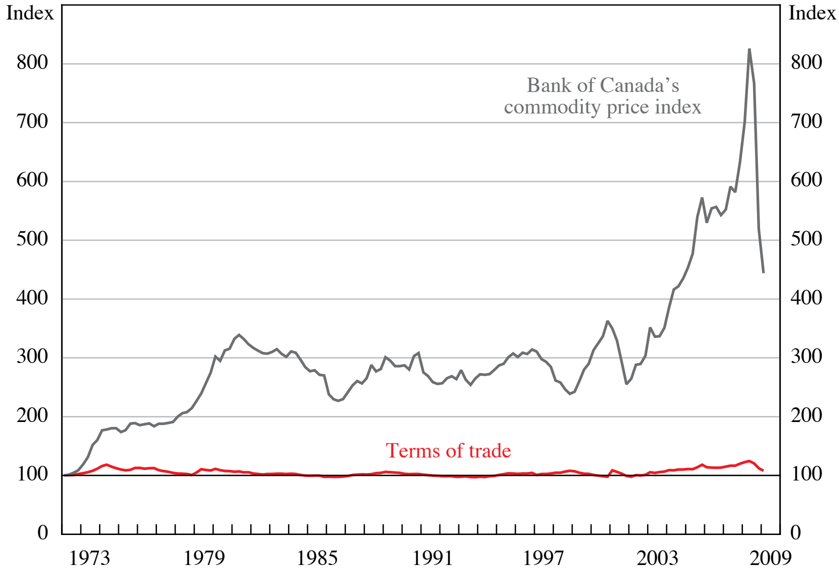
Figure 2: Terms of Trade

March quarter 1972 = 100



Source: IMF

Figure 3: Terms of Trade and Commodity Price Index – Canada
March quarter 1972 = 100



Sources: Bank of Canada; IMF

Political economy considerations

The paper's main finding that the response of fiscal positions to terms of trade movements differs greatly between developing and developed economies raises the question of why this may be true. Although the paper does raise some political economy issues, it does not explore them fully in the regression analysis. Two popular explanations of the different fiscal responses in developing and developed countries that are worth considering more carefully are known as the 'resource curse' and the 'Dutch disease'.

The resource curse argues that when there is a natural resource revenue windfall either because of a discovery or a rapid rise in prices, this serves to undermine a country's governance structure. Politicians have the incentive to use the windfall to maintain power by effectively buying votes or empowering their supporters so that they can eventually divert some of the windfall to themselves.[6] Hence, rather than smooth the consumption of this windfall by saving a portion of it, their incentive is to spend it immediately upon receipt. Consequently, fiscal expenditures would be procyclical in developing countries without appropriate governance controls.

In the case of the Dutch disease, the political effect is often felt more in developed economies with relatively diversified economies because a resource windfall will

6. See Sachs and Warner (2001) and Mehlum, Moene and Torvik (2006) for a more detailed explanation of the 'resource curse'.

typically cause inter-sectoral resource reallocation that entrenched interests will attempt to resist.[7] In particular, because the windfall will accrue to the private sector as well as the public sector, there will be an increased demand for non-traded goods (chiefly housing and government services) as well as for resources. To accommodate this demand the remaining export-oriented/import-competing traded goods sector will have to contract. Because this sector often consists of manufacturing firms and their associated unions, they represent a potent political interest group and will pressure governments to prevent or mitigate the real appreciation (higher non-traded goods prices) and resultant resource reallocation. The only effective government response to limit the sectoral impact is to implement a countercyclical fiscal policy that taxes the windfall and reduces spending. The consequent increase in government savings not only reduces the domestic demand for non-traded goods and restrains resource reallocation, but it also has the effect of smoothing the consumption impact of the resource windfall across generations.

It would be useful to consider these potential explanations in the theoretical section of the paper, as well as to include institutional and political economy variables that capture the quality of governance and the impact of entrenched interest groups in the pooled regressions, to better understand the differential responses of the fiscal position to terms of trade (commodity price) movements across countries.

The limits of pooling

Although there are potentially sizable efficiency gains from pooling the large number of observations available in panel datasets, the resultant coefficient estimates are sensitive to the econometric approach to controlling for cross-sectional parameter heterogeneity and for time-series parameter instability. The approach used in the paper imposes restrictions on parameter homogeneity and stability that are not adequately tested. To better understand the robustness of the empirical results, these restrictions should be tested, and if rejected, more flexible forms of parameter estimation should be considered.[8]

Another important consideration in panel data estimation is which variation in the sample should be used to identify the parameter of interest for the hypothesis being examined: cross-section or time series. In practice, many counterfactual 'what if' economic questions are best addressed with parameter estimates based on time series or 'within' variation. These key policy or impact parameters can be best estimated by controlling for the 'across' variation with fixed-country or group effects or by dividing the sample, if tests reject the assumption of homogeneous coefficients. In this paper, the coefficients of interest measure the impact of a terms of trade movement on the fiscal stance over time. Hence, the econometric technique should place more weight on the 'within' rather than the 'across' variation. One way

7. See Corden (1984) for a survey of the Dutch disease, which is also known as the 'booming sector' phenomenon.

8. Wooldridge (2002) provides a recent survey of such techniques.

this could be accomplished is by dividing the sample into commodity importers and exporters as well as by income.

Concluding remarks

The paper successfully highlights some key stylised facts present in the data on the relation between the stance of fiscal policy and terms of trade movements. The next steps in the research program will be to drill down to better understand the sources of the terms of trade fluctuations and the broader factors that influence the fiscal policy response across countries.

References

Corden WM (1984), 'Booming Sector and Dutch Disease Economics: Survey and Consolidation', *Oxford Economic Papers*, 36(3), pp 359–380.

Lalonde R and D Muir (2007), 'The Bank of Canada's Version of the Global Economy Model (BoC-GEM)', Bank of Canada Technical Report No 98.

Mehlum H, K Moene and R Torvik (2006), 'Institutions and the Resource Curse', *Economic Journal*, 116(508), pp 1–20.

Sachs JD and AM Warner (2001), 'The Curse of Natural Resources', *European Economic Review*, 45(4-6), pp 827–838.

Silver M (2007), 'Do Unit Value Export, Import, and Terms of Trade Indices Represent or Misrepresent Price Indices?', IMF Working Paper No 07/121.

Wooldridge JM (2002), *Econometric Analysis of Cross Section and Panel Data*, MIT Press, Cambridge.

2. General Discussion

The discussion of Graciela Kaminsky's paper first focused on the institutionalised fiscal policies adopted by some countries. One participant referred to the experience of Chile, where a countercyclical rule required the government to target a structural fiscal surplus after adjusting for the position of the economy relative to its trend path and the deviation of the copper price from a longer-term forecast (made by an independent panel of experts). Also, in Germany a constitutional amendment was recently implemented to enshrine countercyclical fiscal policy. Another participant referenced the experience of Norway, for which the intergenerational fiscal framework plays a key role in sequestering tax revenues from the energy sector. Graciela Kaminsky replied by welcoming interest in the question of why some countries adopt fiscal rules and others do not, but she stressed that this was beyond the scope of the analysis in her paper.

In subsequent discussion, a participant said that they thought that Graciela Kaminsky's paper was predicated on the idea of there being a deterministic or, at least, a frequent cycle in the terms of trade. However, the question of interest in Australia and elsewhere over recent years has been about the extent to which movements in commodity prices and the terms of trade are permanent. This was important since the optimal response of fiscal policy depended on the persistence of shocks, with a permanent increase in the terms of trade consistent with permanently higher revenue and expenditure. Adding to this point, another participant suggested that China's recent integration into the world economy implied a persistent, if not permanent, change in Australia's terms of trade, whereas previous shocks to the terms of trade tended to be driven by the global business cycle.

A participant asked how we could be sure whether a shock was permanent or transitory. One participant replied by arguing that the only thing to do was to wait; in the meantime policy should respond cautiously by acting as if there is some chance that the shock is temporary. Consistent with this, another participant noted that the Chilean fiscal rule implicitly treats shocks to copper prices as if they were transitory in the first instance, but if the shock persists, it will eventually be reflected in forecasts of the longer-term price of copper.

There followed a series of comments about the possibility of empirically decomposing the terms of trade shocks into transitory and permanent shocks. In response, Graciela agreed that this would be relevant to public policy, but she suggested that carrying out that analysis requires a more focused approach based on a more limited sample of countries and a richer dataset.

Relative Price Shocks, Inflation Expectations, and the Role of Monetary Policy

Pierre L Siklos[1]

Abstract

The aim of this paper is to rely on a wide variety of forecasts and survey-based estimates of inflationary expectations since the early 1990s for a group of nine economies, five of which explicitly target inflation, and ask: to what extent are disagreements over forecasts of inflation driven by movements in relative prices? The empirical evidence leads to the following conclusions. First, there is little doubt that inflation targeting has contributed to narrowing the forecast differences *vis-à-vis* inflation forecasts for the United States. Second, there is some evidence that, at least since 1990, inflation forecasts in the economies considered that had deviated substantially from US forecasts show signs of converging towards US expectations. Third, examining the mean of the distribution of forecasts potentially omits important insights about what drives inflation expectations. Finally, commodity and asset prices clearly move inflation forecasts, although this is a phenomenon of the second half of the sample. Prior to around 1999 relative price effects on expectations are insignificant.

1. Introduction

The last two decades have seen a remarkable convergence in inflation rates around the world. The role that monetary policy plays in achieving this outcome continues to be debated. There is, of course, a long tradition in the profession linking inflation performance to monetary policy. For example, during the depths of the Great Depression, in a landmark 1932 study of commodity prices covering two centuries of data, Warren and Pearson (1932) remarked: 'Any price level that is out

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of adjustment with the monetary situation should not be expected to be maintained permanently' (p 67). A look at any of the recent inflation reports published by several central banks would doubtlessly produce very similar sentiments about the behaviour of inflation. Yet, there is also a case to be made that economists have yet to fully grasp the dynamics of inflation (for example, Bernanke 2008). This state of affairs also carries over to our understanding of what moves inflation forecasts. Adding to the mix, sharp movements in both commodity and asset prices in recent years (see Section 3 below) raise a host of questions about what factors drive expectations of inflation (see also Reis and Watson 2009).

The financial and economic crisis that began in July–August 2007 only deepens the mystery about what influences inflation rates around the world since aggregate price level movements have been relatively benign over the past two years, at least in the industrialised world. There has been no shortage, however, of commentary by central banking officials and other analysts over prospects of a spiralling inflation or deflation.[2] As Trichet (2009) remarked concerning the conduct of monetary policy in turbulent times: '… the evidence supports the view that a central bank's ability to ease monetary conditions – and thereby support the stabilisation of inflation and output – is significantly enhanced by its ability to anchor private expectations'. However, what explains this ability to anchor expectations, and the role played by the monetary policy regime in place, remains open to debate and more research. Therefore, studying the determinants of inflation and, in particular, how relative price shocks interact with inflationary expectations remains an important task.

Adding to the difficulties in our understanding of the inflationary process is the fact that observers of inflation forecasts normally have very little information about the model, or models, that were used to generate a forecast, or the extent to which certain economic variables (for example, commodity prices), as opposed to informed judgment, drive changes in forecasts over time. The problem of identifying the signal from the noise is, of course, an old one.

This paper relies on a wide variety of forecasts and survey-based estimates of inflationary expectations since the early 1990s for a group of nine economies, five of which explicitly target inflation, and asks: to what extent are disagreements over forecasts of inflation driven by movements in relative prices? As there has been considerable interest about whether inflation has been driven by global factors, it is equally important to examine to what extent inflationary expectations are idiosyncratic or driven by factors common to all the economies considered. A variety of subsidiary issues also emerge from the questions that this paper sets out to explore. For example, while small changes in commodity prices may have no significant effect on inflation forecasts, larger changes could have a substantial influence on inflation forecasts. As we shall see, this asymmetric effect appears plausible. In this regard, it is also of interest to examine the extent to which large shocks have permanent or transitory effects on inflationary expectations. Moreover,

2. Worries over whether the fiscal stimuli in place in many parts of the world will work has led to suggestions that a 'little' inflation (for example, 2 to 3 per cent) is preferable to near-zero current levels. Others worry that inflation, once unleashed, cannot be controlled with such precision.

it is also natural to consider whether these sorts of effects are influenced by the adoption of inflation targeting.

Disagreements about inflationary expectations are almost always defined in terms of a distribution of forecasts prepared in individual countries and are presumably focused on the determinants of the domestic inflationary experience.[3] In the present study I depart from this norm to consider disagreement relative to a different benchmark, namely the US experience. This is done for at least three reasons. First, on both historical and economic grounds, the US experience with inflation remains a useful benchmark, particularly over my sample periods given the earlier success in controlling inflation in the United States. Needless to say, there is considerable debate about the role played by the US Federal Reserve (Fed). While Fed officials have long defended their dual mandate, the recent fashion in central banking and policy-making circles has been to adopt a form of inflation targeting (for example, see Siklos 2009a and references therein). The extent to which this distinction matters is an ongoing research topic. Finally, the decade of the 1990s and early 2000s was a period of substantial globalisation, for both finance and trade. Hence, it is reasonable to posit that inflationary expectations also contain a global element. Consequently, if US inflation and inflation expectations represent a global benchmark, then it is sensible for forecasters, businesses and households to take this information into account perhaps in a more explicit fashion than has heretofore been the case.

An additional contribution of the present study is to generate evidence about the behaviour of inflation expectations by exploiting as broad a sample in terms of the number of forecasts or forecasters as I was able to collect for each economy. Thus, for example, for the United States, Japan, and the euro area, inflation expectations from almost a dozen sources are considered. This comprehensive dataset provides us with some new insights into the behaviour of inflation expectations over time.

The rest of the paper is organised as follows. In the following section I provide a brief overview of the literature linking relative price shocks and central bank strategies to inflation and expectations of inflation. Section 3 introduces the data and provides a bird's eye view of the stylised facts. Section 4 presents some econometric evidence which relies on a variety of techniques, each of which is aimed at providing evidence about the various questions raised in this study. Section 5 concludes. Appendix A documents the inflation forecasts used in this paper and the sources of those forecasts.

2. Relative Price Shocks, Inflation and Monetary Policy

It is perhaps surprising that some prominent economists claim we do not sufficiently understand the dynamics of inflation. Nevertheless, we have learned a great deal about the determinants of inflation over the past decade or so, no doubt assisted by

3. In related work, I am investigating disagreement in inflation expectations across a wider set of economies than considered here relying on this more conventional benchmark. In addition, I am considering whether there are cross-country divergences that depend on whether or not the economy in question is an emerging market.

the spread of inflation targeting around the world.[4] What follows then is a concise summary of the existing consensus about some stylised facts.

First, while inflation is persistent, it appears to have fallen substantially in many parts of the world (Benati 2008), possibly more so in inflation-targeting (IT) economies than elsewhere (for example, Siklos 1999a). Whether the combination of lower and more stable inflation has led to expectations of inflation becoming better anchored remains unsettled (for example, Bernanke 2007, Mishkin 2007a, and references therein). Two sets of questions arise here. Can we say whether certain monetary policy regimes (for example, inflation targeting) are better able to hold down inflation expectations than others? If this is the case, what are the sources of disagreements in expectations? It may be that an unstable economic environment leads to persistent deviations in inflation expectations from a path to which the monetary authority plans to adhere. It is also possible that inflation expectations react excessively to relative price shocks, particularly ones that are large and believed to contain a significant permanent component. A relevant consideration here is that the literature has not come to a definitive understanding over how such disagreements are to be measured (for example, see Lahiri and Sheng 2008, and references therein).[5] It should be emphasised at this stage that data limitations pose a serious constraint on the information that can be extracted from inflation forecast and survey data.[6] It is typically the case that point forecasts are used. However, other than for a very few economies (for example, the United States and the United Kingdom), researchers generally do not have access to the distribution of forecasts. This consideration can be crucial since, as shown by Mankiw, Reis and Wolfers (2004), the information content of mean or median forecasts can mask considerable underlying forecast disagreements.[7]

Second, the notion that expectations are rational, which leads to the testable implication that they are both correct, on average, and efficient and unbiased, does imply that there is little additional information that could have been brought to bear to improve on them. It can be said, rather charitably, that this view has

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4. Cecchetti *et al* (2007) provide a comprehensive overview of what drives inflation in a cross-section of countries.

5. In what follows, this paper uses the concept of 'forecast disagreement', defined by what is essentially one of the moments in the distribution of inflation forecasts.

6. There is another important type of data limitation that is the subject of ongoing research with the dataset used in the present study, namely the difficulties posed in forecasting inflation because of disagreement over the measurement of the output gap and the resort to revised data, as opposed to the real-time data that is more germane to the information set that would be used by forecasters in preparing forecasts over time. Clearly, these are important considerations but space limitations prevent further discussion here.

7. In recent years there has been a burgeoning interest in so-called density forecasts, namely an estimate of the probability distribution of possible future values of the variable in question. For a recent survey, see Tay and Wallis (2000). An example of a distribution of forecasts is the Survey of Professional Forecasters in the United States. Part of the appeal of density forecasts is that they can capture asymmetries that could be of considerable interest to policy-makers. In particular, if short-run expectations of inflation are higher than the mean inflation rate, forecasts are generally negatively skewed while the opposite holds when inflation is below its historical mean.

received mixed support.[8] In any event, the view that forecasts are rational and/or unbiased contradicts the increased emphasis placed by central banks on improving and intensifying their communication function (for example, Blinder *et al* 2008). Then there is the literature that points out fairly convincingly not only that learning takes place in any economic environment but that the policy regime itself can assist in the learning process (for example, Sargent 1999 and Orphanides and Williams 2007).

Third, contrary to what one might believe *a priori*, the low and stable inflationary environment of the past 15 years or so has not necessarily made inflation easier to forecast. Indeed, arguably the most widely used inflation model in the profession, namely a New Keynesian-style Phillips curve, performs rather poorly (for example, Rudd and Whelan 2007 and Stock and Watson 2007) in spite of its strong micro-foundations (for example, Kiley 2008). There continues to be a wide-ranging debate about the links between inflation and inflation expectations, and the relative weight that ought to be placed on certain factors over others. For example, for a time, there was increasingly prominent discussion devoted to the influence of price developments in China as a source for global disinflation (for example, Rogoff 2003, Ball 2006, Borio and Filardo 2007, Ihrig *et al* 2007 and Côté and de Resende 2008). However, it proves to be extremely difficult to identify a separate role for China from the impact of the global consensus in favour of lower inflation or, for that matter, the role played by institutional mechanisms that ensure that low inflation remains in place (for example, Acemoglu *et al* 2008, and Bohl, Mayes and Siklos, forthcoming). Beyond these considerations, there is the apparent tenuous connection between expectations and actual inflation rates (for example, Blinder 1999) which must be contrasted with the view that the public does care very much about inflation (for example, Shiller 1997). The relationship between these two crucial variables is further complicated by the evidence that pass-through effects, either via the exchange rate, or through the influence of changes in commodity prices, have diminished considerably in recent years (for example, Hooker 2002 and Gagnon and Ihrig 2004). Interestingly, investigations of the behaviour of commodity prices, for example, and how their movements are linked to ones in aggregate price levels, generally fail to exploit the possibility that the appropriate relationship is asymmetric

8. Testing such hypotheses requires estimation of the following specification: $a_t = \alpha_0 + \alpha_1 f_{1,t-1} + e_{t|t-1}$, where a is the realised value of the variable of interest, here inflation, and $f_{1,t-1}$ is, say, the one-year-ahead inflation forecast, conditional on information available at time t–1. Unbiasedness requires the non-rejection of the null $\alpha_0 = 0, \alpha_1 = 1$. Efficiency also requires that no additional useful information can be used to improve upon existing forecasts. This implies that, if $\mathbf{X}_t$ represents a vector of omitted variables, this could not statistically explain $a_{t+1} - f_{1|t}$, that is, the forecast error. Given the form in which most forecasts are presented (see below), there are potentially additional econometric problems stemming from serial correlation in the errors to name just one hurdle with this testing framework.

in nature.[9] Hence, a rise in oil prices might feed into inflation rates more quickly, and remain more persistent, than a reduction in the price of oil.[10]

Brief mention also ought to be made about the horizon over which expectations are evaluated and how these are constructed. Only a handful of industrial countries have developed inflation-indexed bond markets which provide researchers with a source of data on long-run inflationary expectations. Moreover, the extent to which these markets are liquid, and the length of time they have been in place, also pose additional constraints for a cross-country study of the kind undertaken here. It is also the case that there is a paucity of survey or other longer-horizon forecasts for a large cross-section of countries.[11] This is unfortunate since this information directly pertains to the role of the monetary policy regime.[12] Accordingly, the empirical evidence that follows focuses on short-term forecasts. If there is a significant probability that any existing regime will change – a likelihood that may well have risen in some cases in light of the Global Financial Crisis, even though there are few outward signs that policy-makers are contemplating changing their monetary policy regime – then one factor that explains what drives inflation expectations will have been omitted. Otherwise, the empirical evidence below provides some evidence about the role of central banks, their policies, as well as the influence of relative prices, on the evolution of inflationary expectations.

Most studies rely on forecast or expectations data from one or a very small number of sources. For example, an analysis of the properties of inflation forecast errors is usually conducted on a single forecast from a public institution (such as the IMF or the OECD), a private firm (such as Consensus Economics), or a formal survey of forecasters (such as the Survey of Professional Forecasters). It is interesting to consider, however, whether the source provides any additional clues about what drives the forecasts and this study is an attempt to do so.[13]

Finally, there has been considerable debate about the desirability of the central bank publishing its own forecasts. There is no consensus about this question and it is inappropriate here to delve into the relevant issues (see, however, Mishkin 2007b, Ch 5). Nevertheless, it is worth considering such forecasts as well. They, together with forecasts from other sources, provide indirect clues about whether, *ex post*, prior beliefs about differences in information sets that go into producing such forecasts explain how well expectations are anchored. They also provide clues about how

9. Of course, asymmetries, for example, in the movement of oil prices are well known (see Hamilton 2009, and references therein). What is less well understood is whether changes in commodity prices also feed into the aggregate price level in an asymmetric fashion.

10. This type of asymmetry may not, however, always have operated in this fashion. For example, in a well-known study (Warren and Pearson 1932), the asymmetry went in the other direction in the period over which commodity prices were examined (1814–1931).

11. Consensus forecasts do exist for the 10-year horizon for a relatively small number of countries.

12. There is some evidence that inflation contains a long memory component (for example, see Hassler and Wolters 1995; Baillie, Chung and Tieslau 1996; and Siklos 1999b).

13. Alternatively, one might examine forecast dispersion among the forecasters surveyed by a particular firm, such as Consensus Economics. A recent example is Dovern, Fritsche and Slacalek (2009).

sensitive forecasts may be to the different pressures on inflation over time, including those stemming from relative price changes, the monetary regime in place, as well as some of the other factors noted above.

3. A Bird's Eye View of the Data

Appendix A provides details of the data sources and definitions used in this study. All tests and estimates are based on data converted to a quarterly frequency. Original forecasts are monthly (M), quarterly (Q) or half-yearly (H). Generally, the sample covers the period 1990 to 2008. Inflation is defined in terms of the headline rate for the CPI for all the economies considered, expressed in annualised terms. The empirical evidence shown below examines the experience of five IT economies – Australia, Canada, New Zealand, Sweden and the United Kingdom – and four non-IT economies – the euro area, Japan, Switzerland and the United States. The expectations data are time series of current-year and one-year-ahead forecasts. Three types of forecast data are used: professional forecasts; forecasts derived from survey data; and any available central bank forecasts.

There are several difficult issues that arise when resorting to these data. First, most of the forecasts are for the calendar year. For example, each month (usually around the third week of the month) *The Economist* publishes private-sector forecasts of inflation (and real GDP growth) for the current and following calendar years (one-year-ahead forecasts). Other forecasts are presented in a similar manner (for example, Consensus forecasts). Some forecasts (those of the OECD, for instance) are published semi-annually while others (for example, the RBNZ) release forecasts on a quarterly basis.[14] As a result, there is both an issue of timing and the horizon to which the forecast pertains. Studies that rely on these data are aware of this, but adjustments to correct for such problems are often *ad hoc* or are said to have little influence on the outcome of empirical tests. Given the persistence properties of inflation, it is conceivable that calendar-year forecasts pose little difficulty. In what follows, no special adjustments are made to the data. While some experiments were conducted to determine how large the resulting biases might be, it appears (in line with other studies) that they do not appear to be large.[15]

In the case of survey data, the researcher faces the additional difficulty that the data are not always presented in the form of an inflation rate. Instead, many surveys (for example, those of the European Commission and the Centre for European Economic Research (ZEW)) report an index. Generally, the literature has adopted two approaches to convert the data into usable form. Smith and McAleer (1995) provide a nice survey of the methodologies originally due to Carlson and Parkin (1975) and Pesaran (1985, 1987). The former is generally referred to as the probability approach, whereas the latter is a regression-based technique used to convert an index into an estimate of inflation expectations. Both techniques were implemented in this study and readers are referred to the relevant papers for additional details.

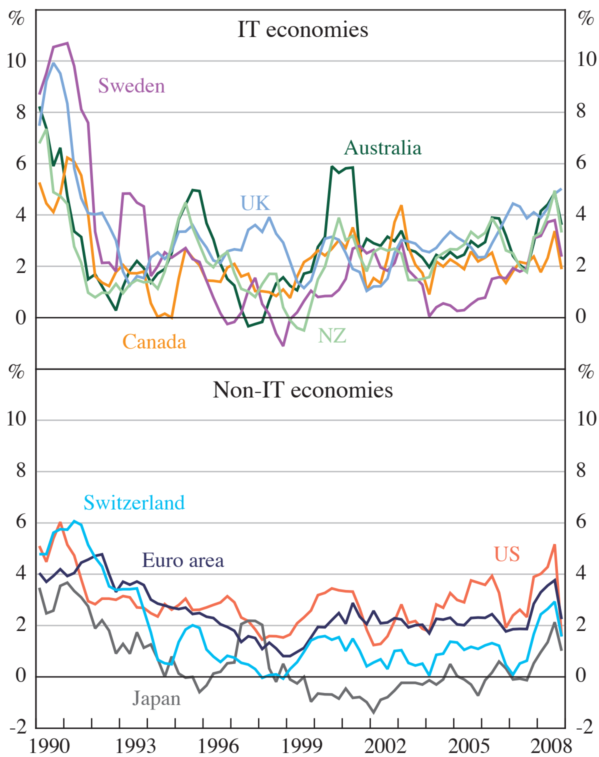
14. The RBNZ, for one, does publish one-quarter-ahead forecasts, so there are some forecasts that are not presented on a calendar-year basis.

15. Put differently, the issue concerns the implications of relying on fixed-event versus fixed-horizon forecasts. In the present application, as will be explained below, the averaging used to investigate cross-country differences in inflation forecasts may also contribute to mitigating any biases from the timing and horizon problem.

A final comment concerning forecasts is also in order. While the measurement of forecast disagreement used in this study treats all forecasts on an equal footing, the researcher does not observe the objective function implicit in the construction of these forecasts, that is, whether the aim of the forecaster is to find the best forecast of inflation or one that might attract the greatest public attention. The implications are not formally explored in this study but should be borne in mind in future extensions of the present research.

Consider first overall inflation performance, as shown in Figure 1. The top and bottom panels show CPI inflation in the IT and non-IT economies, respectively. There is little evidence of notable differences between IT and non-IT economies' inflation rates in the period since inflation targeting was adopted. Prior to 1994, however, one does clearly see the rapid disinflation that took place in the IT camp.[16] As will be seen below, appearances can be deceiving as some persistent differences in overall inflation performance between the IT and non-IT economies can be observed. The figure also highlights why there is continuing debate not only about the relative superiority of an IT regime but also whether forces more global in nature, including commodity price movements, are driving inflation rates around the world.

Figure 1: Inflation Rates – Selected Economies
Year-ended headline CPI



Sources: See Appendix A

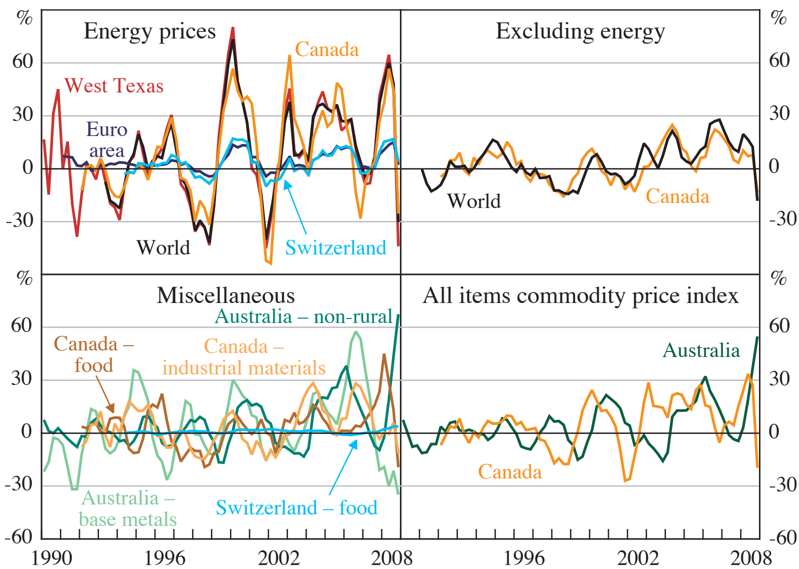
16. The dating of the IT period as beginning in 1994 is adopted purely for visual purposes. In some of the tests that follow, actual adoption dates are used (see Bernanke *et al* 1999, Siklos 2002 or Rose 2007 for the exact dates).

Figures 2 and 3 plot a number of commodity and asset prices.[17] These do not exhaust the set of relevant commodity prices that may have affected inflation expectations over time in each of the economies considered. Nevertheless, the various series shown are fairly representative of the data that various authors in the relevant literature have used to investigate the macroeconomic role of commodity and asset prices.[18] The series displayed in the figures consist of individual commodity price indices as well as aggregate commodity price indices that some of the central banks in our sample publish and monitor on a regular basis. The variability of commodity prices (Figure 2) is quite apparent. Nevertheless, it is usually the case that broader indices of commodity prices are relatively less volatile than many of the individual commodity prices sampled. In addition, most of the series appear to be mean-reverting and there is also a visual hint at least of some asymmetry in commodity price movements (somewhat steadier increases and more rapid decreases). Formal testing of the statistical properties of these series follows below.

Figure 3 plots the rate of change in the BIS's aggregate asset price index (Borio and Lowe 2004) for the IT and non-IT group of economies in our example. One can interpret fluctuations in these indices as a relative price of sorts – that is, for current versus future consumption. Alternatively, movements in these indices may provide clues about imbalances in the economy to which monetary policy and,

Figure 2: Selected Measures of Commodity Prices

Year-ended percentage change

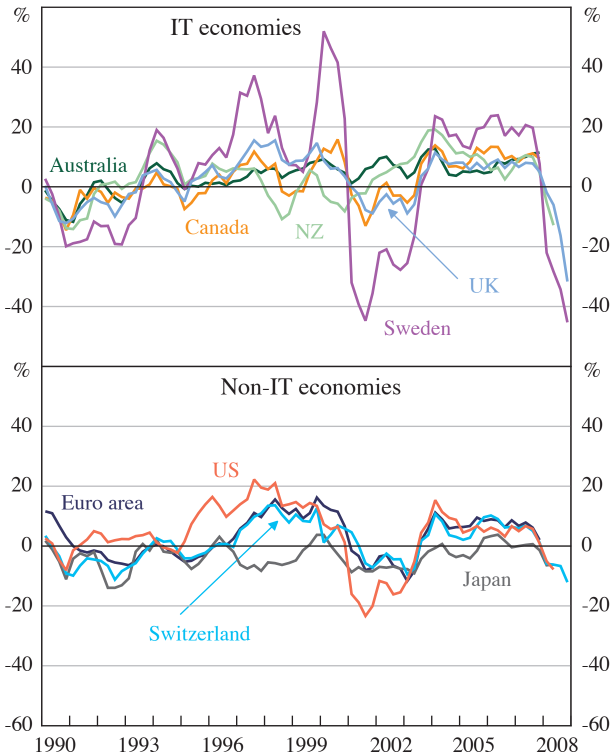


Sources: Australia, Canada and Switzerland – central bank websites; other – IMF

17. Commodity prices are expressed in US dollars before transforming them into growth rates. All asset prices (also in US dollars) are in index form, again prior to computing rates of change.

18. Whether these are the 'right' prices to consider is another matter entirely. For example, Reis and Watson (2009) find that conventional relative price indicators are less informative than a linear combination of them (obtained via principal components analysis).

Figure 3: Asset Prices
Year-ended percentage change



Note: The data are the BIS's aggregate asset price indices
Sources: BIS; Borio and Lowe (2004); author's calculations and Appendix A

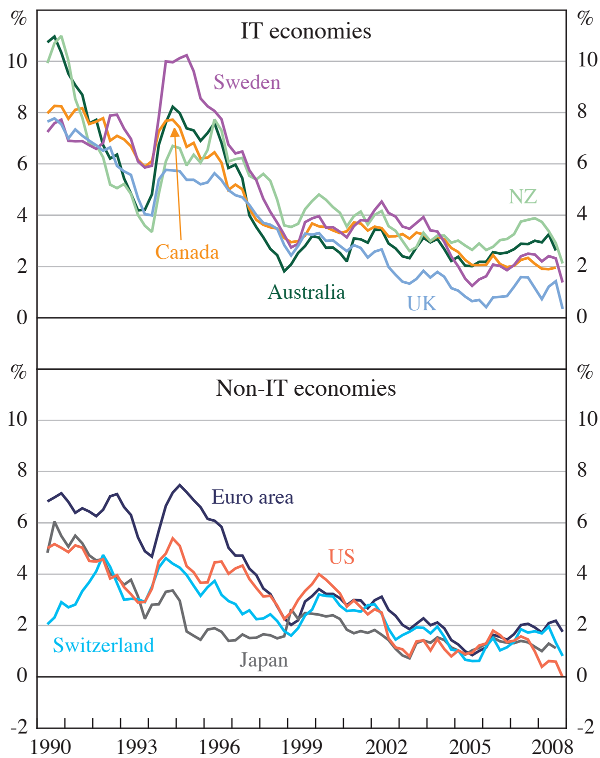
presumably, inflation expectations, might react. The plots suggest considerable variability in asset prices in all the economies considered, although, on balance, volatility appears relatively larger in the IT economies. Also notable is asymmetry in growth rates of asset prices, with the exception of the Japanese experience.[19]

Figure 4 plots an estimate of the real interest rate based on the difference between the nominal long-term government bond yield and a three-year moving average of inflation. Needless to say, there is considerable debate about the proper measurement of real interest rates, let alone how to proxy longer-term expectations of inflation. Nevertheless, while estimates of the real interest rate may vary depending on the details of the calculations, it is likely that the series shown in Figure 4 offer a fair portrayal of how the stance of monetary policy has evolved across the economies

19. The apparent differences in variability between IT and non-IT economies and the asymmetrical behaviour of commodity and asset price movements also seems to be reflected in real exchange rate and output gap data (not shown).

considered since 1990.[20] During the first half of the 1990s, real interest rates were relatively higher in the IT group of countries. As several authors have suggested, this stylised fact captures both the adjustment towards a lower inflation rate the newly IT countries were aiming for at the time, as well as an expression of the attempt by these central banks, given their historical experience with inflation, to establish *bona fides* in delivering inflation control. However, by the late 1990s it generally becomes difficult to distinguish the stance of monetary policy in IT economies from that in non-IT economies. This feature of the data also captures the stalemate in the debate between supporters of inflation targeting and others who have found it difficult to see, or are sceptical of, the superiority of one type of policy regime over another.

Figure 4: Real (*Ex Post*) Interest Rates



Note: Nominal interest rate (long-term government bond yield) less three-year moving average of inflation

Sources: See Appendix A

20. An obvious alternative, other than using surveys of long-term expectations or index-linked bonds (though not a feasible option for the collection of economies examined here) is to estimate a policy rule, such as a Taylor rule. It is unlikely, however, that the conclusions drawn from such an exercise would yield substantively different results. It is now becoming widely accepted that monetary policy in recent years had become looser over time (see Siklos 2009a, Taylor 2010 and references therein).

I now turn to some stylised facts about inflation expectations. Figure 5 plots CPI inflation in the IT economies on the horizontal axis against various available measures of one-year-ahead inflation expectations (see Appendix A for details).[21] The same plots are generated for the non-IT economies in Figure 6. As noted previously, it is useful to distinguish between a general disinflationary phase versus a period when inflation remained relatively low and stable. Clearly, it is not straightforward to identify any such 'break' over the period examined. Moreover, it is likely to be difficult to pinpoint a common break across the nine economies considered in this study. Hence, I compare the full sample (1990–2008) to a sub-sample consisting of observations for the 1999–2008 period.[22] Most observers would agree that by that time all IT regimes were in place long enough to avoid problems arising from initial conditions biasing the results in favour of inflation targeting. Accordingly, the left-hand-side panels display the evidence for the full sample while sub-sample results are summarised in the right-hand-side panels. There are three notable features about the simple relationship between inflation and inflation expectations displayed here. First, with the possible exception of New Zealand, the country that first adopted inflation targeting in 1990, higher current inflation is generally associated with a rise in one-year-ahead inflation. The same relationship is apparent for Switzerland and Japan, but somewhat less so for the other non-IT economies. Second, the relationship between inflation and one-year-ahead expectations is considerably tighter after 1999 in the IT group of countries. This phenomenon is less apparent among the non-IT economies, except for Switzerland, who is not an inflation targeter but does target a forecast for inflation. The apparent clustering of inflation and inflation forecasts is suggestive of an anchoring of inflation expectations and the change is most visible among the IT group of countries. Whether inflation targeting alone, or in combination with other factors, can explain the difference is, of course, an empirical question. Finally, regardless of the nature of the monetary policy regime, there are fewer 'outliers' after 1999 in the various scatter plots shown. This suggests that the era since 1999 is, broadly speaking, characterised by fewer inflation surprises.

21. The plots for current-year inflation expectations (not shown) reveal broadly similar patterns. There are too few series for forecasts two years ahead, or more, to conduct the same experiment as shown in Figures 5 and 6.

22. Later in the empirical section I also consider the 2001–2008 sub-sample as this may also represent a useful dividing line between the period of disinflation and stable inflation.

Figure 5: Inflation versus Inflation Expectations – IT Economies

(*continued next page*)

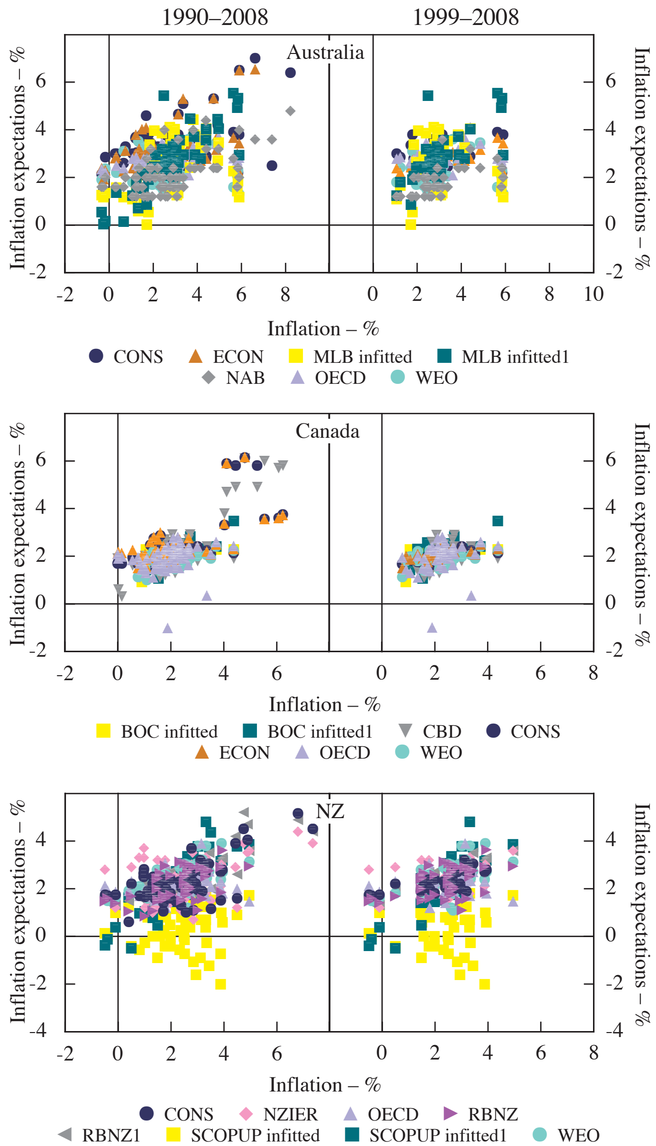
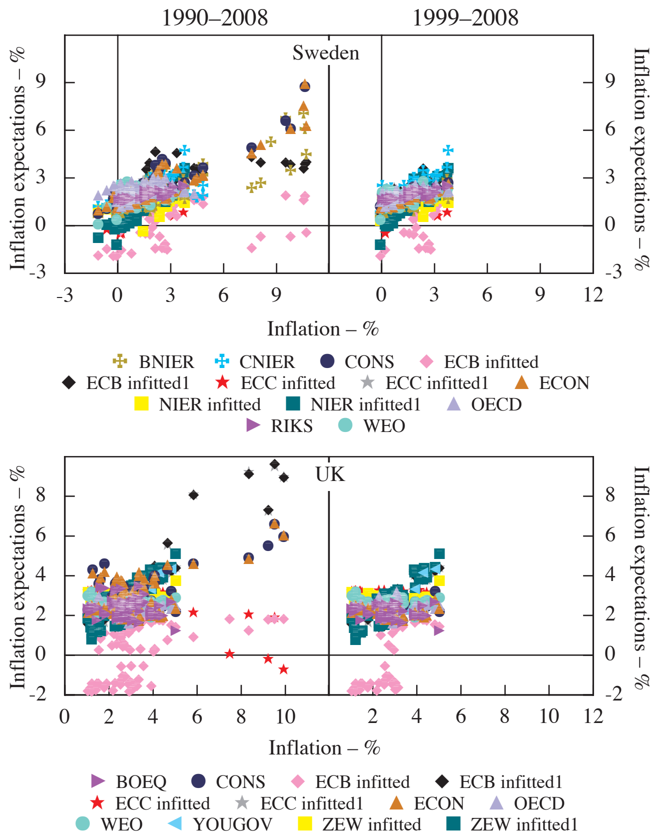


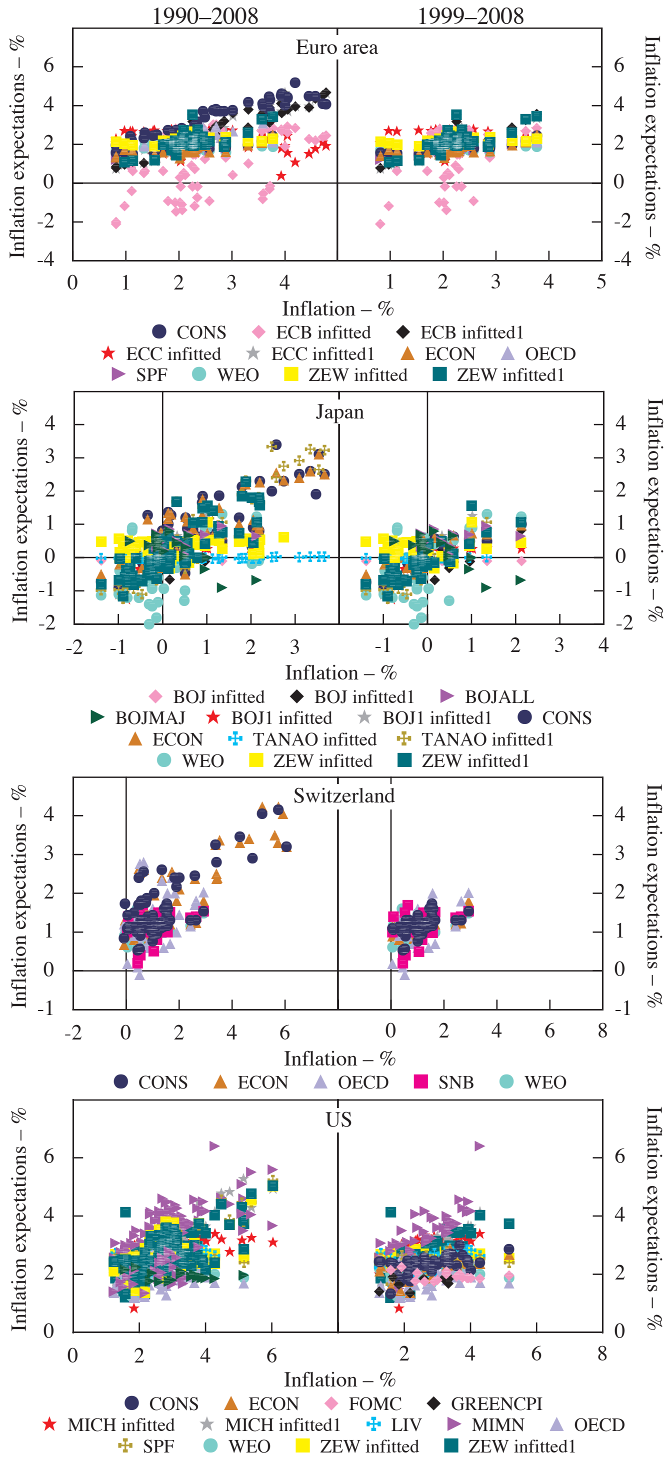
Figure 5: Inflation versus Inflation Expectations – IT Economies
(*continued*)



Notes: See Table A5 for the forecast codes. Inflation expectations are one-year-ahead forecasts as defined in the text. Inflation is as defined in Figure 1.

Sources: See Appendix A

Figure 6: Inflation versus Inflation Expectations – Non-IT Economies



Notes: See Table A5 for the forecast codes. Inflation expectations are one-year-ahead forecasts as defined in the text. Inflation is as defined in Figure 1.

Sources: See Appendix A

Figure 7 displays evidence of the range of inflation expectations across economies and sources of data. As noted previously, it is customary to examine inflation forecasts or surveys relative to some domestic benchmark. However, since this study partly aims to assess the role of global forces on inflation, as proxied by the US experience, the figure shows differences in expectations relative to a US benchmark.[23] Examination of the data in Figure 7 suggests that in at least three of the five IT economies (Australia, Canada and Sweden), the differences *vis-à-vis* one-year-ahead US inflation forecasts have diminished somewhat over time while a similar pattern is less apparent for New Zealand and the United Kingdom. Equally interesting is the fact that inflation expectations are persistently below those of the United States, especially beginning in the mid 1990s, except possibly for the United Kingdom. It seems then that there is both a global element to the determination of inflation expectations (what one might loosely call a trend component) and a domestic component suggestive of the decoupling of these expectations relative to the United States, perhaps due to the adoption of inflation targeting. As seen in Figure 7, no such interpretation is evident for the non-IT economies in the sample. The idiosyncratic experience of Japan is evident, while there is seemingly little change in the behaviour of expectations in Switzerland relative to the United States. Only the euro area begins to resemble the US experience and this may point toward the success of the fledgling central bank in anchoring expectations to levels comparable to ones exhibited in the United States.

Finally, Figure 8 plots our measure of forecast disagreement for each of the nine economies in this study. The shaded areas highlight, where relevant, the period before inflation targets were introduced.[24] As noted previously, there is no universally agreed-upon measure of forecast disagreement. However, some researchers typically resort to the following definition

$$d_{th} = \frac{1}{N-1}\sum_{i=1}^{N}\left(F_{ith} - \bar{F}_{\bullet th}\right)^2 \tag{1}$$

where: d is the measure of disagreement for a particular country; F_{ith} is the i-th forecast for horizon h at time t; and $\bar{F}_{\bullet th}$ is the mean across the N available forecasts for that country.[25] To highlight the evolution of disagreement over time, Equation (1) is evaluated in a five-year rolling sample.[26] In what follows, h is always set to 1 to

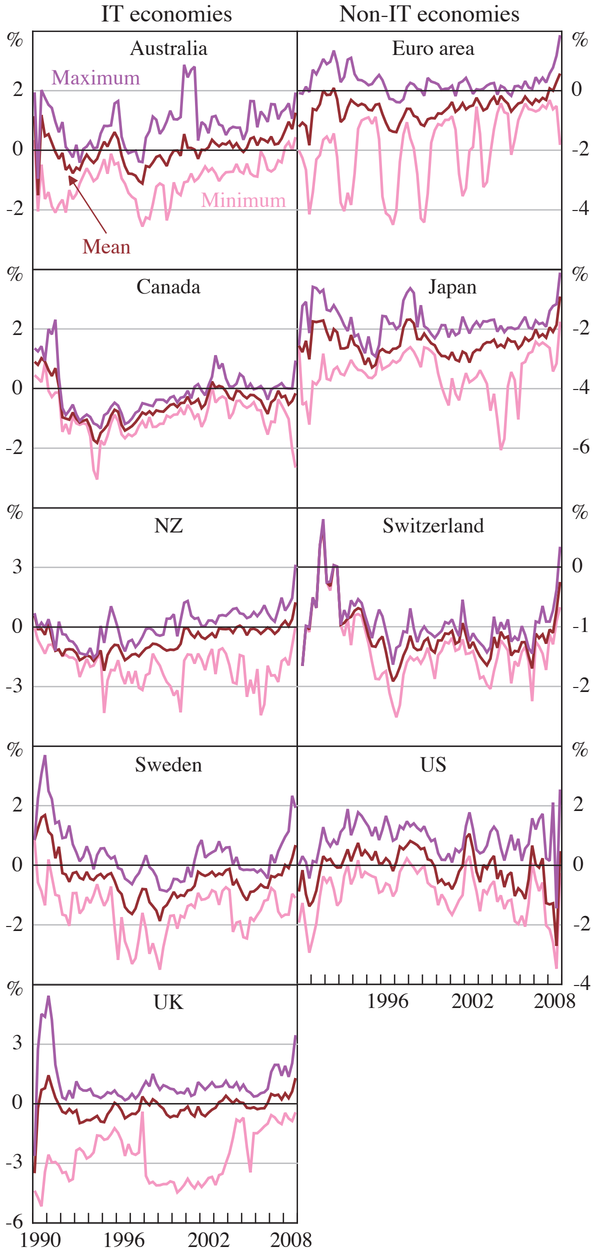
23. Namely, the US one-year-ahead inflation forecast from the Survey of Professional Forecasters, often thought to be the most accurate of the forecasts over time. Clearly, other US benchmarks could have been used and it is possible that the results may be sensitive to this choice.

24. There is no shaded area shown for New Zealand which introduced inflation targeting at the very start of the available sample.

25. Alternatively, forecast disagreement can be expressed in terms of forecast errors, as in $\frac{1}{N-1}\sum_{i=1}^{N}\left(\varepsilon_{ith} - \frac{1}{N}\sum_{i=1}^{N}\varepsilon_{ith}\right)^2$, where ε is the forecast error. Other definitions of forecast disagreement also exist. See, for example, Dovern *et al* (2009).

26. This explains why levels cease changing in the last few years of the sample. It was thought to be preferable to show the results in this manner rather than, say, reduce the span of the sample over which d was estimated.

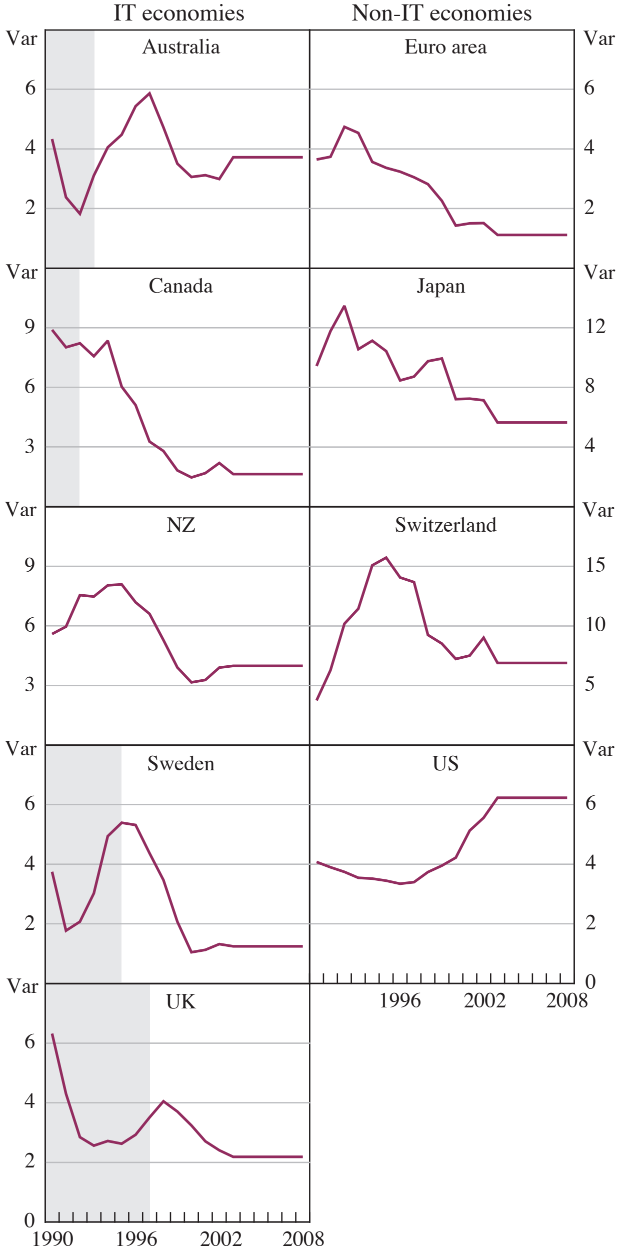
Figure 7: Differential of Inflation Expectations



Notes: Inflation expectations are one-year-ahead forecasts less the benchmark US forecast (from the Survey of Professional Forecasters), except for the US, which is against the actual inflation outcome

Sources: See Appendix A

Figure 8: Disagreements in Inflation Expectations



Notes: The shaded areas represent the period before IT is introduced, where relevant. These are the one-year-ahead forecast disagreements based on the forecasts underlying Figure 7 (see Equation (1)). Quarterly disagreement was averaged to form an annual series. All subsequent econometric tests rely on disagreements measured at the quarterly frequency.

Sources: See Appendix A

indicate that the focus is on one-year-ahead forecasts. The results indicate that in all IT economies, disagreement tended to rise in the early phases of the new monetary policy regime. Nevertheless, the rise is typically very brief in duration with the possible exception of New Zealand where disagreement increased over a six-year period. In contrast, disagreement rose over five years in Australia, two years in the United Kingdom, and one year in Canada. Arguably, the 'shock' associated with the change in monetary policy regime was greatest for New Zealand. It is notable as well that disagreement tends to fall sharply in some cases following the adoption and adjustment to the IT regime.

Comparisons with the record of forecast disagreement in non-IT economies are particularly instructive. Disagreement in the euro area rises over a three-year period then permanently falls, but what is most notable is that disagreement falls around the start of European Monetary Union (EMU). Contrast this with the Japanese experience, which shows a period of elevated disagreement essentially covering the so-called 'lost decade' before falling since the turn of the century. The experience of Switzerland reveals a sharp rise in forecast disagreement during the first half of the 1990s and, in spite of a small dip in the second half of that decade, disagreement remains permanently higher than at the beginning of the sample. There is a less dramatic but equally pronounced rise in forecast disagreement in the United States, with estimates of disagreement for the most part increasing steadily until 2002. Clearly, there is considerable diversity in the forecasting experience across this sample of economies, but one should not exaggerate the differences. After all, every single economy in the sample experiences a rise in forecast disagreement sometime during the 1990s precisely when central banks in the industrial world, whether they formally targeted inflation or not, emphasised the desirability of low and stable inflation. It is likely that changes in monetary policy credibility, the actual design and implementation of inflation control strategies, as well as the international environment, have each played a role in the emergence and subsequent reversal of these forecast disagreements. I now turn to some preliminary evidence estimating the significance of some of these factors.

4. Empirical Evidence

Table 1 provides some summary statistics about the stationarity, or otherwise, of the key series under investigation. The top portion of the tables presents panel unit root tests. The two most widely used tests, namely those of Levin-Lin-Chu (LLC) and Im-Pesaran-Shin (IPS), are reported.[27]

Both panel tests are essentially versions of the well-known Augmented Dickey-Fuller (ADF) test that would be applied to time-series data for individual countries. The test equation in a panel setting (omitting constants and deterministic components) is written

$$\Delta y_{jt} = \alpha_j y_{jt-1} + \sum_{j=1}^{k}\sum_{i=1}^{p} \beta_{ij} \Delta y_{jt-1} + \varepsilon_{it} \tag{2}$$

where: j identifies the particular economy in the sample; and y is the differential between domestic forecasts and the US benchmark forecast. The unit root test statistic then consists of the sample mean of the ADF *t*-statistics. IPS (2003) provide the critical values. The ADF tests tend to have a downward bias, which is corrected for when a panel test is used. Generally, if all independent parameter estimates are unbiased, then the mean of these estimates is also unbiased (Enders 2004, p 225). Notice that the test based on Equation (2) estimates a unit root test statistic for each cross-section, as well as a country-specific lag augmentation term. In contrast, if the hypothesis that $\alpha_j \neq \alpha_{j'}$, where $j \neq j'$, cannot be rejected, then an alternative specification of Equation (2), where α and β are fixed across all countries, results in the so-called LLC (2002) panel unit root test.[28] Since the panels considered refer to the differential between domestic forecasts and a US forecast, the test also amounts to asking whether cointegration holds between the various individual forecasts and the representative US forecast. Panels are also subdivided according to whether the forecast is survey-based or not.

In the case of the threshold cointegration test, attention focuses on the stationarity of the individual series of mean domestic forecasts versus the benchmark US forecast. While the benefits of panel estimation are lost, it is possible to determine whether cointegration is a feature of the data once we permit the error correction term to adjust in an asymmetric fashion.[29] The remainder of the table presents various unit

27. There are other panel unit root tests that have been shown to be more powerful in a statistical sense. Siklos (2009b) and references therein consider some of these. Given the results reported below, it is unlikely that the conclusions will be much changed. Moreover, the extant literature is more familiar with the tests reported here.

28. LLC advocate removing the overall mean of the series (that is, $\bar{y}$) prior to running the test. It is not immediately obvious that this is necessary when the series under investigation is a differential between two existing series.

29. Enders and Siklos (2001) propose a strategy to test for threshold cointegration. The test relies on the ADF form for the test equation where the error correction term is replaced with two error corrections terms that switch depending on whether the series in question is above or below some estimated threshold, resulting in the threshold autoregressive (TAR) formulation. For reasons having to do with the statistical power of such tests, the so-called momentum TAR (M-TAR) is preferred. In this version, it is the change in the error correction term *vis-à-vis* some threshold that switches from a positive to a negative state that adds asymmetry to the conventional ADF-type specification.

Table 1: Panel Unit Roots, Cointegration and Threshold Cointegration, Unit Roots (*continued next page*)

A. Panel unit root test: cointegration of domestic and US forecasts

	LLC	IPS	Observations
Australia I	–2.44 (0.01)	–3.47 (0.00)	425
Australia II	–2.55 (0.01)	–3.77 (0.00)	192
Combined	–2.83 (0.00)	–3.72 (0.00)	
Canada I	–4.09 (0.00)	–5.84 (0.00)	375
Canada II	–3.33 (0.00)	–4.72 (0.00)	188
Combined	–4.10 (0.00)	–5.84 (0.00)	
New Zealand I	*0.52 (0.70)*	*–0.70 (0.24)*	454
New Zealand II	–3.81 (0.00)	–4.70 (0.00)	157
Combined	*0.53 (0.70)*	*–0.70 (0.24)*	
Sweden I	*–1.36 (0.09)*	–3.49 (0.00)	621
Sweden II	–3.10 (0.00)	–3.62 (0.00)	174
Combined	*–1.36 (0.09)*	–3.49 (0.00)	
United Kingdom I	–2.97 (0.00)	–4.94 (0.00)	746
United Kingdom II	–4.35 (0.00)	–4.53 (0.00)	299
Combined	–2.97 (0.00)	–4.94 (0.00)	
Euro area I	*0.28 (0.61)*	*–1.32 (0.09)*	629
Euro area II	–3.87 (0.00)	–4.03 (0.00)	200
Combined	*0.28 (0.61)*	–1.32 (0.10)	
Japan I	*0.49 (0.69)*	*–1.47 (0.07)*	593
Japan II	–4.51 (0.00)	–4.25 (0.00)	283
Combined	*0.49 (0.69)*	–1.47 (0.07)	
Switzerland I	*–0.04 (0.49)*	–2.82 (0.00)	257
Switzerland II	–3.94 (0.00)	–5.35 (0.00)	213
Combined	*–0.04 (0.49)*	–2.82 (0.00)	
United States I	*1.24 (0.89)*	–7.62 (0.00)	756
United States II	–2.70 (0.00)	–7.05 (0.00)	504
Combined	*1.24 (0.89)*	*–7.62 (0.90)*	

B. Threshold cointegration tests

	ρ_1	ρ_2	F_1	F_2	τ
Australia	–0.02 (0.05)	–1.74 (0.17)	49.55*	89.25*	–0.30
Canada	–0.09* (0.04)	–0.28 (0.13)	4.45*	2.02	–0.62
New Zealand	–0.02 (0.06)	–0.53* (0.24)	9.47*	6.02	–0.84
Sweden	–0.11* (0.04)	0.28 (0.14)	5.24*	7.03*	–0.65
United Kingdom	–0.04 (0.05)	–1.14* (0.10)	60.75*	89.52*	–0.64
Euro area	–0.05 (0.08)	–0.82 (0.17)	12.43*	17.89*	–0.64
Japan	–0.19* (0.08)	1.06 (1.42)	2.91*	0.77	–2.35
Switzerland	–0.16* (0.07)	–1.10 (0.45)	5.84*	4.35	–1.05
United States	–0.09 (0.06)	–1.63* (0.15)	24.06*	38.94*	–0.85

Table 1: Panel Unit Roots, Cointegration and Threshold Cointegration, Unit Roots (*continued next page*)

C. Unit root tests: commodity and asset prices			
	ERS (ADF)	LLC	IPS
Energy		*3.13 (0.99)*	*1.06 (0.86)*
Brent	–1.56 (5)		
West Texas	–1.50 (5)		
Canada	–1.68 (4)		
New Zealand	–1.06 (3)		
Switzerland	–1.43 (6)		
World	–1.47 (5)		
Other commodities		*4.37 (1.00)*	*2.79 (0.99)*
Metals	–2.45 (2)		
Non-rural	–0.79 (1)		
Canada – food	–2.70 (1)		
Switzerland – food	–2.17 (3)		
Australia – total	–0.69 (1)		
Canada – total	–1.77 (2)		
Canada – non-energy	–2.32 (4)		
World – non-fuel	–2.50 (7)		
Asset prices		*0.001(0.50)*	*–0.09 (0.47)*
Aggregate		*2.61 (0.99)*	*3.50 (0.99)*
Australia	–0.14 (2)		
Canada	–1.74 (1)		
New Zealand	–2.69 (8)		
Sweden	–2.34 (2)		
United Kingdom	–2.42 (1)		
Euro area	–2.02 (12)	*–1.12 (0.13)*	*–1.41 (0.08)*
Japan	–1.25 (4)	*–1.49 (0.13)*	*0.29 (0.62)*
Switzerland	–3.17 (4)		
United States	–2.32 (4)		
Equities		*–1.43 (0.08)*	*–2.84 (0.00)*
Australia	–1.50 (1)	*–0.87 (0.19)*	*–1.16 (0.12)*
Canada	–2.23 (1)		
New Zealand	–2.51 (11)		
Sweden	–1.83 (5)		
United Kingdom	–1.72 (1)		
Euro area	–1.75 (3)	*–0.18 (0.43)*	*0.36 (0.64)*
Japan	–2.01 (3)	*–1.52 (0.07)*	*–1.14 (0.13)*
Switzerland	–1.26 (1)		
United States	–1.40 (1)		

Table 1: Unit Roots, Panel Unit Roots, Cointegration and Threshold Cointegration (*continued*)

C. Unit root tests: commodity and asset prices

	ERS (ADF)	LLC	IPS
Housing		*–3.26 (0.00)*	–0.49 (0.31)
Australia	–1.35 (1)		
Canada	–1.83 (8)		
New Zealand	–2.35 (1)		
Sweden	–1.49 (3)		
United Kingdom	–1.31 (1)		
Euro area	–2.30 (4)		
Japan	–1.77 (4)		
Switzerland	–0.72 (2)		
United States	–4.04 (4)		

Notes: In Part A, the test statistic is shown with *p*-values in parentheses; italicised numbers are those with *p*-values that are larger than 0.05 to identify cases where the null is rejected. I refers to non-survey-based forecasts while II refers to the group of survey-based forecasts. Part B gives the estimates of the error correction terms, the test for asymmetry (F_1) and the test for whether both error correction terms are jointly equal to zero (F_2). The test specification is from Enders and Siklos (2001). * indicates rejection at the 5 per cent significance level. In Part C, the column labelled ERS (ADF) gives the lag length used in the lag augmentation portion of the test equation, chosen according to the Schwarz information criterion (ERS = Elliot-Rothenberg-Stock test). Otherwise, *p*-values are shown in parentheses in the remaining columns along with the test statistic. A trend was not included in the test specifications.

root and panel unit root tests for commodity and asset prices. Asymmetric unit root tests are omitted, as the discussion in the previous section made clear the presence of asymmetric behaviour in these time series.

The null of no cointegration is rejected in most cases. In the case of IT regimes, the only exception is for New Zealand forecasts that are not survey-based. The results are mixed for non-survey-based forecasts for Sweden with the LLC test leading to a non-rejection, unless of course one wishes to adopt a 5 per cent critical value, in which case Sweden's non-survey-based forecasts are cointegrated with US forecasts. Turning to the non-IT economies, there are many more rejections of the no cointegration null. This is the case, regardless of the testing procedure employed, for non-survey-based forecasts for the euro area and Japan. The results are more mixed for non-survey-based forecasts for Switzerland and the United States. Therefore, there is some evidence that forecast dispersion behaviour is not the same in IT versus non-IT regimes. It is also interesting to note that the null of no cointegration is never rejected for survey-based forecasts. When the panel stacks together both survey- and non-survey-based one-year-ahead forecasts, the null of no cointegration is almost always rejected. The only exception is New Zealand, although once again the results for the non-IT economies are sensitive to the assumption of a common unit root in the test specification.

If we permit asymmetric adjustment of the momentum-threshold variety, the bivariate cointegration tests suggest that the cointegration property tends to hold. This result holds in five of the nine economies considered, but for this type of cointegration there is no obvious evidence of a distinction between IT and non-IT economies. Further, in absolute value, the attractor toward cointegration is always stronger from below the threshold than from above. This implies that a negative change in the error correction term, explained either by a rise in US inflationary expectations or a fall in the forecast for domestic inflation, exerts a relatively stronger pull than changes in the other direction. Of course, not all cases are statistically significant and, indeed, there are four cases (Canada, Sweden, Japan and Switzerland) where the attractor in the other direction exerts a stronger pull back to equilibrium. It is important to underscore that these results are based on mean forecasts. Consequently, some information is lost and, as shall be seen below, the interpretation of what moves inflationary expectations may be affected by this choice.

Turning to commodity and asset prices, it is not surprising that individually these series exhibit the unit root property. This much should have been apparent from the earlier discussion. Stacking all commodity prices in a panel does not change the conclusions. The same conclusion is reached for the BIS's aggregate asset price indices, although the results are somewhat sensitive in the case of non-IT economies, assuming a 10 per cent critical value is adopted.

Since a fairly large number of individual forecasts were retained for each economy,[30] a natural question to ask is how important is the relative information content of the individual forecasts. While there are many ways of addressing the issue, Table 2 provides summary information of a principal components analysis of the various available forecasts on an economy-by-economy basis.[31] The second and third columns of Table 2 shows the most important forecasts based on the estimated eigenvalues, measured on the basis of explanatory power (as a proportion of the total value). The second column lists the forecasts that would have the greatest weight if a linear combination of forecasts were used instead of, say, a simple mean of available forecasts. There are at least two notable features in the results. First, in practically all cases, either Consensus, *The Economist* forecasts, or both, are among the first or second principal components of the forecasts. Second, most forecasts contribute a relatively small fraction of the total variation. Consequently, there is no such thing as a dominant forecast. Indeed, it is often the case that at least four to five forecasts are needed to explain close to two-thirds of the variation in one-year-ahead inflation forecasts.

30. For Australia, a total of 7 forecasts were retained. For the other countries the numbers are provided in parentheses: Canada (7), New Zealand (8), Sweden (11), the United Kingdom (10), euro area (11), Japan (8), Switzerland (5) and the United States (11).

31. Space constraints prevent a full discussion. However, the object of the exercise is to find the highest eigenvalues from the eigenvectors estimated from the covariance matrix that describes the relationship between the series of interest. Additional details can be found in, among other sources, Maddala (1977, pp 193–194) and Jolliffe (1986).

Table 2: Principal Components of Inflation Forecasts

Economy	Principal component (PC)	Proportion of total variation (%)[a]
Australia	ECON, OECD, CONS, NAB	0.37, 0.18, 0.16, 0.09
Canada	PC1: ECON, CONS, BOC, WEO PC2: CBD, BOC, OECD	0.39, 0.20, 0.14, 0.12, 0.07
Euro area	ECB(2), SPF, OECD, ECC(2), CONS, ECON	0.41, 0.20, 0.09, 0.09, 0.06, 0.05
Japan	TANAO(2), ZEW(2), CONS, ECON	0.36, 0.21, 0.12, 0.09
New Zealand	RBNZ, CONS, RBNZ-Survey	0.47, 0.16, 0.14
Sweden	NIER(2), CONS, ECON, RIKS	0.52, 0.15, 0.10, 0.07
Switzerland	CONS, ECON, SNB, OECD	0.55, 0.17, 0.14, 0.10
United Kingdom	PC1: ECC(2), ECB(2), ZEW(2), YOUGOV PC2: ECON, BOE, CONS	0.29, 0.20, 0.13, 0.08
United States	ECON, CONS, SPF, LIV	0.40, 0.15, 0.13, 0.07, 0.07

Notes: PC: (1) = probability approach; (2) = regression approach. See Table A5 for the forecast codes.
(a) Eigenvalues

Finally, we turn to some regression estimates of the determinants of the forecast differential. Once again, to conserve space, only a selection of the results are displayed in Table 3.

The estimated specification is a straightforward one and, as such, imposes restrictions that future research will need to consider. I am interested in the determinants of the differences between forecasts of one-year-ahead inflation in economy *i*, at time *t*, generated by forecaster *j*, and the US forecast (SPF). The resulting relationship can be expressed as

$$fd_{jit} = \mathrm{A}_i + \mathrm{B}_t + \kappa \mathbf{X}_{jit} + \delta \mathbf{I}_{it} + \xi_{jit} \quad (3)$$

where: *fd* represents the difference between forecaster *j*'s one-year-ahead forecast for economy *i* at time *t* and the benchmark US forecast (SPF); A and B are fixed effects; **X** is a vector of control variables; and, since we are interested in, among other questions, the impact of inflation targeting, **I** is a dummy variable for this policy regime. One immediate difficulty, noted earlier, is that we are unlikely to have ample information on controls for each country. Moreover, as discussed in Bertrand, Duflo and Mullainathan (2004), standard errors from OLS estimation of Equation (3) can be distorted. Among the possible solutions is to estimate Equation (3) at the economy-wide level, in which case many more covariates are available. This is the strategy adopted below. In addition, as pointed out previously, there is potentially a loss of information when focusing only on the mean value of

Table 3: The Determinants of Inflation Forecast Differentials

Coefficient (standard error)

Variable	Mean: Full 1990–2008	Mean: 2001–2008	Mean: 1999–2008	MIN: Full	MAX: Full
	Dependent variable: Mean fd_{it}			$a_t = \alpha_0 + \alpha_1 f_{1,t-1} + e_{t\|t-1}$	$f_{1,t-1}$
Brent	–0.05 (0.07)	–0.37 (0.10)*	–0.12 (0.07)*	–0.16 (0.13)	0.02 (0.10)
Non-fuel	0.21 (0.22)	0.20 (0.27)	–0.28 (0.26)	–0.06 (0.43)	0.23 (0.10)
Housing	0.01 (0.01)	0.01 (0.005)	0.01 (0.004)*	0.01 (0.01)	0.005 (0.008)
Equities	–0.001 (0.001)	–0.001 (0.001)	–0.001 (0.0008)*	–0.001 (0.002)	–0.0004 (0.001)
$\Delta fd_{it-1}*H$	–0.30 (0.06)*	–0.06 (0.09)	0.03 (0.08)	0.11 (0.11)	–0.31 (0.09)*
$\Delta fd_{it-1}*(1-H)$	–0.05 (0.05)	–0.05 (0.10)	–0.01 (0.08)	–0.05 (0.10)	0.02 (0.07)
KURT	–0.01 (0.01)	–0.01 (0.008)*	–0.01 (0.007)*	–0.20 (0.02)*	–0.006 (0.01)
DIS	–0.02 (0.01)*	–0.12 (0.04)*	–0.07 (0.02)*	–0.05 (0.02)*	–0.02 (0.01)*
ITDUR	0.003 (0.001)*	0.007 (0.002)	0.007 (0.002)*	0.01 (0.002)*	0.004 (0.002)*
IT	–0.07 (0.05)	na	na	–0.17 (0.10)*	–0.17 (0.08)*
fd_{it-1}	0.82 (0.03)*	0.60 (0.07)*	0.66 (0.05)*	0.59 (0.03)*	0.75 (0.03)*
Inflation – news			–0.01 (0.01)		
Interest rate – news			0.004 (0.004)		
Recession – news			0.02 (0.003)		
US dollar – news			–0.04 (0.02)		
Constant	–0.05 (0.05)	–0.02 (0.13)	–0.14 (0.10)*	–0.13 (0.10)	0.10 (0.10)*
$a_{t+1} - f_{1\|t}$	0.91	0.95	0.95	0.80	0.87

Notes: Variables are defined in the text. Cross-section fixed effects are not shown. * indicates statistical significance at least at the 10 per cent level. OLS estimation is used. Standard errors are shown in parentheses. *H* is the Heaviside indicator used to discriminate between positive (*H*) and negative (1–*H*) changes in *fd*.

fd. Hence, three set of results are shown in Table 3. Estimates of Equation (3) for the mean, the lowest (MIN) and highest (MAX) forecast differential are presented. One may view the MIN estimates as proxying the reactions of those who are most optimistic about future domestic inflation while the MAX estimates capture the most pessimistic forecasts.[32] In addition, two sets of sub-sample estimates are provided as it is likely, based on the stylised facts, that the behaviour of inflation and inflation expectations may well have undergone a change around 1999 to 2001.[33] Sub-sample estimation also permits the addition of another variable that is labelled 'news'. Various dummy variables are constructed (see Appendix A for details) that are set to 1, and are otherwise set to 0, when headlines, primarily in the financial press, highlight a rising fear of *future* inflation, *future* rises in the policy interest rate, a *future* recession or a depreciation of the US dollar – that is, there are separate dummy variables for each of these types of news events.

The vector **X** consists of the following variables. Oil and commodity prices are proxied by the world price of Brent crude and a world index of non-fuel prices. Both series are in HP-filtered form.[34] Asset prices, namely housing and equity prices that exceed or fall below some HP-filtered trend, are also included. Next, for reasons discussed above, I allow for asymmetric type of adjustment by creating a variable that is set to 1 when the *change* in the mean differential is greater than zero and is zero otherwise. This gives the opportunity to ascertain whether large positive or negative movements in domestic inflation forecasts relative to the US benchmark measure have a separate impact on *fd*. The specification also allows for uncertainty, proxied here by the kurtosis (KURT) in the distribution of forecast differential, as well as disagreement in the forecasts (DIS), to influence *fd*.[35] These variables not only capture the role of second and third moments but, in so doing, include some distributional information, omitted in the process of aggregation. Finally, other than a lagged dependent variable, included to measure persistence in *fd*, a variable that measures how long a country has been in an IT environment is also included (ITDUR).

32. An alternative approach, currently the subject of ongoing work, consists of estimating a version of Equation (3) via quantile regressions in order to better exploit the information contained in the distribution of forecasts.

33. A Hausman test (results not shown) does suggest that the full-sample model may be mis-specified. What is unclear is the form of the mis-specification. It could be that the null that $\varkappa$ is constant across cross-sections is incorrect or it could be the case that it is inappropriate to pool all the economies in our sample together. For example, one might consider a separate pool of IT economies and non-IT economies. This extension is left for future research.

34. Using rates of change in these series does not appear to make much difference. However, in line with the earlier discussion, it seems preferable to think in terms of a measure of disequilibrium in relative prices. Needless to say, there are well-known drawbacks in using the HP filter but it is so widely applied that whatever it loses in terms of precision, it makes up for by remaining comparable with the relevant literature. The default smoothing parameter of 1 600 is used in all HP-filtered estimates.

35. The variance of *fd* was also considered but was generally found to be statistically insignificant. Hence, it was omitted from the final specification.

It is clear from the estimated coefficients that our suspicion that something changed around 1999 to 2001 is borne out.[36] For example, the asymmetry found for the 1990–2008 sample, where a rise in the inflation forecast differential is reversed (but not vice versa), is not apparent in the most recent period. Second, uncertainty about future inflationary expectations are statistically significant in the sub-samples but not in the full sample. Finally, and perhaps most interestingly, relative prices, as proxied by oil, housing and equity prices, are not statistically significant in the full sample but have a clear impact in the sub-sample estimates shown.

The results for the lowest (MIN) and highest (MAX) imply some rather interesting and important differences *vis-à-vis* the panel estimate based on the mean. First, notice that the IT dummy is statistically significant in both cases. In addition, at both ends of the distribution, as it were, we find that the introduction of inflation targeting reduces the differences in one-year-ahead inflation forecasts by 0.17 per cent. This is only trivially offset by the length of time the country in question has been targeting inflation (ITDUR). Next, it is clearly the case that the high level of persistence found for the mean-based estimates is more a feature of the 'pessimists' among the group of forecasters than for the 'optimists', with the latter specification yielding significantly lower persistence in the forecast differential (0.59 versus 0.75). In contrast, optimistic forecasters are relatively more worried about future uncertainty, which tends to narrow inflation forecast differentials. Similarly, disagreement among forecasters has twice as large an effect on the forecast differential when the forecast is a relatively optimistic one.

Before concluding, it is worth delving into the changing persistence properties of the forecast differential and the role of inflation targeting in the individual economies in the sample. To do this, a version of Equation (3) is estimated for each economy separately (not shown) and Table 4 summarises what happens to the estimates of persistence as well as the IT dummy. It is rather striking that the full sample sees all coefficients highly significant while every single coefficient in both sub-samples shown are statistically insignificant at the 5 per cent level. This result is to be expected since, as noted previously, much of the disinflation was achieved by the mid 1990s.[37] Just as with headline inflation, there is effectively much less persistence in inflation forecasts in the more recent sample period. While it is plausible to suppose that forecasters are now less backward-looking, the robustness of this result has yet to be properly tested. To be sure, there are differences in the estimates and clearly one can imagine specifications similar to Equation (3) that are equally plausible. However, some of the results in Table 4 do not seem to be greatly at variance with the summary estimates provided in Table 3. Of the five IT economies, separate estimates of δ (the coefficient on the IT dummy variable) can be provided for in only four cases. The results suggest that the reduction in the forecast differential due to inflation targeting is primarily a feature of the Canadian and Swedish experiences but not of Australia and the United Kingdom.

36. All specifications include fixed effects A_t and this version of Equation (3) could not be rejected.

37. The somewhat arbitrary choice of sub-samples does not address the question of whether the reduction in inflation persistence was achieved faster in IT or non-IT economies, nor is the precise year when persistence became statistically significant identified for each economy.

Table 4: Inflation Persistence and the Role of Inflation Targeting – Summary of Individual Economy Estimates

Economy	**Full: 1990–2008**	**1999–2008**	**2001–2008**	**Inflation targeting**
	Dependent variable: Mean fd_t			
Australia	0.46*	0.05	–0.12	0.03 (0.86)
Canada	0.70*	–0.09	0.22	–0.28 (0.07)
New Zealand	0.54*	–0.35	0.02	na[(b)]
Sweden	0.84*	0.29	0.63	–0.18 (0.10)
United Kingdom	0.46*	0.17	0.15	0.15 (0.29)
Euro area	0.55*	–0.26	–0.27	na
Japan	0.78*	0.47[(a)]	0.44	na
Switzerland	0.88*	0.18	0.25	na
United States	0.39*	0.29	0.36	na

Notes: The first three columns give the coefficient estimates and * indicates statistically significant at the 5 per cent level. The last column gives the estimate of the response to the IT dummy (see Equation (3) for the panel version of the same specification). *p*-values in parentheses.

(a) *p*-value is 0.10.

(b) New Zealand introduced inflation targeting in 1990:Q1.

5. Conclusions

This paper began by noting that there is still much to be learned from analysing the behaviour of inflation expectations. In contrast with most studies of this kind, the strategy followed here is to extract information contained in the reasonably large variety of inflation forecasts. I then considered how forecasts in five IT and four non-IT economies have evolved since the early 1990s. What can we make of the results? First, there is little doubt that inflation targeting has contributed to narrowing the forecast differences *vis-à-vis* US inflation forecasts. Second, there is some evidence that, at least since 1990, inflation forecasts in the economies considered that deviate considerably from US forecasts show signs of converging towards US expectations. Third, examining the mean of the distribution of forecasts potentially omits important insights about what drives inflation expectations. Finally, commodity and asset prices clearly move inflation forecasts, although this is a phenomenon of the second half of the sample. Prior to around 1999, relative price effects on expectations are insignificant.

There is clearly scope for more research. It is unclear whether the specification used is the best one for extracting all of the useful information contained in the dataset. In addition, one may wish to examine the behaviour of forecasts using a different metric than the one employed here. Finally, one may consider some interaction effects and add some other omitted variables in Equation (3). For example, inflation targeting may operate jointly to reduce inflation forecast uncertainty and disagreement among inflation forecasts. In addition, central banking in the 1990s has been marked by a trend towards greater transparency. Explicit accounting for this characteristic would be useful. These are only a few of the many avenues open for future research.

Appendix A

Table A1: Inflation Surveys/Forecasts (*continued next page*)

Economy	Forecast	Horizons[a]	Start	Survey	Horizons[a]	Start
Australia	ECON	cy, 1y	1990:M8	MLB	ya–balance[b]	1993:Q2
	CONS	cy, 1y	1990:M1			
	WEO	cy, 1y	1993:H1			
	OECD	ya	1990:H1			
Canada	ECON	cy, 1y	1990:M8	BOC	2y–bins[b]	2001:Q2
	CONS	cy, 1y	1989:M10			
	WEO	cy, 1y	1993:H1			
	CBD	cy, 1y	1990:Q1			
	OECD	ya	1990:H1			
Euro area	ECON	cy, 1y	1998:M11	SPF	cy, 1y, 2y, 5y	1999:Q1
	CONS	cy, 1y	1989:M10	ECB/ECC	ya–balance[b]	1985:M1
	OECD	ya	1990:H1	ZEW	ya–bins[b]	1991:M12
Japan	ECON	cy, 1y	1990:M8	ZEW	ya–bins[b]	1991:M12
	CONS	cy, 1y	1989:M10	BOJ	ya, 5y–bins[b]	2001:Q2
	WEO	cy, 1y	1993:H1			(2004:
	OECD	ya	1990:H1	TANAO	Diffusion	Q2/5y)
					index	1985:Q1
New Zealand	CONS	cy, 1y	1990:M1	RBNZ	qa, 1y, 2y	1987:Q3
	WEO	cy, 1y	1993:H1	SCOPE	ya–bins[b]	1987:Q4/
	NZIER	cy, ya, 2, 3, 4 ya	1988:Q1			1995:Q1
	OECD	ya	1990:H1			
Sweden	ECON	cy, 1y	1990:M8	ECB/ECC	ya–balance[b]	1995:M1
	CONS	cy, 1y	1989:M11			1990:M1
	WEO	cy, 1y	1993:H1			
	OECD	ya	1990:H1			
Switzerland	ECON	cy, 1y	1990:M8	ZEW	ya–bins[b]	1991:M12
	CONS	cy, 1y	1989:M11			
	WEO	cy, 1y	1997:H2			
	OECD	ya	1990:H1			
United Kingdom	ECON	cy, 1y	1990:M8	ECB/ECC	ya–balance[b]	1985:M1
	CONS	cy, 1y	1989:M11	YOUGOV	ya	2005:M12
	WEO	cy, 1y	1993:H1	BOE/NOP	1y–bins[b]	2000:Q1
	BOEMPC	1y	1993:Q1			
	OECD	ya	1990:H1			

Table A1: Inflation Surveys/Forecasts (*continued*)

Economy	Forecast	Horizons(a)	Start	Survey	Horizons(a)	Start
United States	ECON	cy, 1yr	1990:M8	SPF	cq, qb, cy, ya, 1qa, 2qa, 3qa, 4qa, 10y	1981:Q3 (1991:Q4 for 10y)
	CONS	cy, 1y	1989:M11			
	GREEN	cy, 1q, 2q, 3q, 4q, 5q, 6q, 7q, 8q, 9q	1965:Q4, 1966:Q1, 1968:Q1, 1969:Q4, 1972:Q3, 1979:Q1, 1981:Q4, 1989:Q4, 1990:Q3	MIMN	ya	1978:Q1
				LIV	cm, cy, 6m, 12m, 1y, 2y, 10y	1985:H1
				ZEW	ya–bins(b)	1991:M12
	WEO	cy, 1y	1993:H1			
	OECD	ya	1990:H1			
	Wall Street Journal	cy	2003:H1			

(a) 'cy', '1y' and 'ya' represent current year, one-year-ahead and year ahead, respectively. There is little substantive difference between '1y' and 'ya' other than different sources use different language to refer to forecasts that pertain to the year following the publication of the forecast. In some cases, however, the forecast can refer to the calendar year ahead, or to a forecast for a calendar year ahead from the time of publication, in which case the forecast horizon may overlap the current and following calendar year. '#m', '#q' or '#y' refer to forecasts # months, quarters or years ahead. 'qb' is the quarter before the quarter for the particular observation.

(b) 'Balance' refers to the horizon stated applicable to the remainder (i.e. balance) of the year; 'bins' refers to the fact that forecasts are arranged in the form of a distribution of responses.

Table A2: Central Bank Forecasts

Country	Frequency	Horizons	Start
Japan	Half-yearly	Current and 1 year ahead	2000
New Zealand	Quarterly	Up to 12 quarters ahead	1997
Sweden	Quarterly	Up to 8 quarters	2000
Switzerland	Quarterly	Up to 2 years ahead	2003
United Kingdom	Quarterly	Up to 8 quarters ahead	1993, 1998 (conditional on market interest rates)
United States	Half-yearly	Up to 9 quarters	2000

Table A3: Internet Sources for Forecasts and Surveys (*continued next page*)

Economy	Sources
Australia	http://www.melbourneinstitute.com/ http://www.consensuseconomics.com/ http://www.imf.org/external/ns/cs.aspx?id=29 http://www.economist.com/ http://www.oecd.org/document/59/0,3343,en_2649_34109_42234619_1_1_1_37443,00.html
Canada	http://www.consensuseconomics.com/ http://www.imf.org/external/ns/cs.aspx?id=29 http://www.conferenceboard.ca/ http://www.economist.com/ http://www.oecd.org/document/59/0,3343,en_2649_34109_42234619_1_1_1_37443,00.html http://www.bankofcanada.ca/en/
Euro area	http://www.consensuseconomics.com/ http://www.economist.com/ http://ec.europa.eu/economy_finance/db_indicators/db_indicators8650_en.htm http://www.ecb.int http://www.oecd.org/document/59/0,3343,en_2649_34109_42234619_1_1_1_37443,00.html
Japan	http://www.consensuseconomics.com/ http://www.economist.com/ http://www.imf.org/external/ns/cs.aspx?id=29 http://www.zew.de/en/daszew/daszew.php3 http://www.boj.or.jp/en/ http://www.oecd.org/document/59/0,3343,en_2649_34109_42234619_1_1_1_37443,00.html
New Zealand	http://www.consensuseconomics.com/ http://www.rbnz.govt.nz/ http://www.nzier.org.nz/ http://www.oecd.org/document/59/0,3343,en_2649_34109_42234619_1_1_1_37443,00.html

Table A3: Internet Sources for Forecasts and Surveys (*continued*)

Economy	Sources
Sweden	http://www.consensuseconomics.com/ http://www.economist.com/ http://ec.europa.eu/economy_finance/db_indicators/db_indicators8650_en.htm http://www.imf.org/external/ns/cs.aspx?id=29 http://www.oecd.org/document/59/0,3343,en_2649_34109_42234619_1_1_1_37443,00.html http://www.riksbank.com/
Switzerland	http://www.consensuseconomics.com/ http://www.economist.com/ http://www.imf.org/external/ns/cs.aspx?id=29 http://www.zew.de/en/daszew/daszew.php3 http://www.oecd.org/document/59/0,3343,en_2649_34109_42234619_1_1_1_37443,00.html http://www.snb.ch/
United Kingdom	http://www.consensuseconomics.com/ http://www.economist.com/ http://ec.europa.eu/economy_finance/db_indicators/db_indicators8650_en.htm http://www.imf.org/external/ns/cs.aspx?id=29 http://www.bankofengland.co.uk/ http://www.yougov.com/frontpage/home http://www.oecd.org/document/59/0,3343,en_2649_34109_42234619_1_1_1_37443,00.html
United States	http://www.consensuseconomics.com/ http://www.economist.com/ http://www.imf.org/external/ns/cs.aspx?id=29 http://www.philadelphiafed.org/research-and-data/real-time-center/ http://www.src.isr.umich.edu/http://www.src.isr.umich.edu/ http://www.oecd.org/document/59/0,3343,en_2649_34109_42234619_1_1_1_37443,00.html http://online.wsj.com/home-page http://www.zew.de/en/daszew/daszew.php3

Table A4: Basic Data Series Information

Economy	Series	Sources
Australia	Real GDP, CPI, commodity prices, real and nominal exchange rates, stock price index, money market rate, LIBOR rates, long-term government bond yields, housing prices, central bank policy rate	Reserve Bank of Australia, BIS, IMF, www.econstats.com, Australian Bureau of Statistics
Canada	Real GDP, CPI, commodity prices, real and nominal exchange rates, stock price index, money market rate, LIBOR rates, long-term government bond yields, housing prices, central bank policy rate	Bank of Canada, BIS, IMF, www.econstats.com, Statistics Canada
Euro area	Real GDP, CPI, commodity prices, real and nominal exchange rates, stock price index, money market rate, LIBOR rates, long-term government bond yields, housing prices, central bank policy rate	European Central Bank, BIS, IMF, www.econstats.com
Japan	Real GDP, CPI, commodity prices, real and nominal exchange rates, stock price index, money market rate, LIBOR rates, long-term government bond yields, central bank policy rate	Bank of Japan, BIS, IMF, www.econstats.com, Cabinet Office
New Zealand	Real GDP, CPI, commodity prices, real and nominal exchange rates, stock price index, money market rate, LIBOR rates, long-term government bond yields, housing prices, central bank policy rate	Reserve Bank of New Zealand, BIS, IMF, www.econstats.com
Sweden	Real GDP, CPI, commodity prices, real and nominal exchange rates, stock price index, money market rate, LIBOR rates, long-term government bond yields, housing prices, central bank policy rate	Sveriges Riksbank, BIS, IMF, www.econstats.com
Switzerland	Real GDP, CPI, commodity prices, real and nominal exchange rates, stock price index, money market rate, LIBOR rates, long-term government bond yields, central bank policy rate	Swiss National Bank, BIS, IMF, www.econstats.com
United Kingdom	Real GDP, CPI, real and nominal exchange rates, stock price index, money market rate, LIBOR rates, long-term government bond yields, housing prices, central bank policy rate	Bank of England, BIS, IMF, www.econstats.com, Nationwide
United States	Real GDP, CPI, commodity prices, real and nominal exchange rates, stock price index, money market rate, LIBOR rates, long-term government bond yields, housing prices, central bank policy rate	Federal Reserve, BIS, IMF, www.econstats.com, Office of Federal Housing Enterprise Oversight (OFHEO), Bureau of Labor Statistics

Table A5: Descriptors Used for Forecasts in Tables and Figures
(*continued next page*)

Code	
BNIER	National Institute of Economic Research Business Tendency Survey
BOC	Bank of Canada Business Outlook Survey
BOE	Bank of England
BOEMPC	Bank of England Monetary Policy Committee
BOEQ	Bank of England quarterly forecasts (unconditional)
BOJ	Bank of Japan – Forecast of Monetary Policy Committee (all members)
BOJ1	Bank of Japan – Survey of Inflation Perceptions
BOJALL	Bank of Japan Monetary Policy Board – All members
BOJMAJ	Bank of Japan Monetary Policy Board – Majority of members
CBD	Conference Board of Canada
CNIER	National Institute of Economic Research Consumer Tendency Survey
CONS	Consensus Economics
ECB	European Commission Business Survey (Economic Sentiment Indicator)
ECC	European Commission Consumer Survey (Economic Sentiment Indicator)
ECON	*The Economist*
FOMC	Federal Open Market Committee
GREEN	Greenbook (Federal Reserve Board)
LIV	Livingston Survey (Federal Reserve Bank of Philadelphia)
MICH	University of Michigan Survey – median
MIMN	University of Michigan Survey – mean estimate
MLB	Melbourne Institute of Applied Economic and Social Research, University of Melbourne
NAB	National Australia Bank
NIER	National Institute of Economic Research
NOP	National Opinion Poll (UK)
NZIER	New Zealand Institute of Economic Research
OECD	Organisation for Economic Cooperation and Development (*Economic Outlook*)
RBNZ	Reserve Bank of New Zealand – 1-year-ahead inflation forecast
RBNZ1	Reserve Bank of New Zealand – average of quarterly forecasts over a 1-year-ahead period
RIKS	Riksbank Forecast
SCOPE	Market Scope (New Zealand)
SCOPUP	Bankscope
SNB	Swiss National Bank
SPF	Survey of Professional Forecasters (US, euro area)
TANAO	Tankan Survey

Table A.5: Descriptors Used for Forecasts in Tables and Figures (*continued*)	
Code	
YOUGOV	YouGov Survey (UK)
WEO	*World Economic Outlook* (IMF)
ZEW	Centre for European Economic Research – Financial Market Surveys and Indicators of Economic Sentiment
infitted	Regression method conversion (see Section 3)
infitted1	Probability approach conversion method (see Section 3)

References

Acemoglu D, S Johnson, P Querubín and JA Robinson (2008), 'When Does Policy Reform Work? The Case of Central Bank Independence', *Brookings Papers on Economic Activity*, 1, pp 351–417.

Baillie RT, C-F Chung and MA Tieslau (1996), 'Analyzing Inflation by the Fractionally Integrated ARFIMA-GARCH Model', *Journal of Applied Econometrics*, 11(1), pp 23–40.

Ball LM (2006), 'Has Globalization Changed Inflation?', NBER Working Paper No 12687.

Benati L (2008), 'Investigating Inflation Persistence across Monetary Regimes', *Quarterly Journal of Economics*, 123(3), pp 1005–1060.

Bernanke BS (2007), 'Inflation Expectations and Inflation Forecasting', speech given at the Monetary Economics Workshop Summer Institute of the National Bureau of Economic Research, Cambridge, 10 July.

Bernanke BS (2008), 'Outstanding Issues in the Analysis of Inflation', speech given at the Federal Reserve Bank of Boston's 53rd Annual Economic Conference, Chatham, 9 June.

Bernanke BS, T Laubach, FS Mishkin and AS Posen (1999), *Inflation Targeting: Lessons from the International Experience*, Princeton University Press, Princeton.

Bertrand M, E Duflo, and S Mullainathan (2004), 'How Much Should We Trust Differences-In-Differences Estimates?', *Quarterly Journal of Economics*, 119(1), pp 249–275.

Blinder AS (1999), *Central Banking in Theory and Practice*, MIT Press, Cambridge.

Blinder AS, M Ehrmann, M Fratzscher, J De Haan and D-J Jansen (2008), 'Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence', *Journal of Economic Literature*, 46(4), pp 910–945.

Bohl MT, DG Mayes and PL Siklos (forthcoming), 'The Quality of Monetary Policy and Inflation Performance: Globalization and Its Aftermath', *The Manchester School*.

Borio C and P Lowe (2004), 'Securing Sustainable Price Stability: Should Credit Come Back from the Wilderness?', BIS Working Paper No 157.

Borio C and A Filardo (2007), 'Globalisation and Inflation: New Cross-Country Evidence on the Global Determinants of Domestic Inflation', BIS Working Paper No 227.

Carlson JA and M Parkin (1975), 'Inflation Expectations', *Economica*, 4(166), pp 123–138.

Cecchetti SG, P Hooper, BC Kasman, KL Schoenholtz and MW Watson (2007), 'Understanding the Evolving Inflation Process', report presented at the 2007 Meeting of the U.S. Monetary Policy Forum, Washington DC, 9 March. Available at <http://www.princeton.edu/~mwatson/papers/USMPF_Report_July_2007.pdf>.

Côté D and C de Resende (2008), 'Globalization and Inflation: The Role of China', Bank of Canada Working Paper No 2008-35.

Dovern J, U Fritsche, and J Slacalek (2009), 'Disagreement among Forecasters in G7 Countries', ECB Working Paper No 1082.

Enders W (2004), *Applied Time Series Analysis*, 2nd edn, John Wiley & Sons, New York.

Enders W and PL Siklos (2001), 'Cointegration and Threshold Adjustment', *Journal of Business and Economic Statistics*, 19(2), pp 166–176.

Gagnon JE and J Ihrig (2004), 'Monetary Policy and Exchange Rate Pass-Through', *International Journal of Finance & Economics*, 9(4), pp 315–338.

Hamilton JD (2009), 'Causes and Consequences of the Oil Shock of 2007–08', *Brookings Papers on Economic Activity*, 1, pp 215–261.

Hassler U and J Wolters (1995), 'Long Memory in Inflation Rates: International Evidence', *Journal of Business and Economic Statistics*, 13(1), pp 37–45.

Hooker MA (2002), 'Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regime', *Journal of Money, Credit and Banking*, 34(2), pp 540–561.

Ihrig J, SB Kamin, D Lindner and J Marquez (2007), 'Some Simple Tests of the Globalization and Inflation Hypothesis', Board of Governors of the Federal Reserve System International Finance Discussion Paper No 891.

Im KS, MH Pesaran and Y Shin (2003), 'Testing for Unit Roots in Heterogenous Panels', *Journal of Econometrics*, 115(1), pp 53–74.

Jolliffe IT (1986), *Principal Component Analysis*, Springer-Verlag, New York.

Kiley MT (2008), 'Monetary Policy Actions and Long-Run Inflation Expectations', Board of Governors of the Federal Reserve System Finance and Economics Discussion Series No 2008-03.

Lahiri K and X Sheng (2008), 'Measuring Forecast Uncertainty by Disagreement: The Missing Link', Ifo Working Paper No 60.

Levin A, C-F Lin and C-SJ Chu (2002), 'Unit Root Tests in Panel Data: Asymptotic and Finite Sample Properties', *Journal of Econometrics*, 108(1), pp 1–24.

Maddala GS (1977), *Econometrics*, McGraw-Hill, New York.

Mankiw NG, R Reis and J Wolfers (2004), 'Disagreement about Inflation Expectations', in M Gertler and KS Rogoff (eds), *NBER Macroeconomic Annual 2003*, 18, MIT Press, Cambridge, pp 209–248.

Mishkin FS (2007a), 'Headline versus Core Inflation in the Conduct of Monetary Policy', speech presented at the 'Business Cycles, International Transmission and Macroeconomic Policies' Conference, HEC Montréal, Montreal, 20 October.

Mishkin FS (2007b), *Monetary Policy Strategy*, MIT Press, Cambridge.

Orphanides A and JC Williams (2007), 'Robust Monetary Policy with Imperfect Knowledge', *Journal of Monetary Economics*, 54(5), pp 1406–1435.

Pesaran MH (1985), 'Formation of Inflation Expectations in British Manufacturing Industries', *Economic Journal*, 95(380), pp 948–975.

Pesaran MH (1987), *The Limits to Rational Expectations*, Basil Blackwell, Oxford.

Reis R and MW Watson (2009), 'Relative Goods' Prices, Pure Inflation, and the Phillips Correlation', working paper, Princeton University, January.

Rogoff KS (2003), 'Globalization and Global Disinflation', in *Monetary Policy and Uncertainty: Adapting to a Changing Economy*, a Symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, pp 77–112.

Rose AK (2007), 'A Stable International Monetary System Emerges: Inflation Targeting is Bretton Wood, Reversed', *Journal of International Money and Finance*, 26(5), pp 663–681.

Rudd J and K Whelan (2007), 'Modeling Inflation Dynamics: A Critical Review of Recent Research', *Journal of Money, Credit and Banking*, 39(s1), pp 155–170.

Sargent TJ (1999), *The Conquest of American Inflation*, Princeton University Press, Princeton.

Shiller RJ (1997), 'Why Do People Dislike Inflation?', in CD Romer and DH Romer (eds), *Reducing Inflation: Motivation and Strategy*, University of Chicago Press, Chicago, pp 13–65.

Siklos PL (1999a), 'Inflation-Target Design: Changing Inflation Performance and Persistence in Industrial Countries', Federal Reserve Bank of St. Louis *Review*, 81(2), pp 47–58.

Siklos PL (1999b), 'Pitfalls and Opportunities for the Conduct of Monetary Policy in a World of High-Frequency Data', in *Information in Financial Asset Prices*, Proceedings of a Conference, Bank of Canada, Ottawa, pp 331–369.

Siklos PL (2002), *The Changing Face of Central Banking: Evolutionary Trends since World War II*, Cambridge University Press, Cambridge.

Siklos PL (2009a), 'As Good as It Gets? The International Dimension to Canada's Monetary Policy Strategy Choices', *C.D. Howe Institute Commentary*, No 292. Available at <http://www.cdhowe.org/pdf/commentary_292.pdf>.

Siklos PL (2009b), 'Meeting Maastricht: Nominal Convergence of the New Member States toward EMU', Wilfrid Laurier University, Department of Economics Working Paper, August.

Smith J and M McAleer (1995), 'Alternative Procedures for Converting Qualitative Response Data to Quantitative Expectations: An Application to Australian Manufacturing', *Journal of Applied Econometrics*, 10(2), pp 165–185.

Stock JH and MW Watson (2007), 'Why Has U.S. Inflation Become Harder to Forecast?', *Journal of Money, Credit and Banking*, 39(s1), pp 3–33.

Tay AS and KF Wallis (2000), 'Density Forecasting: A Survey', *Journal of Forecasting*, 19(4), pp 235–254.

Taylor JB (2010), 'Globalization and Monetary Policy: Missions Impossible', in J Galí and M Gertler (eds), *International Dimensions of Monetary Policy*, University of Chicago Press, Chicago, pp 609–624.

Trichet J-C (2009), 'Credible Alertness Revisited', intervention at the Symposium on 'Financial Stability and Macroeconomic Policy' sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, 22 August.

Warren GF and FA Pearson (1932), *Wholesale Prices for 213 Years, 1720 to 1932: Part I*, Memoir 142, Cornell University Agricultural Experiment Station, Ithaca.

Discussion

1. Øyvind Eitrheim

The paper by Pierre Siklos provides a comprehensive overview of developments relevant to inflation expectations (based on survey and non-survey measures of inflation forecasts) in nine economies over the past two decades. In his presentation he made it clear that he would use the terms inflation expectations and inflation forecasts interchangeably. I will mainly use the latter term in this discussion.

Key research questions

The paper can be seen as a contribution to better understanding the driving forces behind inflation (and inflation dynamics) and the role of monetary policy. Specifically, it addresses the following important questions. Can shocks to relative prices explain inflation forecast differentials (relative to the United States)? What is the role of commodity prices and asset prices? Is inflation driven by global factors? Or, are idiosyncratic factors the dominant forces? And, what role does the monetary policy regime play, notably the adoption of inflation targeting (IT)?

The strategy of the paper

The paper examines inflation forecasts for nine economies, five of which are pioneering IT countries (Australia, Canada, New Zealand, Sweden and the United Kingdom) and four non-inflation targeters (the euro area, Japan, Switzerland and the United States). For each economy, inflation forecasts are collected from many different sources (survey- and non-survey-based). These are all considered relative to a benchmark forecast for the United States. Data span the period 1990:Q1 to 2008:Q4.

There is a comprehensive discussion of developments over the past two decades, supported by nice descriptive graphs of actual inflation, commodity and asset prices, (one-year-ahead) inflation forecast persistence (scatter plots), (one-year-ahead) forecast disagreement relative to the United States. The figures show converging inflation rates over the sample, volatile commodity and asset prices, an increasing concentration of (one-year-ahead) inflation forecast persistence and declining (one-year-ahead) forecast disagreements relative to the United States (for ITers as well as for non-ITers).

The econometric analysis includes analysis of the convergence properties and determinants of convergence for (one-year-ahead) inflation forecasts relative to the United States. This is based on tests of whether or not the forecast differentials are stationary using (panel) unit root tests, (threshold) co-integration tests (allowing for asymmetry) and regression models estimated on panel data (OLS), which try to pin down the main determinants of convergence.

The paper reports four main findings. First, the adoption of IT has contributed to a narrowing of forecast differentials (*vis-à-vis* the US inflation forecast benchmark). Second, there are signs of asymmetric convergence towards US expectations (that is, stronger convergence for economies deviating further from the United States), mostly in the early part of the sample. Third, one needs to look beyond the mean of the forecast distribution to learn about the effect of the adoption of IT as well as the persistence of forecast differentials. And fourth, (de-trended) commodity and asset prices have become more important determinants of inflation forecasts in the second half of the sample (that is, from 1999 onwards).

Questions and comments

This is a nice paper with many interesting empirical results. My questions and comments concern their robustness and fall into three main categories. First, there is the problem of model uncertainty and unknown instabilities. The usual suspects are parameter non-constancies, invalid parameter restrictions, and omitted information. Second, there is the problem of potential heterogeneity among forecasters, who may differ with respect to the information they have available to make their forecasts and their objectives, as well as their abilities, particularly across different forecast horizons. Third, what is the effect of adopting IT? Are we able to separately identify this policy effect?

Before I get to the details of these, let me mention a few more specific comments. First, I commend the author for the compilation of a very interesting international dataset. I understand that they have data for additional countries within the European Union (both within and outside the euro area); one could ask whether there would be a gain from adding data for more countries to the analysis. Second, Table 1C (unit root tests) needs clarification; critical values and/or indications of significance would help. And finally, why not include inflation forecast data for Norway, which has been an inflation targeter over the second half of the sample?

Model uncertainty and unknown instabilities

The paper's focus on (relative) forecast differentials is problematic for several reasons. First, there is a concern that the models considered may suffer from unknown parameter non-constancies. Sub-sample evidence (Table 4) indicates that there has been a shift in the mean forecast differential (relative to the United States) between the two sub-periods. This shift may need to be parameterised to avoid an upward bias in the estimates of (relative) persistence in the full sample.

Second, the modelling of relative forecast differentials imposes potentially invalid restrictions on model dynamics. In particular, short-run homogeneity restrictions are imposed, whereby shocks to inflation expectations in any given country are restricted to have the same effects as shocks to US inflation expectations.

Furthermore, in order to account for the effects of shocks to inflation, one could alternatively analyse (relative) forecast errors instead of (relative) forecast differentials. This would allow shocks to inflation in each economy and the United States to be addressed more explicitly.

Another aspect of model uncertainty stems from specification uncertainty. Other papers have cast a wider net and included more variables among the potential determinants of inflation; for examples, see Mishkin and Schmidt-Hebbel (2007) and Calderón and Schmidt-Hebbel (this volume). In both of these studies the authors argue that it is important to account for structural and institutional variables in an attempt to account for the determinants of inflation (forecasts). Pierre's paper finds that (de-trended) commodity prices and asset prices help to explain forecast differentials from 1999 onwards (and only for the mean of the forecast distribution, but I will come back to this in my discussion of forecaster heterogeneity). The HP-filter is used for de-trending but Pierre reports that the results for growth rates are similar. Further tests of robustness might consider using one-sided filters instead of the two-sided HP-filter.

Heterogeneity among forecasters

Pierre aims to combine as many sources of inflation forecasts (survey- and non-survey-based) as possible. This is a strength since it allows for a wider information set but is also a potential weakness since there are more details to attend to. These issues are addressed by analysing the principal components of the inflation forecasts (Table 2). However, there are several potential problems with survey data (Figures 5 and 6). Some of the scatter plot clusters have a rather strange location which does not seem to have a straight forward interpretation. It would be worth discussing when the surveys contain news and when they may be contaminated by noisy observations. I would also like consideration to be given to the circumstances under which survey data are more informative (even superior) to data from other sources. In Table 1A it seems that the empirical results based on survey data tend to deviate from those based on non-survey data (and the joint dataset) and this could be discussed in the text.

Pierre applies the mean, MAX and MIN operators to represent the distribution of inflation forecast differentials. Interestingly, the statistical significance of some of the candidate determinants of forecast inflation differentials appears to depend critically on which operator is used. It seems reasonable, therefore, to analyse several measures extracted from the distribution of forecast differentials to take into account the heterogeneity among the forecasters and see how robust the results are. In future research, one might consider introducing a weighting scheme for forecasters, defining an *ensemble of forecasters* like in Ravazzolo and Vahey (this volume), or one could use *entropy measures* like the Kullback-Leibler information criterion to characterise the distribution of forecast differentials as suggested in Filardo and Genberg (2009).

Another issue is whether forecast disagreement is higher for longer horizons. This paper focuses solely on the one-year-ahead horizon but results in Lahiri and Sheng (2008), for example, indicate that forecast disagreement is higher for longer forecast horizons. Finally, one could also argue that forecast disagreement rises (for a given horizon) in abnormal times and that there might be a need for extending the information set in this case.

The role of IT adoption

I believe it is a useful empirical exercise to try to pin down the (partial) role of economic policy. This would indeed come in handy during periods of crisis since it would help debates of the type illustrated in Skånland (1989), where the ongoing banking crisis in Norway at the time was characterised as being the unfortunate consequence of 'bad banking, bad policies, and bad luck'. Some authors argue that the role of 'bad regulation' should be added to this list in the aftermath of the current crisis. But how much weight should be put on each? There is a growing literature which examines the effects of adopting IT (for a range of different approaches, see Bernanke *et al* 1999; Ball and Sheridan 2004; Vega and Winkelried 2005; Mishkin and Schmidt-Hebbel 2007; and Filardo and Genberg 2009). Most of these studies find a significant and beneficial effect from adopting IT, although Ball and Sheridan find that adopting IT has an insignificant effect in a model which allows for mean reversion.

In Pierre's paper, the significance of adopting IT seems to depend rather critically on how the information from the distribution of forecasts differentials is aggregated. The IT dummy variable is found to be not significantly different from zero when the regression is based on the mean of the forecast differentials, while it is negative and significantly different from zero for differentials based on the maximum and minimum inflation forecasts (taken to represent the most pessimistic and the most optimistic views among the forecasters, respectively). Two questions arise from this finding. Is this result robust to the choice of the control group, in this case the non-IT economies? Also, is this result robust to the removal of potential outliers among heterogeneous forecasters or robust to using alternative aggregators such as entropy measures (Filardo and Genberg 2009) or different weighting schemes (Ravazzolo and Vahey, this volume)?

In contrast to Ball and Sheridan (2003, 2004), Hyvonen (2004) finds that adopting IT leads to a significant decrease in inflation – based on an extension of the Ball and Sheridan dataset. But there are some caveats with respect to the robustness of this result. Mishkin and Schmidt-Hebbel (2007) found that the control group is critical for the statistical significance of IT. Vega and Winkelried (2005) propose using statistical methods like propensity score matching to define the most appropriate control group, and they found statistically significant and beneficial effects of adopting IT.

In summary, it would be of interest to see results for a larger group of countries. Pierre argues that IT adoption has led to a decline in forecast disagreement – but how can we be sure? The distinction between IT central banks and non-IT central banks may in practice be somewhat blurred. One can argue that central banks like the Swiss National Bank, the European Central Bank and the Federal Reserve all have a strong focus on controlling inflation, and that since both IT and non-IT economies have been reasonably successful in this regard, one may need to go beyond the pioneers to analyse this. This would be in line with the results in Mishkin and Schmidt-Hebbel (2007), and also with the results in Calderón and Schmidt-Hebbel (this volume) who report results using inflation data (not inflation forecast data) from a much larger set of countries, and test for the (partial) effect of adopting IT using a wider information set including structural and institutional variables, among others.

In the empirical results in Table 3, Pierre allows for persistence by including lagged inflation differentials. Since the adoption of IT is potentially endogenous, it would of course be of interest to analyse whether the results hold when the model is estimated using IV methods (Mishkin and Schmidt-Hebbel 2007 are relevant in this respect), and the author might also want to apply robust standard errors as a safeguard against untested error heterogeneity.

Conclusions

This is a nice paper with useful empirical evidence about topics highly relevant for policy-makers who need to understand the driving forces behind inflation (and inflation dynamics). Pierre has constructed an international dataset for inflation forecasts from a total of 16 economies (nine of which are included in the study) and from many different sources (both survey- and non-survey-based inflation forecasts). The results provide convincing evidence that there has indeed been convergence in inflation forecasts. But will that remain so? The question is: what drives this convergence and what role should be assigned to monetary policy? The adoption of IT seems to have worked quite well for many countries, but why? It seems that the jury is still out on many of these important research questions and I look forward to future research in this area, including from Pierre.

References

Ball LM and N Sheridan (2003), 'Does Inflation Targeting Matter?', NBER Working Paper No 9577.

Ball LM and N Sheridan (2004), 'Does Inflation Targeting Matter?', in BS Bernanke and M Woodford (eds), *The Inflation-Targeting Debate*, University of Chicago Press, Chicago, pp 249–282.

Bernanke BS, T Laubach, FS Mishkin and AS Posen (1999), *Inflation Targeting: Lessons from the International Experience*, Princeton University Press, Princeton.

Filardo A and H Genberg (2009), 'Targeting Inflation in Asia and the Pacific: Lessons from the Recent Past', paper presented at the 6th Norges Bank Monetary Policy Conference, Oslo, 11–12 June.

Hyvonen M (2004), 'Inflation Convergence across Countries', RBA Research Discussion Paper No 2004-04.

Lahiri K and X Sheng (2008), 'Measuring Forecast Uncertainty by Disagreement: The Missing Link', Ifo Working Paper No 60.

Mishkin FS and K Schmidt-Hebbel (2007), 'Does Inflation Targeting Make a Difference?', in FS Mishkin and K Schmidt-Hebbel (eds), *Monetary Policy under Inflation Targeting*, Central Bank of Chile, Santiago, pp 291–372.

Skånland H (1989), 'Economic Perspectives', Norges Bank *Economic Bulletin*, 1989/1, p 15.

Vega M and D Winkelried (2005), 'Inflation Targeting and Inflation Behavior: A Successful Story?', *International Journal of Central Banking*, 1(3), pp 153–175.

2. General Discussion

The broad range of forecasts highlighted in the paper presented by Pierre Siklos generated much discussion among conference participants. A participant concurred that the paper's concern with disagreement over forecasts of inflation is a relevant policy consideration, and pointed to studies that find that the outliers for forecasts of inflation tend to be extreme relative to forecasts of other economic variables. The discussion went on to consider the present forecasts of inflation for the United States, which highlighted considerable disagreement regarding inflation over the next five years, though with the bulk of them implying some potential for deflation, whereas forecasts of inflation for the next ten years suggest inflation is still the longer-run concern. It was noted that it was difficult to interpret the implications of these observations for modelling and official forecasts. A subsequent comment suggested that the distribution of the forecasts might be skewed, which implied that it was worth examining non-normally-distributed forecast densities.

The role of the different motivations of forecasts received some attention. Some participants noted that some private-sector forecasters may want to gain notoriety by deviating from the general consensus – that is, their forecasts were essentially marketing tools for the financial institutions themselves. One participant thought that this was unfortunate to the extent that such forecasts might influence household and financial market expectations of inflation, potentially in an adverse way. Another participant added that it was important to understand the source of the inflation forecasts when evaluating their usefulness.

A participant suggested that the regression analysis of Pierre Siklos's paper should include a variable to account for differences in the variance in actual inflation across economies. Following on from this, a participant thought that current forecast dispersion is potentially useful conditioning information for forecast disagreements at longer horizons. In his response, Pierre Siklos mentioned that he uses the kurtosis of inflation in his specification to try to capture some of the variance in inflation forecasts.

A participant asked if there was evidence that the monetary policy regime influenced the forecasts, in particular, whether inflation targeting contributes to a narrowing of the distribution of forecasts. Related to this point, it was suggested that the paper could investigate whether external forecasts converge to published central bank forecasts of inflation. This might also shed some light on issues related to the effectiveness of central bank communication.

The use of the inflation performance of the United States as the benchmark in Pierre Siklos's model was raised by a few participants. One participant wondered whether countries that peg their currencies to the US dollar also have inflation rates that are close to those of the United States. This line of reasoning suggested that the mix of countries in the dataset might be a relevant consideration. Pierre Siklos responded by saying that the comparison between the United States and other economies was designed to capture global factors that affect inflation forecasts, and that replicating the analysis with Europe as the benchmark yields the same results.

Global Relative Price Shocks: The Role of Macroeconomic Policies

Adam Cagliarini and Warwick McKibbin[1]

Abstract

We use the multi-sector and multi-country G-Cubed model to explore the potential role of three major shocks – to productivity, risk premia and US monetary policy – to explain the large movements in relative prices between 2002 and 2008. We find that productivity shocks were major drivers of relative price movements, while shocks to risk premia and US monetary policy contributed temporarily to some of the relative price dispersions we observe in the data. The effect of US monetary policy shocks on relative prices was most pronounced in countries that fix their currency to the US dollar. Those countries that float were largely shielded from these effects. We conclude that the shocks we consider cannot fully capture the magnitude of the relative price movements over this period, suggesting that other driving forces could also be responsible, including those outside of the model.

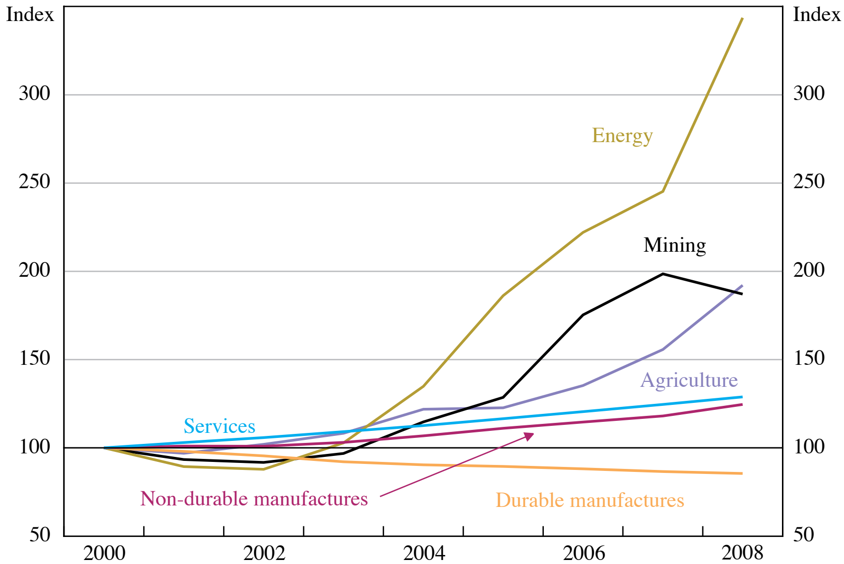
1. Introduction

Between 2002 and 2008, the world experienced a very large shift in the prices of resources and commodities relative to other goods and services. For instance, between their trough in December 2003 and their peak in December 2008, resource export prices for Australia rose on average by 26 per cent annually in Australian dollar terms. Over the same period, prices for Australia's manufactured, agricultural and service exports rose on average by 2.7, 6.2 and 3.5 per cent annually. The IMF indices for primary commodity prices also imply significant relative price movements – relative to non-durable manufactured goods, energy prices almost tripled and agricultural prices rose by more than 50 per cent (Figures 1 and 2).

We explore the likely key drivers of these relative price movements by applying a range of shocks to the multi-sector, multi-country G-Cubed model. The goal is to improve our understanding of how major shocks are transmitted to inflation and changes in relative prices in different economies. These shocks include stronger productivity growth, particularly in manufacturing in developing economies (especially China), and an investment boom due to a reduction in risk premia globally. We also explore the role that monetary policies, particularly in China and the United States, may have had in driving these movements in relative prices. We then combine the various shocks and explore whether they are able to explain the global experience between 2002 and 2007.

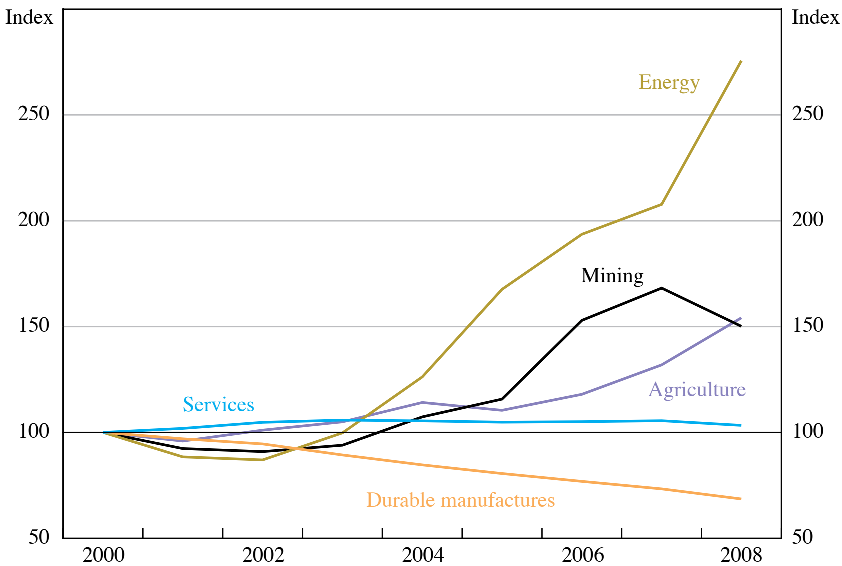
1. We would like to thank Nicholas Bailey, David Jennings and Hyejin Park for their excellent research assistance. We would also like to thank Renée Fry, Christopher Kent, Mariano Kulish, Ivan Roberts and Andy Stoeckel for useful discussions.

Figure 1: Commodity, Manufacturing and Services Prices
US$, 2000 = 100



Sources: Bureau of Economic Analysis; IMF; authors' calculations

Figure 2: Prices Relative to Non-durable Manufactured Goods
2000 = 100



Sources: Bureau of Economic Analysis; IMF; authors' calculations

2. The Role of Developing Economies

During the 1990s and 2000s, much of east and south-east Asia experienced a prolonged period of strong economic growth spurred by growth in productivity. The adoption of production processes from more developed economies helped to boost productivity levels of the economies in this region, while growth in investment helped to boost labour productivity. According to the IMF, labour productivity in Asia grew on average by 3.3 per cent per year between 1970 and 2005, of which capital accumulation contributed about 2 percentage points and total factor productivity (TFP) growth contributed 0.9 percentage points. Since 1979, labour productivity in China has grown by around 6 per cent annually (Table 1). TFP growth is estimated to account for half this growth while capital accumulation accounts for a significant proportion. Estimates of average annual TFP growth in China's manufacturing sector are as high as 10.5 per cent since 1998.[2]

Table 1: Growth in Labour Productivity to 2005
Annual average, per cent

	Start date	Labour productivity	Physical capital	Human capital	TFP
Japan	1955	3.1	2.0	0.4	0.7
NIEs	1967	4.5	2.6	0.6	1.5
ASEAN-4	1973	2.8	1.6	0.9	0.0
China	1979	6.1	3.0	0.9	3.6
India	1982	2.7	1.4	0.8	1.7
Other Asia	1990	2.6	1.3	0.8	0.4

Notes: NIEs (newly industrialised economies) consists of Hong Kong SAR, Singapore, South Korea and Taiwan Province of China. ASEAN-4 consists of Indonesia, Malaysia, the Philippines and Thailand.
Source: IMF (2006)

While growth in productivity has had direct effects on relative prices, particularly on the goods that Asian economies export, the effects on relative prices have not solely been driven by supply-side factors. In particular, the increase in productivity sparked an investment boom in these economies, and economies that industrialise increase their demand for resources. Accordingly, the energy needs of Asia increased significantly. China, which by 2007 accounted for about 7.5 per cent of global energy consumption, was responsible for nearly 50 per cent of the growth in global energy consumption between 2000 and 2007, while the rest of the Asia-Pacific region accounted for 18 per cent of growth in world energy consumption (see BP 2008). In comparison, North America was responsible for only 5 per cent of the growth in global energy consumption. The effect of the increased demand for resource commodities, as well as the downward pressure on prices for

2. For a range of estimates and a comparison with other countries, see Brandt, Van Biesebroeck and Zhang (2008).

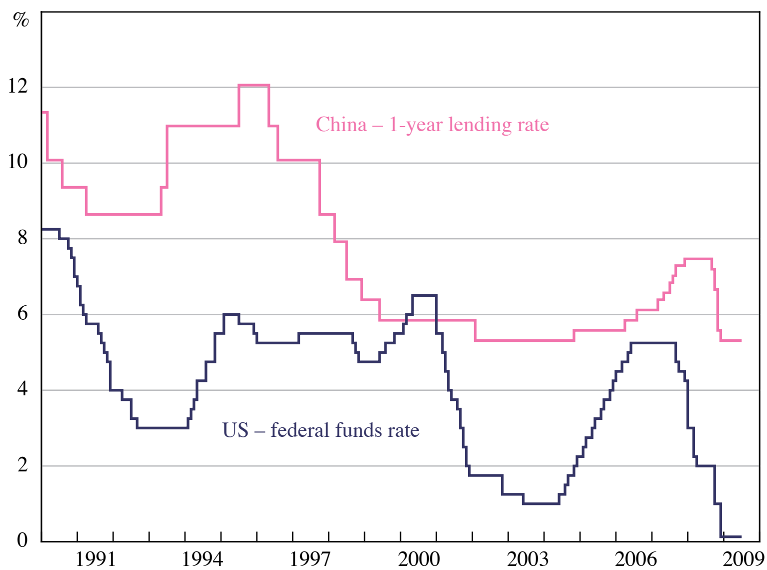
manufactured goods that Asia produces and exports, were major contributors to the large relative price movements.

Of course, changes in relative productivity levels, taxes and shifts in consumer preferences may also affect relative prices. However, the trends in relative prices, such as we have seen in the past decade, have also been driven by demand for certain goods from countries at earlier stages of their economic development. China and India have had the effect of increasing demand for certain commodities, especially energy and mineral products, while the prices of the products they export, for which they have a comparative advantage, have not risen by as much and in some cases have fallen.

3. Monetary Policies around the World

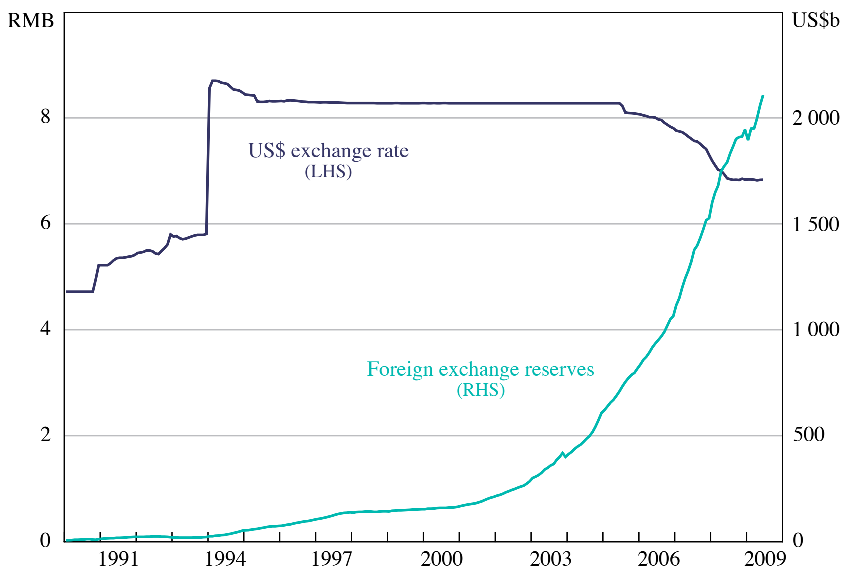
To some extent, the dramatic changes in relative prices could be the result of a combination of monetary policies adopted in the United States, China and elsewhere in the world. Following the events of 11 September 2001, the bursting of the dot-com bubble and at the onset of the 2001–2002 recession, the Federal Reserve Board (FRB) lowered interest rates aggressively, only gradually increasing rates as the US economy recovered (Figure 3). By fixing its exchange rate to the US dollar for a prolonged period of time after devaluing its currency in 1993 (Figure 4), China substantially reduced exchange rate risk for investors. The fixed exchange rate regime adopted by China, combined with the large interest rate differential that resulted from China not adjusting its interest rates to the same extent as the United States, encouraged firms to borrow in US dollars to invest in China, receiving higher returns with little fear of a devaluation of the Chinese currency. This is evident in the rapid growth of the gross flow of foreign direct investment into China, from US$47 billion in 2001 to US$108 billion in 2008, driven mainly by firms domiciled in east Asia, particularly from Hong Kong (Figure 5). Also, China's foreign exchange reserves grew exponentially – foreign reserves by July 2009 were about US$2.1 trillion, 10 times their level at the beginning of 2002 (Figure 4) – and gross fixed capital formation as a share of GDP rose quite rapidly in China (Figure 6). This boom in investment led directly to increased demand for raw materials and a large increase in commodity prices, particularly energy prices. Even as China increased interest rates and used other tools to tighten monetary policy, such as increasing its reserve requirement ratio (Figure 7), investment remained high and foreign direct investment rose rapidly. While the increase in the reserve requirement ratio acted to restrict lending by banks in China (Figure 8), it did not stop firms reinvesting their profits nor did it slow the inflow of foreign direct investment.

Figure 3: Monetary Policy Rates



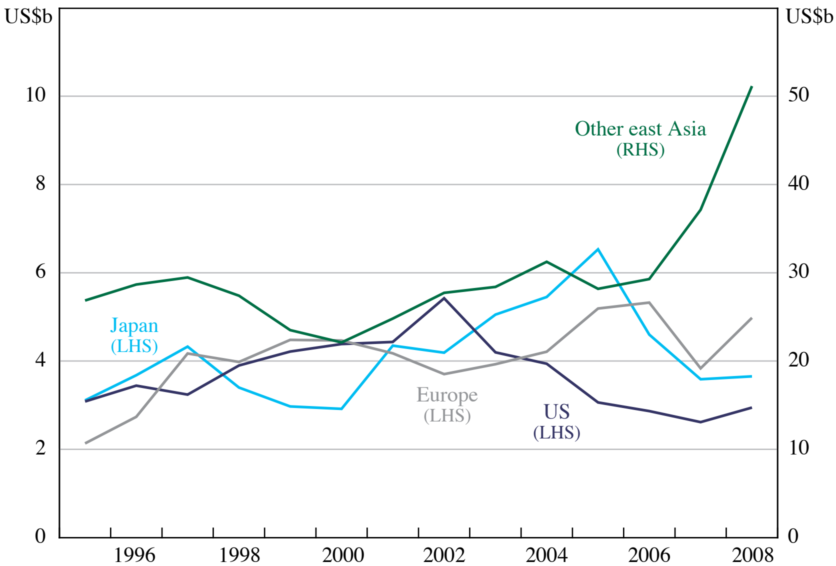
Sources: CEIC; Thomson Reuters

Figure 4: China – Exchange Rate Policy



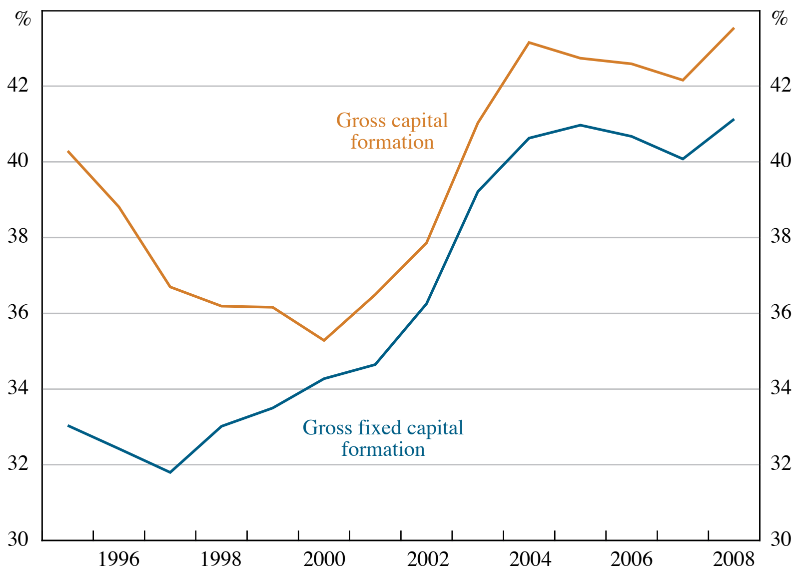
Sources: CEIC; Thomson Reuters

Figure 5: China – Foreign Direct Investment Inflows
Selected regions



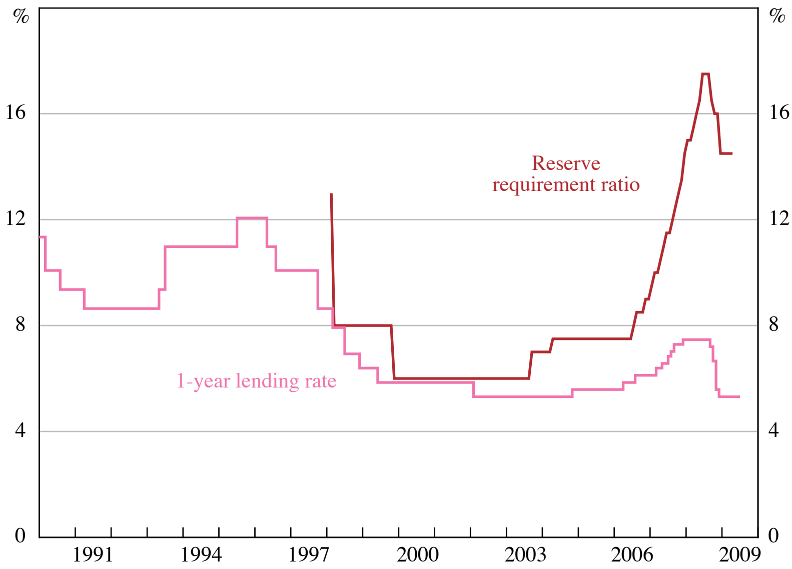
Source: CEIC

Figure 6: China – Investment Share
Per cent of GDP



Source: CEIC

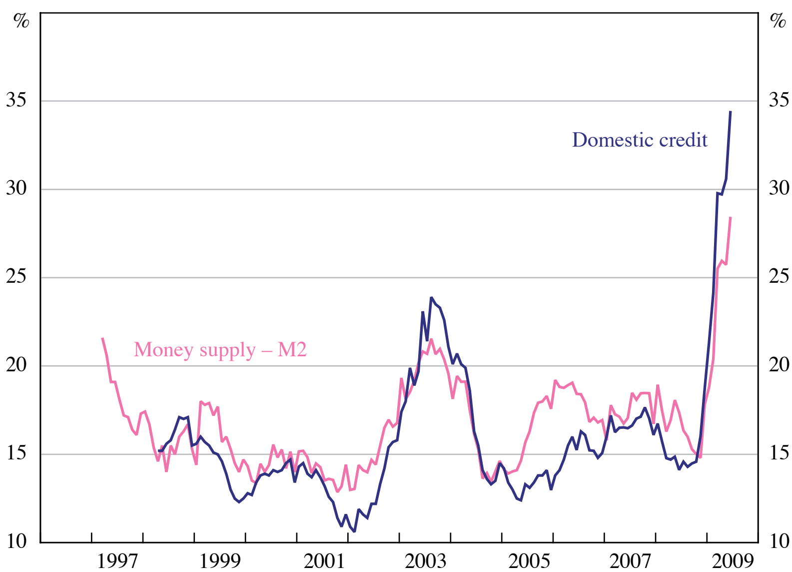
Figure 7: China – Monetary Policy



Sources: CEIC; Thomson Reuters

Figure 8: China – Credit and Money Supply

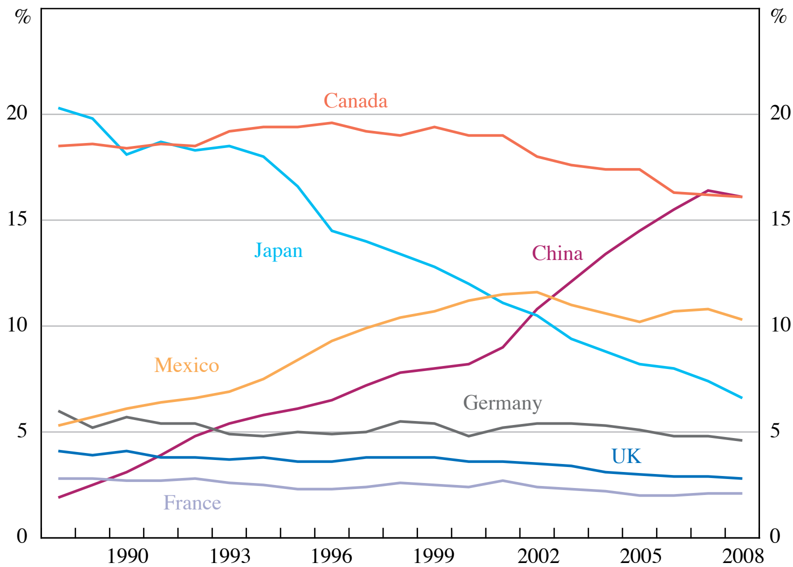
Year-ended percentage change



Source: CEIC

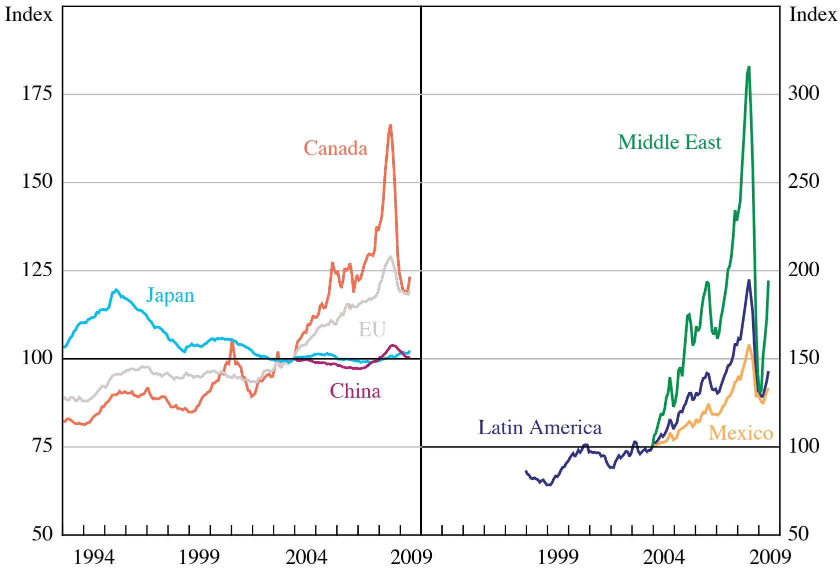
Import prices from countries such as China clearly exerted some downward pressure on US inflation. Although some have argued that US monetary policy was too easy between 2002 and 2006, it is difficult to argue that US monetary policy alone was behind the large movement in relative prices. The United States, during this period, was increasing its imports from China, to the point where China was close to becoming the largest source of US imports (Figure 9). This was the result of the lower prices of goods imported from China, mainly at the expense of imports from Mexico. The resulting downward pressure on inflation enabled the FRB to keep nominal interest rates reasonably low without risking rising inflation for prices of goods and services. Conversely, import prices from commodity-producing countries were rising rapidly (Figure 10), although some of this movement, especially between the middle of 2005 and the middle of 2008, could be attributed to the depreciation of the US dollar. The price of imports from China began to rise in 2006 following China's move to revalue its currency against the US dollar.

Figure 9: Composition of US Goods Imports



Source: Thomson Reuters

Figure 10: United States – Import Prices
December 2003 = 100



Source: Thomson Reuters

In the remainder of this paper, we apply a sequence of shocks to the multi-sector global G-Cubed model to see the extent to which the relative price movements that were observed across six different sectors can be replicated. The six sectors are: agriculture, mining, energy, durable manufactures, non-durable manufactures and services. Although the model contains many economies, we focus on just three: the United States, China and Australia. The shocks we consider are those to productivity, risk premia and monetary policy. We use these shocks to approximate some of the key features of the data, namely the large relative price movements and the boom in investment, particularly in China and other developing economies.

4. The Model

G-Cubed is a widely used dynamic intertemporal general equilibrium model of the world economy (which can be thought of as a hybrid dynamic stochastic general equilibrium (DSGE) model).[3] In the version used in this paper, there are 15 regions (Table 2), each with six sectors of production. The model produces annual results for trajectories running decades into the future.

Table 2: Economies in G-Cubed Model

United States	China
Japan	India
United Kingdom	Other Asia
Germany	Latin America
Rest of euro area	Other LDC (less developed countries)
Canada	Eastern Europe & former Soviet Union
Australia	OPEC
Rest of the OECD	

Because G-Cubed is an intertemporal model, it is necessary to calculate a baseline, or 'business-as-usual' solution before the model can be used for policy simulations. In order to do so, we begin by making assumptions about the future course of key exogenous variables. We take the underlying long-run rate of world population growth plus productivity growth to be 1.8 per cent per year, and take the long-run real interest rate to be 4 per cent. We also assume that tax rates and the shares of government spending devoted to each commodity remain unchanged.

In the G-Cubed model, projections are made based on a range of input assumptions. There are two key inputs into the growth rate of each sector in the model. The first is the economy-wide population projection, which differs by economy according to the mid-projections made by the United Nations.[4] The second is the sectoral productivity growth rate. For the baseline, we follow McKibbin, Pearce and Stegman (2007), where each energy sector in the United States is assumed to have a rate of productivity growth of 0.1 per cent over the next century. Each non-energy sector has an initial productivity growth rate close to historical experience but gradually converging to 1.8 per cent per year in the long run. We then assume that each equivalent sector in each of the other economies will catch up to the US sector in terms of productivity, closing the gap by 2 per cent per year, except for developing countries, which are assumed to close the gap by 1 per cent per year. The initial gaps are therefore critical for the subsequent sectoral productivity growth rate. We assume that the initial gap between all sectors and the US sectors are equal to the gap between aggregate purchasing-power-parity (PPP) GDP per capita between each economy and the United States. We cannot easily use sectoral PPP gap measures because these are difficult to get in a consistent manner and with a sufficient coverage

3. Appendix A provides additional details. See McKibbin and Wilcoxen (1998) for a complete description. This paper uses version 84O of G-Cubed.

4. See <http://esa.un.org/unpp/index.asp>.

for our purposes. Thus the initial benchmark is based on the same gap for each sector as the initial gap for the economy as a whole. If we then have evidence that a particular sector is likely to be closer to, or further away from, the US sectors than the aggregate numbers suggest, we adjust the initial sectoral gaps while attempting to keep the aggregate gaps consistent with the GDP per capita gaps.

Given these exogenous inputs for population growth and the growth of productivity across sectors, we then solve the model with the other drivers of growth, namely capital accumulation and sectoral demand for inputs of energy and other materials, which are all endogenously determined. Critical to the nature and scale of growth across economies are the assumptions outlined above plus the underlying assumptions that: financial capital flows to where the return is highest; physical capital is sector-specific in the short run; labour can flow freely across sectors within a country but not between economies; and international trade in goods and financial capital is possible, subject to existing tax structures and trade restrictions. Thus the economic growth of any particular economy is not completely determined by the exogenous inputs in that country alone, since all countries are linked through goods and asset markets.

In the analysis in this paper, we start with a projection of the model from 2002 onwards assuming steady-state growth in productivity as described above. We impose each shock, generate results in terms of deviations from the baseline and thereby determine the contribution of each shock to changes in relative prices and macroeconomic variables.

4.1 Policy responses

The results of this exercise will depend on the monetary and fiscal reactions. We assume that fiscal deficits are not changed in these results so as to focus on the core shocks without any fiscal stabilisers; that is, any changes in revenue are offset by changes in government spending spread across sectors based on historical spending shares. Of course, alternative assumptions regarding fiscal policy will change the results. The monetary responses have each economy following a Henderson-McKibbin-Taylor (HMT) rule shown in Equation (1), with different weights on inflation (π) relative to target (π^T), output growth (Δy) relative to potential growth (Δy^T) and the change in the exchange rate (Δe) relative to target (Δe^T).

$$i_t = i_{t-1} + \beta_1\left(\pi_t - \pi_t^T\right) + \beta_2\left(\Delta y_t - \Delta y_t^T\right) + \beta_3\left(\Delta e_t - \Delta e_t^T\right) \qquad (1)$$

The assumed parameter values are set out in Table 3. Note that China and most developing economies have a non-zero weight on the change in their exchange rate relative to the US dollar.

Table 3: Coefficients in Henderson-McKibbin-Taylor Rules in Each Economy

Economy	Inflation (β_1)	Output growth (β_2)	US$ exchange rate (β_3)
United States	0.5	0.5	0
Japan	0.5	0.5	0
United Kingdom	0.5	0.5	0
Germany[(a)]	0.5	0.5	0
Rest of euro area[(a)]	0.5	0.5	0
Canada	0.5	0.5	0
Australia	0.5	0.5	0
Rest of the OECD	0.5	0.5	0
China	0.0	0.0	–10 000
India	0.5	0.5	–10
Other Asia	0.5	0.5	–1
Latin America	0.5	0.5	–1
Other LDC	0.5	0.5	–1
Eastern Europe & former Soviet Union	0.5	0.5	–1
OPEC	0.5	0.5	–10

(a) Germany and the rest of the euro area have a fixed exchange rate with each other with a common interest rate, inflation target and output growth target.

5. The Shocks

A number of shocks to the model are considered and although the focus is on producing multipliers for the effect of each shock on inflation and relative price changes, the shocks are scaled in such as way as to be plausible and to give a crude indication of how much of the observed changes in relative prices from 2002 might be explained within the model.

We first consider a surge in productivity growth in both durable and non-durable manufacturing sectors in developing economies, particularly China. The assumption is that TFP growth in China rises above baseline for a decade before returning to baseline (that is, closing the now smaller gap with the United States at 2 per cent per year). The actual shocks are shown in Table 4; the other economies are scaled to the Chinese shocks as shown. We also set growth in energy, mining and agriculture productivity to zero so that supply shortages emerge gradually over time.

The second shock is a fall in global risk, most notable for China, in the form of a reduction in equity risk premium in each sector. This leads to an investment boom in China and some other economies. The scale of the changes to risk premia are also shown in Table 4.

The third shock is to monetary policy over a number of years, with interest rates kept lower than otherwise. The logic for this is as follows. The Taylor rule (also known in the literature in a more general form as the HMT rule) is often used

Table 4: Assumptions

Productivity growth rate	
Energy (all countries)	0 forever (1.8% below trend)
Mining (all countries)	0 forever (1.8% below trend)
Agriculture (all countries)	0 forever (1.8% below trend)
Services (all countries)	Trend
Durable manufactures (LATC)[(a)]	
China	12% above trend for 9 years
India	6% above trend for 9 years
Other Asia	6% above trend for 9 years
Latin America	6% above trend for 9 years
Non-durable manufactures (LATC)[(a)]	
China	12% above trend for 9 years
India	6% above trend for 9 years
Other Asia	6% above trend for 9 years
Latin America	6% above trend for 9 years
Risk premia shock	
China (all sectors)	–10% forever
All other countries and sectors	–5% forever

(a) LATC = labour-augmenting technical change

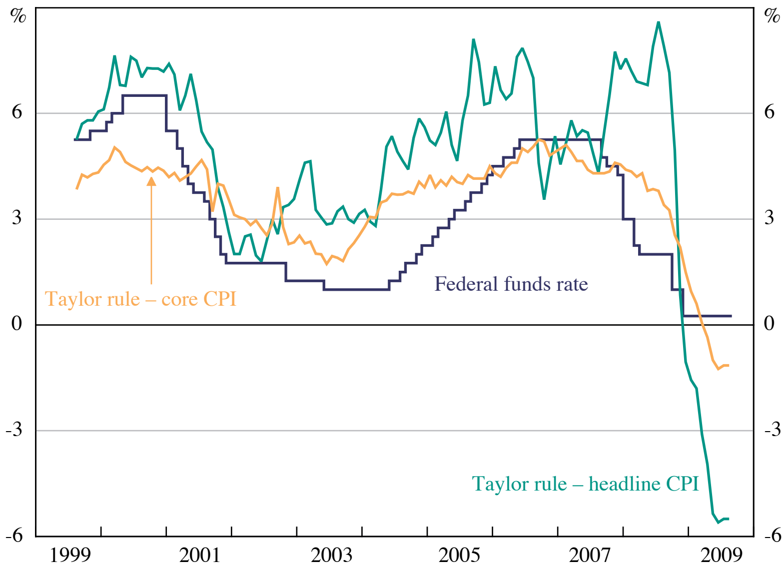
as a guide to measure the level of the short-term nominal interest rate. Between 2001 and 2006, the federal funds rate was below the rate implied by a widely used parameterisation of the Taylor rule by a significant margin (see Taylor 1993, 2009).[5] Using the core PCE measure of inflation, between June 2001 and January 2006, the federal funds rate was below the standard Taylor rule recommendation by an average of around 125 basis points (Figure 11). By this metric, monetary policy was very accommodative during this period. There are a number of ways of trying to engineer a path of interest rates that is below that recommended by some stylised rule. We could use additive shocks to generate a path for interest rates that deviates from the rule. Another way of generating this deviation is to argue that the FRB had assumed a higher growth rate for potential output, thereby lowering their estimation of the output gap leading to lower interest rate settings. Whatever the justification, the key point is that the shocks imply an interest rate path in line with those actually implemented by the FRB from 2001 to 2006.

The size of the shocks we incorporate seem reasonably plausible in light of actual developments over the past seven years or so. The key question then is whether, when combined in the model, they are sufficient to explain the movements of inflation and relative prices over this period. To the extent that the shocks might

5. That is, a Taylor rule specified as: $i_t = 2 + \pi_t + 0.5 * (\pi_t - \pi^T) + (u_t^T - u_t) + \varepsilon_t$. The coefficient on the unemployment gap is 1 because there is an implicit coefficient on the output gap of 0.5 with an 'Okun's Law' coefficient of 2. The NAIRU u_t^T is assumed to be 5 per cent and the inflation target (π^T) is 2 per cent.

not be sufficient, other shocks may need to be incorporated into a further analysis, and/or the model may need to be modified in some way.

Figure 11: Federal Funds Rate and the Taylor Rule



Sources: Bloomberg; authors' calculations

6. Results

The results of each shock are shown in Figures 12 through 17. These figures display the deviations from the baseline of key variables. Figures 12 and 13 contain results for China, Figures 14 and 15 for the United States, and Figures 16 and 17 for Australia. The figures show the response to each of the three shocks (separately and combined) of: GDP; investment; the real interest rate; and inflation. The responses of prices for each of the six sectors in each economy (relative to the output price index of each economy) are also shown for the combination of the three shocks.

To understand the results it is important to note a key feature of the G-Cubed model. A good produced in a sector within a country is an imperfect substitute for the same good produced in the same sector in another country. Thus, although there are six sectors of production in each country, and each sector within each country has a similar name, in effect there are actually 90 different goods in the model (6 sectors times 15 economies). Every sector has the same production function in each economy, with the same elasticity of substitution between the factors of production. The initial input share coefficients are from recent input-output tables for each economy and differ across sectors and across economies.[6] Thus mining in China is initially relatively labour intensive whereas mining in Australia is relatively

6. We use the GTAP 6 Data Base as detailed in Dimaranan (2006).

capital intensive.[7] Since the production technologies to produce investment goods, and goods and services consumed by governments and households have finite elasticities of substitution, there is never complete convergence in the production technologies of the sectors across economies.

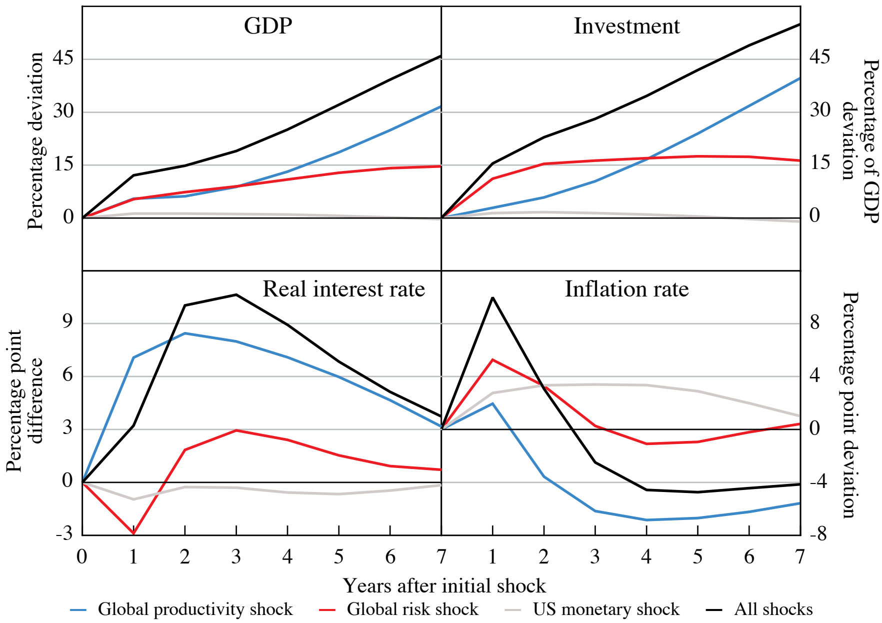
6.1 Productivity shocks

First consider the effect of productivity shocks. The rise in manufacturing productivity in developing economies raises investment in the manufacturing sectors in those economies. The lack of growth in energy, mining and agriculture productivity worldwide tends to retard investment in those sectors. In China, the rise in productivity raises GDP growth and the level of GDP rises further above the baseline each year (Figure 12). Note that the results for GDP in each figure are shown as percentage deviations from the baseline in levels, while the productivity shock is to the growth rate of productivity. Higher productivity growth in manufacturing offsets the low productivity growth in non-manufacturing so that aggregate investment rises and the capital stock grows to the new higher level. Because the shock to the growth rate eventually disappears, the level of GDP and capital will remain permanently higher. Higher expected incomes in China raise consumption. Together with higher investment, aggregate demand temporarily rises above aggregate supply and inflation temporarily rises even though it falls over time. This latter effect follows because the higher growth in China implies that the real exchange rate needs to depreciate (since China has to sell more goods to the rest of the world). Since the nominal exchange rate is fixed, this real depreciation occurs via lower inflation in China (helped about by higher real interest rates).

The top-left panel of Figure 13 shows the relative price impacts of the shock to productivity for China. The sectors in which there is strong productivity growth (durable and non-durable manufactures) experience falling input costs and lower prices relative to the economy average. Sectors that are not growing quickly (energy, mining and agriculture) are in greater demand as inputs into manufacturing production but also for higher investment and consumption. Thus the relative prices of these sectors tend to rise as their output becomes increasingly scarce relative to that of the manufacturing sectors. The demand for services also increases as this is a major input into production and consumption. By year 7 the price of energy is 16 per cent higher than the price of non-durable manufactures.

7. The relative intensities can change as relative prices adjust to shocks. So, for example, if the wage-rental ratio increases in China, mining may become more capital intensive there.

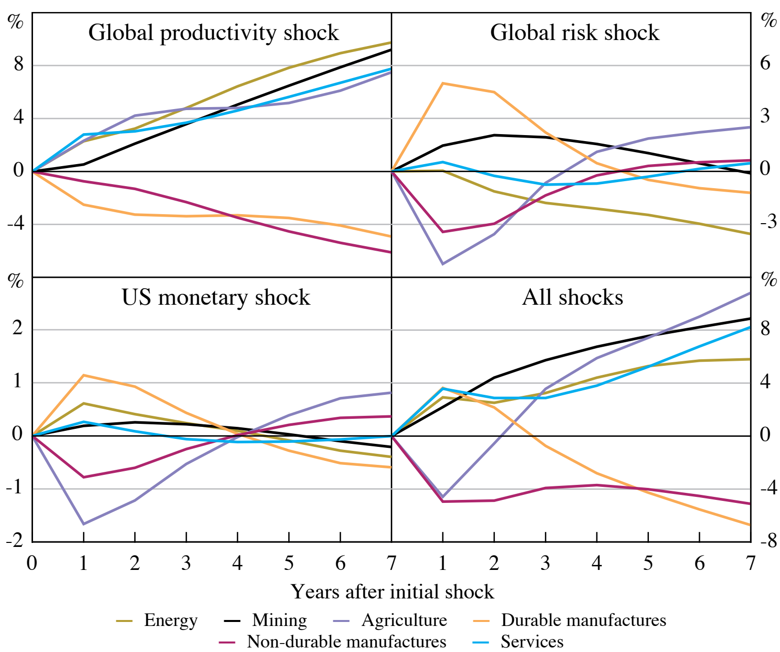
Figure 12: China – Deviations from the Baseline



Source: authors' calculations

Figure 13: China – Relative Prices Deviations from the Baseline

Percentage deviation



Source: authors' calculations

There is an additional important effect on durable versus non-durable goods. A rise in real interest rates tends to reduce the demand for output of the sectors that are producing inputs into capital goods or for goods whose demand depends on the calculation of the present value of a flow of future services. This is particularly an issue for the durable goods sector since it is a large input into producing the investment good that is purchased by all sectors. At the same time, sectors that are relatively capital intensive experience a larger increase in the rental cost of capital and therefore will contract relative to labour-intensive sectors when the real interest rate rises relative to the real wage. In China, the durable goods and energy sectors are capital intensive. Mining is relatively labour intensive in China but relatively capital intensive in the United States and Australia.

The macroeconomic implications of the rise in developing country productivity for the United States are shown in Figure 14. US GDP rises as a result of the shock in the developing economies, with consumption rising due to higher income from investments in developing economies. However, the GDP increase is short-lived as capital flows from the United States into developing economies in response to higher returns to manufacturing in those economies and due to higher energy and mining prices in the world. The hollowing-out of US manufacturing implies that GDP is 2.5 per cent below baseline by year 7 even though the growth rate of US GDP has returned to its long-run steady state.[8] The restructuring of US manufacturing also drives the response of aggregate investment (panel 4, Figure 14). While there is additional investment in non-energy sectors, this is outweighed by the decline of manufacturing. The outflow of capital from the United States to developing econommies increases real interest rates in the United States, which further acts to reduce US investment. As for inflation, the initial strength of consumption in the United States, together with higher non-manufacturing prices, is sufficient to initially offset the lower price of imported manufactured goods. However by year 4, the productivity shock is deflationary for the United States.

The outcomes for relative prices in the United States are shown in the top left panel of Figure 15. The pattern is very similar to that in China, with the relative price of energy, mining and agriculture rising relative to manufacturing. Despite the manufacturing productivity shock occurring outside the United States, the fall in the relative price of manufactured goods by year 7 in the United States is larger than in China (22 versus 16 per cent respectively).[9] The one difference between the United States and China, apart from the scale of the response, is that the price of services rises in China whereas it is flat in the United States. This is because there is a larger rise in consumption and, particularly, investment in China, which raises the demand for services by more than in the United States.

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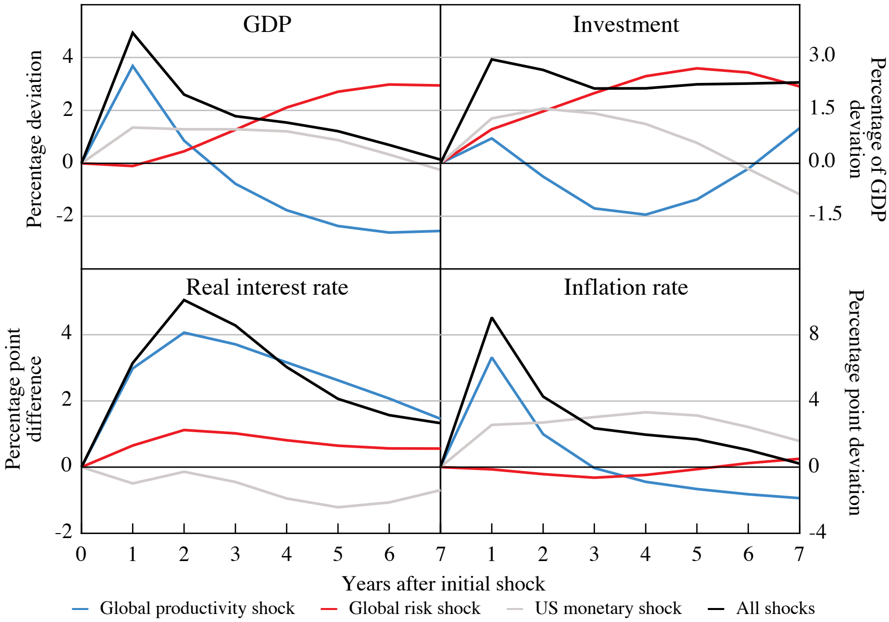
8. While GDP in the United States falls below baseline, the United States receives higher income from investments abroad and faces lower prices for imports and other goods. So even though production in the United States is below baseline, real incomes are higher and US households are better off overall.

9. Demand for manufactured goods is relatively weaker in the United States, given that Chinese income directly benefits from the higher level of productivity there.

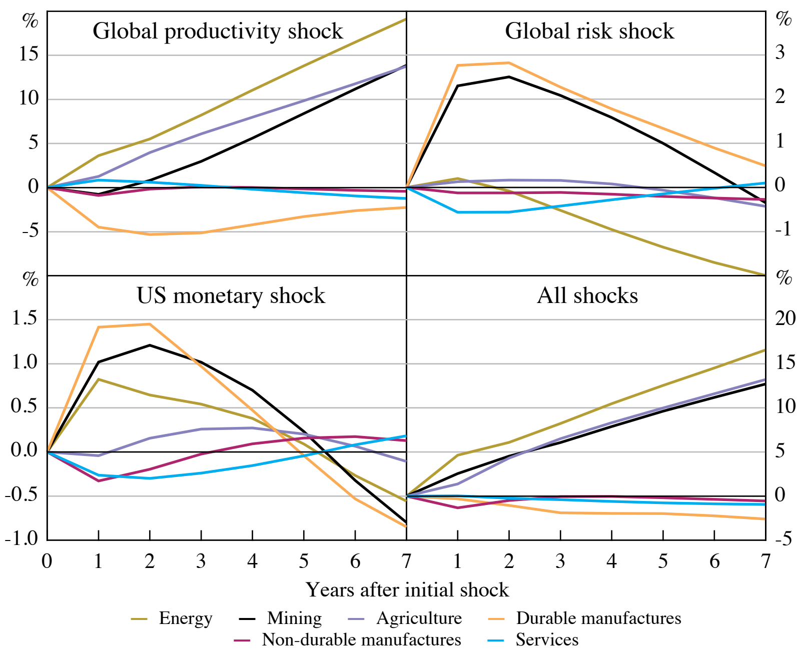
Figure 14: United States – Deviations from the Baseline



Source: authors' calculations

Figure 15: United States – Relative Prices Deviations from the Baseline

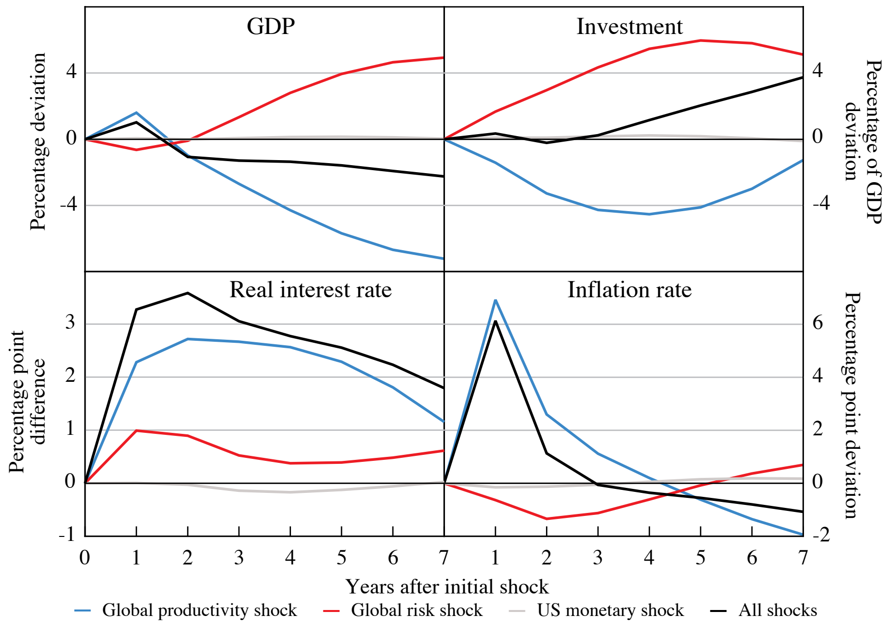
Percentage deviation



Source: authors' calculations

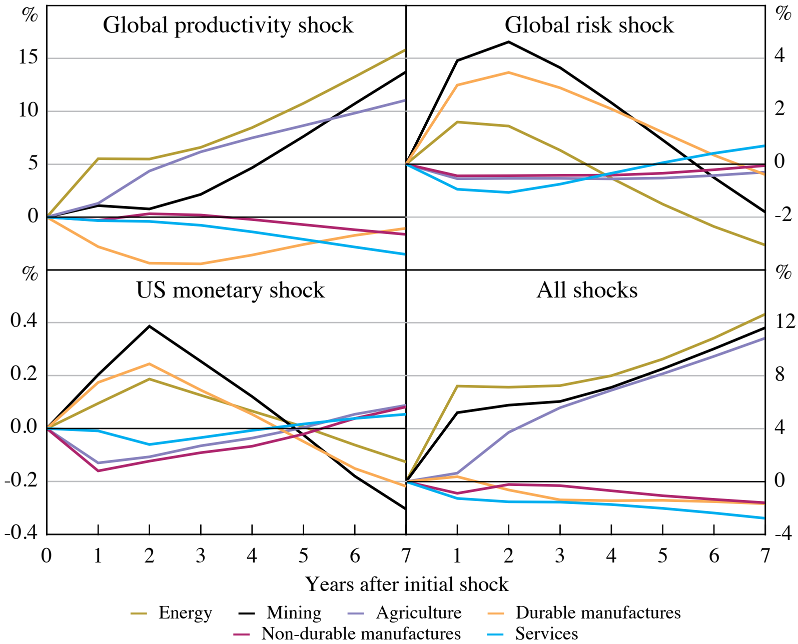
The responses in Australia to the productivity shocks are shown in Figure 16 and the top left panel of Figure 17. The results for GDP are similar to the United States in the short run. However, over time the assumption of no productivity growth in the relatively large sectors of the Australia economy – energy, mining and agriculture – weigh heavily on the growth of overall GDP. The increase in the real interest rate also reflects the flow of capital out of Australia into developing economies' manufacturing sectors, but this effect is smaller than for the United States because there is an inflow of investment into mining for export to the rapidly growing developing economies, which are demanding more raw materials.

Figure 16: Australia – Deviations from the Baseline



Source: authors' calculations

Figure 17: Australia – Relative Prices Deviations from the Baseline
Percentage deviation



Source: authors' calculations

6.2 Global risk shocks

The reduction in global risk (larger in China than everywhere else) takes the form of a fall in the equity risk premium. The adjustment mechanism in the model occurs through a rise in Tobin's Q for investment in each sector. This causes an investment boom in all countries, especially in China where the shock is largest. As can be seen from the macroeconomic results for China (Figure 12), the United States (Figure 14) and Australia (Figure 16), the adjustment across economies is very similar and as expected. Strong investment raises GDP via short-run demand effects. Over the medium term, GDP rises with the level of potential output, in line with higher capital accumulation. However, there are some subtle differences across countries. In China, monetary policy targets the exchange rate. Whereas real interest rates rise in the United States and Australia – following the initial shock to demand – in China, real interest rates fall initially as otherwise the Chinese currency would tend to appreciate (given the larger decline in the equity risk premium there).

The sectoral story for the risk shock is very different to the results for the productivity shock. As discussed above, the changes in real interest rates relevant to firms and households have very different impacts across sectors depending on how sectoral output is used and on the capital-labour ratio of each sector. The fall in the interest rates faced by households and firms tends to increase the demand for capital-intensive goods, inputs into capital-intensive industries and durable goods. In all economies, the fall in risk premia causes a rise in the demand for durable manufacturing goods and a rise in the relative price of these goods.[10] Note that mining output rises slightly in China because despite being relatively labour intensive, it is a large input into durable goods production. In both the United States and Australia, where mining is relatively capital intensive, there is a rise in the relative price. Agriculture prices fall sharply in China because agriculture is relatively labour intensive whereas in the United States and Australia, services prices fall by most because they are relatively labour intensive. (Agriculture is more capital intensive in these economies than in China.)

Another interesting insight from the results is that the initial demand change determines the short-run relative price changes in the model. However, over time investment and movements of labour across sectors change the supply side of some sectors. Thus, the medium-term relative price changes reflect a combination of demand and supply effects. So although the price of durable goods increases most in the short run in China, this induces greater investment in durable goods, which expands the supply of these goods and by year 7, the relative price of durables has fallen below the output price index.

6.3 Monetary policy shock

The final shock we consider is to monetary policy with the FRB setting policy rates below those implied by a standard Taylor rule. It is useful to start the analysis with the results for the United States shown in Figure 14. The US real interest rate is 50 basis points lower than baseline initially, falling to 1 percentage point below baseline by year 5. This stimulates investment, which raises real GDP above trend for a number of years, but at the same time it pushes up inflation by 2.5 to 3 percentage points. The integral of the difference in real GDP over time is zero because the higher real GDP in the first six years is then followed by GDP below base in subsequent years (not shown).

It is interesting to observe that the change in US monetary policy does change relative prices in the short run (Figure 15). The channel of adjustment is through the impact of real interest rate changes on the demand for durable goods and investment, and depends on the capital intensity of production of different sectors (as discussed above). In year 1, inflation rises by almost 3 percentage points and the price of durable goods relative to non-durable goods rises by 1.7 per cent. As would be expected, this relative price adjustment is largely gone by year 5. The persistence partly reflects the investment changes which propagate a supply response well after the demand response has passed. Thus relative prices overshoot in subsequent years due to the capital accumulation dynamics.

10. This effect is particularly important for understanding the consequences of the global financial crisis on durable goods production and trade in the context of a large increase in risk premia. See McKibbin and Stoeckel (2009).

Interestingly, and perhaps not surprisingly, the results for China are very similar to the results for the United States – given that China pegs its currency to the US dollar. Thus the real interest rate falls in China as US monetary policy is relaxed in order to hold the exchange rate fixed. It is difficult to see in Figure 12 because of the scale of the other shocks, but Chinese inflation rises by 3.5 per cent by year 3 as China imports the easier US monetary policy. Chinese real GDP is 1.3 per cent higher by year 2 due to the monetary expansion. Although not as large as the results for the productivity shocks in China, this effect is nonetheless significant. The dispersion of relative price changes in China is also similar to that for the United States and for the same reasons. The one difference again is the mining sector, which is relatively labour intensive in China and therefore does not receive as much stimulus as in the United States where it is relatively capital intensive.

From the results in Figure 16 and 17, it is clear that the floating exchange rate largely insulates the Australian economy from the change in US monetary policy. Real interest rates fall but the effect is small. Nonetheless there are changes in relative prices because of a minor capital intensity effect in Australia, which is due in part to the small change in Australian real interest rates, but more importantly because the United States and China are a large share of the global economy. The dispersion in US relative prices of 1.8 percentage points and in China of 2.7 percentage points is reflected in the dispersion in relative prices in Australia of 0.8 percentage points. The flexible exchange rate only offsets aggregate price relativities but has little influence on the relative price differences across sectors.

6.4 Combining the shocks

Each of the figures also contains the results of combining all of the shocks in order to get a rough sense of how they offset or reinforce each other. Several interesting insights emerge when compared to the actual experience since 2001. First, while the developing economy productivity shocks are deflationary, this effect is offset by the change in US monetary policy so inflation is largely unchanged in the United States. Hence, from this perspective, US monetary policy appears to have been successful given the announced concern at the time regarding the potential for US deflation after the dot-com bubble burst in 2001.

Second, although the relative prices of energy, mining and agriculture after seven years move in the same direction as that experienced in the world economy over the period 2002 to 2007, the magnitudes are far smaller than the actual experience. The extraordinary magnitudes of the relative price changes between 2005 and 2007 observed in the global economy are not captured by the shocks to fundamentals considered in this modelling exercise. The sharp rise in the relative prices of commodities in excess of the model simulations could be explained by three different causes: speculative activities not built into the analysis in this paper; a set of shocks not considered in this paper; or misspecification of the model (that is, the model may not adequately reflect reality).

7. Relative Prices and the Role of Policy

Although monetary policy may have had only a minor role in driving the trends in relative prices over the past decade, our simulations show that it is possible for monetary policy to have an effect on relative prices in the short to medium term. It is also possible that the decline in global risk premia up to 2007 as investors searched for yield was also driven, at least in part, by monetary policies globally, even though we assume it to be a separate shock in this paper. Although we do not formally explore the optimal policy responses to the shocks driving the large relative price movements that the world economy has experienced, it is worth discussing some of the principles that macroeconomic policies should follow in response to these forces.

The presence of nominal rigidities, affecting some wages and/or prices, and real rigidities, such as capital adjustment costs, make it possible for monetary policy to have some effect on relative prices, including the terms of trade and real exchange rates. In an economy with sticky wages or prices, an easing of monetary policy will result in prices that are more flexible rising faster than those that are more sticky. This leads to a temporary shift in demand towards the sticky-price sectors. As sticky prices gradually adjust, relative prices and output will eventually return to long-run equilibrium. In the meantime, given a temporary fall in real interest rates, demand for durable goods, for example, should expand faster than in other sectors. Accordingly, the prices of capital-intensive sectors should rise by more while real interest rates are low.

When and how monetary policy should respond to relative price movements will depend on the nature of the shocks driving these changes. If they are very temporary, there may be little if any time to respond given the lag with which monetary policy can take effect. If the shocks are more persistent (though still temporary), much of the literature would argue that there are circumstances under which it is optimal for policy-makers to essentially do nothing – that is, not to respond to the shocks driving relative prices and to tolerate the resulting deviation of inflation from a target for a short time so long as this does not jeopardise hitting the inflation target over the medium term. There are circumstances, however, when policy may want to actively respond so as to speed the transition to the new relative price equilibrium; along the way inflation may well deviate from target, so again, the monetary authorities will need to ensure that inflation remains anchored to the target over the medium term. Of course, in practice it is difficult for policy-makers to recognise in real time whether a shift in relative prices is being driven by temporary or permanent factors, nor can they be certain about the extent to which policy can successfully fine-tune a faster transition if required.

Aoki (2001) examines the optimal monetary policy responses to relative price changes in both a closed economy model and a small open economy model and draws similar conclusions to those presented here. The models are based around two sectors, one with flexible prices, the other with sticky prices. The main findings are that stabilising relative prices around their efficient level should be a goal of a central bank and that targeting inflation in the sticky-price sector is sufficient to achieve this goal. In an open economy context, Aoki argues that the central bank should target domestic inflation since imported prices are typically flexible. By targeting domestic inflation, the central bank can effectively keep the real exchange rate at its optimal level, which is desirable from a welfare perspective. The argument that central banks should try to stabilise relative prices around their efficient levels could be extended to a world with other distortions not resulting from nominal rigidities.

Benigno (2002) examines optimal policy in an open economy, sticky-price model. In a closed economy model, optimal monetary policy tends to be somewhat expansionary in order to offset the distortion implied by monopolistic competition. In an open economy setting, if monetary authorities behave non-cooperatively, there is another mechanism that works in the opposite direction. Each policy-maker aims to improve their terms of trade and to shift the burden of production to the other country by appreciating their currency in the presence of nominal rigidities. The incentive for such contractionary policy is greater the more open an economy and the more substitutable domestic and foreign goods are in consumption. Others, like Canzoneri and Henderson (1991), find a similar contractionary bias but for a different reason. In their one-shot, two-country game, tighter monetary policy in one country leads to a real depreciation and higher inflation for the other country. Hence, following a common shock that raises inflation in both economies, monetary authorities in both countries try to engineer a real exchange rate appreciation by tightening monetary policy. The result of this combined action by the two policy authorities in a non-cooperative Nash equilibrium is that monetary policy becomes excessively tight in both economies compared to an equilibrium when the policy actions in the two countries are coordinated.

While monetary policy can only have relatively temporary effects on relative prices[11], fiscal policy can have more enduring effects. The use of fiscal instruments to address permanent changes in relative prices, however, is not without its problems and policy-makers need to take some care when using spending and taxing instruments to effect a change in relative prices. Should the shift in relative prices be the result of reduced competition in a particular market, or distortions due to fiscal policies abroad, there may be a case for a government to levy taxes or provide subsidies to offset the effect of these other distortions on relative prices. However, if relative prices are changing due to more fundamental factors, such as a shift in relative productivity levels, a fiscal authority working to offset the resulting shift in relative prices will lower welfare by distorting the allocation of resources.

There are other questions related to how a fiscal authority should deal with the boom in revenues that may result from a large terms of trade boost. Countries whose industries are highly concentrated in the production of a few commodities that may experience large increases in their prices will need to manage revenues carefully. Should the price of a particular commodity rise temporarily, it would be prudent of fiscal authorities to invest the windfall in another economy. This way, the fiscal authority, whose revenues may already be sensitive to the domestic economic cycle,

11. Although monetary policy can have a more sustained (but not permanent) effect if it has some effect on the appetite for risk of investors.

can diversify its revenue risk; should commodity prices fall, along with the economy's real and nominal exchange rates, the domestic currency value of the government's investments overseas will rise as a result. Examples of this type of fund, known as sovereign wealth funds, include Chile's Economic and Social Stabilization Fund and Norway's Government Pension Fund Global (a continuation of the Petroleum Fund). Ideally, these funds would be invested in sectors not related to the sources of the shifts in the price of the commodity in question.

8. Conclusions

This paper considers a stylised representation of three major shocks affecting the global economy during the period from 2002 to 2008. These shocks were: a large rise in the productivity growth of manufactures relative to non-manufacturing sectors in developing economies; a fall in global risk premia; and the relatively easy monetary policy stance of the FRB starting after the bursting of the dot-com bubble in 2001 and lasting up until the early part of 2006. The three shocks are considered in a global model that captures the interdependencies between economies at both the macroeconomic and sectoral levels.

There are a number of insights that suggest a need for further empirical analysis. The first is that the shift in relative prices observed since 2002 can be partly explained by the adjustment in the model in response to the assumed shocks, however, the scale of the actual rise in the prices of energy, mining and agriculture relative to manufacturing since 2004 are not well captured. Other factors outside the fundamentals in the model are needed to explain the scale of this more recent experience. The second insight is that the model suggests that there was some contribution to global inflation due to the FRB keeping interest rates low after the bursting of the dot-com bubble in 2001, and that this effect was reinforced by the fact that the Chinese and other monetary authorities pegged to the US dollar. However, the effect on global relative prices of US monetary policy is relatively small compared to the productivity shocks in developing economies. One interpretation of these results is that the short-term deflationary impact of developing economy productivity growth on the US economy was to a large extent neutralised in the United States by the change in FRB policy as modelled in this paper.

An interesting conclusion of the simulations in this paper is that monetary policy tends to affect relative prices for up to four years because the effect of a temporary change in real interest rates varies across sectors. The effect depends on each sector's relative capital intensity as well as on the change in the demand for the output of each sector as consumption and investment adjust. Eventually the effect of monetary policy on relative prices dissipates.

Interestingly, a country that pegs to the US dollar when the United States relaxes monetary policy inherits both the overall inflationary consequences of the US policy shift as well as the dispersion in relative prices, although this partly depends on the relative capital intensity of the sectors in the pegging economy. A country, such as Australia, which maintains a flexible exchange rate is largely shielded from the inflationary effect of changes in US monetary policy (via an appreciation of the exchange rate) but it is not shielded from the relative price effects. These are transmitted through global trade channels and are even larger when a significant part of the world economy pegs to the US dollar and experiences similar inflationary and relative price movements.

Finally, it is important to note that there are many caveats surrounding the methodology adopted in this paper. It is not meant to be a definitive empirical assessment of the role of various shocks in the world economy between 2002 and 2008. Rather, it is meant to give some insights into the relationships between relative prices and overall inflation in a world characterised by a variety of different shocks.

Appendix A

The G-Cubed model is an intertemporal general equilibrium model of the world economy. The theoretical structure is outlined in McKibbin and Wilcoxen (1998).[12] A number of studies – summarised in McKibbin and Vines (2000) – show that the G-Cubed modelling approach has been useful in assessing a range of issues across a number of countries since the mid 1980s.[13] Some of the principal features of the model are as follows:

- The model is based on explicit intertemporal optimisation by the agents (consumers and firms) in each economy. In contrast to static computable general equilibrium (CGE) models, time and dynamics are of fundamental importance in the G-Cubed model. The MSG-Cubed model is known as a dynamic stochastic general equilibrium (DSGE) model in the macroeconomics literature and a dynamic intertemporal general equilibrium (DIGE) model in the CGE literature.
- In order to track the macroeconomic time series, the behaviour of agents is modified to allow for short-run deviations from optimal behaviour either due to myopia or to restrictions on the ability of households and firms to borrow at the risk-free rate on government debt. For both households and firms, deviations from intertemporal optimising behaviour take the form of rules of thumb, which are consistent with an optimising agent that does not update predictions based on new information about future events. These rules of thumb are chosen to generate the same steady-state behaviour as optimising agents so that in the long run there is only a single intertemporal optimising equilibrium of the model. In the short run, actual behaviour is assumed to be a weighted average of the optimising and rule-of-thumb assumptions. Thus aggregate consumption is a weighted average of consumption based on wealth (current asset valuation and expected future after-tax labour income) and consumption based on current disposable income. Similarly, aggregate investment is a weighted average of investment based on Tobin's Q (a market valuation of the expected future change in the marginal product of capital relative to the cost) and investment based on a backward-looking version of Q.
- There is an explicit treatment of the holding of financial assets, including money. Money is introduced into the model through a restriction that households require money to purchase goods.
- The model also allows for short-run nominal wage rigidity (by different degrees in different economies) and therefore allows for significant periods of unemployment depending on the labour market institutions in each economy. This assumption, when taken together with the explicit role for money, is what gives the model its 'macroeconomic' characteristics. (Here again the model's assumptions differ from the standard market-clearing assumption in most CGE models.)

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12. Full details of the model can be obtained by contacting the authors.
13. These issues include: Reaganomics in the 1980s; German unification in the early 1990s; fiscal consolidation in Europe in the mid 1990s; the formation of NAFTA; the Asian crisis; and the productivity boom in the United States.

- The model distinguishes between the stickiness of physical capital within sectors and within countries and the flexibility of financial capital, which immediately flows to where expected returns are highest. This important distinction leads to a critical difference between the quantity of physical capital that is available at any time to produce goods and services, and the valuation of that capital as a result of decisions about the allocation of financial capital.

As a result of this structure, the G-Cubed model contains rich dynamic behaviour, driven on the one hand by asset accumulation and, on the other, by wage adjustment to a neoclassical steady state. It embodies a wide range of assumptions about individual behaviour and empirical regularities in a general equilibrium framework. The interdependencies are dealt with by using a computer algorithm that solves for the rational expectations equilibrium of the global economy. It is important to stress that the term 'general equilibrium' is used to signify that as many interactions as possible are captured, not that all economies are in a full market-clearing equilibrium at each point in time. Although it is assumed that market forces eventually drive the world economy to neoclassical steady-state growth equilibrium, unemployment does emerge for long periods due to wage stickiness, to an extent that differs between economies due to differences in labour market institutions.

References

Aoki K (2001), 'Optimal Monetary Policy Responses to Relative-Price Changes', *Journal of Monetary Economics*, 48(1), pp 55–80.

Benigno P (2002), 'A Simple Approach to International Monetary Policy Coordination', *Journal of International Economics*, 57(1), pp 177–196.

BP (2008), *BP Statistical Review of World Energy June 2008*, BP p.l.c., London.

Brandt L, J Van Biesebroeck and Y Zhang (2008), 'Firm-Level Productivity in the Chinese Manufacturing Sector', mimeo. Available at <http://www.upjohninst.org/enterpriseresearch/cost//workshop/vanbriesebroeck.pdf>.

Canzoneri MB and DW Henderson (1991), *Monetary Policy in Interdependent Economies: A Game-Theoretic Approach*, MIT Press, Cambridge.

Dimaranan BV (ed) (2006), *Global Trade, Assistance, and Production: The GTAP 6 Data Base*, Center for Global Trade Analysis, Purdue University, West Lafayette.

IMF (International Monetary Fund) (2006), *World Economic Outlook – Financial Systems and Economic Cycles*, World Economic and Financial Surveys, IMF, Washington DC.

McKibbin WJ, D Pearce and A Stegman (2007), 'Long Term Projections of Carbon Emissions', *International Journal of Forecasting*, 23(4), pp 637–653.

McKibbin WJ and A Stoeckel (2009), 'The Potential Impact of the Global Financial Crisis on World Trade', World Bank Policy Research Working Paper 5134.

McKibbin WJ and D Vines (2000), 'Modelling Reality: The Need for Both Inter-Temporal Optimization and Stickiness in Models for Policy-Making', *Oxford Review of Economic Policy*, 16(4), pp 106–137.

McKibbin WJ and P Wilcoxen (1998), 'The Theoretical and Empirical Structure of the G-Cubed Model', *Economic Modelling*, 16(1), pp 123–148.

Taylor JB (1993), 'Discretion Versus Policy Rules in Practice', *Carnegie-Rochester Conference Series on Public Policy*, 39(1), pp 195–214.

Taylor JB (2009), 'The Financial Crisis and the Policy Responses: An Empirical Analysis of What Went Wrong', NBER Working Paper No 14631.

Discussion

1. Don Harding

These comments are presented in two parts. The first relates to some general issues that arose with the treatment of relative prices in the papers at the conference – the bulk of my discussion at the conference related to this topic. The second part of my comments relates to the revised draft of the paper by Adam Cagliarini and Warwick McKibbin.

Relative prices

My sense is that the conference papers never really came to grips with the issue of how to define relative prices and what are their main features. In these comments I briefly set out the issues that arise in defining relative prices, suggest a useful measure and then summarise some key features of relative commodity prices.

All of the papers at the conference defined relative prices as

$$q_{it} = \frac{P_{it}}{P_{jt}} \tag{1}$$

where P_{it} is the price of the i^{th} commodity in period t, with $P_{it} \geq 0$. The alternative is to define relative prices via a price simplex, let p_{it} to be the i^{th} element of the price simplex then

$$p_{it} = \frac{P_{it}}{\sum_{i=1}^{I} P_{it}} \tag{2}$$

The key feature of the p_{it} is that they are bounded below by 0 and above by 1. Thus we are guaranteed that all moments of $(p_{1t}, \ldots, p_{It})$ exist for all data-generating processes for the nominal price vector $(P_{1t}, \ldots, P_{It})$, something that is not true of $(q_{1t}, \ldots, q_{It})$. This means that one can use moments to summarise the features of $(p_{1t}, \ldots, p_{It})$, something that we cannot be assured is valid when summarising the features of $(q_{1t}, \ldots, q_{It})$.

A second important difference between Definitions (1) and (2) is that the former depends on the choice of numerator while the latter does not. This means that summary statistics built on Definition (1) will depend on the choice of numerator.

The price simplex for the commodity price data used in the paper by Jeffrey Frankel and Andrew Rose is shown in Figure 1.

The most dramatic feature evident in Figure 1 is the cornering of the silver market by the Hunt brothers around 1980. The next most dramatic feature is the rise of platinum and oil prices in the past decade. The figure also makes clear the point that not all relative prices can rise – some must fall. Indeed, when correctly defined, the average relative price, by definition, is 1/11. This figure should make it clear that the conference should have focused on the variance of relative prices rather than the relative price changes themselves.

Figure 1: Time Series of Price Simplex for Eleven Commodities

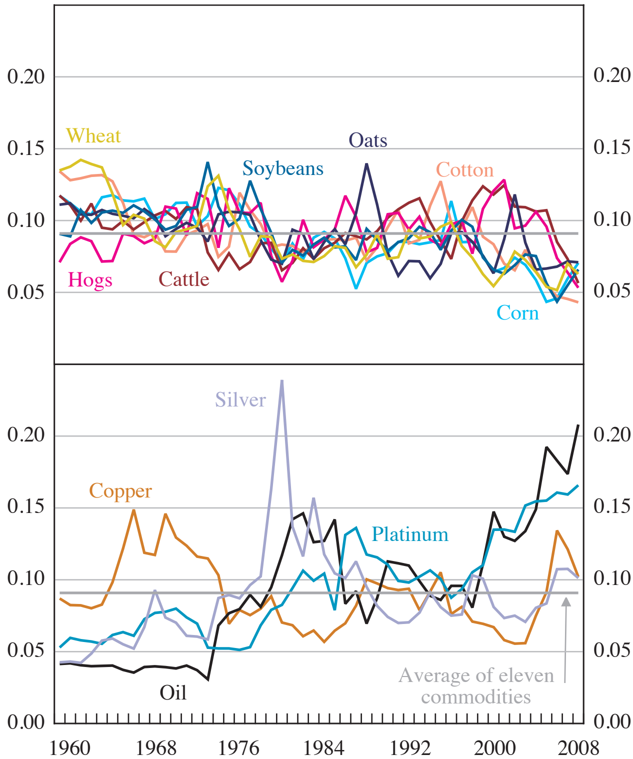
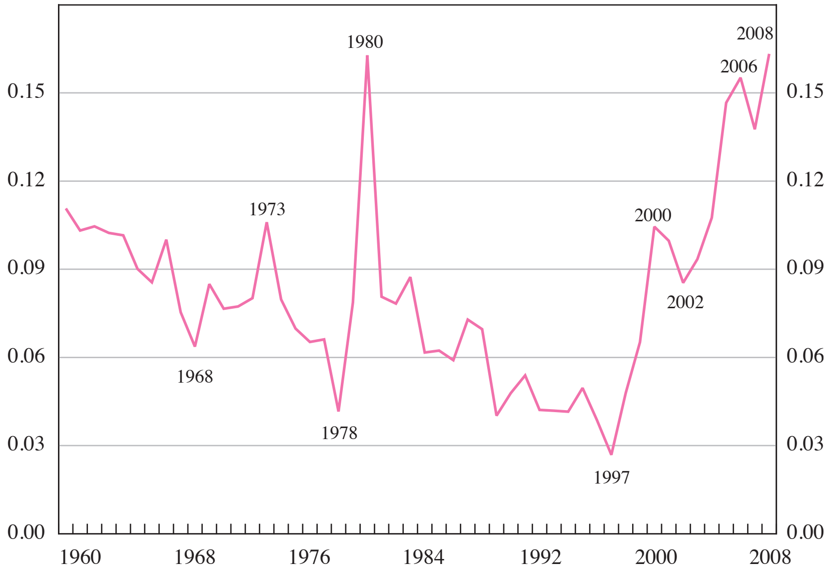


Figure 2 shows the overall variability of relative prices as measured by the sum of the squared deviations for the commodity prices contained in Figure 1. As can be seen from this figure, leaving aside the Hunt episode around 1980, there was a trend decline in volatility of relative prices until 1997. However, since that date there has been a marked increase in the volatility of relative prices. It is these features of the data (and their implications for inflation, if any) that I would argue should have been the centre piece of the conference.

In my discussion at the conference, I presented material showing the correlations between various groups of prices in the simplex, and discussed the usefulness of those statistics in summarising features of the data and in testing how well models capture those features of the data. I also provided a decomposition of the variability of the GDP simplex. These items have been removed from this written discussion for reasons of space.

Figure 2: Square Root of Sum of Squared Commodity Price Simplex Deviations from 1/11



Specific comments on global relative price shocks: the role of macroeconomic policies

The paper by Adam and Warwick uses G-Cubed, a multi-sector and multi-country general equilibrium model, to study the capacity of shocks to productivity, risk premia and United States monetary policy to explain the large movements of relative prices between 2002 and 2008. They find that productivity shocks provide some of the explanation for the large relative price movements, but the other two shocks only provide limited and temporary explanations.

One of their main findings is that taken together these three shocks cannot provide a complete explanation of the movement in relative prices. They conclude that this suggests that '… other driving forces could also be responsible, including those outside of the model' (p 305). This finding should not be a surprise as there have been large shifts in patterns of world production and expenditure and, if these countries differ in the intensity with which they use various commodities, then one would expect these shifts to have big implications for relative commodity prices.

To provide some evidence on this hypothesis I constructed a simplex of world real GDP and then calculated the variability of that simplex in exactly the same way as I calculated the variability of relative commodity prices. The two series are shown in Figure 3.

Figure 3: Square Root of Sum of Squared Commodity Price and GDP Simplex Deviations

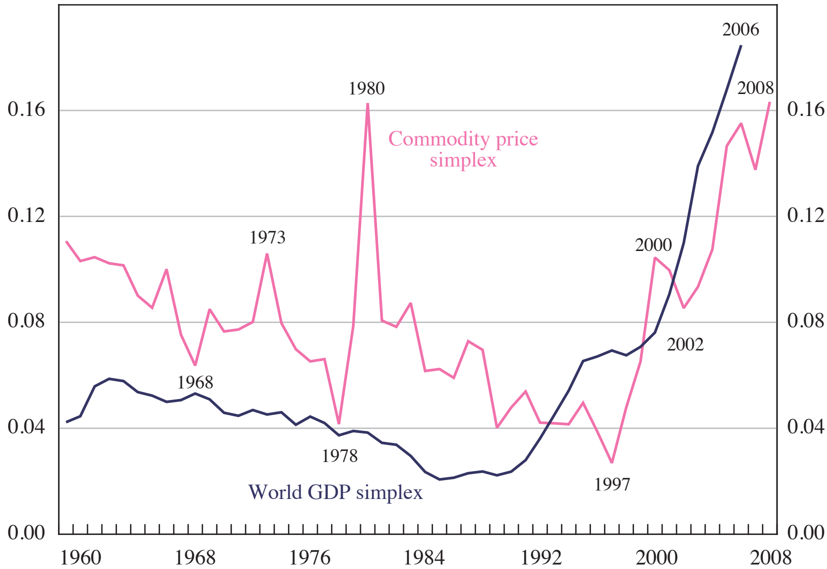


Figure 3 clearly establishes that that there is a strong correlation between the variability of real GDP and the variability of relative prices in the commodity sector. This suggests that shifts in the pattern of world production and expenditure may be associated with the increased variability of relative prices.

It is not clear from the paper whether G-Cubed can explain the shifts in the patterns of world production and expenditure and capture the links between these shifts and relative price movements. Thus, while the exercise is of some value, one is left with considerable uncertainty about how much weight can be placed on the conclusions.

2. General Discussion

The initial discussion developed around the consequences of a positive productivity shock in China. One participant pointed out that over the past decade, China's exports had risen relative to GDP, but the opposite was true of consumption. This is contrary to the idea that consumption should rise at least as fast as output in response to a permanent improvement in productivity. Another participant raised the possibility that this was not an anomaly since excess labour in the rural sector was keeping wages in the urban sector low, implying that the benefits of rising productivity were accruing to firms as profits, which are in turn being reinvested. Adam Cagliarini responded by noting that wages in the model could be made very sticky in China to help generate such a result.

The debate then turned to the behaviour of China's current account. Over recent years, as China experienced significant productivity gains without corresponding rises in Chinese consumption, savings flowed out of China. By contrast, the model in the paper implies a net inflow of capital to China. Warwick McKibbin agreed with these observations and said that they would consider the issue in future iterations of their paper.

In response to large relative price movements, participants suggested that the paper implied that monetary policy should tolerate deviations of inflation from target and stabilise prices around the new relative price level. In line with the earlier discussion of Lutz Kilian's paper, one participant suggested that a central bank should instead allow other prices to move in an offsetting manner in order to hit a price-level target. However, it was argued by another participant that this was not optimal if these other prices were relatively inflexible. Yet another participant thought that the optimal policy response will depend on whether shocks were revealed over a relatively short period or more gradually over a long period (in which case even inflexible prices would have time to adjust).

The remainder of the discussion focused on clarification of the structure of the model and the underlying assumptions. A participant questioned the frequency of price adjustments in the model, and also asked whether the model was consistent with the observed quantities of commodities traded. In response, Warwick McKibbin noted that the model is Keynesian, in that it incorporates sticky wages, but not New Keynesian, because it does not include sticky prices. Prices adjust annually to clear the market; how prices adjust depends on the flexibility of wages in the production of those commodities. Relating this to the policy implications of the research, Adam Cagliarini noted that central banks may target the prices of the sectors which are labour intensive in production, in an environment of sticky prices. Finally, in response to a question about the modelling strategy, Warwick McKibbin noted that the model used in the paper does not forecast well, rather it was intended to provide insights into the consequences of marginal changes over time compared to a baseline case.

Wrap-up Discussion

1. Michael Dooley[1]

The unifying theme of the conference has been that the inflationary effects associated with changes in commodity prices depend on the more fundamental shocks that drive commodity prices. Moreover, since changes in prices of oil and other commodities are relative price shocks they do not cause inflation. In contrast, central banks can cause inflation and they respond to real shocks, so it is necessary to understand central banks' reactions to changes in relative prices. In looking at any historical episode three sets of issues must be resolved. First, what caused the change in the relative prices of commodities and how did this affect other real variables? Second, how did this combination of real changes influence nominal price setting behaviour? And finally, how did the monetary authorities react to these economic developments?

The central empirical regularity confronted by conference participants is that recent commodity price increases have not yet been associated with increases in inflation rates. If we accept the conventional wisdom that oil shocks did generate inflation in the past, it follows that something in the long path from relative price changes to inflation has changed. The list of possibilities is a long one and the papers prepared for the conference provide an excellent summary of the more plausible candidates.

A generic explanation for a circuit breaker between commodity price changes and inflation is that real responses are muted because recent commodity price changes are, and are expected to be, temporary. Commodity price shocks could be less persistent for a number of reasons. The paper by Jeffrey Frankel and Andrew Rose makes two important points in this regard. First, the run-up and collapse in oil and other commodity prices in 2008 and the recent rebound are unusual in that they seem to be responding to a common macro shock. Second, the real macro shocks that would generate permanent changes in commodity prices do not seem to be having very powerful effects in the recent episode. In particular, changes in expected world GDP growth or changes in real long-term interest rates do not seem to have played an important role recently.

They do, however, find that speculation and monetary policy seem to have played important roles. To me this raises the possibility that something has changed, either in the structure of commodity markets or in the private sector's reaction to expected inflation, that has made commodity prices more volatile. For example, the bandwagons suggested by Jeffrey and Andrew are by definition transitory.

The recent behaviour of oil and other commodity prices has revived a very old debate about the role of speculation and the structure of markets in determining

1. University of California, Santa Cruz.

prices in these markets. A new twist on an old story is that a new class of 'index investors' is now indirectly participating in commodity futures markets. The facts are that investment banks offer institutional and other investors funds for which the return is indexed to a popular index of commodity prices. The investment bank then hedges its short fund exposure by rolling over long positions in commodity futures markets. As investors that would not have been willing or able to participate directly in commodity futures markets are attracted to index funds, the proximate result is upward pressure on commodity futures prices. This is not exactly a general equilibrium result, but since I am now a market participant I will try to put some respectable clothing on the idea.

My conclusion is that an important change in the rules of the game did lead to the entry of a new class of speculators into commodity markets. Moreover, this change in market structure has generated, and will continue to generate, much more volatility in commodity prices. An intriguing possibility is that the inflationary effects of swings in commodity prices will be reduced in this more volatile market structure.

Some fundamentals of speculation

Jeffrey and Andrew's paper uses the simple but powerful Hotelling model to link spot prices, futures prices and inventories. Suppose some group of investors receives new information that demand for oil will grow more rapidly if China continues to grow at 10 per cent per annum. They bid up the futures price to the expected future spot price. The spot price also rises as storage becomes profitable and oil is withheld from the market. The effects on spot and futures prices are the same as if the speculator had purchased and stored spot oil. The spread between spot and futures prices depends on financing costs and the cost of storage, both of which, in turn, are an increasing function of market interest rates and the volume of storage.

How much oil has to be withheld from the spot market to move the spot price? If demand in the short run is inelastic, not much. This is where the peculiarities of the world oil market start to intrude on a simple story. Once oil is pumped out of the ground where can it be stored? We have up-to-date numbers on inventories of crude oil and products but it is difficult to interpret these data. The striking aspect of the inventory data is that it is very stable. In particular, it does not look like the stock of inventories varies over time to smooth prices except for seasonal variations.

Why not? My conjecture is that the almost infinitely larger stock of oil still in the ground has a much lower storage cost relative to oil above ground. It seems very likely that oil producers have an underground inventory strategy. Producers' Hotelling strategy rests on two simple and intuitive ideas. First, oil in the ground has to provide about the same yield as alternative financial assets. Second, and more important, the price of oil cannot rise to the choke price, a level where no one wants it, while the swing producer still has oil in the ground. I am quite sure this is how dominant producers think about their pricing and inventory problem. Other producers with 5 to 10 years of oil remaining want the highest price the swing producer will tolerate. This makes negotiations within the Organization of the

Petroleum Exporting Countries (OPEC) difficult and constrains the swing producer from reacting as quickly as it might want to.

Those who blame index speculators for recent swings in oil and commodity prices tell the following story. The United States Congress, in legislation that was supported by most economists and the Administration, effectively removed restrictions for participation in energy futures markets in December 2000. The argument was, and is, that restrictions limit the ability of legitimate hedging and sharing of risk. With deregulation, a large group of amateurs entered the oil and other commodity markets. In particular, after 2006, index positions grew rapidly as new investors were sold on the idea that commodities are an 'asset class' like US equities, and that they offered fair rates of return and some diversification.

What index investors did not understand is that their bid for forward positions could not be met by an increase in the stock of above-ground oil. There is of course lots of oil underground and I think what investors have in mind is that they are buying a claim on this underground oil, the stock of which is very large relative to the bid of this new class of investors. The problem is that underground oil cannot be purchased and delivered to satisfy a short position in the near-date futures market. It follows that the long index speculator position must be offset by a naked short speculative position.

Economists tend to believe that this is not a problem because stabilising speculation will accommodate this long index position. Market participants believe that other speculators will get in front of a large, predictable flow of bids for futures contracts, but they will require a large risk premium to do so. Oil producers could have arbitraged the spot-forward spread but no one else could, simply because they had no place to put above-ground inventories. So for a short time all this new demand fell on a stock of oil above ground that was already owned by market participants that were long in crude oil because they planned to turn it into products. These participants watched as prices went up and had good reason to hold on to their positions.

The net result of this market structure is that spot oil prices rose to levels that are inconsistent with the swing producer's optimal price path. Oil at US$150 a barrel encourages innovation and generates the risk that they will be left with oil in the ground that can only be sold at a much lower price. They could have entered the futures market directly but this risks a political reaction to manipulating the market. Their alternative was to increase production and eventually force spot prices down.

So commodities are an asset class but one that is (eventually) dominated by producers. Producers manage inventories below ground to minimise departures from their desired price path. The imperfect but politically acceptable control variable is current output. The swing producer could also participate in the futures market but normally does not do so. In this environment there is little economic incentive to invest in above-ground storage facilities in order to profit from short-run price fluctuations. The swing producer does that already.

So we have a problem, but is it a problem for public policy? Clearly we do not want commodity prices to be distorted by index speculators. They will eventually learn to buy oil companies with reserves rather than oil futures but that could take a while. More hopeful is the idea that there are other ways to arbitrage the spot-forward spread that is now an unusual feature of some commodity markets. A steep futures curve means that selling futures and buying anything highly correlated with the spot commodity is a profitable strategy. Currencies such as the Australian dollar are an obvious possibility. Hedge funds may be willing to absorb the basis risk generated by this strategy and restore market efficiency.

2. John C Williams[2]

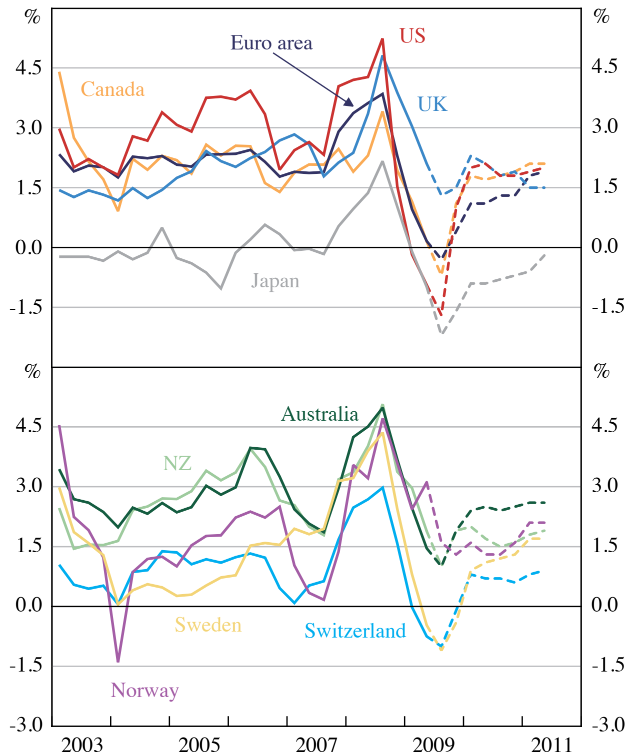
Five years ago, the topic of this conference was 'The Future of Inflation Targeting'. Despite the apparent success of the inflation-targeting central banks at maintaining low and stable inflation, many participants at that particular conference expressed the concern that inflation targeting had not yet truly been 'battle-tested' in a sufficiently adverse macroeconomic environment. Glenn Stevens summed up the prevailing sense of caution at the time, saying '… an issue for the future is how well we will cope with supply shocks when they come' (Stevens 2004, pp 290–291). The tumultuous events since then have provided such a test, yielding valuable lessons for central banks, whether they follow a strategy of inflation targeting or not. The papers in this year's conference address a number of key issues related to how well central banks have weathered these storms.

Soaring oil and other commodity prices from 2004 through mid 2008 provided one critical test of inflation targeting and other monetary policy strategies. The dramatic movements in commodity prices have left their imprint on headline inflation rates over the past several years. The solid lines in Figure 1 shows headline consumer price inflation rates along with the most recent consensus forecasts for a number of economies. Headline inflation rates peaked in mid 2008 and then plummeted as commodity prices collapsed and the global recession intensified.

Although the one-two punch of commodity price shocks and the global financial crisis and recession have caused inflation rates to rise well above desired levels and then to fall rapidly, into negative territory in many economies, inflation expectations have remained remarkably well anchored in major industrialised economies. The dashed lines in Figure 1 show the most recent consensus forecasts for headline consumer price inflation. In all cases, private forecasters expect inflation to return to near the inflation targets for inflation-targeting countries (as described by Kuttner 2004) or near historical norms in non-inflation-targeting countries by early 2011. Indeed, longer-run inflation expectations have remained very stable in these countries throughout the past five years. Figure 2 shows consensus long-run inflation forecasts for the same set of industrialised economies included in Figure 1.

2. Federal Reserve Bank of San Francisco. The opinions expressed are those of the author and do not necessarily reflect the views of the management of the Federal Reserve Bank of San Francisco or anyone else in the Federal Reserve System.

Figure 1: Headline Inflation
Year-ended

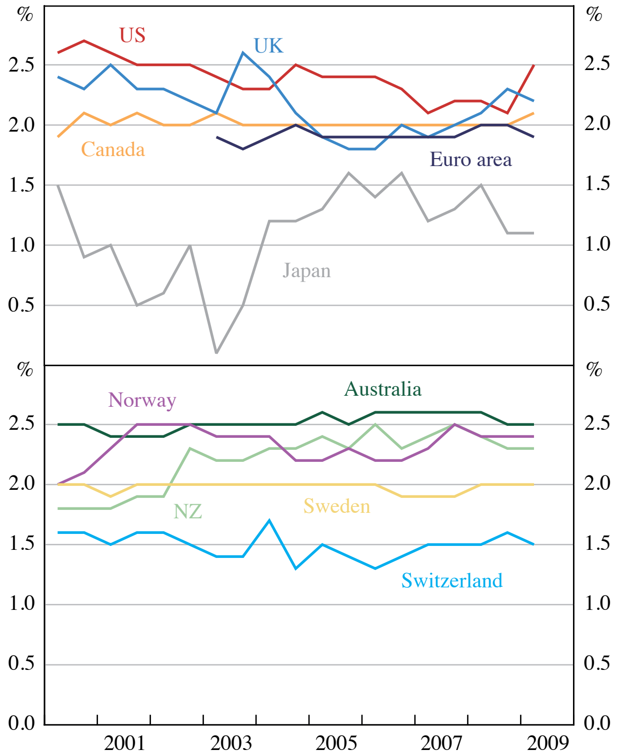


Note: Dashed lines are forecasts
Source: Consensus Economics

Inflation expectations have remained well-anchored even as central banks have taken aggressive actions to stimulate economic growth during the recent global downturn. As discussed in Williams (2009), central banks in most major industrialised economies reduced overnight interest rates to near zero in late 2008 or early 2009. In addition, several central banks have undertaken unconventional monetary policies aimed at stimulating growth. Evidently, inflation-targeting and non-inflation-targeting central banks have demonstrated the flexibility to stabilise economic activity while maintaining well-anchored inflation expectations. Indeed, the anchoring of expectations has likely provided central banks with greater willingness to respond aggressively to the global downturn.

In summary, many inflation-targeting and non-inflation-targeting central banks have coped well with extremely large supply and demand shocks over the past five years. The papers in this conference provide valuable insights into why this has been the case. In particular, the papers by Robert Anderton *et al*, Christiane Baumeister, Gert Peersman and Ine Van Robays, and Lutz Kilian show that over the past two decades, oil supply shocks have had only transitory effects on

Figure 2: Long-run Inflation Expectations



Note: 5–10 year Concensus Economics forecasts; from biannual surveys taken in April and October

Source: Consensus Economics

inflation rates. Christiane, Gert and Ine's paper also documents that responses to oil supply shocks differ across economies, with a key difference being the magnitude of second-round effects on wages and non-energy prices.

What explains the relatively benign responses of inflation to oil supply shocks found in these papers? A number of factors are assuredly at work, including fiscal and monetary policy regimes, the subject of the papers by Graciela Kaminsky, and César Calderón and Klaus Schmidt-Hebbel, respectively. Importantly, the better anchoring of inflation expectations in the past 20 years has likely played a significant role in explaining the absence of second-round effects of oil price shocks on wages and other prices. For example, Orphanides and Williams (2007) show that well-anchored inflation expectations mute and shorten the response of inflation to supply shocks. The paper by Pierre Siklos provides valuable information on the behaviour of various measures of inflation both across and within economies.

That leaves the question of how monetary policy *should* respond to oil supply shocks in order to both contain inflation and keep inflation expectations well-anchored. The papers by Lutz and Christiane, Gert and Ine provide an intriguing answer: do nothing. Both papers find that the nominal short-term interest rate barely responds to a sizable oil supply shock, based on a sample starting in the mid 1980s. Evidently, the countervailing influences of weaker output and higher inflation resulting from an oil price increase are nearly offsetting as far as monetary policy-making is concerned. Of course, this evidence does not imply that such passivity is the optimal policy response, but it does suggest that such a response is consistent with the favourable behaviour of inflation following oil supply shocks, such as we have witnessed over the past two decades in the United States.

This finding – that the interest rate does not respond to oil supply shocks – poses some difficulties for the communication of monetary policy decisions. Some members of the public might wonder why the central bank is doing nothing while inflation soars, fearing a return to the high inflation of the past. For this reason, at times of large supply shocks, it is especially important for the central bank to reinforce its commitment to low inflation. The use of core measures of inflation and/or inflation forecasts is an important tool in public communication of the rationale for policy actions (or *inactions*). But, both of these approaches have their shortcomings. The paper by Francesco Ravazzolo and Shaun Vahey makes an important contribution in this regard by developing better methods to forecast inflation in the presence of large relative price shocks.

The flip side of the issue of how monetary policy should respond to oil and other commodity price shocks is the question of whether monetary policy is itself the source of commodity price fluctuations and other asset market booms and busts. For example, Taylor (2007) argues that deviations from the historical monetary policy rule fuelled the US housing boom earlier this decade. However, the papers in this conference suggest that such effects are relatively small. Jeffrey Frankel and Andrew Rose find no empirical evidence of effects of interest rates on commodity prices. Adam Cagliarini and Warwick McKibbin use a structural model of the global economy and show that while relative prices do respond to monetary policy, this channel cannot explain the magnitude of the wild swings in these prices over the past five years.

Finally, it is notable that all but one of the papers in this conference are purely empirical in nature. Of course, solid empirical research is essential to understanding these important issues. But, the design of monetary policy in the presence of relative price shocks also depends on theoretical concepts, such as the natural rates of output and interest, and the choice of which inflation measure to target. For example, the papers in this conference find that negative oil supply shocks lead to highly persistent decreases in real output in the United States, as well as the euro area, Japan and Switzerland. However, the empirical evidence does not tell us to what extent this decline reflects a reduction in the natural rate of output or an opening of an output gap. The effects of relative price shocks on natural rates are highly model-dependent. As shown by Natal (2009), with a Cobb-Douglas specification for household preferences and technology with respect to energy, the natural rate of labour hours is unaffected by a change in the relative price of oil. But, with a more realistic assumption of less short-run substitutability, the natural rate of labour hours falls in response to the shock. Similarly, Bodenstein, Erceg and Guerrieri (2008) examine the optimal inflation rate to target in the presence of oil price shocks. Further development and synthesis of empirical and model-based research into these important issues is needed in order to inform the discussion of the optimal policy response to commodity and asset prices.

References

Bodenstein M, CJ Erceg and L Guerrieri (2008), 'Optimal Monetary Policy with Distinct Core and Headline Inflation Rates', Board of Governors of the Federal Reserve System International Finance Discussion Paper No 941.

Kuttner KN (2004), 'A Snapshot of Inflation Targeting in its Adolescence', in C Kent and S Guttmann (eds), *The Future of Inflation Targeting*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 6–42.

Natal J-M (2009), 'Monetary Policy Response to Oil Price Shocks', Federal Reserve Bank of San Francisco Working Paper No 2009-16.

Orphanides A and JC Williams (2007), 'Inflation Targeting under Imperfect Knowledge', in FS Mishkin and K Schmidt-Hebbel (eds), *Monetary Policy under Inflation Targeting*, Proceedings of a Conference, Central Bank of Chile, Santiago, pp 77–123.

Stevens G (2004), 'Wrap-up Discussion', in C Kent and S Guttmann (eds), *The Future of Inflation Targeting*, Proceedings of a Conference, Reserve Bank of Australia, Sydney, pp 289–292.

Taylor JB (2007), 'Housing and Monetary Policy', in *Housing, Housing Finance, and Monetary Policy*, a Symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, pp 463–476.

Williams JC (2009), 'Heeding Daedalus: Optimal Inflation and the Zero Lower Bound', *Brookings Papers on Economic Activity*, 2, pp 1–37.

3. General Discussion

The wrap-up presentations provoked debate on the role of speculation in the oil market and the role of monetary policy in responding to shocks to relative prices. Regarding speculation in the oil market, a number of participants doubted whether speculation had had a significant effect in driving the spot price of oil. First, it was suggested that if speculation played a substantial role, futures prices should predict future spot prices, but empirically this was not the case. Second, there is little evidence that inventories have increased to imply that speculation has contributed to the run-up in the price of oil. One participant suggested there is little evidence that large oil-exporting countries are attempting to manipulate the oil market through the adjustment of their inventories, that is, unexploited oil under the ground. Another participant noted that it is difficult to extend the speculative theory about oil price determination to other commodities such as natural gas that had also experienced a run-up in price. Michael Dooley responded by reiterating his argument that the interpretation of the results of existing econometric analysis was difficult because the models supporting this work did not account for the strategic behaviour of the major oil producers.

A comment was made about the time scale of 2000 onwards chosen in John Williams' presentation of inflation expectations. It was suggested that it would be better if the analysis started in the early 1990s to be consistent with literature suggesting that the US Federal Reserve's implicit inflation target can be dated from then. John Williams agreed that the stability in long-run inflation expectations dates back to the 1990s. He remarked that the focus of his analysis was on the importance of the monetary policy regime and inflation expectations for both the direct and indirect responses of inflation to relative price shocks. He noted that the indirect response to changes in commodity prices appears to have become weaker over time and that it was important for policy to be designed to reduce indirect or second-round effects.

There was some discussion about the long-term view for commodity prices. One participant noted that real commodity prices had been falling since the 1700s, reflecting a long history of strong productivity growth in primary production relative to manufacturing. In this respect, the current experience was something of an anomaly. The question was whether productivity growth in primary production would reassert itself as the dominant influence, driving commodity prices back down. Michael Dooley responded by saying that whatever happened to the level of commodity prices, we should expect them to be more volatile given that structural change had made speculation in commodity markets easier. Even so, it was suggested that much like the shift from fixed to floating exchange rates, this extra volatility in relative prices would have only minor real effects. Another participant noted that, even if it were true that speculative activities have an effect on the price of commodities, fundamental factors would ultimately determine those prices.

There was also discussion on the evolution of monetary policy over the next half-decade as the global economic structure changes – in particular, how monetary policies should respond to global factors, such as those related to the emergence of China and India. John Williams suggested that, in the past, many US macroeconomists considered changes in global factors and the external environment to be of second-order importance, but he could see that this could well change in the future.

Biographies of Contributors

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Professor Heather Anderson is an elected Fellow of the Academy of the Social Sciences in Australia, and the Maureen Brunt Professor of Economics and Econometrics at Monash University. She is also Co-director of the Macro-econometric Models and Methods program of the Centre for Applied Macroeconomic Analysis at the Australian National University. Her research interests include nonlinear time series analysis, empirical finance, empirical macroeconomics and forecasting. She is co-editor of *Empirical Economics*, and she is on the editorial board of several other academic journals including the *Journal of Applied Econometrics*, the *Economic Record* and *Studies in Nonlinear Dynamics and Econometrics*.

Robert Anderton

Robert Anderton is an Adviser at the European Central Bank (ECB). His current work involves analysing euro area trade and capital flows. Recent work at the ECB has covered a wide range of topics, including exchange rates, euro area trade, the trade effects of the euro monetary union, euro area FDI flows and the impact of the external dimension of the euro area. Before joining the ECB in 1999, Robert was a Research Fellow at the National Institute of Economic and Social Research (NIESR). At NIESR, he contributed to the development of NIESR's Global Econometric Model, and co-authored the UK and global forecasts published in the quarterly *National Institute Economic Review*. Later research at NIESR covered a range of economic themes, including topics in euro area macroeconomics, financial asset portfolio allocations and labour markets. He has published widely in journals including *Oxford Economic Papers*, *The Manchester School*, the *Bulletin of Economic Research*, the *Scottish Journal of Political Economy*, *Weltwirtschaftliches Archiv* and the *National Institute Economic Review*. Robert Anderton holds an MA from the University of Victoria, Canada.

Christiane Baumeister

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