A SMALL MODEL OF THE AUSTRALIAN MACROECONOMY: AN UPDATE

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Research Discussion Paper
2005-11

December 2005

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Reserve Bank of Australia

Since the publication of Beechey *et al* (2000), many people have played a part in the further development of the model of the Australian economy described there. Particular thanks are due to Kenneth Leong, Tim Robinson, Marileze van Zyl and Thomas Walker for their direct contributions over recent years, including the instigation or implementation of many of the changes to the model described here. The views expressed in this paper are, however, solely those of the authors, and should not be attributed either to these individuals or to the Reserve Bank of Australia.

Abstract

Almost a decade ago David Gruen and Geoff Shuetrim constructed a small macroeconomic model of the Australian economy. A comprehensive description of this model was subsequently provided by Beechey *et al* (2000). Since that time, however, the model has continued to evolve.

This paper provides an update on the current structure of the model and the main changes which have been made to it since Beechey *et al*. While the details of the model have changed, its core features have not. The model remains small, highly aggregated, empirically based, and non-monetary in nature. It also retains a well-defined long-run steady state with appropriate theoretical properties, even though its primary role is to analyse short-run macroeconomic developments.

JEL Classification Numbers: E10, E17, E31, E37, E52
Keywords: Australian economy, macroeconomic model, monetary policy

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1. Introduction and Overview

Almost a decade ago David Gruen and Geoff Shuetrim constructed a small macroeconomic model of the Australian economy. Details of this model were first presented publicly at a one-day symposium on monetary policy in June 1996. Four years later a comprehensive description of the then-current version of the model was provided by Beechey *et al* (2000). Since 2000, however, the model has continued to evolve, and the purpose of this paper is to provide an update on the current structure of the model and the major changes which have been made to it since Beechey *et al*.

One thing which has not changed over the past five years is the philosophy underpinning the model. It remains small, highly aggregated, empirically based, and non-monetary in nature. Its smallness means that it continues to provide a framework for thinking about the Australian economy which, unlike most models, can be 'carried around in one's head'. Nevertheless, it remains rich enough to encompass many of the subtleties of the interactions between key variables in the Australian economy. In particular, it retains a well-defined long-run steady state with appropriate theoretical properties, despite most commonly being used to study macroeconomic developments over a short-run horizon of one to three years.[1]

The model now consists of six estimated (or behavioural) equations – one more than in 2000. Two of these equations continue to concern real variables: real non-farm output and the real exchange rate. The remaining four (previously three) explain nominal variables. These are: import prices, nominal unit labour costs, and two different measures of consumer prices – a headline and a (new) underlying measure.

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1 Within the Reserve Bank of Australia (RBA) the model is primarily used for policy analysis and research purposes (see Stevens 2001 for further details).

All six equations are specified so as to enforce theoretically desirable long-run behaviour, overlaid with short-run dynamics. For five of the six, this is achieved by means of an equilibrium correction framework; for the sixth (the unit labour cost equation), by the imposition of a vertical long-run Phillips curve constraint. To ensure appropriate steady-state behaviour, suitable restrictions are placed on certain coefficients in each of the model's nominal equations, as discussed in greater detail in Section 2.

1.1 Structure of the Model

Macroeconomic models lie along a spectrum, from the purely data-driven at one extreme to the wholly micro-founded at the other.[2] The current model continues to lie at the empirical end of this spectrum, with its behavioural equations all econometrically estimated (subject to the handful of coefficient restrictions just mentioned).

With the addition of only one behavioural equation since 2000, the highly aggregated nature of the model has also been maintained. In particular, non-farm output continues to be modelled as a single entity, rather than disaggregated into its standard expenditure components. This represents a deliberate decision intended to maintain the simple, linear structure of the model.[3] The model continues to be distinguished from typical small vector auto-regression models by the fact that, in addition to its six behaviourally determined endogenous variables, a further 19 exogenous variables appear in one or more of its estimated equations.

Finally, the model retains two other features of its previous structure. First, it remains non-monetary in nature, for the same reasons as discussed in

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2 As discussed in Beechey *et al* (2000), this spectrum exists because there is a trade-off between macroeconomic models' ability to fit the data and the degree to which they are rigorously based upon microeconomic foundations. While there has been some improvement over the past five years in the ability of carefully micro-founded models to replicate key features of the empirical data, a gap between the ends of this spectrum remains.

3 Larger macroeconomic models which break output into its major expenditure (or production, or income) components almost invariably sacrifice linearity for the sake of the additional detail available from such disaggregation. Non-linearity arises because these expenditure components are typically modelled in *logs*, whereas the accounting identity under which total output is the sum of these components – a linear relationship – relates to the *unlogged* components.

Beechey *et al* (2000); as such, a short-term real interest rate continues to be used to measure the stance of monetary policy. Secondly, it continues to include no rational (model-consistent) expectations, although a forward-looking component of inflation expectations is allowed for through the inclusion of bond market inflation expectations in the model's unit labour cost equation.[4]

Overall, the current model contains 33 variables (not counting growth rates of levels series as distinct variables). These may be broken into three categories: 19 exogenous variables (those whose future behaviour is pre-specified, in advance of solving the model); 6 behaviourally determined endogenous variables (forecasts of which are determined by econometrically estimated behavioural equations); and finally, 8 non-behaviourally determined endogenous variables (whose forecast profiles are determined by accounting identities involving behaviourally determined endogenous variables). The relationships between these variables are summarised in the flow chart shown in Figure 1 (where the model's behaviourally determined endogenous variables are shown in bold type, while shaded boxes indicate exogenous variables). An initial feel for the main changes to the model since Beechey *et al* (2000) may be obtained by comparing this flow chart with Figure 5 of that paper.

Monetary policy is modelled as affecting the economy through several channels. Changes in the nominal cash rate result in corresponding changes to the real cash rate, the level of which affects output both directly and indirectly (through its effect on the real exchange rate).

Non-farm output growth is now inferred from forecast changes in the output gap – the difference between (log) actual and potential non-farm output – rather than modelled directly. Specifically, forecast output growth is derived from changes in the output gap, together with an exogenous assumption about the future potential growth rate of the economy.[5] The output gap is modelled as a function of: lags of

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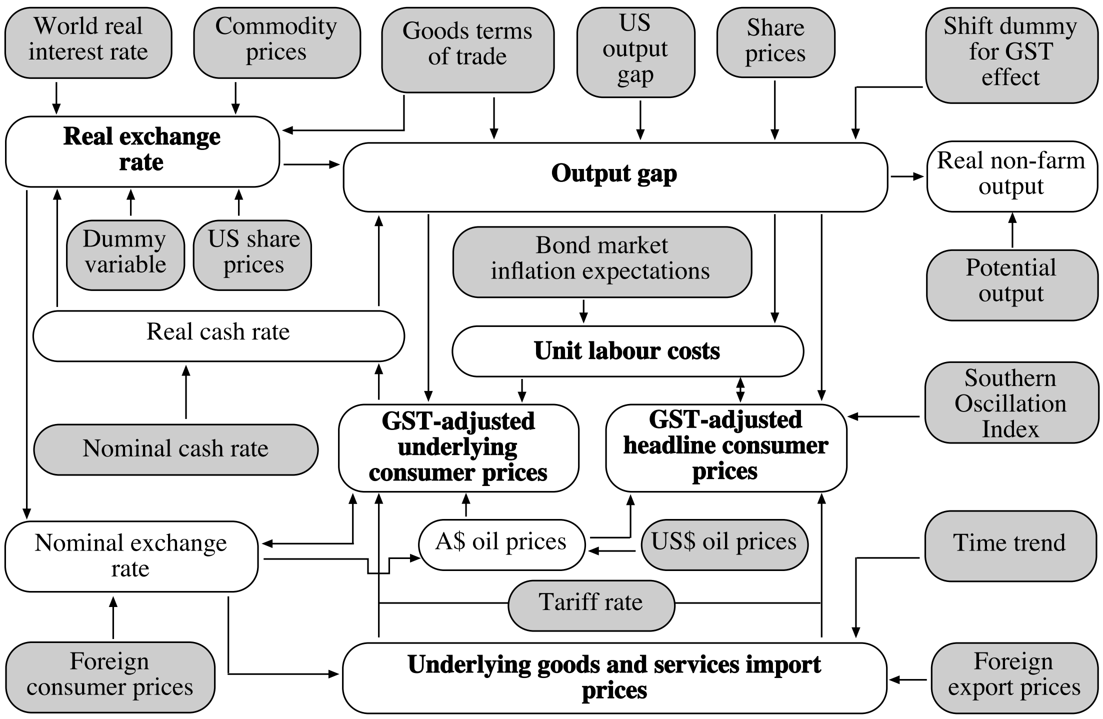
4 Calculation of the real interest rate and real exchange rate, however, remains based purely on current, rather than expected, domestic consumer price inflation – although underlying rather than headline inflation is now used. See Section 2 for further details.

5 Over history, the potential growth rate of the economy, and level of potential output, are estimated via a multivariate Hodrick-Prescott filter conditioned on developments in both unit labour costs and underlying inflation. This estimation method differs from that used in Beechey *et al* (2000), and is described in detail in Section 3.1 and Appendix A.

Figure 1: Flow Chart Representation of the Model



the real cash rate; changes in the real exchange rate; changes in the terms of trade for merchandise goods; a measure of share prices; a dummy variable to capture the effect of the introduction of the Goods and Services Tax (GST) in July 2000; and a measure of foreign demand.

The output gap in turn influences the nominal side of the economy, directly affecting both consumer prices and unit labour costs. The latter are influenced not only by the gap, but also by inflation expectations, which are modelled as a mixture of past consumer price and unit labour cost inflation and bond market inflation expectations. As in Beechey *et al*, unit labour costs are modelled using a Phillips curve which is required to be vertical in the long run so as to tie the steady-state growth rate of these costs to that of inflation (see Sections 1.2 and 2.4 for further details).

Likewise, for headline consumer price inflation we retain the modelling approach adopted in Beechey *et al* (2000), involving an equilibrium correction framework. The level of headline consumer prices is modelled as a mark-up over input costs, which are assumed to consist of unit labour costs, import prices and oil prices. Disequilibrium between the levels of these prices generates an impetus to headline inflation – over and above the impact of other short-run influences such as the output gap, oil price inflation and unit labour cost growth – which acts to gradually unwind such disequilibrium. The same basic framework is also used to model underlying consumer price inflation.

Finally, import prices are assumed to depend on the nominal exchange rate, foreign export prices and the average level of tariffs, while the real exchange rate is determined by the (merchandise goods) terms of trade and the real interest differential between Australia and the rest of the world (together with short-run influences from commodity prices and the performance of US shares). Note also that there are no arrows in the flow chart running from consumer prices and the output gap to the nominal cash rate. This reflects that, for the purposes of the chart, we have elected not to be explicit about any possible link between these variables and the setting of monetary policy, with the latter treated as purely exogenous at this stage. A variety of monetary policy reaction functions could, of course, be adopted to formalise such a link. One such reaction function – an optimal policy rule – is discussed in more detail in Section 3.3.

1.2 Main Changes to the Model since Beechey *et al*

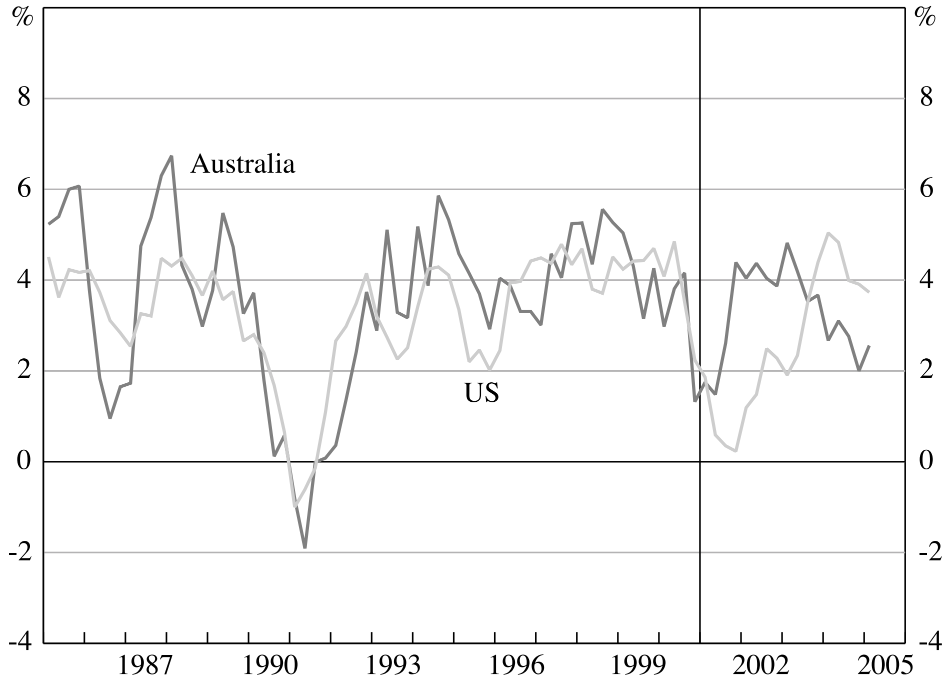
Overall, there have been seven main alterations to the model since 2000 (some of which have already been mentioned in passing).

First, a further behavioural equation has been added to the model describing the evolution of a second measure of domestic consumer price inflation. In addition to the headline inflation measure previously incorporated in the model, an underlying measure – weighted median inflation – is also now modelled. Moreover, variables such as the real interest rate, previously computed as the difference between the nominal cash rate and headline inflation, are now computed using underlying inflation.

Secondly, the treatment of non-farm output growth has been changed from an equation based on a cointegrating relationship between the levels of Australian and US output, to one in which the non-farm output gap is instead modelled. Forecast output growth is then derived from the forecast behaviour of this gap, together with an exogenous assumption about the potential growth rate of the non-farm economy. The primary reason for this change is that, almost immediately following the publication of Beechey *et al* (2000), the strong correlation which had existed between Australian and US output growth over the 1980s and 1990s started to break down, as illustrated in Figure 2.

Figure 2: Australian Real Non-farm Output and US Real Output

Year-ended percentage change



A third change to the model since Beechey *et al* (2000) is that the method used to estimate potential output (and hence also the output gap) over history has been altered. This is now carried out via a multivariate Hodrick-Prescott filter conditioned on developments in both unit labour costs and underlying inflation – see Section 3.1 and Appendix A for further details. One consequence of this change is that the vertical long-run Phillips curve condition in the model's unit labour cost equation can now be imposed over the whole sample for this equation, rather than just the latter part of it (as was the case in Beechey *et al*).

Fourthly, dummy variables associated with the impact of the introduction of the GST in July 2000 have been incorporated in the model's consumer price inflation and output gap equations. In the case of the model's inflation equations, the impact of the GST is modelled as leading to a one-off spike in inflation in the September quarter 2000, the magnitude of which is estimated, with an associated upwards shift of equal size in the level of the corresponding consumer price index. In the case of the output gap equation, the dummy variable is designed to capture the net effect of bring-forwards and deferrals of activity associated with the introduction of the tax.

A fifth change since June 2000 has been the inclusion, in the model's real exchange rate equation, of a further dummy variable covering the period mid 1999 to mid 2003. Inclusion of this dummy has been necessitated by the apparent temporary breakdown of the formerly strong relationship between the levels of Australia's trade-weighted real exchange rate and terms of trade. At the same time, the goods and services measure of the terms of trade previously used in both the model's real exchange rate and output equations has been replaced with a measure based on goods alone – for reasons outlined in Section 2.

Sixthly, definitional changes have been made to a number of series used in the model. Most notably, the import price series, formerly for goods, has been replaced by one for goods and services, so as to capture the impact of services import prices on consumer prices in the model's inflation equations.[6] Similarly, the nominal exchange rate and foreign export price series used in the model's import price equation, formerly computed as G7 GDP-weighted averages, have been replaced with corresponding trade-weighted averages, in the hope of better reflecting the true mix of import price pressures in Australia resulting from either source.

Finally, the economy-wide unit labour cost series previously used in the model has been replaced by a smoothed version of the same series – with the chief aim of increasing the 'signal-to-noise' ratio of this series.[7] In addition, where unit labour costs are used as an explanator in the model's headline and underlying inflation equations, the Balassa-Samuelson adjustment – for differences in the trend productivity growth rates of the traded and non-traded sectors of the economy – has been applied to this series, rather than to the model's import price series (as was done in Beechey *et al* 2000 for reasons of algebraic simplicity). Overall, therefore, the model now contains two principal measures of unit labour costs: a smoothed version of the economy-wide, national accounts-based series

6 At the same time, the level of oil prices has now been included in the long-run components of each of the model's consumer price inflation equations. This change allows for the fact that the import price measure used in these equations remains an underlying one, which excludes petroleum prices.

7 The smoothing itself is carried out using a 5-term Henderson moving average. For a more detailed discussion of the reasons for this change, see Section 2.4.

used in Beechey *et al*; and a Balassa-Samuelson adjusted version of this smoothed series, for use as an explanator in the model's consumer price inflation equations.

2. Equations

The model's six behavioural equations continue to be estimated separately by ordinary least squares (OLS).[8] The equations exhibit no simultaneity, which might require us to estimate them as a system so as to avoid obtaining biased coefficients. Moreover, as was the case in Beechey *et al* (2000), the cross-equation variance-covariance matrix for the estimated residuals (reported in Appendix B) suggests that little is lost by estimating the equations separately rather than as a system.

2.1 Output Gap

As discussed in Section 1.2, the main change to the model's output equation since Beechey *et al* (2000) is that it no longer includes a long-run relationship between the levels of Australian and US output. Instead, the equation is now specified as an output gap equation, rather than directly as a model of output growth. The current specification is

$$\begin{aligned} gap_t \; = \; & \alpha_1 gap_{t-1} + \alpha_2 \textstyle\sum_{i=1}^{7} (r_{t-i} - \tilde{r}) + \alpha_3 \Delta gap_t^{US} + \alpha_4 s_{t-1} + \\ & \alpha_5 \left(\Delta rer_t + \Delta rer_{t-1}\right) + \alpha_6 \left(\Delta tot_{t-4} + \Delta tot_{t-5}\right) + \alpha_7 D_t^{yGST} + \varepsilon_t \end{aligned} \quad (1)$$

where: *gap* is the Australian real non-farm output gap; $r - \tilde{r}$ denotes the deviation of the real cash rate from its neutral level; gap^{US} is the US output gap; s is a de-trended real share accumulation index for Australia; *rer* is the real exchange rate, measured as a trade-weighted average of the Australian dollar against the currencies of major trading partners, adjusted for consumer prices in each country;

8 Note that, throughout the remainder of the paper, levels variables such as actual and potential output, consumer prices, import prices and unit labour costs are expressed in log terms, unless otherwise stated. Hence, period-on-period changes in these variables may be interpreted, to a very good approximation, as percentage growth rates expressed as decimals. The principal exception is interest rates, which are not converted to logs, but are also expressed as decimals for consistency.

tot is the (goods) terms of trade; and D^{yGST} is a dummy variable to allow for shifts in the timing of activity around the introduction of the GST.[9]

Table 1 shows coefficient estimates and associated standard errors for this equation, over the sample 1985:Q1 to 2005:Q1. The positive coefficient on the GST dummy suggests that, in net terms, activity was brought forward from 2000–01 into 1999–2000 in response to the introduction of the GST in mid 2000.

Table 1: Estimation Results for the Output Gap Equation

Coefficient	Variable	Value	*t*-statistic
α_1	Output gap	0.846	25.221
α_2	Real cash rate	–0.021	–4.343
α_3	US output gap (change)	0.235	1.619
α_4	De-trended real share index	0.026	3.640
α_5	Real exchange rate (changes)	–0.018	–1.598
α_6	Terms of trade (changes)	0.069	3.273
α_7	GST dummy	0.016	3.695
Summary statistics		Value	
Adjusted R^2		0.925	
Standard error of the regression		0.006	
Breusch-Godfrey LM test for autocorrelation (p-value):			
First order		0.177	
First to fourth order		0.436	
White test for heteroskedasticity (p-value)		0.436	
Jarque-Bera test for normality of residuals (p-value)		0.935	
Wald test for equality of real cash rate term coefficients (p-value)		0.648	
Wald test for equality of coefficients on Δrer terms (p-value)		0.727	
Wald test for equality of coefficients on Δtot terms (p-value)		0.759	

Notes: The equation is estimated by OLS using quarterly data over the period 1985:Q1–2005:Q1. All levels variables are in logs except for interest rates (which are expressed in unlogged form as decimals). If the equation is mechanically re-arranged to make quarterly growth in non-farm output the dependent variable then the adjusted R^2 of the equation becomes 0.42.

9 This dummy variable is chosen to reflect observed shifts in the timing of activity associated with the introduction of the new tax system. It is set equal to one in the December quarter 1999 and negative one in the December quarter 2000, with the majority of changes to the tax system having taken formal effect on 1 July 2000.

The real cash rate is defined here as the nominal cash rate less year-ended underlying inflation. Calculation of its deviation from neutral is then based on an assumed constant neutral real cash rate, $\tilde{r}$, of 3 per cent *per annum*, both over history and going forward. A role is found in the equation for numerous lags of the deviation of the real cash rate from neutral – specifically, we include lags 1 to 7 of this variable. So as to avoid spurious over-fitting of the dynamics of the response of the output gap to changes in the real cash rate, we impose the restriction that the coefficients on these terms be equal, a restriction accepted by the data based on the results of a Wald Test. As a result, the estimated effect of a change in monetary policy on output is quite smooth over time. The restricted coefficient on the cash rate terms is negative (as expected) and highly significant.

With a long-run levels relationship between Australian and US output no longer part of the equation, a foreign output gap variable is now included as a short-run explanator, to allow for the impact of foreign activity on domestic output. The preferred such variable is the contemporaneous quarterly change in the US output gap.[10] Several broader measures of foreign output gaps were also considered, including a PPP-based GDP-weighted G7 output gap and an export-weighted trading partner output gap. However, none of these alternatives were found to offer additional explanatory power over the US output gap. Since estimates of US potential output are available directly from the Congressional Budget Office, we prefer to use the US output gap, given that this obviates the need to construct near-term estimates of the relevant potential output measure.

Following Beechey *et al* (2000) and de Roos and Russell (1996), a de-trended measure of the return on Australian shares is included in the equation. This is estimated to have a strongly positive net effect on output in the short run, consistent with the notion that higher share prices might be expected to boost consumption and investment through increasing the wealth of share-owners, lowering the cost of equity and boosting both consumer and business sentiment.[11]

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10 The contemporaneous change in the US gap provides a better fit than either current or lagged levels of this gap. Note that US potential output growth in the model is fairly stable over time. This variable is thus little different (up to a constant) from the contemporaneous growth rate of US real output.

11 Alternatively, Australian share prices may simply be forward-looking, and so provide an early indication of the likely strength of future activity, without necessarily playing any causal role.

Finally, a depreciation in the real exchange rate or a rise in the terms of trade would be expected to increase the output gap temporarily. While we might expect to find a role for the levels of these variables (or some measure of the difference between them), their explanatory power turns out to be greater when quarterly changes are instead used. Empirically, the primary impact of changes in the real exchange rate appears to occur with a relatively short lag. In contrast, there appears to be a moderate lag of a little over a year before the bulk of the impact of a change in the terms of trade feeds through to the output gap. Note that common coefficients on the lags of each of these variables are imposed (and accepted), to avoid over-fitting of the dynamics resulting from quarter-to-quarter changes in either one.

2.2 Real Exchange Rate

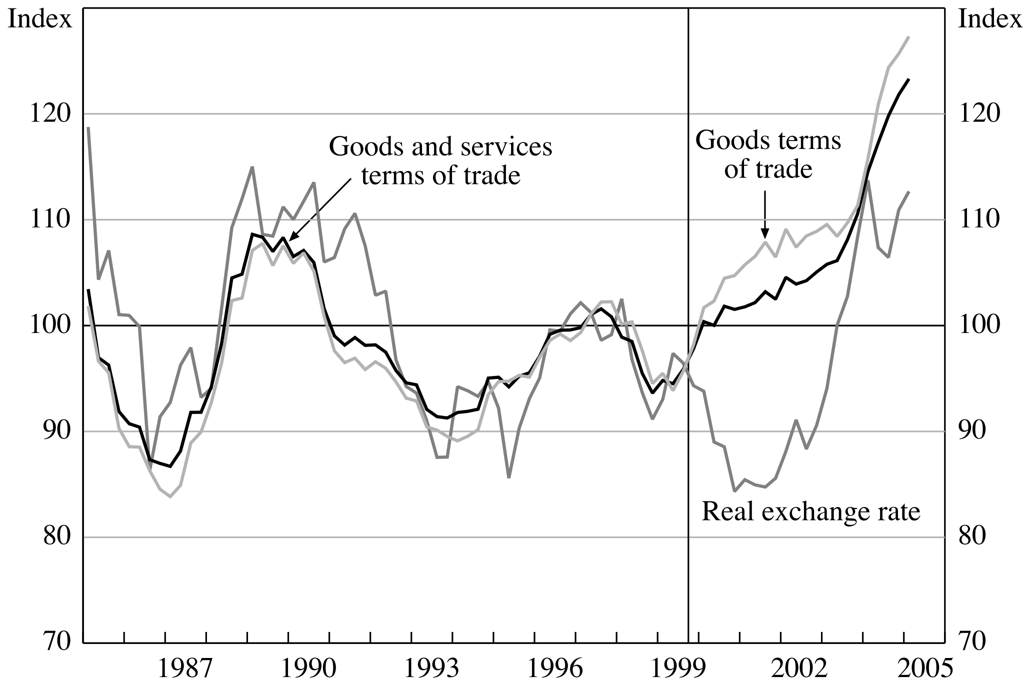
We continue to model the real exchange rate using an unrestricted equilibrium-correction framework, based on a long-run relationship between the level of the real exchange rate, the level of the terms of trade, and the real interest differential between Australia and the rest of the world. The use of this framework by Beechey *et al* (2000) was based on the strong relationship which existed up to mid 1999, as shown in Figure 3, between Australia's trade-weighted real exchange rate and its terms of trade for goods and services.

Two issues arise with the continued use of this framework. The first is that, since mid 1999, Australia has experienced a prolonged divergence between the levels of its trade-weighted real exchange rate and terms of trade. From mid 1999 until late 2001 the former underwent a substantial downward shift, even as the latter (whether for goods or goods and services) trended upwards. The resultant gap then closed significantly over 2002 and 2003, but did not disappear – and indeed has opened again over the past 18 months. Such a prolonged and substantial divergence had not previously arisen since the floating of the Australian currency in December 1983, and is not accounted for by the real interest differential between Australia and the rest of the world.

Despite this sustained divergence, we are reluctant to abandon any form of long-run relationship between Australia's real exchange rate and terms of trade, given the strength and durability of the relationship for the preceding 15 years (and the narrowing of the divergence since early 2002). We therefore accommodate this prolonged period of divergence through the introduction of a dummy variable.

Figure 3: Terms of Trade and Real Exchange Rate

Post-float average = 100



The second issue concerns the choice of terms of trade series to use in our real exchange rate model. Beechey *et al* (2000) used the terms of trade for goods and services, but noted a possible problem with endogeneity between changes in this series and in the real exchange rate.

Such endogeneity could arise because changes in the exchange rate are passed through to import prices faster than to export prices (Dwyer, Kent and Pease 1993), resulting in temporary swings in the terms of trade in response to shifts in the exchange rate. A more general possibility relates to the common assumption that Australia is a price-taker in world markets, so that movements in the exchange rate will have no impact on the terms of trade. While plausible for commodities, and for many increasingly commodity-like manufactured goods, this assumption may not be appropriate for all categories of Australia's trade. In particular, it would seem likely that Australia's services terms of trade is significantly affected by movements in the exchange rate, reflecting the tendency for many service exports to be priced according to domestic considerations.

To overcome this potential endogeneity problem, we use the terms of trade for goods, rather than goods and services, in the model's real exchange rate equation.[12] Accordingly, the current specification of this equation is

$$\begin{aligned}\Delta rer_t \;=\;& \gamma_1 + \gamma_2\big(rer_{t-1} - \gamma_3 tot_{t-1} - \gamma_4(r_{t-1} - r^f_{t-1})\big) + \\ & \gamma_5 \Delta s^{US}_{t-3} + \gamma_6 D^{rer}_t + \gamma_7 \Delta p^{com}_t + \omega_t \end{aligned} \tag{2}$$

where: *rer* denotes the real exchange rate; *tot* is the goods terms of trade; r^f denotes the foreign real interest rate (proxied by a GDP-weighted average of real short-term policy rates in the G3 economies); p^{com} is the RBA index of commodity prices in foreign currency terms; s^{US} is a de-trended real share accumulation index for the US; and r is the domestic real cash rate (defined earlier). D^{rer} denotes the dummy variable included to allow for the divergence between the real exchange rate and the terms of trade over the early years of this decade.[13] Table 2 shows coefficient estimates and associated standard errors for this specification, over the sample 1985:Q1 to 2005:Q1.

A significant role continues to be found for the differential between domestic and foreign real interest rates. This is consistent with Australia's real exchange rate adjusting so as to offset potential gains or losses from shifts in real interest rates in Australia relative to the rest of the world (Gruen and Wilkinson 1991). Overall, the estimated long-run semi-elasticity of the real exchange rate with respect to this differential is now around 1.8 – somewhat stronger than the corresponding figure in Beechey *et al* of around 1.2.

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[12] An alternative would be to control for possible endogeneity by using instrumental variables estimation. Beechey *et al* found that this yielded little evidence of simultaneity bias, and did not reduce the extent of short-run overshooting of the exchange rate in response to terms of trade shocks. We find that use of the goods terms of trade does reduce the short-run responsiveness of the exchange rate to such shocks, compared with that implied by using the goods and services terms of trade, but that the difference is not large.

[13] The value of this dummy increases linearly from 0 to 1 over 1999–2000, remains at 1 over 2000–01 and 2001–02, and then decreases linearly to 0 again over 2002–03. Of course, the need for such a dummy in the recent past suggests that more than usual caution would be called for if including this equation as part of generating any forecasts using the model – at least until it becomes clearer whether or not the previous levels relationship between Australia's real exchange rate and terms of trade has indeed reasserted itself. An obvious alternative, for purposes of generating such forecasts, would be to 'turn the equation off' temporarily and instead impose an exogenous assumption for either the real or nominal exchange rate.

Table 2: Estimation Results for the Real Exchange Rate Equation

Coefficient	Variable	Value	t-statistic
γ_1	Constant	0.519	2.385
γ_2	Equilibrium correction term	–0.324	–5.540
γ_3	Terms of trade (level)	0.629	4.943
γ_4	Real interest differential	1.841	3.036
γ_5	US de-trended real share index (change)	–0.182	–3.245
γ_6	Real exchange rate dummy	–0.057	–4.029
γ_7	Commodity price inflation	0.607	5.921
Summary statistics		Value	
Adjusted R^2		0.518	
Standard error of the regression		0.029	
Breusch-Godfrey LM test for autocorrelation (p-value):			
First order		0.313	
First to fourth order		0.108	
White test for heteroskedasticity (p-value)		0.143	
Jarque-Bera test for normality of residuals (p-value)		0.205	

Notes: The equation is estimated by OLS using quarterly data over the period 1985:Q1–2005:Q1. All levels variables are in logs except for interest rates (which are expressed in unlogged form as decimals).

The equation also finds a role for a lagged change in US real share prices, possibly reflecting that periods of above-average growth in US share prices may provide an early indication of shifts in international flows towards ‘safe haven’ currencies (or, in the late 1990s, towards ‘new economy’ investment opportunities and away from so-called ‘old economies’ such as Australia). The sign of the coefficient on this variable is consistent with such a rationale, and its statistical significance is robust to varying the sample to exclude the 1987 stock market crash.[14]

Finally, unlike in Beechey *et al* (2000), the model now does find a role for the contemporaneous change in commodity prices, in preference to changes in the goods terms of trade. Commodity prices are widely viewed as an important influence on the real exchange rate due to the large share of commodities in Australia’s export basket. We find that, with an added 22 quarters of data, the

14 We experimented with using instead, either in levels or in changes, lags of the *difference* between de-trended real share accumulation indices for the US and Australia. Despite such terms being theoretically preferable, the equation displays a strong empirical preference for use of the US index alone.

contemporaneous change in commodity prices now outperforms changes in the goods terms of trade as a short-run explanator for Australia's real trade-weighted exchange rate.[15]

2.3 Import Prices

There are two important changes to the way in which we model import prices, relative to Beechey *et al* (2000). First, while we continue to model an underlying measure of import prices, this measure now covers both goods and services imports, not just goods imports. This change reflects that, as discussed in Sections 2.5 and 2.6, we model consumer prices as a mark-up over a range of input costs, including import prices. These consumer prices will be influenced by the costs of both goods and services imports, rather than those of goods imports alone.

Secondly, both the foreign export price and nominal exchange rate data we use are now computed on a trade-weighted, rather than G7 GDP-weighted, basis. Beechey *et al* opted to use the latter for the relative ease with which timely export price data are available for G7 countries. However, the former would seem preferable on theoretical grounds – especially given the breakdown following the Asian crisis in the tendency for Australia's G7 GDP-weighted and trade-weighted nominal exchange rates to move closely together.[16]

Turning to the equation itself, numerous studies have modelled Australian import prices using an equilibrium-correction framework (see, for example, Dwyer *et al* 1993, Beechey *et al* 2000 and Webber 1999). Under such a framework, (relative) purchasing power parity (PPP) is typically assumed to hold in the long run, so that the level of import prices should move one-for-one with that of foreign export prices, converted to Australian dollars, in steady state.

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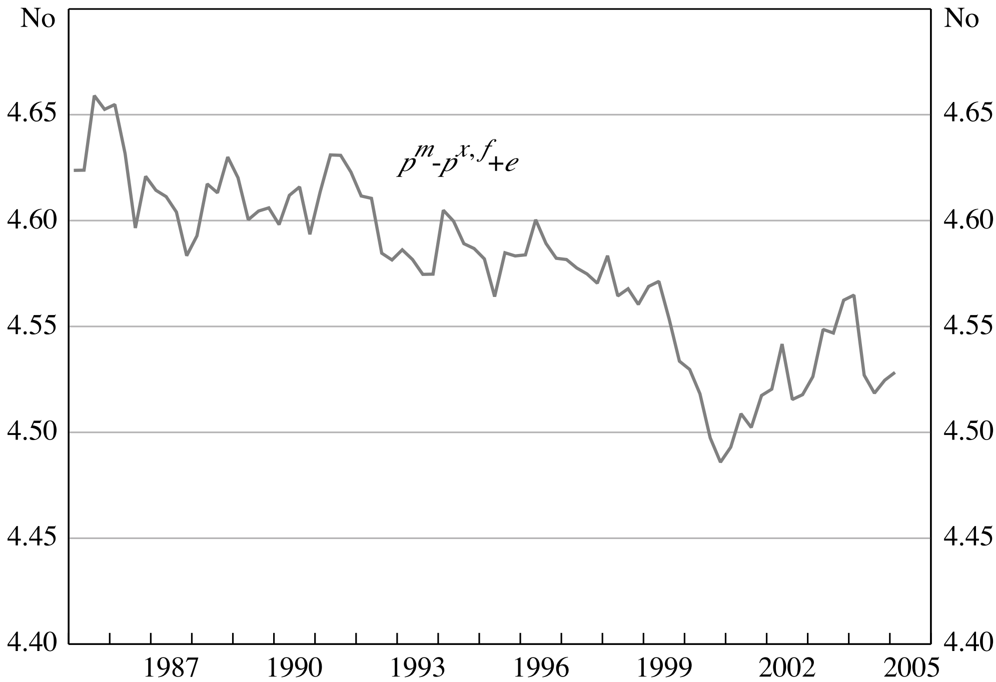
15 Indeed, we find that the use of p^{com}_{t-1} in place of tot_{t-1} in the equilibrium correction component of the model would produce a further improvement in the equation's goodness-of-fit. However, this improvement is slight. We therefore opt not to incorporate this change in light of the difficulty of settling on a suitable steady-state assumption for the level of commodity prices, a nominal variable, relative to doing so for the goods terms of trade.

16 In the aftermath of the Asian crisis the value of the Australian dollar fell much more sharply in G7 GDP-weighted terms than on a trade-weighted basis, reflecting the even larger falls in the currencies of many of Australia's Asian trading partners.

Empirically, there are two features of the data since 1985 which might appear to be at odds with such a long-run model. The first is the steady downward trend in the quantity $(p^m - p^{x,f} + e)$ evident in Figure 4. This suggests that, on average, import prices, p^m, have risen less rapidly over the past two decades than the behaviour of trade-weighted foreign export prices, $p^{x,f}$, converted to Australian dollars using the trade-weighted nominal exchange rate, e, would have led one to expect. Fitting a linear trend to the data suggests that this discrepancy has averaged around 0.6 percentage points *per annum* over the period 1985:Q1 to 2005:Q1.

Figure 4: Import Price Equation Equilibrium Correction Term

Index 1989–90 = 100, log scale



In Beechey *et al* (2000) a similar but considerably stronger trend discrepancy was reported, which they attributed to their use of G7 GDP-weighted export price and nominal exchange rate measures. The use of such measures, they noted, meant that 'deviations [from G7 export prices] by non-G7 trading partners will not be captured', which 'necessitated the addition of ... a time trend to capture the gradual shift in Australia's imports towards lower-priced goods from non-G7 countries (particularly in Asia)' (p 18). While our move to using trade-weighted foreign export price and nominal exchange rate data appears to have reduced the scale of the trend discrepancy, it has not eliminated it.[17]

One possible explanation for the remaining long-run price growth discrepancy relates to differences regarding the way in which prices of automatic data processing (ADP) equipment are treated statistically in Australia and in other countries. As discussed by Dwyer *et al* (1993), the Australian Bureau of Statistics (ABS) use a hedonic approach to pricing computer and associated equipment, the effect of which is 'to equate the dramatic rise in power of computers ... with a fall in the unit price of such power'. This approach, however, differs from that adopted by many statistical agencies abroad, and this creates 'a significant downward bias in Australian import ... prices' relative to the prices recorded for such items by many of the exporters of such equipment to Australia.[18] In any event, whatever the cause of this trend discrepancy, we continue to handle it through the inclusion of a time trend in the long-run component of the model's import price equation.

The second feature of Figure 4 which could seem at odds with a PPP-framework for modelling Australian import prices is the substantial divergence which arose between these prices and foreign export prices (converted to Australian dollars) between 1999 and 2003. During this period, import prices remained persistently below the level which might have been expected given the fall in the exchange rate from 1999 to 2001, together with developments in foreign export prices.

Such a divergence, however, is not necessarily inconsistent with PPP, which relates only to the long-run relationship between import prices and foreign export prices. It may have reflected merely a prolonged reduction in margins by exporters to Australia, anxious to maintain market share in the face of an exchange rate fall which they may not have believed to be a permanent shift. In line with this

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[17] Theoretically, a further shift to using import- rather than trade-weighted foreign export price and nominal exchange rate data would seem appealing in this equation. However, we find that doing so does not help to reduce the remaining discrepancy. Hence, in the interests of parsimony, we continue to use a single trade-weighted nominal exchange rate measure throughout the model.

[18] Consistent with this hypothesis, if we replace our preferred import price index with one which excludes ADP equipment prices we find that the quantity $(p^{m\,ex\,ADP} - p^{x,f} + e)$, rather than trending downwards over time, gradually drifts upwards. This reflects that ADP equipment prices, which have consistently exhibited weak or negative price growth over the past 20 years, are thereby excluded from Australia's import prices but not from foreign export prices.

hypothesis, we choose to view the marked divergence over the period 1999–2003 as a temporary deviation of import prices from equilibrium – albeit a larger and more sustained one than at any other time over the past 20 years.[19]

Overall, the model's import price equation is now specified as follows

$$\begin{aligned} \Delta p_t^m &= \varphi_1 + \varphi_2 \left(p_{t-1}^m - p_{t-1}^{x,f} + e_{t-1} + \varphi_3 trend_{t-1}^{pm} \right) + \\ & \quad \varphi_4 \Delta p_t^{x,f} + \textstyle\sum_{i=0}^{1} \varphi_5^i \Delta e_{t-i} + \nu_t \end{aligned} \tag{3}$$

where: p^m is an index of underlying goods and services import prices (free on board) in Australian dollars; $p^{x,f}$ denotes a corresponding trade-weighted index of foreign export prices in foreign currency terms; e denotes the trade-weighted nominal exchange rate; and $trend^{pm}$ denotes a simple time trend. Coefficient estimates and associated standard errors for this specification are shown in Table 3.

Table 3: Estimation Results for the Import Price Equation

Coefficient	Variable	Value	*t*-statistic
φ_1	Constant	0.673	2.738
φ_2	Equilibrium correction term	–0.145	–2.736
φ_3	Time trend	0.002	6.022
φ_4	Foreign export price inflation	0.813	10.757
φ_5^0	Nominal exchange rate (change)	–0.722	–30.172
φ_5^1	Nominal exchange rate (change)	–0.093	–3.687
Summary statistics		Value	
Adjusted R^2		0.930	
Standard error of the regression		0.008	
Breusch-Godfrey LM test for autocorrelation (p-value):			
First order		0.818	
First to fourth order		0.306	
White test for heteroskedasticity (p-value)		0.127	
Jarque-Bera test for normality of residuals (p-value)		0.190	

Notes: The equation is estimated by OLS using quarterly data over the period 1985:Q1–2005:Q1. All levels variables are expressed in logs.

19 The unusual character of this divergence could alternatively be handled through the introduction of a suitable dummy variable – akin to Beechey *et al*'s use of a dummy in their import price equation to 'capture extra price-undercutting by Asian exporters following the Asian crisis'.

As in Beechey *et al*, the equation includes changes in both foreign export prices and the nominal exchange rate as short-run explanators. These variables continue to enter the equation with short lags and sizeable coefficients, so that the adjustment of import prices to shocks in either foreign export prices or the nominal exchange rate remains relatively fast. However, it also remains the case that the coefficients on these terms are such that the joint restrictions required for the equation to exhibit dynamic homogeneity are not accepted by the data.[20]

2.4 Nominal Unit Labour Costs

As in Beechey *et al* (2000), we use an expectations-augmented Phillips curve to describe the growth of economy-wide unit labour costs (although we now express the equation in terms of quarterly rather than year-ended growth). The output gap is used to capture wage pressures arising from capacity constraints in the economy, while inflation expectations are modelled as a combination of backward-looking (lagged headline inflation and unit labour cost growth) and forward-looking (bond market inflation expectations) components.

We have, however, made one key change to the treatment of unit labour costs in the model. Rather than working directly with the national accounts-based measure of unit labour costs used in Beechey *et al*, we choose to model instead a smoothed version of this series.

The reason for this change is that the raw unit labour costs series is highly volatile from quarter to quarter. For example, over the period 1992:Q1 to 2005:Q1 the standard deviation of the quarterly growth rate of this series was 1.04 percentage points, while the average growth rate itself was only 0.42 per cent. By way of comparison, the corresponding figures for (GST-adjusted) headline inflation are 0.31 percentage points and 0.62 per cent, while for (GST-adjusted) median inflation they are 0.19 percentage points and 0.56 per cent.

[20] These restrictions are that $\varphi_4 = 1$ and $\varphi_5^0 + \varphi_5^1 = -1$ (see Beechey *et al* for a detailed explanation). For a brief discussion of the implications of this rejection, see Section 3.2.

Of course, the use of a smoothed version of the unit labour costs series would not be justified by the mere presence of such volatility. Indeed, to the extent that such volatility reflects true quarter-to-quarter variability in unit labour cost growth, it would be more appropriate econometrically to leave these fluctuations in the data.

However, it seems likely that some part of this volatility may represent statistical noise, given the indirect way in which unit labour costs data must be inferred from information on aggregate output, hours worked and compensation of employees, and the inevitable difficulties in measuring each of these aggregates precisely. In this event, there would be a cost to leaving such statistical noise in the model's unit labour costs series, whenever attempting to use either the level of this series or its growth rate as an explanator in any of the model's equations. Such noise would result in the 'errors in variables' phenomenon of downward bias in the estimated magnitude of relevant coefficients – such as the speed-of-adjustment coefficients (β_2 and κ_2) on the equilibrium correction components of both the model's headline and median inflation equations (see Sections 2.5 and 2.6 below).

Ultimately, we have chosen to make a smoothed version of unit labour costs the primary measure of such costs in the model, in the hope that this will reduce the extent of noise in the data.[21] We are thus implicitly thinking of this smoothed series as representing a more reliable quarter-to-quarter indicator of the true level of labour costs across the economy, with the raw series representing a 'noisier' version of this same series. For comparison, the quarterly changes in both the smoothed and unsmoothed series are shown in Figure 5.

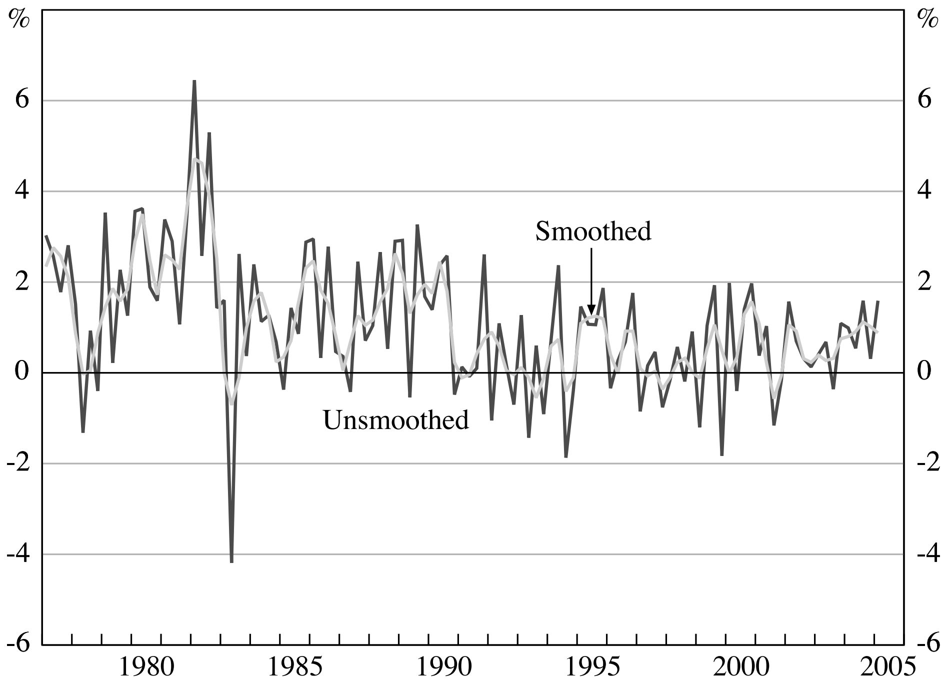
The template Phillips curve for (smoothed) unit labour cost growth we adopt is

$$\begin{aligned}\Delta ulc^{*}dev_t = {} & \textstyle\sum_{i=0}^{4}\rho_1^i gap_{t-i} + \sum_{i=1}^{8}\rho_2^i \Delta ulc^{*}dev_{t-i} + \\ & \textstyle\sum_{i=1}^{8}\rho_3^i\left(\Delta ulc^{*}_{t-i} - \Delta p^{c,h,exGST}_{t-i}\right) + \sum_{i=1}^{8}\rho_4^i bonddev_{t-i} + \\ & \textstyle\sum_{i=1}^{8}\rho_5^i\left(\Delta p^{c,h,exGST}_{t-i} - \Delta p^{c,h,exGST}_{t-i-1}\right) + \eta_t\end{aligned} \tag{4}$$

where: $p_t^{c,h,exGST}$ represents headline consumer prices adjusted to exclude the impact of the GST (see Section 2.5 below); $\Delta ulc^{*}dev_t \equiv \Delta ulc_t^{*} - 0.25\Delta_4 p_{t-1}^{c,h,exGST}$

[21] Specifically, we use a 5-term Henderson moving average to generate this smoothed series. This choice is motivated by our desire to apply a 'light touch' in the smoothing process, softening rather than fully overriding the quarter-to-quarter fluctuations in the unit labour costs data.

Figure 5: Smoothed and Unsmoothed Unit Labour Costs
Quarterly percentage change



denotes the deviation of the quarterly growth rate of our smoothed measure of economy-wide nominal unit labour costs from year-ended (GST-adjusted) headline inflation to the prior quarter expressed in quarterly terms; and $bonddev_t \equiv (\pi_t^{e,bm} - \Delta_4 p_t^{c,h,exGST})/4$ denotes the deviation, converted to quarterly terms, of bond market inflation expectations from year-ended headline inflation.

This general specification is then optimised as part of an iterative procedure, outlined in Appendix A, in which potential output is simultaneously estimated. The reason for writing Equation (4) in the form shown is to ensure that, throughout this optimisation procedure, the restriction that the Phillips curve be vertical in the long run is always imposed, regardless of the estimated values of the equation coefficients or of which terms are omitted from the equation. We impose this verticality (or dynamic homogeneity) restriction to ensure that, in steady state, if headline inflation and bond market inflation expectations settle at some common rate then unit labour cost growth will also equilibrate to this same rate. Such a constraint is required to guarantee this, since there is no equilibrium correction term in the unit labour cost equation to tie the long-run level of unit labour costs to that of consumer prices.[22]

It is somewhat involved to test formally whether this verticality restriction is accepted by the data over the whole estimation sample, 1977:Q1 to 2005:Q1.[23] The complication is that the model's potential output data are now constructed concurrently with the estimation of Equation (5). Hence, standard econometric tests of significance are technically rendered invalid by the generated regressor problem (as, strictly speaking, are the OLS-based statistics shown in Table 4).

Leaving this issue aside, however – for further discussion of it see Appendix B – the optimisation procedure outlined in Appendix A then yields the following particular specification, coefficient estimates for which are provided in Table 4:

$$\begin{aligned}\Delta ulc_t^* \;=\; & 0.25\Delta_4 p_{t-1}^{c,h,exGST} + \rho_1^1 gap_{t-1} + \rho_2^1 \Delta ulc^* dev_{t-1} + \\ & \rho_3 \textstyle\sum_{i=2}^{4}\left(\Delta ulc_{t-i}^* - \Delta p_{t-i}^{c,h,exGST}\right) + \rho_4^1 bonddev_{t-1} + \eta_t \,. \end{aligned} \qquad (5)$$

The results in Table 4 suggest that our Phillips curve framework does a reasonable job of explaining the variability in our smoothed, economy-wide measure of unit labour costs over the past 28 years.[24] The coefficient estimates also suggest that employees' inflation expectations are best modelled empirically as a linear

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[22] As in Beechey *et al* (2000), we were unable to find a statistically significant role for such an equilibrium correction term, $ulc_{t-1}^* - p_{t-1}^{c,h,exGST}$, in Equation (4).

[23] For their analogous Phillips curve, Beechey *et al* were unable to impose such a restriction over their whole sample, 1985:Q1 to 1999:Q3. They were thus forced to resort to imposing the restriction only from 1996:Q1 onwards – on which it was easily accepted by the data.

[24] As a check on the appropriateness of our use of a smoothed version of unit labour costs, it is interesting to re-estimate Equation (5) with unsmoothed quarterly unit labour costs as the dependent variable. Since our appeal to the 'errors in variables' phenomenon strictly only justifies our using a smoothed measure of unit labour costs on the right-hand side of Equation (5), we would hope that this would leave the equation's coefficients largely unchanged (notwithstanding the reduction in the equation's adjusted R^2). Happily, this is indeed what we find, which supports our decision to use only our smoothed measure of unit labour costs throughout Equation (5) – as well as in Equations (6) and (7) below – on the grounds of parsimony.

Table 4: Estimation Results for the Unit Labour Cost Equation

Coefficient	Variable	Value	t-statistic
ρ_1^1	Output gap	0.148	7.208
ρ_2^1	$\Delta ulc^{*}dev$ term	0.614	10.306
ρ_3	$\left(\Delta ulc^{*}_{t-i} - \Delta p^{c,h,exGST}_{t-i}\right)$ terms	–0.145	–6.529
ρ_4^1	*bonddev* term	0.571	5.413
Summary statistics		**Value**	
Adjusted R^2		0.710	
Standard error of the regression		0.005	
Breusch-Godfrey LM test for autocorrelation (p-value):			
First order		0.000	
First to fourth order		0.000	
White test for heteroskedasticity (p-value)		0.856	
Jarque-Bera test for normality of residuals (p-value)		0.855	
Test for vertical long-run Phillips curve (p-value)[(a)]		0.485	

Notes: The equation is estimated by OLS using quarterly data over the period 1977:Q1–2005:Q1. All levels variables are in logs except for bond market inflation expectations (which are expressed in unlogged form as decimals). Although the equation displays evidence of autocorrelation, the t-statistics reported are not based on Newey-West corrected standard errors, since any OLS-derived t-statistics are in any case rendered technically invalid by the generated regressor problem. If we were to treat the output gap as exogenous rather than as a generated regressor, however, the Newey-West correction would not seriously alter the statistical significance of any of the coefficients reported above.

(a) As discussed in greater detail in Appendix B, this test is not strictly correct since the output gap is a generated regressor. However, it is still likely to give a broad indication as to whether or not this restriction is accepted by the data.

combination of lags of (headline) inflation, bond market inflation expectations (converted to quarterly terms) and unit labour costs growth, with respective weights of around 0.25, 0.57 and 0.18.[25]

2.5 Headline Consumer Price Inflation

Following de Brouwer and Ericsson (1998) and Beechey *et al* (2000) we model headline inflation using an equilibrium correction framework. Under this framework, the level of headline consumer prices is determined, in the long run,

25 These figures represent the combined coefficients on $\{\Delta p^{c,h,exGST}_{t-i}\}$ terms, on $\{\pi^{e,bm}_{t-i}/4\}$ terms and on $\{\Delta ulc^{*}_{t-i}\}$ terms when the relevant right-hand side variables in Equation (5) are unravelled and re-grouped.

by a mark-up over the unit input costs of production. These input costs are assumed to be unit labour costs, import prices and oil prices.

The inclusion of import prices captures the direct cost of imported consumer products, as well as the impact on production costs of those intermediate and capital goods sourced from overseas. We use a tariff-adjusted measure of import prices, $p^{m,trf}$, to capture the impact of tariffs on final consumer prices. Furthermore, the price of oil, which was considered but not ultimately included by Beechey *et al* in the equilibrium correction component of their equation, is incorporated here to allow for the fact that the import price index we use is an underlying one which excludes fuel and lubricants.

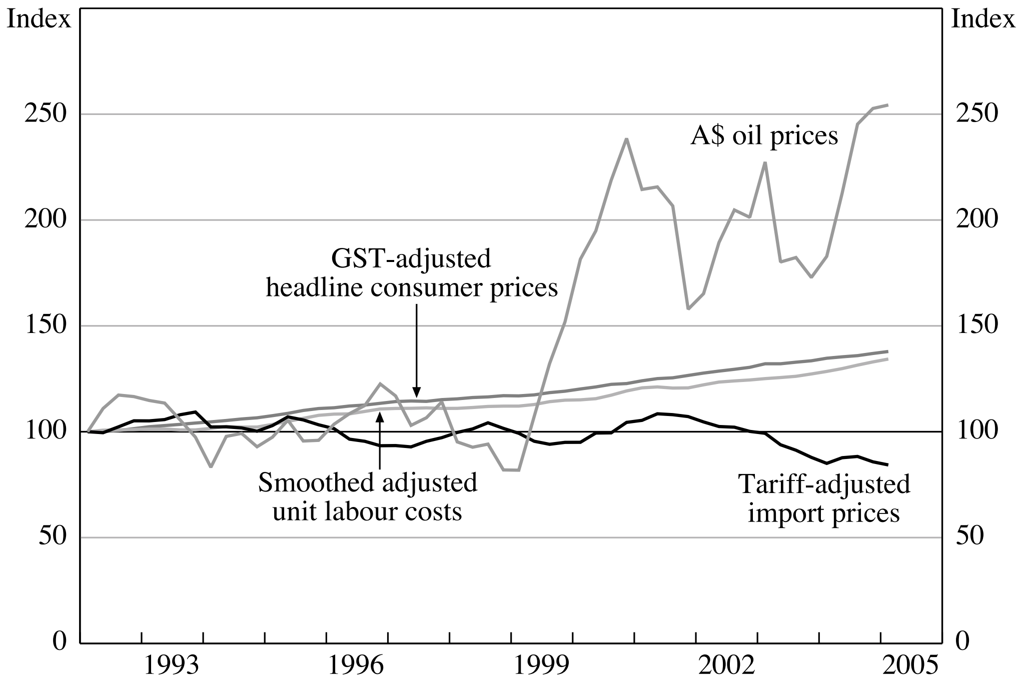
Unit labour costs are included to capture the cost of domestic labour inputs per unit of output (that is, allowing for labour productivity). Since labour costs associated with the production of exports do not feed into domestic inflation, we need to exclude these from the measure of unit labour costs used in this equation. We therefore use a measure of these costs which, in addition to the smoothing applied as per Section 2.4, is further adjusted for the Balassa-Samuelson effect. This correction accounts for differences in the rate of productivity growth in the traded and non-traded sectors. Details of the precise adjustment adopted, and its implementation in the model, are provided in Appendix C.

One difficulty with adopting an equilibrium correction approach to modelling headline inflation is the lack of a clear cointegrating levels relationship between consumer prices and our three input costs over our preferred sample period from 1992:Q1 to 2005:Q1 – particularly if static homogeneity is imposed on the model. This is the restriction that the long-run elasticities of consumer prices with respect to the three input costs – import prices, oil prices and unit labour costs – should sum to one; or in other words, in terms of the coefficients in Equation (6) below, $\lambda_m + \lambda_o + \lambda_u = 1$.

We would like to impose such a restriction, to ensure suitable steady-state behaviour (such as the property that, if the levels of import prices, oil prices and unit labour costs were all to double, consumer prices would also double in the long run). However, absent placing an implausibly large weight on oil prices, this

Figure 6: Levels of Consumer Prices and Input Costs

March quarter 1992 = 100



restriction would appear to be rejected by the data over the past 13 years – as illustrated by Figure 6.[26]

Despite this result, we can ask the following weaker question of the data: if we impose economically plausible values for the long-run elasticities λ_m, λ_o and λ_u (see below) which satisfy the static homogeneity constraint, does the resultant mark-up represent a useful explanator of quarterly headline inflation over the period since 1992:Q1?

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26 In part, the problem may stem from our choice of sample period. This starts after the downward shift in inflation associated with the early 1990s recession, lest the inflation process itself was different in the high inflation era of the 1970s and 1980s (see Dwyer and Leong 2001 for a discussion of this issue). Since that time, however, the Australian economy has experienced an abnormally long period of expansion (barring a single quarter of negative growth in December quarter 2000). As a result, our sample does not yet include even a single full business cycle, the period over which the mark-up of consumer prices over input costs would typically be expected to fluctuate. That said, other more fundamental issues also appear to be playing a role. In particular, alternative consumer price measures which might be natural candidates for a mark-up model – such as the implicit price deflator for private consumption in the national accounts – have exhibited markedly different average growth rates over our sample period. This illustrates the difficulty of trying to fit a mark-up model based on our standard set of input costs, with static homogeneity imposed, to any one of these alternative consumer price series.

Interestingly, we find that it does (as is indicated by the statistically significant speed-of-adjustment coefficient, β_2, in Table 5 below). Given our strong theoretical preference for static homogeneity to hold in Equation (6), we thus adopt this approach. The elasticities we impose are selected on the basis of both empirical testing and economic plausibility (with reference to factors such as the share of imports as a proportion of GDP and the direct weight accorded to fuel prices in the CPI). These imposed elasticities are 0.2, 0.04 and 0.76 with respect to import prices, oil prices and unit labour costs respectively.[27]

Overall, the model's headline inflation equation is specified as follows

$$\begin{aligned}\Delta p_t^{c,h} \;=\; & \beta_1+\beta_2\left(p_{t-1}^{c,h}-\beta_3 D_{t-1}^{pGST}-\lambda_m p_{t-1}^{m,trf}-\lambda_o p_{t-1}^{oil}-\lambda_u ulc_{t-1}^{*,bs}\right)+ \\ & \beta_3\Delta D_t^{pGST}+\beta_4 gap_t+\beta_5\Delta ulc_t^{*,bs}+ \\ & \beta_6 soi_{t-2}+\beta_7\left(\Delta p_t^{oil}+\Delta p_{t-1}^{oil}+\Delta p_{t-2}^{oil}\right)+\xi_t\end{aligned} \tag{6}$$

where: $p^{c,h}$ is the headline consumer price index; $ulc^{*,bs}$ is our Balassa-Samuelson-adjusted, smoothed measure of domestic unit labour costs; $p^{m,trf}$ denotes import prices adjusted for tariffs; p^{oil} is the Australian dollar price of crude oil; soi is the Southern Oscillation Index; and D^{pGST} is a dummy variable discussed shortly. The speed-of-adjustment parameter β_2 captures how much of any disequilibrium between the level of consumer prices and the levels of the three input costs will be removed each quarter, all other things equal. Estimates for this and the equation's other coefficients, together with associated standard errors, are provided in Table 5.

In addition to the equilibrium correction component of Equation (6), other variables used to explain short-run changes in inflation include: changes in (Balassa Samuelson-adjusted) smoothed unit labour costs; changes in oil prices; and the level of the output gap. Consistent with our priors, we find that the coefficients on each of these variables are positive.

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[27] It is interesting to note that Heath, Roberts and Bulman (2004) report a long-run elasticity of consumer prices with respect to import prices of 0.17, for a similar mark-up model of inflation, over the sample 1990:Q1 to 2004:Q1 (see Table 6, p 191). In obtaining this estimate, however, they did not impose a static homogeneity constraint, and the import price measure they used excluded ADP equipment prices.

Table 5: Estimation Results for the Headline Consumer Price Inflation Equation

Coefficient	Variable	Value	t-statistic
β_1	Constant	0.006	7.443
β_2	Equilibrium correction term	–0.078	–2.837
β_3	GST effect	0.027	8.779
β_4	Output gap	0.090	2.324
β_5	Smoothed, adjusted unit labour cost inflation	0.223	2.672
β_6	Southern Oscillation Index	–0.0001	–1.459
β_7	Oil price inflation	0.004	1.973
λ_m	Tariff-adjusted import prices (level)	0.20	–
λ_o	Oil prices (level)	0.04	–
λ_u	Smoothed, adjusted unit labour costs (level)	0.76	–

Summary statistics	Value
Adjusted R^2	0.720
Standard error of the regression	0.003
Breusch-Godfrey LM test for autocorrelation (p-value):	
First order	0.462
First to fourth order	0.828
White test for heteroskedasticity (p-value)	0.367
Jarque-Bera test for normality of residuals (p-value)	0.412
Wald test for equality of coefficients on Δp^{oil} terms (p-value)	0.758

Notes: The equation is estimated by OLS using quarterly data over the period 1992:Q1–2005:Q1. All levels variables are in logs except for the Southern Oscillation Index.

A dummy is also included to capture the permanent increase in the price level associated with the introduction of the GST on 1 July 2000. This dummy, D^{pGST}, is zero up to and including June quarter 2000 and one thereafter. The coefficient on this dummy, β_3, thus represents the model's assessment of the impact of the GST on headline consumer prices, currently estimated to have been 2.7 percentage points. The spike dummy term, $\beta_3 \Delta D^{pGST}$, captures the corresponding one-off jump in headline inflation in September quarter 2000 associated with this sustained upward shift in the price level. Note also that the variable $p^{c,h,exGST}$ used earlier in Section 2.4 simply denotes the series $p^{c,h} - \beta_3 D^{pGST}$.

Finally, the negative coefficient on the second lag of the Southern Oscillation Index, *soi*, with a t-statistic of around 1.5, presumably reflects the correlation between negative values of this index and periods of below average rainfall.

Such periods of reduced rainfall typically lead to higher food prices, so boosting headline inflation.

2.6 Underlying Consumer Price Inflation

The model's new underlying inflation equation is also specified as a mark-up model, akin to that for headline inflation. As there, we constrain the equation to satisfy static homogeneity by imposing the same long-run elasticities with respect to input costs as for headline consumer prices: $\lambda_m = 0.2$, $\lambda_o = 0.04$ and $\lambda_u = 0.76$. Our preferred underlying inflation equation is as follows

$$\begin{aligned} \Delta p_t^{c,u} \;=\; & \kappa_1 + \kappa_2\left(p_{t-1}^{c,u} - \kappa_3 D_{t-1}^{pGST} - \lambda_m p_{t-1}^{m,trf} - \lambda_o p_{t-1}^{oil} - \lambda_u ulc_{t-1}^{*,bs}\right) + \\ & \kappa_3 \Delta D_t^{pGST} + \kappa_4 \textstyle\sum_{i=0}^{3} gap_{t-i} + \kappa_5(\Delta p_{t-1}^{c,u} - \kappa_3 \Delta D_{t-1}^{pGST}) + \\ & \kappa_6 \Delta e_{t-7} + \kappa_7 \textstyle\sum_{j=0}^{2} \Delta ulc_{t-j}^{*,bs} + \zeta_t \end{aligned} \tag{7}$$

where $p^{c,u}$ denotes an index of underlying (weighted median) consumer prices, and all other variables are as discussed previously. Coefficient estimates and associated standard errors for this equation, over the sample 1992:Q1 to 2005:Q1, are shown in Table 6.[28]

Comparing the short-run dynamics of the model's headline and underlying inflation equations, both contain suitable dummies for the impact of the GST on consumer prices in September quarter 2000 – with the estimated GST effect on underlying prices of 2.6 percentage points very similar to that for headline prices. Both equations also contain output gap and unit labour cost inflation terms, albeit with different lag structures. However, unlike for headline inflation, there is no role for lagged changes in Australian dollar oil prices in the underlying inflation equation. This is consistent with such oil prices being distinguished by large quarterly swings. When such swings occur they tend to lie in one or other tail of that quarter's distribution of price changes for the roughly one hundred goods and services categories which make up Australia's CPI basket. Hence, they would not be expected to affect weighted median inflation in that quarter.[29]

[28] As with headline prices, the series $p^{c,u,exGST}$ is then defined simply to be $p^{c,u} - \kappa_3 D^{pGST}$.

[29] The slower second-round impact of sustained shifts in oil prices on median prices, through changes in general production and distribution costs, is still captured through the presence of the oil price level in the equation's equilibrium correction term.

Table 6: Estimation Results for the Underlying Consumer Price Inflation Equation

Coefficient	Variable	Value	t-statistic
κ_1	Constant	0.006	7.814
κ_2	Equilibrium correction term	–0.058	–3.758
κ_3	GST effect	0.026	16.784
κ_4	Output gap	0.019	4.147
κ_5	Lagged GST-adjusted underlying inflation	–0.274	–2.190
κ_6	Nominal exchange rate (change)	–0.015	–2.434
κ_7	Smoothed, adjusted unit labour cost inflation	0.062	3.304
λ_m	Tariff-adjusted import prices (level)	0.20	–
λ_o	Oil prices (level)	0.04	–
λ_u	Smoothed, adjusted unit labour costs (level)	0.76	–
Summary statistics		**Value**	
Adjusted R^2		0.893	
Standard error of the regression		0.001	
Breusch-Godfrey LM test for autocorrelation (p-value):			
First order		0.347	
First to fourth order		0.240	
White test for heteroskedasticity (p-value)		0.541	
Jarque-Bera test for normality of residuals (p-value)		0.266	

Notes: The equation is estimated by OLS using quarterly data over the period 1992:Q1–2005:Q1. All levels variables are expressed in logs. Note that the statistics reported here are rendered technically invalid by the generated regressor problem, since this equation is used as one of the conditioning equations for estimation of the output gap. However, this is unlikely to be causing any of the coefficient estimates or t-statistics above to be seriously misrepresented (see Appendix B for further details).

In a similar vein, no role is found for lags of the Southern Oscillation Index in the underlying inflation equation. This accords with our earlier rationale for the presence of such a term in the headline equation. Occasional drought-related surges or collapses in food prices also tend to lie in the tails of the relevant quarter's consumer price change distributions, and so directly affect headline but not weighted median inflation. Finally, the underlying inflation equation also includes: the first lag of (GST-adjusted) underlying inflation itself; and a long lag of the change in the nominal exchange rate, presumably supplementing the role of the equation's equilibrium correction term in capturing the gradual pass-through of exchange rate shifts into consumer prices via import prices.[30]

3. Remaining Components of the Model

In this section we summarise the remaining key aspects of the model. These are: the model's estimation of potential output and the output gap over history; the steady-state assumptions adopted for the model's exogenous variables to ensure that it displays appropriate long-run behaviour under any suitably stabilising monetary policy reaction function; and finally, an outline of one such reaction function, namely optimal policy with respect to a standard quadratic loss function.

3.1 Potential Output

The non-farm output gap is defined as the difference between actual and potential non-farm output, as a percentage of potential output. This gap plays a central role in the model, appearing as an explanatory variable in both the model's inflation and unit labour cost equations. It is designed to capture inflationary pressures, with a zero gap consistent with constant ongoing inflation in steady state (assuming bond market inflation expectations are equal to this constant inflation rate).

We obtain estimates of the output gap for Australia directly within the model. In this section we briefly describe how this is done and discuss the results of the estimation process. Further details are provided in Appendix A.

There are various ways to estimate potential output, a number of which were reviewed by de Brouwer (1998) for Australia. In Beechey *et al* (2000) potential output was calculated by iteratively applying a Hodrick–Prescott filter to non-farm output, and adjusting the level of this filtered series so as to ensure the model's unit labour cost equation satisfied a vertical long-run Phillips curve constraint

[30] Surprisingly, the seventh lag of the change in the exchange rate performs marginally better in explaining median inflation than a similar direct lag of import price inflation. The negative coefficient on this term indicates that an appreciation of the exchange rate reduces underlying inflation with a long lag, beyond its impact through the model's equilibrium correction term.

(see pp 29–33 of Beechey *et al* for further details). While not dissimilar, we now use instead a multivariate filter, like that used by Gruen, Robinson and Stone (2002). This filter estimates potential output using information from the model about the relationships between the output gap, consumer prices and unit labour costs.

Since the output gap reflects short-term inflationary pressures in consumer prices and unit labour costs, one would expect it to be positive when the inflation rates of these variables are rising, and negative when they are falling (all other influences equal). The multivariate filter exploits these relationships by iteratively searching for the potential output series (and, hence, output gap) which provides the best fit to the model's unit labour cost and underlying inflation equations, subject to a smoothness criterion.[31] Formally, it seeks the potential output series y_t^* which minimises the loss function

$$\mathscr{L} = \lambda_U \sum \eta_t^2 + \lambda_I \sum \zeta_t^2 + \lambda_S \sum (\Delta y_{t+1}^* - \Delta y_t^*)^2 \qquad (8)$$

where η_t and ζ_t are the residuals from the unit labour cost and underlying inflation equations. The third term penalises volatility in the growth rate of potential output, encouraging the algorithm to allow only gradual changes in this growth rate over time. The weights λ_U, λ_I and λ_S determine the relative weight given to each of the three terms. Further details on the solution for potential output and the role of the weights are given in Appendix A.

The resultant estimates of the output gap are shown in Figure 7. The gap displays a prominent cyclical pattern, with the recessions of 1982–83 and 1990–91 marked by sharp falls. Following both recessions are periods of above-potential growth, when the output gap narrowed. Most recently, the gap has remained around zero. However, it has been below zero on average over the sample period. As noted in Gruen *et al* (2002, p 12), this is consistent with the decline in the inflation rate

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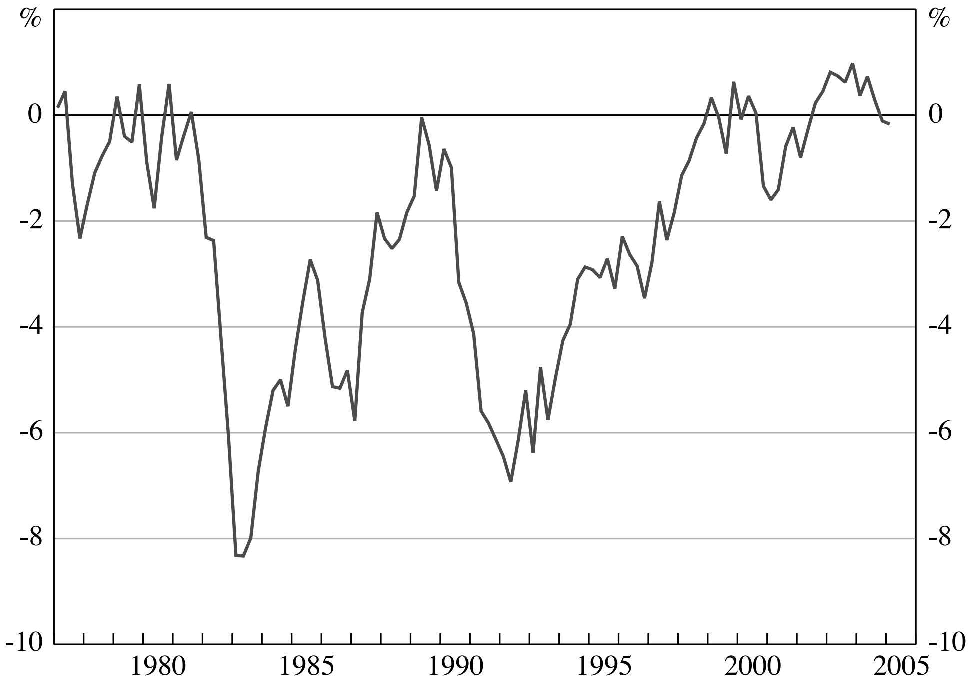
[31] Since underlying and headline inflation are generally quite similar, we condition our potential output estimates only on the former. Underlying inflation is less volatile and easier to model, which may make its equation better suited for use in estimating potential output.

over the 1980s and 1990s, especially given that bond market inflation expectations were almost invariably above actual inflation over this period.[32]

Figure 7: Estimated Non-farm Output Gap

Per cent deviation of actual output from potential



32 Bond market inflation expectations are, of course, difficult to measure – even for the period during which Australia has been issuing inflation indexed bonds (given the illiquidity of these instruments relative to nominal bonds). Nevertheless, our bond market expectations series fits well with what one might expect regarding the relativities between it and actual inflation over history. The former remained below the latter for several years following the initial step-up in inflation in the early to mid 1970s, as markets expected policy-makers to regain control over inflation. Thereafter, following the further spike in inflation in the late 1970s, bond market expectations stayed persistently above actual inflation until around five years after the sustained downward shift in Australian inflation in the early 1990s, when markets finally became convinced of policy-makers' determination to prevent any renewed outbreak of inflation. Figure 3 in Gruen, Robinson and Stone (2005) also suggests that, with regard to any errors introduced into the gap estimates shown in Figure 7 by problems with measuring bond market inflation expectations, these are likely to be small compared with those entailed by excluding a role for such expectations in the model's unit labour cost conditioning equation altogether.

3.2 Steady State Assumptions

Table 7 summarises our assumptions with regard to the steady-state behaviour of the model's exogenous variables. With these assumptions, we can deduce the steady-state properties of the model's six endogenous variables. By this we mean the levels or growth rates to which these variables would converge in the long run, in the absence of future shocks (and with monetary policy set in a suitably stabilising fashion).[33] These steady-state properties are set out in Table 8.

Beginning with the real side of the model, the core autoregressive structure of the output gap equation, with a coefficient on the first lag of the gap between zero and one, ensures that in steady state the output gap must equal zero. Hence, the steady-state growth rate of non-farm output in the model simply equals the exogenously imposed long-run growth rate of potential output – which is currently set at 3.25 per cent *per annum*.[34] The real exchange rate is constant in steady state, consistent with an assumption of no long-run differential between the productivity growth rates of Australia and her trading partners.

Turning to the nominal side of the model, as discussed in Beechey *et al* (2000) the homogeneity restrictions we impose upon the model's price equations have several implications for its behaviour in steady state. First, since the consumer price equations exhibit static homogeneity and PPP is imposed in the import price equation, no real variables are affected in the long run by sustained level shifts

[33] One method for setting monetary policy so that such convergence occurs is described in Section 3.3.

[34] By contrast, the core of Beechey *et al*'s model of domestic output growth was a cointegrating relationship between Australian and US real output, so that steady-state domestic output growth was determined by an exogenous assumption about the potential growth rate of US output.

Table 7: Steady State Assumptions for Exogenous Variables

Variable	Steady state assumption
Δy^{*}	The steady state growth rate of potential non-farm output is assumed to equal 3.25 per cent per annum.
tot	In steady state the goods terms of trade is assumed to equal its average value over the sample 1985:Q1 to 2005:Q1.
s	The real share accumulation index is assumed to be at trend in steady state, so that the de-trended series is zero.
$\tilde{r}$	The neutral real cash rate is assumed to be 3.0 per cent per annum. A necessary but not sufficient condition for the model to converge to steady state in the long run, in the absence of ongoing exogenous shocks, is that monetary policy be set such that the real cash rate converges to this neutral level.
Δp^{com}	In steady state, Australian commodity prices are assumed not to be changing in foreign currency terms.
$\pi^{e,bm}$	In steady state, bond market inflation expectations are assumed to equal the target rate for headline inflation set by policy-makers (assumed to be 2.5 per cent *per annum*, the midpoint of the RBA's medium-term target for inflation).
soi	The Southern Oscillation Index is assumed to equal zero (corresponding to average rainfall) in steady state.
trf	The average tariff rate on imports is assumed to remain constant in steady state.
gap^{US}	The US output gap is assumed to close to zero in steady state.
r^{f}	In steady state the world (G3) real interest rate is assumed to equal its average value (of 1.84 per cent) over the sample 1985:Q1 to 2005:Q1.
s^{US}	The US real share accumulation index is assumed to be at trend in steady state, so that the de-trended series is zero.
$\Delta p^{c,f}$	Trade-weighted foreign consumer price inflation is assumed to equal 0.5 per cent per quarter, close to its average value over the sample 1985:Q1 to 2005:Q1.
$\Delta p^{x,f}$	Trade-weighted foreign export price inflation is assumed to be zero in steady state (consistent with 2 per cent annual foreign consumer price inflation, offset by a Balassa-Samuelson adjustment of the same magnitude as for Australia).
Δp^{usoil}	In steady state the US$ price of oil is assumed to rise at the same annual rate as trade-weighted foreign consumer prices (while the US$/A$ exchange rate, used to derive an A$ oil price, is assumed to move in line with changes in the trade-weighted exchange rate).
$trend^{pm}$	The trend in the import price equation, after increasing linearly over history, is assumed to cease rising at some point, so remaining constant in steady state.

Note: The choice of 3.25 per cent for the steady state growth rate of potential output represents a round number a little below the average growth rate of Australian non-farm GDP over the past decade, during which the output gap is assessed to have been closing from an initially negative level. It is also consistent with the out-year GDP growth rate projection recently adopted by the Australian Treasury in the 2005–06 Budget.

Table 8: Steady State Properties of the Model's Endogenous Variables

Variable	Steady state property
gap	The output gap closes to an equilibrium level of zero in steady state. Hence, the growth rate of non-farm output in steady-state is equal to that of potential output, which is assumed to be 3.25 per cent *per annum*.
rer	The real exchange rate is constant in steady state at a level determined by the (constant, exogenously set) long-run levels of: the goods terms of trade; and the real interest differential between Australia and the rest of the world (where real interest rates in both regions are assumed to revert to neutral).
Δp^{m}	Import price inflation is constant in steady state at a rate equal to that of foreign export price inflation plus the differential between steady-state domestic and foreign consumer price inflation. This rate would thus be 0.5 per cent *per annum* in the event that the steady-state rate of domestic consumer price inflation were 2.5 per cent *per annum*.
Δulc^{*}	(Smoothed) economy-wide unit labour cost inflation is constant in steady state at a rate equal to that of headline inflation.
$\Delta p^{c,h}$	Headline consumer price inflation is constant in steady state at a rate determined by policy-makers. Under the optimal policy routine described in Section 3.3 below, this constant rate is assumed to be 2.5 per cent *per annum*, the midpoint of the RBA's medium term inflation target.
$\Delta p^{c,u}$	Underlying consumer price inflation is constant in steady state at a rate equal to that of headline inflation.

in either consumer prices or import prices.[35] Indeed, these restrictions are enough to ensure that long-run neutrality also holds with respect to sustained shifts in the level of unit labour costs, notwithstanding that the model's unit labour cost equation exhibits dynamic rather than static homogeneity.

[35] To illustrate, suppose (for simplicity) that the model were in steady state, and that the level of underlying consumer prices then increased by (say) 1 per cent and remained this far above baseline thereafter (but with the steady state growth rates of all nominal variables unchanged). In the long run, this would induce a 1 per cent devaluation in the nominal exchange rate (noting that the long-run real exchange rate would be unaffected), which would raise the level of import prices by 1 per cent relative to baseline (in view of the PPP restriction in the model's import price equation). This would then force unit labour costs (both economy-wide and Balassa-Samuelson adjusted) to equilibrate to a level 1 per cent higher than baseline, as a result of the static homogeneity restriction in the model's underlying inflation equation; which would also then cause headline consumer prices to settle at a level 1 per cent above baseline.

Empirically, however, there remains a lack of dynamic homogeneity in both the model's consumer price and import price equations. For the consumer price equations this implies that, were there to be a shift in the steady-state rate of inflation, this would have a permanent effect on the mark-up of consumer prices over input costs (as well as the level of real unit labour costs). Likewise, for the import price equation the lack of dynamic homogeneity implies that, were the steady-state rate of import price growth to change, this would have a permanent effect on the margin between the cost of imported goods and their landed prices (as given by foreign export prices converted to Australian dollars). As noted in Beechey *et al* (2000), while it is difficult to see theoretically why such shifts would occur, there is some empirical evidence for such phenomena (see, for example, Banerjee and Russell 1999).

3.3 Optimal Policy

Short-term model-based forecasts often assume that the nominal interest rate is held constant over the forecast horizon, to assess how the economy might evolve were policy to remain unchanged. A common supplement to such an approach is to allow monetary policy to be determined by some suitable rule, such as a Taylor rule or an optimal policy routine.

Optimal policy routines determine the future path for a policy instrument – in the current setting, the cash rate – on the basis of a summary measure (loss function) which quantifies the objectives of policy, and the relative preference policy-makers attach to achieving each. While central banks would never, of course, actually implement policy simply to mechanically minimise such a loss function, such routines can provide a useful theoretical benchmark for *ex post* assessments of the stance of policy or for other research purposes.

Common objectives considered for optimal policy routines used to analyse monetary policy issues include: that year-ended inflation should be at some target level, π^* (which for Australia we assume to be 2.5 per cent *per annum*, the midpoint of the Reserve Bank's medium-term target); that output should be at potential, so that the output gap is zero; and that movements in the cash rate, i_t, should be kept to a minimum, so as not to induce unnecessary volatility in financial markets. Optimal policy based on such objectives would typically be implemented by solving for the policy interest rate that minimises the expected value of the quadratic loss function

$$\mathscr{L} = E_t \sum_{j=1}^{k} \frac{1}{(1+\delta)^{j-1}} \left[\lambda_1 \left(\Delta p_{t+j}^{c,h} - \pi^*/4 \right)^2 + \lambda_2 gap_{t+j}^2 + \lambda_3 \left(\Delta i_{t+j} \right)^2 \right] \qquad (9)$$

where: E_t represents expectations at time t; k denotes the length of the horizon over which policy-makers assess their loss; δ represents a time discount factor; and λ_1, λ_2 and λ_3 denote the respective weights attached by policy-makers to avoiding deviations of inflation from target, of the output gap from zero, and of this period's interest rate from last period's.[36] Minimising such a loss function provides one natural way of selecting a stabilising path for future interest rates under which the model's variables would be expected to converge over time towards their steady state levels or growth rates (absent unforeseen future shocks to the economy).[37]

4. Simulations

We now illustrate the properties of the model by showing impulse responses for selected endogenous variables under a range of scenarios. In this section we show these responses for five simulations: a sustained 1 percentage point increase in the real cash rate; a sustained 10 percentage point increase in the real exchange rate; and one-off 1 percentage point shocks to the level of the output gap, unit labour cost growth and consumer price inflation (both underlying and headline). For each simulation we report the results in terms of the deviation of relevant variables from their baseline values absent the given shock.

To illustrate different feedbacks within the model, we treat monetary policy differently across these scenarios. For the sustained cash rate increase scenario and the one-off shock to the output gap, the real cash rate is held fixed (relative to baseline) over the 10-year forecast horizon. For the sustained increase in the real

36 A common choice is to place equal weights on the output gap and deviations of inflation from target ($\lambda_1 = \lambda_2$), with λ_3 then chosen so that the routine yields interest rate paths which display a degree of volatility, in the face of typical shocks, broadly consistent with that seen over history.

37 A description of the main elements of the linear algebra involved in implementing such a routine in the current model is set out in Shuetrim and Thompson (1999) – albeit in the context of a stochastic simulations process.

exchange rate and one-off shock to underlying and headline consumer prices, the nominal cash rate is instead held constant, thereby allowing the real cash rate to vary in line with changes in underlying inflation. Finally, for the one-off shock to unit labour cost growth, the cash rate is set in accordance with an optimal policy recommendation, to illustrate features of the model when monetary policy is set so as to drive consumer price inflation (and hence also import price and unit labour cost inflation) back to their baseline values in the long run. Note that, for all scenarios, bond market inflation expectations are assumed constant throughout the simulations (although this could easily have been varied, if desired).

A Sustained Increase in the Real Cash Rate

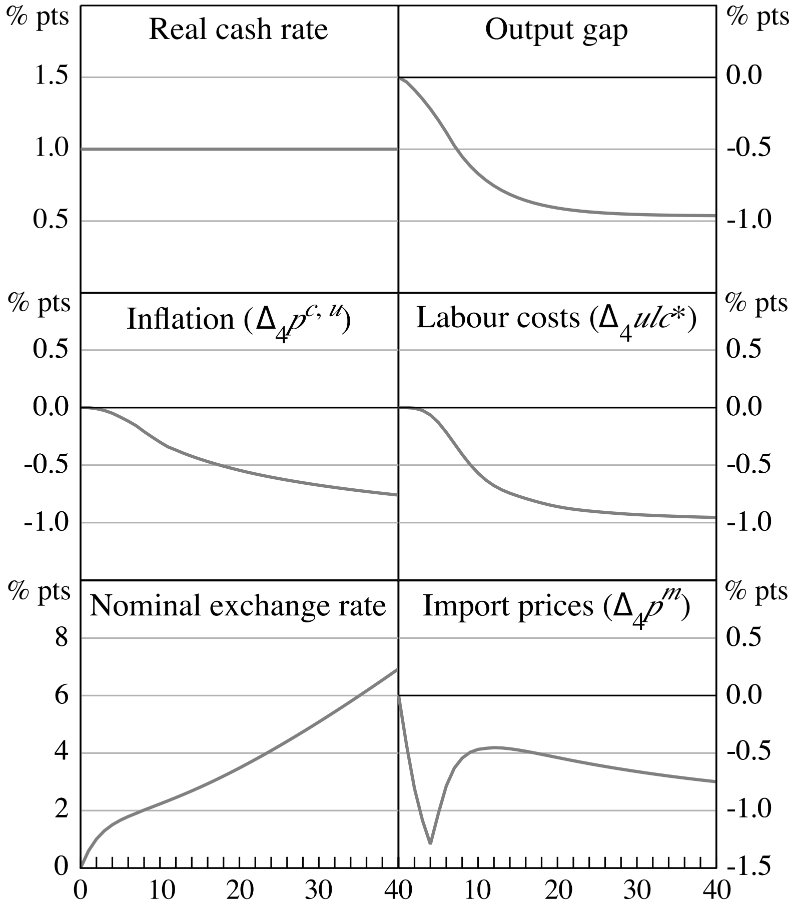
The contractionary effect of a real monetary policy tightening is marginally greater in the current model than was the case in Beechey *et al* (2000), with the long-run elasticity of output with respect to the real cash rate now around 1.0 (compared with 0.8 previously). The decline in the output gap following a sustained real cash rate increase of 100 basis points is reasonably rapid, with the bulk of this adjustment occurring within three years (Figure 8).

The opening-up of a permanent output gap in turn initiates an ongoing decline in the levels of unit labour costs and prices, relative to baseline. Year-ended underlying inflation is just under 0.4 percentage points lower than baseline after three years, and continues to decline thereafter. The permanently lower output gap also lowers year-ended unit labour cost inflation, which declines rapidly during the second and third years after the real cash rate shock, and also continues to fall thereafter. Finally, higher domestic real interest rates result in ongoing appreciation of the nominal exchange rate relative to baseline – initially through their direct impact on the real exchange rate, and subsequently reflecting lower domestic consumer price inflation. This in turn reduces import price inflation, placing further downward pressure on consumer prices.[38]

[38] Holding bond market inflation expectations constant is likely to be particularly important for these results. If bond market inflation expectations were allowed to adjust (say) in line with changes in underlying inflation, such a real cash rate shock would have a still larger effect on consumer and import price inflation and wages growth.

Figure 8: Responses to a Sustained Increase in the Real Cash Rate

Deviation from baseline

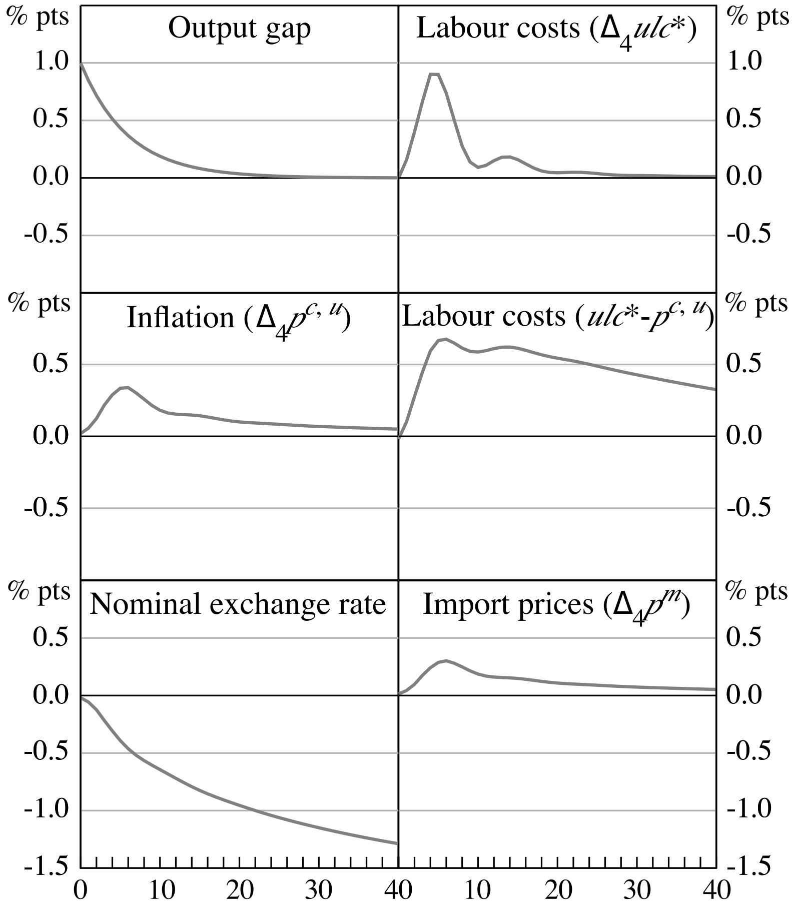


A One-off Shock to the Output Gap

A one-off 1 percentage point shock to the output gap, with no change in the real cash rate, leads to higher rates of consumer price, import price and unit labour cost inflation, which persist for an extended period (Figure 9).

The effect of the shock on the gap itself dissipates smoothly and fairly rapidly over time. However, the initially positive gap quickly spurs both higher underlying inflation and even stronger additional unit labour cost growth – resulting in an uptick in the level of real unit labour costs during the first year after the shock. The rise in underlying inflation also triggers a gradual depreciation of the nominal exchange rate, since the real exchange rate remains unaffected, so driving an increase in the rate of import price inflation (which in turn acts to hold up consumer price inflation).

Figure 9: Responses to a One-off Shock to the Output Gap
Deviation from baseline



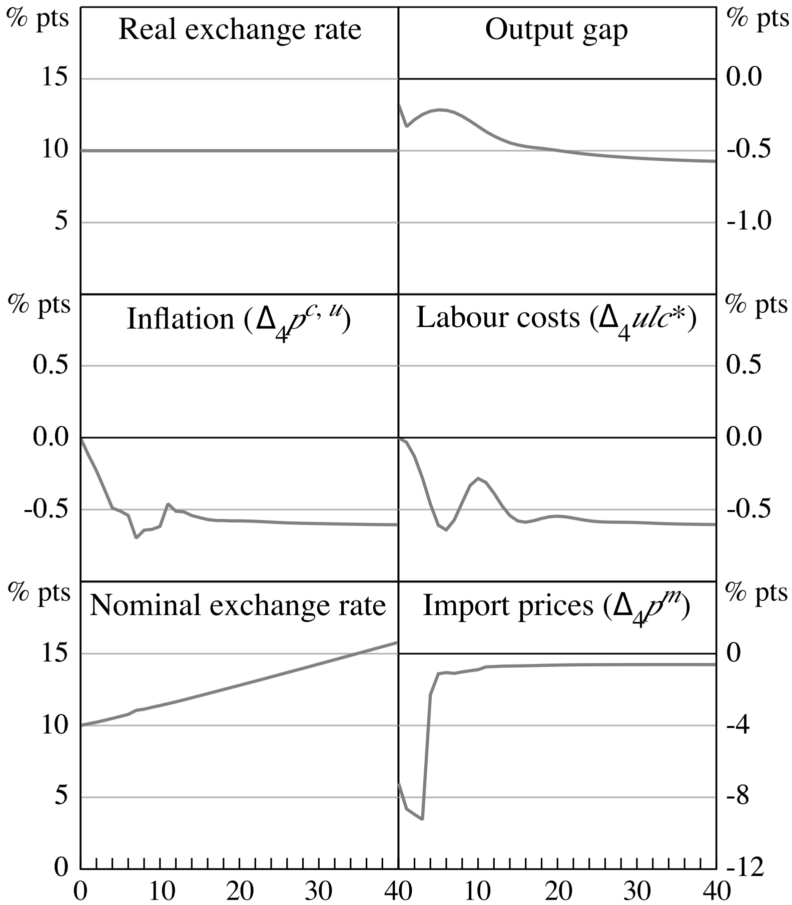
Eventually, consumer price, import price and unit labour cost inflation do turn out to re-equilibrate to their baseline rates in the long run – and hence so does the level of real unit labour costs (due to the static homogeneity constraints built into the model's consumer and import price equations) – but this process is very prolonged.

A Sustained Increase in the Real Exchange Rate

A sustained 10 percentage point real exchange rate appreciation corresponds to the nominal exchange rate initially jumping by 10 per cent, and thereafter continuing to appreciate gradually, just sufficiently to offset the decline in the real exchange rate which would otherwise result from declining inflation (Figure 10). Such a shock flows directly into correspondingly lower import price inflation, so generating rapid downward pressure on consumer price inflation. It also causes an immediate decline in the output gap, which further contributes to lower consumer price inflation and, with the nominal cash rate held constant, initiates a cycle of higher real cash rates, lower output growth and still lower inflation. Year-ended unit labour cost inflation also falls comparably to the decline in underlying consumer price inflation, but with mild (and rapidly decaying) oscillations in this variable over the first few years.

Figure 10: Responses to a Sustained Increase in the Real Exchange Rate

Deviation from baseline



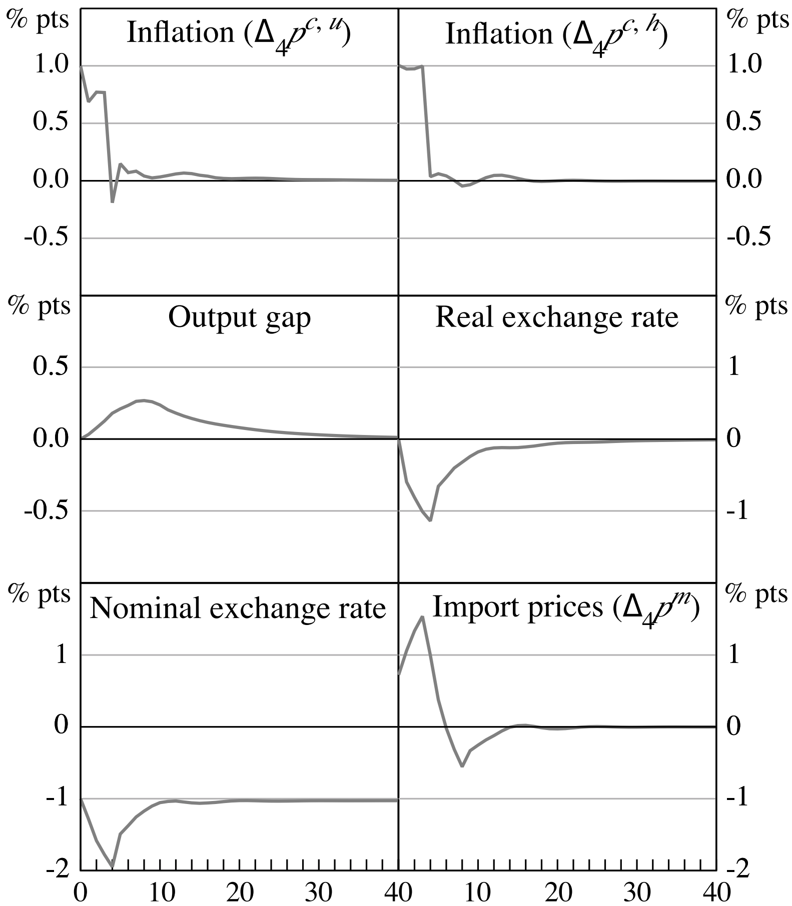
In this scenario, with the nominal cash rate constant there is nothing forcing the model to re-equilibrate in the long run. As a result, the output gap, consumer price inflation and unit labour cost growth all continue to decline indefinitely – albeit extremely slowly – as does the level of real unit labour costs (not shown).

A One-off Shock to Consumer Prices

Simultaneous one-off 1 percentage point shocks to headline and underlying consumer prices, with the nominal cash rate held constant, initially lower the real cash rate. This leads to an increase in the output gap, which is affected both directly and via the real exchange rate (Figure 11). The real exchange rate declines by a little over 1 per cent in the first few quarters after the shock. This corresponds to a somewhat steeper nominal depreciation (which in turn drives up import price inflation in the near term), partially offset by the higher near-term rate of underlying inflation. The real exchange rate then recovers most of its initial fall over the second year following the shock. The associated recovery of the nominal exchange rate, to a level a little under 1 per cent below baseline, results in a

Figure 11: Responses to a One-off Shock to Consumer Prices

Deviation from baseline



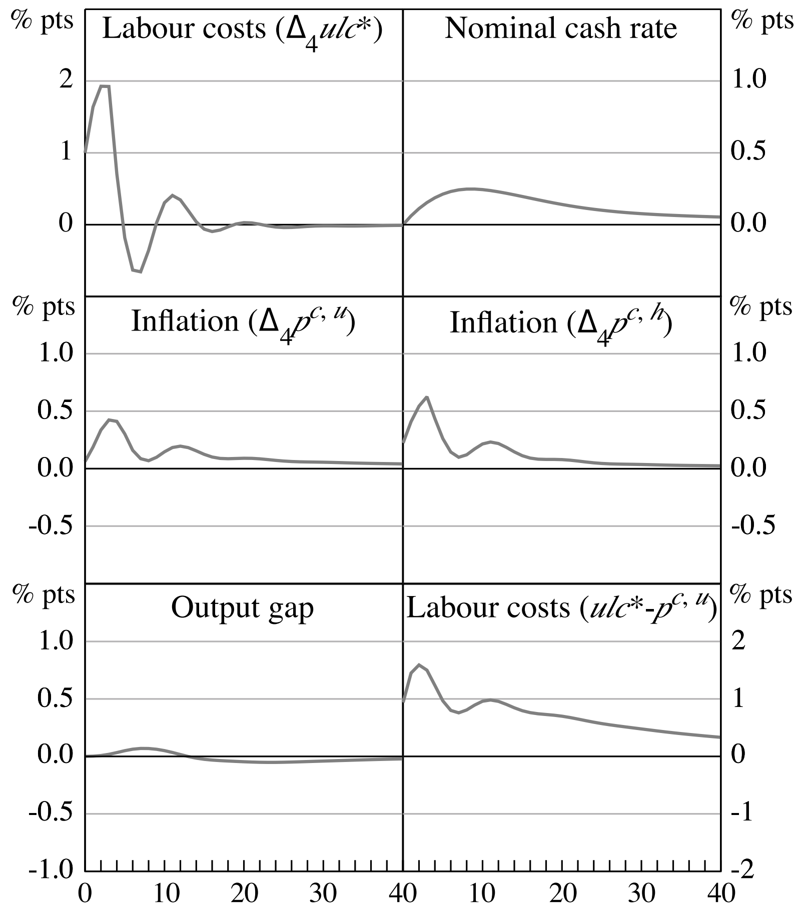
small fall in import prices during this second year, which partially offsets the rise generated during the first.[39]

A One-off Shock to Nominal Unit Labour Costs

Figure 12 shows the effect of a one-off 1 percentage point shock to the model's smoothed measure of unit labour cost growth, with the model's nominal cash rate set according to optimal policy (as described in Section 3.3 with weights $\lambda_1 = \lambda_2 = 1$ and $\lambda_3 = 10$).

Figure 12: Responses to a One-off Shock to Nominal Unit Labour Costs

Deviation from baseline



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39 If the real cash rate were instead held constant in this scenario then there would be no response of the output gap (or the real exchange rate) to such a shock to consumer prices. However, there would still be an effect on unit labour cost growth, due not only to the initial shock to headline inflation, but also to the flow-through from changes in the nominal exchange rate to both import prices and the Australian dollar price of oil.

The shock initiates oscillatory behaviour in year-ended (smoothed) unit labour cost inflation, with this variable sharply higher in the first year, but then below baseline in the second year. This induces corresponding oscillations in both headline and underlying consumer price inflation, albeit with both of these rates remaining persistently above baseline in year-ended terms. In all cases, however, these fluctuations die away fairly quickly, becoming almost imperceptible after three to four years.

Policy-makers react to the added inflation induced by the shock by raising the nominal cash rate, although the peak response is quite muted at only 25 basis points. Since the cash rate initially increases by less than underlying inflation, the real cash rate briefly declines, causing a small rise in the output gap. However, this situation later reverses, causing the non-farm output gap to slip slightly below baseline for a period, before slowly reverting to baseline. Finally, after an initial jump, the level of real unit labour costs also gradually returns to baseline in the long run, although this re-equilibration is very drawn out.

5. Summary

This paper provides an update on the current structure of the model of the Australian macroeconomy presented in Beechey *et al* (2000). Over the past five years quite a number of changes have been made to the model. However, it remains small, highly aggregated and non-monetary in nature. It also remains empirically based, so as to be consistent with the behaviour of key variables in the Australian economy over recent decades.

The most significant changes to the model since Beechey *et al* have been made either in response to changes in the behaviour of certain variables (such as the decision to model the output gap rather than the level of output), or in an attempt to better capture the underlying behaviour of a particular series (such as the decision to model a smoothed version of the unit labour cost series). The model now includes six behavioural equations, all of which are estimated econometrically. Each of the equations is specified so as to generate suitable long-run behaviour in the model, as well as appropriate short-run dynamics.

The model remains a convenient tool with which to analyse past developments in the economy and generate forecasts – while remaining simple enough to ‘carry around in one’s head’. Its dynamic properties are illustrated by simulations which show the response of key variables to a variety of different shocks (including a shift in monetary policy). As these simulations highlight, the model continues to provide a useful framework for analysing and quantifying the main macroeconomic inter-relationships in the Australian economy.

Appendix A: Calculating Potential Output

The model's multivariate filtering procedure seeks the potential output series which best fits the model's unit labour cost and underlying inflation equations, subject to a smoothness criterion. This involves jointly finding the potential output series y_t^*, and parameters for these two equations, which minimise the loss function

$$\mathscr{L} = \lambda_U \sum_{t=1}^{n} \eta_t^2 + \lambda_I \sum_{t=n-p+1}^{n} \zeta_t^2 + \lambda_S \sum_{t=-3}^{n-1} (\Delta y_{t+1}^* - \Delta y_t^*)^2 \qquad \text{(A1)}$$

where η_t and ζ_t are the residuals from the unit labour cost and underlying inflation equations respectively.[40]

The estimation process is iterative. The steps are as follows:

1. Initialise potential output by taking a Hodrick–Prescott filter of the level of non-farm output over the full sample period of available quarterly data, 1959:Q3 to 2005:Q1; hence form a corresponding initial output gap series.

2. Estimate the unit labour cost and underlying inflation equations by OLS, using the current output gap series.

3. Fix the parameters in these equations at their estimated values and then re-solve for the potential output series which minimises the loss, $\mathscr{L}$, given by Equation (A1).

4. Repeat steps 2 and 3 in turn until convergence is achieved (that is, until changes from one iteration to the next in both the potential output series and the parameters in the unit labour cost and underlying inflation equations fall below a pre-determined tolerance threshold).

[40] The first two summation terms in Equation (A1) cover different periods because the samples used for estimating the two equations are different (covering $n = 113$ and $p = 53$ quarters respectively). The unit labour cost equation is estimated from 1977:Q1, while the equation for underlying inflation is estimated only from 1992:Q1. The series y^* is estimated for $t = -3, \ldots, n$ because the unit labour cost equation allows for up to four lags of the output gap.

The interested reader is referred to Appendix A of Gruen, Robinson and Stone (2002) for further algebraic details on the iterative procedure for estimating potential output. While the discussion in Gruen *et al* relates to a filter with only one conditioning equation, the modifications required for two conditioning equations are reasonably straightforward.

A final issue concerns the role and selection of the weights in Equation (A1). The three weights control the relative importance attached, in the determination of potential output, to the fit of the unit labour cost equation, the fit of the underlying inflation equation, and the smoothness constraint. Because the inflation equation has a much better fit than the unit labour cost equation and covers a smaller sample, the former's sum of squared errors (SSE) term is much smaller than that of the latter. As a result, if the weights λ_I and λ_U were chosen to be equal, the filter would pay little attention to optimising the fit of the underlying inflation equation (relative to that of the unit labour cost equation) in conditioning potential output. To overcome this problem, we first express λ_I in the form $\lambda_I = \chi\lambda_I^*$, where χ is a multiplicative factor which 'scales up' the inflation equation SSE to be of comparable magnitude to the unit labour cost SSE.[41] We then fix values for λ_U and λ_I^* which reflect the relative importance we wish to place on the unit labour cost and underlying inflation equations, respectively, in conditioning our estimates of potential output – and which, without loss of generality, we require to sum to one.[42]

The weight λ_S, meanwhile, controls the importance placed on the smoothness constraint, relative to that attached to the goodness of fit of the conditioning equations. The larger is λ_S, the smoother will be the growth rate of potential output. We choose a value for λ_S (currently $\lambda_S = 200$) which allows for long-lived changes in the growth rate of potential output, without permitting high-frequency 'noise' in its level.

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41 The scaling factor is determined by the ratio of the unit labour cost SSE to the inflation equation SSE, and is continuously updated after step 2 in each iteration.

42 Somewhat arbitrarily, these parameters were set to be $\lambda_U = 0.8$ and $\lambda_I^* = 0.2$ in generating the output gap estimates shown earlier in Figure 7.

Appendix B: Econometric Issues

In this appendix we address two econometric issues, discussion of which was deferred from the main body of the paper.

Covariance-correlation Matrix of the Equation Residuals

The first relates to the variance-covariance and correlation matrices of the residuals from the model's six behavioural equations, when estimated separately using OLS. As noted in Section 2 these equations do not exhibit any simultaneity, which might require us to estimate them as a system so as to avoid obtaining biased coefficients. However, the residuals from one equation might still display some correlation with those from another, which would indicate that a system estimator such as Seemingly Unrelated Regressions (SUR) would be preferable to estimating each equation independently.

To assess this, Table B1 below – which updates the corresponding table on page 43 of Beechey *et al* – takes the various equation residuals and shows the correlations between them above the main diagonal, their variances along the main diagonal and the covariances between them below the main diagonal.[43]

Consistent with Beechey *et al* the estimated residuals from the real exchange rate equation display by far the largest variance, while those from the consumer price equations display the smallest. As might be expected, the largest absolute correlation coefficient of 0.39 arises between the two sets of inflation residuals. There are also moderate correlations between the residuals from the output gap and unit labour cost equations, and between those from the output gap and underlying inflation equations.[44] The other cross-equation correlations are very small.

These results suggest that the only sets of equations we might wish to estimate as part of a system would be the inflation equations as a pair and/or, to a lesser degree, the output gap, unit labour cost and underlying inflation equations as a

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[43] These statistics are based on data over the period 1985:Q1 to 2005:Q1, with the exception of those involving residuals from the inflation equations, which cover 1992:Q1 to 2005:Q1.

[44] The former likely reflects that non-farm output data are used to construct the unit labour costs data. Both results may also partially reflect that the unit labour cost and underlying inflation equations are used to condition the model's estimates of the output gap.

Table B1: Covariance-correlation Matrix of Residuals

	Output gap	Real exchange rate	Import prices	Unit labour costs	Weighted median inflation	Headline inflation
Output gap	**0.3221**	–0.0138	0.0262	–0.1972	0.1900	–0.1108
Real exchange rate	–0.0219	**7.9416**	0.0186	–0.0179	–0.0557	–0.0295
Import prices	0.0119	0.0418	**0.6540**	0.1118	–0.0223	0.0986
Unit labour costs	–0.0484	–0.0218	0.0391	**0.1914**	0.0043	0.0608
Weighted median inflation	0.0135	–0.0195	–0.0021	0.0002	**0.0186**	0.3944
Headline inflation	–0.0149	–0.0195	0.0173	0.0065	0.0135	**0.0660**

trio. However, when these blocs of equations are estimated using SUR, we find that this has only a very small effect on any of the coefficient estimates or their statistical significance. We conclude that it is unnecessary to estimate the model as a system.

The Vertical Long-run Phillips Curve Condition in the Unit Labour Cost Equation

In Section 2.4 we noted that the model's potential output data are constructed concurrently with estimation of its unit labour cost equation, Equation (5). Hence, standard econometric tests of significance for coefficients in this equation are rendered technically invalid by the generated regressor problem, making it complicated to test whether or not a vertical long-run Phillips curve restriction is accepted by the data over the equation's whole estimation sample, 1977:Q1 to 2005:Q1.

To do so formally would involve a bootstrapping procedure to first create multiple sets of 'pseudo data' for unit labour costs (as well as for headline and underlying inflation), and then generate distributions for the estimated values of the parameters in Equation (5) – with no verticality restriction imposed – by applying the iterative procedure outlined in Section 3.1 and Appendix A to each pseudo data set. However, rather than pursue such a complex and time-consuming Monte Carlo simulation procedure, we content ourselves with a much simpler, if only indicative, test of the likelihood of accepting the verticality restriction in Equation (5).

This indicative test rests on the fact that the high smoothness parameter used in the model's new multivariate Hodrick-Prescott filter for estimating potential output allows only very gradual, long-lived changes in the estimated growth rate of potential output over history. The filtering process is therefore unlikely to be over-fitting the model equations used to condition it – including the unit labour cost equation – to any serious degree.[45]

An illustration of this point is provided by Gruen *et al* (2002), in which a closely analogous multivariate filtering procedure was used to generate vintages of potential output and output gap data, conditioned on Phillips curves for underlying inflation (each of which was required to satisfy a long-run verticality condition). In that case, with a similarly high choice of smoothing parameter, bootstrapping tests suggested that the Phillips curve coefficients were 'not subject to significant biases', and that the generated regressor problem was unlikely to be causing the statistical significance of these coefficients to be seriously misrepresented (Gruen *et al*, footnote 5, p 8 and Appendix B).

Thus, while not strictly correct, it seems likely that standard tests of the verticality restriction in Equation (5), ignoring the generated regressor issue, should still provide a broadly reliable guide as to whether or not this restriction is accepted by the data. When such a test is carried out, the freely estimated sum of the relevant coefficients, over the whole sample 1977:Q1 to 2005:Q1, is 0.975, which is not significantly different from 1. Hence, the verticality restriction appears to be easily accepted by the data.[46]

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45 Technical details of this issue are discussed briefly in Section 3.1 and Appendix A. However, the basic principle is akin to that which holds for ordinary Hodrick-Prescott filtering. In that case, if the filter's smoothing parameter is low then the filter of a series will closely match the original series, as there is little penalty for closely fitting even quite volatile original data. The analogue here is that, if our multivariate filter's smoothness parameter were low, this would result in an output gap profile yielding near-optimal overall goodness of fit of the filter's conditioning equations. Conversely, with a high smoothing parameter, the filter is strongly penalised for trying to over-fit these equations if this requires a volatile profile for estimated potential output.

46 Formally, the test reported here involves replacing the imposed coefficient of 0.25 on the term $\Delta_4 p_{t-1}^{c,h,exGST}$ on the right-hand side of Equation (5) with a freely estimated one, and then re-estimating the equation using the iterative procedure outlined in Appendix A. This leaves all coefficient restrictions implicit in Equation (5), other than the verticality restriction, intact. When this is done the freely estimated coefficient on $\Delta_4 p_{t-1}^{c,h,exGST}$ is 0.244, with a reported standard error of 0.009.

Appendix C: Adjusting for the Balassa-Samuelson Effect

In modelling the impact of labour costs on domestic consumer prices, we ought to exclude those labour inputs ultimately associated with the production of exports – since the prices of these do not feed into domestic inflation. In industrialised economies there is an observed tendency for productivity to grow faster in the export sector than in the remainder of the domestic economy, which we refer to as the Balassa-Samuelson effect. All other things equal, such a productivity differential would lead the economy-wide growth rate of unit labour costs to understate the growth rate of those unit labour costs feeding into domestic consumer prices.

An adjustment for the Balassa-Samuelson effect was included in Beechey *et al* (2000). However, for reasons of algebraic simplicity this adjustment was made to the model's import price series, rather than to unit labour costs directly. By contrast, for reasons of transparency we apply this adjustment directly to the model's unit labour cost series. Hence, it is a Balassa-Samuelson adjusted version of ulc^{*}, denoted $ulc^{*,bs}$, which now enters the model's consumer price inflation equations.

In line with the scale of correction adopted in Beechey *et al*, the Balassa-Samuelson adjustment we impose is given by

$$ulc^{*,bs} \equiv ulc^{*,Non-export} = ulc^{*} + (\lambda_m/\lambda_u)\,xt \tag{C1}$$

where x, the differential between the growth rate of unit labour costs in the export sector and in the remainder of the domestic economy, is taken to be 0.005 (0.5 per cent per quarter). This formula follows, in a manner analogous to the derivation in Beechey *et al*, from the assumptions that

$$ulc_t^{*,Export} = ulc_t^{*} - xt \tag{C2}$$

and

$$ulc_t^{*} = \delta ulc_t^{*,Non-export} + (1-\delta)ulc_t^{*,Export} \tag{C3}$$

together with the presumption that the ratio $\delta{:}(1-\delta)$ is proportional to $\lambda_u{:}\lambda_m$ (where λ_u and λ_m are as specified in the model's consumer price inflation equations, Equations (6) and (7)).

The choice of $x = 0.005$ is based on an assumption that the productivity differential between the export and domestic sectors in Australia is the same as that in Australia's trading partners, so that x is equal to the average differential between foreign consumer price and export price inflation. This difference, on an annualised basis, was exactly 2.0 per cent *per annum* over the period 1992:Q1 to 2005:Q1, the sample used for estimating the model's inflation equations.[47] The choice $x = 0.005$ is also quite close to the value we would obtain (*viz* 2.3 per cent *per annum*) were we to attempt to estimate x, using non-linear least squares applied to Equation (7), along the lines set out in Beechey *et al*.

[47] This choice for x is therefore also consistent with our steady-state assumption of a 2 per cent *per annum* differential between foreign consumer price and export price inflation, as well as with generating the steady-state model properties set out in Table 8.

Appendix D: Glossary and Data

Glossary

Tables D1 and D2 provide a complete list of the variables used in the model. All levels variables are expressed in logs except: interest rates, bond market inflation expectations and the tariff rate series *trf* (which are expressed as decimals); together with the Southern Oscillation Index.

Table D1: List of Exogenous Model Variables

Variable	Description
Domestic variables	
y^*	Potential real non-farm output
tot	Merchandise goods terms of trade
s	De-trended real share accumulation index
i	Nominal cash rate
$\tilde{r}$	Neutral real cash rate
p^{com}	Index of commodity prices in foreign currency terms
$\pi^{e,bm}$	Bond market inflation expectations, expressed on an annualised basis
soi	Southern Oscillation Index
trf	Average tariff rate on Australian imports
D^{yGST}	Dummy for output shifts associated with the introduction of the Goods and Services Tax (GST)
D^{pGST}	Dummy to allow for a step up in the level of consumer prices in September quarter 2000 associated with the introduction of the GST
D^{rer}	Real exchange rate dummy
$trend^{pm}$	Time trend used in the import price equation
Foreign variables	
gap^{US}	US real output gap
r^f	Foreign (G3) real interest rate
s^{US}	De-trended US real share accumulation index
$p^{c,f}$	Trade-weighted foreign consumer prices
$p^{x,f}$	Trade-weighted foreign export prices
p^{usoil}	Oil price per barrel in US dollars

Table D2: List of Endogenous Model Variables

Variable	Description
Behaviourally determined endogenous variables	
gap	Real non-farm output gap ($y - y^*$)
rer	Real trade-weighted exchange rate
p^m	Import prices across the docks, measured in Australian dollars
ulc^*	Smoothed economy-wide nominal unit labour costs
$p^{c,h}$	Australian consumer prices – headline measure
$p^{c,u}$	Australian consumer prices – underlying (weighted median) measure
Non-behaviourally determined endogenous variables	
y	Real non-farm output
r	Real cash rate
$p^{m,trf}$	Tariff-adjusted import prices, measured in Australian dollars
$ulc^{*,bs}$	Balassa-Samuelson adjusted, smoothed nominal unit labour costs
$p^{c,h,exGST}$	Headline Australian consumer prices, adjusted to exclude the one-off impact of the GST in September quarter 2000
$p^{c,u,exGST}$	Underlying Australian consumer prices, adjusted to exclude the one-off impact of the GST in September quarter 2000
e	Nominal trade-weighted exchange rate
p^{oil}	Oil price per barrel in Australian dollars

Data Sources and Definitions

The data used in estimation were those available on 19 July 2005.

Real non-farm output

Definition: Seasonally adjusted chain volume non-farm gross domestic product at 2002–03 reference prices.

Source: National Income, Expenditure and Product, December Quarter 2004, ABS Cat No 5206.0.

Real US output

Definition: Seasonally adjusted chain volume gross domestic product (GDP) in US dollars at 2000 reference prices.

Source: Datastream, $USGDP\ldots D$

Real US potential output

Definition: Real US potential GDP in US dollars at 2000 reference prices.

Source: Congressional Budget Office, US Congress.

Nominal exchange rate

Definition: Australian dollar against a trade-weighted basket of major-trading-partner currencies, indexed to March quarter 1995 = 100.

Source: Reserve Bank of Australia, <http://www.rba.gov.au/Statistics/>.

Real exchange rate

Definition: Australian dollar against a trade-weighted basket of major-trading-partner currencies, adjusted for domestic and foreign consumer prices, indexed to March quarter 1995 = 100.

Source: Reserve Bank of Australia, <http://www.rba.gov.au/Statistics/>.

Nominal cash rate

Definition: From July 1998 onwards, quarterly average of monthly data for the official interbank overnight rate. Up to June 1998, quarterly average of monthly data for the unofficial 11am call rate.

Source: Reserve Bank of Australia *Bulletin*, Table F.1.

De-trended real share accumulation index

Definition: Accumulated index for nominal share market returns in Australia (including both capital gains and the re-investment of dividends), deflated by the weighted median consumer price index, and de-trended using a Hodrick-Prescott (H-P) filter with smoothness parameter $\lambda_{HP} = 1\ 600$.

Sources: From 1992:Q3 onwards, the nominal share accumulation index used is the quarterly average of the daily close of the Standard and Poor's (S&P)/Australian Stock Exchange (ASX) 200 accumulation index available from Datastream (code: ASX200(RI)). From 1990:Q1 to 1992:Q2, this index is back-cast using changes in the quarterly average of the daily closing values of the old ASX All Ordinaries Index (since renamed the ASX Share Price Index) available from Datastream (code: AORDASX(RI)). From 1980:Q1 to 1989:Q4, this back-casting procedure is repeated using the quarterly average of the end-month values of the ASX Share Price Index available from Reserve Bank of Australia *Bulletin*, Table F.7.

De-trended US real share accumulation index

Definition: S&P500 Composite Price Index, deflated by the chain type price index for personal consumption less food and energy, and de-trended using a Hodrick-Prescott (H-P) filter with smoothness parameter $\lambda_{HP} = 1\ 600$.

Sources: Data used for the period from January 1988 onwards are from Datastream (code: S&PCOMP(RI)). Data prior to January 1988 are from Global Financial Data (SPXD.csv), available at <http://www.globalfindata.com/>.

Goods terms of trade

Definition: Implicit price deflator for goods credits divided by implicit price deflator for goods debits (both seasonally adjusted), indexed to 2002–03 = 100.

Source: Balance of Payments and International Investment Position, ABS Cat No 5302.0.

Commodity prices

Definition: RBA Index of Commodity Prices, converted to foreign currency terms by multiplying by the nominal trade-weighted exchange rate. The resultant series is indexed to 2001–02 = 100.

Source: Reserve Bank of Australia, <http://www.rba.gov.au/Statistics/>.

Headline consumer price index

Definition: From 1986:Q4 to 1998:Q2, this is the all-groups consumer price index (CPI) excluding mortgage interest and consumer credit charges, indexed to 1989–90 = 100. Prior to 1986:Q4, the series is back-cast using quarterly growth in the all groups CPI. Beyond 1998:Q2 it is extended using the same method.

Source: Consumer Price Index, ABS Cat No 6401.0.

Underlying (weighted median) consumer price index

Definition: Weighted median consumer price index calculated using quarterly price change distributions for items in the CPI basket, indexed to 1989–90 = 100.[48]

Source: Reserve Bank of Australia, <http://www.rba.gov.au/Statistics/>.

Unit labour costs

Definition: Non-farm unit labour costs per hour for wage and salary earners. Computed as total non-farm labour costs (wage and salary earners) per hour divided by productivity per hour in the non-farm sector. The resultant series is indexed to 2002–03 = 100 and then smoothed as described in Section 2.4.

Source: Reserve Bank of Australia *Bulletin*, Table G.6 (based on ABS Cat No 5206.0 data).

Bond market inflation expectations

Definition: From 1993:Q1 onwards, difference in the yield between a 10-year government bond and an indexed bond of comparable maturity, where both yields are calculated as the quarterly average of the daily values. Before 1993:Q1, difference between the yield on a 10-year government bond and an estimated equilibrium 10-year real interest rate. Details of the calculation of this equilibrium real interest rate are provided in Gruen *et al* (2002).

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[48] Since this underlying inflation measure was selected, further research has been undertaken at the Reserve Bank on the properties and relative merits of alternative underlying inflation measures for Australia (Roberts 2005). While too late to be taken into account here, these alternative measures will be monitored, with a view to changing the measure used in the model if warranted.

Sources: Australian 10-year government bond yield available from Reserve Bank of Australia *Bulletin*, Table F.2; Australian Treasury capital-indexed bond yields available from Bloomberg (screen: ILB).

Import prices

Definition: From 1986:Q2 onwards, implicit price deflator (IPD) for underlying imports of goods and services indexed to June quarter 1986 = 100.[49] Prior to 1986:Q2 the series is back-cast using the IPD for imports of goods and services.

Source: National Income, Expenditure and Product, ABS Cat No 5206.0; Reserve Bank of Australia imports of gold data not publicly available.

Tariff rate

Definition: Customs duty receipts divided by the value of merchandise imports (excluding fuels and lubricants, civil aircraft and Reserve Bank of Australia imports of gold). Seasonally adjusted.

Source: Australian Customs Service.

Foreign consumer prices

Definition: Geometric trade-weighted index of major-trading-partner core consumer price indices, indexed to March quarter 1995 = 100. In those cases where core consumer price measures are not available, the headline CPI is either used for the whole sample or spliced onto the core consumer price series.

Source: Consumer price indices from Datastream.

Foreign export prices

Definition: Geometric trade-weighted index of major-trading-partner export price indices, indexed to March quarter 1995 = 100. For Saudi Arabia and the United Arab Emirates (whose exports are overwhelmingly dominated by oil) we replace their export price indices with consumer price indices.

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49 This measure excludes imports of fuels and lubricants, civil aircraft, ferries, major military equipment, oil rigs, an LPG tanker, goods for processing, repairs on goods, goods procured in ports and RBA imports of gold.

Source: Export price indices and consumer price indices from Datastream.

World real interest rate

Definition: Nominal GDP-weighted average of short-term policy interest rates of the euro area, Japan and the US (G3), where these interest rates are the quarterly average of monthly data, less four-quarter-ended core inflation in each country. Prior to January 1999 the German repo rate is used as a proxy for the euro area.

Sources: For interest rates, Reserve Bank of Australia *Bulletin*, Table F.13; for the German repo rate prior to January 1999, Datastream, BDI60B..; for core inflation, Datastream, BDUSFB76E, JPCPXFFDF, USCPXFDEF.

US dollar oil prices

Definition: US dollar price of West Texas Intermediate crude oil per barrel.

Source: Bloomberg (code: USCRWTIC).

Australian dollar oil prices

Definition: Australian dollar price of West Texas Intermediate crude oil per barrel, calculated using the US dollar oil price and the A$/US$ nominal exchange rate.

Source: A$/US$ exchange rate data from Reserve Bank of Australia, <http://www.rba.gov.au/Statistics/>.

Southern Oscillation Index

Definition: Quarterly average of monthly data for this index, which is calculated as the standardised anomaly of the Mean Sea Level Pressure difference between Tahiti and Darwin. (Lower values are associated with an increased probability that rainfall over eastern and northern Australia will be below average.)

Source: Available from the Commonwealth Bureau of Meteorology at <http://www.bom.gov.au/climate/current/soihtm1.shtml>.

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