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Inflation Targeting and Price-Level-Path Targeting in the GEM: Some Open Economy Considerations

by

Donald Coletti, René Lalonde and Dirk Muir

International Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
dcoletti@bankofcanada.ca

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Abstract

This paper compares the relative merits of IT and PLPT rules in a two-country, two-sector (tradables and nontradables) version of the Global Economy Model (GEM). To do this, the authors test the relative capability of simple monetary rules to minimize the variance of inflation and output. They conclude that the performance of simple PLPT rules perform slightly better than simple IT rules. In the presence of partial indexation of prices and wages, the authors also conclude that the performance of PLPT relative to IT rules depends on the relative importance of the different shocks included in the model. In addition, they show that the presence of terms-of-trade shocks tend to bolster the case for PLPT. Lastly, the authors demonstrate that the choice of monetary policy framework in the United States does not affect the relative merits of IT versus PLPT in Canada.

JEL classification: JEL classification: C51, C52, E17, E31, E52
Bank classification: Economic models; Inflation: costs and benefits; Inflation and prices; Monetary policy framework

Résumé

Cette étude compare les mérites relatifs de cibler l'inflation (IT) ou un sentier de prix (PLPT) au sein d'une version du GEM incluant 2 pays (Canada et États-Unis) et deux secteurs (biens échangeables et non échangeables). Pour ce faire, les auteurs testent la capacité relative de règles monétaires simples à minimiser la variance de l'inflation et de l'écart de production, et ce, sous les deux régimes (IT vs. PLPT). Ils concluent que la performance des règles simples spécifiées en termes de cibles d'un sentier de prix est légèrement supérieure à celle de règles simples définies en termes de cibles d'inflation. En présence d'indexation partielle des prix et salaires, les auteurs concluent toutefois que cette superiorité dépend de l'importance relative des différents chocs incluent dans le modèle. Ils concluent également que la présence de chocs touchant les termes d'échange accroit la supériorité de règles spécifiées en termes de cibles de sentier de prix (PLPT). Finalement, les auteurs démontrent que le choix du cadre de politique monétaire effectué par les autorités monétaires américaines n'affecte pas les mérites relatifs de IT versus PLPT au Canada.

Classification JEL : C51, C52, E17, E31, E52
Classification de la Banque : Inflation: coûts et avantages; Inflation et prix; Modèles economiques; Mise en oeuvre de la politique monetaire

1. Introduction

In recent years, the adoption of formal inflation targets has become an increasingly popular means of implementing a strong nominal anchor for the economy.[1] The basic principles of inflation targeting (IT) are straightforward. In the advent of a shock that pushes inflation away from target, the central bank moves policy interest rates so as to push inflation back to target over some specified time period. Monetary policy affects inflation through both the level of spending in the economy and through inflation expectations.

Inflation targeting in Canada and in many other countries has proved to be quite successful as inflation expectations have become better anchored leading to a reduction in inflation volatility and persistence with no increase in output volatility (Mishkin and Schmidt-Hebbel (2002)). Despite these notable achievements, it is also clear that IT may have some important limitations. In particular, due in part to the fear of hitting the lower zero bound on nominal interest rates, inflation targets worldwide typically remain at about two per cent despite a consensus in the economics community that there should be benefits associated with moving towards true price stability (Fischer (1996)). In addition, under IT price level movements are not completely reversed, leading to price level drift. As a result, the variance of the expected future price level is unbounded creating significant uncertainty about the future price level. This uncertainty is problematic for agents who are risk averse and who enter into long-term, nominal contracts (e.g. home mortgages).

An alternative way to achieve a strong nominal anchor for the economy that may help alleviate these problems is price-level-path targeting (PLPT). PLPT differs from IT because under PLPT a shock that pushes the price level above its target path would require the monetary authority to reverse fully the initial positive shock by creating a period in which prices must rise by less than the growth rate of the target path. With price-level-path targets there is good reason to believe that they could serve to anchor inflation expectations even when there is significant downward pressure on nominal interest rates thus reducing the likelihood of encountering the zero bound on nominal interest rates (Eggertsson and Woodford (2003), Wolman (2005), Laxton, N'Diaye and Pesenti (2006)). If this is true then, everything else being equal, the relative benefits of PLPT versus IT rise as the underlying trend increase in prices falls. PLPT also caps the variance of expected future prices thus leading to a fall in price level uncertainty. PLPT however do not offer a panacea. Many authors have argued that PLPT has the potential to increase in the volatility of inflation

[1] Although the specific institutional details differ, 20 countries were inflation targeters in 2005 (Roger and Stone (2005)).

and/or output relative to inflation targeting (for example Lebow, Roberts, and Stockton (1992), Fillion and Tetlow (1994) and Fischer (1996)).

Our paper focuses on the aforementioned argument against PLPT by comparing the capability of simple IT and PLPT interest rate feedback rules to minimize inflation and output gap variability in a simplified, two-country, two-sector (tradable and nontradable goods) version of the Global Economic Model (GEM) calibrated for Canada and the United States.[2] We find that simple PLPT interest rate feedback rules perform (slightly) better than simple IT rules. We also find that our results are sensitive to the interaction between the degree of forward-lookingness in the price formation process and the incidence of different types of shocks. In addition, our analysis suggests that the presence of terms-of-trade shocks tend to bolster the case for PLPT. Lastly, we show that choice of monetary policy framework in Canada is completely independent of the choice of the United States.

The paper is organized as follows. Section 2 reviews the relevant literature. Section 3 provides a high-level overview of the version of the GEM that we use for our analysis. Section 4 discusses the calibration of the model. Section 5 employs the model to investigate the relative merits of IT and PLPT. Finally, Section 6 reviews our main conclusions and outlines directions for future research.

2. Literature Review

PLPT significantly pre-dates IT in both academic and policy making circles.[3] In fact, Wicksell first presented the view that price level stabilization should be the proper guide for central bank policy in Sweden in 1898 (Berg and Jonung (1998)). To the best of our knowledge, interest in PLPT waned in both academic and policy making circles for a considerable period before returning in the early 1990s. A considerable amount of research has been published on the subject since then and the conclusions of that research vary depending on a number of key assumptions.

The first papers in the 1990s focused on models in which expectations were formed adaptively and independent of the nature of monetary policy. See Lebow, Roberts and Stockton (1992), and Haldane and Salmon (1995) for examples. In these models, PLPT results in higher short-run variability of both inflation and output. Under PLPT, periods of higher-than-average inflation are necessarily followed by periods of lower-than-average inflation.

[2] For a full model description, see Faruqee *et al.* (2007)

[3] For a more thorough discussion of the issues, see Duguay (1994) and Barnett and Engineer (2000).

On the other hand, under IT, periods of higher-than-average inflation are followed only by average inflation. Thus, inflation variability is higher under PLPT than under IT. Higher inflation volatility in presence of nominal rigidities in the models, in turn, leads to higher output volatility under PLPT. Subsequent papers including Fillion and Tetlow (1994) and Black, Macklem and Rose (1998) focused on cases where expectations are formed as mixed processes. Recently, Yetman (2005) argues that even if a small proportion of agents form expectations using a rule of thumb rather than using rational expectations, then IT dominates PLPT provided that society's preferences are specified in terms of inflation variability.

This general line of thought has been challenged by numerous authors who placed great importance on rational expectations and forward-looking behavior. In models where expectations are formed rationally and the Phillips' curve takes the New Keynesian form (NKPC), that is inflation today is a function of expected inflation tomorrow, policy stands to play a more important role through the restraint of expectations. As a result, when monetary policy can credibly commit to future, PLPT is preferred to IT. Intuitively, when firms face a positive mark-up shock, having a policy that commits to creating future excess supply in the economy leads firms to set current prices lower than otherwise. In fact, under PLPT, the monetary authority commits to creating disequilibrium in the good market until the price level returns to its target path. Thus, the firm's expectations of future price level and its choice of current prices is lower than it would be if policy committed only to returning the inflation rate back to average levels and accepting an upward shift in the price level. Examples of papers that compare PLPT to IT when the inflation process is characterized by a NKPC and monetary policy is solved under commitment include Giannoni (2000), Smets (2000) and Williams (1999). In general, these results also hold when policy is solved under discretion (Dittmar and Gavin (2000), and Vestin (2005)). The results are however quite sensitive to modifications in the Phillips' curve. If the Phillips' curve is specified as a hybrid NKPC (that is, if the determination of current inflation includes some weight on lagged inflation) then monetary policy under PLPT becomes less effective. Roisland (2005) shows that assuming a hybrid NKPC as well as assuming that the central bank cannot commit to future policy implies that the optimal amount of price level drift is related to the degree of price indexation. If indexation is complete as argued by Giannoni and Woodford (2003) and Christiano, Eichenbaum and Evans (2005) then inflation targeting is the optimal policy.[4]

[4] An alternative strand of the literature makes use of the New Classical Phillips' curve (NCPC) rather the NKPC. The key difference is that contemporaneous inflation expectations are predetermined in the NCPC. Svensson (1999) argues that when central banks face a NCPC and act under discretion, then PLPT is preferable to IT as long as there is a moderate degree of persistence in the output gap. IT is preferable under commitment.

A limited number of recent studies have been done in a small-open economy context. Batini and Yates (2003) investigate the relative merit of PLPT, IT, and hybrid rules using a small-scale, open-economy, rational expectations model of the United Kingdom. The authors conclude that the relative merits of the alternative regimes, are a function of several modelling and policy assumptions including the degree of forward-lookingness embodied in price-setting and the relative weight on inflation and output in the central bank's loss function. Ortega and Rebei (2005) examine the PLPT - IT debate in the context of a New Keynesian, small open economy DSGE model of the Canadian economy featuring a tradable and a nontradable sector. They find that the welfare implications of moving from IT to PLPT or a combination of both (i.e. hybrid monetary policy rule) are negligible.

Our paper differs from the existing literature in several important ways. For example, our focus is on open economy issues, in particular, assessing the potential importance of terms-of-trade shocks and monetary policy choices of major trading partners on the relative merits of IT and PLPT. The two-country, multi-sector (tradable and nontradable goods) nature of our model is unlike others used in the literature and is particularly well suited to address these issues. Although some papers have addressed the Canadian and United States' economies, our paper uses a more detailed set of data.(particularly the sectoral decomposition) when calibrating our model, in a way that attempts to take advantage of the model structure.

3. The model

3.1 General structure

In order to facilitate our analysis, we use a stripped-down version of the International Monetary Fund's Global Economy Model (GEM), a dynamic stochastic general equilibrium (DSGE) model in the new-open-economy macroeconomics (NOEM) tradition.[5] In this section, we provide a non-technical overview on the model. We highlight model features that turn out to be particularly important for our results. More details about the GEM are available in Faruqee *et al.* (2007).

The world economy consists of two countries, a small country (Canada) and a large country (United States). Each country is populated by consumers/workers, firms (final goods producers and intermediate goods producers), and a government (fiscal and monetary au-

[5] For our work, we use a VAR representation of the first-order Taylor approximation of the model (Juillard (2001)).

thorities). The production structure for a single region is illustrated in Figure 1. In each country, final goods are produced by perfectly competitive firms that use a continuum of intermediate goods as inputs. There are two types of final goods: consumption goods (private and public), and investment goods (private and public). Final consumption and investment goods are produced using constant elasticity of substitution (CES) technology that combines various nontradable goods, domestically-produced tradable goods and imports. To model realistic dynamics of import volumes we assume that it is costly to change the share of imported goods in production. Private agents can consume the final consumption and investment goods while the fiscal agent consumes a public good which consists of consumption, investment and nontradable goods.

Intermediate goods (tradable and nontradable) are produced by monopolistically competitive producers who combine domestic labour and capital using CES technology. In addition to producing goods to be used in the production of final goods, firms can also export tradable goods to the foreign country. Firms purchase inputs in perfectly competitive capital markets and in monopolistically competitive labour markets. Firms can adjust their use of both capital and labour but face adjustment costs of changing the capital stock and investment. Monopolistic competition means that firms can still enter and exit the market, but because each firm's good is slightly differentiated from those produced by other firms, each firm is able to set a price above its marginal cost, allowing for a markup. When prices (p_t) are fully flexible firms set prices according to the standard markup rule:

$$p_t = \frac{\theta_t}{\theta_t - 1} mc_t \tag{1}$$

where the gross markup ($\frac{\theta_t}{\theta_t - 1}$) is a negative function of the elasticity of input substitution (θ_t) and mc_t denotes real marginal cost.[6] Deviations from markup pricing occur if firms face costs for modifying their prices in the short term. Prices are subject to adjustment costs as in Rotemberg (1982) due to the presence of nominal rigidities (e.g. contracts or menu costs). The adjustment costs are expressed in terms of deviations of current inflation from a weighted average of last period's inflation and the inflation target. The speed of adjustment in response to shocks depends on the trade-off between current and future expected costs, making the price-setting process forward-looking, but also allowing for a lag of inflation in the implied Phillips' curve.[7] In particular, the linearized Phillips' curve in our version of the

[6] The fewer the varieties of goods (i.e. θ is a higher value since this implies a higher elasticity of substitution amongst varieties of goods), the lower is the potential mark-up that a firm can charge over its real marginal cost.

[7] This form of the Phillips' curve applies to price setting of tradable, nontradable and imported goods.

GEM, abstracting from growth, takes the following form:

$$\hat{\pi}_t = \frac{\phi_2}{1+\beta\phi_2}\hat{\pi}_{t-1} + \frac{\beta}{1+\beta\phi_2}E_t\hat{\pi}_{t+1} + \frac{\theta(\theta-1)}{\phi_1(1+\beta\phi_2)}(\widehat{mc}_t) + \epsilon_{\pi,t} \quad (2)$$

where $\hat{\pi}$ is the deviation of the inflation rate from the target, ϕ_1 is the nominal adjustment cost parameter, ϕ_2 is the degree of indexation to lagged inflation, E_t is an expectations operator conditioned by information available at time t and β is the discount rate.[8]

Households are infinitely-lived consumers of the final consumption good and are also monopolistically-competitive suppliers of differentiated labour inputs to domestic firms. Household welfare depends positively upon consumption and negatively upon labour effort. There is habit formation in both consumption and leisure. Differentiation of labour inputs allows workers to charge a wage above the marginal rate of substitution between consumption and leisure. Wages are also subject to adjustment costs as in Rotemberg (1982). Households own all firms and the capital stock, which they rent to firms.

Households can also buy short-term nominal bonds denominated in U.S. currency that are internationally traded. Canadian households incur financial intermediation costs for transactions in the international bond market that increase (decrease) as they diverge (converge) to their desired holdings of the international bond. This financial friction is introduced to guarantee that net asset positions follow a stationary process and the economies converge to a steady state.

Our version of the GEM deviates from the baseline GEM in that we attempt to capture the forward premium puzzle. The forward premium puzzle is the empirical observation that risk premia are often strongly negatively correlated with expected future depreciations (Fama (1984)). The forward premium puzzle implies that Canadian investors will accept a lower return on their holdings of the U.S. bond relative to their holdings of domestic debt, if the real exchange rate is expected to depreciate consecutively. As a result the risk-adjusted uncovered interest rate parity (UIRP) condition is modified as in Adolfson *et al.* (2005)

For example, if nominal rigidities in the export market are highly relevant, the prices of home country's goods in the foreign market will be characterized by significant inertia. Exporters price their good in terms of producer-currency pricing. In this case, short-term exchange rate pass-through in the foreign economy will be rather low due to the fact that prices are sticky in the consumer currency, (i.e. domestic exports are invoiced in the foreign currency). There is full exchange rate pass-through to prices in the long run.

[8] For ease of exposition, we ignore the effects of balanced growth, which serves only to slightly modify the slopes of each coefficient in the Phillips' curve.

by introducing a lag of the exchange rate in the log-linearized model helping the model to generate the hump-shaped responses typically found in VARs.

Government spending is on final and intermediate nontradable goods. Governments finance public expenditures through non-distortionary lump-sum taxation. Governments are required to run balanced budgets at all times and thus no domestic bonds are issued.

The monetary authority controls the short-term interest rate and targets deviations of current output from potential and either future consumer price inflation relative to target or the price-level relative to a price-level-path target. We assume that central banks can credibly commit to the simple rule.

4. Calibration and model properties

4.1 Calibration methodology

The calibration of the model reflects our desire to match a number of selected unconditional moments in the historical data (temporal cross-correlations, autocorrelations and relative variances) as well as impulse responses to specific domestic shocks (e.g. technology, demand, monetary policy) from the Bank of Canada's model of Canada, ToTEM (Terms-of-Trade Economic Model - see Murchison and Rennison (2006)) and to the Bank of Canada's model of the U.S. economy MUSE (Model of the United States Economy - see Gosselin and Lalonde (2005)). The parameterization process involves selecting a set of candidate model parameters and then using the historical data to "back-out" a historical path for the model's shock terms that allows us exactly replicate history.[9] Using the variance of the historical shocks, we then conduct stochastic simulations to determine the key moments of the model variables, and then compare them to those estimated in the historical data[10]. Impulse responses from the model are also simulated and compared to those from ToTEM and MUSE. This process is repeated until the model is able to replicate closely both the unconditional moments in the data and the impulse responses suggested by the other models.

[9] Each shock is modelled as a first-order autoregressive stochastic process with standard error of the random disturbance σ_ϵ and persistence λ

$$z_t = \lambda z_{t-1} + \epsilon_t.$$

[10] The stochastic simulations are based on numeric perturbation methods conducted with DYNARE (based in MATLAB) as *per* Juillard (2001).

The model has 23 behavioural shocks.[11] The shocks have been grouped into five categories that occur in both Canada and the United States. Demand shocks (consumption, investment, imports, government spending and interest rates) share the common feature that they originate in the home country and generate a positive covariance between output (as well as the output gap) and inflation. The second broad class of shock are supply shocks, where output and inflation covary negatively. Supply shocks are further disaggregated depending on the behaviour of the output gap. For productivity shocks (technology shocks to the production of tradable and nontradable goods), movements in the output gap covary positively with inflation. The remaining supply shocks - the three mark-up shocks (prices in the tradable goods sector; prices in nontradable goods sector; and the real wage) and a labour supply shock - are different from the productivity and demand shocks because they generate a negative covariance between inflation and the output gap. Finally, Canada has a unique shock - the shock to financial intermediation costs, which behaves like an exchange rate shock (as it found in the modified risk-adjusted UIRP condition). From the Canadian perspective, all shocks in the United States can all be thought of as demand shocks since they all cause Canadian inflation and the output gap to covary positively.

To identify the shocks empirically we use 21 historical data series and an assumption regarding the split between wage shocks and labour supply shocks in both countries based on previous empirical work (Juillard *et al.* (2006)).[12] The historical series that we use are: real consumption, real investment, real government spending, real imports, the price of consumption goods (core CPI for Canada and core PCE for the United States), the price of nontradable consumption goods, wages, total employment in the nontradable-goods sector, total employment in the tradable-goods sector, the real Canada-U.S. exchange rate (deflated by the prices of consumption goods), and the 90-day commercial paper rate. For Canada, consumer price data is the Consumer Price Index excluding eight volatile components and the effects of indirect taxes (CPIX). Nontradable goods prices are proxied by the prices of services excluding financial services in the core Canadian CPI. Similar price series are used for the United States based on the U.S. Personal Consumption Expenditure (PCE) deflator. Total employment in the nontradable goods sectors is set equal to employment in services excluding financial services in the Canadian Labour Force Surveys. Similar data for the United States is provided by the Bureau of Economic Activity.

The raw data has been adjusted on a number of margins. First, we have assumed that

[11] In addition, there are measurement errors on equations for the price of investment, the price of government expenditure and the capital stock.

[12] Our results are robust to alternative decompositions of labour supply and wage mark-up shocks.

levels of Canadian trade as found in the National Income and Expenditure Accounts (NIEA) are solely with the United States. As for the United States, the U.S. NIEA data has been replaced by the Canadian NIEA data, transformed by the nominal exchange rate. Data on net foreign asset holdings reflect net Canada-U.S. positions only. Real data are detrended using a Hodrick-Prescott (H-P) filter with a stiffness parameter of 10,000. All Canadian nominal variables are detrended using the inflation target post-1991 and the implied inflation target calculated from the Staff Economic Projection over the 1983 to 1990 period (Amano and Murchison (2005)) while all U.S. nominal variables are detrended using an estimate of the implied inflation target in the United States (Lalonde (2006)). The historical sample studied covers 1983Q1 to 2004Q2.

4.2 Baseline Parameters

Tables 1 to 4 report the parameterization of Canada and the United States for our two-country, two-sector GEM. The steady-state ratios have been set to match the adjusted national accounts data. Canada accounts for about 10 per cent of the world and the United States accounts for the remaining 90 per cent (Table 1). The steady state consumption-to-GDP ratio is lower in Canada than in the United States (57 per cent compared with 67 per cent), but investment, government expenditure, exports, and imports, are higher in Canada than in the United States. The key observation that should be made here is that while trade is very important for Canada (exports plus imports are 74 per cent of GDP), for the United States it is not (exports plus imports are 5 per cent of GDP). Therefore, domestic shocks in the United States have the strong effect on Canada; the converse is not true. At steady state, Canada is assumed to run a negative net-foreign-liability position equal to about 5 percentage points of GDP. This translates into a net foreign asset position of 0.4 percentage points of GDP for the United States. Because of its net-foreign-liability position, Canada must generate a small trade surplus in the long run equal to 0.1 per cent of Canadian GDP.

Domestically-produced tradable goods are combined with a imported goods and nontradable goods to produce consumption and investment goods. Like Erceg, Guerrieri and Gust (2005), we set the elasticity of substitution between domestically-produced and imported tradable goods for both Canada and the United States at 1.5 (see Table 2), which is lower than the values assumed in previous published work using the GEM (i.e. 2.5 - see Faruqee *et al.* (2007)). The elasticity of substitution between tradables and nontradables in both consumption and investment goods in each country is set at 0.5, reflecting the relatively low substitutability of tradable and nontradable goods in the consumption and investment baskets. The share of nontradable goods in the consumption (investment) basket is similar across countries - 47 (33) per cent for Canada, and 53 (37) per cent for the United States. However, the baseline calibration reflects the significant difference across the two countries in terms of the relative magnitude of import shares. For the given elasticities of substitution, the bias towards domestically-produced tradable goods over imports in the production of the consumption (investment) good is consistent with an import-to-GDP ratio of 28 (9) per cent in Canada but only 2 (0.3) per cent in the United States.

Production in the monopolistically competitive intermediate goods sectors combines capital and labour using CES technology. The elasticity of substitution between labour and capital is set at 0.70 in both the tradable and nontradable sectors in both countries. This setting proves useful in helping to reduce the sensitivity of capital to changes in interest rates and to increase the procyclicality of real marginal cost. We assume that the tradable sector is more capital intensive than the nontradable sector in both countries. The bias toward the economy-wide use of capital has been set to replicate the actual average investment-to-GDP ratio. The depreciation rate on capital is assumed to be two per cent per quarter (eight per cent a year).

The mark-ups on the price of tradable and nontradables, which reflect the pricing power of firms under monopolistic competition, are based on estimates from Martins, Scarpetta, and Pilat (1996) for Canada and the United States (Table 3). Markups in Canada are higher than in the United States for both tradable and nontradable goods prices. In the labour market, workers have more pricing power in Canada than in the US with a wage mark-up of 20 per cent versus 16 per cent, indicative of higher minimum wage laws, more generous employment insurance and a slightly higher degree of unionization.

With regard to consumption behaviour (Table 2), the two countries share the same rate of time preference (the inverse of the subjective discount factor) of 1.6 per cent. The intertemporal elasticity of substitution $1/\sigma$ is also assumed to be identical in both countries at 0.7. Combining these three parameters with a steady-state balanced-growth trend rate g_{SS} for the world economy of 1.9 per cent implies a real world interest rate of three per cent, consistent with the lower bound of the typical calibration of three to four per cent (Christiano, Eichenbaum and Evans (2005)).

The habit persistence parameter in consumption is set at 0.80 for both regions. There is also habit persistence in labour supply which is set at 0.70 for both countries We calibrate the Frisch elasticity of labour supply at 0.25, well within the range of the 0.05-0.33 range of estimates obtained using micro data. Since habit persistence means that agents place a large weight on their past behaviour in terms of consuming and use of leisure time, we can better match the "humped-shape response" of consumption demand and labour effort supplied that is a stylized fact in most economies in the face of a large variety of shocks.

The dynamics of the key macroeconomic aggregates are largely dependent upon the assumptions made on the adjustment costs parameters associated with the nominal and real aggregates (Table 4). Although we generally use similar adjustment costs in Canada and the United States, we assume a significant heterogeneity across sectors. In particular, we set the adjustment cost parameter (ϕ_1) for nontradable goods prices in both countries at 450 and at 250 for tradable goods prices. For nominal wages, we set the adjustment cost parameter to 500. [13]

In order to match the persistence of price and wage inflation in both countries, we find that it is necessary to calibrate adjustment cost technology so that the weight on lagged inflation in the linearized Phillips' curve $\frac{\phi_2}{1+\beta\phi_2}$ is equal to 0.41 and the weight on forward-looking expectations of inflation next period is 0.58. Adjustment costs on import prices in both countries are set at 4500. This setting reflects the fact that in the data we have seen a relatively low and gradual short-run exchange rate pass-through.[14]

On the real side, there are also important adjustment costs. Like Faruqee *et al.* (2007) and Juillard *et al.* (2006), we assume that the adjustment costs related to a change in the level of capital are relatively small whereas those related to the change in the level of investment are large. Modelling the capital adjustment costs as a function of the change in investment allows the model to capture the hump-shaped response of investment to various shocks including monetary policy shocks.

The response of imports to changes in fundamentals and their price elasticities are typically observed to be smaller in the short run than in the long run. To model realistic dynamics of import volumes (such as delayed and sluggish adjustment to changes in relative prices)

[13] In terms of the Calvo (1983) model, our calibration implies price contracts in the nontradable goods sector that are re-optimized once every 8 quarters in Canada and once every 7 quarters in the United States. The corresponding contracts lengths for the tradable goods sector in Canada and the United States are considerably shorter at 3.5 and 2.7 quarters. Nominal wage contracts are re-optimized every 5 and 4 quarters in Canada and the United States.

[14] Alternatively, we could address the issue of exchange rate pass-through by adding a distribution sector to the model. This would allow us to reduce exchange rate pass-through and insure that domestic import prices never converge to foreign producer prices. In the absence of this model feature, we have elected to set high nominal adjustment costs, thereby breaking the law of one price in the short run, even as it holds in the long-run.

we assume that imports are subject to real adjustment costs These costs are specified as a function of the one-period change in import shares relative to the firm's output in the home country.

The financial intermediation cost parameters in the international bond market are chosen so as to ensure a slow reversion of net asset position between the two countries to its steady-state value within 15 to 20 years after a shock to the desired level.[15] Modification of the model to address the forward premium puzzle leads to the presence of a lag of the exchange rate in linearized version of the modified risk-adjusted UIRP condition, with a weight of 0.3.

When running our model over history we use simple Taylor rules to broadly reflects the behavior of monetary policy in the United States and Canada. The parameterization of these rules are based on the historical ToTEM and MUSE reaction functions and our moment matching exercises. For the U.S., the calibration of the Taylor rule is:

$$i_t^{us} = 0.7 i_{t-1}^{us} + 0.3 i_t^* + 0.9(\pi_t^{us} - \pi_t^{TARus}) + 0.2(y_t^{us} - y_t^{POTus}) \tag{3}$$

while for Canada it is:

$$i_t^{ca} = 0.8 i_{t-1}^{ca} + 0.2 i_t^* + 0.5(\pi_t^{ca} - \pi_t^{TARca}) \tag{4}$$

where π is the year-over-year change in core consumer prices; π^{TAR} is the inflation target, y is (the log of) real GDP; y^{POT} is (the log of) potential output; i is the nominal interest rate; and i^* is the equilibrium nominal interest rate.[16]

The last set of parameters, are those that pertain to the stochastic part of the model. As discussed earlier, there are twenty-seven structural shocks, eleven in each of the United States and Canada and one on the financial intermediation costs that affect the adjustment

[15] This speed of adjustment is a compromise. Faster convergence of the NFA gap implies the bilateral U.S. dollar exchange rate deviates too strongly from the standard uncovered interest rate parity condition even in the short run. However, a speed of adjustment that is too low eliminates, in practice, the stock-flow dynamics between the current account and the net foreign asset position, and creates extremely long-lived gaps throughout each economy.

[16] Throughout this paper, we use a measure of potential output that is consistent with the conventional measure usually used at central banks. This measure is calculated based on a production function approach where output is evaluated with actual trend factor productivity, actual capital stock and steady-state labour supply.

of the exchange rate. Each shock is modelled as a first-order autoregressive stochastic process with standard error of the random disturbance σ_ϵ and persistence λ :

$$z_t = \lambda z_{t-1} + \epsilon_t. \tag{5}$$

Table 5 reports the persistence and the standard errors of each of the stochastic disturbances in the model. In general, the stochastic processes exhibiting the most persistence for Canada and the United States are the government absorption shocks, the shock to international financial intermediation, the import of investment goods shock and both tradable and nontradable sector productivity shocks. The shocks with least persistence are the mark-up shocks that have a root of zero in the case of nontradable-goods prices and wages.

The estimates of the standard errors of the shock can be more difficult to interpret. As a result, we focus on how these shocks account for the variability of the observed series. Table 6 shows the decomposition of the long-run variance of output growth, the output gap, inflation, nominal interest rates, the real exchange rate and the terms of trade.[17] In Canada, foreign shocks account for about 50 per cent of the variance in Canadian real GDP and about 35 per cent of the variation in consumer price inflation while domestic demand shocks explain about 20 percent of the variability in real GDP and about 10 percent of inflation variability. Exchange rate shocks are important for the variation in inflation (roughly 15 percent) but seem to matter very little for output variability. Mark-up and labour supply shocks account for about 25 per cent of the variation in real GDP and 40 per cent of the variation in consumer price inflation. The contributions of productivity shocks in Canada to real GDP and consumer price inflation variability are quite small. On the other hand, in the United States, productivity shocks play a much more important role in explaining the variability of output and inflation than they do in Canada, accounting for about 20 per cent of both output and inflation variability. Demand shocks in the United States are the largest contributor to GDP variability accounting for approximately 55 per cent and 40 per cent of inflation variation. Mark-up and labour supply shocks account for the remaining volatility.

[17]The model structure assumes that the shocks are independent. However, we find that one in five covariances are statistically significant at conventional levels, although most are relatively small. Almost all of the covariances are limited to shocks that are within the same major grouping. Our main results, at least qualitatively, are not sensitive to allowing for these covariances.

4.3 Matching unconditional moments

In this section, we demonstrate the ability of the Canada-U.S. version of the GEM to reproduce some key unconditional moments from history.[18]The model-generated data is then compared to moments calculated from the historical data based on the 1983Q1 to 2004q2 historical sample.[19]

First, we explore whether our calibration of the GEM is able to generate data that has a similar degree of persistence to that found in the historical data. Figures 2 and 3 graph several of the autocorrelation functions. The GEM does well at matching the persistence of consumption growth, investment growth, import growth, GDP growth, the output gap, year-over-year core inflation, year over-year growth in the real wage, as well as the nominal and real interest rate.

Next, we turn to an examination of the several bivariate temporal correlations[20]. From Figure 4 we see that the GEM is able to generate correlations between output growth and the consumption growth, as well as output growth and investment growth that match the shape found in the data very well. For both the model-generated and empirical data, the maximum positive correlation occurs contemporaneously and falls monotonically towards zero on either side. The absolute magnitude of the correlations also appear to be roughly in line with the data.

We then consider the GEM's ability to match the dynamic correlations between interest rates and consumption (investment) growth. From Figure 4 we see that the GEM captures the broad pattern of the correlation between the real interest rate and consumption (investment) growth. The maximum negative cross-correlation between real interest rates and consumption (investment) growth in the GEM occurs about two quarters earlier than in the historical data. [Note, however, that the empirical correlations do not appear to be significant at 95 per cent confidence level.]

Next, we explore some foreign economy links in the Canadian bloc of the GEM. Figure

[18] Evidence of the model's ability to match these moments as well as the model's impulse responses are available from the authors upon request.

[19] The solid red lines represents the average correlations based on the GEM data, the solid black lines are the historical correlations and the dashed lines represent the 95 per cent confidence intervals around the historical correlations.

[20] Each figure plots the correlation between the first variable identified in the figure title and the six lags and leads of the second variable identified. The vertical axis marks the degree of correlation and the horizontal axis represents the timing of the dynamic correlation. For example, the number -6 along the horizontal axis represents a lag of six periods for the second variable. The corresponding lead is denoted as 6.

5 plots the temporal correlations between the change in exports (imports) and the change in the real exchange rate. Our calibration of the GEM produces correlations that are consistent with the point estimates in data. Note however that the correlations estimated in the historical data are statistically insignificant at 95% confidence level since that interval includes zero, implying that these series may be entirely uncorrelated.[21] Figure 5 also shows the GEM's correlation between domestic and foreign output growth. The GEM generates an unconditional bivariate relationship between the two variables that is similar to that found in the data. The ability of the GEM to match the correlation between domestic output growth and import growth is even better.

We also consider the GEM's ability to match a key real-nominal dynamic correlation that is especially important to monetary-policy decision makers. Figure 6 shows the relationship between output and inflation. Although the GEM matches the historical pattern found in the data, it over-predicts the strength of the positive correlation between lagged output growth (or alternatively the lagged output gap) and leads of inflation. The GEM also generates a phase shift in the correlation between price and wage inflation relative to the historical data.

Now we turn our attention to the second moment of the data and examine the GEM's ability to match the standard deviations of key macro aggregates. We find that the GEM tends to significantly overpredict the degree of volatility in most of the key macro series when compared to the actual data. If, on the other hand, we consider a weaker test (see Table 7), a comparison of relative volatility by normalizing for the standard deviation in the output gap, we find that the model generates relative variability that is much closer to the empirical estimates. In fact, we see that in the case of Canada that the GEM does a good job at matching the relative volatility of inflation, nominal interest rates and the real exchange rate. In the case of the United States, the GEM creates slightly more volatility than suggested by the data for both inflation and the nominal exchange rate.

4.4 Matching impulse responses

In this section we examine the responses of the Canadian economy to some of the key structural shocks in the GEM. In general, the GEM provides reasonable responses to a large variety of deterministic shocks. Our calibration ensures that the GEM's responses to "vanilla" domestic shocks (e.g. interest rates, consumption demand, and technology shocks) match those

[21] This is not an uncommon feature of this class of model (see Murchison and Rennison (2006) and de Walque, Smets and Wouters (2006)).

for ToTEM and MUSE reasonably well.[22]

Here we focus on a monetary policy shock in Canada, a shock to the competitiveness of the labour sector in Canada and a shock on import demand in the United States. Each shock is equal to one standard deviation, using the persistence estimated over the 1983q1 to 2004q2 sample period. All the shocks are conducted using the historical monetary policy rules for each country.

4.4.1 A positive shock to the short-term interest rate in Canada

This shock (Figure 7) demonstrates the role of the monetary policy transmission mechanism in the economy, and its strength. The shock is a temporary increase of 20 basis points in the Canadian short-term interest rate with a persistence of 0.40. Inertia in monetary policy insures that interest rates stay above control for around two years. The shock increases the rental price of capital and therefore reduces investment. Consumers increase their saving and reduce their consumption. The increase in the interest rate induces a 0.36 per cent appreciation of the real effective exchange rate which increases the price of Canadian goods abroad and decreases the price of foreign tradable goods in Canada, thereby reducing demand for Canadian goods abroad and increases in Canadian imports. Overall, GDP drops by 0.06 percentage points, reaching its trough after four quarters.[23] The reduction in domestic demand induces firms to reduce their demand for the variable factors of production. The real wage falls (as does the real rental price of capital in the medium term), and, by extension, so does real marginal cost. Consequently, year-on-year inflation decreases by 0.07 percentage points about five quarters after the initial impact of the shock.

4.4.2 A positive shock to competitiveness in the labour sector in Canada

This shock (Figure 8) illustrates the supply side of the Canadian economy. The labour market becomes more competitive as the wage mark-up in Canada falls from 20 per cent to 17 per cent for one period. The real wage falls by 0.95 percentage points after two quarters, but does not return to control for more than 10 quarters due to nominal rigidities in the wage formation process. This stimulates labour demand by 0.6 per cent, which raises the level of investment (almost 0.8 per cent), temporarily increasing the capital stock to take

[22] Comparisons of the various model responses are available from the authors upon request.

[23] This result is in line with results found in other versions of GEM and the Bank of Canada projection model, ToTEM. For example, in the BoC-GEM, a 100 basis-point increase in the Canadian interest rate elicits a peak response of 0.34 per cent of GDP, which scales almost exactly to the result stated here (Lalonde and Muir (2007)).

advantage of the increased labour available for production. The resulting increase of output peaks at 0.5 per cent above its original level after eight quarters. The decrease in the real wage puts downward pressure on marginal cost, leading to lower inflation of 0.2 percentage points and a fall in the short-term interest rate of almost 30 basis points after eight quarters. Because of the higher marginal product of labour, the price of exported goods falls, and there is a depreciation of the real exchange rate. On net, the trade balance improves by 0.23 percentage points of GDP after three quarters, before reversing and dipping into deficit relative to control, as the real exchange rate returns to its original level, and import demand peaks from the higher output effect.

4.4.3 A negative shock to import demand in the United States

Finally, a shock in the United States to import demand (Figure 9) illustrates the effects of foreign shocks on Canada. We assume that the U.S. bias towards home-produced investment goods shifts up from 98.0 per cent to 98.4 per cent in the first period, with a persistence of 0.85. We see that U.S. real imports fall by 0.8 per cent at most after 3 quarters, returning to control after twelve quarters. Canadian real exports, of course, mirror this decline exactly. The effects on the two countries' GDP are very different however. It has almost no impact in the United States - only an increase of 0.08 per cent of U.S. GDP at its peak - since the United States is not very open, and Canada is a much smaller country (approximately one-tenth the size of the United States). Conversely, Canadian real GDP falls by 0.50 per cent, as does consumption. The main reason real GDP does not fall as much as real exports is the depreciation of the real exchange rate (peaking at 0.55 per cent) helps dampen Canadian import demand, as seen in the trade balance to GDP, which moves very little (although there is also a price effect stabilizing the nominal trade balance coming from the real exchange rate movement). On net there is some slight downward pressure on inflation (offset by the depreciation) causing a slight easing of monetary policy.

5. Inflation versus price-level path targeting

5.1 Methodology

In order to assess the relative merits of the alternative monetary policy frameworks, we assume that central bank preferences can be described by a quadratic loss function based on inflation deviations about target, deviations in the log of real GDP from potential output, and the first difference of the nominal interest rate:

$$L_t = E_t \sum \beta^j \left[\lambda_p \left(\pi_{t+j} - \pi^{TAR} \right)^2 + \lambda_y \left(y_{t+j} - y^{POT} \right)^2 + \lambda_i \left(\triangle i_{t+j} \right)^2 \right] \quad (6)$$

λ_π, λ_y and λ_i are the respective weights on deviations from target, β is the rate at which the central bank discounts future losses and E_t is the conditional expectations operator, based on information available in period t. When $\beta \to 1$, the value of the intertemporal loss function approaches the unconditional mean of the period loss function given by:

$$\overline{L} = \lambda_p \sigma_\pi^2 + \lambda_y \sigma_y^2 + \lambda_i \sigma_{\triangle i}^2,$$

where σ_π^2, σ_y^2 and $\sigma_{\triangle i}^2$ are the unconditional variances of the deviations of year-over-year inflation from its targeted level, the output gap, and the first difference of the nominal interest rate, respectively.[24]

In our baseline, we assume that the central bank cares equally about both inflation and output volatility (relative to desired levels) so we set $\lambda_\pi = \lambda_y = 1$. A weight is also placed on the change in the nominal interest rate ($\lambda_i = 0.1$) in order to eliminate calibrations that lead to the nominal short-term interest rate hitting the zero lower bound more than 5 percent of the time (Rotemberg and Woodford (1997)).[25]

We only consider simple instrument rules in this study.[26] Simple rules differ from fully optimal rules in that they only consider a subset of the variables that are included in the fully optimal rules. Our choice to focus on simple rules is motivated by the belief that they are more likely to be robust across plausible models than are fully optimal rules (Levin, Wieland, and Williams (2003)) and because central banks have a preference for simple rules because they are easier to communicate to the public. We assume that the central bank can follow either a PLPT rule or an IT rule. No consideration is given to the possibility of hybrid rules. A generic form that nests the simple instrument rules considered in this study is given by: (7):

[24] Woodford (2003) shows that a second order approximation to consumer's utility in a model that includes partial indexation of inflation leads to a loss function that is modified to take into account lagged inflation:
$L_t = E_t \sum \beta^j \left[\lambda_p \left(\pi_{t+j} - \frac{\phi_2}{1+\beta\phi_2} \pi_{t+j-1} - \pi^{TAR} \right)^2 + \lambda_y \left(y_{t+j} - y^{POT} \right)^2 \right]$

[25] This calculation is based on a real interest rate of 3 percent and an inflation target of 2 percent (or alternatively a price-level target that grows by 2 percent per year).

[26] Svensson (2005) criticizes the use of these types of monetary policy rules on the grounds that they are *ad hoc* in nature. Instead, he advocates the use of fully optimized policy.

$$i_t = \omega_i i_{t-1} + (1 - \phi_i)\, i_t^* + \omega_p(E_t p_{t+k} - \eta E_t p_{t+k-1} - p_{t+k}^{TAR} + \eta p_{t+k-1}^{TAR}) + \omega_y(y_t - y_t^{POT}) \quad (7)$$

where i_t^* is the equilibrium interest rate. The central bank attempts to minimize the unconditional mean of the period loss function ($\overline{L}$) by choosing the degree of interest rate smoothing ω_i, the short-run elasticity of the nominal interest rates to expected deviations of prices(inflation) from target ω_p, and the short-run elasticity of the nominal interest rates to expected deviations of real GDP from potential output ω_y and the feedback horizon over which policy is conducted k. When $k = 0$, then we get the simple Taylor (1993) rule and policy feeds backs from current-period inflation only. Alternatively, if $k = 3$, then the central bank feeds back instead from deviations of three-quarter ahead forecasts of inflation (or the price-level) from target. For inflation targeting η is assumed to be unity; for price-level-path targeting it is zero.[27]

We minimize the central bank loss function by searching over all of the coefficients and the feedback horizon using stochastic simulations conducted with numerical perturbation methods.[28] Since we are searching over four different parameters the process is extremely computationally intensive.

5.2 Results

Table 8 reports the optimized parameters for the simple rule, the value of the loss function, and the variances of the key variables for the optimized rules in the United States and Canada, while Table 9 reports the standard deviations of output, CPI inflation and the change in the interest rate under each of the rules. For the United States, there are only two rules - the optimal IT and the optimal PLPT rule. In the case of Canada there are four - the optimal IT and PLPT rules when the United States pursues inflation targeting, and the same again when the United States pursues price-level-path targeting.

[27] We do not consider intermediate values of η. A useful extension of this work would be to consider hybrid inflation and price-level-path targeting rules as in Batini and Yates (2003).

[28] As discussed in section 4.3, our version of the GEM tends to overpredict the degree of volatility of key macro series when compared to the actual data. On the other hand, our version of the GEM generates relative variability of the key macro variables which is much closer to the empirical estimates. To better replicate the absolute variability of the key macro variables we scale the variance of the shocks used in the stochastic simulations by a common factor.

5.2.1 The relative merits of IT versus PLPT

The first question that we focus on the relative merits of IT and PLPT. Our discussion concentrates on the case of Canada assuming that the United States chooses inflation targeting.[29] From Tables 8 and 9 we see that in the case of our baseline model calibration that PLPT is preferred to IT in terms of minimizing a weighted average of output gap and inflation variability. It is however interesting to note that under PLPT lower inflation variability comes at the expense of higher output variability. Furthermore, the optimized PLPT rule delivers slightly lower variability in nominal interest rates. In general, we can conclude that PLPT rules can deliver a reduction in the likelihood of hitting the zero lower bound on nominal interest rates as well as providing a reduction in price-level uncertainty while simultaneously reducing inflation variability. This is achieved at the cost of a small increase in output gap variability.

Our results also show that simple PLPT feedback rules tend to be more forward looking than simple IT feedback rules. The optimized PLPT feedback rule has a target feedback horizon of three quarters, longer than two quarters in the case of the IT rule. Also note the very high value for the degree of interest rate smoothing of $\omega_i = 0.97$ in the IT rule. Everything else being equal, as $\omega_i \to 1$, the degree of price-level drift under IT falls and IT looks increasingly like PLPT. Optimal IT in the model implies a degree of interest rate smoothing which is much higher than what is suggested by estimates of historical policy rules for both Canada and the United States.

To assess the robustness of our results we conduct a number of sensitivity analyses. First, we acknowledge that there have been many changes to the behaviour of inflation in Canada since the adoption of IT in 1991. In particular, the autocorrelation of quarterly core inflation (deviations from target) over the 1995 to 2006 period has fallen to zero from an estimated 0.8 over the 1983q1 to 2004q2 sample used to calibrate the benchmark model. If instead we chose to match the persistence of inflation over the 1995 to 2006 sample, we would reduce the weight of lagged inflation in the Phillips' curve to zero. To study the importance of this assumption, we recalculate the optimized feedback rules for both PLPT and IT under this alternative hypothesis.[30] We confirm the results found in the literature (for this class of model) and find that the more forward-looking inflation is, the greater the advantage of PLPT over IT. In particular, the relatively poor performance of PLPT rules in terms of

[29] We choose this configuration since it more closely approximates the current U.S. policy

[30] More precisely, this is accomplished by setting the weight on the deviation of current inflation from lagged inflation in price (and wage) adjustment costs to zero. This implies that nominal adjustment costs are based on solely on deviations of inflation from steady-state inflation.

output gap stabilization in the base-case disappears.

Our most interesting finding concerns the robustness of our results to the distribution of the shocks. To address this issue we re-calculate optimized PLPT and IT monetary feedback rules separately for each of the major types of domestic shocks in Canada first under the baseline calibration and then under the alternative assumption that inflation (and wage) determination is completely forward-looking (see Tables 10 and 11 for the mark-up shock results).

Under the baseline model calibration we find that IT is preferred in the mark-up and labour supply shocks but that PLPT is favoured for all other shocks. Alternatively, in the model with perfectly forward-looking inflation determination, PLPT is preferred in all shocks including the mark-up shocks. These simulations lead us to conclude that the relative merits of IT and PLPT are sensitive to an important interaction between the degree of forward-lookingness in inflation determination and the importance of price/wage mark-up and labour supply shocks to relative to demand and productivity shocks.

So why is it that the source of the shock matters when inflation is partially indexed to lagged inflation? To gain some insight first consider a price mark-up shock in the model with fully forward-looking inflation. PLPT offers disadvantages and advantages relative to IT. On the downside, the simple idea of having to return the price level to its target path, everything else being equal, means that the variance of inflation under PLPT must be larger than under IT. On the plus side, PLPT offers a powerful expectations channel. The commitment to a lower future inflation rate under PLPT than would be implied under IT means that current period inflation will be lower under PLPT than under IT. To generate this result, the central bank must create more cumulative excess supply under PLPT (i.e. as long as the price-level is above the target, PLPT requires excess supply). Everything else being equal, a PLPT central bank will find it optimal to create less initial excess supply that lasts longer. Taken together, this means that although the cumulative output gap is larger under PLPT, the PLPT output gap has a smaller variance than that generated under IT.

Now consider a positive demand shock. As in the case of the price mark-up shock, the commitment of the central bank to the price-level-path target implies that future inflation rates must be lower under PLPT than under IT. This leads to inflation that is initially lower than under IT. To support this outcome, the central bank needs to create excess supply at some time in the future under PLPT but not under IT. In addition, the initial jump in the output gap under PLPT is also smaller than under inflation. As a result, both the cumulative output gap and the variance of the output gap under PLPT is smaller than under IT.

We can conclude that in the perfectly-forward-looking model that the relative benefits from PLPT versus IT are larger in demand shocks than in mark-up shocks. If we then gradually increase the weight on lagged inflation in the Phillips' curve the monetary control problem becomes more difficult and the relative advantage of PLPT begins to disappear. Our calibration of the model lies in the zone for which PLPT is still favoured in demand shocks but the degree of indexation in inflation is high enough to tilt the results towards IT in mark-up shocks.

In our final sensitivity analysis, we consider the uncertainty around policymakers relative preferences for inflation versus output gap stabilization by doubling the relative weight on inflation variability in the central bank's loss function (Tables 12 and 13). As expected, doubling the weight leads PLPT to be more preferred than in the base case.

5.2.2 Does the presence of terms-of-trade shocks matter?

In the second part of our analysis, we focus on the role played by terms-of-trade shocks. Our interest in this question is motivated, in part, by arguments that suggest that stabilizing the aggregate price level in face of relative price shocks could increase the variability in output and possibly outweigh the benefits associated with reduced price-level uncertainty (Bank of Canada (2006)).

The first question that we consider is the definition of a terms-of-trade shock. Based on the long-run historical variance decomposition suggested by the model we conclude that the shocks that have had the most important influence on Canada's terms of trade are: i) the exchange rate shock, ii) the U.S. consumption shock, iii) the U.S. import demand shock and iv) the Canadian tradable price mark-up shock, as they account for sixty percent of the total variation in the terms of trade. We then re-optimize the simple PLPT and IT rules for this basket of shocks only and find that PLPT is favoured over IT. This result comes about because Canadian terms-of-trade movements have been principally associated with shocks that generate a positive covariance between the output gap and inflation (e.g. variations in the demand for Canadian goods).

5.2.3 Does the choice of monetary policy framework in the United States matter for Canada?

Finally, we consider another open economy element of our analysis. Srour (2001) suggests that if alternative monetary policy regimes in the large foreign country lead to significantly different behavior of real variables in the foreign economy, then it is possible that exchange rate adjustment will not completely insulate the small home country from the consequences of the foreign regime choice. This possibility is enhanced in our model because of our use of a modified risk-adjusted UIRP condition that slows the adjustment of the real exchange rate to shocks.

Table 8 shows, however, that the choice of PLPT or IT in the United States has no influence on the relative merits of IT and PLPT in Canada. This result comes through because the choice of PLPT or IT in the United States has little influence on the real factors important for Canada such as U.S. demand variability or the variability of U.S. interest rates (see Table 9). These variables represent the main channels through which the United States effects Canada in the GEM. In fact, the choice of IT versus PLPT in the United States has negligible implications for the parameterization of the monetary policy rule in Canada.

6. Conclusions and future extensions

We find that simple PLPT rules are slightly better than simple IT rules in terms of minimizing inflation and output-gap variability. Our analysis also highlights an important interaction between the degree of forward-lookingness in price determination and the distribution of the shocks in the economy. For a model calibration that includes a moderate amount of predetermination in price formation,as mark-up and labour supply shocks becoming more important in variance of inflation (relative to demand and productivity shocks) then the relative merits of PLPT to IT fall.

Our work also addresses two important open economy considerations. First, we isolate the contribution of terms-of-trade shocks on the relative merits of PLPT and IT. We find that most shocks that have important implications for explaining the Canadian terms of trade over history also imply a positive covariance between inflation and the output gap. Consequently, our analysis suggests that macroeconomic stabilization is best achieved by following a simple PLPT rule. Lastly, we find that the choice of monetary policy framework in the United States does not affect the relative merits of IT versus PLPT in Canada.

The are many possible extensions to our work. In particular, given the importance of fluctuations in commodity prices to the terms of trade for Canada and the United States, we think that it would be prudent to use a version of the GEM that incorporates commodities. Second, we would also like to add a distribution sector to the model to better address the issue of exchange rate pass-through from measured border prices to consumer prices. Finally, we are also interested in extending our analysis by optimizing the rules for the two monetary policy frameworks based on a model-consistent welfare measure.

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Table 1: Steady-State National Accounts - Expenditure Side (Percentage Shares of GDP)

	CA	US
Private Consumption C/GDP	57	67
Private Investment $p_E E/GDP$	17	16
Public Expenditure G/GDP	26	17
Trade balance $TBAL/GDP$	0.1	-0.01
Imports IM/GDP	37	3
Consumption Goods $p_{MA} M_A/GDP$	28	2
Investment Goods $p_{ME} M_E/GDP$	9	0.3
Net Foreign Assets $b_{F,RAT}$	-5.0	0.4
Share of World GDP (per cent) s	10	90

Table 2: Parameterization for Households and Firms

	CA	US
Depreciation rate δ	0.02	0.02
Intertemporal elasticity of substitution $1/\sigma$	0.70	0.70
Habit persistence in consumption b_c	0.80	0.80
Frisch elasticity of labour ς	0.25	0.25
Habit persistence in labour b_ℓ	0.70	0.70
Tradable Intermediate Goods		
Substitution between factors of production ξ_T	0.70	0.70
Weight of capital α_T	0.70	0.70
Nontradable Intermediate Goods		
Substitution between factors of production ξ_N	0.70	0.70
Weight of capital α_N	0.60	0.60
Final Consumption Goods		
Substitution between domestic and imported goods μ_A	1.50	1.50
Weight of domestic goods ν_A	0.10	0.90
Substitution between domestic tradables and nontradables ε_A	0.50	0.50
Weight of tradable goods γ_A	0.6	0.6
Final Investment Goods		
Substitution between domestic and imported goods μ_E	1.50	1.50
Weight of domestic goods ν_E	0.30	0.98
Substitution between domestic tradables and nontradables ε_E	0.50	0.50
Bias towards tradable goods γ_E	0.70	0.70

Table 3: Price and Wage Markups

	CA	US
Tradables Prices		
Total $\theta_T/(\theta_T-1)$	1.20	1.15
Nontradables Prices		
Total $\theta_N/(\theta_N-1)$	1.31	1.28
Wages		
Total $\psi_W/(\psi_W-1)$	1.20	1.16

Table 4: Real Adjustment Costs and Nominal Rigidities

	CA	US
Real Adjustment Costs		
Capital accumulation ϕ_{I1}	1.00	1.00
Investment changes ϕ_{I2}	100	100
Imports of consumption goods ϕ_{MA}	0.95	0.95
Imports of investment goods ϕ_{ME}	0.95	0.95
Nominal Rigidities		
Wages ϕ_W	500	500
Prices of domestic tradables ϕ_{PQ}	250	250
Prices of nontradables ϕ_{PN}	450	450
Prices of imports ϕ_{PM}	4500	4500
Financial Intermediation Costs		
Speed of adjustment for NFA ϕ_{F1}	0.25	...
Amplitude of adjustment for NFA ϕ_{F2}	0.03	...
Modified Risk-Adjusted UIRP Condition		
Weight on the lagged exchange rate ϕ_{F3}	0.30	

Table 5: Parameterization of the Stochastic Processes

		AR(1)Root λ		Standard Error ϵ	
		CA	US	CA	US
Demand					
Consumption	ZU	0.30	0.46	0.0496	0.0161
Investment	$ZEYE$	0.00	0.53	0.0172	0.0148
Government Consumption	GC	0.93	0.89	0.0026	0.0020
Government Investment	GI	0.90	0.89	0.0022	0.0020
Government Nontradables	GN	0.94	0.87	0.0051	0.0020
Imports in Investment	ν_E	0.83	0.85	0.0733	0.0023
Supply					
Labour Supply	ZV	0.87	0.87	0.0331	0.0171
Productivity in Tradables	ZT	0.83	0.51	0.0052	0.0045
Productivity in Nontradables	ZN	0.93	0.91	0.0019	0.0012
Prices					
Markup on Tradable Prices	θ_T	0.26	0.73	0.8290	0.0362
Markup on Nontradable Prices	θ_N	0.00	0.00	0.1423	0.0893
Markup on the Real Wage	ψ	0.00	0.00	1.4290	0.7405
Others					
Interest Rate	i	0.36	0.50	0.0021	0.0012
Financial Intermediation (UIRP)	ZBF	0.93		0.0009	

Table 6: Variance Decomposition Using Model-Generated Data

	Standard Deviation	Demand ϵ_{ZU},ϵ_{ZI},ϵ_{GC}, ϵ_{GI},ϵ_{GN},ϵ_{ν_E},ϵ_i	Productivity ϵ_{ZT},ϵ_{ZN}	Prices ϵ_{θ_T},ϵ_{θ_N}, ϵ_{ψ},ϵ_{ZV}	Exchange Rate ϵ_{ZBF}	Foreign Shocks
Canada						
CPI inflation	0.7	9.9	2.8	39.2	12.7	35.4
Output	2.2	19.2	3.3	25.8	2.8	48.9
Output Gap	2.1	22.3	7.0	7.9	4.7	58.1
Interest Rate (chng)	0.4	36.9	2.0	32.8	4.7	23.6
Exports	3.0	3.9	1.8	12.9	6.9	74.5
Imports	3.1	43.7	4.0	11.1	13.6	27.6
Real Exchange Rate	2.9	8.7	2.5	17.7	19.6	48.6
Terms of Trade	1.7	8.6	2.4	22.3	21.5	45.2
United States						
CPI inflation	0.6	38.9	17.5	42.9	0.1	0.6
Output	1.3	54.8	17.4	26.5	0.1	1.2
Output Gap	1.2	39.8	35.0	15.1	0.1	1.0
Interest Rate (chng)	0.7	50.1	30.4	18.8	0.0	0.7

Table 7: Relative Standard Deviations

Variable	History		GEM	
	CA	US	CA	US
	5^{th} - 95^{th}percentile	5^{th} - 95^{th}percentile		
Inflation (π_t)	0.2-0.4	0.2-0.4	0.3	0.5
Interest Rate (i_t)	0.6-1.0	0.6-1.2	0.6	1.4
Real Exchange Rate ($\widehat{s}_t$)	1.1-3.7		1.4	

Table 8: Results for Simple Optimized Rules

$$L_t = E_t \sum \beta^j \left[\left(\pi_{t+j} - \pi_{t+j}^{TAR}\right)^2 + \left(y_{t+j} - y_{t+j}^{POT}\right)^2 + 0.1 \left(\triangle i_{t+j}\right)^2 \right]$$

			United States			
			Inflation		Price Level	
	United States		Canada		Canada	
	Inflation	Price Level	Inflation	Price Level	Inflation	Price Level
Lead on π or Price-level	1	2	2	3	2	3
ω_i	0.862	0.883	0.968	0.849	0.980	0.861
ω_π	2.946	-	2.444	-	2.452	-
ω_{CPI}	-	2.195	-	3.735	-	3.840
ω_y	1.220	1.827	0.700	0.854	0.696	0.854
Loss	0.962	0.903	2.148	2.134	2.167	2.154

Table 9: Standard Deviations of Key Variables Under the Optimized Rules

			United States			
			Inflation		Price Level	
	United States		Canada		Canada	
	Inflation	Price Level	Inflation	Price Level	Inflation	Price Level
Loss function	0.962	0.903	2.148	2.134	2.167	2.154
CPI inflation	0.350	0.363	0.499	0.407	0.498	0.405
Output Gap	0.800	0.750	1.335	1.366	1.343	1.373
Interest Rate (chng)	1.410	1.440	1.087	1.020	1.079	1.017
Real Exchange Rate	-	-	4.429	4.454	4.430	4.457

Table 10: Results for Simple Optimized Rules For Shocks to Price Mark-Ups

$$L_t = E_t \sum \beta^j \left[\left(\pi_{t+j} - \pi_{t+j}^{TAR}\right)^2 + \left(y_{t+j} - y_{t+j}^{POT}\right)^2 + 0.1 \left(\triangle i_{t+j}\right)^2 \right]$$

	No lag in Phillips' Curve		Lag in Phillips' Curve	
	Inflation	Price Level	Inflation	Price Level
Lead on π or Price-level	1	3	1	3
ω_i	0.709	0.771	0.752	0.843
ω_π	0.354	-	0.403	-
ω_{CPI}	-	0.088	-	0.148
ω_y	0.176	0.198	0.203	0.197
Loss	0.095	0.092	0.202	0.211

Table 11: Standard Deviations of Key Variables Under the Optimized Rules for Shocks to Price Mark-ups

	No lag in Phillips' Curve		Lag in Phillips' Curve	
	Inflation	Price Level	Inflation	Price Level
Loss function	0.095	0.092	0.202	0.211
CPI inflation	0.295	0.291	0.406	0.406
Output Gap	0.089	0.084	0.183	0.212
Interest Rate (chng)	0.099	0.063	0.185	0.104
Real Exchange Rate	0.809	0.807	1.131	1.158

Table 12: Results for Simple Optimized Rules Under a Different Loss Function Parameterization

$L_t = E_t \sum \beta^j \left[2\left(\pi_{t+j} - \pi_{t+j}^{TAR}\right)^2 + \left(y_{t+j} - y_{t+j}^{POT}\right)^2 + 0.1\left(\triangle i_{t+j}\right)^2 \right]$		
	Canada	
	Inflation	Price Level
Lead on π or Price-level	2	3
ω_i	0.959	0.841
ω_π	2.939	-
ω_{CPI}	-	4.494
ω_y	0.650	0.873
Loss	2.369	2.294

Table 13: Standard Deviations of Key Variables Under the Optimized Rules with a Different Loss Function Parameterization

	Canada	
	Inflation	Price Level
Loss function	2.369	2.294
CPI inflation	0.447	0.403
Output Gap	1.354	1.362
Interest Rate (chng)	1.167	1.070
Real Exchange Rate	4.332	4.400

Table 14: Variance Decomposition Using Model-Generated Data for the Terms-of-Trade Shocks

	Consumption (United States) ϵ_{ZU}	Imports (United States) ϵ_{ν_E}	Tradables Markup (Canada) ϵ_{θ_T}	Exchange Rate ϵ_{ZBF}
Canada				
CPI inflation	17.5	5.9	28.6	12.7
Output	16.5	22.0	11.4	2.8
Output Gap	25.8	15.2	3.2	4.7
Interest Rate (chng)	12.1	3.8	25.5	4.7
Exports	22.8	37.5	5.6	6.9
Imports	6.4	16.5	3.6	13.6
Real Exchange Rate	15.6	16.7	7.3	19.6
Terms of Trade	14.0	14.4	14.0	21.5

Figure 1: Structure of the Production Side of the GEM

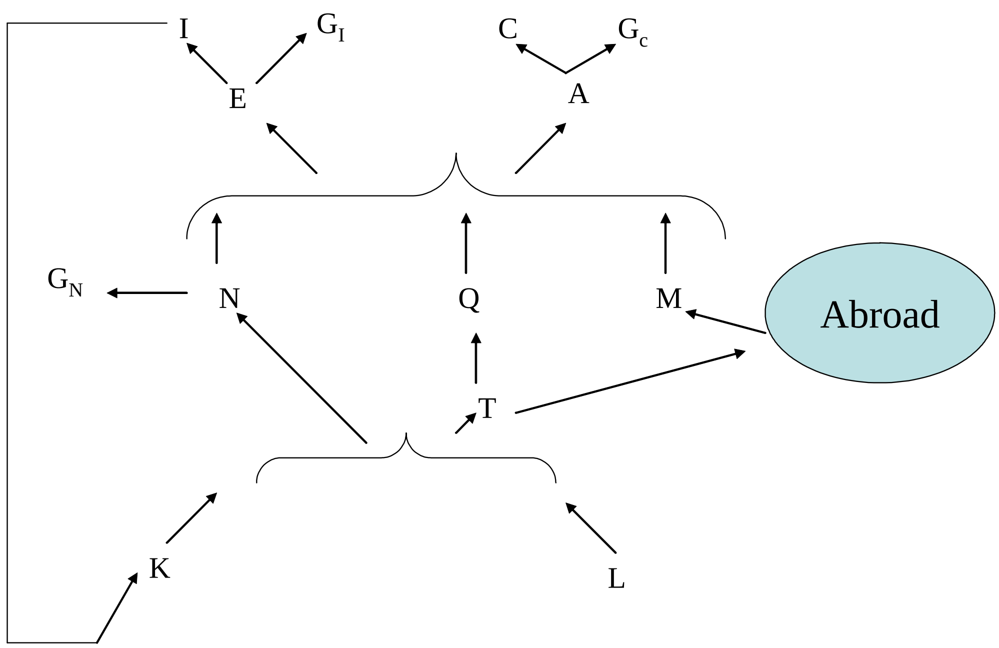

Figure 2: Autocorrelation Functions: The GEM Against Historical Data in Canada - Part I

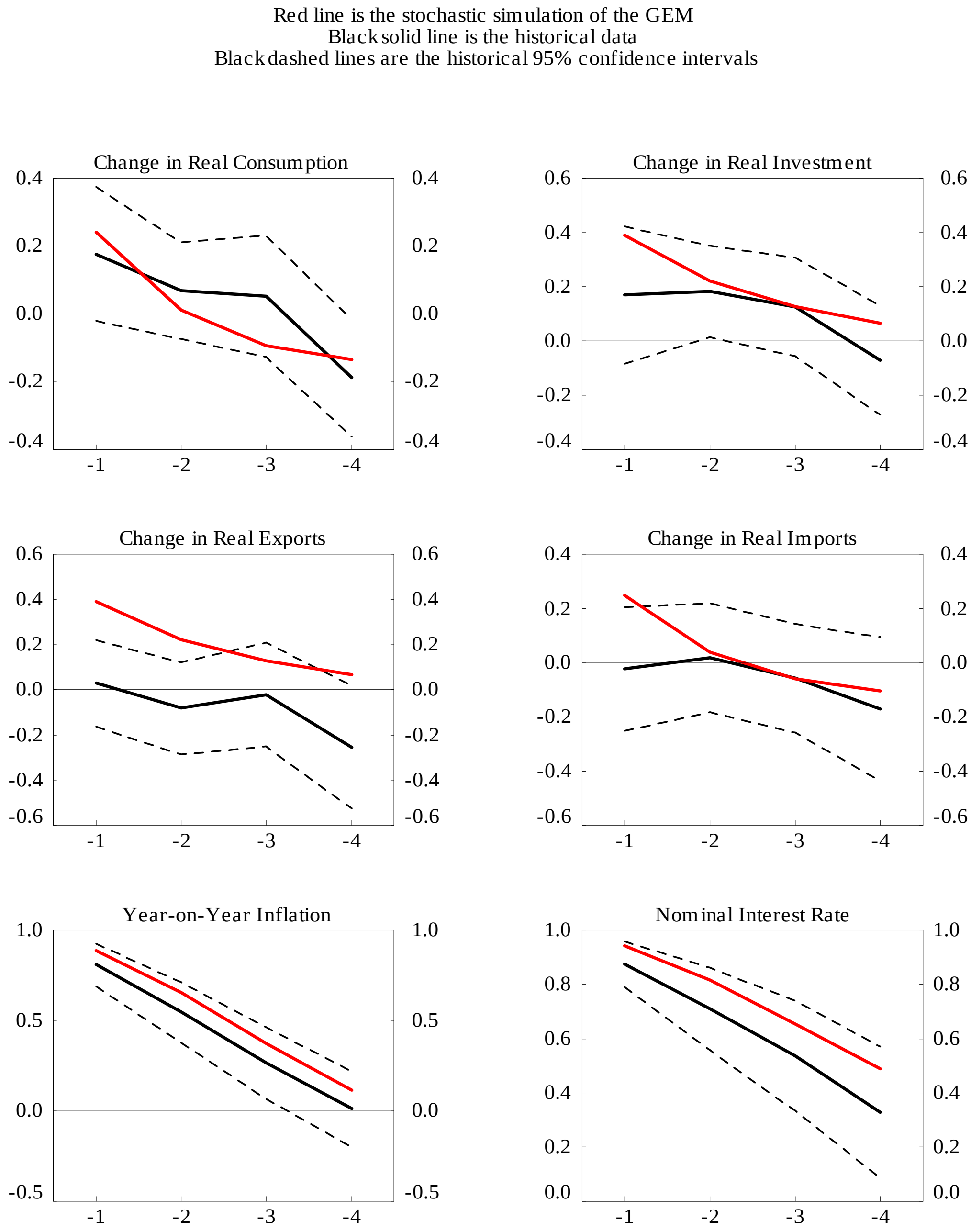

Figure 3: Autocorrelation Functions: The GEM Against Historical Data in Canada - Part II

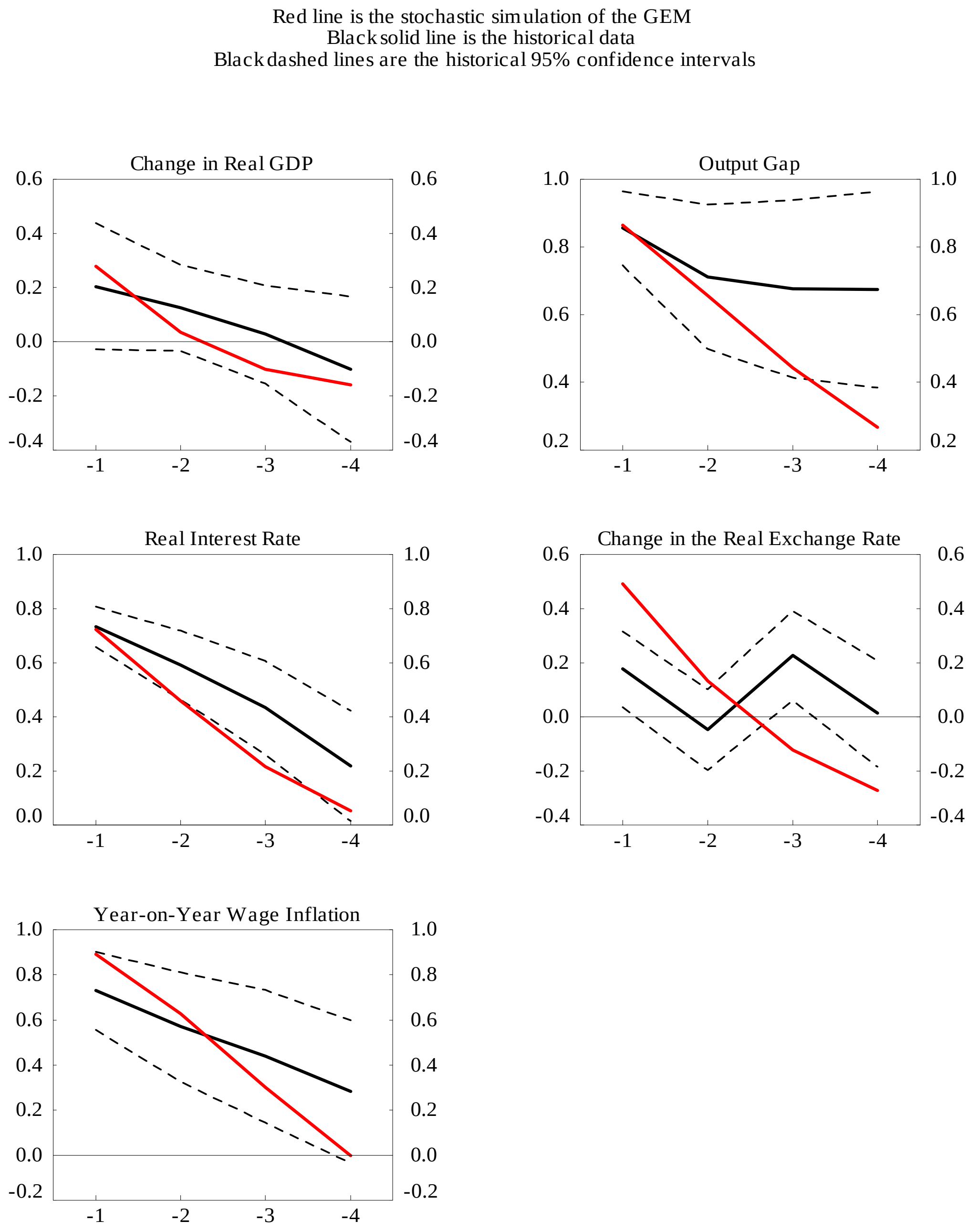

Figure 4: Temporal Cross-correlation Functions: The GEM Against Historical Data in Canada - Part I

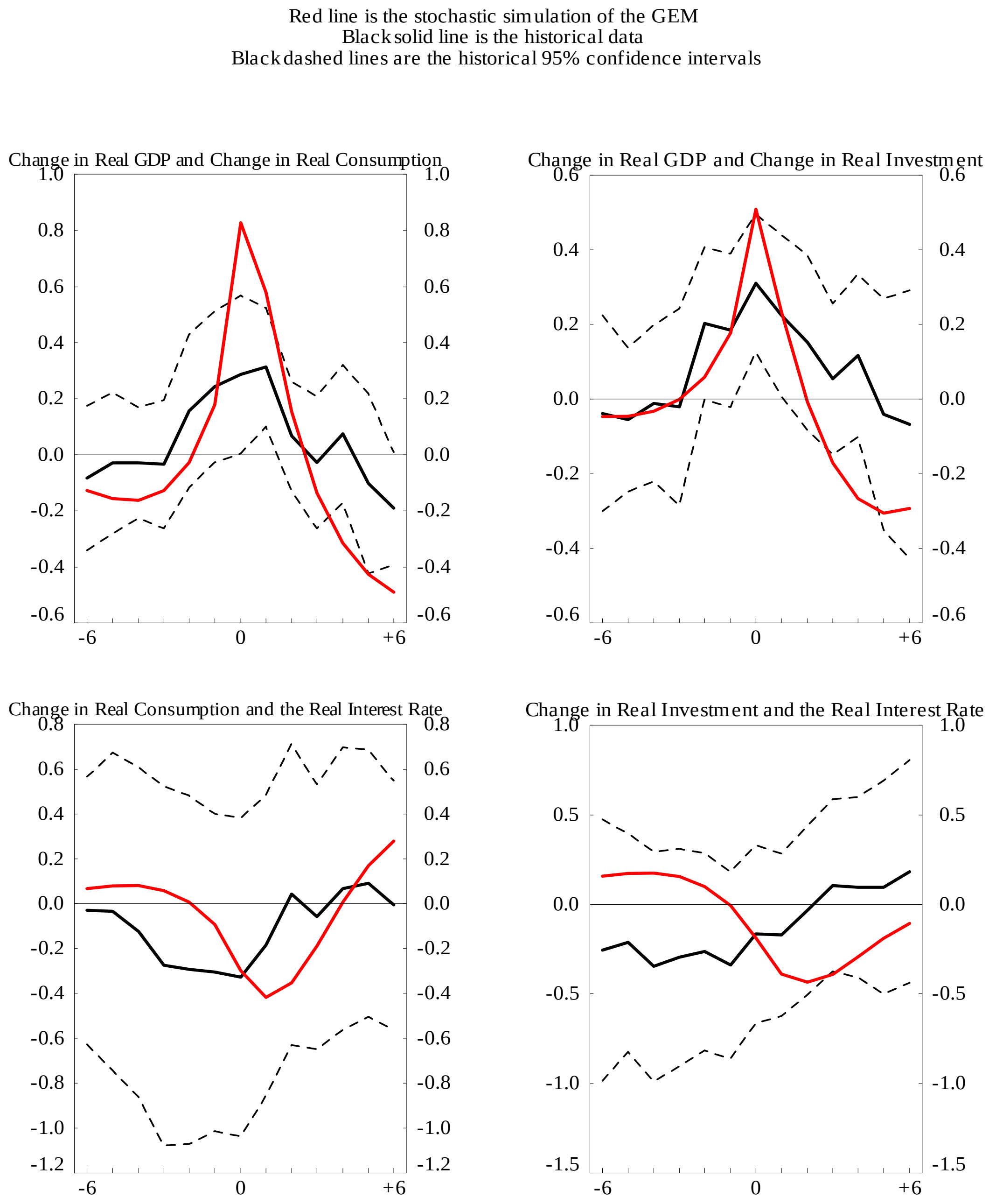

Figure 5: Temporal Cross-correlation Functions: The GEM Against Historical Data in Canada - Part II

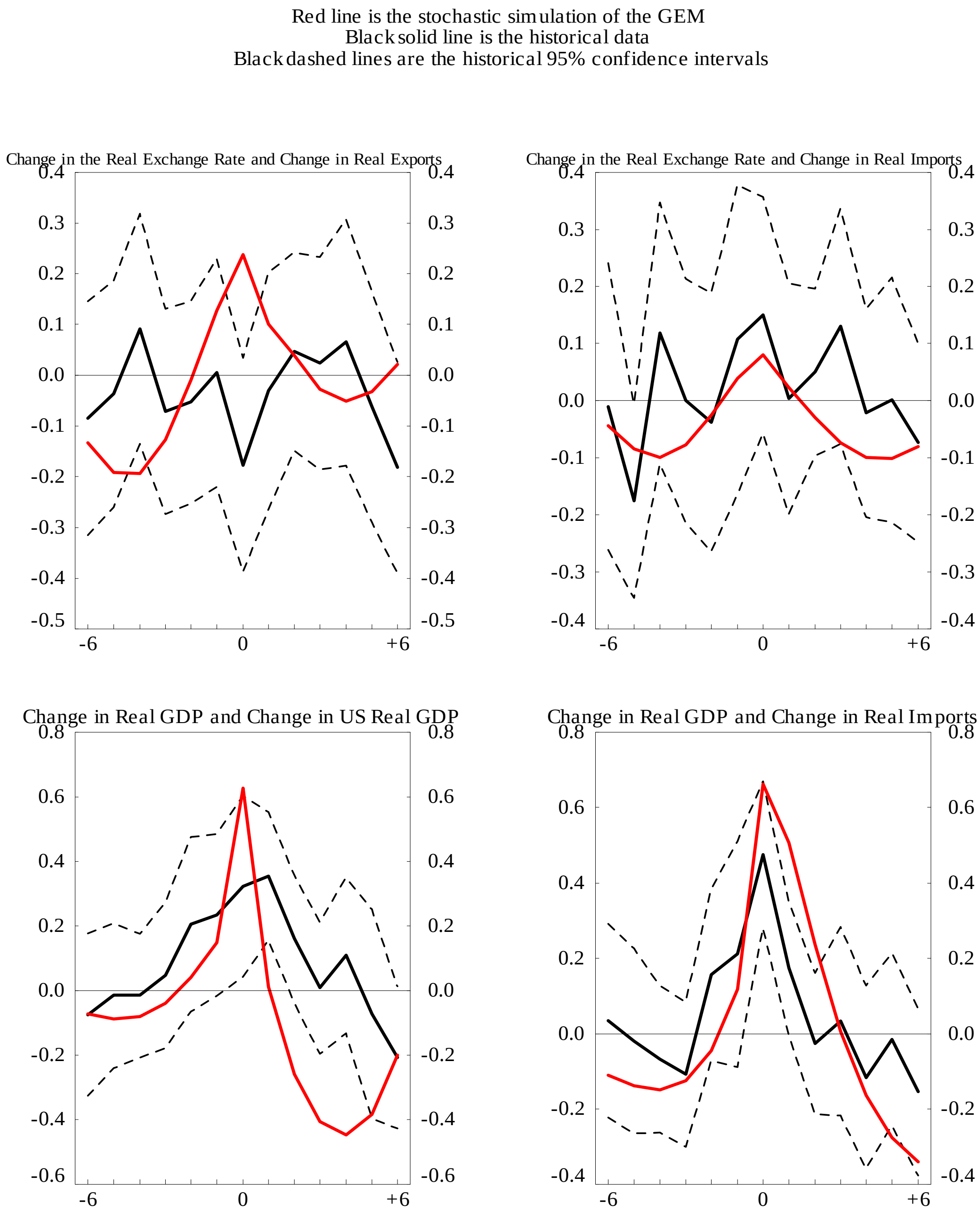

Figure 6: Temporal Cross-correlation Functions: The GEM Against Historical Data in Canada - Part III

Red line is the stochastic simulation of the GEM
Black solid line is the historical data
Black dashed lines are the historical 95% confidence intervals

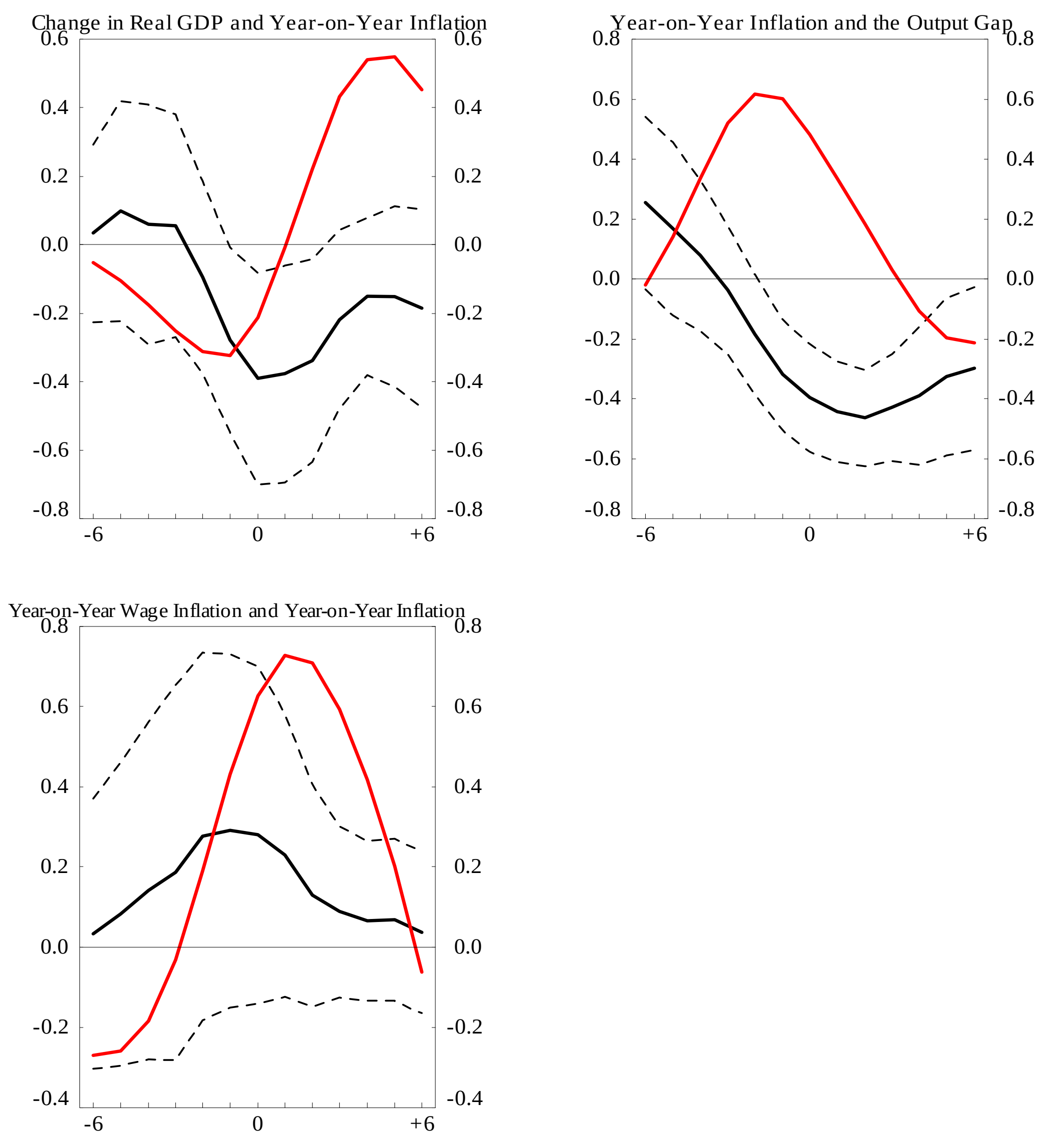

Figure 7: A Positive Shock to the Short-term Interest Rate in Canada - Impulse Responses

(Deviation from control, in percent)

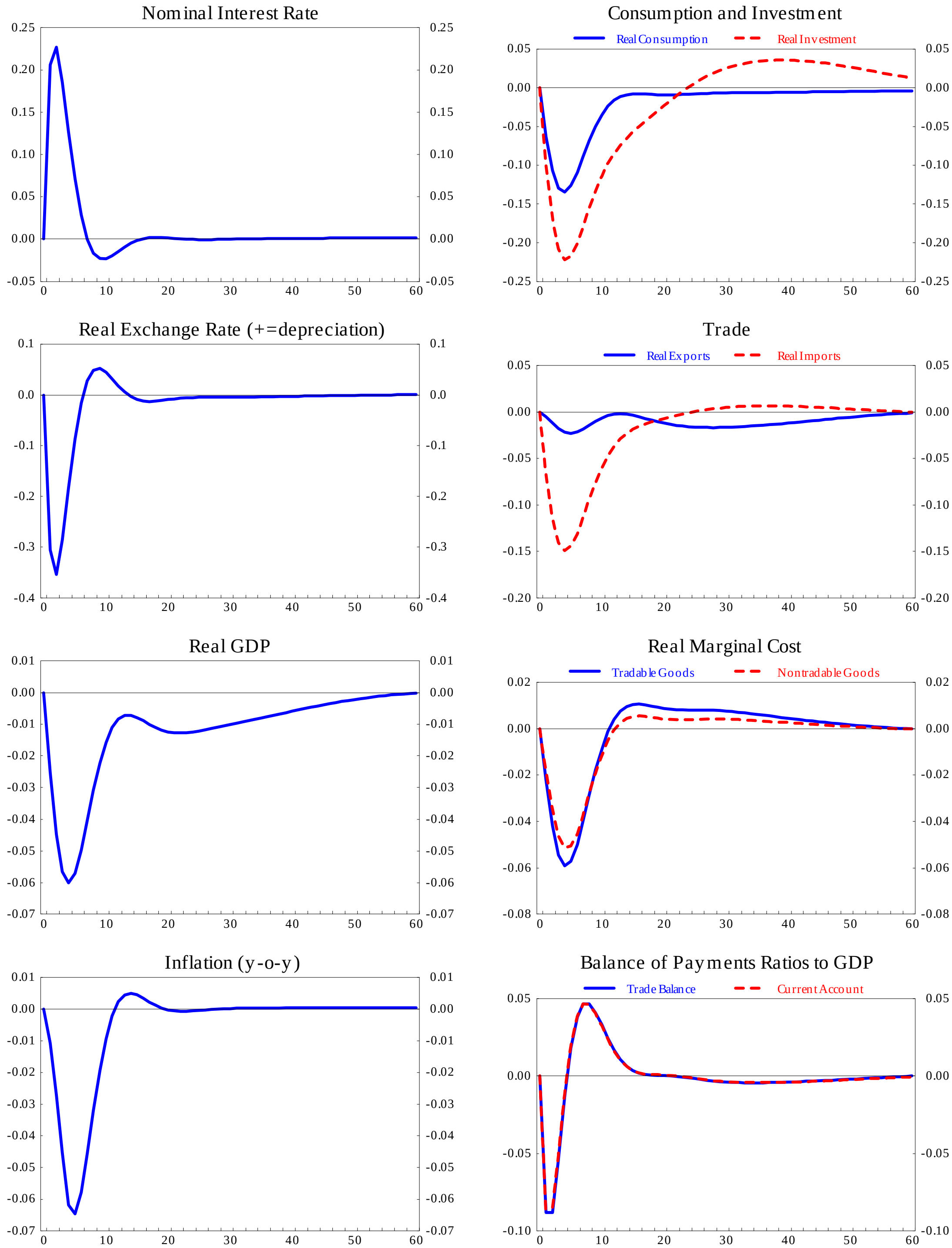

Figure 8: A Positive Shock to Competitiveness in the Labour Sector in Canada - Impulse Responses

(Deviation from control, in percent)

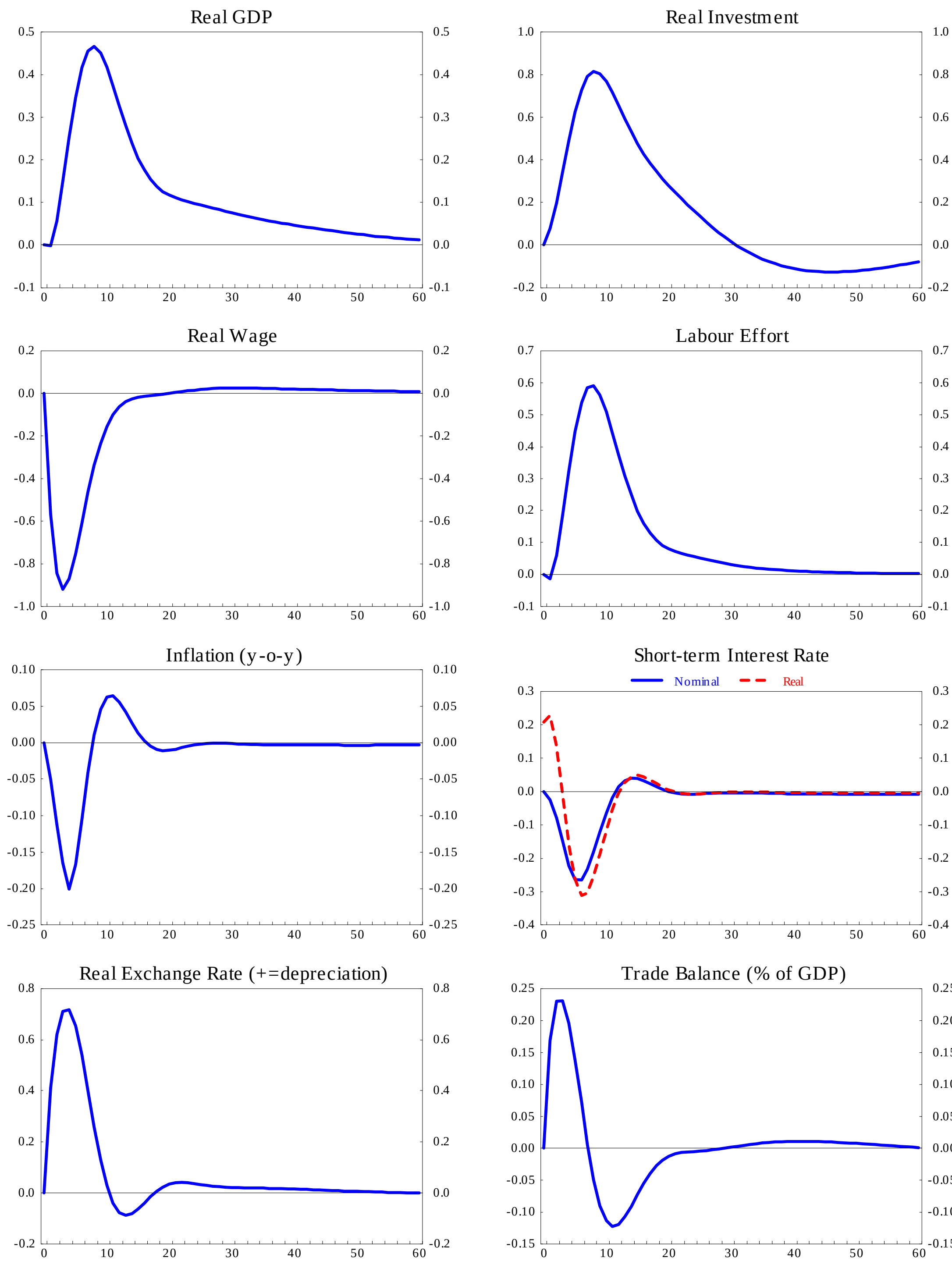

Figure 9: A Negative Shock to Import Demand in the United States - Impulse Responses

(Deviation from control, in percent)