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Abstract

This paper compares the performance of simple inflation targeting (IT) and price-level path targeting (PLPT) rules to stabilize the macroeconomy, in response to a series of shocks, similar to those seen in Canada and the United States over the 1983 to 2004 period. The analysis is conducted in a two-country (Canada and the United States), two-sector (tradables and nontradables) version of the International Monetary Fund's Global Economy Model (GEM). The authors conclude that PLPT is slightly preferred to IT for delivering macroeconomic stability, as it delivers a reduction in inflation and nominal interest rate volatility, at the expense of slightly higher output gap variability. When the analysis is restricted to the shocks that have been most important for explaining movements in Canada's terms of trade over this period, PLPT is still preferred to IT. The authors also show that their results are sensitive to the interaction between the relative importance of the different types of macroeconomic shocks that hit the economy, and the extent to which price and wage setting is forward looking. Lastly, the authors demonstrate that the choice of monetary policy framework in the United States does not affect the relative merits of PLPT versus IT in Canada.

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

Résumé

Les auteurs comparent la capacité de règles simples, comportant soit une cible d'inflation soit une cible de niveau des prix, à stabiliser l'économie dans son ensemble à la suite de chocs similaires à ceux survenus au Canada et aux États Unis entre 1983 et 2004. Pour ce faire, ils utilisent une version de GEM – le modèle de l'économie mondiale élaboré par le Fonds monétaire international – qui met en scène deux pays (le Canada et les États Unis)et deux secteurs (celui des biens échangeables et celui des biens non échangeables). Ils concluent que les régimes prenant pour cible le niveau des prix parviennent un peu mieux que les régimes de cibles d'inflation à stabiliser l'économie, atténuant la volatilité de l'inflation et des taux d'intérêt nominaux au prix d'une légère accentuation de la variabilité de l'écart de production. La conclusion reste la même lorsque l'analyse est limitée aux chocs jugés les plus déterminants pour l'évolution des termes de l'échange de 1983 à 2004. Les auteurs montrent également que leurs résultats sont sensibles à l'interaction entre l'importance relative des différents types de chocs macroéconomiques et le degré de prospectivité du processus d'établissement des prix et des salaires. Enfin, ils démontrent que le cadre adopté aux États-Unis en matière de politique monétaire n'influence pas les mérites relatifs des régimes ciblant le niveau des prix et des régimes de cibles d'inflation au Canada.

Classification JEL : C51, C52, E17, E31, E52
Classification de la Banque : Cadre de la politique monétaire; Inflation : coûts et avantages; Inflation et prix; Modèles économiques

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. If a shock pushes inflation away from target, the central bank moves policy interest rates, so as to bring 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 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, does 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 argument that PLPT generates increased macroeconomic instability relative to IT. We address this issue 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 non-tradable goods) version of the Global Economic Model (GEM) calibrated for Canada and the United States. We find that when the macroeconomy is confronted by shocks ,similar to those seen over the 1983 to 2004 period, that simple PLPT interest rate feedback rules perform slightly better than simple IT rules. Furthermore, our analysis examines the proposition that PLPT may not stabilize the macroeconomy as well as IT, when faced by terms-of-trade shocks (Bank of Canada 2006). Under PLPT, persistent movements in the terms of trade will require large movements in non-tradable goods prices in order to return the average price level back to target. In the presence of nominal rigidities, this could induce increased output variability. Furthermore, since prices are stickier in the non-tradable goods sector than the tradable goods sector, overall output gap variability may increase. On the contrary, we find that when the analysis is limited to the shocks that have been most important for explaining fluctuations in Canada's terms of trade, PLPT delivers superior macroeconomic stability relative to IT. Interestingly, we find that these 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. 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. 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). Interest in PLPT returned 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.[2] 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. 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.

This general line of thought has been challenged by numerous authors who placed great importance on rational expectations and forward-looking behaviour. In models where expectations are formed rationally and the Phillips curve takes the New Keynesian form (NKPC -, where current inflation is a function of expected future inflation), 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 goods market until the price level returns to its target path. Thus, a firm's expectations of the 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 Woodford (1999), Giannoni (2000) and Williams (2003). 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 Christiano, Eichenbaum, and Evans

[2] More comprehensive reviews of the literature can be found in Duguay (1994), Barnett and Engineer (2000), Ambler (2007) and Cote (2007).

(2005), then inflation targeting is the optimal policy.[3]

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 non-tradable sector. They find that the welfare implications of moving from IT to PLPT, or a combination of both (i.e. a 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 non-tradable 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. The extension of the data set permits the inclusion of more stochastic shocks within the structure of the model.

3. The Model

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.[4] In this section, we provide a non-technical overview on the model. We highlight one model innovation as well as other model features that turn out to be particularly important for our results. A

[3] 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.

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

more thorough and technical explanation of the GEM are available in Faruqee *et al.* (2007), Lalonde and Muir (2007), and Pesenti (2008).

The world economy is assumed to consist of two countries, a small country (Canada) and a large country (United States). Each country is populated by private agents that consume and work, firms that produce intermediate goods and final goods, and a government that serves as both the fiscal agent and the monetary authority. The production structure for a single region is illustrated in Figure 1. 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 a continuum of differentiated non-tradable goods and tradable intermediate goods (both domestically produced, and imported).[5] Private agents can consume the final consumption and investment goods while the fiscal agent consumes a public good which consists of consumption, investment and non-tradable goods.

Intermediate goods (tradable and non-tradable) are produced by monopolistically competitive producers for the domestic market, and also for export, in the case of tradable goods. Firms use a CES technology to combine factor inputs (labour and capital) that are mobile across production sectors, but immobile internationally. 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 real adjustment costs of changing the capital stock and investment. Since 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. If 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 demand across differentiated goods produced by firms (θ_t) and mc_t denotes real marginal cost of production. Deviations from markup pricing occur, if firms face costs for modifying their prices in the short term. Prices are subject to adjustment costs similar to Rotemberg (1982), because of 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 steady-state inflation rate, an extension to the Rotemberg form, as in Ireland (2001). The speed of adjustment in response to shocks depends on the trade-off

[5] To model realistic dynamics of import volumes we assume that it is costly to change the share of imported goods in production.

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.[6] In particular, the linearized Phillips curve in our version of the GEM takes the following form:

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

where $\hat{\pi}$ is the deviation of the inflation rate from steady-state, 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.[7]

Households are infinitely-lived consumers whose welfare depends positively upon consumption of the final consumption good and negatively upon labour effort. There is habit formation in both consumption and leisure. Households are also monopolistically-competitive suppliers of differentiated labour inputs to domestic firms. Differentiation of labour inputs allows workers to charge a wage above the marginal rate of substitution between consumption and leisure. Wages are subject to adjustment costs, similar to Ireland (2001). Households own all firms and the capital stock, which they rent to firms.

Households can hold internationally traded, short-term nominal bonds which are denominated in U.S. currency. Canadian households that take a position in the international bond market must deal with financial intermediaries, who charge a transactions fee on sales/purchases of the international bond. The transactions fee is modelled as a function of the economy-wide holdings of (net) foreign assets, relative to its (exogenous) desired holdings. As a region becomes a larger net debtor, it must pay an increasing fraction of its international bond returns to the financial intermediaries. As in Pesenti (2008), this financial friction is introduced to guarantee that the net foreign asset position follows a stationary process and the economies converge to a steady state. The financial intermediation cost equation is an integral part of the risk-adjusted uncovered interest rate parity (UIRP) condition.

Our interest in the questions of terms-of-trade shocks, and the potential for policy choices abroad to affect the choice of the optimal monetary policy framework in Canada, have the potential to bring the issue of exchange rate adjustment to the forefront of the analysis. As a result, we have attempted to introduce an additional degree of realism in exchange rate

[6] This form of the Phillips curve applies to price setting of tradable, non-tradable and imported goods. Exports are invoiced and prices are set in the currency of the destination market. This is more commonly known in the literature as "local currency pricing" (Corsetti and Pesenti 2005).

[7] 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.

determination in the GEM. In particular, we are interested in slowing down the adjustment of the exchange rate to shocks, so that the model can generate the hump-shaped responses typically found in VARs. As a result, the financial intermediation cost is further modified, as in Adolfson *et al.* (2005):

$$1 - \Gamma_{B,t}^{M} = \frac{1 - \Gamma_{B,t}}{\exp\left(\phi_{B3}\left[\Delta_{t,t+1}/\Delta_{t-1,t} - (\pi/\pi^{US})^{0.25}\right]\right)} \tag{3}$$

where $1 - \Gamma_{B,t}^{M}$ is the modified financial intermediation cost, $1 - \Gamma_{B,t}$ is the financial intermediation cost found in Pesenti (2008), and $\Delta_{t-1,t}$ is the depreciation of the real exchange rate from period $t-1$ to period t. This modification serves to capture the forward premium puzzle – 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 in two consecutive periods. As a result, in both the non-linear model, and the log-linearized model, the risk-adjusted UIRP condition contains a lag of the exchange rate.

Government spending is on final goods and intermediate non-tradable 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 output and either 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 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 from the Bank of Canada's model of the U.S. economy, MUSE (Model of the United States Economy – see Gosselin and Lalonde

2005). We do not attempt to formalize these criteria as an explicit maximization function that could be optimized.[8] As a result, we pursue an informal parameterization strategy with no explicit objective function. Nonetheless, we believe that our baseline parameterization does well as replicating many of the salient features of the data.

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, which allows us exactly replicate history.[9] Using the variance of the historical shocks, we 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.

The model has 23 behavioural shocks.[11] The shocks have been grouped into five categories. Domestic demand shocks (consumption, investment, imports, government spending and interest rates) share the common feature that they generate a positive covariance between output (as well as the output gap) and inflation in the home country.[12] 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 domestic productivity shocks (technology shocks to the production of tradable and non-tradable goods), movements in the output gap covary positively with inflation in the home country. The remaining supply shocks – the three domestic mark-up shocks (prices in the tradable goods sector; prices in non-tradable goods sector; and the real wage) and a domestic labour supply shock – are different from the productivity and demand shocks, because they gen-

[8] One possibility is to use Bayesian techniques. This approach allows modellers to incorporate priors on the set of structural parameters. In practice however, we agree with the views expressed in Murchison and Rennison (2006) that the priors (especialy those of policymakers) are actually more closely related to the behaviour of the model rather than the structural parameters themselves.

[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).

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

[12] Throughout this paper, we use a measure of potential output that is calculated using a production function approach, where output is evaluated with total factor productivity, the capital stock, and steady-state labour supply.

erate a negative covariance between inflation and the output gap in the home country. In addition, there is a shock to financial intermediation costs, which behaves like an exchange rate shock, since it is found in the modified risk-adjusted UIRP condition. The shock to financial intermediation generates a positive correlation between the output gap (and output) and the rate of inflation. Finally, all shocks originating in the foreign country can all be thought of as demand shocks, since they all cause inflation and the output gap to covary positively in the home country. For example, a positive U.S. demand shock leads to higher Canadian exports, a positive Canadian output gap, higher Canadian import prices, and a rise in Canadian inflation. Alternatively, a negative U.S. price (or positive U.S. productivity) shock in the non-tradable goods sector leads to a rise in the prices of traded goods in the United States, a rise in Canadian import prices, and an increase Canadian activity, because of an expansion of exports to the United States.

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).[13] 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 non-tradable consumption goods, wages, total employment in the non-tradable-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). Non-tradable 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 non-tradable 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 Labor Statistics.

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

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

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 the shares of government expenditure, exports, and imports, are notably higher in Canada than in the United States. While trade with the United States is very important for Canada (exports plus imports are 74 per cent of GDP), for the United States, trade with Canada is not (exports plus imports are 5 per cent of GDP). Therefore, domestic shocks in the United States have a 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 imported goods, which are in turn combined with non-tradable 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 non-tradables in both consumption and investment goods in each country is set at 0.5, reflecting the relatively low substitutability of tradable and non-tradable goods in the consumption and investment baskets. The share of non-tradable 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 non-tradable 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 non-tradable sector, in both countries. The bias toward the economy-wide use of capital, which is governed by the distribution parameter, has been set to replicate the 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 non-tradables, 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 non-tradable 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 (Jean and Nicoletti 2002).

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 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).

There is habit persistence in both consumption (0.80, for both countries), and labour supply (0.70, for both countries). 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, which is a stylized fact in most economies in the face of a large variety of shocks. We calibrate the Frisch elasticity of labour supply at 0.25, well within the 0.05-0.33 range of estimates obtained using micro data, but at the low end of those typically found in the macro literature. Our choice is significantly lower than if preferences were logarithmic in leisure, but is in the range of estimates used in other studies with similar utility functions (Erceg *et al.* 2006 and Faruqee *et al.* 2007).

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 significant heterogeneity across sectors. In particular, we set the adjustment cost parameter (ϕ_1) for non-tradable 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.[14] 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.[15] 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 price and wage 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 price and wage inflation in the next period is 0.58.

On the real side, there are substantial 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), we assume that imports are subject to real adjustment costs These costs are specified as a function of the one-period change in imports, as a share of the final good.

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

[15] Alternatively, we could address the issue of exchange rate pass-through by adding a distribution sector to this version of the GEM, as in Laxton and Pesenti (2003). 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.

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. Modification of the model to address the forward premium puzzle, as discussed in the previous section, leads to the presence of a lag of the exchange rate in 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 reflect the behavior of monetary policy in the United States and Canada. The parameterization of these rules are based on our moment matching exercises. For the United States, the calibration of the Taylor rule is:

$$i_t^{us} = 0.7 i_{t-1}^{us} + 0.3 i_t^* + 0.9(\pi_t^{us} - \pi_t^{TARus}) + 0.2(y_t^{us} - y_t^{POTus}) \tag{4}$$

while for Canada it is:

$$i_t^{ca} = 0.8 i_{t-1}^{ca} + 0.2 i_t^* + 0.5(\pi_t^{ca} - \pi_t^{TARca}) \tag{5}$$

where π is the year-over-year change in 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.

The last set of parameters are those that pertain to the stochastic shock processes of the model. As discussed earlier, there are 23 structural shocks, eleven in each of the United States and Canada and one on the financial intermediation costs that affect the adjustment of the exchange rate. Each shock, z, is modelled as a first-order autoregressive stochastic process with standard error of the random disturbance, σ_ϵ, and persistence, λ:

$$z_t = \lambda z_{t-1} + \epsilon_t. \tag{6}$$

Table 5 reports the persistence and the standard errors of each of the stochastic disturbances in the model. In general, the stochastic processes that exhibit 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 of the tradable and non-tradable sector productivity shocks. The shocks with least persistence (λ

equals zero) are those to the non-tradable goods price mark-up, the wage mark-up, and investment.

The estimates of the standard errors of the shocks 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 consumer price inflation, the output gap, nominal interest rates, exports, imports, the real exchange rate, and the terms of trade.[16] In Canada, foreign shocks account for about 60 per cent of the variance in the output gap, and about 35 per cent of the variation in consumer price inflation, while domestic demand shocks explain about 25 percent of the variability in the output gap 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 gap variability. Mark-up shocks account for about only 10 per cent of the variation in the output gap, but explain a large proportion of the variation consumer price inflation (40 per cent). The contributions of productivity shocks in Canada to output gap 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 the output gap and inflation than they do in Canada. Demand shocks in the United States are also important, explaining about 40 per cent of output gap and consumer price inflation variability. Mark-up and labour supply shocks account for the remaining volatility.

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 historical unconditional moments for Canada.[17] The model-generated data is then compared to moments calculated from the historical data based on the 1983Q1 to 2004q2 historical sample.[18]

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

[16] 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.

[17] 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.

[18] 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.

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 rates.

Next, we turn to an examination of the several bivariate temporal correlations[19]. 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 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 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.

Next, we explore some foreign economy links in the Canadian bloc of the GEM. Figure 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. Once again, the correlations estimated in the historical data are statistically insignificant at 95% confidence level. 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.

Furthermore, we 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 real output and inflation. The GEM over-predicts the strength of the

[19] 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.

positive correlation between lagged output growth (or alternatively the lagged output gap) and leads of inflation. It 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, 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 Selected model 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, and consumption demand shocks) broadly match those for ToTEM and MUSE.

To demonstrate the model's ability to generate sensible impulse responses to a variety of shocks we report the results of three different shocks: i) a monetary policy shock in Canada; ii) a shock to the competitiveness of the labour sector in Canada; and iii) 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. Overall, GDP drops by 0.06 percentage points, reaching its trough after four quarters.[20] 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-over-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 almost 1 percentage point after two quarters, and remains below control for more than 10 quarters, because of the existence of nominal wage and price rigidities. The fall in the real wage 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 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 year-over-year 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 reduction in marginal cost, the price of Canadian exported goods falls. On net, the trade balance improves by 0.2 percentage points of GDP after three quarters.

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 increases from 98.0 per cent to 98.4 per cent in the first period. The shock process is quite persistent with a lagged value of 0.85.

[20]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)).

U.S. real imports fall by 0.8 per cent after 3 quarters, returning to control after twelve quarters. Canadian real exports, of course, mirror this decline exactly. However, the effects on the two countries' GDP are very different. It has almost no impact in the United States – only an increase of about 0.1 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 consumption and overall real GDP falls by about 0.5 per cent. The depreciation of the Canada-U.S. real exchange rate (peaking at almost 0.6 per cent) helps to dampen Canadian import demand. 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:

$$L_t = E_t \sum \beta^j \left[\lambda_p \left(\pi_{t+j} - \pi^{TAR}\right)^2 + \lambda_y \left(y_{t+j} - y^{POT}\right)^2 + \lambda_i \left(\triangle i_{t+j}\right)^2\right] \tag{7}$$

where 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 $\beta \rightarrow 1$, 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. We believe that this characterization of the objectives of monetary policy match up very well to the statements of central banks particularly their desire to stabilize business cycle fluctuations.[21]

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 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, and Williams 2003).[22]

We only consider simple instrument rules in this study.[23] 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 since 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: (8):

$$i_t = \omega_i i_{t-1} + (1 - \omega_i)\, i_t^* + \omega_p (E_t p_{t+k} - \eta E_t p_{t+k-1} - p_{t+k}^{TAR} + \eta p_{t+k-1}^{TAR}) + \omega_y (y_t - y_t^{POT}) \quad (8)$$

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 or 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 the policy decision depends on current-period inflation only. Alternatively, if $k = 3$, then the central bank bases its policy decision on 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.[24]

[21] An alternative approach is to maximize the welfare of the models' representative agent.

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

[23] Svensson (2007) 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.

[24] 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).

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.[25] 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 rules for the United States and Canada, while Table 9 reports the values of the loss functions, the standard deviations of the output gap, year-over-year 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.

5.2.1 The relative merits of IT versus PLPT

We focus first on the relative merits of IT and PLPT. Our discussion concentrates on the case of Canada, assuming that the United States chooses inflation targeting.[26] 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, inflation and interest rate variability. However, the overall gain is quite small, as the incremental benefits of moving from the optimized IT rule to the optimized PLPT rule is only 0.5 percent of the gain of moving from the historical Taylor rule to the optimized IT rule. It is interesting to note that, under PLPT, lower inflation and nominal interest rate variability comes at the expense of higher output variability. Our results suggest 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.

Moreover, our results show that simple PLPT feedback rules tend to be more forward

[25] 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.

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

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. Central banks choose a longer horizon for PLPT relative to IT, because it allows them to trade off less output volatility for higher inflation variability (Smets 2003). Also, note the very high value for the degree of interest rate smoothing ($\omega_i = 0.97$) in the IT rule. Everything else being equal, as $\omega_i \rightarrow 1$, 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.[27] 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 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 response to mark-up and labour supply shocks, but that PLPT is favoured in response to all other shocks. Alternatively, in the model with perfectly forward-looking inflation determination, PLPT is preferred in response to all shocks, including the mark-up shocks. These simulations lead us

[27] 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.

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 size of mark-up shocks relative to demand and productivity shocks in the variance decomposition of inflation.

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 (in Figure 10, top panels). 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 (in Figure 10, bottom panels). 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 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, in the perfectly-forward-looking model, that the relative benefits from PLPT versus IT are larger under demand shocks than under 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 response to demand shocks, but the degree of indexation in inflation is high enough to tilt the results towards IT in response to 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 to PLPT being more preferred than in the base case.

5.2.2 Do 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, possibly outweighing 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 influence on Canada's terms of trade are: i) the exchange rate (financial intermediation) 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. We find that PLPT is favoured over IT, because Canadian terms-of-trade movements have been principally associated with shocks that generate a positive covariance between the output gap and inflation in Canada (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. Srour (2001) suggests, 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 addition, 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 suggests that this result is sensitive to the interaction between the degree of forward-lookingness in price determination and the distribution of the shocks in the economy. PLPT's relative advantage is negatively related to the degree of indexation of current inflation to past inflation, and the relative importance of shocks that generate a negative correlation between domestic inflation and output gaps, to those that generate a positive correlation.

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 PLPT versus IT in Canada.

The are many possible extensions to our work. In particular, given the importance of fluctuations in commodity prices for the terms of trade of Canada and the United States, we would like to use a version of the GEM that incorporates commodities. Second, we could 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
Non-Tradable 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 non-tradables 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 non-tradables 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
Non-Tradables 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 non-tradables 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 Non-Tradables	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 Non-Tradables	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 Non-Tradable 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 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 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

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	2.135	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	1.444	1.087	1.020	1.079	1.017

Table 10: Results for Simple Optimized Rules For Shocks to Domestic 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

Table 11: Standard Deviations of Key Variables Under the Optimized Rules for Shocks to Domestic 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	0.081	0.084	0.183	0.212
Interest Rate (chng)	0.099	0.063	0.185	0.104

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	1.069
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 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

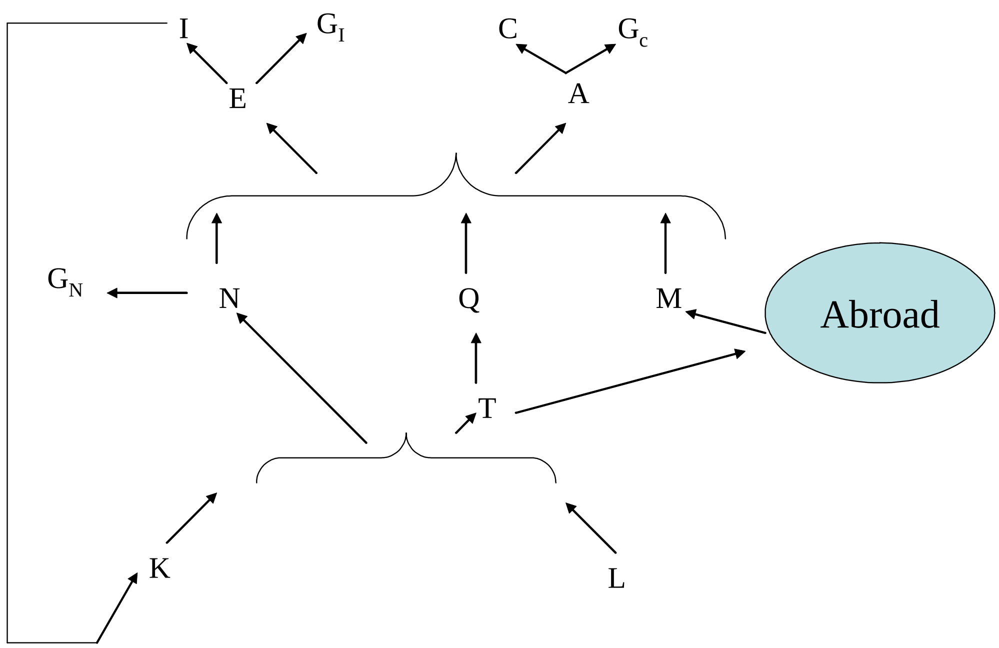


Figure 2: Autocorrelation Functions: The GEM Against Historical Data in Canada - Part I

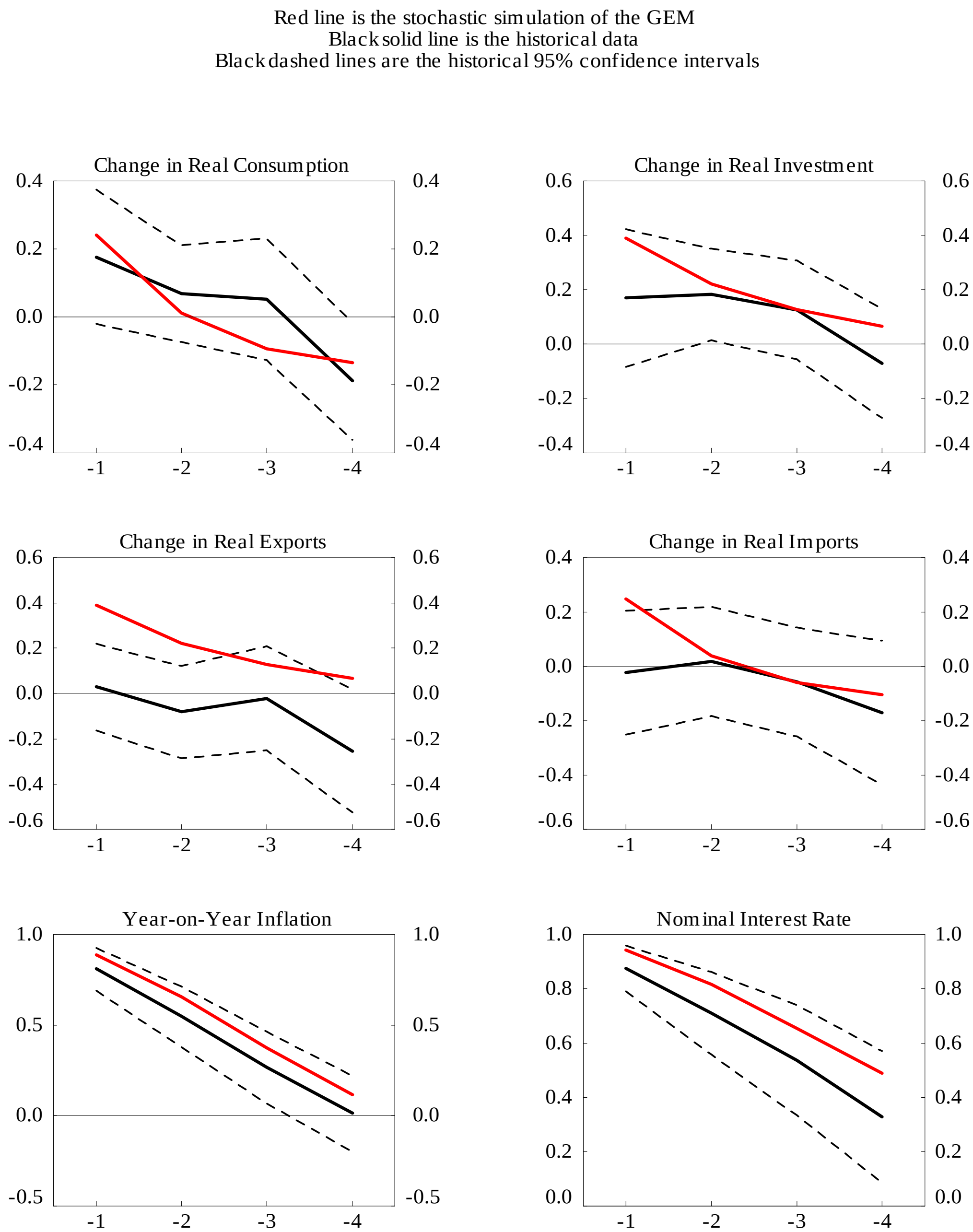


Figure 3: Autocorrelation Functions: The GEM Against Historical Data in Canada - Part II

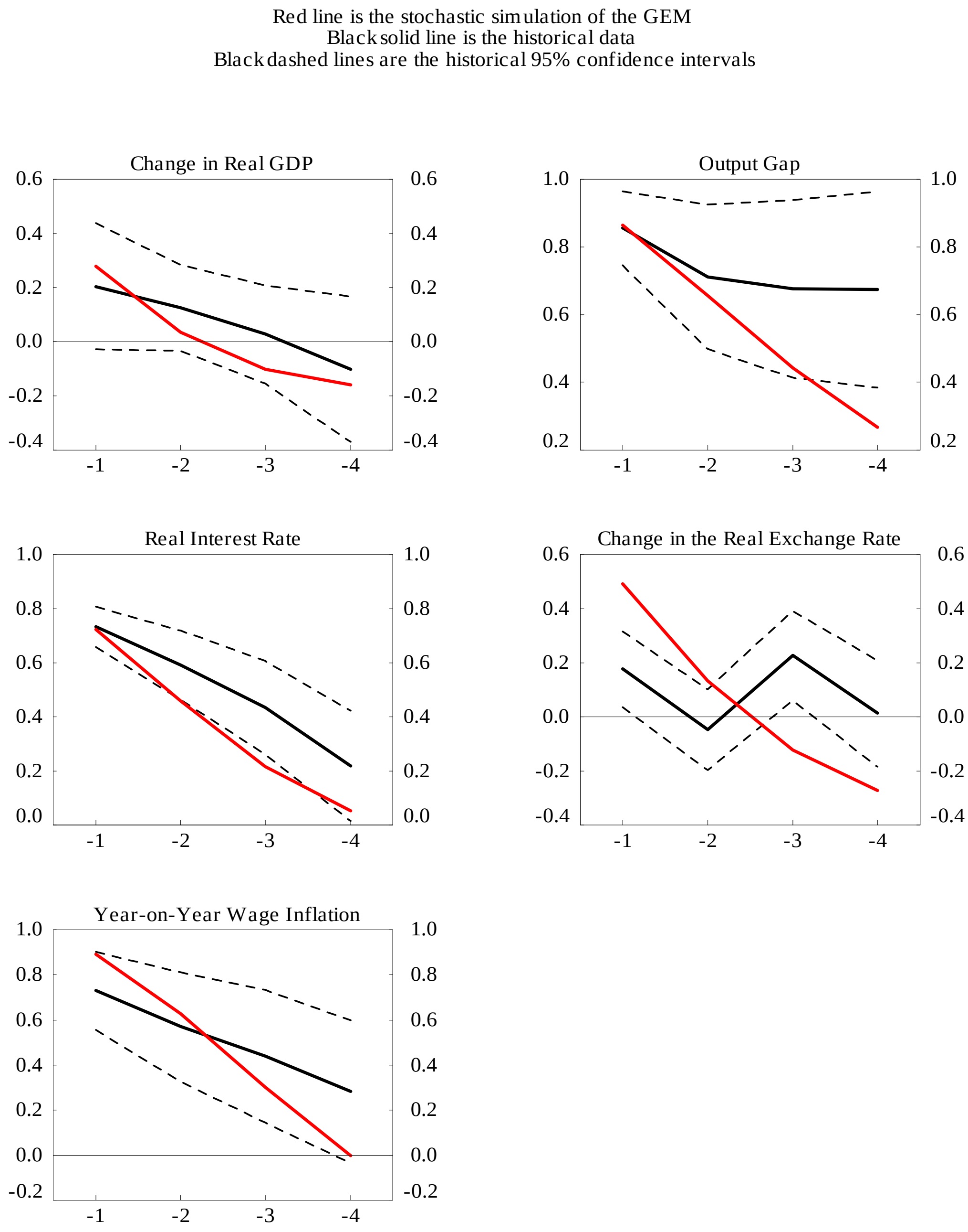


Figure 4: Temporal Cross-correlation Functions: The GEM Against Historical Data in Canada - Part I

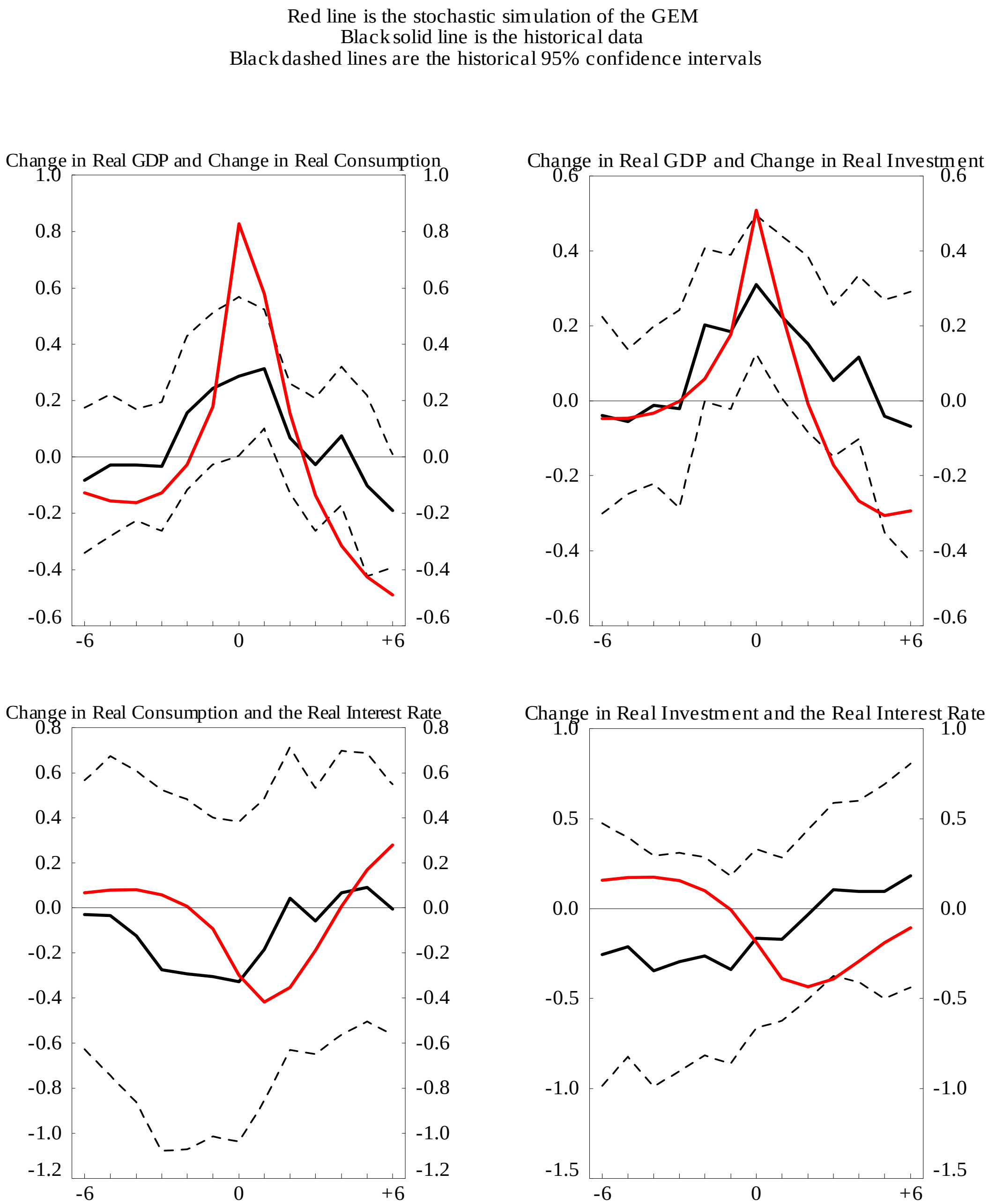


Figure 5: Temporal Cross-correlation Functions: The GEM Against Historical Data in Canada - Part II

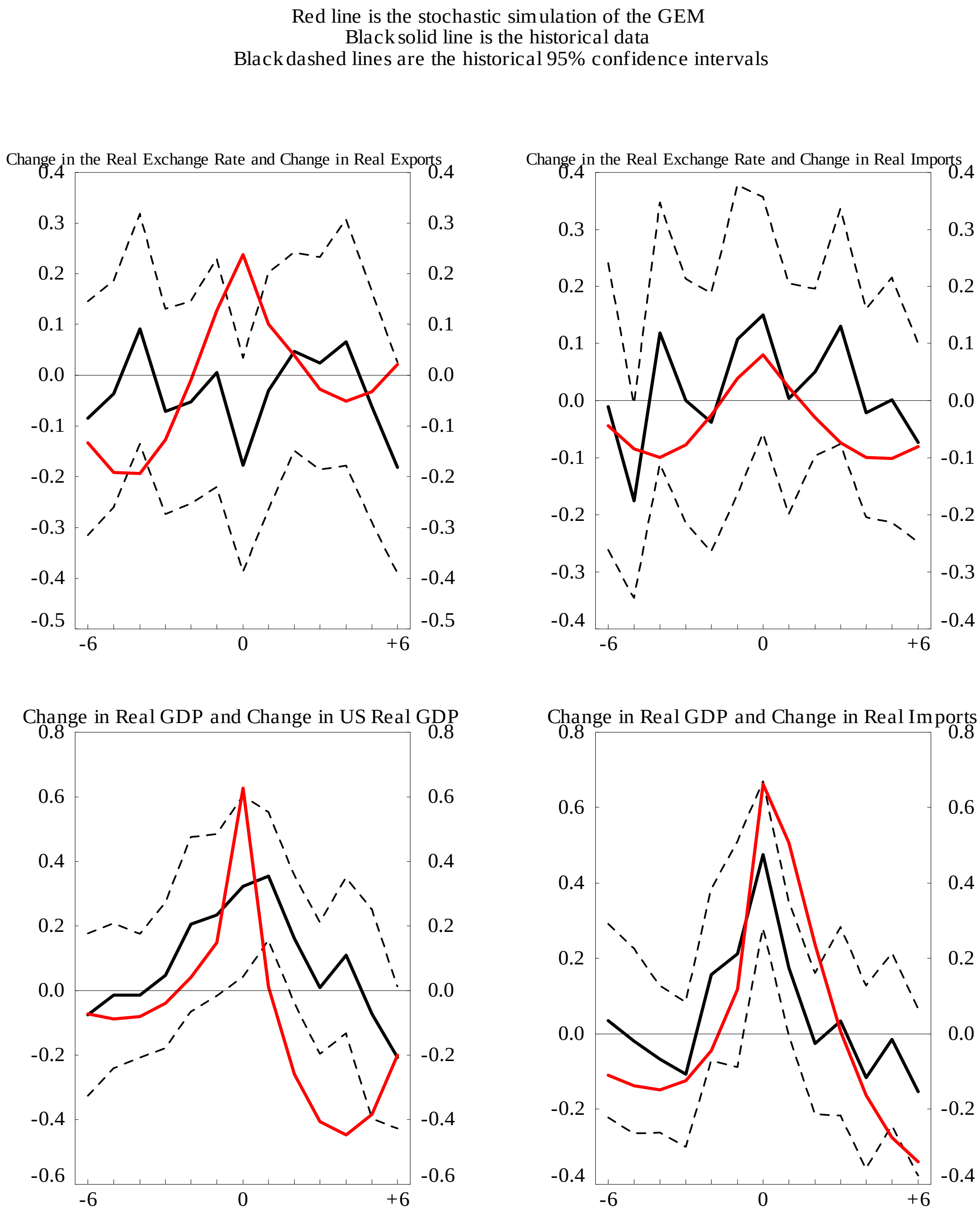


Figure 6: Temporal Cross-correlation Functions: The GEM Against Historical Data in Canada - Part III

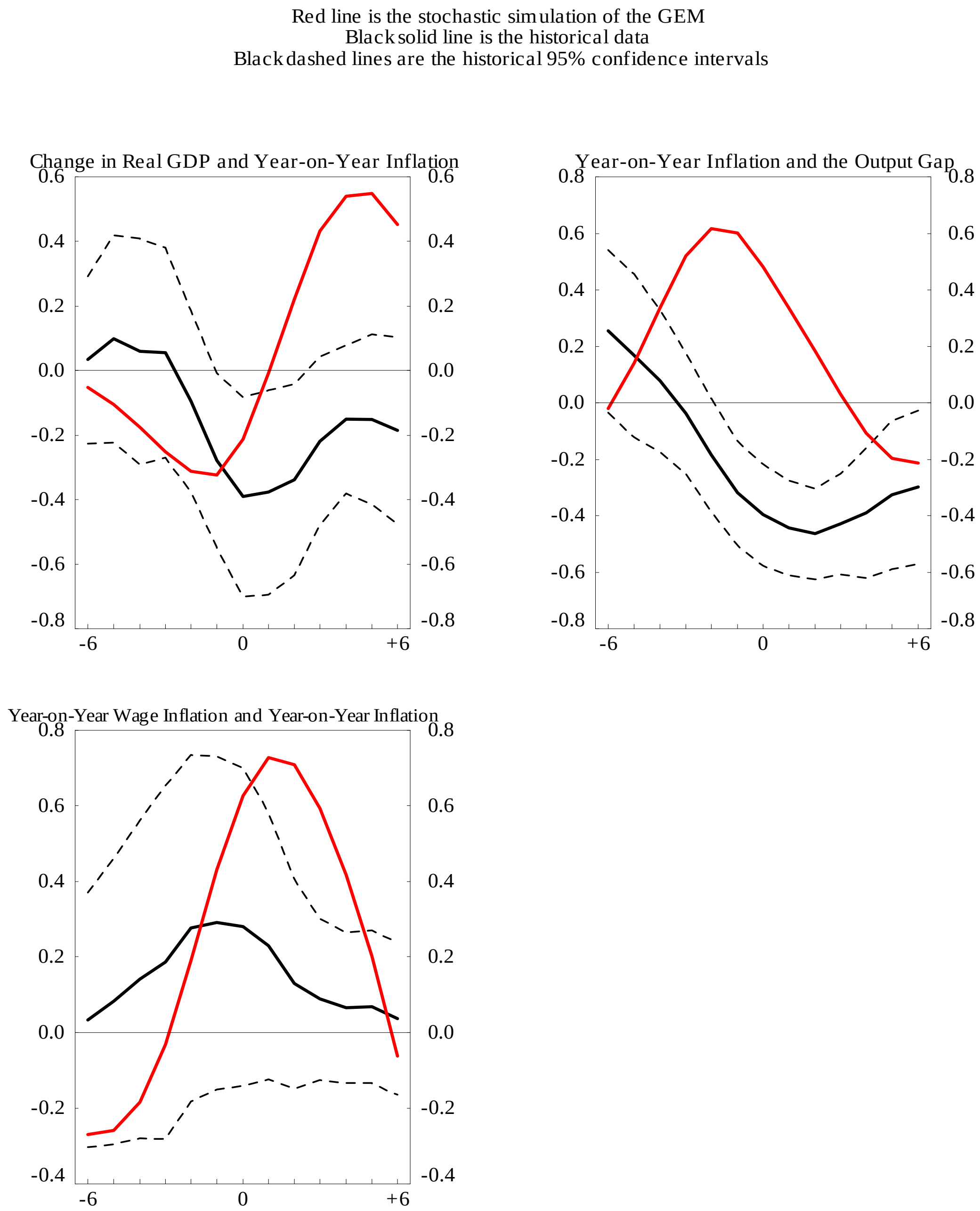


Figure 7: A Positive Shock to the Short-term Interest Rate in Canada - Impulse Responses

(Deviation from control, in percent)

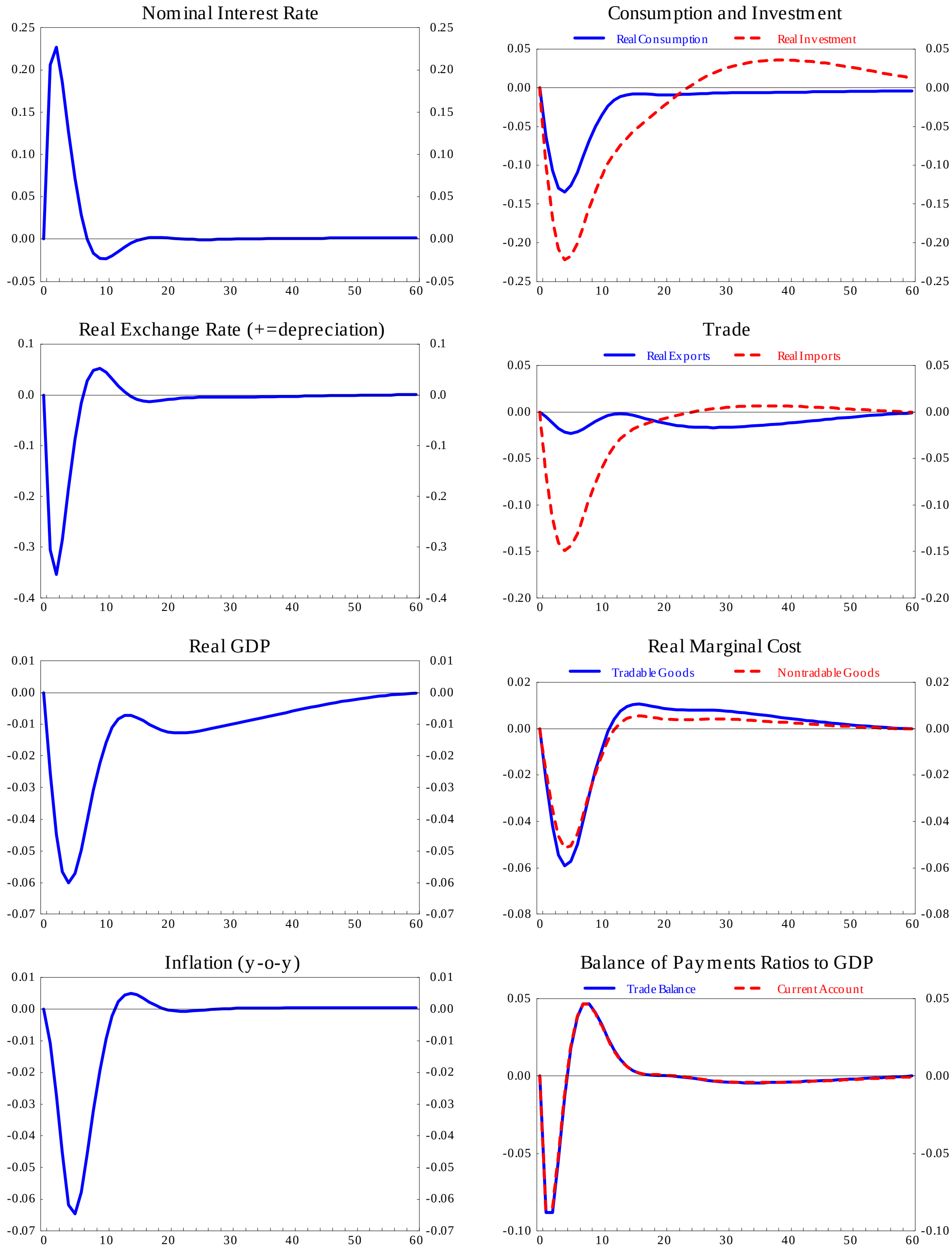


Figure 8: A Positive Shock to Competitiveness in the Labour Sector in Canada - Impulse Responses

(Deviation from control, in percent)

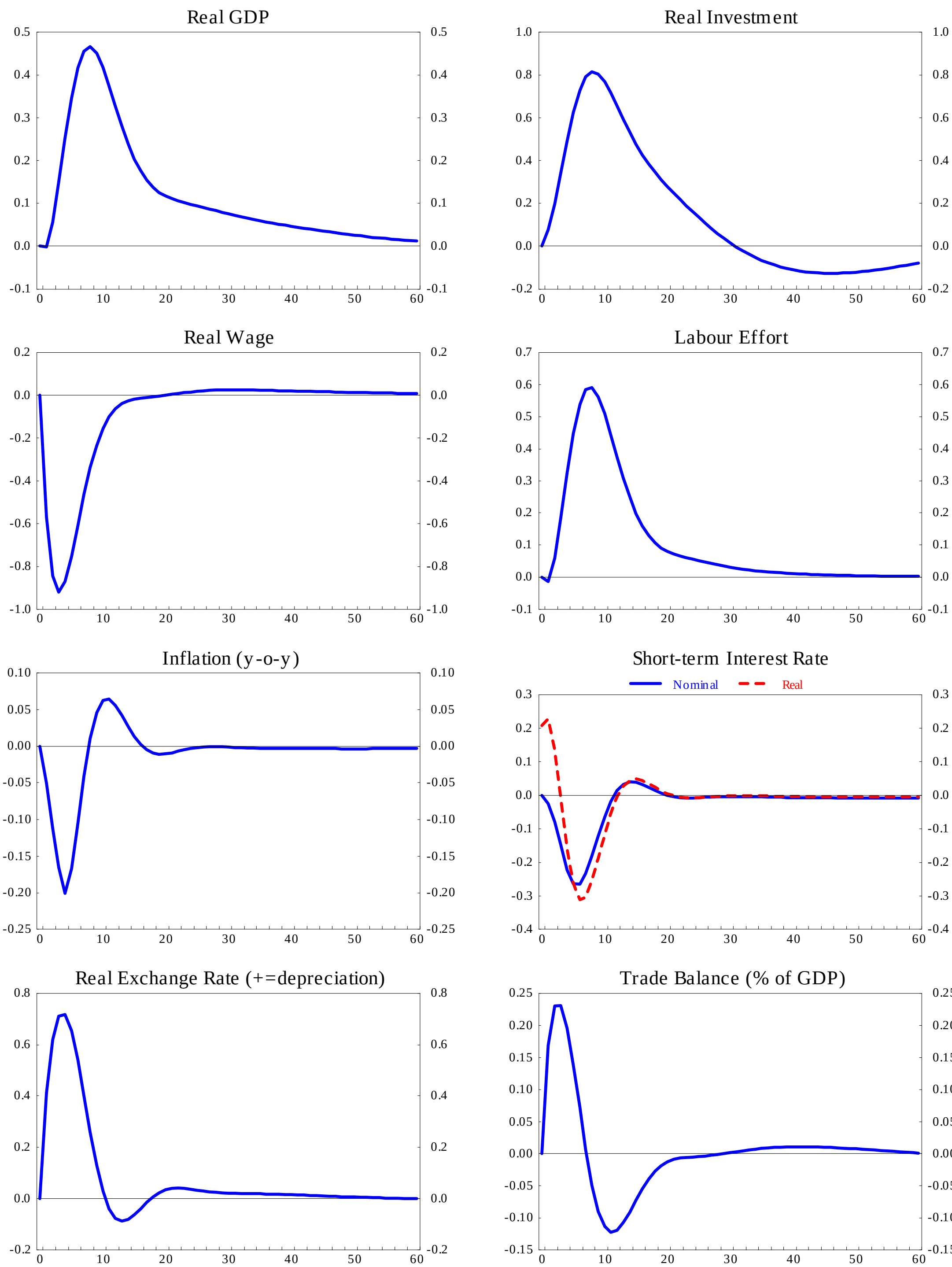


Figure 9: A Negative Shock to Import Demand in the United States - Impulse Responses

(Deviation from control, in percent)

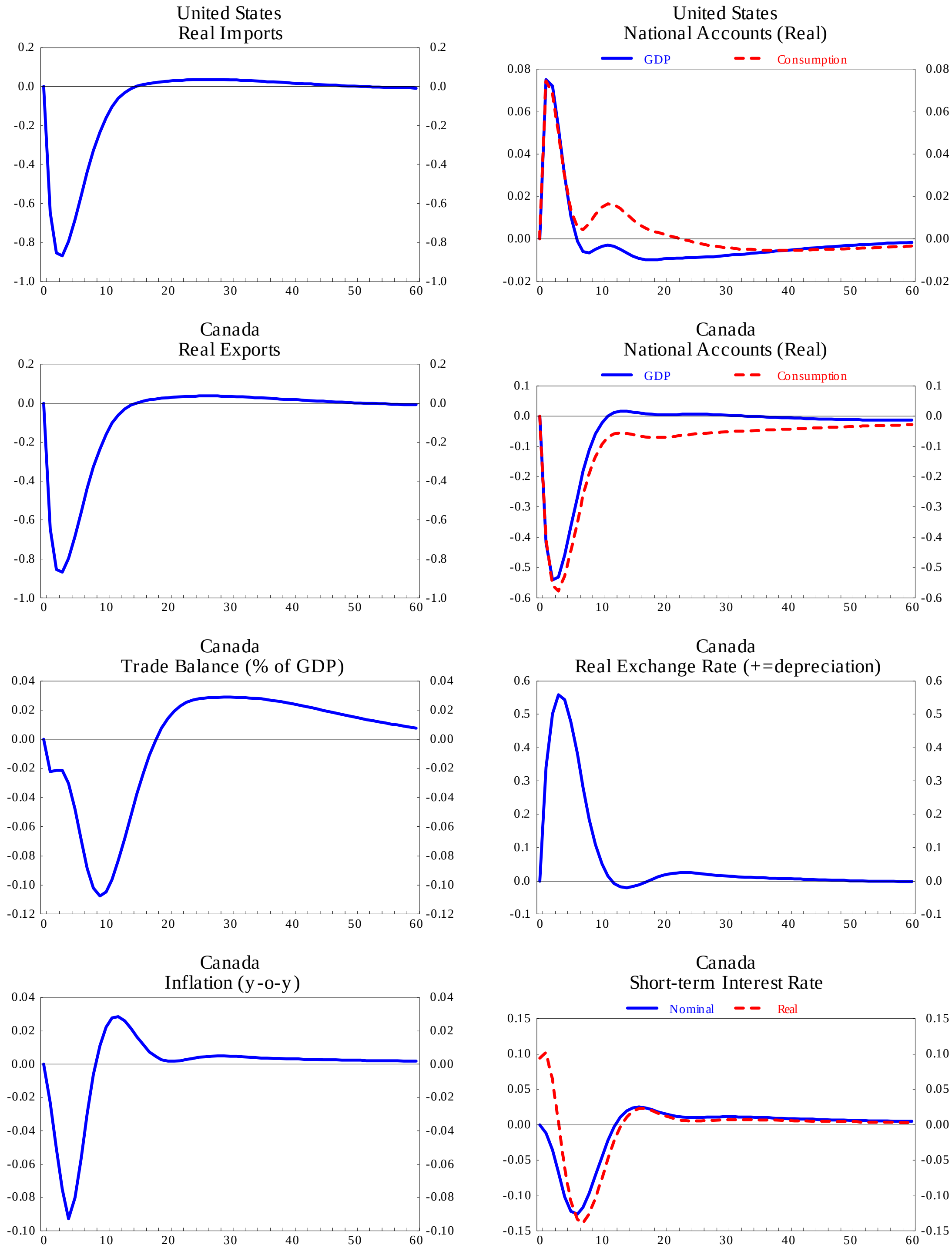
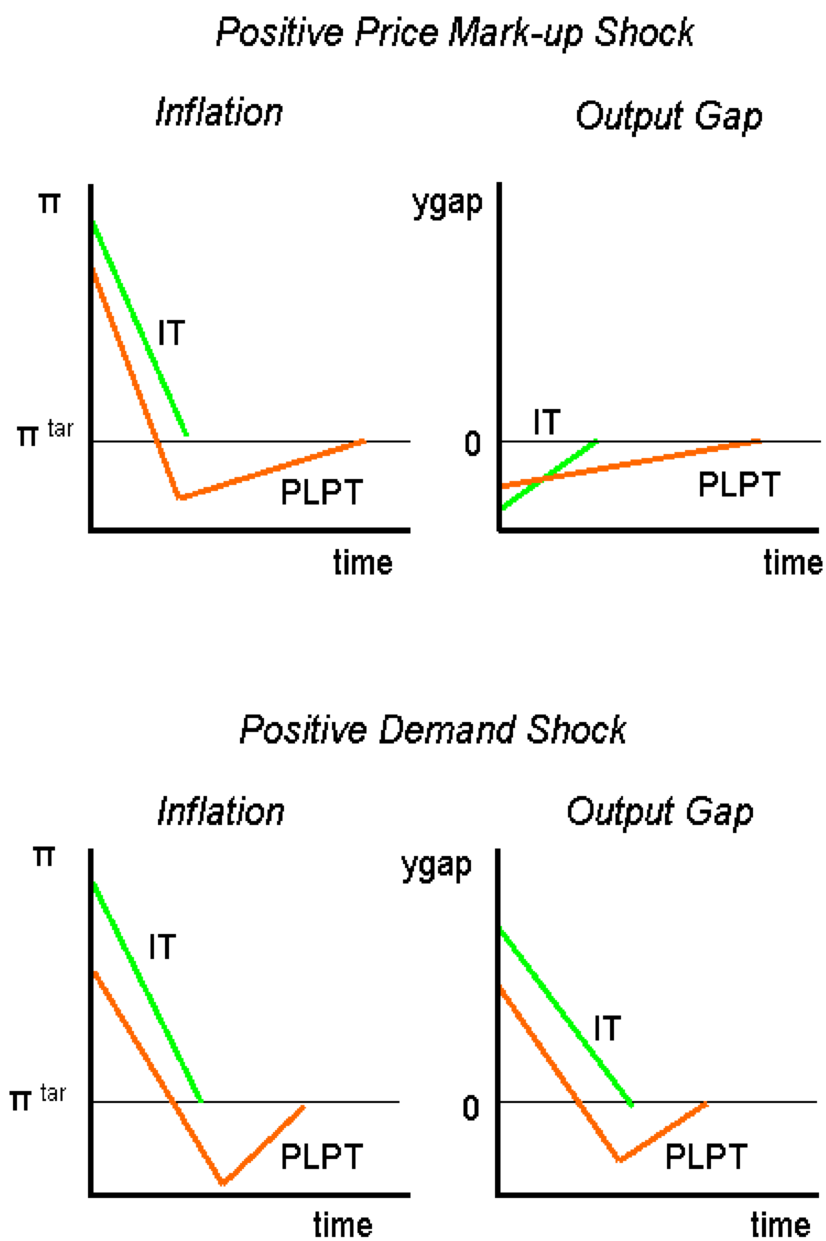


Figure 10: Stylized Shocks under a Forward-Looking Phillips Curve



IT -- Inflation targeting regime; PLPT -- Price-level-path targeting regime