Inflation-targeting (IT) and Price-level-path Targeting (PLPT) in the GEM: Some Open Economy Considerations[1]

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Abstract

This paper compares the relative merits of inflation targeting (IT) to price -level-path targeting (PLPT) in a two-country, two-sector verion of the **G**lobal **E**conomic **M**odel **(GEM)** calibrated for Canada and the United States. In general, we find that PLPT rules outperform IT rules in Canada. We show that the relative merits of the alternative frameworks are sensitive to the distribution of the historical shocks, the degree of indexation to past inflation in nominal variables and the relative weight of inflation and output gap variability in the central bank's loss function. We also show that extending the analysis from a closed to an open economy framework has important implications for Canada. In particular, including shocks to the terms of trade can have an affect on the relative merits of IT versus PLPT. 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.

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1 Introduction

One way of implementing a strong nominal anchor for the economy that has become particularly popular in recent years is the adoption of formal inflation targets. Although the specific institutional details in individual countries differ, 20 countries were inflation targeters in 2005 (Roger and Stone (2005)). Canada joined the ranks of the inflation targeting (IT) countries in 1991, the second country in the world to do so after New Zealand in 1990. The basic principles of inflation targeting 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. Since monetary policy effects inflation by both affecting the level of spending in the economy and directly through inflation expectations, the benefits of inflation targeting are maximized if the policy is well communicated and well understood by the public. Inflation targeting in Canada and in many other countries has proved to be quite successful as inflation expectations have become better anchored (Levin, Natalucci and Piger (2004)) leading to a reduction in inflation volatility and persistence (Levin and Piger (2002)) with no increase in output volatility (Mishkin and Schmidt-Hebbel (2002)).

As inflation-targeting central banks take stock of their experiences it becomes incumbent upon them to critically assess the approach and to identify possible improvements. Two particular issues stand out as deserving more attention. The first is related to the level of inflation typically targeted and the second is related to long-term price level uncertainty. Inflation targets worldwide typically remain at about two per cent despite a consensus in the economics profession that there would be significant benefits associated with moving towards true price stability.[1] One often cited explanation of why central banks have decided not to more actively pursue lower target inflation rates is their concern about hitting the zero lower bound on nominal interest rates (Fischer (1996)). Since no one will lend money at negative nominal interest if cash is costless to carry over time, the power to lower short-term interest rates to fight deflation and recession is likely limited when nominal rates are low on average.[2] As a result, for fear of losing a power policy instrument some have argued that central bank not ought to chose an inflation target that is too low (Summers (1991) and Fischer (1996)).[3]

The second potential shortcoming of inflation targeting is that 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 leaving uncertainty about future price levels higher than it needs to be. This is problematic for agents who are risk averse and who enter widely into long-term, nominal contracts (e.g. home mortgages). If agents are better able to predict future prices, then they will make more use of longer-term contracts and avoid fluctuations is consumption arising from inaccurate expectations of the future price level.

An alternative way to achieve a strong nominal anchor for the economy that may help alleviate these problems is price-level-path targeting (PLPT). Price-level-path targets differ

[1] The literature describes the source of these benefits as a reduction in the tax on money holdings, a more efficient allocation of resources due to lower relative price dispersion, a reduction in distortions introduced by the interaction between inflation and the nominal accounting system and/or the tax system, and an improvement in the information content coming from nominal prices with lower uncertainty.

[2] Goodfriend (2001) discusses various options for overcoming the zero bound on interest rates. Of particular interest is his proposal for a variable carry tax on electronic bank reserves that could enable a central bank to target negative nominal interest rates.

[3] The upward bias on measured inflation is also often cited as a reason for targeting a positive inflation rate.

from inflation targets in that a shock that pushed the price level above its target path would require the monetary authority to fully reverse 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 can 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 price-level-path targeting versus inflation targeting rise as the underlying trend increase in prices falls. Second, adding a measure of the price-level-path targeting caps the variance of the prices thus leading to a fall in price level uncertainty. This should be welfare enhancing for agents who enter into long-term nominal contracts.

Price-level-path targets however do not offer a panacea. Many authors have argued that price-level-path targeting has the potential to increase in the volatility of inflation and/or output relative to inflation targeting (Lebow, Roberts, and Stockton (1992), Fillion and Tetlow (1994), Fischer (1996)). Some have also argued that price-level-path targets would increase the probability of hitting the zero bound on nominal interest rates because of the need to force prices downward in the advent of a shock that causes prices to rise above target (Minford and Peel (2003)) while others have argued that the benefits from more stable long-term nominal contracting are not likely to be substantial given the availability of other measures to address long-run price uncertainty such as indexed bonds (Fischer (1994)).

Our analysis of the relative merits of inflation and price-level-path targeting is conducted using a two-country, two-sector version of the Global Economic Model (GEM) calibrated for the United States and Canada. First, we compare price-level-path and inflation targeting for Canada and the United States. We asses the relative merits of each policy framework using an *ad hoc* loss function that seeks to minimize the variability of inflation (relative to target), the output gap, and the change in nominal interest rates.[4] For the baseline calibration of the model, our analysis suggests that price-level-path targeting is preferable to inflation targeting in Canada. Sensitivity analyses confirm the general results found in the literature for the class of model that we consider. More specifically, the relative merits of price-level-path targeting varies negatively with the degree to which current price and wage inflation depends on lags of inflation, negatively with the degree to which current output is predetermined and positively with the importance of inflation stabilization in the central bank's loss function. We also show that our base-case results are sensitive to the distribution of the historical shocks. The relative advantage of PLPT declines with the increasing incidence of domestic price/wage mark-up shocks and domestic labour supply shocks. For the baseline model calibration, PLPT performs particularly badly in terms of output stabilization in these shocks.

In the second part of our analysis, we focus on the role played by terms-of-trade shocks. It has been suggested that stabilizing the aggregate price-level in face of large and persistent relative price shocks could introduce increased variability in output that would outweigh the benefits associated with reduced price-level uncertainty (Bank of Canada (2006)). Given the historical variance decomposition of the model we identify the key shocks that have played

[4]Doing a full welfare analysis using the GEM has not been feasible so far, since it requires a second order Taylor approximation of the model, which is too large and computationally intensive for most of the computers currently being used.

a particularly important role in influencing the terms of trade. Based on this identification, we conclude that PLPT is the preferred policy in face of shocks to the terms of trade. Our analysis also suggests that this outcome is sensitive to the distribution of the shocks and the base-case calibration. For example, PLPT generates more favorable outcomes if movements in the terms of trade stem from a change in preferences in the United States towards Canadian goods from a U.S. demand shock or from an exchange rate shock. On the other hand, if movements in the terms of trade are driven by domestic price mark-up shocks in the tradable goods sector then IT is preferred.

Lastly, we investigate the possibility that monetary policy choices in the United States can affect the policy choices in a relatively small but very open economy such as Canada (Bank of Canada (2006)). Our interest in this question is motivated in part, by Srour (2001) that argues that if alternative monetary policy arrangements in the large foreign country leads 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 choice. Our analysis suggests that choice of monetary policy framework in Canada is robust to the choice of monetary policy regime in the United States.

The paper is organized as follows. Section 2 reviews the relevant literature. Section 3 provides a high-level discussion of the two-country, two-sector version of the GEM that we use for our analysis. Section 4 discusses the calibration of the model to the stylized facts for Canada and the United States. Section 5 employs the model to investigate the relative merits of inflation and price-level path targeting. Finally, Section 6 reviews our main conclusions and outlines directions for future research.

2 Literature Review[5]

Price-level path targeting significantly pre-dates inflation targeting 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 (1999)). His policy prescription was quite simple. The central bank should raise its discount rate when prices were rising and lower them when prices were falling. His theories proved to be an important force that helped steer Sweden to make stabilization of the domestic price level the official goal of monetary policy in the early 1930s. The policy was quite successful when compared to those followed in other countries at the time, including the United States, leading a much smaller fall in the price level and a smaller rise in unemployment than those countries that remained on the gold standard. Eventually, the rise of Keynesian economics and the predominance of fiscal policy lead the Swedish central bank to target output /employment directly without any emphasis on price targets (Duguay (1994)).

To the best of our knowledge interest in price-level-path targeting 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. Barnett and Engineer (2000) conclude that the case for price-level-path targeting depends on various factors: i) whether the monetary authority can credibly commit to future policy ("commitment") or whether it sets a new plan each period ("discretion"); ii) whether current inflation is controllable by the monetary authority; and iii) how inflation expectations are formed.

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

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 *et al* (1992), and Haldane and Salmon (1995) for examples. In those models, price-level-path targeting rules result in higher short-run variability of both inflation and output. Under price-level-path targeting, periods of higher-than-average inflation are necessarily followed by periods of lower-than-average inflation. On the other hand, under inflation targeting, periods of higher-than-average inflation are followed only by average inflation. Thus, inflation variability is higher under price-level-path targeting than under inflation targeting. Higher inflation volatility in presence of nominal rigidities in the models, in turn, leads to higher output volatility in price-level-path targeting rules. 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 inflation targeting dominates price-level-path targeting provided that society's preferences are specified in terms of inflation variability.

This general line of thought was challenged by numerous authors. These authors 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, policy price-level-path targeting is preferred to inflation targeting. 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 price-level-path targeting, 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. For examples of papers that compare PLPT rules to IT rules when the inflation process is characterized by a NKPC and monetary policy is solved under commitment see, for example, 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)). These results are however quite sensitive to the specification of 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 NKPC and 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.

Other studies in the literature make use of the New Classical Phillips' curve (NCPC) rather the NKPC. The key difference is that contemporaneous inflation expectations are predetermined in the NCPC. In a very influential paper, Svensson (1999) argues that when central banks face a new-classical Phillips' curve and act under discretion that price-level-path targeting is preferable to inflation targeting as long as there is a moderate degree of persistence in the output gap. The intuition behind his result comes from the fact that under inflation targeting, inflation depends on the variability of the output gap while under price-level-path targeting inflation depends on the variability of the change in the output gap. As long as the output gap shows a moderate degree of persistence, the change in the output gap is less variable than the output gap itself. On the other hand, Svensson's basic result does not hold under commitment. Under commitment, the inflation targeting rules dominate because committing to bring the price level back to target in the future does not influence inflation today and hence no benefit is gained.

Finally, all of the studies discussed above were done in the context of closed economy one-good models. Other studies were 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 UK. The authors conclude that the relative merits of PLPT and IT, as well as hybrid 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 as well as imperfect competition and staggered prices in the product and labour markets. Monetary policy is characterized by a simple Taylor-rule and the model is solved under commitment. The authors evaluate the welfare gains of alternative monetary policy based on the welfare of the model's representative agent and also compare monetary policy rules computing the volatility that they induce in the main macro variables. They find that the welfare implications of moving from inflation targeting to pure price-level-path targeting or a combination of both (i.e. hybrid monetary policy rule) are negligible.

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.[6] 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 Pesenti (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 authorities). 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 domestically-produced 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.

[6] For our work, we rely most on the version of the GEM written as a VAR representation of the first-order Taylor approximation of the model (Juillard (2001)).

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.[7] 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 the possibility of a lag in inflation.[8] In particular, the linearized Phillips' curve in our version of the GEM, abstracting from growth, takes the following form:

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

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 and β is the discount rate.[9]

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) due to the presence of nominal rigidities. Households ultimately own all firms and the capital stock, which they rent to firms.

[7] As the varieties of goods produced by firms n are more alike (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.

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

[9] 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.

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. The 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 there is a risk premium on exchange rate transactions that is negatively correlated with expected future depreciations (Duarte and Stockman (2005)). 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 future real exchange rate is expected to depreciate in consecutive periods. In such an instance they expect that in domestic currency terms that their holdings of the international bond will increase in value simply from a shift in the bilateral real exchange rate, hence a lower return from the real interest rate is acceptable. As a result the risk-adjusted uncovered interest rate parity (UIRP) condition is modified as in Adolfson *et al.* (2005) such that in the linearized model there is a lag of the exchange rate.

Government spending is on final and intermediate nontradable goods. Governments finance public expenditures through non-distortionary lump-sum taxes on labour income. 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 set of key unconditional moments in the historical data (temporal cross-correlations, autocorrelations and relative variances) as well as our desire to generate impulse responses that are consistent with well-established priors.

The process of parameterization involves selecting a set of model parameters and then using the historical data to calculate the variance of the model's stochastic disturbances. The model has 23 behavioural shocks.[10] Each country has two sector specific technology shocks - to the tradable sector and to the nontradable; four domestic demand shocks -consumption (through the marginal utility of consumption), investment (through investment adjustment costs), imports (through the bias towards imported over domestically-produced tradable goods) and government spending on goods and services (through the three government components); three mark-up shocks- prices in the tradable goods sector; prices in nontradable goods sector; the real wage; a monetary policy shock (directly to the short-term interest rate); and a labour supply shock (through the disutility of labour). There is an additional

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

shock to the international financial intermediation costs in Canada (which serves as the exchange rate shock). To identify the shocks empirically we use twenty-one actual 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)).

The series 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.[11]

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 also 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 (Gosselin and Lalonde (2006)).The historical sample studied covers 1983Q1 to 2004Q2.

We run stochastic simulations based on the historical distribution of shocks. Key moments are calculated from the model-based data and then compared to those estimated in the historical data. Standard errors are calculated for the statistics based on the historical data. Impulse responses from the model are then simulated and compared to those 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)).

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 (see above) 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

[11] For Canada, consumer price data is the Consumer Price Index excluding the eight most 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 statistics. Similar data for the United States is provided by the Bureau of Economic Activity.

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) and Murchison and Rennison (2006), 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.* (2005)). 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. Our baseline calibration also reflects the significant difference across the two countries in terms in the relative magnitude of their import shares. The bias towards domestically-produced tradable goods over imports in the production of the consumption (investment) good is set to 0.10(0.30) in Canada and 0.90(0.98) in the United States. The bias towards tradable over nontradable goods in consumption (investment) in both countries is 0.60(0.70).

Production in the monopolistically competitive intermediate goods sectors combines capital and labour using a 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 tradable goods prices and less importantly, for 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 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, consistent with values used in previous studies. 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. For example, consistent with the finding of Bils and Klenow (2004) who document a significant heterogeneity in the frequency of price changes across retail goods and services, we find that contract lengths are longer in the nontradable goods sector than in the tradable goods sector[12]. In particular, we set the adjustment cost parameter (ϕ_1) for nontradable goods prices and nominal wages in both countries at 500 and at 250 for tradable goods prices.[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 0.4 and the weight on forward-looking expectations of inflation next period is 0.6.

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. Alternatively, we could address this issue 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.

On the real side, there are also important adjustment costs. Like Faruqee *et al.* (2005) 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 import shares relative to firm x's output in the home country.

The financial intermediation costs 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.[14] Modification

[12]Bils and Klenow (2004) document significant differences in the frequency of price adjustment across different components of the U.S. consumer price index. For example, prices rarely change for newspapers, haircuts and taxi services all non-tradable goods. On the extreme, prices change quite most frequently for clothing, computer equipment, food and energy – all traded goods.

[13]Combined with our assumptions about the steady-state elasticity of substitution in Canada and the United States in the various sector implies that the time between re-optimizations in the Calvo (1983) pricing model of: i) 8 quarters in Canada and 7 quarters in the United States for nontradable goods prices, ii) 3.5 and 2.7 quarters in Canada and the United States for tradeable goods and iii) 5 and 4 quarters for nominal wages in Canada and the United States.

Ortega and Rebei (2006) estimate longer contract lengths in nontradable than tradable goods. These authours however estimate the contract lengths as 2.5 and 3 quarters respectively considerably shorter than those implied by our calibration. The difference likely reflects different detrending methodologies. Ortega and Rebei (2006) detrend Canadian inflation using an H-P filter while we detrend inflation using the inflation target over the 1991 to 2005 period and the implied target taken from the Bank of Canada staff economic projection for the earlier sample.

[14]This speed of adjustment is a compromise. Faster convergence of the NFA gap implies the bilateral

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 that 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.

The last set of parameters, are those that pertain to the stochastic part of the model. As discussed earlier, there are twenty-three 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 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 (λ_{GC}, λ_{GI}, λ_{GN}),the shock to international financial intermediation (λ_{ZBF}), the import of investment goods shock and both tradable and nontradable sector productivity shocks (λ_{ZT} and λ_{ZN}). 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 (λ_{θ_n} and λ_ψ).

The estimates of the standard errors of the shock can be more difficult to interpret.[15] As a result, we instead 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. The shocks have been group into five categories: domestic demand shocks, domestic productivity shocks, domestic mark-up shocks, exchange rate shocks and foreign shocks. Domestic demand shocks are shocks that originate in the home country in which output and inflation covary positively. On the other hand, domestic supply shocks are shocks that originate in the home country in which output and inflation covary negatively. Domestic

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. This would generate a disequilibrium in the current account for an implausibly long period of time. Given the current context of global imbalances, this result would be an undesirable property for the model.

[15] The model structure assumes that the shocks are independent. We find a statiscally signficant covariance in 20 percent of all the possible covariances. Most are relatively small. Our main qualitative results are not sensitive to incorporation of these terms.

supply shocks are further disaggregated depending on the behaviour of the output gap. In domestic productivity shocks movements in the output gap covary positively with inflation while in domestic mark-up and labour supply shocks output gaps vary negatively with inflation. The remaining two shocks - shocks originating in the foreign country and those emanating from a shock to the cost of financial intermediation (exchange rate shocks)- have a stronger foreign economy flavour. These shocks can all be thought of as demand shocks from a Canadian perspective in that inflation and the output gap are positively correlated.

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 exchange rate shocks matter importantly for the variation in inflation (about 15 percent) but very little for output variability. Mark-up and labour supply shocks are also quite important accounting for about 25 per cent of the variation in real GDP and 40 per cent of the variation in consumer prices. The contribution of productivity shocks in Canada to real GDP and consumer price inflation variability is quite small and the remaining variability in output and inflation in Canada is explained by demand shocks. 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.

4.3 Matching unconditional moments

In this section we discuss the GEM's ability to reproduce some key unconditional moments from history. The GEM-generated data is then compared to moments calculated from the historical data. 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. The historical sample period is from 1983q1 to 2004q2.

First, we explore whether the GEM is able to generate data that has a similar degree of persistence to that found in the historical data. In particular, we consider the model data's ability to replicate the empirical autocorrelation functions. Figures 2 and 3 graph several of the autocorrelation functions. In most cases the GEM does a good job at replicating the broad shape of the autocorrelation functions. For example, the GEM does well at matching the persistence of consumption growth, investment growth, import growth, GDP growth, quarterly core inflation, and the nominal interest rate. On the other hand, the baseline calibration does not do as well matching the persistence of the output gap, the real exchange rate, the real interest rate and the real wage.

In the case of inflation persistence, our calibration leads to inflation persistence which is on the high side of the historical estimates. Matching the persistence of inflation over history reasonably well proves to be critical in this exercise since it plays an important role in determining the weight of lagged inflation in the hybrid Phillips' curves used in the GEM, a key factor in the analysis. Until recently, the notion that high inflation persistence is an inherent feature of industrialized economies was the conventional wisdom. Indeed, a simple autoregressive model of inflation for Canada estimated over the 1964 to 2003 period appears to confirm this view (Coletti and Demers (2004)). More recent literature challenges this view. Failure to account for breaks in the mean of inflation in empirical work introduces a spurious increase in the estimated degree of inflation persistence. When these means shifts are accounted for the results suggest that inflation persistence, within established regimes has been modest. For a simple autoregressive model of quarterly core inflation, average persistence over the 1964 to 2004 period falls from 0.9 in the naive model to 0.3 once we allow for shifts in the model's intercept (Coletti and Demers (2004)).[16]

Next we turn to an examination of the several bivariate temporal correlations[17]. 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 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 5 plots the temporal correlations between the change in exports (imports) and the change in the real exchange rate. The historical data suggests that these relationships are statistically insignificant at 95% confidence level. The GEM produces correlations that are consistent with the data. 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 correlation between contemporaneous output growth and leads of inflation. The GEM does not match the broad correlation between output gaps and inflation as well as the relationship between price and wage inflation.

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 overpredict the degree of volatility in most of the key macro series when compared to the actual data. For example, we find that the GEM overpredicts the variability in real output growth by a factor of four. 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

[16] Nonetheless, inflation can be more persistent during a transition from one regime to another. the recent litarature suggets that, in disinflations, the degree of inflation persistence (and the associatd output loss) varies inversely with the degree of monetary credibility (see Andolfatto, Hendry and Moran (2002), Erceg and Levin (2003)).

[17] 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.

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. Here we focus on three shocks that are often encountered in some form in the discussion of our results. In particular, 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 (which means Canadian monetary policy does not have a weight on the output gap).

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 0.30. 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.[18] 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 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

[18] 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)).

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 for the most part 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.[19]

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: [20]

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

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. Under certain conditions, when $\beta \rightarrow 1$, the value of the intertemporal loss function approaches the unconditional mean of the period loss function given by:

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

[19] The easing would be more substantial if the output gap was a factor in the historical policy rule for Canada.

[20] In this paper potential output is defined 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.

where σ^2_π, σ^2_y and $\sigma^2_{\triangle i}$ 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.[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 also placed on the change in the nominal interest rate ($\lambda_i = 0.1$) in order to minimize the occurrences which the nominal short-term interest rate hits the zero lower bound (Rotemberg and Woodford (1997)).

We only consider simple instrument rules in this study. Our choice to focus on simple rules is motivated on the basis that they are more likely to be robust across plausible models than are more complex rules that have been optimized to a particular model (Levin, Wieland,Williams (2003)). In addition, 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 price-level-path targeting rule or an inflation targeting rule. A generic form that nests the simple instrument rules considered in this study is given by: (7):

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

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 time horizon over which policy is conducted k. Notice if $k = 0$, then we get the simple Taylor (1993) rule; otherwise we are looking at inflation/output-forecast-based rules. For inflation targeting η is assumed to be unity; for price-level-path targeting it is zero.[22]

We minimize the central bank loss function by conducting a grid search over all of the coefficients and the feedback horizon using stochastic simulations conducted with numerical perturbation methods. 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.

[21] 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:
$L_t = E_t \sum \beta^j \left[\lambda_p \left(\pi_{t+j} - \frac{\phi_2}{1+\beta\phi_2}\pi_{t+j-1} - \pi^{TAR} \right)^2 + \lambda_y \left(y_{t+j} - y^{POT} \right)^2 \right]$

[22] 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).

5.2.1 The relative merits of IT versus PLPT

The first question that we focus on the relative merits of inflation and price-level-path targeting in Canada. We examine the case of Canada assuming that the United States chooses inflation targeting.[23]From Tables 8 and 9 we see, given the historical distribution of shocks and our baseline calibration of the model, that price-level-path targeting is preferred to inflation targeting. Price-level-path targeting delivers better inflation and interest rate stabilization at the expense of higher output variability. It is interesting to note that the optimized PLPT rule delivers slightly lower variability in the change in nominal interest rates as well and is more forward looking that the IT rule. Also note the very high weight of 0.97 assigned to the lagged interest rate in the IT rule.

To understand the robustness of our results we conduct a number of sensitivity analyses. First, we examine the implications of varying the degree to which the Phillips' curve is forward-looking by setting the weight on lagged inflation in the Phillips' curve equal to zero and recalculating the optimized feedback rules for both PLPT and IT. We confirm the results found in the literature (for this class of model) and find that the less predetermined inflation is, the greater the advantage of PLPT over IT. In particular, the relatively poor performance of PLPT rules compared to IT rules in terms of output gap stabilization found in the base-case disappears. In our second sensitivity analysis, we varied the degree to which the output gap is predetermined. Preliminary results suggest that the less output is predetermined, the more PLPT is favoured relative to IT. In future work, we plan to calculate the upper bound on both the weight on lagged inflation in the Phillips' curve and the amount of adjustment costs on real variables that are required to overturn the overall baseline results to favour IT.

Our third sensitivity analysis relates to the robustness of our results to the distribution of the shocks. We begin our analysis by re-calculating optimized PLPT and IT monetary feedback rules separately for each of the major types of domestic shocks in Canada, first under the base-case calibration and then under the assumption that the weight on lagged inflation in the Phillips' curve is zero. In the case of the baseline calibration, our simulations suggest that IT is preferred in the mark-up and labour supply shocks but that PLPT is favoured in all other shocks (see Tables 10 and 11 for the mark-up shock results). On the other hand, under the alternative calibration of the Phillips' curve, PLPT is preferred in all shocks including the mark-up shocks.

The intuition behind this result can be gleaned by considering the following simple perfectly-forward-looking New Keynesian model:

$$\pi_t = E_t\pi_{t+1} + \kappa_1 y_t + \varrho_{\pi,t} \tag{8}$$

$$y_t = E_t y_{t+1} - \kappa_2(i_t - E_t\pi_{t+1} - i_t^*) + \varrho_{y,t} \tag{9}$$

$$i_t = \kappa_3(\pi_t) \tag{10}$$

where κ_1, κ_2, > 0 and $\kappa_3 > 1$.Consider a positive price-mark-up shock (Figure 10, Panel A). PLPT offers disadvantages and advantages relative to IT. On the downside, the simple idea of having to return the price level to its target, 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 must

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

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 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.

Although things are a bit different in a positive demand shock, the expectations channel is again key (Figure 10, Panel B). 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. As in the mark-up shock, this implies that inflation 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. Figure 10, Panel B shows that both the cumulative output gap and the variance of the output gap under PLPT is smaller than under IT.

We conclude that, in the simple model, 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. In this exercise we double 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 large and persistent relative price shocks could introduce increased variability in output that would 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. In principle, each shock in each country influences the terms of trade and hence qualifies as a terms-of-trade shock. For our purposes, we limit the analysis to include the set of shocks that are most important for explaining the historical variation in Canada's terms of trade. The variance decomposition from Table 14 suggests that these shocks are a mix of mark-up and demand shocks: i) the Canadian tradable price mark-up shock, ii) the exchange rate shock, iii) the U.S. consumption shock and iv) the U.S. import demand shock. We then re-optimize the simple PLPT and IT rules for this basket of shocks only. Our results show that with this basket of shocks that PLPT is favoured over IT. This result is predicated on the fact that, on average, terms-of-trade movements are associated with a positive covariance between the output gap and inflation. In short, we conclude that under the baseline calibration that PLPT is preferred to IT in terms-of-trade shocks but that this outcome is sensitive to increases in the weight of lagged inflation in the Phillips' curve and to the composition of the basket of the shocks themselves.

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

Lastly, 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. The variability of U.S. demand affects the demand for Canadian exports while the variability of U.S. interest rates affects Canada through the uncovered interest rate parity condition in the model. 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

This paper has examined the relative merits of PLPT and IT in a two-country (United States - Canada) version of GEM. We have shown that PLPT is more advantageous than IT the less contemporaneous inflation and output are predetermined, the more weight that is placed on inflation variability in the loss function and the more important demand and productivity shocks are in the economy compared to mark-up or labour supply shocks.

We have also focused on two important open economy elements of the PLPT - IT debate. First, our baseline suggests that, on net, the macroeconomic implications of terms-of-trade shocks are best stabilized by PLPT rules. This result is, however, sensitive to the source of the movement in the terms of trade, the extent to which contemporaneous inflation and output are predetermined and the relative weights of inflation and the output gap in the loss function. Lastly, we examined whether or not the choice of monetary policy framework in the Canada is influenced by the choice between PLPT and IT in the United States. Our results suggest that the choice of monetary policy framework in the United States does not have any important implications for the Canadian choice.

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 incorporate commodities into the model. 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. Third, we would like to consider other model modifications that would help us match the unconditional moments of the historical data. In addition to these model modifications, we would like to be able to conduct formal welfare analysis.

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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 $\epsilon_{ZU}, \epsilon_{ZI}, \epsilon_{GC}, \epsilon_{GI}, \epsilon_{GN}, \epsilon_{\nu_E}, \epsilon_i$	Productivity $\epsilon_{ZT}, \epsilon_{ZN}$	Prices $\epsilon_{\theta_T}, \epsilon_{\theta_N}, \epsilon_{\psi}, \epsilon_{ZV}$	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

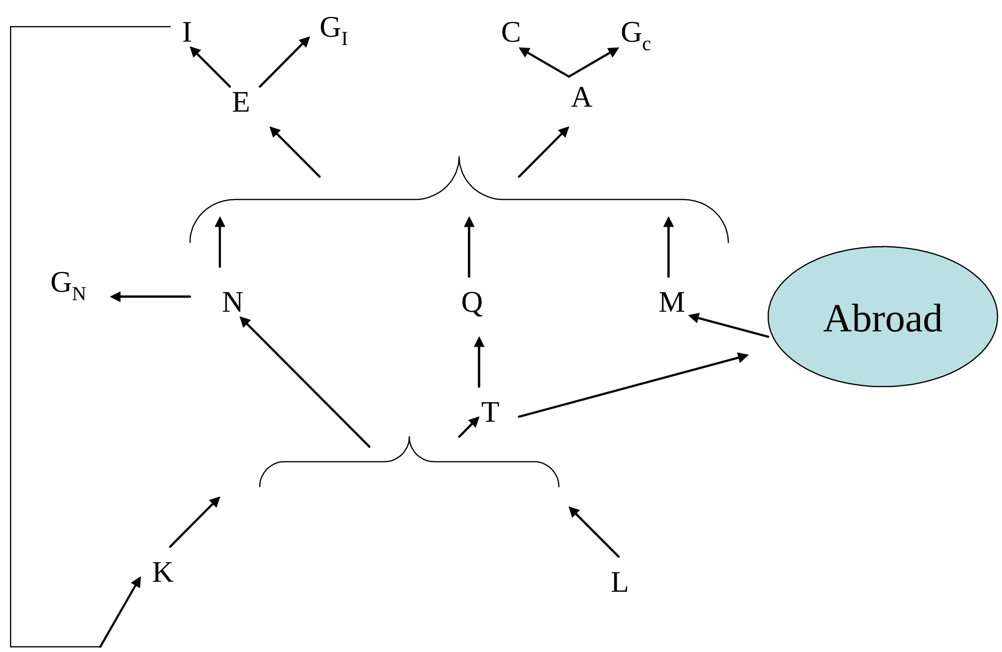

Figure 2: Autocorrelation Functions: The GEM Against Historical Data in Canada - Part I

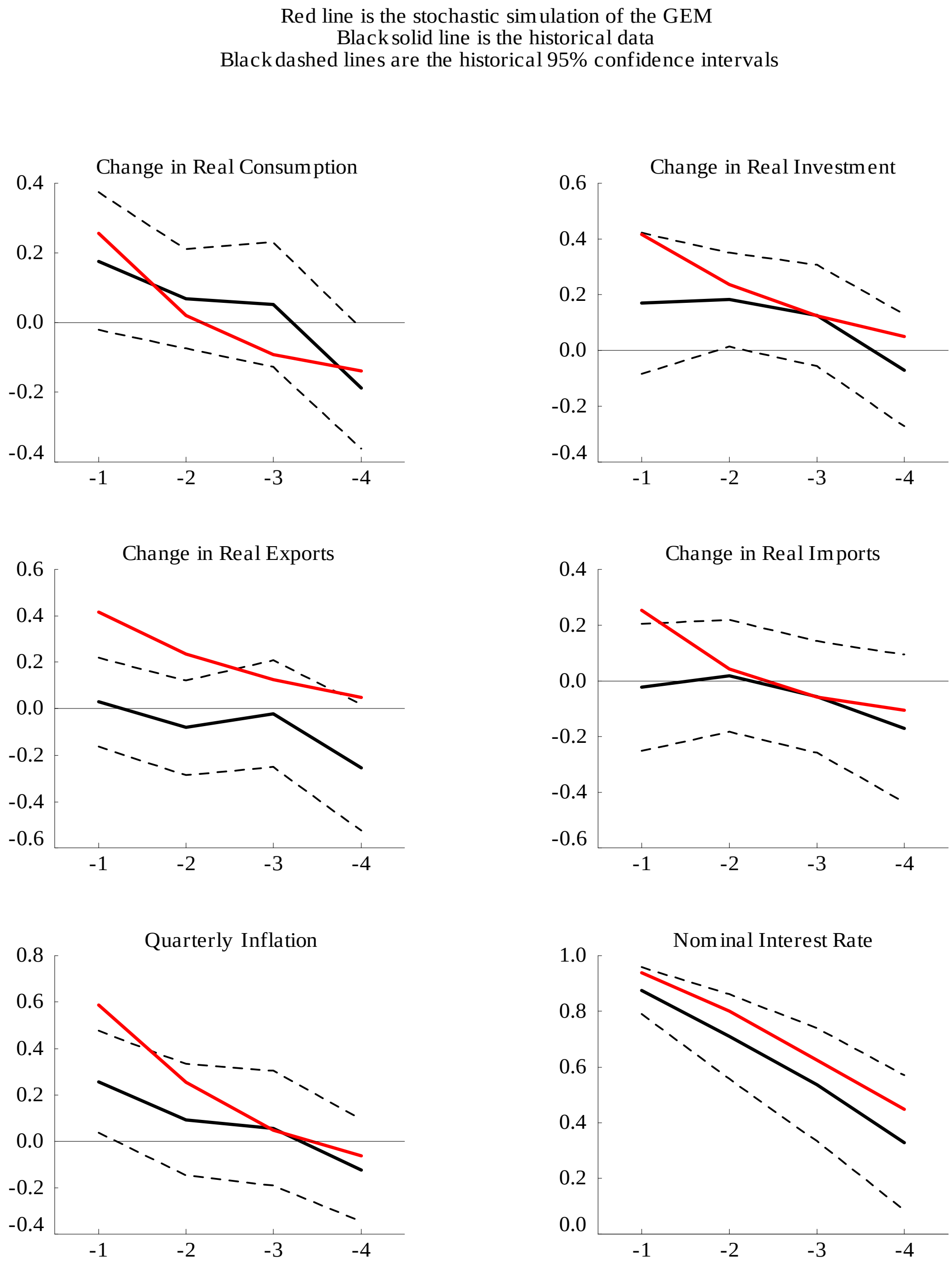

Figure 3: Autocorrelation Functions: The GEM Against Historical Data in Canada - Part II

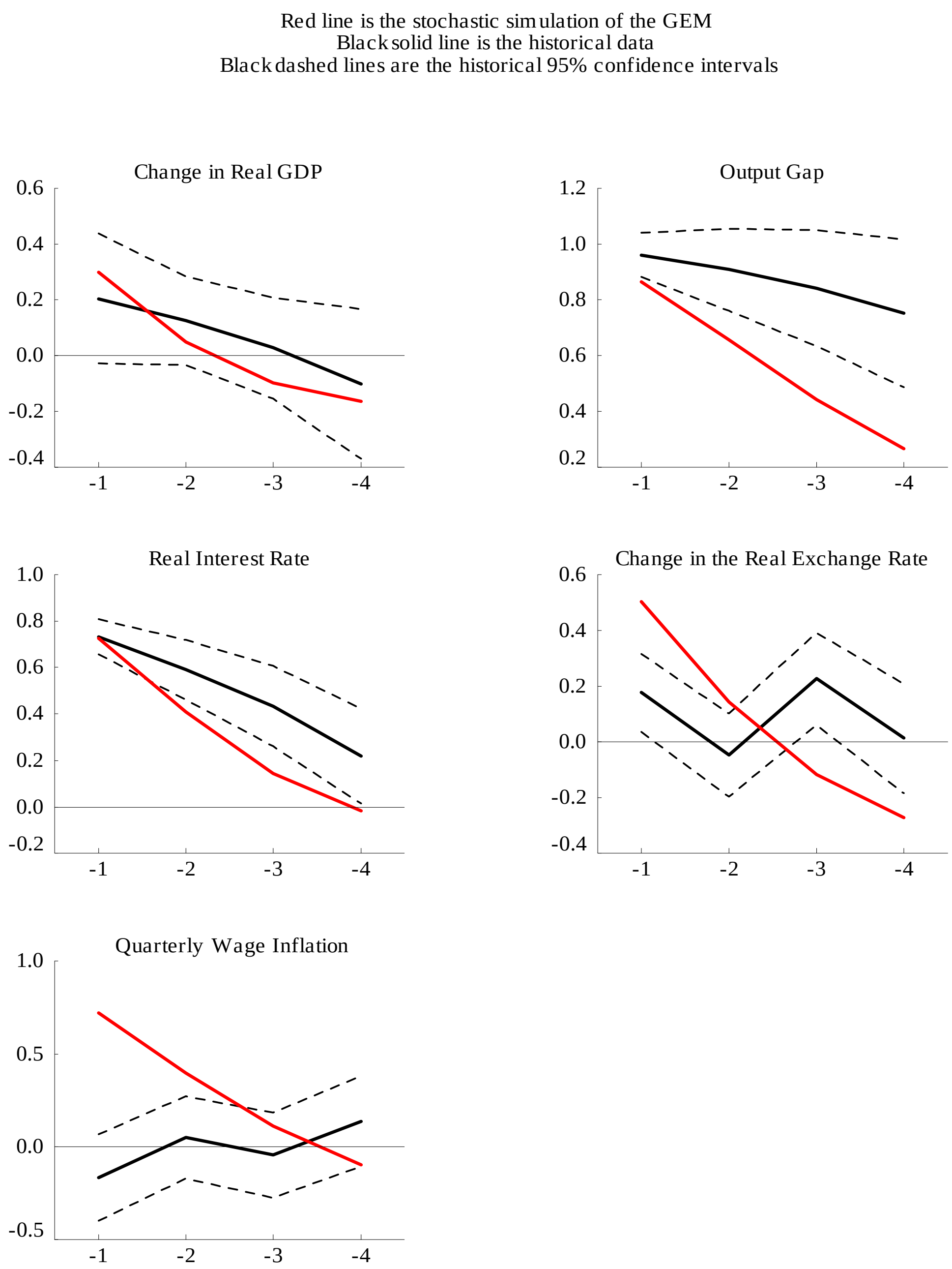

Figure 4: Temporal Cross-correlation Functions: The GEM Against Historical Data in Canada - Part I

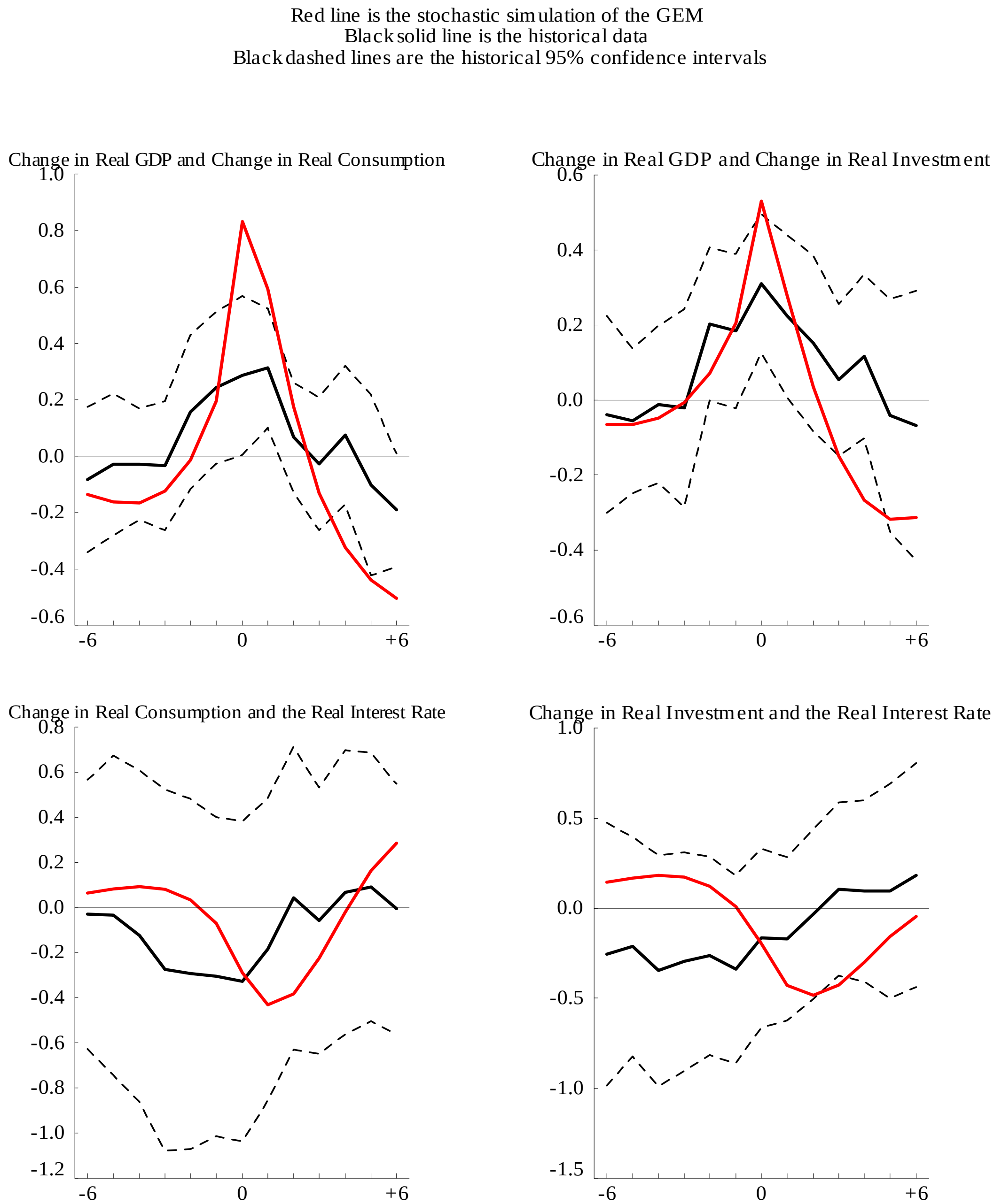

Figure 5: Temporal Cross-correlation Functions: The GEM Against Historical Data in Canada - Part II

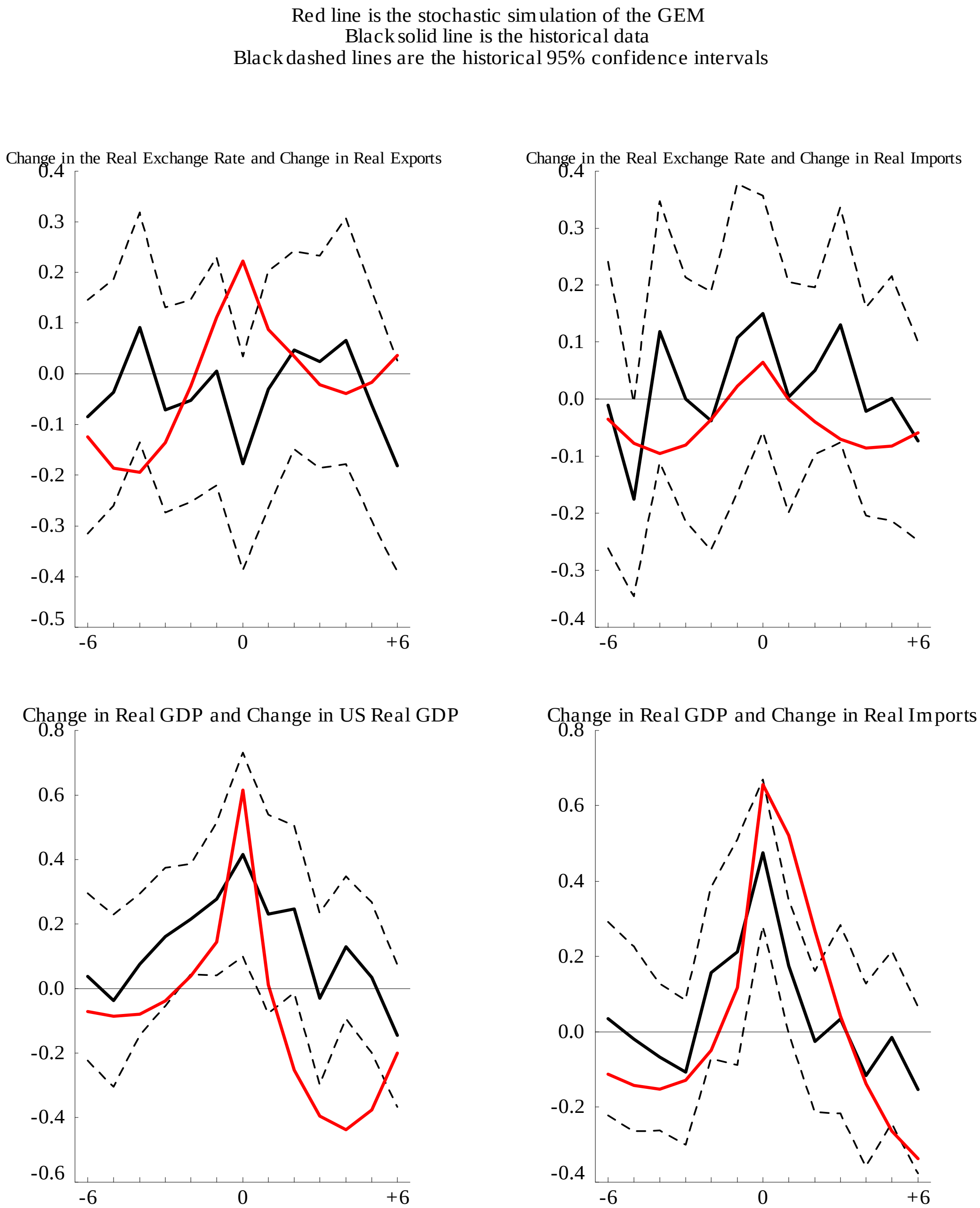

Figure 6: Temporal Cross-correlation Functions: The GEM Against Historical Data in Canada - Part III

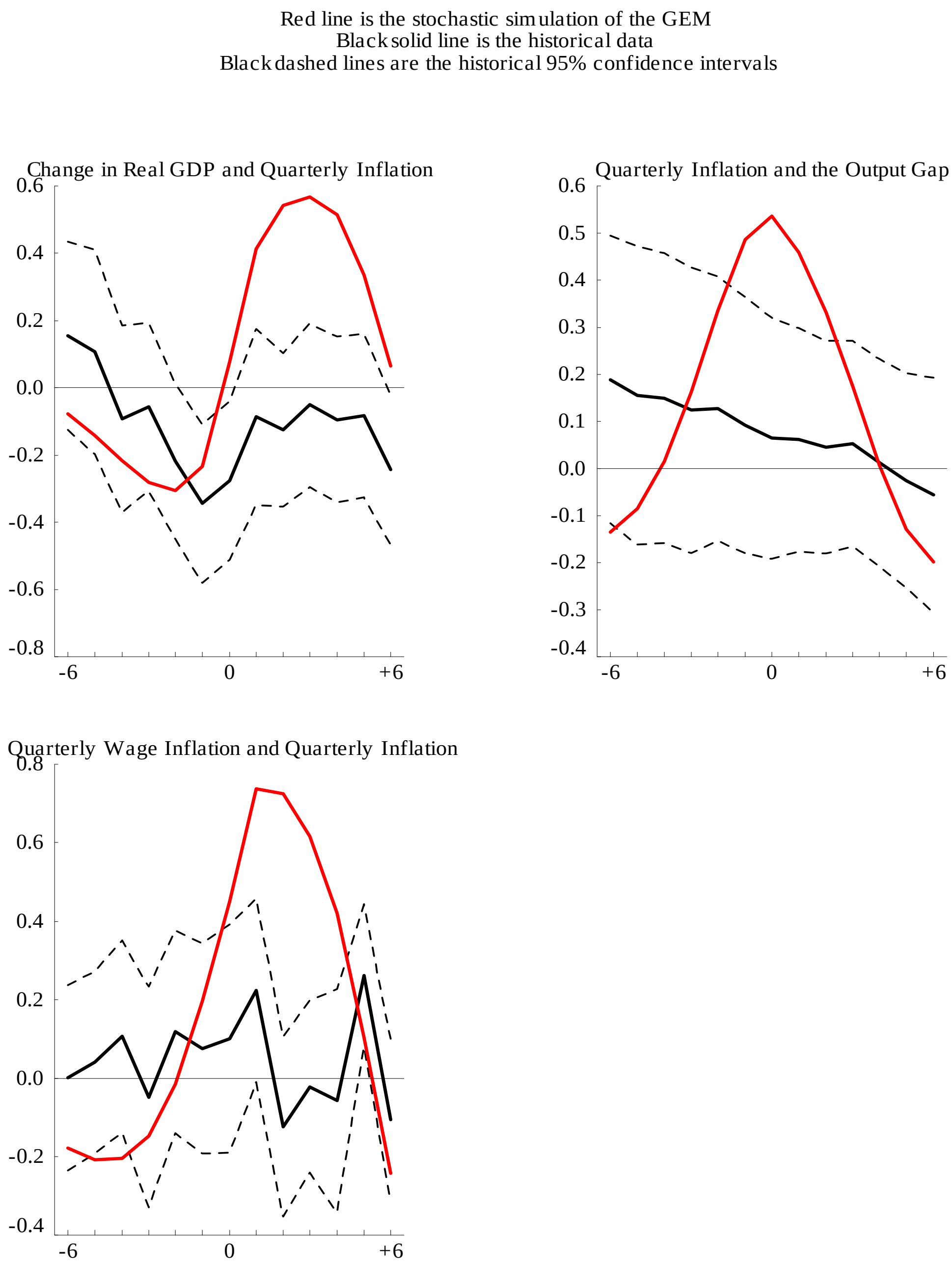

Figure 7: A Positive Shock to the Short-term Interest Rate in Canada - Impulse Responses

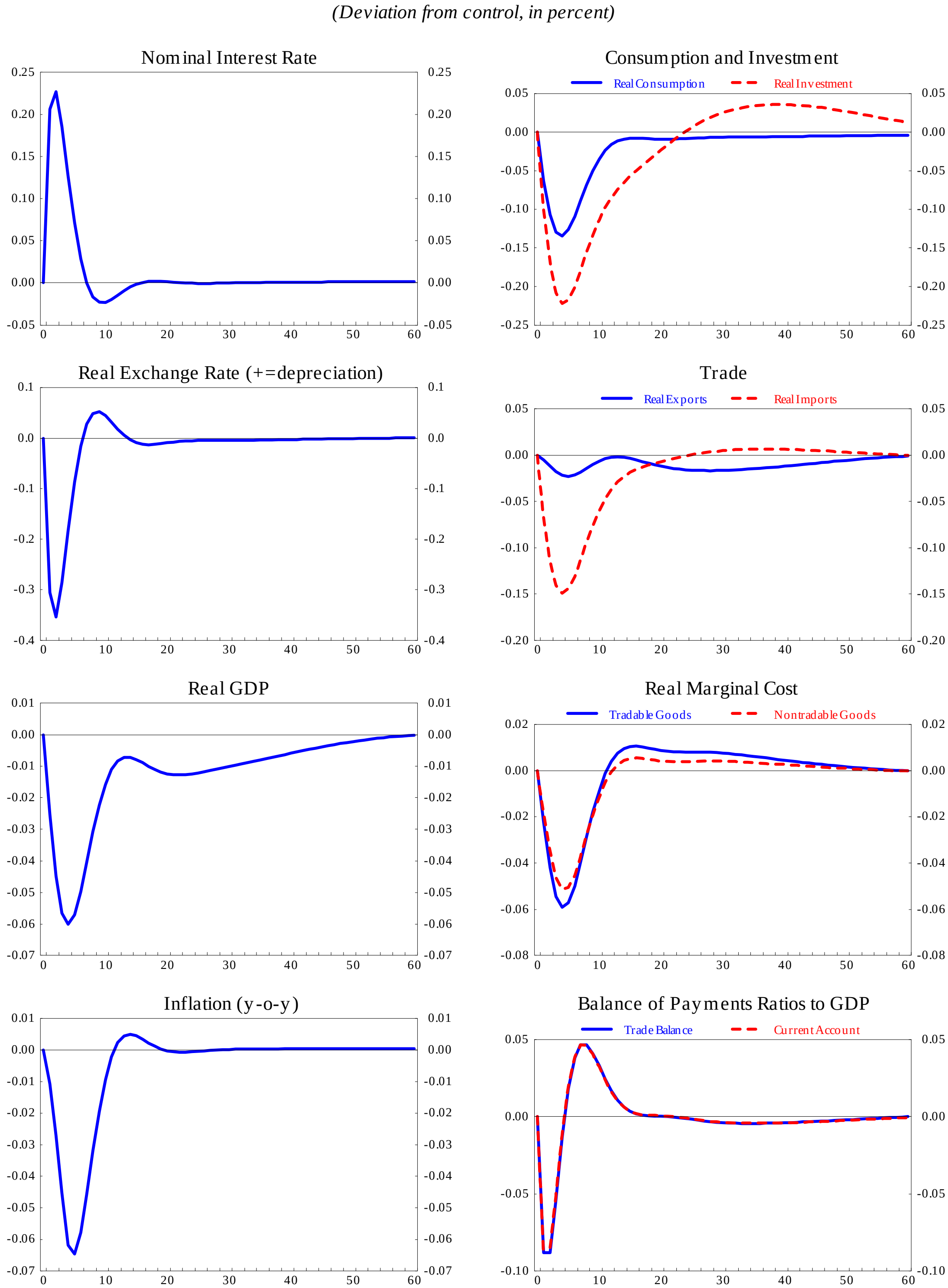

Figure 8: A Positive Shock to Competitiveness in the Labour Sector in Canada - Impulse Responses

(Deviation from control, in percent)

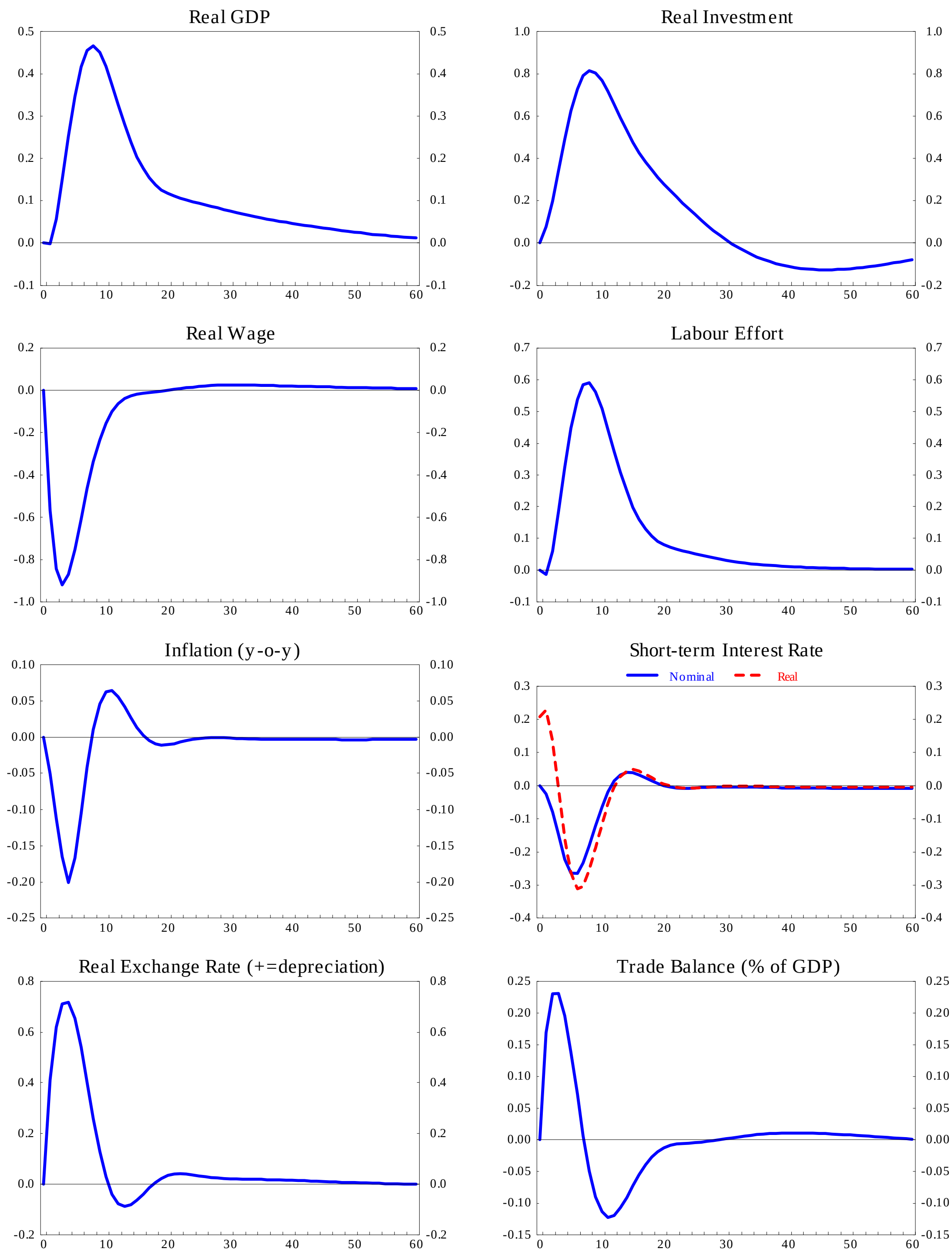

Figure 9: A Negative Shock to Import Demand in the United States - Impulse Responses

(Deviation from control, in percent)

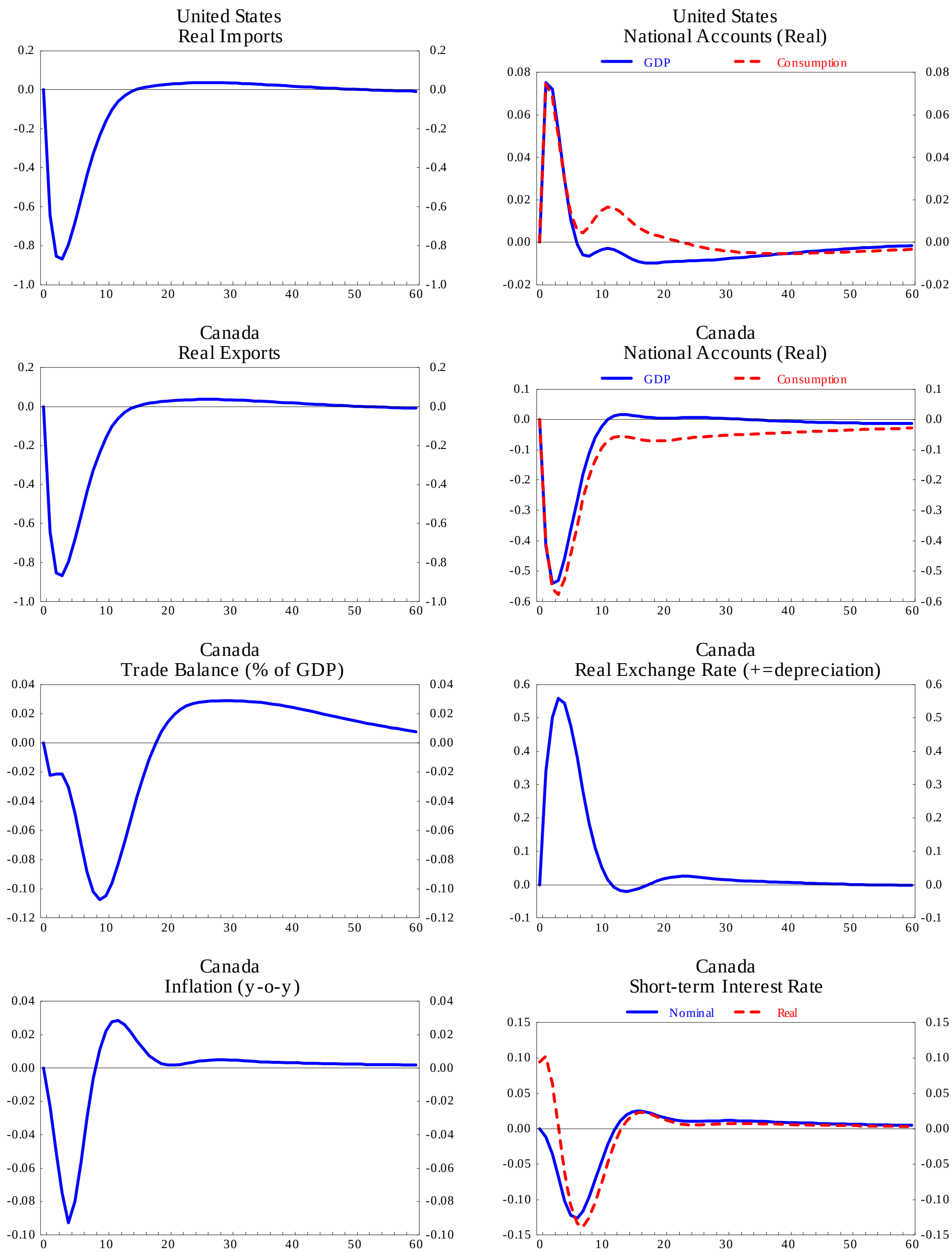

Figure 10: The Relative Merits of IT Versus PLPT - Some Intuition Using a Simple Model With No Indexation