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Abstract

We examine the relative ability of simple inflation targeting (IT) and price level targeting (PLT) monetary policy rules to minimize both inflation variability and business cycle fluctuations in Canada for shocks that have important consequences for global commodity prices. We find that commodities can play a key role in affecting the relative merits of the alternative monetary policy frameworks. In particular, large real adjustment costs in energy supply and demand induce highly persistent cost-push pressures in the economy leading to a significant deterioration in the inflation – output gap trade-off available to central banks, particularly to those pursuing price level targeting.

JEL classification: E17, E31, E37, E52, F41, Q43
Bank classification: Economic models; Inflation and prices; Monetary policy framework; International topics

Résumé

Les auteurs examinent la capacité relative de règles simples de ciblage de l'inflation et de ciblage du niveau des prix à minimiser tant la variabilité de l'inflation que les fluctuations économiques au Canada lorsque les chocs subis ont d'importantes retombées sur les cours mondiaux des produits de base. Ils constatent que ces derniers peuvent jouer un rôle déterminant dans les mérites relatifs de ces deux types de règles de politique monétaire. En particulier, des coûts d'ajustement réels considérables de l'offre et de la demande d'énergie engendrent des pressions très persistantes sur les coûts et donc sur l'inflation. Ces pressions entraînent une nette détérioration de l'arbitrage entre l'inflation et l'écart de production, surtout pour les banques centrales qui poursuivent une cible de niveau des prix.

Classification JEL : E17, E31, E37, E52, F41, Q43
Classification de la Banque : Modèles économiques; Inflation et prix; Cadre de la politique monétaire; Questions internationales

1 Introduction

Every five years, the Government of Canada and the Bank of Canada renew their agreement regarding the framework guiding the conduct of monetary policy. In 2006, the Bank of Canada identified several topics that required further research. Among them was the relative merits and costs of switching from an inflation target (IT) to a price level target (PLT). One potential complication associated with targeting the level of prices is the presence of persistent terms-of-trade shocks. In a background document on the renewal of the inflation control target, the Bank of Canada asked: "What are the relative merits of inflation targeting versus price level targeting in an open economy susceptible to large and persistent terms-of-trade shocks?" (Bank of Canada 2006). In Canada, the terms of trade are dominated by commodity price shocks. Under a credible inflation targeting regime, the central bank could potentially look through the effects of commodity price shocks on inflation, but under a price level targeting regime, the central bank will need to reverse the initial effect of such shocks on aggregate prices by generating offsetting price level movements in other sectors. This process could be costly in terms of output and inflation variability – particularly for commodity price shocks as they tend to be both persistent and volatile.

Coletti, Lalonde and Muir (2008) analyzed the effect of terms-of-trade shocks on the relative merits of IT versus PLT in a Canada-U.S. configuration of the Bank of Canada's version of the Global Economy Model (BoC-GEM). They concluded that PLT can do a better job at macroeconomic stabilization (that is, a lower variance of inflation and the output gap) than IT for the types of shocks that drive most of the fluctuations of the Canadian terms of trade. Their study is subject to two main caveats. First, they use detrended variables which underestimate the persistence of term of trade shocks. Second, their version of BoC-GEM does not explicitly include the energy and non-energy commodity sectors to drive their terms-of-trade shocks. These two sectors differ from an aggregated representation of the tradables sector in several important aspects. Commodity sectors are often characterized by notably inelastic short- and medium-term demand and supply curves. These real adjustment costs are particularly important for the energy sector. As a consequence, commodity demand and supply shocks tend to have very persistent and large effects on commodity prices which, as previously mentioned, could be difficult to handle under PLT. This paper tries to address these two main caveats by using the full global version of BoC-GEM and, more importantly, including explicit non-energy and energy commodity sectors. In accordance with the literature and empirical evidence, this DSGE framework assumes strong real adjustment costs in both the demand and the production of energy and non-energy commodities. Another reason for sluggish adjustment in the supply of commodities is the presence of a fixed factor of production. From the perspective of macroeconomic stabilization, we focus our attention on the relative merits of IT versus PLT under the presence of permanent (or very persistent) demand and supply shocks in the energy and non-energy commodity sectors.

More precisely, we define a permanent demand shock for all commodities as a permanent increase of the productivity level of the tradable and non-tradable sectors in all the commodity-importing regions, including emerging Asia and the United States. Permanent supply shocks are defined as permanent increase of the productivity in the energy and non-energy commodities sectors separately. For each of these shocks, we determine forward-looking interest rate feedback rules that minimize a loss function based on the variances of inflation, output gap and the change of the nominal interest rate, under both IT and PLT.

Results show that adding an energy sector to the analysis can have important implications for the choice of monetary policy regime. For the cases of a permanent energy supply shock and a global permanent demand shock for both energy and non-energy commodities, we conclude that PLT is inferior to IT. The advantage of IT is particularly important for the demand shock as this shock induces a persistent increase of both relative prices of energy and non-energy commodities. The relative advantage of IT is explained by the short- and medium-term real adjustment costs present in the demand and the supply of both energy and non-energy commodities. Sensitivity analysis demonstrates that these results are robust to targeting headline or core CPI inflation, and, to some extent, to the parameterization of the loss function. As shown in previous studies on the relative merits of IT versus PLT, the level of indexation or inertia in the inflation process for prices and nominal wages is critical for the results.

The paper is organized as follows: Section 2 reviews some of the basic stylized facts about commodities. Section 3 describes the features of model relevant to this study. Section 4 discusses the methodology and examines the results. Section 5 concludes and outlines directions for future research.

2 Stylized facts

In considering the implications of commodities for the framework of monetary policy, it is useful first to identify some regularities affecting this sector. The global nature of commodities markets, the source of fluctuation of commodity prices, the elasticities of demand and supply of commodities, and the persistence of trends in commodity prices are all important factors to consider. In this section we briefly review the available literature and evidence.

Commodity prices tend to be determined by global markets rather than being heavily influenced by local costs of production or levels of demand. Thus, although there are differences in prices for different grades of crude oil (Brent light, West Texas Intermediate, heavy oil), there remains a single global market for crude oil, which is a tradable commodity par excellence (Gurcan Gulen, 1999; Kleit, 2001). Other forms of energy have less integrated regional markets. For instance, the transportation of natural gas depends primarily on a limited number of pipelines linking producers with consuming countries, primarily within North America and Europe – including Russia (Serletis and Rangel-Ruiz, 2004). As a result, natural gas prices can differ significantly across different regional markets.

Non-energy commodities are more differentiated than energy. The price index used for calibration purposes in this paper, the IMF's non-energy commodity price index, includes a composite of different commodities, including metals, food and other agricultural products. For example, in many countries agricultural commodities are subject to trade barriers, production quotas, and price support mechanisms. Nevertheless, Table 1 shows that, between 1995 and 2010, the three components of non-energy commodities are strongly correlated with the total non-energy index. Therefore, in the BoC-GEM, we assume more product differentiation for the non-energy commodity sector than the energy sector.

In recent years, China has become a large player in international trade. As a result, fluctuations in the prices of oil and other commodities may be dominated by demand shocks, even though supply and speculative demand factors still play a role. Table 1 shows that, from 1995 to 2010, commodity prices, including oil, are positively correlated with each other. All else being equal, this points toward a large role for demand shocks as these shocks tend to move different commodity prices together while supply shocks tend to be sector specific. Gervais, Kolet and Lalonde (2010) demonstrate that, since the mid-90s, both the price of oil and non-energy commodities could be explained most notably by Chinese demand. In a structural VAR framework, Kilian and Murphy (2010) demonstrate that the fluctuations of the price of oil are dominated by demand shocks. Elekdag et al. (2008) show that, during the run-up of oil prices over the 2000-2007 period, the successive persistent/permanent revisions of the path of the future price of oil were systematically linked to the successive upward revisions of real global GDP. These revisions were particularly evident in emerging Asia's real GDP. By using the IMF's Global Economy Model (GEM) with an energy (oil and natural gas) sector (the predecessor to BoC-GEM), Elekdag et al. (2008), show that a combination of productivity shocks and energy intensity shocks in China can explain a large share of the increase of the price of energy between 2000 and 2007.

The assumed level of real adjustment costs in both the production and the usage of energy and non-energy commodities, which govern the "steepness" of the demand and the supply curves in BoC-GEM, is potentially important for this study. In order to measure the short term sensitivity of oil and other commodity prices to movements of demand (e.g. to proxy the elasticity of demand) we analyze the relationship between global GDP and the commodity prices. Figure 1 plots global real GDP growth and the rates of change of real prices of oil and non-energy commodities. Metals, food, and agricultural raw materials prices are divided by the U.S. GDP price deflator. In general, there is a relatively strong positive correlation between real commodity prices and economic activity.

In Table 2, we report the results of simple bivariate GMM regressions between the change in real commodity prices and economic growth over the 1995-2010 period. Results are robust to the choice of instruments and to the exclusion of the financial crisis period from the estimation sample. Our regression model suggests that the elasticities of real metals and crude oil prices to changes in real economic growth are quite high, implying that a 1 percentage point increase in GDP growth raises their relative prices by 11 per cent and 13 per cent, respectively. The elasticity of other agricultural products' prices and food prices to changes in real economic activity is much less pronounced, at about 4, reflecting more flexibility in supply and lower income elasticities of demand (IMF 2006). Overall, the global price elasticity of demand for non-energy commodities is about 6 – well below the price elasticity of oil demand.

Using a cointegration model framework, Gervais, Kolet and Lalonde (2010) report similar results. In their model, a 1 per cent increase of global GDP generates a peak response of 15 per cent in the price of oil and 4 per cent in non-energy commodity prices. For the price elasticity of oil demand, Krichene (2002) provides a comprehensive survey of the literature and concludes that "...most of the studies tend to establish a highly price-inelastic [crude oil and natural gas] demand schedule in the short-run and a more elastic, though still lower than unity, demand price elasticity in the long run." Baumeister (2009), using a time varying coefficient VAR framework, shows a noteworthy and continuous steepening of the oil demand curve over the 1980-2006 period. According to her results, over most of the 1970-1985 period a 1 per cent decrease in oil supply generated a rise in the price of oil of around 2 per cent compared to around 10 per cent in the later sample.

The persistence of the increase in the real prices of energy and non-energy commodities, while linked to the role of real adjustment costs in the usage and production of commodities, can also be considered on their own. Table 3 shows the results of unit root tests for the real prices of several commodities over different samples. Even over a large sample from 1957 to 2010 (including or excluding the financial crisis), the presence of a unit root cannot be rejected for the real prices of oil, food and metals. The only exception is the price of other agricultural products, which appears to be stationary.

Overall, this evidence indicates that:

- the supply and demand curves for commodities are very inelastic particularly for oil and metals.
- real commodity prices are affected by permanent, or at least very persistent, demand and supply shocks.
- especially since 1995, the real prices of both energy and non-energy commodities are dominated by demand shocks.

In this paper, we explicitly take into account effects of these three features of global commodity markets when analyzing the preferred choice for the Canadian monetary policy regime.

3 The theoretical model

Our analysis is conducted using the Bank of Canada's version of the Global Economy Model (BoC-GEM). The BoC-GEM is a dynamic stochastic general equilibrium (DSGE) model based on the GEM (Global Economy Model) built at the IMF (Pesenti, 2008, and Faruqee et al., 2007). The BoC-GEM is particularly well suited for our purposes because it was both designed to study the international transmission of shocks that have an impact upon commodity prices. Further, the model is carefully calibrated to match some of the salient features of the global economy, including those for the commodity markets discussed in the previous section and those for the Canadian economy as a whole. In this section we provide an overview of the model and its calibration with an emphasis on the supply and demand for commodities. A more complete discussion of the structure and the calibration of the BoC-GEM can be found in Lalonde and Muir (2007).

3.1 Model description

In the BoC-GEM, the global economy is divided into five regional blocs: Canada (CA), the United States (US), emerging Asia (AS), the commodity exporters (CX), and the remaining countries bloc (RC). AS aggregates China, India, Hong Kong SAR of China, South Korea, Malaysia, the Philippines, Singapore and Thailand. CX includes the world's most prominent exporters of energy and non-energy commodities (except Canada): the OPEC countries, Norway, Russia, South Africa, Australia, New Zealand, Argentina, Brazil, Chile and Mexico. RC is dominated by Europe and Japan.

Each regional bloc is populated by households that consume and supply labour, firms that produce raw materials, 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 2.

Consumption goods and investment goods are final goods purchased by private and public agents but are not traded internationally. Final goods are produced by perfectly competitive firms that combine intermediate goods as inputs.

Three intermediate goods – tradable goods, non-tradable goods and refined energy products (henceforth gasoline) – are produced by monopolistically competitive producers for the domestic market, and also, in the case of tradable goods, for export. Intermediate goods are produced by combining labour, capital and commodities. Capital and labour are mobile across production sectors, but immobile internationally. Commodities, on the other hand, are mobile across sectors as well as internationally. Firms purchase capital in perfectly competitive capital markets and labour in monopolistically competitive labour markets. Firms can adjust their use of both capital and labour but face real adjustment costs when changing the capital stock and investment. In accordance with empirical evidence, we also assume that is very costly for firms to adjust commodity usage in the production of intermediate goods.

Since each intermediate producer's good is differentiated from those produced by other firms, each producer is able to set a price above its real marginal cost, allowing for a positive mark-up. Deviations from markup pricing occur in the case of the tradable and non-tradable goods producing firms, because these firms face costs for modifying their prices in the short-term (as in Rotemberg, 1982, and Ireland, 2001). As a result, the model's linearized Phillips curves take a similar form to the hybrid New Keynesian Phillips' curve as in Galí and Gertler (1999):

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

where $\hat{\pi}$ is the deviation of the inflation rate from its target, ϕ_1 is the nominal adjustment cost parameter, ϕ_2 is another nominal adjustment cost parameter that drives the weight on the lagged inflation (equivalent to the level of indexation), E_t is an expectations operator conditioned by information available at time t, β is the discount rate, θ_t is the elasticity of input substitution and $\widehat{mc}$ denotes the deviation of real marginal cost from its steady-state.[1] A similar linearized Phillips' curve exists in the labour market for wage inflation. Price inflation in the case of the energy, non-energy commodities and gasoline sectors, is a function of the real marginal cost gap because there is a lack of nominal rigidities. Price dynamics in those sectors are driven by the real adjustment costs on the returns to capital and labour, intrinsic to their real marginal costs.

The model includes two types of commodities – energy (oil and natural gas = "oil" in the model structure) and non-energy (agriculture, fishing, forestry, metals and minerals = "commodities" in the model structure). Commodities are produced by combining capital, labour and a fixed factor – "land" in the case of non-energy commodities and "(oil) reserves" in the case of energy production. Figures 3 and 4 illustrate the production structure for energy and non-energy commodities. We assume that commodities producers have some market power, but, unlike intermediate goods producers, changing prices do not incur nominal adjustment costs. On the other hand, we assume the presence of large real adjustment costs in commodity supply. Our specification limits the short-run and mid-run substitutability among the factors of production, while keeping a scope for substitution in the long run.

The model also allows commodity production costs to differ significantly across regional economies, justified by different endowments of resources and different costs of extraction. Despite potentially large differences in marginal production costs, commodity prices move closely together worldwide,

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

especially energy prices, reflecting an assumed very high elasticity of substitution in demand between domestically produced and imported commodities (both energy and non-energy).

3.2 Model calibration

Each regional bloc has been calibrated to reflect its size, as well as trade links with the rest of the world, and the composition of production and spending.[2] Since our focus is the role of commodities, we will primarily describe the calibration of each region's commodity production, demand intensities, and trade flows.

Energy production is the most important among the commodity exporting region (see Table 4). The fixed factor in the production of energy reflects the global distribution of oil reserves (see Table 6). Accordingly, about seventy-five per cent of global energy reserves are assumed to be located in the commodity exporting region, while about 10 per cent are in Canada. The regional intensity of the fixed factor for the production of energy and non-energy commodities are calibrated to be different (see Table 5). For example, OPEC production is far more reserve-intensive than offshore oil fields like those in Norway and the Gulf of Mexico or tar sands production in Alberta, Canada, which rely relatively more on labour and capital inputs. Consequently, the share of crude oil reserves in the production costs of energy in the commodity exporting region is 79.1 per cent, while in Canada it is only 58.4 per cent. In contrast, the share of capital in production is 10.8 per cent for the commodity exporting region, but 27.6 per cent for Canada. Smaller differences exist across regions in the share of the fixed factor in the production of non-energy commodities.

In Table 4, we see that emerging Asia has the highest demand for both energy and non-energy commodities as a share of its GDP. Canada, the United States, and Europe have the lowest demands for energy, at 3.7 per cent, 3.5 per cent, and 2.7 per cent of GDP, respectively. The United States has the lowest purchases of non-energy commodities at 2.6 per cent of GDP. Canada's ratio is fairly high, at 4.5 per cent of GDP, reflecting its role as a producer of downstream, commodity-intensive intermediate goods for export.

The BoC-GEM explicitly models bilateral trade linkages of energy and non-energy commodities based on the IMF's Direction of Trade Statistics and the United Nations' COMTRADE database. Net exports of energy as a per cent of GDP are largest in the commodity exporting region and Canada at 8 per cent and 3.5 per cent of GDP, respectively. Emerging Asia and the United States run the largest trade deficits in energy commodities at 2 and 1.5 per cent of GDP, respectively. Net exports of non-energy commodities are the most important for the Canadian economy at 3.4 per cent of GDP, followed by the commodity exporting region at 2.1 per cent.

Final consumption and investment goods are produced by combining both domestically-produced

[2] The data used to calibrate the model is taken from the U.N.'s COMTRADE database, national accounts from the various countries, and the U.S. Department of Energy. The calibration itself reflects our reading of the key trends apparent in the data since 2003.

and imported non-tradable goods with tradable goods and domestically-produced gasoline. The elasticity of substitution between tradable and non-tradable goods in both consumption and investment goods in each country is 0.5, relatively low as in Faruqee et al. (2007). The substitution between gasoline and other intermediate goods in the final consumption good is set to 0.3, reflecting even less sensitivity to relative price changes. This assumption is a key factor reducing the elasticity of energy demand.

Intermediate tradable and non-tradable goods production combines energy and non-energy commodities, both domestically produced and imported, with capital and labour. In contrast, the gasoline sector only combines domestically produced and imported energy goods with capital and labour. The calibration of the elasticity of substitution between domestic and imported energy is 10. For non-energy commodities, it is 5. The high elasticity of substitution between domestic and foreign energy sources results in a single, global energy price. We allow for greater divergence amongst domestic and imported non-energy commodity prices to reflect the heterogeneity in the types of commodities produced in different regions.

The common elasticity of substitution between the factors of production, capital, labour, and commodities, is set to 0.70 in all of the intermediate goods sectors in all countries. This helps reduce the sensitivity of capital to changes in its relative price (Perrier, 2005). Independent empirical studies suggest that our calibration of the long-run price elasticity of demand for commodities is at the upper range of estimates in the literature. For example, Gately (2004) estimates the long-run price elasticity of global oil demand to be in the range of -0.3 to -0.6. Lord (1991) estimates the long-run price elasticity of demand for a variety of non-energy commodities with an average of -0.3.

The elasticity of substitution among inputs in both energy and non-energy commodities production between capital, labour and the fixed factor, is 0.6. This supply elasticity is also at the upper range of estimates in the literature. For example, Krichene (2002) reports a long-run price elasticity of crude oil (natural gas) supply of 0.3 (0.6) over the 1918-1999 period, with a much lower crude oil estimate of 0.1 (0.8) over the 1973-1999 period. This reflects the change in oil market structure brought about by OPEC in 1973. There is a large range for estimated long-run price elasticities of commodity supply. Moroney and Berg (1999) estimate a long-run oil supply price elasticity between 0.1 to 0.2; while Dahl and Duggan (1996) estimate it to be closer to 0.6. Gately (2004) estimates the long-run price elasticity of non-OPEC oil supply to be in the 0.2 to 0.6 per cent range. The long-run price elasticity of supply for various non-energy commodities as estimated by Lord (1991) and IMF (2006) averaged about 0.3. The higher calibration of the long run elasticity of substitution among inputs in the production and supply of commodities is mitigated by the presence of real adjustment costs which bind for several decades.

There are substantial real adjustment costs in the production of commodities to capture the large costs and time associated with changing production such as opening new mining capacity. To mimic the sluggish adjustment of the demand for energy to changes in relative prices, we assume that energy usage in intermediate goods production is subject to large real adjustment costs. This reflects the observation that over the short-run and mid-run, substitutability towards and away from energy usage in the production of intermediate goods is very limited due to the embodied technology of a fixed capital stock. A symptom of these real adjustment costs is the need to adopt alternative, often more advanced, technology in order to increase energy efficiency in response to higher oil prices. The muted short-run response of energy demand to relative price changes is borne out in a number of empirical studies, best summarized in Krichene (2002).

In contrast, there is considerable evidence that short-run energy demand is quite responsive to changes in income (Krichene 2002). Accordingly, firm adjustment costs are specified as a function of the one-period change in energy usage relative to the industry average, as a share of intermediate goods production. This implies that energy inputs that grow with the scale of production do not incur adjustment costs. Using the non-tradable good (N) as an example, the real adjustment cost, Γ_{ON}, associated with a change in the usage of energy, O, in time t, by firm n is assumed to take the form:

$$\Gamma_{ON,t} = \frac{\phi_{ON}}{2} \left[\left(O_t(n)/N_t(n) \right) / \left(O_{N,t-1}/N_{t-1} \right) - 1 \right]^2 \tag{2}$$

The calibration of ϕ_{ON} is set to 300 to ensure a very muted short-term demand response to changes in prices. Table 7 gives further information on the calibration of the demand-side real adjustment costs in the commodities sectors.

Real adjustment costs in the factors of production are also used to mimic the very sluggish adjustment of commodity supply to changes in relative prices. This reflects the fact that short-run supply is determined by existing capacity and that producers tend to respond to higher prices only after the trend in prices becomes persistent (Krichene 2002). We also assume real adjustment costs in regions that rely heavily on capital intensive production, such as off-shore oil in Norway, the United Kingdom, and the United States, and the tar sands in Canada, are twice as high as those in OPEC countries. Using real adjustment costs, our calibration, found in Table 7, is consistent with the bulk of empirical evidence, which demonstrates that the short-run price elasticity of crude oil and natural gas supply is nil or even negative as in Krichene (2002) and Gately (2004).

In contrast, the supply of energy is responsive to the discovery of new reserves. Krichene (2007) estimates the short-run elasticity of global crude oil production to the discovery of new reserves is 0.2. Our calibration incorporates the assumption that energy supply is more responsive to the discovery of new reserves in regions where production is very reserve intensive such as Saudi Arabia but much less so in more capital intensive regions such as Canada. Thus, our formulation of adjustment costs allows for time-varying price elasticities, extremely low in the short run and higher in the long run, while allowing for a higher degree of short-run responsiveness of energy supply to new reserve discoveries.

The overall size of the adjustment costs on energy supply were calibrated, in part, to match empirical studies of the relationship between real economic activity and energy prices, as shown in the simulations found in Lalonde and Muir (2007). The results are summarized in Table 2. In accordance with empirical results, we assume that the short-run price elasticity of non-energy commodities supply is higher than that of energy, partly because supply responses associated with the planting, gestation, and harvesting of agricultural products are faster than the response of energy production as noted in Lord (1991).Therefore, we calibrate the real adjustment cost parameter in both the supply and demand of non-energy commodities to be two-thirds the size of that for energy.

The ability of the BoC-GEM to capture key features of the commodity sector is further illustrated when we compare the model's response to a supply-driven shock to real energy prices with the results of an International Energy Agency study (IEA 2004). The study concludes that a sustained 40 per cent increase in oil prices would lead global GDP to fall by at least 0.5 per cent in the next year, but with a more limited impact in the longer term. The study also shows that the impact of the oil price shock on each country depends upon the degree of net oil imports as well as on the oil intensity of their economies, with real GDP declining by approximately 0.8 per cent in emerging Asia, 0.5 per cent in the euro area, 0.4 per cent in Japan, and 0.3 per cent in the United States. Lalonde and Muir (2007) show that the calibration of the BoC-GEM exhibits similar peak effects after 3 years on real GDP and broadly matches these regional differences identified by the IEA.

3.3 Model properties

In this section, we describe the results of simulating three shocks with the BoC-GEM: i) the global productivity shock – a permanent increase in global demand for commodities, ii) the global energy supply shock – a permanent decline, and iii) the global non-energy commodities supply shock – also a permanent decline. Consistent with the notion that Canada's terms of trade are largely determined externally, we assume that the shocks occur outside of Canada. For simplicity, we assume that monetary policy in all regions, except emerging Asia, follows an inflation-forecast-based rule for their interest rate feedback rule. For emerging Asia, we assume that their monetary authority pegs the nominal exchange rate to the U.S. dollar. In Canada, the policy rule is similar to that of the Bank of Canada's main projection and policy analysis model, ToTEM (Cayen, Corbett and Perrier 2006):

$$i_t = 0.95 i_{t-1} + 0.05 i^* + 20(\pi_{t+3} - \pi^{TAR}) \tag{3}$$

where π_{t+3} is the year-over-year change in core consumer prices (excluding gasoline) 3 quarters ahead, π^{TAR} is the inflation target, i is the nominal interest rate, and i^* is the equilibrium nominal interest rate.

The first shock that we consider is a positive shock to the global demand for commodities. This is done in the BoC-GEM by permanently increasing the level of total factor productivity in the tradable and non-tradable goods production in the commodity-importing regions (AS, US, and RC), which represent 88 per cent of global GDP.

Figure 5 shows that the commodity-importing blocs experience a permanent rise in real GDP of about 1.5 per cent. As a result, there is an increase in the demand for all factors of production, including energy and non-energy commodities. Because of the short-run insensitivity of energy supply to an increase in the relative price of energy, there is little supply response over the first two years. Instead, there is a rather significant 10 per cent rise in the real U.S. dollar price of energy.[3] Over the long run, the energy supply gradually responds, with about 90 per cent of the long-run response occurring after about 15 years. The shock elicits a more muted response in the non-energy commodities sector because of the lower adjustment costs and a lower intensity of usage in production. As a result, there is a more pronounced short-term supply response and real non-energy commodity prices increase by only 3 per cent in U.S. dollar terms. It only takes about 4 years for 90 per cent of the long-run supply response to occur.

In commodity-exporting countries like Canada, the rise in global commodity prices combined with the fall in imported tradable goods prices implies a positive terms-of-trade shock and hence a rise in real GDP, an appreciation of the currency against the U.S. dollar, and a reduction of imported goods prices. The latter include investment goods, and consequently this produces a rise in potential output.

There are conflicting forces acting on inflation in Canada. On one hand, higher prices for energy and non-energy commodities exert upward pressure on the real marginal cost of production in Canada (particularly for gasoline production), while on the other hand, lower imported goods prices put direct downward pressure on CPI inflation. Lower investment goods prices also encourage capital deepening, which in turn puts downward pressure on production costs. Strength in consumption spending resulting from the improvement in the terms of trade also exerts upward pressure on production costs. On net, headline CPI inflation in Canada increases sharply and there is a mild fall in core CPI inflation. The policy interest rate fall in response to the weaker core CPI inflation outlook, but the monetary reaction to the shock is highly dependent on the specification of the policy rule. An alternative specification based on headline rather than core CPI inflation as an intermediate target would result in a rise in the policy interest rate.

The second and third shocks that we consider are negative supply shocks that highlight different channels for energy and non-energy commodity sectors. The energy supply shock (Figure 6) is a

[3] See Elekdag et al.(2008) for an analysis that isolates the implications of real adjustment costs in the energy sector in a very similar framework.

negative shock to the productivity of energy reserves in CX. This can be thought of as resulting from a number of different events: a decline in the quality of reserves or the adoption of new environmental regulations in the production of energy, among others. For non-energy commodities, we assume a negative shock to the productivity of the fixed factor, land. Unlike the global energy supply shock, this shock is implemented in all of the regions other than Canada, reflecting the greater diversification of non-energy commodities production.

The negative energy supply shock results in a reduction in energy production in CX of about 6 per cent in the long run, with about 90 per cent of that reduction occurring within one year. In the rest of the world, including Canada, energy production rises in response to a higher real global energy price, as new oil fields (for example) become economically viable. However, the supply response is quite slow and this, combined with the very low short-term price elasticity of energy demand, leads to a peak rise of in the real global U.S. dollar energy price of about 20 per cent. This price increase has an overall negative effect on global economic growth, especially for energy importers like emerging Asia, which experiences a permanent decrease in real GDP of 0.2 per cent (versus less than 0.1 per cent of real GDP for the United States and the remaining countries bloc). For Canada, the shock has a small positive impact on the level of real economic activity as the benefit from a rise in the terms of trade more than offsets the fall in Canadian exports. The fall in exports is an important feature that distinguishes this shock from the permanent demand shock. Headline inflation rises 0.7 per cent on impact, while core inflation initially barely increases and subsequently slightly decreases as global demand for Canadian tradable goods is falling. The forward-looking response of monetary policy is to reduce the policy rate by 15 basis points in the first year.

The non-energy commodity supply shock (Figure 7) produces similar, but not identical, responses. The real price of non-energy commodities rises by 4 per cent after one year. As commodities become less available, production worldwide contracts, leading to a slight fall in the real global energy price (by almost 1 per cent) from the negative demand effect. Because of the higher elasticities of supply and demand for non-energy commodities (relative to energy), the commodity importing regions (emerging Asia, and the remaining countries bloc) suffer smaller real GDP losses (around 0.2 per cent of real GDP in the long run). Since the United States is a net exporter of non-energy commodities, its real GDP is virtually unchanged on balance. As a net exporter, Canada benefits from higher real GDP (up 0.1 per cent) for an extended period of time. Monetary policy behaves differently than for the negative energy supply shock, as non-energy commodity prices have a greater effect on core than on headline CPI inflation (since commodities play no added role in headline CPI inflation). Core CPI inflation increases slightly because of the increase in real marginal cost in the tradable and non-tradable sectors (both up roughly 0.2 per cent). The increase in the policy interest rate serves to quell inflationary pressures.

4 IT versus PLT

In the rest of this study, we examine the relative merits of IT and PLT to stabilize the Canadian macro-economy in the face of shocks to global economic activity or to the supply of energy and non-energy commodities.

4.1 Methodology

In order to address this question we still need to characterize both the objectives of monetary policy and how it is implemented. As in Coletti, Lalonde and Muir (2008), we assume that the Bank of Canada works to reduce the amplitude of the business cycle as well as the variability of consumer price inflation. In particular, the Bank seeks to minimize a quadratic loss function given by:

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

where σ_π^2, σ_y^2 and $\sigma_{\triangle i}^2$ are the unconditional variances of the deviations of the year-over-year inflation rate from its targeted level, the output gap, and the first difference of the nominal interest rate, respectively.[4] The quadratic functional form is consistent with the notion that central banks view large deviations from the targets as disproportionately more costly than small variations. In our base case, the weights on the various elements in the function imply that the central bank cares equally about inflation and the output gap. The loss function includes a small weight on the change in the policy rate which serves to eliminate rules that cause excessive volatility in the nominal interest rate.

Monetary policy is characterized by a simple interest rate feedback rule . A generic form, that nests both the IT and PLT rules, is given by equation (4):

$$i_t = \omega_i i_{t-1} + (1 - \omega_i)\, i_t^* + \omega_p(E_t p_{t+k} - \eta E_t p_{t+k-1} - p_{t+k}^{TAR} + \eta p_{t+k-1}^{TAR}) + \omega_y(y_t - y_t^{POT}) \qquad (4)$$

where p_t is the price level, p_t^{TAR} is the price level target, y is (the log of) real GDP, and y^{POT} is (the log of) potential output. The central bank attempts to minimize the loss function (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. A value of η equal to unity indicates inflation targeting; for price-level-path targeting, η is zero.

[4] The output gap is defined as the difference between actual output and potential output. We use a measure of potential output that is consistent with the conventional measure typically used at central banks. This measure is calculated based on an aggregate production function approach found in Butler (1996) where output is evaluated with total factor productivity, the capital stock, steady-state labour supply and the steady-state value of land and oil reserves.

Because of the size of the model, we are unable to optimize policy rules in a stochastic environment, where all shocks are considered simultaneously. Consequently, we are restricted to considering single shocks to the economy. However, this has its advantages. Since the relative incidence of shocks in the economy is not under consideration, we are able to optimize policy rules for single, deterministic shocks. Moreover, we are no longer restricted to temporary shocks, since we do not have to linearize the model around a fixed steady state for its solution. Instead, we are able to solve the full non-linear model. Therefore, we consider the three permanent shocks whose properties we discussed in the previous section. We minimize the loss function for both an IT and a PLT regime in Canada for each shock, by conducting a grid search, varying the values of the coefficients (ω_i, ω_p, and ω_y) and the feedback horizon (k) in our simple interest rate feedback rule.

4.2 Results

Table 8 reports the values of the loss functions, the standard deviations of the output gap, year-over-year headline CPI inflation, and the change in the interest rate for each of the shocks being considered, under both the optimized IT and PLT rules. The ranking of IT and PLT, in terms of their ability to stabilize the macro-economy, depends upon which shock is under consideration. IT is slightly favoured over PLT in the case of the energy supply shock, but it is the opposite for the non-energy commodity supply shock. This difference is driven by the calibration of real adjustment cost parameters, which are estimated to be lower for non-energy than energy commodities, as is explained below. Also, the results show a larger difference between the two regimes for the global commodities demand shock. In this case, the value of the loss function associated with IT is 22 per cent lower than PLT. Table 9 shows that all these results are robust to monetary policy targeting core CPI inflation, instead of headline CPI inflation. To some extent, results are also robust to the parameterization of the loss function. For instance, if we assume that monetary authority puts two times more weight on the inflation than on the output gap, the conclusions are qualitatively unchanged.

To illustrate the intuition behind our results, we will first take the case of the permanent energy supply shock. Under the base case calibration, a negative and permanent shock to the level of energy supply from the commodity exporter results in a persistent rise in the real global price of energy. Prices rise considerably and for a prolonged period, because supply from other regions of the world is slow to adjust and demand for energy is also very inelastic in the short- to medium-term. This affects the responses of headline CPI inflation through two main channels:

- First: Energy is an input of production in the gasoline sector, therefore both the real marginal cost and the final price of gasoline increase.

- Second: Given that energy is an input of production for the tradable and non-tradable intermediate goods, the responses of the real marginal costs of production, and therefore their prices, are more persistent and more variable.

The price of gasoline channel accounts for the difference between the responses of headline and core CPI inflation, as opposed to response of core CPI inflation itself. Given that the results are robust to targeting core CPI inflation versus headline CPI inflation, the dominant channel is the channel related to the real marginal cost of intermediate goods. The persistent effect of energy and non-energy commodity prices on real marginal cost affects inflation in much the same manner as the indexation of nominal wages and prices – it creates inflation persistence that is harder to tackle under PLT. Under IT, to some extent, a credible monetary policy can ignore the persistent response of prices induced by the additional persistence of the real marginal cost and focus only on reversing the increase in the inflation rate, and bring it back to its target. In contrast, under PLT, the monetary authority needs to fully reverse the effect on the level of prices. This reversal is complicated by the persistent response of real marginal cost and prices caused by the inelastic demand and supply of energy and non-energy commodities. All else being equal, as with the indexation of nominal wages and prices, a mechanism that increases the persistence and variability of inflation will also increase the macroeconomic fluctuations under a PLT regime.

For the permanent commodities demand shock, the superiority of IT is linked to the fact that this shock is an increase in the level of productivity in the economy, which has a pervasive and positive effect on the demand of both energy and non-energy commodities. Therefore, when facing this kind of demand shock under PLT, monetary policy needs to reverse the effects on aggregate prices of increases of both energy and non-energy commodity prices as opposed to only one of these prices, as is the case for a supply shock.

In order to show the key role played by the inelastic demand and supply curves of commodities in driving our results, we compare the base-case calibration with an alternative counterfactual calibration where we assume zero real adjustment costs associated with the supply and demand for energy and non-energy commodities (see Table 10). In this alternative scenario, supply and demand of energy and non-energy commodities are significantly more elastic than in the base case, which will greatly reduce the persistence and the amplitude of the responses of the prices of these goods. Results show that PLT and IT give practically the same values for the loss function for the case of commodities supply shocks and reduce considerably the difference between the two regimes for the permanent commodities demand shock (that is, a permanent productivity shock). In the case of the global commodities demand shock, under very inelastic demand and supply curves for the energy sector, the value of the loss function is 22 per cent lower under IT than PLT, compared to only 10 per cent if we assume very elastic demand and supply curves. We might expect that assuming no short- and medium- term real adjustment costs in the production and usage of energy and non-energy commodities should invert the result of the base case in favour of PLT, instead of getting only a more similar result between the two policy regimes. However, in the alternative scenario, the production of energy is still based on the fixed factor of production (oil reserves), which continues to limit the capacity of firms to modify their supply of energy rapidly enough to prevent inflation persistence in the wider economy.

In the case of the non-energy commodities supply shock, PLT delivers a slightly better outcome for macroeconomic stabilization than IT. This result is driven by two factors:

- First: the real short- and medium-term real adjustment costs play a smaller role for non-energy commodities than in the energy and gasoline sectors.
- Second: there is no equivalent for non-energy commodities to the real short- and medium-term real adjustment costs in the production and usage of gasoline.

To illustrate these points, we analyze how headline CPI inflation reacts to a non-energy commodity supply shock. The response of headline CPI inflation is mainly driven by three channels:

- First: the rise in the real non-energy commodity prices increases the real marginal costs of the intermediate goods sectors.
- Second: over the short- and medium-term, energy and non-energy commodities are complementary inputs. Therefore, the shock induces a fall in energy demand and prices which offset part of the increase in headline CPI inflation. Given that we assume strong real adjustment costs in energy production and usage, the decrease in the real global price of energy is noticeable when compared to the increase of the real global price of non-energy commodities.
- Third: the fall in the real price of energy generates a decrease in the real price of gasoline that feeds directly into headline CPI. Because of the substantial adjustment costs in the production of gasoline, the fall in the real price of gasoline is noticeable even when compared to the increase in the real global price of non-energy commodities.

The first channel is increasing headline CPI inflation, and its magnitude is positively correlated to the size of the real adjustment costs in the production and usage of non-energy commodities. In contrast, the second and the third channels put downward pressure on headline CPI inflation, and their magnitudes are positively correlated with the size of the real adjustment costs in the production and usage of energy and gasoline. Consequently, the amplitude and the sign of the response of headline CPI inflation depend on the relative importance of real adjustment costs between the non-energy commodities sector and the energy and gasoline sectors. Using the historical rule, Figure 7 shows that the three channels are, to a large extent, offsetting each other, with CPI inflation falling slightly on impact, returning to target after some marginal cycling. Therefore, in accordance with empirical evidence, if we assume that real adjustment costs in the supply and demand of energy and gasoline are stronger than in the non-energy commodities sector, the increase in headline CPI inflation induced by the fall of supply of non-energy commodities is largely compensated by the fall in other real prices, such as those of energy and gasoline. This compensation actually helps to reverse the impact of the shock on the level of the headline CPI under PLT. This compensation effect is not important in the case of an energy supply shock for two reasons. First, we assume substantially stronger real adjustment costs in the energy and gasoline sectors then in the non-energy commodities sector. Second, the price of gasoline moves in the same direction then the price of energy in response to an energy supply shock.

We conduct a sensitivity analysis in which we assume no indexation for nominal wages or prices. Consistent with Coletti, Lalonde and Muir (2008), we confirm that the relative performance of PLT improves when we assume no indexation in nominal wages and prices. In fact, Table 11 shows that PLT is actually slightly better for the permanent commodities demand shock. The lack of indexation also almost entirely closes the gap between the performance of IT and PLT for the permanent energy supply shock.

Finally, we would like to note that a study by Leduc and Sill (2004) presents results that contrast with ours. These authors' simulation results suggest that PLT does a better job in cushioning oil price shocks than IT. While we are not able to identify exactly the source of the difference in results, we would note several differences between our models that are likely to explain it. First, Leduc and Sill (2004) shock exogenous oil prices (estimated to be an AR(1) process, hence not exhibiting a humped-shaped path) rather than determinants of energy supply and demand. Second, their model is of a closed economy. Third, in contrast to this study, which exhibits substitutability with other factors, energy demand is proportional to the utilization rate of capital. Finally, IT and PLT are assumed to hit their respective targets exactly, rather than use feedback rules that have been optimized to minimize discounted present and future deviations from targets. Because of these significant differences, we think that our model framework more accurately reflects how global commodity markets function.

4.3 The role of the model's calibration

Our results demonstrate that the relative performance of inflation targeting (IT) versus price level targeting (PLT) depends on the following:

- The calibration of the supply and demand real adjustment costs of energy and non-energy commodities
- The presence of a fixed factor of production in the energy sector
- The level of indexation of prices and nominal wages.

As seen previously, in the BoC-GEM, the sensitivity of the real price of energy to demand fluctuations is mainly a function of the level of short term supply and demand real adjustment costs combined with the presence of a fixed factor of production. In an attempt to see if the calibration is appropriate, Table 12 compares the BoC-GEM's peak responses of the real prices of energy and non-energy commodities to a 1 per cent shock on global output with results generated by an estimated model that links the price of oil to global output and China's share in global GDP (Gervais, Kolet and Lalonde, 2010). Two-thirds of the shock is attributable to movements in the global output gap and one-third attributable to movements in global potential output. Results demonstrate that the calibration of BoC-GEM assumes slightly more flexibility in the demand and supply of energy and non-energy commodities than the empirical estimates of Gervais, Kolet and Lalonde (2010) suggest. Therefore, the BoC-GEM's calibration somewhat biases the results of its experiments towards PLT. Table 12 also demonstrates that the calibration of the relative strength of the real adjustment costs in the energy sector versus the non-energy commodities sector is in line with the empirical estimate of Gervais, Kolet and Lalonde (2010). We reach this conclusions by comparing the BoC-GEM's baseline calibration with the empirical evidence presented above in Section 2.

The results demonstrate that the relative merits of IT versus PLT also depend on the level of nominal adjustment costs in prices and wages. Since the introduction of the inflation target, inflation persistence had been very low in Canada. The Bank of Canada's Canadian projection model, ToTEM, which is calibrated to replicate the persistence observed in the Canadian data, assumes a slightly lower level of inflation inertia than our calibration. This slightly biases our results toward IT. Note that we only have to assume a small amount of inertia in the inflation process to get the result that IT is superior to PLT for a persistent shock to global demand for commodities.

5 Conclusion

In this paper, we analyze the relative ability of simple interest rate feedback rules optimized for either IT or PLT to limit the variability of inflation and the business cycle in a global model that features explicit energy and non-energy commodities sectors. The model, the BoC-GEM, allows for a role for commodities in the production of goods, services and gasoline while endogenizing the production of commodities themselves. Two important features of the analysis are: i) the role of commodities as a factor of production, and ii) the presence of significant real adjustment costs that make both the supply and demand for energy very inelastic over the short- to mid-term, leading to large and persistent movements in energy prices.

In general, we conclude that adding a realistically calibrated energy sector to the analysis can have important implications for the choice of target by the central bank. When shocks to the supply and demand of energy are very persistent or permanent, the trade-off between the variability of inflation and the variability of economic activity becomes challenging for a central bank pursuing PLT. In particular, in the case of a permanent demand shock for all commodities, results suggest that PLT is likely to be inferior to IT, from a macro-stabilization perspective. This result is crucial, given that the fluctuation of all commodity prices going forward will more likely be driven by demand shocks, as China continues to increase its role as a large player in international markets, during a time of tight supply constraints (particularly in oil markets). Our findings appear to be robust to sensitivity analysis which demonstrate the lack of difference between targeting headline or core CPI inflation, and to some extent, the parameterization of the loss function.

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Table 1: Contemporenous Correlations Between Real Commodity Prices 1995Q1-2010Q4 (Difference of Log.; 1995Q1 - 2008Q3 in parenthesis)

Category	Oil (WTI)	Non-energy	Food	Agriculture
Oil (WTI)	1	-	-	-
Non-energy	0.64 (0.32)	1	-	-
Food	0.52 (0.24)	0.85 (0.81)	1	-
Agricultural products	0.55 (0.39)	0.70 (0.57)	0.40 (0.27)	1
Metal	0.59 (0.27)	0.86 (0.74)	0.52 (0.31)	0.59 (0.29)

Table 2: The Sensitivity of Real Commodity Prices to Changes in Real Economic Activity, 1995-2010

Category	Price Elasticity of Global Output Growth
Oil	12-14
Non-energy	6-7
Food	3-4
Agricultural products	4-5
Metal	11-12

All significant at least at 5%

Range of estimates depending on the set of instruments included

Results are robust to the exclusion of the financial crisis (2008Q3-2010Q4)

Table 3: Unit Root Tests Without Deterministic Trend (ADF Tests)

Category	1957Q1-2010Q4	1972Q1-2010Q4	1980Q1-2010Q4	1986Q1-2010Q4
Oil (WTI)	-	-1.40 (5)	-1.02 (5)	-0.30 (5)
Non-energy	-	-	-2.37 (2)	-0.99 (2)
Food	-1.59 (3)	-1.28 (2)	-2.98* (2)	-1.44 (2)
Agricultural products	-4.22** (1)	-3.74** (1)	-2.85 (1)	-2.37 (1)
Metal	-2.23 (1)	-1.81 (1)	-1.70 (1)	-1.24 (1)

Critical values without trend (1% = -3.49**, 5% = -2.89*)

Results are robust to the lag selection methodology (lag included in the test in parenthesis)

Results are robust to the inclusion of a deterministic trend

Table 4: Demand and Production of Commodities and Other Goods in the BoC-GEM

	CA	US	CX	AS	RC
Production (% share of GDP)					
Tradables	43.3	40.1	35.3	50.9	41.1
Non-tradables	53.5	56.0	62.3	46.5	56.1
Energy	7.3	2.0	11.9	2.8	2.2
NE commodities	8.0	3.3	6.6	4.1	2.1
Demand (% share of GDP)					
Energy	3.7	3.5	3.9	4.8	2.7
NE commodities	4.6	2.6	4.5	5.2	2.9

Note: Production sums to more than 100, since both intermediate goods (not included in GDP) and final goods are reported.

Table 5: Factor Incomes in the Commodities Sectors of the BoC-GEM

	CA	US	CX	AS	RC
Energy (% share of production)					
Capital	27.6	19.6	10.8	20.5	25.2
Labour	14.0	11.2	10.1	24.5	11.5
Reserves	58.4	69.2	79.1	55.0	63.3
Non-Energy (% share of production)					
Capital	25.1	21.9	19.0	23.3	22.2
Labour	20.8	23.1	21.8	22.0	25.0
Land	54.0	55.1	59.2	54.7	52.9

Table 6: Distribution of Crude Oil Reserves Around the World (Per Cent)

	CA	US	CX	AS	RC
BoC-GEM	14	6	75	4	2
Data	11	4	81	3	1

Table 7: Real Adjustment Costs in the BoC-GEM

Parameter	CA	US	CX	AS	RC
Energy (Oil) Sector					
Capital for producing oil ϕ_{KO}	400	300	200	300	300
Labour for producing oil ϕ_{LO}	400	300	200	300	300
Demand for oil in production. ϕ_{OT}, ϕ_{ON}	300	300	300	300	300
Gasoline Sector					
Capital for producing gasoline ϕ_{KGAS}	500	500	500	500	500
Labour for producing gasoline ϕ_{LGAS}	500	500	500	500	500
Demand for gasoline in production. ϕ_{OGAS}	300	300	300	300	300
Non-Energy Commodities (Commodity) Sector					
Capital for producing commodities ϕ_{KS}	200	200	200	200	200
Labour for producing commodities ϕ_{LS}	200	200	200	200	200
Demand for commodities in production. ϕ_{ST}, ϕ_{SN}	200	200	200	200	200

Table 8: Standard Deviations of Key Variables Under the Optimized Rules: The Base Case

	Productivity			Energy Supply			Non-energy supply		
	IT	PLT	IT/PLT	IT	PLT	IT/PLT	IT	PLT	IT/PLT
Loss function	0.14	0.18	**0.78**	1.27	1.34	**0.95**	1.49	1.41	**1.06**
Headline CPI inflation	0.04	0.11	0.36	0.90	0.96	0.94	0.86	1.15	0.75
Output gap	0.09	0.07	1.29	0.36	0.37	0.97	0.63	0.25	2.52
Interest rate (chng)	0.02	0.03	0.67	0.04	0.06	0.67	0.10	0.13	0.77

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

	Productivity			Energy Supply		
	IT	PLT	IT/PLT	IT	PLT	IT/PLT
Loss function	0.275	0.311	**0.88**	0.146	0.181	**0.81**
Headline CPI inflation	0.175	0.209	0.84	0.079	0.065	1.22
Output gap	0.099	0.102	0.97	0.064	0.115	0.56
Interest rate (chng)	0.000	0.004	0.03	0.029	0.008	3.63

Table 10: Standard Deviations of Key Variables Under the Optimized Rules: No Real Adjustment Costs in the Commodities Sectors

	Productivity			Energy Supply			Non-energy supply		
	IT	PLT	IT/PLT	IT	PLT	IT/PLT	IT	PLT	IT/PLT
Loss function	0.047	0.052	**0.90**	0.007	0.007	**1.00**	0.037	0.036	**1.03**
Headline CPI inflation	0.024	0.030	0.80	0.003	0.004	0.80	0.022	0.022	1.00
Output gap	0.023	0.022	1.05	0.002	0.002	1.00	0.012	0.011	1.09
Interest rate (chng)	0.000	0.000	1.00	0.003	0.002	1.50	0.030	0.031	0.97

Table 11: Standard Deviations of Key Variables Under the Optimized Rules: No Indexation

	Productivity			Energy Supply		
	IT	PLT	IT/PLT	IT	PLT	IT/PLT
Loss function	0.23	0.22	**1.05**	1.34	1.36	**0.99**
Headline CPI inflation	0.17	0.19	0.89	1.13	1.08	1.05
Output gap	0.07	0.03	2.33	0.20	0.27	0.74
Interest rate (chng)	0.00	0.01	0.10	0.01	0.03	0.33

Table 12: Peak Responses to a 1 per cent Increase of World GDP

Price Elasticity of Global Output Growth:	Gervais, Kolet and Lalonde (2010)	BoC-GEM
for Energy	15.0%	11.8%
for Non-Energy Commodities	3.8%	2.8%

Figure 1: Real World GDP Growth and Raw Materials Prices, 1990-2007

(per cent, year-over-year)

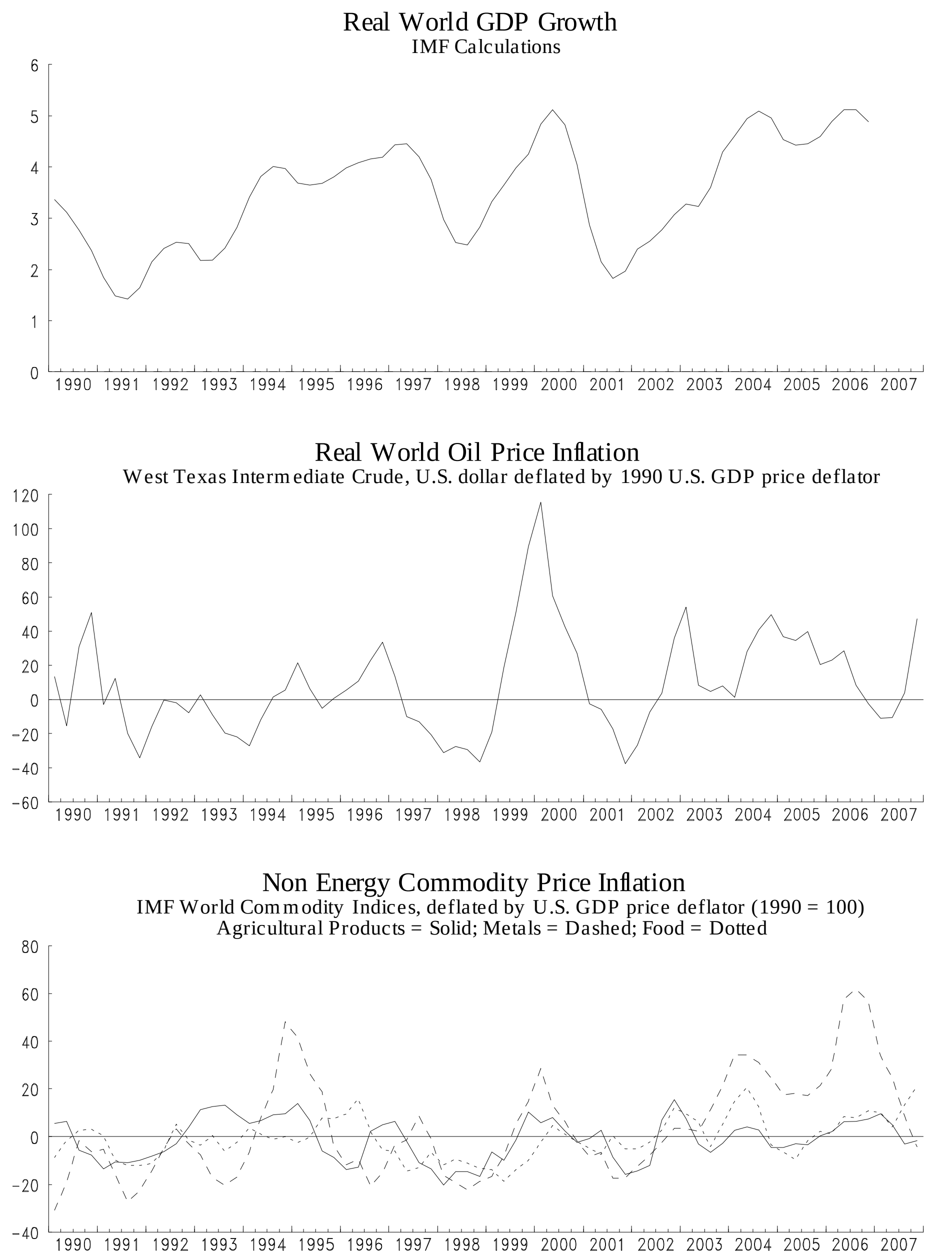
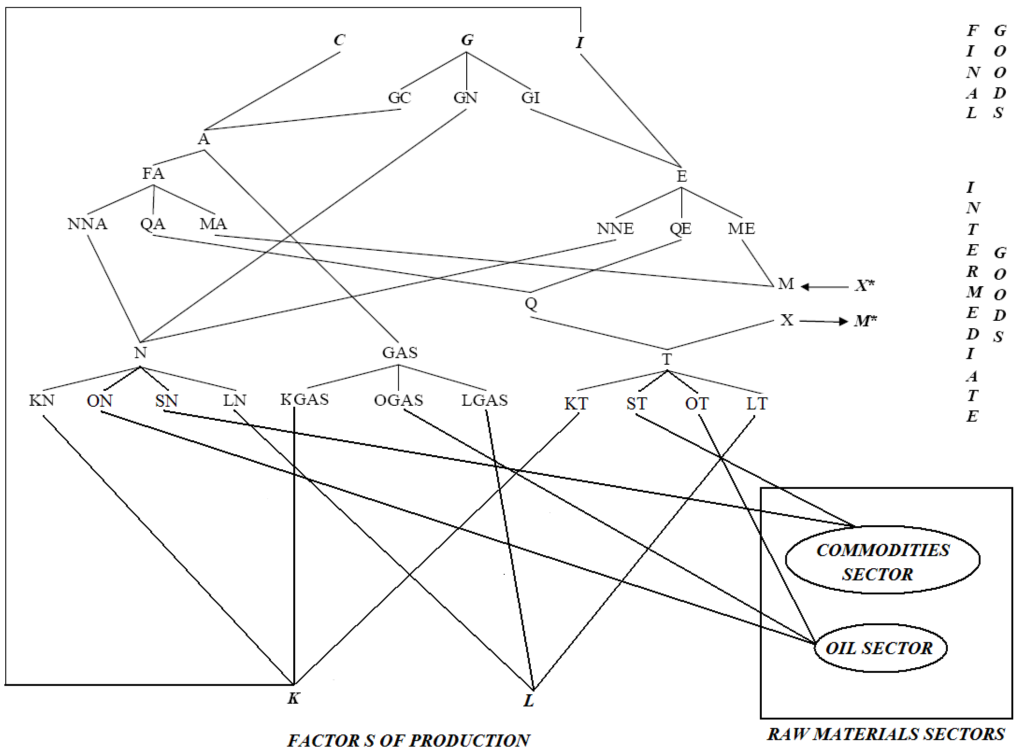


Figure 2: Overview of the Production Sectors in the BoC-GEM



C is private consumption; G is government spending; I is business investment;
A is aggregate consumption; E is aggregate investment;
N is non-tradable goods; GAS is gasoline; T is tradable goods;
Q is domestically produced goods; M is imported goods; X is exported goods;
K is the capital stock; L is labour; S is non-energy commodities (= commodities); O is energy commodities (=oil).
Other symbols are combinations; i.e., QE (Q and E together) is domestically produced investment goods.
For Figures 3 and 4, OIL is crude oil reserves and LAND is the fixed factor for non-energy commodities.

Figure 3: The Energy Sector in the BoC-GEM

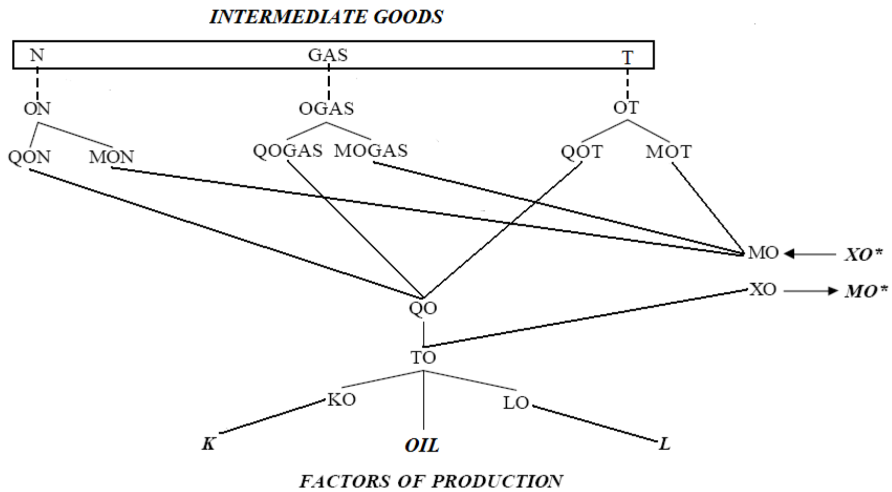


Figure 4: The Non-Energy Commodities Sector in the BoC-GEM

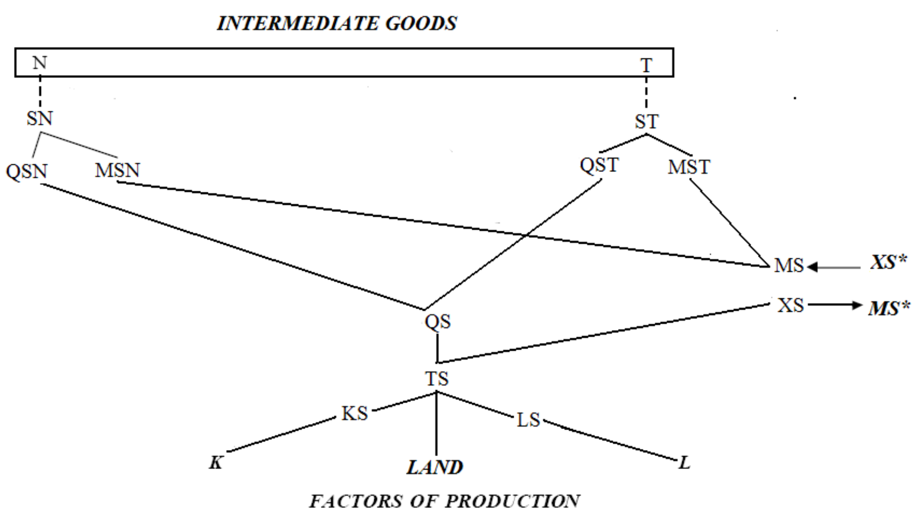


Figure 5: Permanent One Per Cent Increase in the Level of Tradables and Non-Tradables Productivity in the Commodity-Importing Regions

(Deviation from control, in per cent, unless otherwise stated)

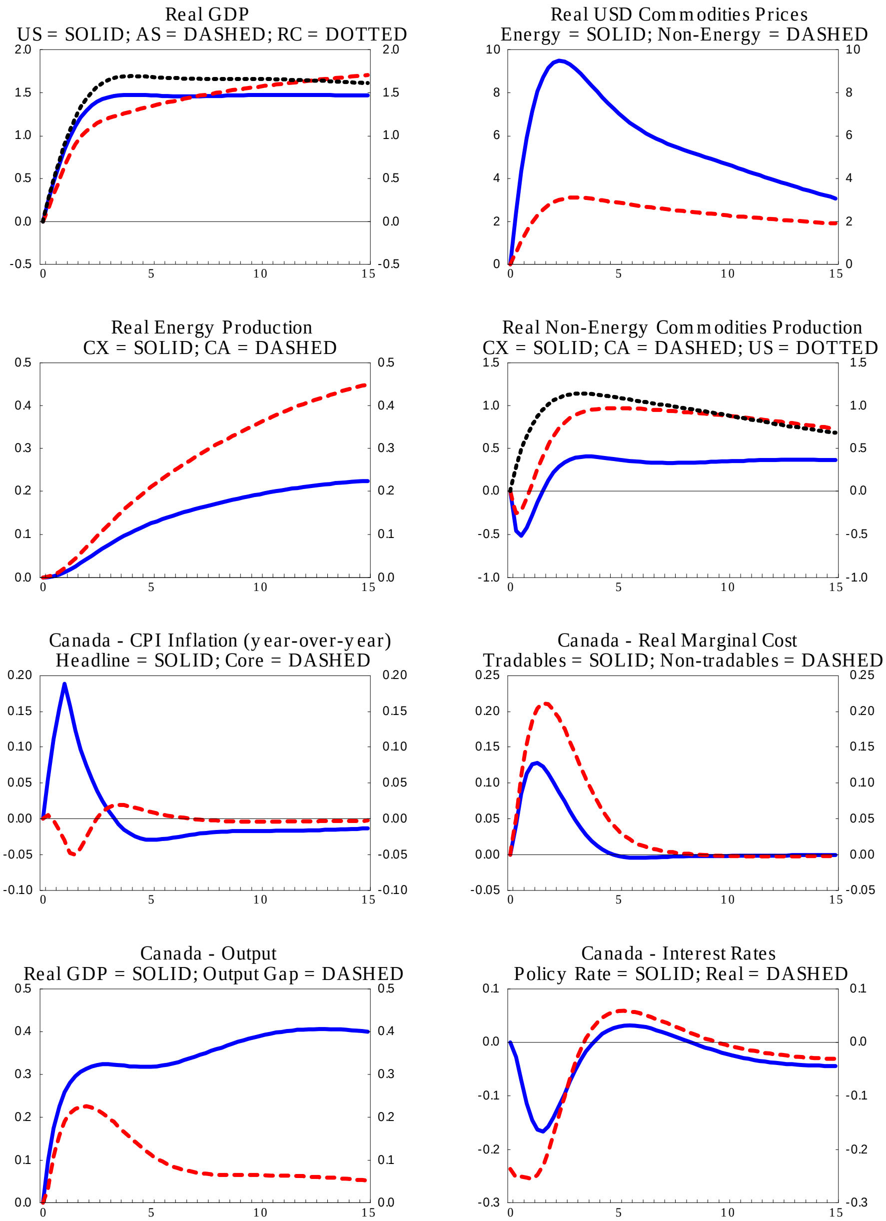


Figure 6: Permanent Six Per Cent Decrease in Energy Production by the Commodity Exporter

(Deviation from control, in per cent, unless otherwise stated)

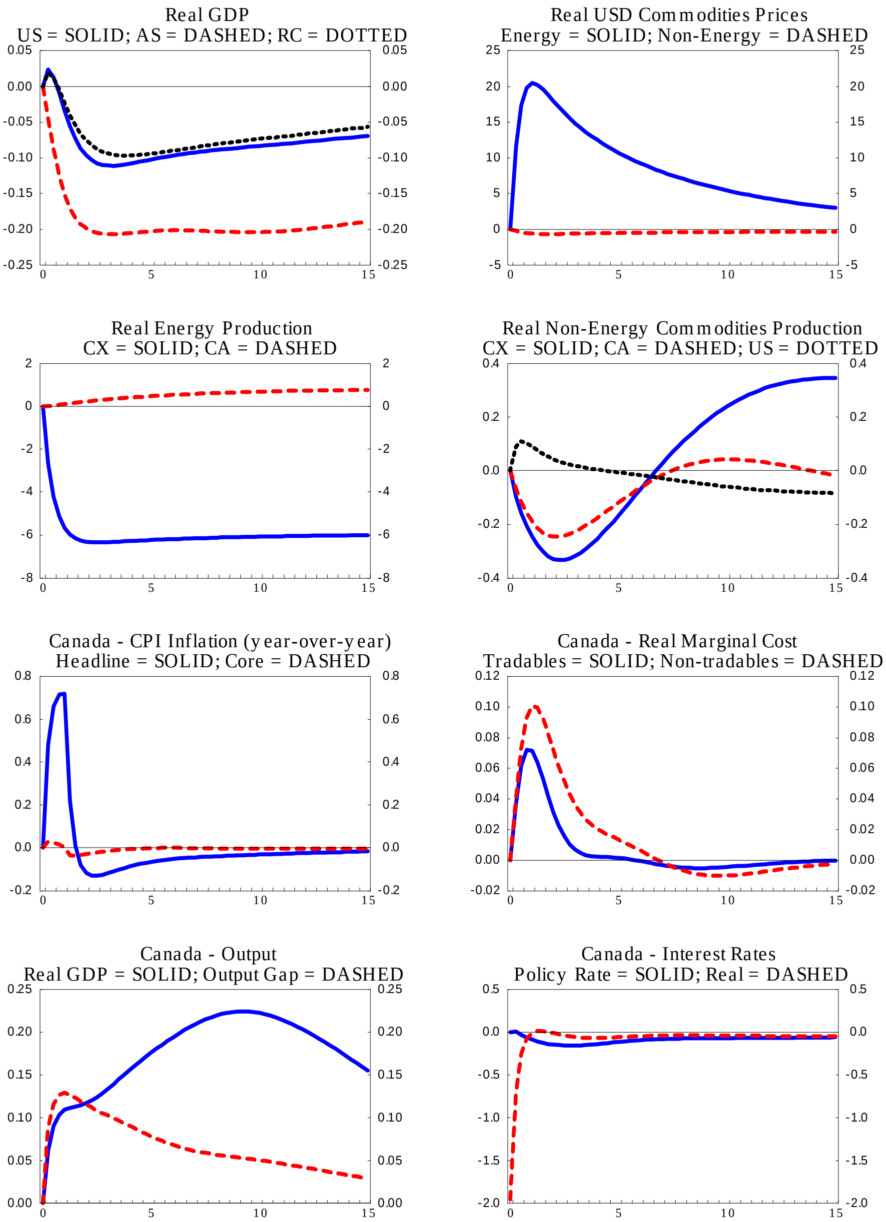


Figure 7: Permanent 12.5 Per Cent Decrease in Non-Energy Commodities Production by the Commodity Exporter

(Deviation from control, in per cent, unless otherwise stated)