Commodities and Monetary Policy: Implications for Inflation and Price Level Targeting *
Running title: Commodities and Price Level Targeting

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Abstract

We examine the relative ability of inflation targeting and price level targeting monetary policy rules to minimize inflation variability and business cycle fluctuations in a commodity-exporting country for supply and demand shocks to global commodity markets. The macroeconomic consequences of oil and non-oil primary commodities differ and affect the relative merits of the alternative monetary policy frameworks. Particularly, the consumption of refined oil products and demand-driven commodity price movements induce highly persistent inflation pressures resulting in a significant deterioration of the inflation-output gap trade-off available to central banks. When such terms-of-trade shocks are prevalent, price level targeting is inferior to inflation targeting.

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1 Introduction

The relative merits of switching from an inflation target (IT) to a price level target (PLT) are of interest to policy makers since PLT is often found to outperform IT in forward looking models when the central bank commits to simple interest rate rules (Svensson, 1999; Hatcher and Minford, 2014). However, one potential complication associated with targeting the price level is persistent terms-of-trade shocks driven by fluctuations in commodity prices (Bank of Canada, 2006; 2011). Under a credible inflation targeting regime, the central bank can choose not to react to the effects of commodity price shocks on inflation. However, under a price level targeting regime, the central bank must 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.

There have been only a few studies comparing the relative merits of PLT to IT when faced with terms-of-trade shocks. Coletti, Lalonde and Muir (2008) analyze the effect of terms-of-trade shocks for the Canadian economy using an open-economy dynamic stochastic general equilibrium (DSGE) model. They concluded that PLT does a better job at macroeconomic stabilization (a lower variance of inflation and the output gap) than IT for the shocks they consider that drive fluctuations in the Canadian terms of trade. However, they do not consider commodity prices as a driver of the terms of trade.

Leduc and Sill (2004) and de Resende et al. (2010) investigate the relative merits of PLT versus IT in the presence of shocks to the relative price of oil. Leduc and Sill (2004) use a closed economy DSGE model and find that PLT does a better job than IT in cushioning oil price shocks. The authors do not explicitly model the oil sectors but link oil demand in production to the utilization rate of capital. In a related study, de Resende et al. (2010) estimate a multi-sector small-open-economy DSGE model with a domestic commodity sector where oil is used as a factor in intermediate production. They find that the welfare implication of IT and PLT are similar for shocks to the relative price of oil. Both papers allow for oil as a factor input in production but do not allow for petroleum products to be consumed directly in consumption.

The oil sector is unique in several important aspects that are not taken into account in these earlier studies. Perhaps most importantly, oil is not only a factor of production in intermediate goods but is also consumed by agents in their consumption basket, such as for oil in heating and gasoline in operating energy-using durables (Edelstein and Kilian, 2009). In particular, consumers' utilization rates are sensitive to fluctuations in energy prices and have significant effects on consumption of non-energy goods (Hamilton, 2008). Natal (2012) finds that, when oil is allowed to be consumed in the consumption basket, the output and inflation trade-off is made quantitatively significant for inflation targeting rules.

The literature on monetary responses to oil price fluctuations often assumes an exogenous price of oil and a closed-economy setting (Leduc and Sill, 2004; Carlstrom and Fuerst, 2006; de Resende et al., 2010; Kormilitsina, 2011; Natal, 2012). These assumptions can lead to misleading results.

The price of oil is determined on the global market for crude oil, and the source of the price shock matters. Empirical studies have identified an important role of broad-based demand driven oil price movements (Kilian, 2009; Kilian and Murphy, 2014; Juvenal and Petrella, 2014). In particular, the run-up of oil prices over the 2000-2007 period have been attributed to the successive upward revisions of real global output, particularly for China (Elekdag et al., 2008; Kilian and Hicks, 2013). Such foreign demand shocks increase the demand for all goods and have different consequences for the output-inflation trade-off of monetary policy (Bodenstein et al., 2012). Bodenstein et al. (2011) show that an open-economy model with endogenous commodity prices is necessary to distinguish foreign supply from demand driven commodity price shocks. In addition, Kilian et al. (2009) and Bodenstein et al. (2011) have shown that the transmission of oil shocks depends on their effects on exchange rates, capital accounts, and the non-oil trade balance.

These studies limit their focus to the case of oil. However, an increase in foreign demand increases the demand for all goods, including non-oil primary commodities. Hence, the relative net export position for both oil and non-oil commodities would have important consequences. In this paper we find that relative movements in non-oil commodity prices have different macro-economic consequences which matter for the relative merits of IT versus PLT. This is primarily due to non-energy commodities not being consumed directly in the consumption basket, resulting in a lower pass-through into headline inflation, and a differing inflation-output trade-off (Snudden, 2013).

We complement the analysis of Bodenstein, et al. (2012) by using a multi-region open-economy New-Keynesian DSGE model focusing on the case of a commodity exporter. The analysis is conducted for Canadian monetary policy. The model including the regional composition is designed to replicate key features of international transmission mechanisms for Canada. For example, the model explicitly includes the United States, emerging Asia, and OPEC. This provides richness in international trade fluctuations, exchange rates, and current accounts from both demand and supply-driven commodity price movements. Distinguishing between supply and demand driven oil price changes is found to be critical in determining the relative merits of IT versus PLT for macroeconomic stabilization.

Three structurally driven foreign commodity terms-of-trade shocks are considered. The first two are permanent declines in the foreign supply of oil and non-oil commodities, in primary commodity producing regions. These shocks drive persistent increases in the price of oil and non-oil commodities, respectively. The third shock is to foreign demand, through a permanent increase in the productivity level of the commodity-importing regions, which includes emerging Asia. For each of these shocks, forward-looking interest rate feedback rules 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.

We find that explicitly modeling the primary commodity sectors (henceforth commodities) has implications for the choice of monetary policy regime. For changes in foreign supply oil and demand, we conclude that PLT is inferior to IT. The advantage of IT is particularly important for the foreign demand shock since the rise in foreign demand induces a persistent increase in the relative prices of both energy and non-energy commodities as well as the non-commodity balance. The results illustrate that switching from an IT to a PLT may be undesirable in the presence of foreign and persistent terms-of-trade shocks in a small-open economy. This contrasts with previous studies which find that PLT outperforms IT in forward looking models when the central bank commits to simple interest rate rules (for a survey of these studies, see Hatcher and Minford, 2014).

Sensitivity analysis demonstrates that these results are robust to targeting headline or core CPI inflation and, to some extent, the elasticity of demand and supply for commodities. As shown in previous studies on the relative merits of IT versus PLT, inertia in the inflation process for prices and nominal wages is critical for the results.

The paper is organized as follows: Section 2 describes the model, highlighting the features relevant to this study. Section 3 discusses the methodology and examines the results. Section 4 concludes and outlines directions for future research.

2 The theoretical model

Our analysis is conducted using a global, open-economy, New-Keynesian dynamic stochastic general equilibrium (DSGE) with multiple regions. The model includes several features important to replicate the dynamic properties of domestic macro-economies, including habit persistence, real rigidities, and nominal rigidities on final good prices and wages (Christiano et al., 2005; Smets and Wouters, 2007). The model has been designed to study the international transmission of shocks to Canada at the Bank of Canada. This includes detailed trade linkages and fully endogenous global commodity markets. In this paper, we use the term "energy" when referring to both oil and gasoline products.

The theoretical foundations and dynamic properties of the model are extensively described in the Bank of Canada technical report of Lalonde and Muir (2007). Hence, this section provides a complete non-technical overview of the model while expanding on aspects of the model important for this analysis. Readers interested in the explicit functional forms and technical explanations will find Lalonde and Muir (2007) complete. [1]

2.1 Model description

Each regional bloc is populated by two types of households: 1) forward looking households who work, consume, and invest in capital and government bonds and 2) a set of liquidity constrained agents who work and consume out of their present labor income. The set of liquidity constrained agents helps capture the short term dynamics and have been shown to be important when considering optimal policy to commodity price fluctuations (Bi and Kumhof, 2011). Households' preferences are represented by a Greenwood, Hercowitz, and Huffman (1988) utility function subject to consumption and labor habit persistence. Both types of households have market power in labor supply, charging a wage mark-up subject to wage stickiness.

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. The consumption basket uses a nested constant-

[1] The model, the Bank of Canadas Global Economy Model (BoC-GEM), described in Lalonde and Muir (2007) is based on the on the International Funds Global Economy Model (GEM) described in Pesenti (2008), extended to include a commodity sectors based on Faruqee et al., (2007).

elasticity of substitution (CES) function to produce a composite of tradable and non-tradable goods with gasoline. Implicitly modeling the share of gasoline in the consumption basket allows us to distinguish between core and headline inflation (Bodenstein et al., 2008). Previous modelling of the consumption of energy (for example, Bodenstein et al., 2011; and Natal, 2012) assumes that oil enters directly into consumption and have ignored the labor and capital shares in gasoline production. This assumption overstates the pass through of oil prices in headline inflation.

Three intermediate goods – tradable goods, non-tradable goods and gasoline – are produced by monopolistically competitive producers for the domestic market and, in the case of tradable goods, for export. The production technology of all sectors is characterized by CES production functions (described below). Intermediate tradable and non-tradable production combines oil and non-oil commodities, both domestically produced and imported, with capital and labour. In contrast, the gasoline sector combines domestically produced and imported oil with capital and labour. Capital and labour are mobile across 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.

Households hold internationally traded, one period, nominal bonds which are denominated in U.S. currency. To introduce a degree of realism in exchange rate dynamics, as in Pesenti (2008), financial intermediation costs are introduced to the risk-adjusted uncovered interest rate parity (UIRP) condition. This slows down the adjustment of the exchange rate to shocks so the model can replicate the hump-shaped responses typically found in vector auto-regressions.

Imports are subject to real adjustment costs to match the sluggish adjustment to changes in relative prices. These costs are specified as a function of the one-period change in import shares relative to the output of the sector and are set very low for all sectors. The model allows for nominal adjustment costs in the imports of consumption and investment goods to mute the pass through of price changes. Nominal adjustment costs are not present for imported commodities. The functional form and calibration of the nominal and real adjustment costs in the import sector are identical to that described in Colletti et al. (2008) and Lalonde and Muir (2007).

De Resende et al. (2010) show that modeling both the tradables and the non-tradables sector is important for accounting for the relative merits of PLT. Domestic price adjustment after term-of-trade shocks will asymmetrically impact sectors depending on their respective rigidities.

In particular, non-tradables sectors are known to have higher rigidity in both nominal and real terms. Further, distinguishing between tradables and non-tradables helps to match the dynamics of exchange rates and transmission of international shocks, as shown in the model by Lalonde and Muir (2007).

Intermediate producers are monopolistically competitive and are able to set their price above real marginal cost which allows 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 Phillips curves take a similar form to the hybrid New Keynesian Phillips' curve, as in Galí and Gertler (1999). Price inflation in the case of the gasoline sector is a function of the real marginal cost gap, because there is a lack of nominal rigidities.

To mimic the sluggish adjustment of the intensity of demand for commodities to relative price changes, we assume that factor usage in intermediate goods production is subject to real adjustment costs in the intensity of production (the same functional form as in commodity production as specified below). This reflects the observation that, over the short-run and mid-run, substitutability of commodities usage in the production of intermediate goods is limited due to the embodied technology of a capital stock. However, 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 oil usage relative to the industry average, as a share of intermediate goods production. This implies that inputs that grow with the scale of production do not incur adjustment costs.

The model includes two types of commodities – oil and non-oil commodities (agriculture, fishing, forestry, metals and minerals). Both types of commodities are produced by combining capital, labour and a fixed factor – "mineral deposits and land" in the case of non-oil commodities and "oil reserves" in the case of oil production. The structure allows for commodities producers to have market power, but prices do not incur nominal adjustment costs.

Taking oil production as an example (non-oil commodities take an identical form), in each region, there is a continuum of firms indexed by $o \in [0, ss]$, where ss is the size of the region in the world ($0 < ss < 1$). Firm o produces $O_t(o)$ at period t of its oil by combining capital $K(o)$, labour $L(o)$, and a fixed factor that is a non-reproducible resource, $OILRES(o)$, using a CES technology:

$$
\begin{aligned}
O_t(o)^{1-\frac{1}{\xi_o}} &= Z_{O,t}[\alpha_{OILO}^{\frac{1}{\xi_O}}(Z_{OILO,t}OILRES(o))^{1-\frac{1}{\xi_O}} \\
&+ (1-\alpha_{KO}-\alpha_{OILO})^{\frac{1}{\xi_O}}\left(L_t(o)(1-\Gamma_{LO,t})\right)^{1-\frac{1}{\xi_O}} \\
&+\alpha_{KO}^{\frac{1}{\xi_O}}(K_t(o)(1-\Gamma_{KO,t}))^{1-\frac{1}{\xi_O}}],
\end{aligned} \tag{1}
$$

where Z_{OILO} is level of productivity of the fixed factor, $OILRES(o)$.

This model specification allows commodity production costs to differ across regional economies, justified by different endowments of resources, labor and capital costs, and productivity levels. Despite differences in marginal production costs, since commodities are traded internationally, the regional differences in prices are influenced by the elasticity of substitution in demand between domestically produced and imported commodities.

The long-run elasticity of substitution between the factor inputs is given by ε_O,but the effective short- and medium-term elasticities are influenced by real adjustment costs incurred when changing the relative shares of capital and labor in oil production, Γ_{KO} and Γ_{LO}. Using the capital in oil production as an example, the real adjustment cost, Γ_{KO}, associated with a change in the usage of capital, K, in time t, by firm o is assumed to take the form:

$$
\Gamma_{KO,t} = \frac{\phi_{KO}}{2}\left[\left(K_t(o)/O_t(o)\right)/\left(K_{O,t-1}/O_{t-1}\right)-1\right]^2 \tag{2}
$$

where the calibration of ϕ_{KO} governs the short-term demand response of capital to changes in prices. These real adjustment costs on input intensities are combined with the fixed factor of production, reserves, and a low elasticity of substitution across inputs. 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 change in prices becomes persistent (Krichene 2002).

Finally, all productivity terms, Z_t, follow a stochastic process with an autoregressive formulation in logarithms, z_t:

$$
z_t = (1-\lambda_Z)\,z + \lambda_Z z_{t-1} + e_{Z,t}, \tag{3}
$$

where $0 < \lambda_Z < 1$, z is the steady-state value of z_t, and $e_{Z,t}$ is a noise term.

2.2 Model calibration

In the BoC-GEM, the global economy is divided into five regional blocs: Canada (CA), the United States (US), emerging Asia (AS), 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 has been calibrated to reflect its size, trade linkages, and the composition of production and spending. 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. All other aspects are consistent with the calibration as documented in Lalonde and Muir, (2007).

Production of each sector as a share of total output is calibrated to match the value added of each industry in gross national product and is summarized in Table 1. Not surprisingly, the CX region has the highest share of oil production in output at 11.9 per cent, due to OPEC. The demand for oil and non-oil commodities as a share of GDP by region is also summarized in Table 1. Emerging Asia has the highest demand for both energy and non-energy commodities as a share of its 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 factor income shares in the production of oil and non-oil commodities reflect the regional capital versus reserve intensities and are described in Table 2. CX is the most reserve-intensive with reserve factor income in oil production at 79.1 per cent and capital in production at 10.8 per cent, again reflecting OPEC. In contrast, the capital share in CA is high at 27.6 per cent due to tar sands production, with reserves factor income at 58.4 per cent. Smaller differences exist across regions in the non-energy commodities and reflect the relative importance of mining versus agriculture within these regions. Table 3 summarizes the distribution of crude oil reserves which closely matches the data provided by the U.S. Department of Energy. 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 BoC-GEM explicitly models bilateral trade linkages of oil and non-oil commodities as well as consumption and investment using the IMF's Direction of Trade Statistics and the United Nations' COMTRADE database. Net exports of oil and non-oil commodities in Canada are 3.5 and 3.4 per cent of GDP, respectively. The United States is Canada's largest trading partner, so its dynamics will primarily affect the Canadian non-commodity balance. The response of the US to oil price shocks is relatively well understood and our calibration builds on previous work from Elekdag et al. (2008) and Lalonde and Muir (2007).

Oil prices are determined on the global market for crude oil, which is a tradable commodity par excellence (Gulen, 1999; Kleit, 2001). The calibration of the elasticity of substitution between domestic and imported oil is 10, generating a single global oil price. In contrast, we allow for more product differentiation for the non-oil commodity sector and set the elasticity of substitution between domestic and imported non-oil primary commodities to 5. The elasticity of substitution between domestically produced tradable goods and imported tradable goods is 1.5, consistent with the Erceg, et al. (2005) and Murchison and Rennison (2006).

Together, the real adjustment costs as well as the elasticities of substitution in both the production and the usage of energy and non-energy commodities govern the "steepness" of the demand and the supply curves. The elasticities of substitution in both production and usage are taken from the literature but, due to the unique production structure, are also jointly determined with the real adjustment costs to match empirical evidence. The properties of the model draw heavily from Elekdag et al. (2008) and Lalonde and Muir (2007), who have the same model structure.

The elasticity of substitution between tradable and non-tradable goods in both consumption and investment goods in each country is 0.5. 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. The common elasticity of substitution between the factors of production, capital, labour, and commodities, is set to 0.7 in all of the intermediate sectors consistent with the findings of Perrier (2005). We assume a slightly lower elasticity of substitution among inputs in both oil and non-oil commodities production (capital, labour and the fixed factor) at 0.6.

The overall size of the adjustment costs in intermediate production were calibrated, in part, to fine tune the models properties and match empirical studies of the relationship between real economic activity and energy prices, as shown in the simulations found in Lalonde and Muir (2007) and Elekdag et al. (2008). The IMF's non-energy commodity price index is used for calibration of non-oil commodities. Table 4 shows that there are large real adjustment costs related to commodities in all sectors in all countries. We assume real adjustment costs for oil in regions that rely heavily on capital intensive production, such as the tar sands in Canada, are twice as high as those in OPEC countries, and hence the supply response in the CX region is slightly higher. The real adjustment costs bind for several decades. The model is able to replicate the finding of the International Energy Agency (2004) for the relative output responses from an increase in the price of oil. The relative impact across economies is heavily influenced by the degree of net oil imports as well as the oil intensity in output.

Real adjustment costs in oil production are large and consistent with the bulk of empirical evidence demonstrating that the short-run price elasticity of crude oil supply is very low (Baumeister and Peersman, 2013; Kilian and Murphy, 2014). The short-run price elasticity of non-oil commodities supply is higher than that of oil, because supply responses associated with the planting, gestation, and harvesting of agricultural products are faster than the response of oil production (Lord, 1991; IMF, 2006). Therefore, we calibrate the real adjustment cost parameter in both the supply and demand of non-oil commodities to be two-thirds the size of that for oil.

For shocks to the relative price of oil, the production of gasoline implies that approximately three quarters of the oil price response will pass-through into gasoline prices. The effective price elasticity of gasoline demand is approximately -0.29 within the first year, consistent with Faruqee et al. (2008) and within the range of plausible estimates, -0.19 to -0.49, provided by Davis and Kilian (2011). The price elasticity of global output growth is 0.12 for oil prices and 0.03 for non-energy commodities close to estimates from IEA (2004). The short-run price elasticity of oil demand is approximately -0.1 within the first year, consistent with the findings of elasticities within the range of -0.07 to -0.14 after the 1990's by Baumeister and Peersman, (2013). The long run effective price elasticity of gasoline and oil demand is approximately -0.45 and -0.6, respectively, slightly higher than the -0.80 cross sectional estimates of Hausman and Newey (1995) and Yatchew and Joungyeo (2001).

2.3 Model properties

This section describes the results of simulating three shocks with the BoC-GEM: i) a permanent increase in foreign demand, ii) a permanent decline in foreign oil supply, and iii) a permanent decline in foreign non-oil commodities supply. Consistent with the notion that Canada's terms of trade are largely determined externally, we assume that the shocks occur outside of Canada.

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. For the purpose of this section, we assume in Canada that the policy rule is close to the optimal rule used in the Bank of Canada's main projection and policy analysis model, ToTEM (Cayen, Corbett and Perrier 2006):

$$i_t = 0.95 i_{t-1} + 0.05 i^* + 20(E_t \pi_{t+3} - \pi^{TAR}) \tag{4}$$

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 global demand. This is achieved by permanently increasing the level of total factor productivity in tradable and non-tradable goods production, $Z_{T,t}$ and $Z_{N,t}$, in the commodity-importing regions (AS, US, and RC), which represent 88 per cent of global GDP. Figure 1 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 oil and non-oil commodities. Because of the short-run insensitivity of oil supply to an increase in the relative price of oil, there is little supply response over the first two years. Instead, there is a 10 per cent rise in the real U.S. dollar price of oil. Over the long run, the energy supply gradually responds, with about 90 per cent of the long-run response occurring after about fifteen years. The shock elicits a more muted response in the non-oil 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-oil commodity prices increase by only 3 per cent in U.S. dollar terms. It only takes about four years for 90 per cent of the long-run supply response of non-oil commodities supply 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. This results in a rise in real GDP, an appreciation of the currency against the U.S. dollar, and a reduction of imported goods prices. The reduction of imported goods prices includes investment goods, which produces a rise in potential output.

There are conflicting forces acting on inflation in Canada. On the one hand, higher prices for commodities exert upward pressure on the real marginal cost of production, particularly oil prices in the production of gasoline resulting in a rise in headline inflation. On the other hand, lower import prices, including investment goods, put downward pressure on real marginal cost of production. On net, headline CPI inflation in Canada increases sharply, and there is a mild fall in core CPI inflation. The policy interest rate falls 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 shock is a permanent decline in the supply of oil in the CX region (Figure 2) generated from a permanent decline in the productivity of oil reserves, $Z_{OILO,t}$. This decline has the standard interpretation of a change in cartel power or a conflict that disrupts production. The negative oil supply shock results in a reduction in oil 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, oil production rises slightly over the medium term in response, 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 in the real U.S. dollar oil price of about 20 per cent.

The 20 per cent increase in the price of crude oil has an overall negative effect on global economic growth, especially for oil importers such as emerging Asia, which experiences a permanent decrease in real GDP of 0.2 percent (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 non-oil exports. The fall in exports is an important feature that distinguishes this shock from a foreign demand increase. 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 fifteen basis points in the first year.

The third shock is a permanent decline in the supply of non-oil commodities (Figure 3). This is generated from a permanent reduction in the productivity of the fixed factor in the non-oil commodity sector, $Z_{SLAND,t}$, in all of the regions other than Canada. The real U.S. dollar price of non-oil commodities rises by 4 per cent after one year. As non-oil commodities become less available, intermediate production worldwide contracts, leading to an almost 1 per cent fall in the real U.S. dollar price of oil from the reduction in demand. Because of the higher elasticities of supply and demand for non-oil commodities relative to oil, the commodity importing regions (emerging Asia, and the remaining countries bloc) suffer smaller real GDP losses than for the case of the oil supply shock (around 0.2 per cent of real GDP in the long run). Since the United States is a net exporter of non-oil 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. Non-oil commodity prices pass through into final good prices by raising the real marginal cost in the tradable and non-tradable sectors. Core CPI inflation increases slightly because of the increase of roughly 0.2 per cent in the real marginal costs in intermediate production sectors. The increase in the policy interest rate serves to quell inflationary pressures.

3 IT versus PLT

The rest of this study examines the relative merits of IT and PLT to stabilize the Canadian macroeconomy in the presence of shocks to global economic activity and the supply of oil and non-oil commodities.

3.1 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:

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

where σ_π^2, σ_y^2 and $\sigma_{\triangle i}^2$ are the unconditional variances of the deviations of the year-over-year headline inflation rate from its targeted level, the output gap, and the first difference of the nominal interest rate, respectively. 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, $\lambda_\pi = \lambda_y = 1$. The loss function includes a small weight on the change in the policy rate, $\lambda_i = 0.1$ which serves to eliminate rules that cause excessive volatility in the nominal interest rate. Alternative weights in the loss function are evaluated as part of the sensitivity analysis.

The output gap is defined as the difference between the log of real GDP, y, and the log of potential output, y^{POT}. Potential output is calculated using the aggregate production function approach. Potential output is evaluated with total factor productivity, the capital stock, steady-state labour supply and the steady-state value of land and oil reserves. This measure allows for model consistent output gaps even in response to permanent shocks as potential output transitions to its new balanced-growth steady state.

Monetary policy is characterized by a simple interest rate feedback rule. We choose this rule since it has been shown to be more robust across model uncertainty and being easier to communicate to the public as motivated by Levin, et al. (2001). Monetary policy nests both the IT and PLT rules and is given by equation (5):

$$i_t = \omega_i i_{t-1} + (1 - \omega_i)\, i_t^* + \omega_p (E_t p_{t+k} - \eta E_t p_{t+k-1} - p_{t+k}^{TAR} + \eta p_{t+k-1}^{TAR}) + \omega_y (y_t - y_t^{POT}) \qquad (5)$$

where p_t is the price level, and p_t^{TAR} is the price level target. 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 headline prices or inflation from target, ω_p, 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.

The optimal rules for both IT and PLT are generally defined, in line with the operational practices of monetary authorizes. For example, note that as ω_i approaches unity, the IT rule can become nearly equivalent to PLT since the monetary authority behaves in a highly history dependent manner. Moreover, the inclusion of the output gap implies that the rules encompass a notion of nominal income targeting (adjusted for changes in the potential output of the economy). This is desirable as in practice monetary authorities do have such operational leeway. We see the generalization of the optimal policy rule to be strength of the paper, as it does not limit the monetary authority to tools that it would likely utilize under the respective regimes.

Moreover, in practice, the monetary authority may desire to "look through" the first-round effects of energy price shocks on inflation, adjusting policy rates only to the extent that underlying inflation is expected to be affected. To examine this case, we also compare optimal IT and PLT for the case where the monetary policy targets core inflation and examine the loss function when evaluated for both headline and core CPI.

We solve the optimal policy for each given shock to the economy. The advantage of this approach is that we do not have to take a stand on the relative incidence of the shocks. This approach should be seen as complimentary to an examination of a generalized optimal rule. Hence, the optimal rule will not be the optimal rule on average, but the optimal rule conditional on the source of the oil price movement. Facing a given shock, the policy characterizes the optimal response to that shock. Moreover, we do not have to limit the analysis to temporary shocks when the model is linearized around a fixed steady state. Instead, we solve the full non-linear model and 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 interest rate feedback rule.

3.2 Results

Table 5 reports the values of the loss functions, the standard deviations of the output gap and 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 when the monetary authority targets headline inflation. The ranking of IT and PLT, in terms of their ability to stabilize the macroeconomy, depends upon the source of the terms-of-trade movement. IT is slightly favoured over PLT in the case of the oil supply shock, but it is the opposite for the non-energy commodity supply shock. This difference is driven by gasoline consumed in the consumption basket as explained below. There is a large benefit of IT over PLT for the foreign demand shock; the value of the loss function associated with IT is 22 per cent lower than PLT.

To illustrate the intuition behind our results, we will first take the case of the permanent oil supply shock. The rise in the price of oil affects headline CPI inflation through two main channels. Oil is an input of production in the gasoline sector, increasing both the real marginal cost of tradable and non-tradable production and the final price of gasoline. The rise in gasoline prices, although muted slightly by the labor and capital share in gasoline production, feeds into headline inflation based on the share of gasoline in the consumption basket. The pass through of gasoline prices into the consumption basket induces a large and persistent headline inflation response that is harder to tackle under PLT. Under IT, a credible monetary policy can bring inflation back to its target by focusing only on reversing the increase in the inflation rate while ignoring the persistent response of prices. In contrast, under PLT, the monetary authority needs to fully reverse the persistent effect on the level of prices. The reversal in headline inflation is costly due to headline response being driven by global factors, implying the domestic reversal occurs from falling demand for non-commodity goods.

In the case of the non-oil 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 sectors. Second, the pass-through into inflation is driven by rising marginal costs since there is no equivalent consumption channel that could drive headline inflation, such as for gasoline in the case of oil. Since energy and non-energy commodities are complementary inputs, a rise in non-oil commodity prices causes oil demand and oil prices to fall slightly. When using the historical rule, Figure 3 shows that core inflation rises, whereas the fall in gasoline prices cause headline inflation to fall slightly on impact.

The pass through of non-commodity prices into real marginal costs is positively correlated to the size of the real adjustment costs in the production and usage of non-energy commodities. In contrast, the strength of the fall in oil prices is positively correlated with the size of the real adjustment costs in the production and usage of oil 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 sectors. In accordance with empirical evidence, the real adjustment costs in the supply and demand of energy are stronger than in the non-energy commodities sector. This implies that the increase in headline CPI inflation induced by the fall of supply of non-oil commodities is largely compensated by the fall in other real prices, such as energy. This compensation helps to reverse the impact of the shock on the level of the headline CPI under PLT.

The superiority of IT for the foreign demand shock is due to the pervasive and positive effect for the demand for all goods, which drives up the real prices of both types of commodities. Under PLT, monetary policy needs to reverse the persistent and large effects on headline prices. The initial rise in headline inflation is particularly difficult to diminish due to global prices set on international markets and already booming non-energy sectors. In this case, PLT induces additional inflation volatility when reversing the impact on the price level.

The optimal rules for both IT and PLT are generally defined in line with the operational practices of monetary authorities. That said, the weight on lagged policy rate, ω_i, is small for the optimal IT regimes for all shocks. In particular, ω_i is 0.3, 0.8, and 0.0 for the demand, energy supply, and non-energy supply shock, respectively. Given that the model is quarterly, these are well within the range of more narrowly defined IT rules. The monetary authority does not behave in a very history-dependent manner. Moreover, the weight on the output gap is small for optimal IT regimes and larger for optimal PLT regimes. This suggests that the superiority of the IT regime is robust to PLT regimes that operationally encompass a notion of nominal income targeting (adjusted for changes in the potential output of the economy).

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. Furthermore, although not reported here, a temporary increase in demand in the commodity importing regions also results in favoring IT over PLT. We have found that the superiority of IT over PLT is very robust for the case of foreign demand driven increases in the price of commodities.

3.3 Targeting Core Inflation

Consider when the monetary authority targets core inflation in response to commodity price movements. This is done by replacing headline by core inflation in the monetary policy reaction function (equation 5). When the loss is evaluated using headline inflation, PLT is found to be superior to IT for both the foreign demand and oil supply shock, see Table 6. PLT better stabilizes inflation expectations and the output losses are marginal due to the monetary authority not trying the reverse the entire response to headline CPI.

However, if the monetary policy objective is to minimize the loss function with headline inflation, it is still optimal for the monetary authority to target headline IT. The desirability to headline IT is due to the positive co-movement between headline inflation and the output gap for a small-commodity exporter. Hence, there are still sizable reductions in headline inflation that the monetary authority can achieve before the output gap becomes negative and incites additional output volatility.

If long-run inflation expectations are firmly anchored, central banks may not want to risk creating a recession to mitigate a temporary movement in headline inflation associated with a commodity price shock, see for example Natal (2012). The loss functions from the optimal regimes are reported in Table 6, where policy rates are adjusted only to the extent that core inflation is expected to be affected. In this case, IT is still desirable over PLT. The volatility in output is still too costly to reverse under PLT for the energy supply shock. Similarly lower volatility of both output and core inflation is achieved under IT for the demand driven oil price shock.

The desirability for the monetary authority to target core over headline inflation also depends on additional considerations not considered here. The targeting core inflation is an operational guide to monetary policy partly due to the lagged peak response of monetary policy and the volatile nature of headline inflation. The above analysis considers that the monetary authority can forecast the price response and can respond optimally. We leave considerations of forecastability and optimal policy to future research.

3.4 The role of the model's calibration

We conduct a sensitivity analysis in which we assume no indexation for nominal wages or prices. Consistent with Coletti et al. (2008), we confirm that the relative performance of PLT improves when we assume no indexation in nominal wages and prices. In particular, Table 8 shows that PLT is actually slightly better for the foreign demand shock. Further, the lack of indexation also almost entirely closes the gap between the performance of IT and PLT for the oil supply shock. In this case the persistent rise in headline inflation is easily corrected in the non-commodity sectors.

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. However, 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.

In order to show the role played by short- and medium-run elasticities of demand and supply in commodities in driving the 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 7). In this alternative calibration, the supply and demand of energy and non-energy commodities are significantly more elastic than in the base case, although not perfectly elastic since the production of commodities is still limited by the fixed factor of production. More elastic commodity markets reduces the persistence and the amplitude of the responses of commodity prices. Results show that PLT and IT give practically the same values for the loss function for the case of an oil supply shock. However, the relative advance of PLT over IT is maintained for the demand shock. Even in the absence of the adjustment costs, the inelastic commodity markets limit the capacity of firms to modify their supply of energy rapidly enough to prevent inflation persistence in the wider economy.

When comparing the models calibration to empirical studies, if anything, the calibration may allow for slightly more flexibility in the demand and supply of energy and non-energy commodities than the empirical estimates of the IEA (2004) and the above mentioned studies suggest. If this is true, the calibration would bias the results of its experiments towards PLT.

4 Conclusion

The terms of trade for small-open commodity exporters, such as Canada, are dominated by fluctuations in commodity prices. These fluctuations are mostly driven by persistent changes in demand and supply in the global market for commodities (Kilian, 2009; Kilian and Murphy, 2014). The pass-through of commodity prices can cause large and persistent movements in headline inflation, which can complicate the output-inflation trade-off for a monetary authority (Natal, 2009; Bodenstein et al. 2012). Our study is the first to consider the role of foreign demand shocks, refined energy in consumption, and non-oil commodities when examining the relative merits of inflation versus a price level targeting regimes.

Based on a multi-sector DSGE model that endogenizes both the production and demand for commodities, 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. We find modeling the open-economy dimension to distinguish between the sources of the commodity price movements is critical when comparing the relative merits of the two regimes. The direct consumption of energy in the consumption basket is also key in distinguishing energy from non-energy commodities and the determining the inflation-output trade-off of the central bank.

Our study builds upon the previous work of Natal, (2009) and Bodenstein et al. (2012), which characterizes optimal monetary policy to oil price shocks. Given shocks to the foreign supply and demand of energy, PLT is found to be inferior to IT for stabilization of the macroeconomy. The relative advantage of PLT is particularly large for foreign demand driven shocks to the commodity terms of trade shocks. Moreover, PLT is found to be inferior for relative price shocks to oil, but superior to relative price shocks to non-oil commodities. The difference is driven by lack of the consumption channel for non-oil commodities and more flexible market structures.

The results illustrate that switching from a IT to a PLT may be undesirable in the presence of foreign and persistent terms-of-trade shocks in a small-open economy. This contrasts with previous studies which find that PLT outperforms IT in forward looking models when the central bank commits to simple interest rate rules (for a survey of these studies, see Hatcher and Minford, 2014).

The desirability of PLT is robust to sensitivity analysis of targeting core CPI, and to some extent, the parameterization of the loss function. The relative performance of PLT over IT for foreign demand shocks is very robust, but is decreasing in: 1) the supply and demand real adjustment costs of energy and non-energy commodities, 2) the level of indexation of prices and nominal wages, and 3) the share of energy consumption in the consumption basket.

A further extension of this would be to allow for agricultural commodities to enter into the consumption basket, particularly in less developed economies. Distinguishing between metals and agriculture commodities price shocks could also be considered. The importance of the non-oil commodity channel could also be examined for countries that differ in their net-export position of commodities, such as the United States. We leave these extensions to future research.

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Table 1: 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 2: 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 3: 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 4: 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
Oil for producing gasoline. 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 5: Standard Deviations of Key Variables Under the Optimized Rules: The Base Case

	Demand			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 6: Standard Deviations of Key Variables Under the Optimized Rules: Targeting Core CPI

	Demand			Energy Supply		
	IT	PLT	IT/PLT	IT	PLT	IT/PLT
Headline Loss function	0.247	0.178	**1.39**	1.710	1.618	**1.05**
Headline CPI inflation	0.198	0.094	2.12	1.679	1.503	1.12
Output gap	0.049	0.084	0.58	0.031	0.115	0.27
Interest rate (chng)	0.000	0.005	0.02	0.000	0.000	1.23
Core Loss function	0.275	0.311	**0.88**	0.146	0.181	**0.81**
Core 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 7: Standard Deviations of Key Variables Under the Optimized Rules: No Real Adjustment Costs in the Commodities Sectors

	Demand			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 8: Standard Deviations of Key Variables Under the Optimized Rules: No Indexation

	Demand			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

Figure 1: 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)

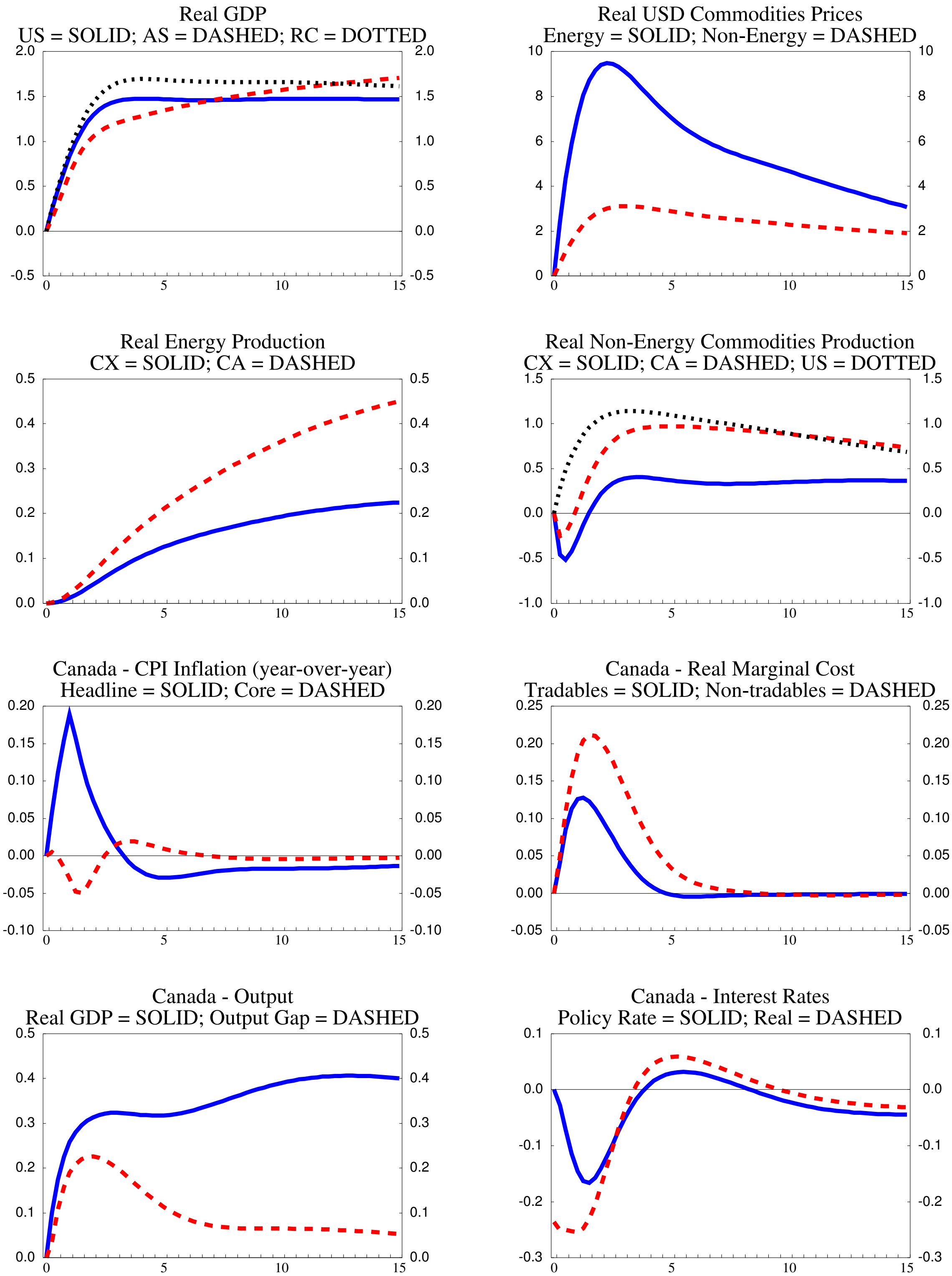

Figure 2: Permanent Six Per Cent Decrease in Energy Production by the Commodity Exporter

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

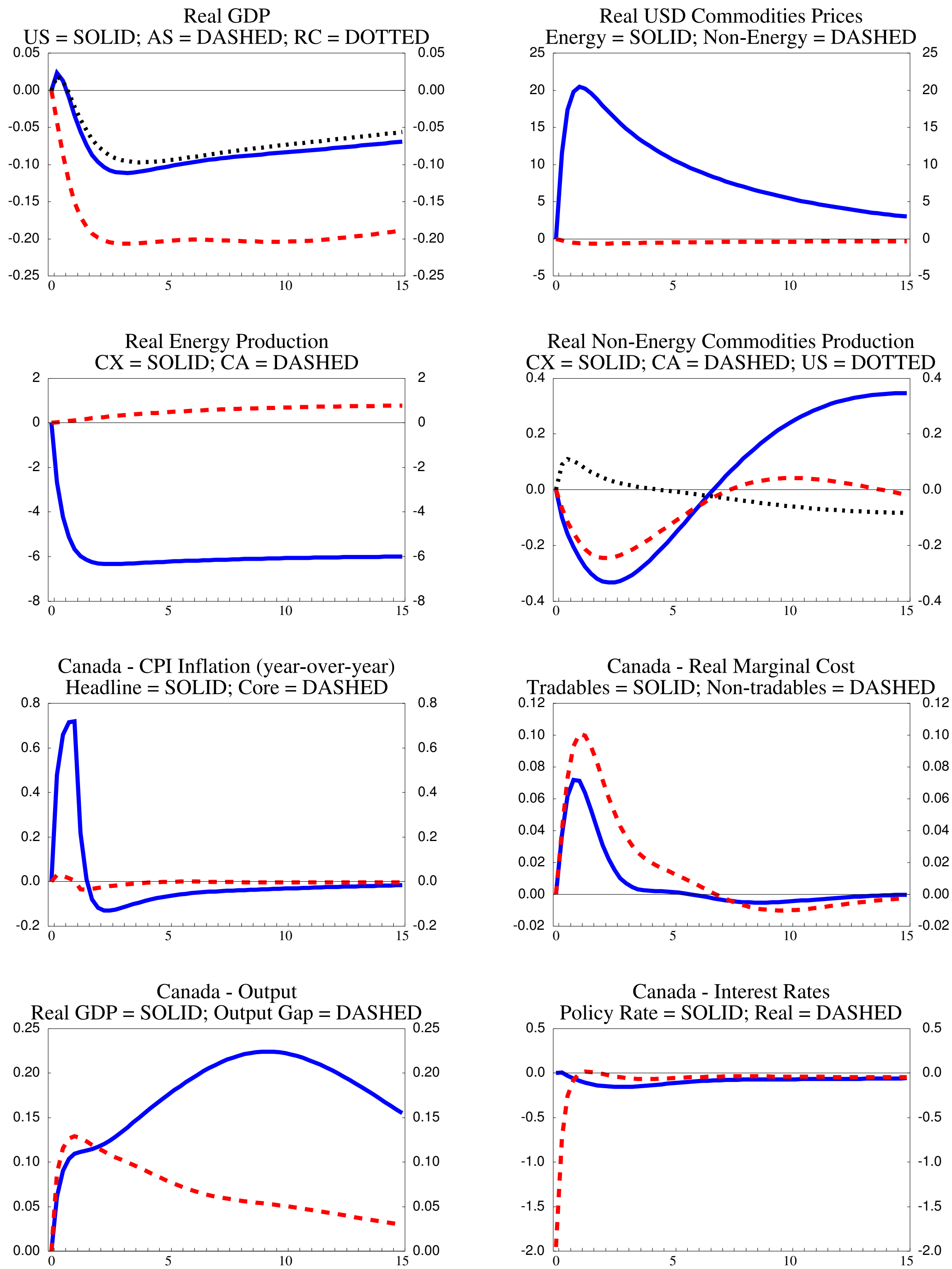

Figure 3: Permanent 12.5 Per Cent Decrease in Non-Energy Commodities Production by the Commodity Exporter

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