NBER WORKING PAPER SERIES

OIL PRICE MOVEMENTS AND THE GLOBAL ECONOMY: A MODEL-BASED ASSESSMENT

Selim Elekdag
Rene Lalonde
Douglas Laxton
Dirk Muir
Paolo Pesenti

Working Paper 13792
http://www.nber.org/papers/w13792

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
February 2008

We thank Ryan Felushko, Laura Leon, Lei Lei Myaing, Susanna Mursula and Chris Tonetti for invaluable research assistance. This paper has benefited from helpful comments from Riccardo Cristadoro of the Banca d?Italia and participants to the Bank of Canada Workshop on Commodity Price Issues, the IMF Workshop on Open Economy Models for Policy Evaluation and presentations at the Bank of Japan, the Hong Kong Monetary Authority and the European Central Bank. This paper should not be reported as representing the views of the IMF, its Executive Board or any member government. The views expressed are those of the authors and do not necessarily reflect the views of the IMF, IMF policy, the Bank of Canada, the Federal Reserve Bank of New York, the Federal Reserve System, the National Bureau of Economic Research or any other institution mentioned herein or with which the authors are affiliated.

Oil Price Movements and the Global Economy: A Model-Based Assessment
Selim Elekdag, Rene Lalonde, Douglas Laxton, Dirk Muir, and Paolo Pesenti
NBER Working Paper No. 13792
February 2008
JEL No. E66,F32,F47

ABSTRACT

We develop a five-region version (Canada, a group of oil exporting countries, the United States, emerging Asia and Japan plus the euro area) of the Global Economy Model (GEM) encompassing production and trade of crude oil, and use it to study the international transmission mechanism of shocks that drive oil prices. In the presence of real adjustment costs that reduce the short- and medium-term responses of oil supply and demand, our simulations can account for large endogenous variations of oil prices with large effects on the terms of trade of oil-exporting versus oil-importing countries (in particular, emerging Asia), and result in significant wealth transfers between regions. This is especially true when we consider a sustained increase in productivity growth or a shift in production technology towards more capital- (and hence oil-) intensive goods in regions such as emerging Asia. In addition, we study the implications of higher taxes on gasoline that are used to reduce taxes on labor income, showing that such a policy could increase world productive capacity while being consistent with a reduction in oil consumption.

Selim Elekdag
International Monetary Fund
700 19th Street
Washington, DC 20431
selekdag@imf.org

Rene Lalonde
Bank of Canada
234 Wellington Street
Ottawa ON Canada K1A 0G9
LALX@bank-banque-canada.ca

Douglas Laxton
International Monetary Fund
700 19th Street
Washington, DC 20431
dlaxton@imf.org

Dirk Muir
Bank of Canada
234 Wellington Street, Ottawa ON Canada K1A 0G9
dmuir@bank-banque-canada.ca

Paolo Pesenti
Federal Reserve Bank of New York
33 Liberty Street
New York, NY 10045
and NBER
paolo.pesenti@ny.frb.org

1 Introduction

Over the last few years, the persistent surge in oil prices in both the spot and futures markets has represented perhaps the most striking challenge to the forecasting abilities of private and public institutions worldwide. Even as the average monthly spot price of oil increased from US$19 per barrel at end-2001 to US$43 at end-2004, market participants expected prices to decline over time to "more reasonable levels". However, since 2005, there have been striking upward revisions of near- and longer-term price expectations from the futures markets, and the oil spot price in 2006 occasionally rose above US$70 per barrel, and has stayed persistently above US$50 per barrel.

The course of events has led to policy-making institutions to ask: what has been the cause in the run-up in oil prices since 2003, and is the run-up fundamentally different from that experienced during the two oil price shocks in the 1970s? Candidate explanations come from both demand and supply trends. On the demand side, robust global growth supported by the rapid (and continual) economic expansion in emerging Asia has been cited as a fundamental break with the past, particularly in China and India,where the actual rate at which these economies are expanding seems to have surprised market participants. Overall, there have been significant upward revisions in global growth prospects and, in fact, global growth is expected to exceed four percent for the fourth year in a row (IMF (2006)).

On the supply side, market participants have also revised their views about how quickly supply will respond to higher prices, given low levels of investment and the fact that the big oil companies are finding it more difficult to replenish their reserves. Indeed, as it takes on average eleven years before an oil discovery is commercially operational, it has not been surprising to some analysts that oil prices have soared when OPEC spare capacity has fallen to very low levels. The more controversial concern of the “peak oil theory”— the concept that the world has reached the natural limits of oil exploitation — is nowadays given more consideration than in the past.

This paper provides a preliminary assessment of these issues — and their relevance for the world macroeconomy — by developing an extended version of the Global Economy Model (GEM) developed at the International Monetary Fund (IMF) that explicitly encompasses consumption, production and trade in oil. The simulation model allows us to study developments in the world economy that have significant effects on oil prices, the international transmission mechanism through terms of trade fluctuations, and the related wealth transfers between oil-importing and oil-exporting regions. We address two key questions. First, what are the underlying causes of the oil price run-up since 2003? And given those causes, what are some potential policy measures that could reduce oil prices with the least amount of (negative) impact on global welfare?

The remainder of this paper is organized in the following way. Section 2 presents some basic stylized facts on the state of the oil sector. Section 3 provides a brief summary of the model while Section 4 discusses its calibration. Section 5 then uses the model to present some preliminary simulation results that we consider to be likely candidates in explaining the run-up in oil prices since 2004, that we expect will extend into the foreseeable future. Specifically, we consider shocks that affect either the demand or supply for oil and discuss their implications for growth in different regions of the world. Section 6 suggests some policy responses to help ameliorate the upward climb in oil prices. In particular, we study the implications of higher taxes on gasoline, that are used to reduce taxes on labor income, showing that such a policy could increase world productive capacity while reducing oil consumption. The final section offers some concluding remarks about possible future extensions.

2 Oil and the world economy: some stylized facts

This section reviews recent developments in the oil market and the world economy as background to the shocks we will use in GEM to explain those developments.

2.1 Oil prices

There has been a persistent upward trend in oil prices over the last few years. Figure 1 depicts the evolution of the IMF's World Economic Outlook (WEO) projections and the actual average petroleum spot price (APSP).[1]

Focusing first on the Winter 2003 vintage in the top panel, we observe a short-term hump, owing to the events unfolding in Iraq. Afterward, oil prices were projected to converge to a much lower level, hovering around $20 per barrel. There seemed to be an expectation that supply would accommodate market needs once the short-term disruptions were resolved. According to the projections made in Winter 2004, a milder uptick in price expectations was accompanied by an upward revision in longer-term prices by about twenty percent relative to the previous projection, as shown in the bottom panel. Next, in 2005 there was both a large near- and longer-term revision to oil prices, owing to significant changes in the oil market.[2] Notice in particular that the long end of the projected oil price curve increased by nearly 100 percent, likely caused by a disappointing supply response. Most recently, compared to the Winter 2003 projections, the longer-term oil price has been revised upwards by about 200 percent. In contrast with the three other curves, the Winter 2006 projections are almost constant going forward, primarily because of heightened concerns over the supply of oil.

2.2 Oil supply and demand

Several mutually reinforcing developments have resulted in low levels of oil supply. The most prominent of these is that OPEC spare capacity (including Iraq) has bottomed out. This fact is highlighted in Figure 2, which shows quarterly figures for OPEC spare capacity as a percent of total supply, and the APSP. Starting in mid-2003, there is a divergence between oil prices and spare capacity (which by June 2006, is estimated at around 1.3 to 1.8 million barrels per day (EIA (2006))). At the same time, lagging investment in infrastructure and refinery construction, as well as the aforementioned fact that it takes on average eleven years before an oil discovery is ready for production, have further compounded supply-side rigidities. Markets have also been keen to note that big oil companies are finding it more

[1] The APSP is the simple arithmetic average of the U.K. Brent, Dubai Fateh, and West Texas Intermediate spot oil prices. The projection of oil prices is based on oil price future contracts traded on the New York Mercantile Exchange (NYMEX).

[2] Technical factors did partially account for this phenomenon in 2005. For instance, the Organization of the Petroleum Exporting Countries (OPEC) suspended its price band mechanism which served to maintain expectations of a future downward correction in prices. The price band mechanism was set up by OPEC at its March 2000 meeting. When the OPEC oil-price basket was above US$28 per barrel for 20 consecutive trading days or below US$22 per barrel for 10 consecutive trading days, there would be production adjustments. However, during its January 2005 meeting, OPEC decided that market developments had rendered the band unrealistic, and temporarily suspended the mechanism.

difficult to replenish their reserves. Along with heightened geopolitical risks, oil supply has become markedly binding, making it excessively vulnerable to even minor disruptions.

Probably the most important driver of world demand for oil is rapid — and underestimated — growth in emerging Asia. Table 1 underscores this point. It reports both the current year forecasts and actual real GDP growth rates from 2003 to 2005 for China and India. For both countries, growth forecasts have been consistently lower than the realized rates. Moreover, solid growth in the United States and the recovery in Japan have led to significant upward revisions in global growth prospects. This is clearly conveyed in Figure 3, which shows the projections for world real GDP growth from the IMF's World Economic Outlook in the top panel and the revisions relative to the Winter 2003 forecasts in the bottom one. In turn, Figure 4 emphasizes this point by focusing on the cumulative growth rates: the compounded effects of seemingly minor revisions can be quite large. To drive home this point, we also show the cumulative growth rates for the emerging Asian countries in Figure 5.

Taking a more historical perspective, we note that there has been a gradual downward trend in oil intensity. As measured in kilograms of oil per unit of PPP-adjusted GDP, Figure 6 shows declining oil intensities for selected countries and regions. Although after the 1970s the decline accelerated, the overall decrease in oil intensity has been protracted. As shown in both panels, advanced countries tend to have higher oil intensities. With populations exceeding one billion each and sustained growth rates well over five percent per year (usually near 10 percent for China), manufacturers and consumers in China and India have been importing energy at ever-increasing rates. As they approach "advanced economy" status, a shift towards production of, and demand for, higher oil-intensity goods is expected (and is occurring). This will probably adversely affect future and — through forward-looking behavior — current oil market developments.

3 The theoretical framework of the model

This section provides a synthetic overview of our simulation model.[3] The world economy consists of five country blocs ('regions'), divided in two groups. The oil-exporting regions consists of Canada and the group of oil-exporting countries (GOEC) which includes OPEC, Mexico, Norway, and Russia.[4] The oil-importing group consists of the United States, emerging Asia[5], and the bloc of remaining countries which includes Japan and the European Union. In each region, there are households, firms, and a government. The overall structure of the model is illustrated in Figure 7, and each sector is described in turn below.[6]

Each household consumes a non-tradable final good (C in Figure 7), and is the monopolistic supplier of a differentiated labor input (L) to all domestic firms. Some households have low monopoly power, are liquidity-constrained, and do not have access to capital markets.

[3]For a more complete presentation of the model equations see Pesenti (2008) for the tradable and non-tradable sectors, and Lalonde and Muir (2007) for the oil and gasoline sectors.

[4]This version of the model was built to originally include both energy and non-energy commodities. Therefore GOEC also includes other major commodity exporters such as Argentina, Brazil, Chile, South Africa, Australia and New Zealand.

[5]Indonesia is excluded and is part of the group of oil exporting countries.

[6]For an algebraic exposition of the model (excluding the treatment of the gasoline and oil sectors) we reader is referred to the Appendices of Faruqee, *et al* (2007, 2008). A simplified variant encompassing both downstream and upstream intermediate goods is presented in Laxton and Pesenti (2003).

They finance their consumption exclusively through disposable labor incomes. The remaining households own domestic firms and the domestic capital stock (K), which they rent to domestic firms. They also own two short-term nominal bonds, one denominated in domestic currency and issued by the region's government, and another denominated in U.S. currency and issued in zero net supply worldwide. There are intermediation costs for national households transacting in the international bond market. Labor and physical capital are immobile internationally. The market for capital is competitive, and capital accumulation is subject to adjustment costs. In the labor market wage contracts are subject to nominal rigidities.

On the production side, there are three layers of production: final goods, downstream intermediate goods (such as semi-finished products), and upstream intermediate goods (such as refined oil products in our setting, and more generally commodities and raw materials).

Perfectly competitive firms produce two final goods — a consumption good (A) and an investment good (E). The final goods are not traded internationally. Both the demand for the consumption good and the investment good is split between private agents (C and I respectively) and the public sector (G_C and G_I respectively). The two final goods are produced by using downstream intermediate goods as inputs.

There are three downstream intermediate goods: refined petroleum products such as gasoline for transportation and fuel used for heating ('gasoline' for short, or GAS), other non-traded goods and services (N), and internationally traded goods (T). Domestic tradables used by domestic firms are denoted Q, imports from all other country blocs are denoted M. To model realistic dynamics of trade volumes, we assume that imports are subject to short-term adjustment costs that temporarily lower the response of import demand to changes in relative prices. Intermediate goods are differentiated, with each variety produced by a single firm under conditions of monopolistic competition worldwide. The prices of intermediate goods are subject to adjustment costs (nominal price rigidities). Gasoline, nontraded and traded intermediate goods are all produced with domestic labor inputs, domestic capital and oil. Oil can be imported (MO) or produced domestically (QO); in both cases the use of oil in production is subject to short-term adjustment costs.

In our model, refined oil ('oil' for short) is the only tradable upstream intermediate good (TO). It is produced with capital, labor, and natural resources ($LAND$). As with other intermediate goods, oil producers have market power that can change over time. Different from intermediate goods prices or labor wages, oil prices are not subject to nominal rigidities. However, there are real adjustment costs in the supply of oil that result in very limited short-term responses of oil production to changes in demand. As a caveat, the fact that oil is assumed not to be a storable commodity whose price is linked to the rate of return on other assets implies that its price is determined entirely on its use value. Since the model does not include oil inventories, oil prices may respond too strongly to temporary shocks. With this in mind, it should be emphasized that the model is not meant to explain short-run variations in oil prices due to market disruption: rather, it has been designed to explain the interaction of oil prices and the world economy over the medium term.

Finally, the government purchases the two final goods as well as nontradable services G_N. As treasury, the government finances the excess of its expenditures over net taxes by borrowing from the domestic private sector. In the long run the government targets a given ratio of public debt to income, adjusting the tax rate on labor incomes as appropriate. As central bank, the government manages the national short-term nominal interest rate. Monetary policy is specified in terms of a credible commitment to an interest rate rule that targets inflation.[7]

4 Calibration

This section describes the calibration of the GEM, with particular attention to the oil and gasoline sectors. In this paper the calibration builds upon work already presented in Faruqee *et al.* (2007, 2008). However, there are some notable differences in terms of the composition of regions and the addition of the oil and gasoline sectors. The notation adopted in this section and in Tables 2 through 10 is usually self-explanatory: for a fuller presentation the reader is referred to the Appendices of Faruqee *et al.* (2007, 2008).

Table 2 includes the parameters relevant for the consumers' and firms' optimization problems. As mentioned above, in each region there are two types of consumers — liquidity-constrained, low-monopoly power households and forward-looking, high-monopoly power households. Their shares differ across regions, with liquidity-constrained consumers being as low as 15 percent of households in the United States, to 50 percent in emerging Asia. Both types of consumers have similar preferences, with a high elasticity of intertemporal substitution ($1/\sigma$) of 5, coupled with a high level of habit persistence in consumption (b_c) of 0.92. This parameterization yields very sluggish consumption behavior in the short-run, with a hump-shaped response that is flexible in the long run. Conversely, for labor we have a low Frisch elasticity of labour supply ($1/\zeta$) of 0.2 coupled with habit persistence in leisure (b_L) of 0.75.

Table 3 contains the calibration of the production side of the model. Labor and capital are assumed to be mobile across sectors, but immobile internationally. The tradable and nontradable sectors are calibrated in much the same manner as Faruqee *et al.* (2007), although the substitutability among factors is more inelastic, in line with recent work on Canada (Perrier (2005)) and the United States (Gosselin and Lalonde (2005)). The elasticity of substitution among factors used in oil production (ξ_O) is 0.6, but it is 0.7 in gasoline production (ξ_{GAS}). The higher degree of inelasticity in oil production reflects some of the long-term costs in switching production technology, whereas the higher degree in gasoline production reflects the fact that there are several methods of varying efficiency (and hence capital and labour intensity) to obtain gasoline from oil. In sum, while the long-run elasticities in the oil-related sectors are low, they may not be sufficient to provide realistic price responses in the short run. The latter require strong short-run real adjustment costs to significantly lower short-term elasticities toward near-Leontief levels, as will be described below.

The regions are differentiated from one another by their economic size, the composition of their domestic economies, and their trade patterns (see Tables 5 and 6). These data are mostly derived from the National Income and Production Accounts of the countries of each region, and then mapped into the corresponding bias parameters in the production functions for tradables, nontradables, oil and gasoline (Table 3) and the demand functions for final goods (consumption and investment) and intermediate goods (domestically produced and imported tradables, nontradables, gasoline and oil, Tables 4 and 3). The role played by differences in technology is immediately evident when we take into account factor incomes in the oil sector (Table 6). Some oil-exporting countries (GOEC) have the least capital-intensive technology, but other oil-exporting countries (Canada in our setup)

[7] Another version of the interest rate rule can limit the flexibility of the nominal exchange rate against the U.S. dollar, which will be used in future simulation exercises for the emerging Asia bloc.

have a relatively capital-intensive technology, meant to capture realistic features of the oil extraction process in the country (i.e. the Athabasca tar sands or the offshore oil-rigs of Hibernia).

Figures 8 and 9 illustrate our calibration of the world trade flows for all goods and for oil, respectively.[8] The aggregate import to GDP ratios reflect the levels of imports in 2003 in the five regions, whereas the aggregate export to GDP ratios are those necessary to support the net foreign asset to GDP ratios we have chosen (Table 5). The United States is a large net debtor (50.0 per cent of GDP), Canada is a small net debtor (7.5 per cent of GDP), while the other three regions are all net creditors of varying degrees (with emerging Asia being the largest net creditor at 35.0 per cent of GDP). The decomposition of aggregate trade flows into bilateral trade flows is also based on 2003 trading patterns found in the IMF's Direction of Trade Statistics and UN's COMTRADE database of commodity-based trade flows.

For aggregate trade, exports plus imports to GDP are 74.1 percent in Canada, 48.0 percent in GOEC, 27.9 percent in the United States, 52.6 percent in emerging Asia and only 17.8 percent in the remaining countries. The higher trade is as a percent of GDP, the more likely an economy will be affected strongly by foreign shocks. Canada is very open, as is emerging Asia, while the United States, the European Union and Japan (part of the remaining countries' bloc) are much more insulated from foreign disturbances. However, this is not necessarily the case in the oil market. Here, not only does the degree of openness matter, but the direction of trade as well. The net exporters are Canada at 3.7 percent of GDP and GOEC at 8.1 percent of GDP, while the other regions are net importers at 1.4 percent of GDP for the United States, 1.9 percent of GDP for emerging Asia and 0.4 percent of GDP for remaining countries. Additionally, the group of oil-exporting countries has the largest amount of its GDP coming from oil production (12.0 percent).

For tradable goods across all regions, imported goods are fairly substitutable with their domestically produced counterparts (μ_A and μ_E = 2.5). Imports of tradable goods can originate from different export countries, and the elasticities of substitution between alternative exporters (ρ_A and ρ_E) are equal to 1.5. By contrast, there is a very low elasticity of substitution between tradable and nontradable goods in all regions (ϵ_A and $\epsilon_E = 0.5$), and a very high elasticities of substitution between domestic and imported oil (μ_{OT}, μ_{ON} and μ_{OGAS} =10). For imported oil, there is less preference as to the region of origin ($\rho_O = 3.0$).

As in all previous work on the GEM, the calibration of markups follows Martins *et al.* (1996) for prices in the monopolistically competitive tradable and nontradable sectors , and Jean and Nicoletti (2002) for wages (see Table 8). However, we have assumed almost no markup in the oil sector for any region, with the exception of the group of exporting countries, which has a markup of 476 percent. It is estimated that the cost of oil production for OPEC countries is somewhere around \$2 to \$5 per barrel, while for a country like Canada it is closer to \$25. So, for any given oil price in the world market that we are considering in the paper, the group of the oil-exporting countries has the largest markup to sustain the price of oil and guarantee production in the other regions where production cost are much higher. For gasoline, the markup is 16 percent in Canada and Japan and the European Union (i.e. the remaining countries) and 17 percent everywhere else. This excludes government taxes on gasoline, which we set for illustrative purposes at 30 percent in Canada and the remaining countries bloc and 15 percent elsewhere (including the United States).

[8] The bias parameters associated with the import demand CES aggregators can be found in Table 7.

The dynamics of the model are further affected by nominal rigidities and real adjustment costs, as found in Table 9. Nominal rigidities in prices and real adjustment costs in investment and trade are calibrated to match moments of other models such as ToTEM for Canada (Murchison and Rennison (2006)), MUSE for the United States (Gosselin and Lalonde (2005)), previous work on the GEM for the United States (Julliard *et al.* (2006)), and the new Area-Wide Model (Coenen *et al.* (2005)) and Smets and Wouters (2005) for the European Union.

The most important real adjustment costs for this paper are those associated with the energy sectors. On the supply side, there are adjustment costs associated with changes in capital (ϕ_{KO} and ϕ_{KGAS}) and labor (ϕ_{LO} and ϕ_{LGAS}) in the production of oil and gasoline. On the demand side, there are adjustment costs associated with changes in the use of oil in the production of intermediate tradables, nontradables and gasoline (ϕ_{OT}, ϕ_{ON} and ϕ_{OGAS} respectively), and in the use of gasoline as a component of the final consumption bundle (ϕ_{GAS}). These real adjustment costs are modeled as quadratic adjustment costs following the Rotemberg (1982) formulation. The parameters associated with the adjustment costs are set at 300, a value high enough to to generate considerably muted short-term price responses of supply and demand for gasoline and oil to changes in fundamentals.[9] This implies that, for any shock affecting the demand or supply of oil, oil prices respond rapidly but volumes remain relatively unchanged for around 5 to 10 years.

The last key element in the dynamics of the model is the conduct of monetary policy, found in Table 10. For simplicity, all regions are assumed to be inflation targeters that follow an inflation-forecast-based (IFB) rule.[10] In order to hit a target of 2 percent (2.5 percent in the United States) for core consumer price inflation four to six quarters in the future, the change in the interest rate must be twice as large as the deviation of core inflation from its target level.[11]

5 Why oil prices have increased: some illustrative experiments

This section starts by presenting some simulation results showing the importance of adjustment costs that limit the short-run responses of demand and supply for crude oil, and their implications for the response of oil prices to productivity shocks. We show that in the presence of these adjustment costs an upward shift in productivity growth can result in the combination of high oil prices and robust global growth Next, we investigate the implications of higher oil reserves in the future. As an extension of the productivity shock, we illustrate how the model can be used to assess major risks to the future demand for crude oil that are the result of uncertainty about future levels of oil intensity and real incomes in emerging Asia. Finally, we analyze the effects of a pure supply-induced shock that increases oil prices through raising the market power of oil producers. Taken in combination, these

[9] However, Canada is assumed to have stronger real rigidities in oil production (because of the difficulty of exploiting the Athabasca tar sands) while the group of oil exporting countries is assumed to have weaker real rigidities (because of the ease with which the abundant near-surface oil in the Middle East can be extracted).

[10] In future versions of this work emerging Asia will be alternatively assumed to pursue a fixed exchange rate target *vis-à-vis* the United States.

[11] Core inflation in this model excludes the effect of gasoline prices on the consumption price deflator (a proxy for the CPI excluding food and energy or some similar measure).

four experiments can provide the explanation for the increase in oil prices over the past several years.[12] In particular, productivity shocks and the types of oil usage that have been seen in emerging Asia have been key drivers.

5.1 Higher productivity growth in oil-importing regions

To investigate the effects of rising global demand for oil we consider a positive shock in the oil-importing regions (the United States, emerging Asia, the remaining countries bloc) that raises productivity growth in both the tradables and nontradables sectors by one percentage point for 20 years. However, before presenting the short- and medium-term implications of higher productivity growth on oil prices and the world economy, we develop a benchmark scenario where all adjustment costs that limit the short-run and medium-term responses of the demand and supply of oil to changes in the price of oil are turned off. The comparison of our simulation results with the benchmark scenario is meant to emphasize two elements: on the supply side, we introduce significant real adjustment costs in the attempt to capture the effects of severe capacity constraints in the energy sector, as well as the multi-year delay between oil discoveries and their commercial availability. On the demand side, these adjustment costs capture the fact that it takes years to change the fuel efficiency of the stock of motor vehicles or to replace the stock of technology that is used for heating and cooling. These real adjustment costs imply that both the demand and supply for crude oil will be extremely inelastic in the short run, requiring large movements in crude oil prices to clear the energy market.

5.1.1 Responses without real adjustment costs in the energy sector

Figures 10 to 12 report results where all the real adjustment costs that affect the short-run demand and supply for oil and gasoline are excluded. The oil-importing regions obviously benefit from higher levels of productivity in their own region, but the increase in oil prices over time also results in a favorable terms-of-trade shock for regions that are net exporters of oil (Canada and the group of oil-exporting countries (GOEC)) and a negative terms of trade shock for the regions that are net importers of oil. To interpret these results it is important to recall that, in the baseline, net exports of oil in Canada and the group of oil-exporting countries are equal to 3.6 and 8.1 percent of GDP, while emerging Asia, the United States and the remaining countries bloc are assumed to be net importers of oil, with oil trade balances equal to –1.9, -1.4, -0.4 percent of GDP, respectively.

The price of oil trends upward in tandem with the increase in the demand for oil, reflecting the assumption of diminishing returns in the production of oil because of a fixed factor (land). For example, for the group of oil-exporting countries, Figure 12 shows that oil prices barely move in the short run, but then rise gradually over time reaching a level that is about 15 percent higher after 15 years. Oil production increases by only 1.5 percent in the group of oil-producing countries. It is important to emphasize that in this simulation we are assuming that there are no new discoveries of oil and that production can only be increased by adding more capital and labor based on existing reserves. It is worth emphasizing that this experiment is based on purely artificial assumptions to be relaxed later.

[12] It is understood that the current level of oil prices is not totally explicable in the context of these three shocks, as some of the volatility in the price of oil has nothing to do with the fundamentals of the market. Rather, they are linked to the perceived political risks attached to the various players (such as the Middle East or sub-Saharan African countries). Quantification of such uncertainty, by definition, has no role in a structural model such as the GEM.

The gradual rise in oil prices results in an improvement in the oil trade balance for Canada and the GOEC and a deterioration in the regions that import oil. The rise in the price of oil results in an upward trend in the relative price of gasoline. While monetary policy is successful at keeping core inflation close to the assumed target, headline inflation is systematically higher than in the baseline.

The dynamics for consumption, investment and GDP are relatively straightforward. In those regions that experience higher productivity growth, investment trends upwards until the capital stock in these economies adjusts to its new higher level. In the medium term, high investment rates in these regions crowd out investment in the oil-exporting countries as their rates of return on non-oil investment projects are significantly lower. However, these effects are eventually offset by higher rates of return in the oil sectors in these economies and aggregate investment rises above baseline. Consumption rises by more than GDP in the oil-exporting regions and by less than GDP in the oil-importing regions, which simply reflects the terms-of-trade improvement that the latter experiences.

There are two major forces that require the real effective exchange rates for the oil-importing regions to depreciate in the long run. The first is a result of the improvement in the terms of trade in the oil-exporting regions and the second reflects the assumption that higher growth in the oil-importing regions stems from higher levels of productivity in both the tradables and nontradables sector. In this case, equal-sized productivity shocks in both the nontradables and tradables sectors lead to a depreciation of the exchange rate in the long run, while the standard Balassa-Samuelson effect — which predicts a real exchange rate appreciation in the long run — relies on productivity growth in the tradables sector exceeding that of the nontradables sector.

Perhaps surprisingly, for the United States the real exchange rate appreciates in the short run. This reflects the fact that this region must absorb most of the depreciation in emerging Asia and the remaining countries bloc, both blocs being characterized by strong trade linkages with the United States. The appreciation also explains the short-run fall in U.S. net foreign liabilities measured as a ratio of nominal GDP, even as the trade balance worsens. In the very long run the desired stock of U.S. net foreign liabilities is actually higher than in the baseline, a fact that contributes to generate pressure toward a long-run depreciation. The latter is needed to generate a trade surplus that finances the higher interest burden on the larger stock of net foreign liabilities.

5.1.2 Responses with real adjustment costs in the energy sector

Figures 13 to 15 report the effects of the productivity shock, except in this case the real adjustment costs that limit the short-run oil supply and oil demand responses are fully operational. Oil prices now jump up on impact, decline over the first year, before rising steadily over time. A comparison of Figures 12 and 15 show that oil prices are substantially higher over the medium term, reflecting the sluggish response of the supply of crude oil. As can be seen in the figures, higher oil prices greatly magnify the near-term and medium-term effects of the terms-of-trade effects and increase the magnitude of the wealth transfer between regions that import oil and regions that export oil.

While this has significant effects on the short-run dynamics, the basic macro dynamics presented earlier remain. Although the magnitudes of the real exchange rate responses are different than in the case without real adjustment costs, they follow the same basic pattern. In spite of the large oil price increase, the stance of monetary policy is adjusted in all regions to keep core inflation close to the target. This requires an increase in nominal interest rates that is larger than the increase in headline inflation, as higher productivity growth increases the marginal product of capital and implicitly shifts up the neutral policy rate.[13]

While we have not performed a detailed accounting of the role of demand shocks behind the hike in oil prices since 2004, this illustrative scenario shows that it is possible in principle to account broadly for the combination of high oil prices and robust global growth, once the role of stronger fundamentals driving underlying productivity growth is appropriately considered.[14]

5.2 An expectation of greater availability of oil reserves in the future

The previous results are likely to overestimate the effects of persistent productivity growth shocks on oil prices in the future because they assume that the available level of reserves is fixed. Our modelling strategy in fact treats available oil reserves as an exogenous variable, without attempting to model new oil discoveries.[15] In addition to finding new oil fields, there are two additional reasons why available reserves could increase in response to higher oil prices. First, the latter create incentives to develop new technology to increase the production of crude oil from existing fields. Second, when access to oil fields has been restricted by governments, they may choose to relax these restrictions either to raise the levels of revenue or because of concerns about energy security.

Figure 16 reports results where we assume a gradual increase in available reserves in the oil-exporting regions starting in the sixth year of the simulation. This results in an increase in oil production after 15 years by about 6 percent in Canada and by about 8 percent in the group of oil exporters. Reflecting the larger supply, there is a downward shift in oil prices by about 10 percent from the sixth year onward. This expected improvement in the terms of trade for oil-importing regions raises consumption, investment and GDP in the short run and reduces consumption in the oil-exporting regions. In the short run, investment also rises in the oil-exporting countries, as the oil extraction process in the future is expected to require additional levels of capital.

The pattern of oil prices clearly shows a potential weakness of the model, which assumes that oil is not a storable commodity but derives its value only from its use in production and consumption. Extending the model to allow for oil inventories would obviously smooth out the decline in oil prices observed after the sixth year. Also, allowing for trade in oil stocks would create an arbitrage condition that would link changes in oil prices to the rates of return on other assets. Unfortunately, both of these assumptions would greatly complicate the structure of the model.

[13] While we do not have a neutral policy rate in the reaction function, the latter is specified in such a way that allows the real interest rate to depart from its long-run equilibrium value when there are shocks that change the marginal product of capital over long periods of time. This, of course, is necessary condition to keep core inflation close to the target.

[14] Once the calibration of the model has been finalized, we plan to develop estimates of demand and supply shocks that can account for high oil prices and the pattern of growth and savings behavior observed over the last few years — for a similar exercise that ignored the role of oil prices see Faruqee *et al.* (2007).

[15] In a future versions we may add an option where available oil reserves will behave as quasi-fixed factor that responds with very long lags to changes in oil prices.

5.3 Increase in the demand for oil in emerging Asia

Long-term projections of the demand for oil depend critically on assumptions about the future use of motor vehicles in emerging Asia. Given its substantial population as well as the potential uncertainty associated with the speed at which its real per capita income is likely to bridge the gap with the OECD countries. Studies that have focused on the implications of this uncertainty have usually taken energy prices as given and assumed that the supply of oil will be sufficient to smoothly accommodate variations in its demand — see for example IMF (2005b). Our simulation introduces the endogenous response of energy prices. To consider the implications of permanent shocks to the future demand for oil in emerging Asia, we first consider a scenario in which the increased demand for oil is the result of two factors: a taste shift that raises consumers' demand for gasoline, and a technology shift that increases the amount of oil needed to produce tradables and nontradables. The shock is phased in slowly over time, and raises the real level of oil consumption by roughly 2.5 percent of GDP by the fifteen year of the simulation. We then consider an alternative scenario that combines the increase of intensity in oil usage with higher productivity growth in emerging Asia.

Figures 17 to 19 report the results. An increase in demand for gasoline in emerging Asia raises oil prices and shifts the terms of trade in favor of the oil-exporting regions and against the oil-importing regions. As a result, consumption increases in the regions that are net exporters of oil and eventually declines in the regions that are net importers.

In terms of quantitative magnitudes, crude oil prices rise by about 10 percent on impact, decline over the first year and then trend upwards over time reaching a peak that is around 25 percent higher than baseline. Again, the profile for oil prices reflects very low short-run elasticities of supply and demand for crude oil, which means that oil prices have to bear all of the burden of adjustment in the short run. The effects on oil trade balances are much larger in the short run for the GOEC and Canada relative to the baseline (equal to 8.1 and 3.6 percent of GDP, respectively). The negative effects on the oil trade balance in emerging Asia builds up over time and reaches about 5 percentage points of GDP after about 15 years.

This analysis assumes that the shock represents a pure shift in tastes toward consumption of transportation services that use gasoline intensively. Obviously, the interaction of higher growth combined with increased intensity of oil usage could have much more important implications for the demand for oil and the world economy. Conventional econometric estimates of the demand for motor vehicles suggest that these goods are luxury items whose consumption shares expand with higher levels of wealth and real income. To understand the importance of this interaction, we consider a scenario where productivity growth is higher in emerging Asia in both the tradable and nontradables sectors and there is a concomitant increase in the intensity of oil usage (Figure 20). The effects of the oil-intensity shock are amplified by the increase in productivity, and vice-versa — the results of the two shocks are closer to being multiplicative, rather than additive. We see the world price of oil increasing almost 20 percent on impact (twice that of the oil demand shock alone) and 60 percent in the long run.

5.4 Supply-induced oil price hike

Figures 21 to 23 report the results for a supply shock that raises the price of oil by about 50 percent after 10 quarters and by about one half as much after 15 years. The decline in oil prices after its initial upward spike, is consistent with a markup over marginal producer costs in the oil sector that rises gradually over time, but faces a loosening of short-run adjustment costs in the adjustment of oil supply.

The increase in the terms of trade in favor of the oil-exporting regions leads to an increase in consumption in the short run. However, to mimic the qualitative behavior of actual current account surpluses in the recent past, we assume that this change is accompanied by an upward shift in the desired net foreign asset positions of all oil-exporting regions. This limits the rise of consumption over the medium term, but allows consumption to be permanently higher in the long run.

Higher wealth also leads to a fall in labor supply, as it results in an increase in time devoted to leisure. For the group of oil exporters, since oil is such an important part of their economy (12 percent of production), real GDP actually falls permanently (by about 2.5 percent) as export volumes drop. This effect may be offset partially by special circumstances in the labor market in these economies — for instance ,because their economies depend heavily on migrant labor.[16] Therefore, we assume a shift in the labor supply function that allows a slight increase in labor effort in the group of oil-exporting countries rather than allowing it to fall over time. The oil-importing regions are clearly worse off, as they face a negative terms-of-trade shock that increases the cost of producing goods and services, which over time results in a decline in investment and lower levels of productive capacity.

6 Some potential policy responses

Given the long-run nature (i.e. usually a minimum of 15 years) of the scenarios offered above, it is appropriate to provide some normative suggestions as to how policymakers (particularly the regions' governments) can help reduce dependence on oil, and reduce the negative impacts that still-increasing and high oil prices will have on future world output growth We focus on concrete policy measures, not regulatory measures or legal restrictions on fuel usage in the automobile sector or industry, since these can be hard to quantify in a model-consistent fashion. While several policy experiments could be carried out with our model involving both (or either) firms and individuals, we demonstrate below that the governments can use a global hike in tax rates on gasoline, in tandem with a reduction in taxes on labor income to achieve a notable reduction in oil prices and use of oil.

6.1 A global increase in gasoline tax rates

We focus on the effects of a 25 percentage point increase in gasoline tax rates in all regions of the world. In each region, it is assumed that the additional tax revenue is used to reduce distortionary taxes on labor income. As a result, productive capacity increases, with positive effects on aggregate employment and investment. The results are reported in Figures 24 to 26.

The tax hike on gasoline eventually results in a substitution away from consumption of energy, but this is a very long and slow process given the low short-run elasticities of demand for oil. Oil prices decline by almost five percent. This decline in prices results in a reduction in the oil trade balance in the group of oil-producing countries that is about twice the effect for Canada, reflecting differences in their initial oil trade balances. The reduction

[16] This is particularly true of the OPEC countries. For example, in 2003, 79 percent of workers in Saudi Arabia were non-Saudi nationals.

in labor tax rates raises the aggregate real wage and results in higher investment and GDP in the oil-importing countries, but this effect is also quite significant in Canada, where the expansion in employment in the non-oil sector outweighs the decline in employment in the oil sector.

Consumption in the oil-importing (oil-exporting) regions increases (decreases) because lower oil prices represent a positive terms of trade shock and a wealth transfer from oil-exporting regions to oil-importing regions. In Canada, this negative terms of-trade shock results in decline in consumption in the short run, but over time the expansion in productive capacity and real income results in higher levels of consumption. Real exchange rates depreciate in the oil-exporting regions and appreciate in the oil-consuming regions.

Many of the short-run effects are reflected in the long-run implications of the shock, as consumption and investment gradually move towards their new equilibrium values, without overshooting during the transition. We consider the long-run effects by calculating the change in consumers' welfare, as shown in Table 11.[17] The steady-state implications of the global gasoline tax among the regions is fairly small, being at most -0.4 percent of consumption. Not surprising, the biggest loser is the group of oil exporting countries. Canada loses the consumption equivalent of 0.29 percent in the long run - less than the other oil exporters because of its more diversified economy. In contrast, oil importers experience minimal welfare losses (less than 0.1 percent of consumption) as they do not face the direct wealth effect that the oil exporters experience from lower oil revenues. In general, liquidity-constrained consumers benefit, as their tax burden falls significantly relative to forward-looking consumers, who bear more of the burden of the gasoline tax (and are owners of the oil wealth which decreases). Welfare declines in all regions as the majority of consumers are forward-looking. In general, the declines in welfare are small, and are not a definitive reason to reject a tax hike on gasoline, particularly since these effects could be easily overturned if the increased tax burden on gasoline also resulted in a fall in oil intensity in production (which could have additional beneficial effects on levels of production, and returns on investment).

7 Conclusion

In this paper, we developed a five-region model of the global economy and carried out scenario analyses to study the implications of different shocks driving oil prices worldwide. The model introduces significant real adjustment costs in the energy sector, making both the demand and supply for crude oil extremely inelastic in the short run, thus requiring large movements in crude oil prices to clear the energy market.

To answer the first question about the underlying causes of the oil price run-up since 2003, the model properties offer a story based on stronger productivity growth in oil importing regions coupled with shifts in oil intensity in production (emerging Asia), and (to a much lesser extent) pure price increases by oil producers. Oil price shocks stemming from higher growth in the oil-importing regions are accompanied by wealth transfers through terms-of-trade movements, leading consumption to grow slower than output in the oil-importing regions. In the medium term, high investment rates in the high-growth regions crowd out investment in the oil-exporting regions. These results need not hold if higher oil prices bring

[17] Welfare is measured in terms of consumption equivalents, defined as the amount of consumption required to achieve a certain level of utility, holding labour supply (leisure) at its pre-shock steady-state level. There may be further benefits that are not quantified, such as any shift to new (less polluting) fuel sources that could occur (but are not captured) in face of the tax shock. Moreover, this section only considers the long-run welfare implications, not those occuring on impact of the tax increase.

about expectations of a larger availability of oil reserves in the future. Moreover, the positive effects of higher oil prices on consumption need not translate into reduced current account surpluses in the oil-exporting regions, to the extent that they are accompanied by an upward shift in the desired net foreign asset positions. The conclusions about the role of increased productivity in the oil-importing regions can be reinforced by considering emerging Asia in particular, with its increased intensive use of oil in the production of tradable goods.

Our second question about whether policy can be used to ameliorate many of negative impacts of increasing and higher oil prices is answered by exploring the implications of a global tax hike on gasoline. Such a measure reduces oil prices by almost five percent, and results in a positive terms-of-trade shock for the oil-importing regions, as well as a wealth transfer from oil-exporting regions to oil-importing regions. This leads to an increase in consumption in the oil-importing regions and decreases everywhere else. Furthermore, the reduction in labor tax rates raises the aggregate real wage and results in higher investment and GDP. On net, the world suffers a small welfare loss, but this masks regional variations, where the effects are negligible in the oil importing regions, but notable in the oil-exporting regions.

Going forward, a number of extensions can be suggested. First, it would be useful to develop a more detailed assessment of the role of demand and supply shocks and their contribution to explaining the rise in oil prices over the last three years. Second, it would be useful to extend the results of Faruqee *et al.* (2007) by developing a baseline scenario for the world economy, which could be used as a reference for studying the implications of alternative policies.

References

[1] Bayoumi, T., D. Laxton and P. Pesenti, 2004, "Benefits and Spillovers of Greater Competition in Europe: A Macroeconomic Assessment", NBER Working Paper No. 10416, National Bureau of Economic Research, Inc.

[2] Coenen, G., P. McAdam and R. Straub, 2008,"Tax Reform and Labour-Market Performance in the Euro Area: A Simulation-Based Analysis Using the New Area-Wide Model", forthcoming in *Journal of Economic Dynamics and Control*, special volume from the conference "DSGE Modelling at Policymaking Institutions: Progress and Prospects", Federal Reserve Board, Washington DC, December 2005.

[3] Faruqee, H., D. Laxton, D. Muir and P. Pesenti, 2007, "Smooth Landing or Crash? Model-based Scenarios of Global Current Account Rebalancing" in R. Clarida (ed.), *G7 Current Account Imbalances: Sustainability and Adjustment,* NBER conference volume: University of Chicago Press.

[4] Faruqee, H., D. Laxton, D. Muir and P. Pesenti, 2008, "Would Protectionism Defuse Global Imbalances and Spur Economic Activity? A Scenario Analysis" forthcoming in *Journal of Economic Dynamics and Control*, special volume from the conference "DSGE Modelling at Policymaking Institutions: Progress and Prospects", Federal Reserve Board, Washington DC, December 2005 (longer version issued as NBER Working Paper No. 12704, November 2006).

[5] Gosselin, M.-A. and R. Lalonde, 2005, "MUSE: The Bank of Canada's New Projection Model of the U.S. Economy", *Bank of Canada Technical Report No. 96,* Bank of Canada.

[6] Energy Information Administration, 2006, *Short-Term Energy Outlook—June 2006*, http://www.eia.doe.gov/emeu/steo/pub/3atab.html.

[7] International Monetary Fund, 2005a, *World Economic Outlook: Globalization and External Imbalances*, IMF: Washington, D.C. (April).

[8] International Monetary Fund, 2005b, *World Economic Outlook: Building Institutions*, IMF: Washington, D.C. (September).

[9] International Monetary Fund, 2006, *World Economic Outlook: Globalization and Inflation*, IMF: Washington, D.C. (April).

[10] Jean, S. and G. Nicoletti, 2002, "Product Market Regulation and Wage Premia in Europe and North America", OECD Economics Department Working Paper 318, OECD Economics Department.

[11] Juillard, M., P. Karam, D. Laxton and P. Pesenti, 2006, "Welfare-based Monetary Policy Rules in an Estimated DSGE Model of the US Economy", ECB Working Paper 613, European Central Bank.

[12] Lalonde, R. and D. Muir, 2007, "The Bank of Canada's Version of the Global Economy Model (BoC-GEM) ", *Bank of Canada Technical Report 98,* Bank of Canada

[13] Laxton, D., and P. Pesenti, 2003, "Monetary Policy Rules for Small, Open, Emerging Economies", *Journal of Monetary Economics* 50, (July), pp. 1109-1146.

[14] Martins, J.O., S. Scarpetta, and D. Pilat, 1996, "Mark-up Pricing, Market Structure and the Business Cycle", *OECD Economic Studies* 27 (II), p.71-106.

[15] Murchison, S. and A. Rennison, 2006, "ToTEM: The Bank of Canada's New Projection and Policy Analysis Model", *Bank of Canada Technical Report 97,* Bank of Canada

[16] Perrier, P., 2005, "La fonction de production et les données canadiennes", Bank of Canada Working Paper 2005-20, Bank of Canada.

[17] Pesenti, P., 2008, "The Global Economy Model (GEM): Theoretical Framework" forthcoming in *IMF Staff Papers*.

[18] Rotemberg, J., 1982, "Sticky Prices in the United States", *Journal of Political Economy*, 90(6), pp.1187–1211.

[19] Smets, F. and R. Wouters, 2005, "Comparing Shocks and Frictions in Business Cycles: A Bayesian DSGE Approach", *Journal of Applied Econometrics* 20 (2), p.161-183.

Table 1: Growth Forecasts for China and India from Consensus Economics

	2003	2004	2005
China			
Forecast	7.4	8.3	8.6
Actual	10.0	10.1	9.9
India			
Forecast	5.6	6.8	6.9
Actual	7.2	8.1	8.3

Table 2: Core Parameters of the GEM

Parameter	CA	OE	US	AS	RC
Rate of time preference $\left(1/\beta^4 - 1\right) * 100$	1.9	1.9	1.9	1.9	1.9
Depreciation rate δ	0.02	0.02	0.02	0.02	0.02
Intertemporal elasticity of substitution $1/\sigma$	5.00	5.00	5.00	5.00	5.00
Habit persistence in consumption b_c	0.92	0.92	0.92	0.92	0.92
Frisch elasticity of labor $1/\zeta$	5.00	5.00	5.00	5.00	5.00
Share of liquidity-constrained consumers SLC	0.20	0.25	0.15	0.50	0.25
Habit persistence in labor b_ℓ	0.75	0.75	0.75	0.75	0.75

CA = CAnada, OE = group of Oil-Exporting countries, US =United States, AS = emerging ASia and RC = Remaining Countries (incl. Japan and EU)

Table 3: Parameterization of the Production Functions

Parameter	CA	OE	US	AS	RC
Tradable Intermediate Goods					
Substitution between factors of production ξ_T	0.70	0.70	0.70	0.70	0.70
Bias towards capital α_{KT}	0.71	0.80	0.70	0.75	0.79
Bias towards oil α_{OT}	0.06	0.07	0.04	0.03	0.04
Nontradable Intermediate Goods					
Substitution between factors of production ξ_N	0.70	0.70	0.70	0.70	0.70
Bias towards capital α_{KN}	0.68	0.73	0.60	0.68	0.74
Bias towards oil α_{ON}	0.04	0.06	0.03	0.03	0.02
Oil					
Substitution between factors of production ξ_O	0.60	0.60	0.60	0.60	0.60
Bias towards capital α_{KO}	0.68	0.14	0.53	0.42	0.59
Bias towards natural resources $(LAND)$ α_{LAND}	0.31	0.85	0.46	0.52	0.40
Gasoline					
Substitution between factors of production ξ_{GAS}	0.70	0.70	0.70	0.70	0.70
Bias towards capital α_{KGAS}	0.45	0.42	0.47	0.43	0.46
Bias towards oil α_{OGAS}	0.54	0.57	0.51	0.52	0.53

Table 4: Parameterization of the Final Demand Functions

Parameter	CA	OE	US	AS	RC
Final Consumption Goods					
Substitution between domestic and imported goods μ_A	2.5	2.5	2.5	2.5	2.5
Bias towards domestic goods ν_A	0.28	0.58	0.86	0.02	0.93
Substitution between domestic tradables and nontradables ε_A	0.5	0.5	0.5	0.5	0.5
Bias towards tradable goods γ_A	0.65	0.65	0.65	0.42	0.65
Substitution between gasoline and the rest ε_{GAS}	0.3	0.3	0.3	0.3	0.3
Bias towards gasoline γ_{GAS}	0.15	0.12	0.15	0.07	0.16
Final Investment Goods					
Substitution between domestic and imported goods μ_E	2.5	2.5	2.5	2.5	2.5
Bias towards domestic goods ν_E	0.25	0.33	0.86	0.02	0.92
Substitution between domestic tradables and nontradables ε_E	0.5	0.5	0.5	0.5	0.5
Bias towards tradable goods γ_E	0.81	0.75	0.75	0.79	0.75
Demand for Oil in Production					
Substitution between domestic and imported oil μ_{OT}, μ_{ON}, μ_{OGAS}	10.0	10.0	10.0	10.0	10.0
Bias towards domestic oil for producing tradables ν_{OT}	0.09	0.00	0.97	0.00	0.86
Bias towards domestic oil for producing nontradables ν_{ON}	0.03	0.00	0.91	0.00	0.60
Bias towards domestic oil for producing gasoline ν_{OGAS}	0.19	0.00	0.99	0.00	0.98

Table 5: Steady-State National Accounts - Expenditure Side

Ratio of GDP	CA	OE	US	AS	RC
Total Consumption $A + P_N G_N$	80.0	81.4	81.0	64.4	79.5
Private C	56.5	64.3	65.8	50.1	58.8
Public $G_C + P_N G_N$	23.5	17.1	15.2	14.3	20.7
Total Investment $P_E E$	19.9	18.8	18.4	36.0	20.8
Private $P_E I$	17.4	16.8	16.4	34.5	18.3
Public $P_E G_I$	2.5	2.0	2.0	1.5	2.5
Trade balance $TBAL$	0.1	-0.2	0.5	-0.4	-0.2
Imports IM	37.0	24.0	13.7	26.5	9.0
Consumption Goods $P_{MA} MA$	23.2	13.8	8.0	11.2	4.6
Investment Goods $P_{ME} ME$	11.6	8.4	4.0	12.5	3.2
Oil for producing Gasoline $P_{OGAS} MOGAS$	0.4	0.3	0.3	0.6	0.2
Other Oil $P_{OT} MOT + P_{ON} MON$	1.8	1.4	1.4	2.3	1.0
Oil Demand $P_{OT} OT + P_{ON} ON + P_{OGAS} OGAS$	3.9	3.9	3.5	5.0	2.7
Gasoline Demand $P_{GAS}(1 + \tau_{GAS}) GAS$	3.0	2.3	3.3	2.5	3.1
Government Debt B	25.0	24.0	15.0	24.0	67.0
Net Foreign Assets B^*	-7.5	21.4	-50.0	35.0	23.0
Share of World GDP (percent)	2.4	9.3	30.1	10.6	47.6

Table 6: Steady-State National Accounts - Production Side

Ratio of GDP	CA	OE	US	AS	RC
Tradables	43.9	36.2	48.2	65.1	45.8
Nontradables	49.5	53.4	50.0	34.3	50.0
Gasoline	2.3	2.0	2.9	2.2	2.4
Oil Production	7.5	11.9	3.1	2.3	2.1
Factor Incomes (% share of oil production)					
Capital	29.7	12.9	20.7	24.0	26.5
Labor	10.8	8.1	8.3	16.2	9.9
Land	59.5	79.0	71.0	59.8	63.6

Columns will not sum to 100, as gasoline and oil production overlap as a share of GDP.

Table 7: Calibrating the International Linkages

Parameter	CA	OE	US	AS	RC
Substitution between imports from different regions ρ_A	1.5	1.5	1.5	1.5	1.5
Bias towards imported consumption goods b_A from					
Canada	...	0.02	0.22	0.02	0.03
Group of oil-exporting countries	0.06	...	0.16	0.12	0.21
United States	0.71	0.45	...	0.28	0.69
Emerging Asia	0.02	0.04	0.07	...	0.07
Remaining countries	0.21	0.49	0.55	0.58	...
Substitution between imports from different regions ρ_E	1.5	1.5	1.5	1.5	1.5
Bias towards imported investment goods b_E from					
Canada	...	0.01	0.14	0.01	0.02
Group of oil-exporting countries	0.06	...	0.21	0.04	0.09
United States	0.64	0.59	...	0.31	0.74
Emerging Asia	0.04	0.06	0.14	...	0.15
Remaining countries	0.26	0.33	0.51	0.64	...
Substitution between imports from different regions ρ_o	3.0	3.0	3.0	3.0	3.0
Bias towards imported oil b_o from					
Canada	...	0.00	0.22	0.00	0.01
Group of oil-exporting countries	0.31	...	0.45	0.38	0.81
United States	0.41	0.26	...	0.05	0.16
Emerging Asia	0.00	0.01	0.00	...	0.01
Remaining countries	0.29	0.73	0.33	0.57	...
Net Foreign Liabilities					
Short-run dynamics ϕ_{B1}	0.25	0.25	0.25	0.25	0.25
Short-run dynamics ϕ_{B2}	0.07	0.07	0.07	0.07	0.07
percent related to domestic government debt ϕ_{F1}	0.50	0.50	0.50	0.50	0.50

Table 8: Price and Wage Markups

Parameter	CA	OE	US	AS	RC
Tradables					
Markup $\theta_T/(\theta_T-1)$	1.20	1.18	1.15	1.14	1.20
θ_T	6.00	6.56	7.67	8.00	5.89
Nontradables					
Markup $\theta_N/(\theta_N-1)$	1.42	1.23	1.28	1.25	1.38
θ_N	3.38	5.34	4.58	5.00	3.63
Oil					
Markup $\theta_O/(\theta_O-1)$	1.01	476	1.01	1.01	1.01
θ_O	100	1.21	100	100	100
Gasoline					
Markup $\theta_{GAS}/(\theta_{GAS}-1)$	1.16	1.17	1.17	1.17	1.16
Markup and Taxes	1.51	1.34	1.34	1.34	1.51
θ_{GAS}	7.15	7.00	7.00	7.00	7.15
Wages					
Markup $\psi/(\psi-1)$	1.20	1.30	1.16	1.16	1.30
ψ	6.00	4.30	7.30	7.30	4.30

Table 9: Real Adjustment Costs and Nominal Rigidities

Parameter	CA	OE	US	AS	RC
Real Adjustment Costs					
Capital accumulation ϕ_{I1}	1.00	1.00	1.00	1.00	1.00
Investment changes ϕ_{I2}	100	100	100	100	100
Imports of consumption goods ϕ_{MA}	0.95	0.95	0.95	0.95	0.95
Imports of investment goods ϕ_{ME}	0.95	0.95	0.95	0.95	0.95
In the Oil and Gasoline Sectors					
Capital for producing oil ϕ_{KO}	375	225	300	300	300
Capital for producing gasoline ϕ_{KGAS}	300	300	300	300	300
Labor for producing oil ϕ_{LO}	375	225	300	300	300
Labor for producing gasoline ϕ_{LGAS}	300	300	300	300	300
Demand for oil in production. ϕ_{OT}, ϕ_{ON}	300	300	300	300	300
Nominal Rigidities					
Weight on past versus steady-state inflation	0.5	0.5	0.5	0.5	0.5
Wages for liquidity-constrained consumers ϕ_{WLC}	900	800	800	1050	800
Wages for forward-looking consumers ϕ_{WFL}	900	800	800	1050	800
Price of domestically-produced tradables ϕ_{PQ}	700	700	700	900	700
Price of nontradables ϕ_{PN}	700	700	700	900	700
Price of imported intermediate goods ϕ_{PM}	4000	4000	4000	4000	4250

Table 10: Monetary Policy Reaction Function Parameters

Parameter	IFB Rule
Lagged interest rate at t-1 ω_i	1.00
Core inflation gap at t+3 ω_1	2.00

Table 11: Steady-State Welfare Implications of a Global Increase in Gasoline Tax Rates of 25 Percentage Points (Percent Change)

Welfare (Consumption Equivalent)	CA	OE	US	AS	RC
All consumers	-0.29	-0.40	-0.02	-0.04	-0.09
Forward looking consumers	-0.30	-0.42	-0.03	-0.07	-0.10
Liquidity-constrained consumers	1.02	0.66	0.56	1.01	0.70

Figure 1: Oil Price Revision

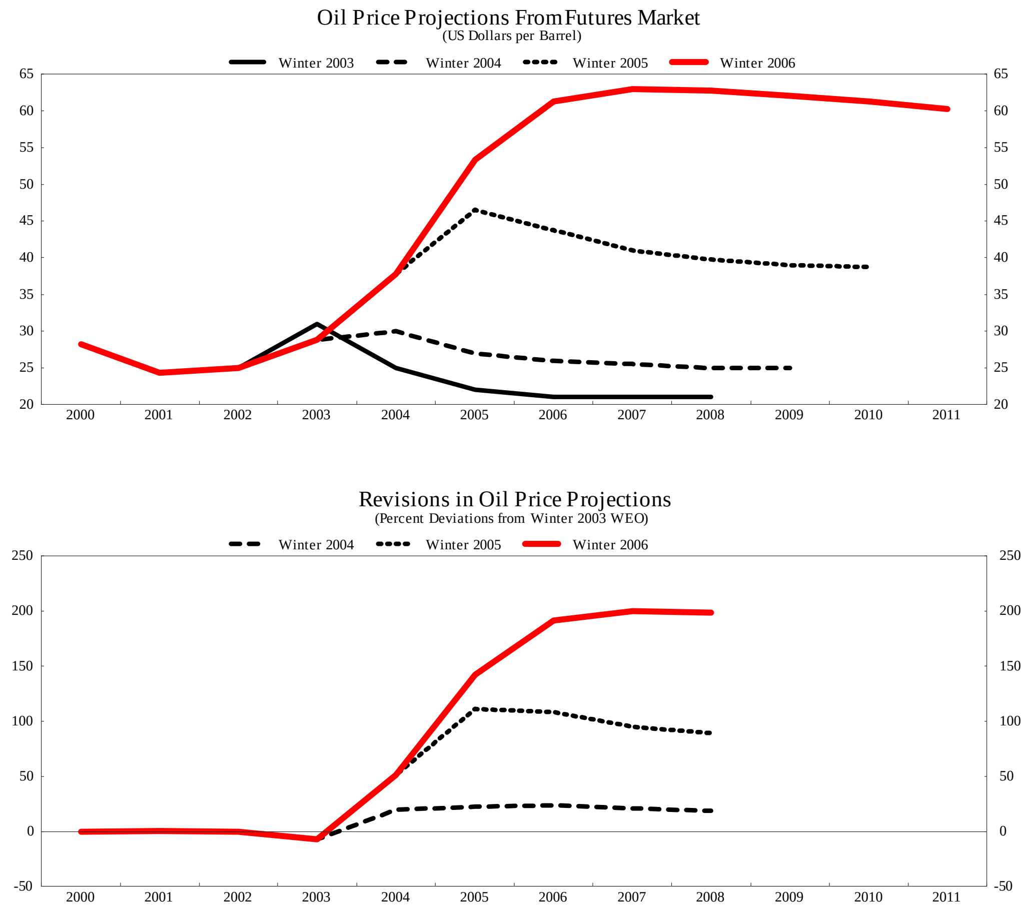


Figure 2: OPEC-11 Spare Capacity and Oil Prices, 2000 to 2005

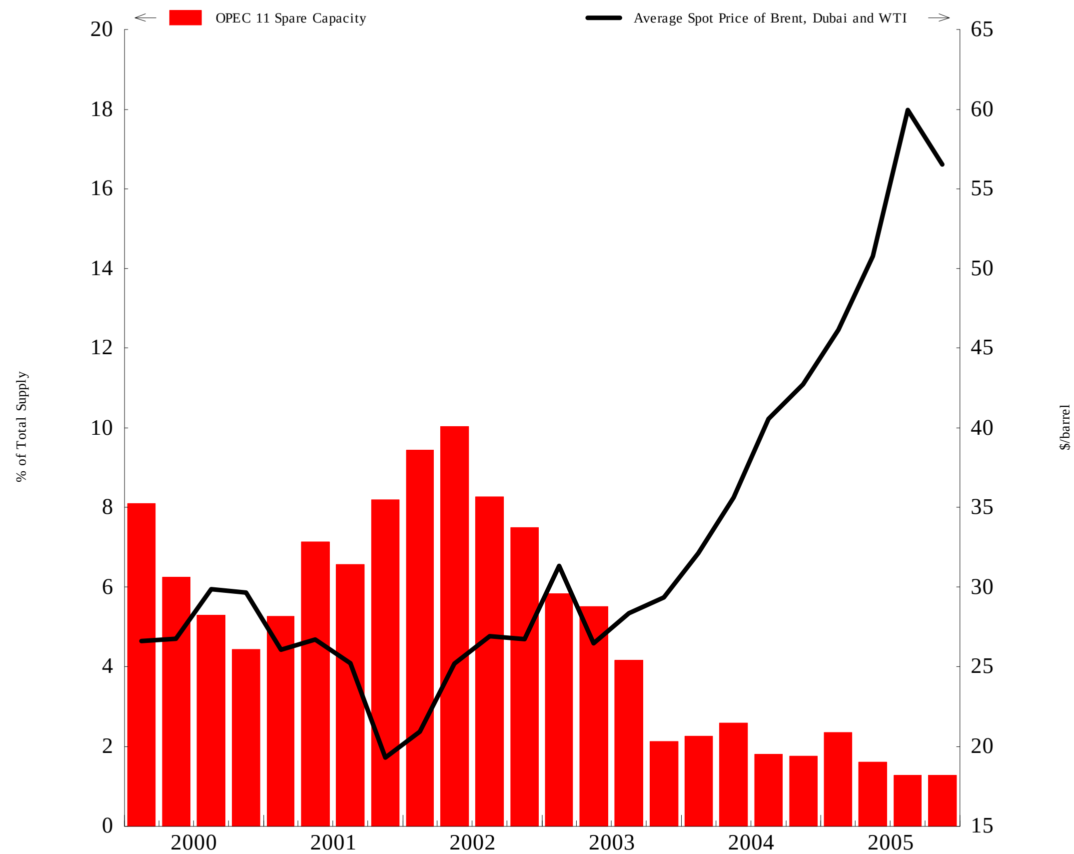
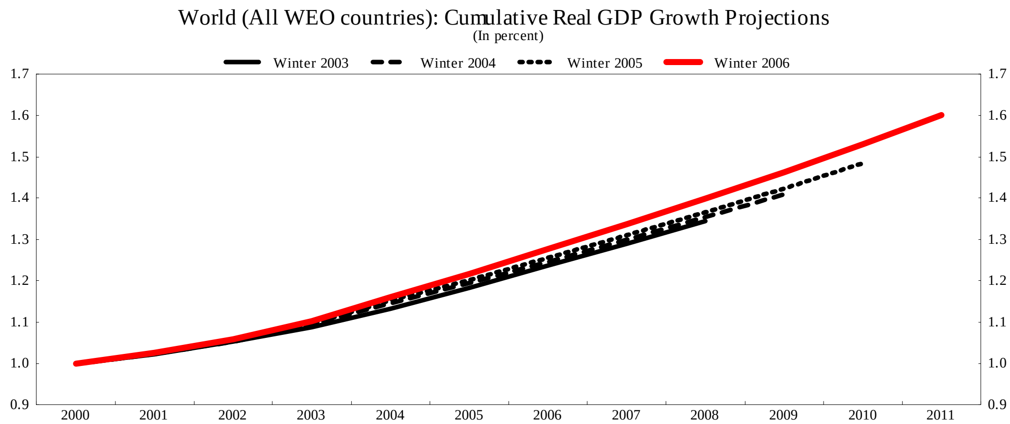


Figure 3: World Real GDP Growth Revisions

Figure 4: World Cumulative Real GDP Growth Revisions



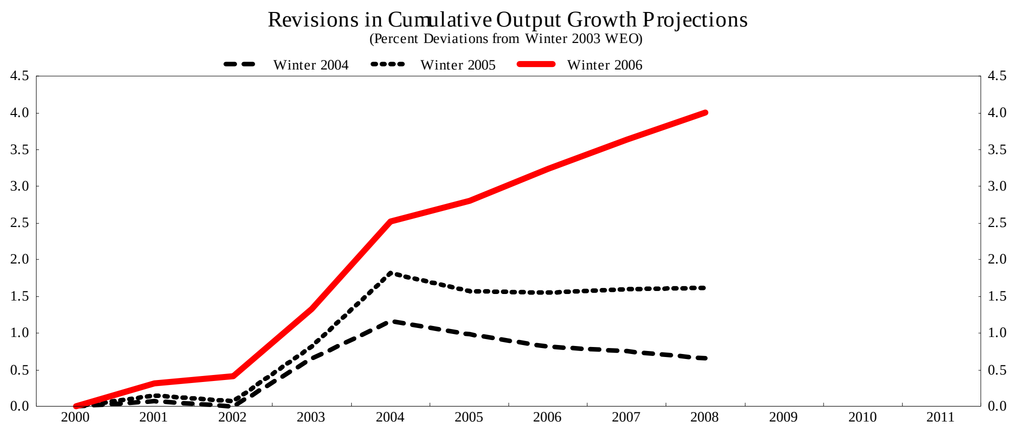
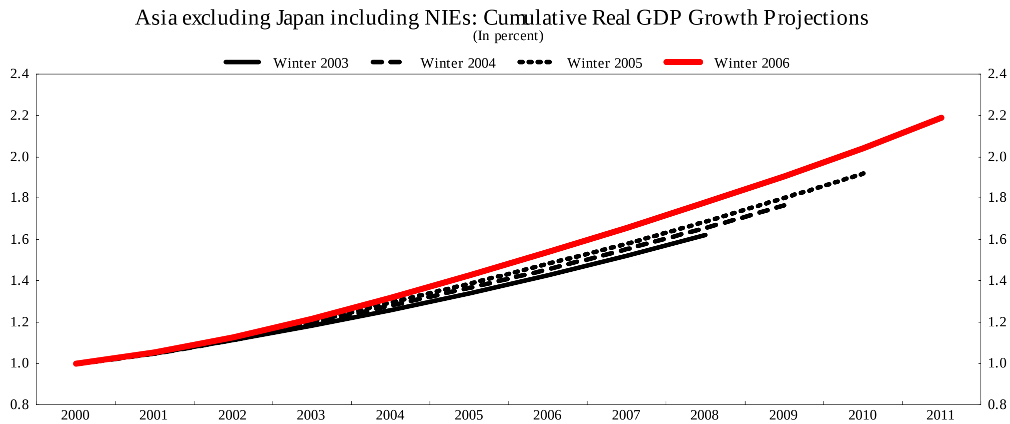


Figure 5: Emerging Asia Cumulative Real GDP Growth Revisions



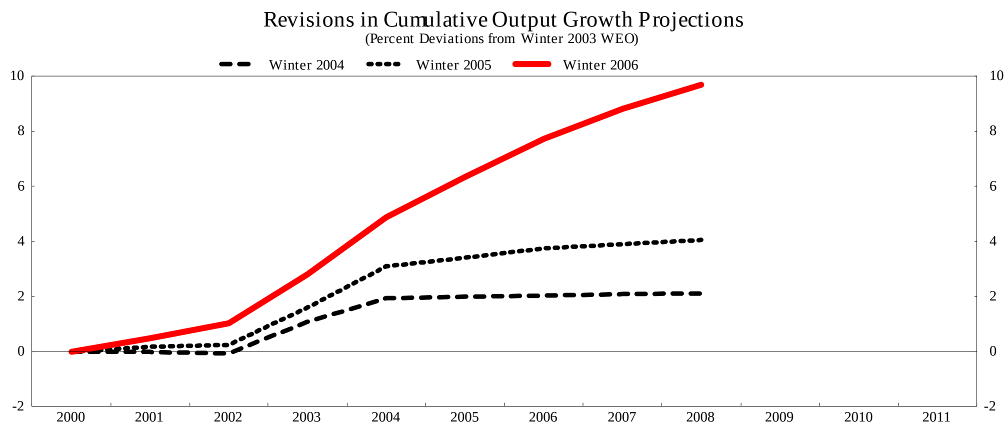
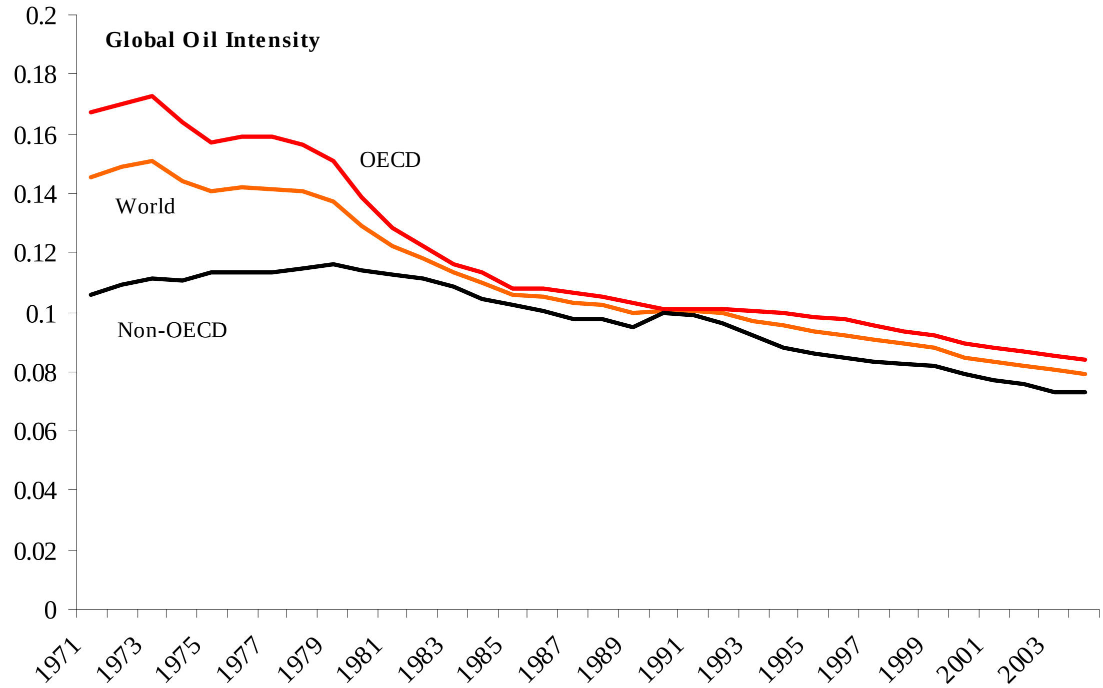
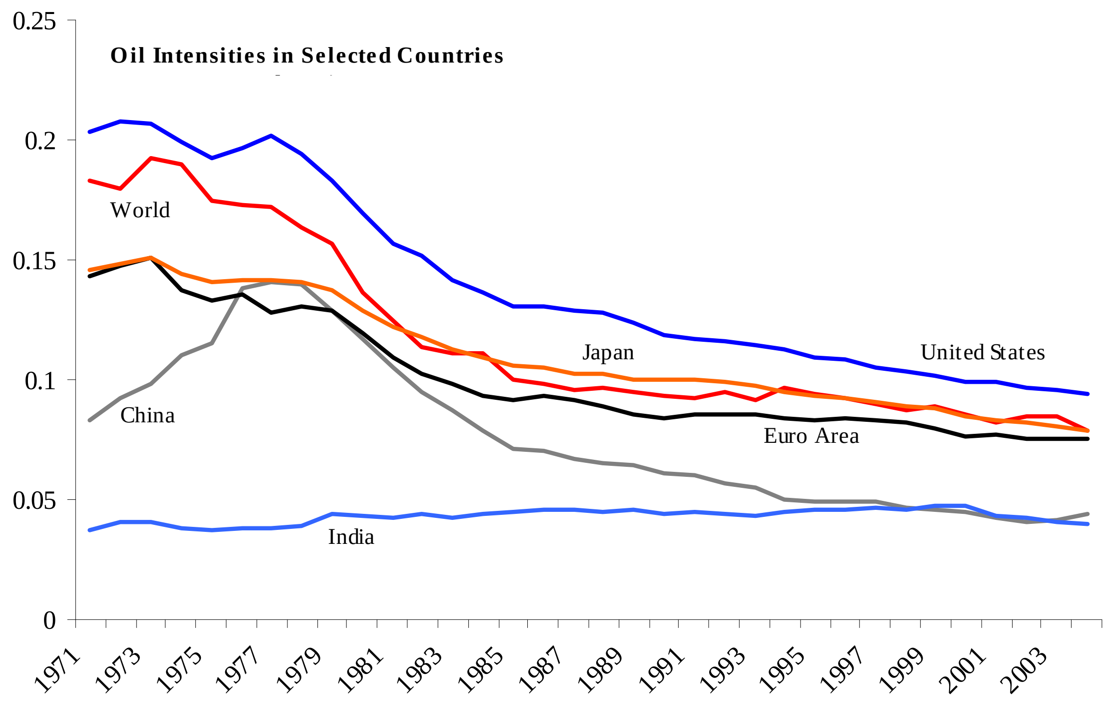


Figure 6: Oil Intensity

Oil Consumption per Unit of Output

(Kilograms per unit of real PPP-adjusted GDP, 1971-2004)





Source: IMF's World Economic Outlook, April 2005.

Figure 7: Production Structure of the GEM

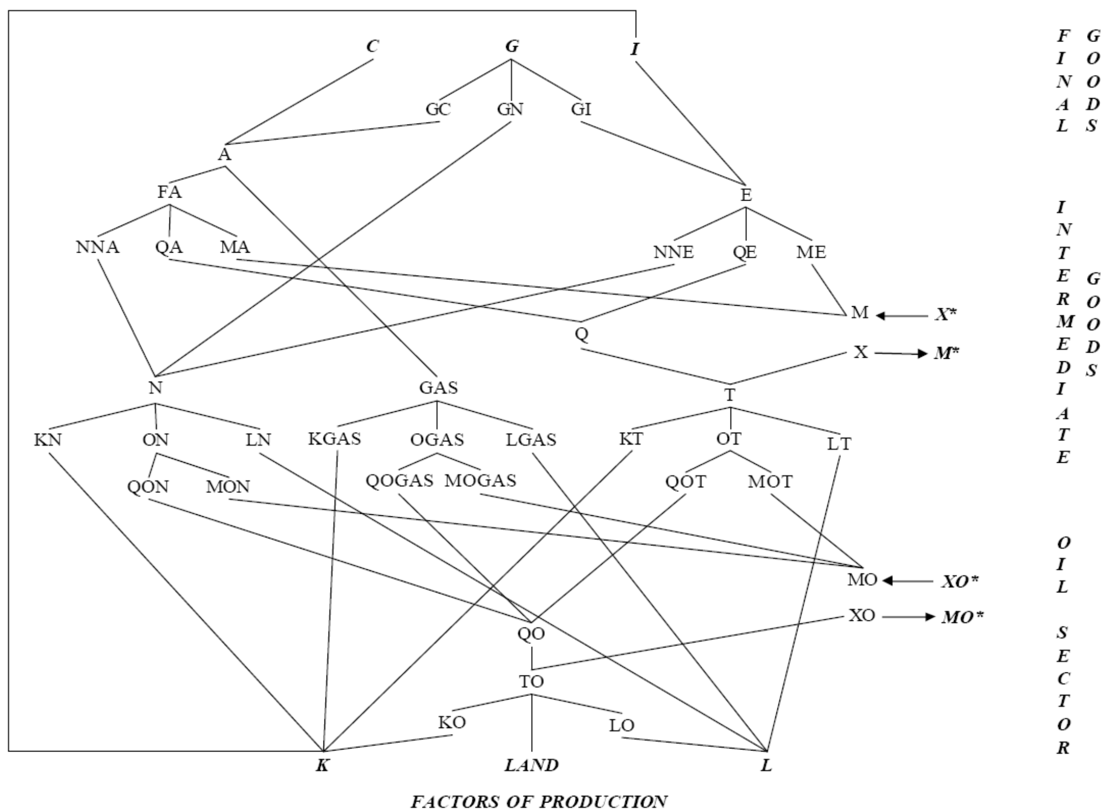


Figure 8: International Trade Linkages (all goods; steady-state calibration; percent of world GDP)

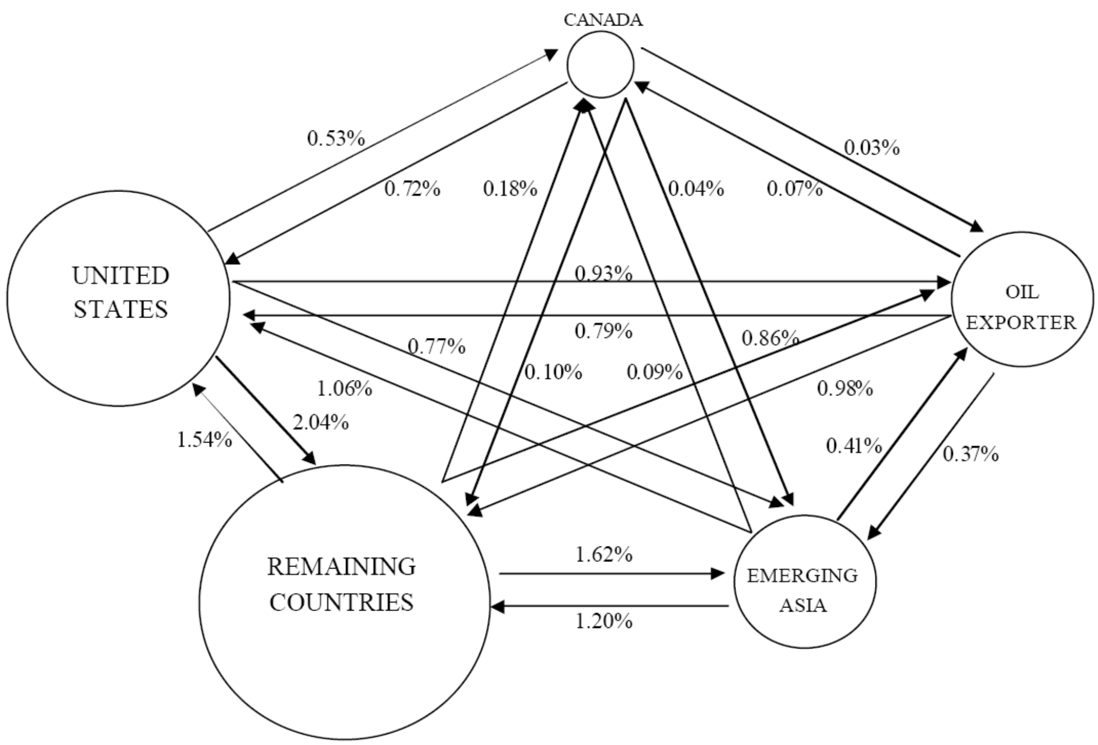


Figure 9: International Trade Linkages (oil sector; steady-state calibration; percent of world GDP)

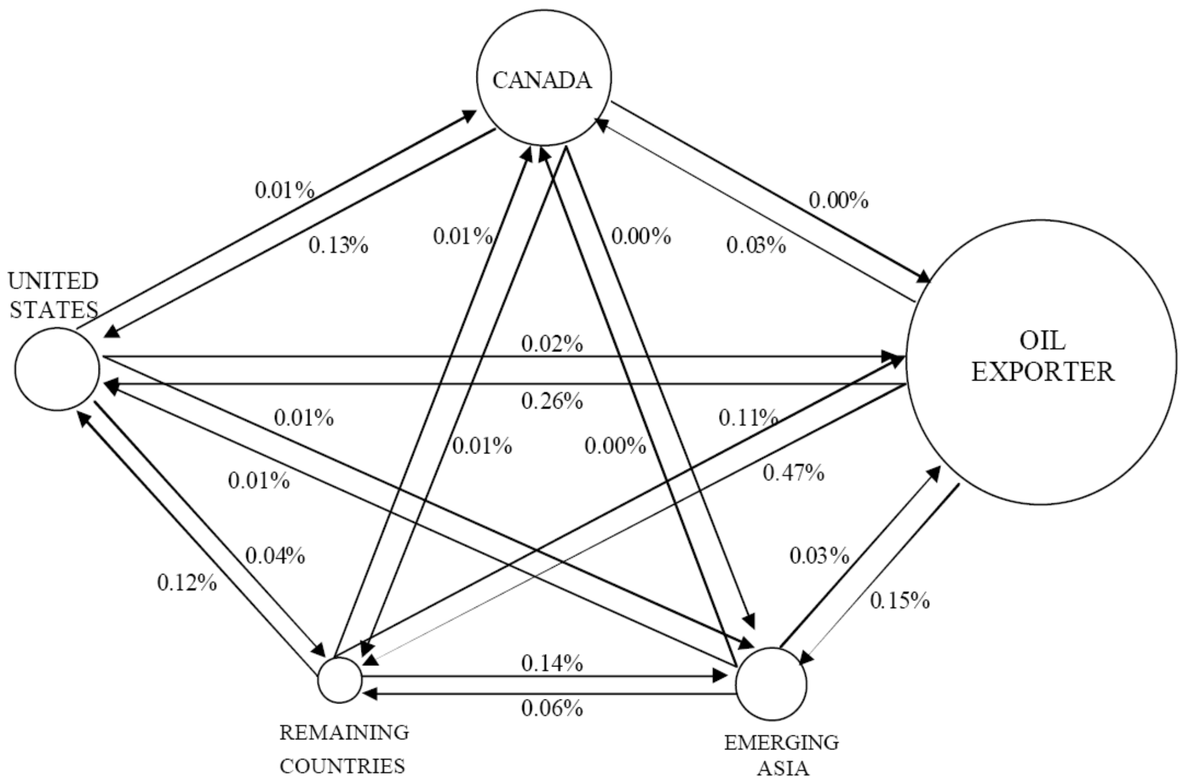


Figure 10: Higher Productivity Growth in Oil Importing Regions (Without Oil Rigidities) - Part I

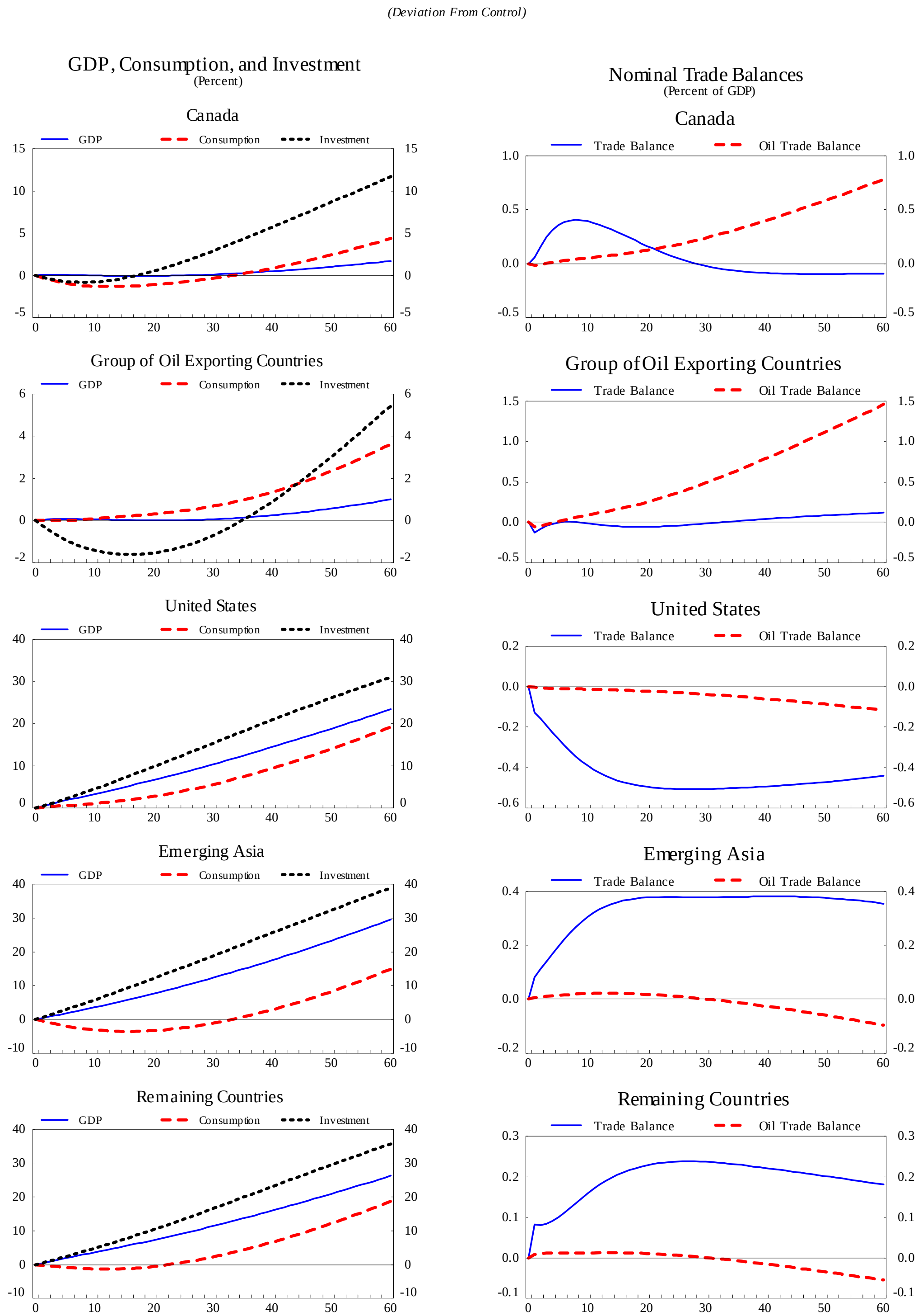


Figure 11: Higher Productivity Growth in Oil Importing Regions (Without Oil Rigidities) - Part II

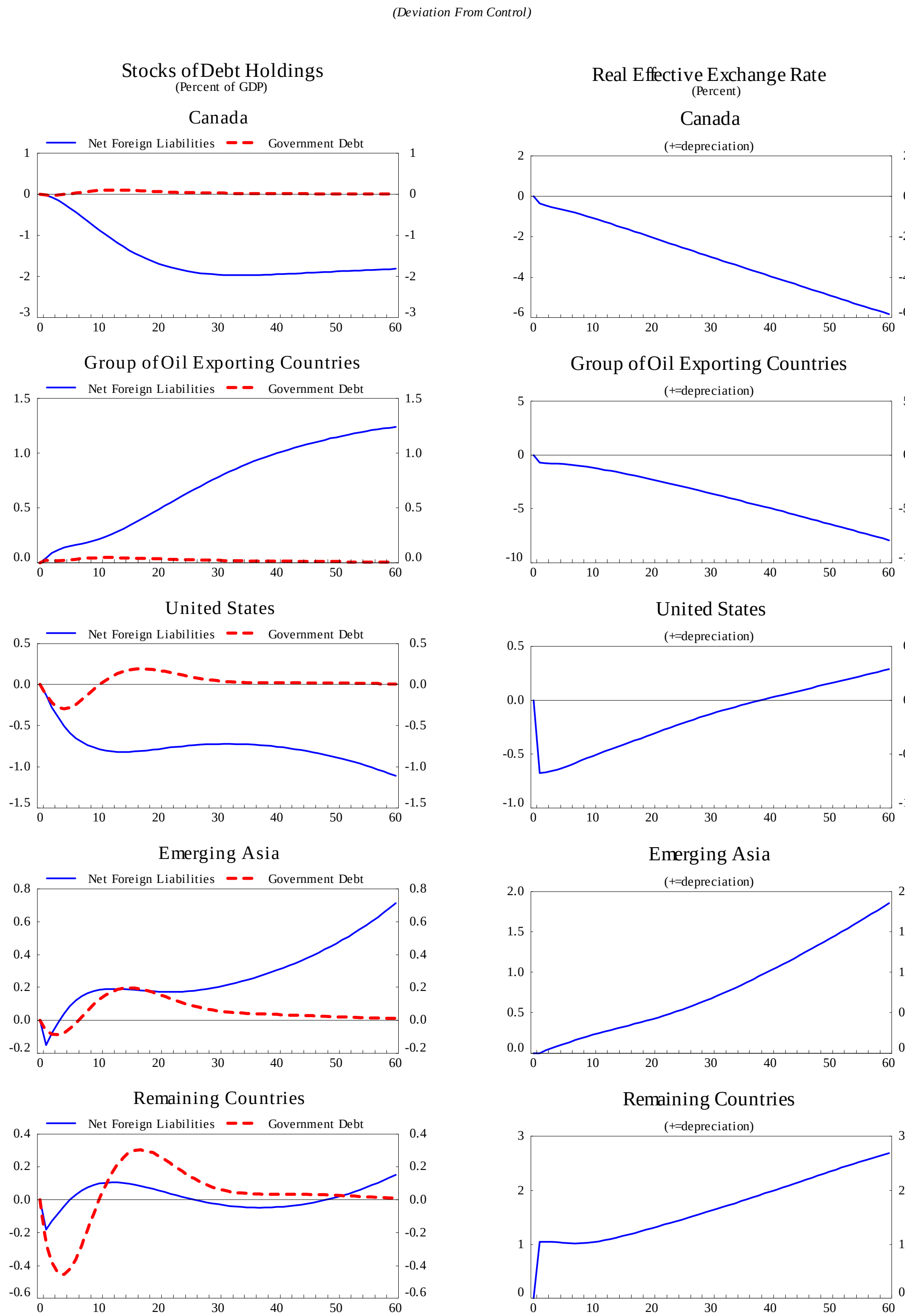


Figure 12: Higher Productivity Growth in Oil Importing Regions (Without Oil Rigidities) - Part III

(Deviation From Control)

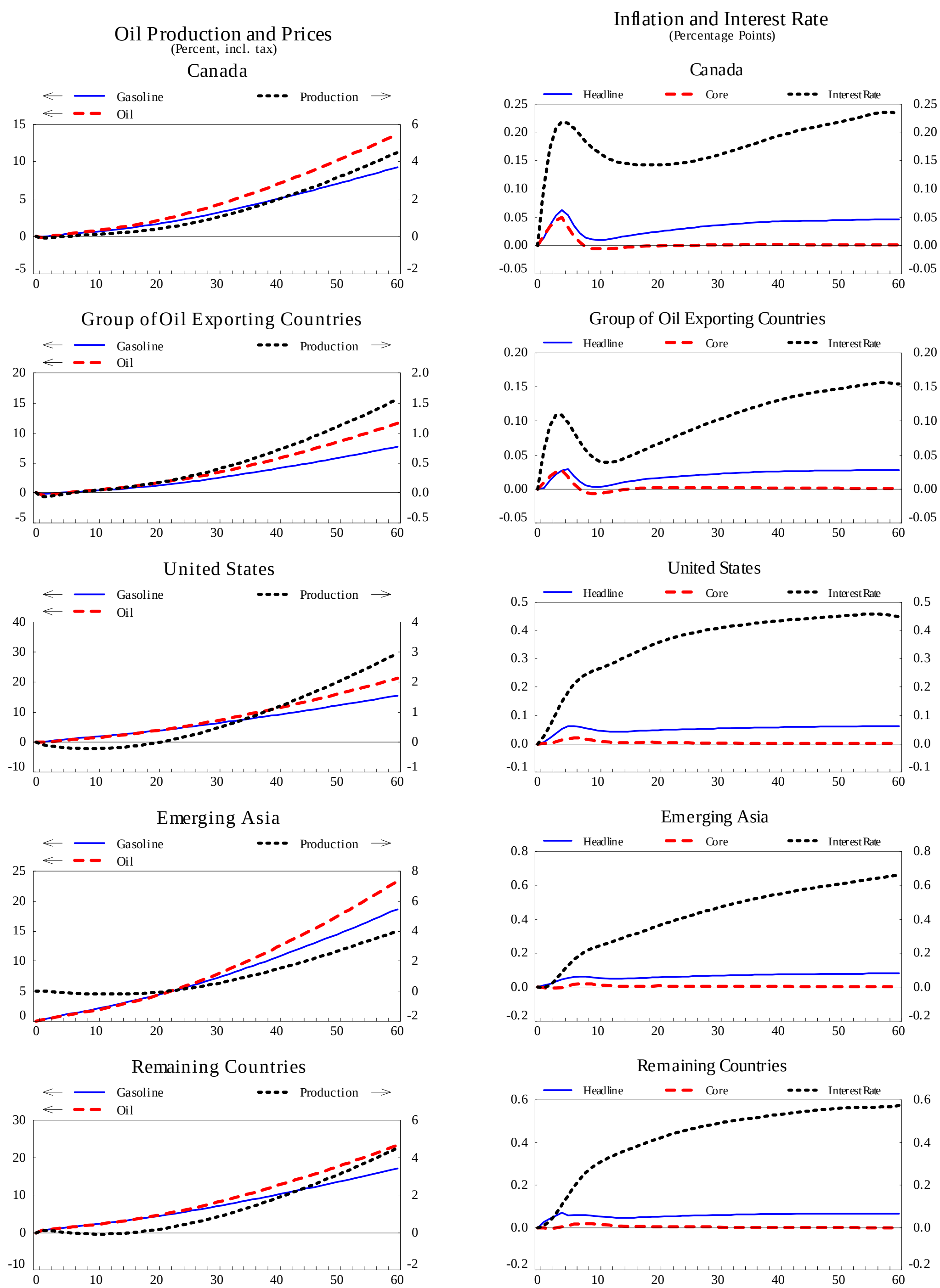


Figure 13: Higher Productivity Growth in Oil Importing Regions - Part I

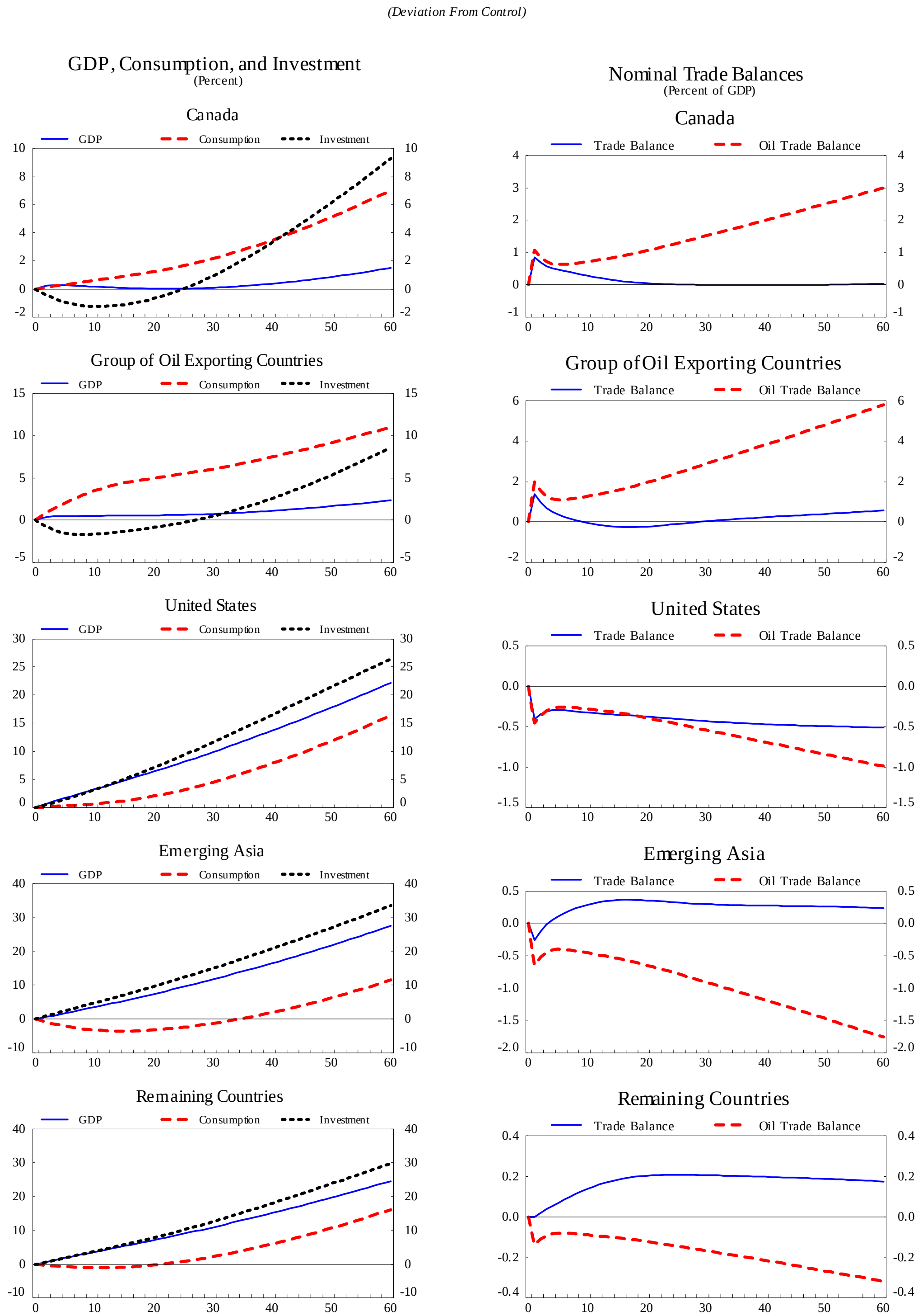


Figure 14: Higher Productivity Growth in Oil Importing Regions - Part II

(Deviation From Control)

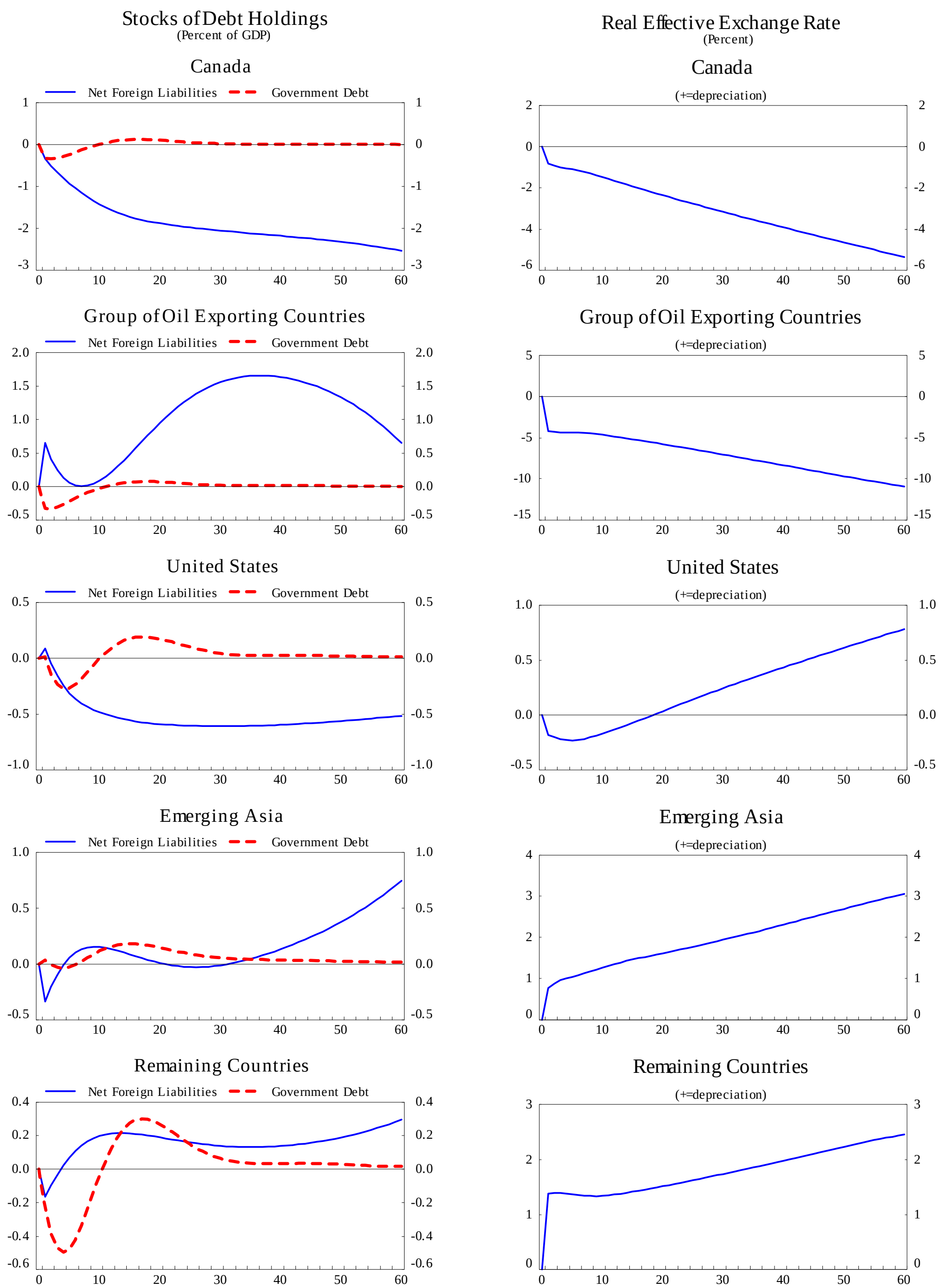


Figure 15: Higher Productivity Growth in Oil Importing Regions - Part III

(Deviation From Control)

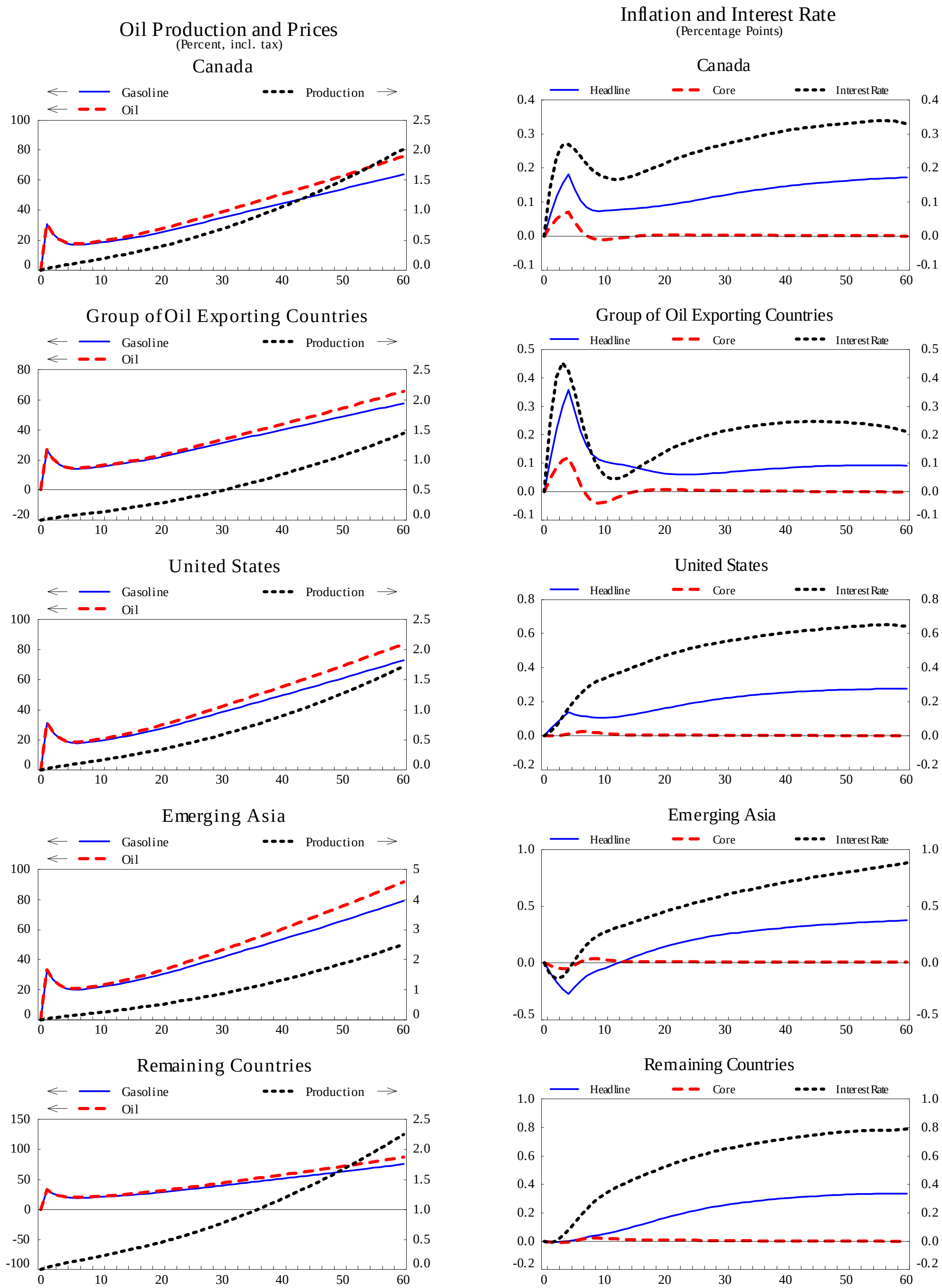


Figure 16: Expectation of More Oil Reserves Available in the Future

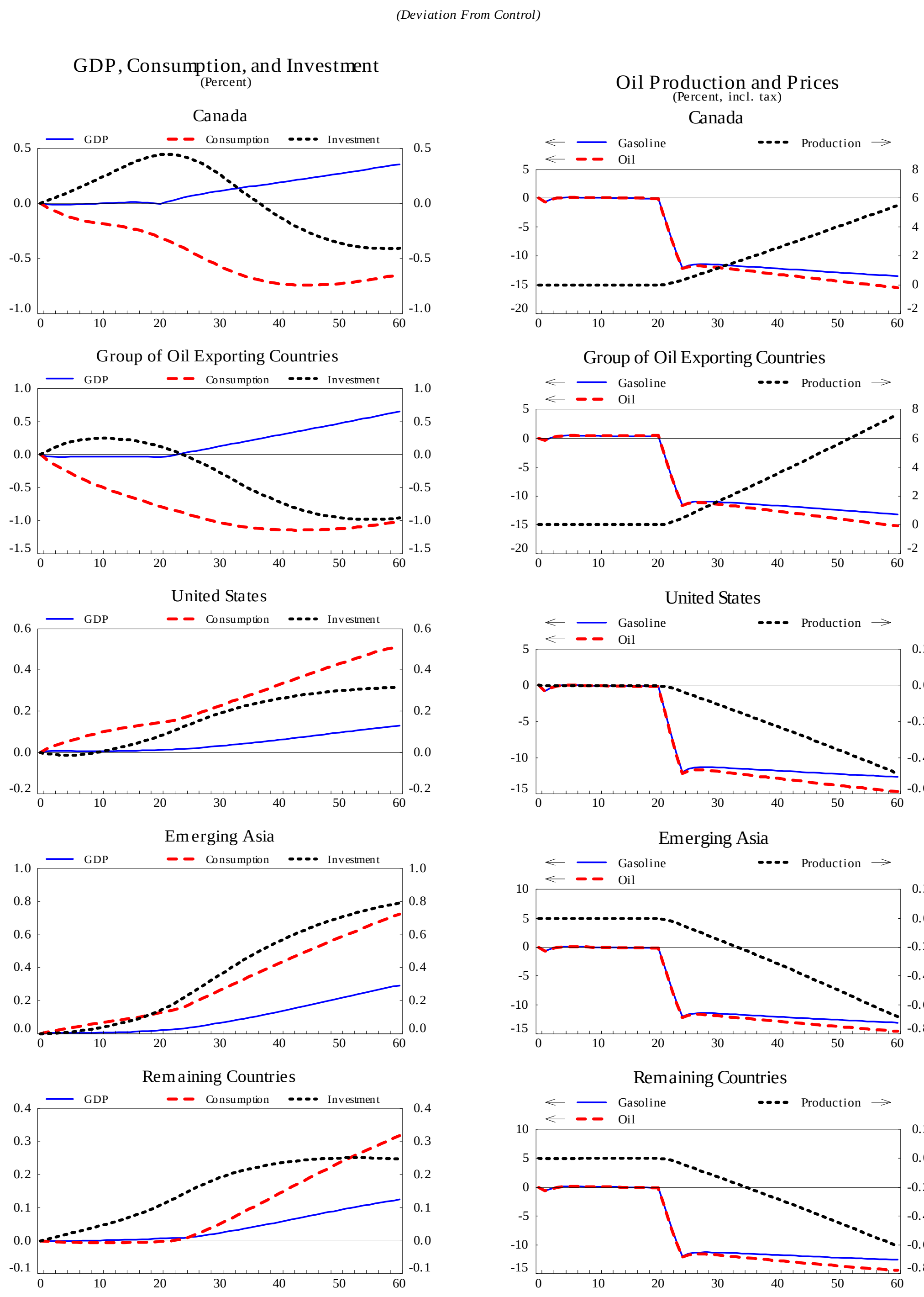


Figure 17: Increase in the Demand for Oil in Emerging Asia - Part I

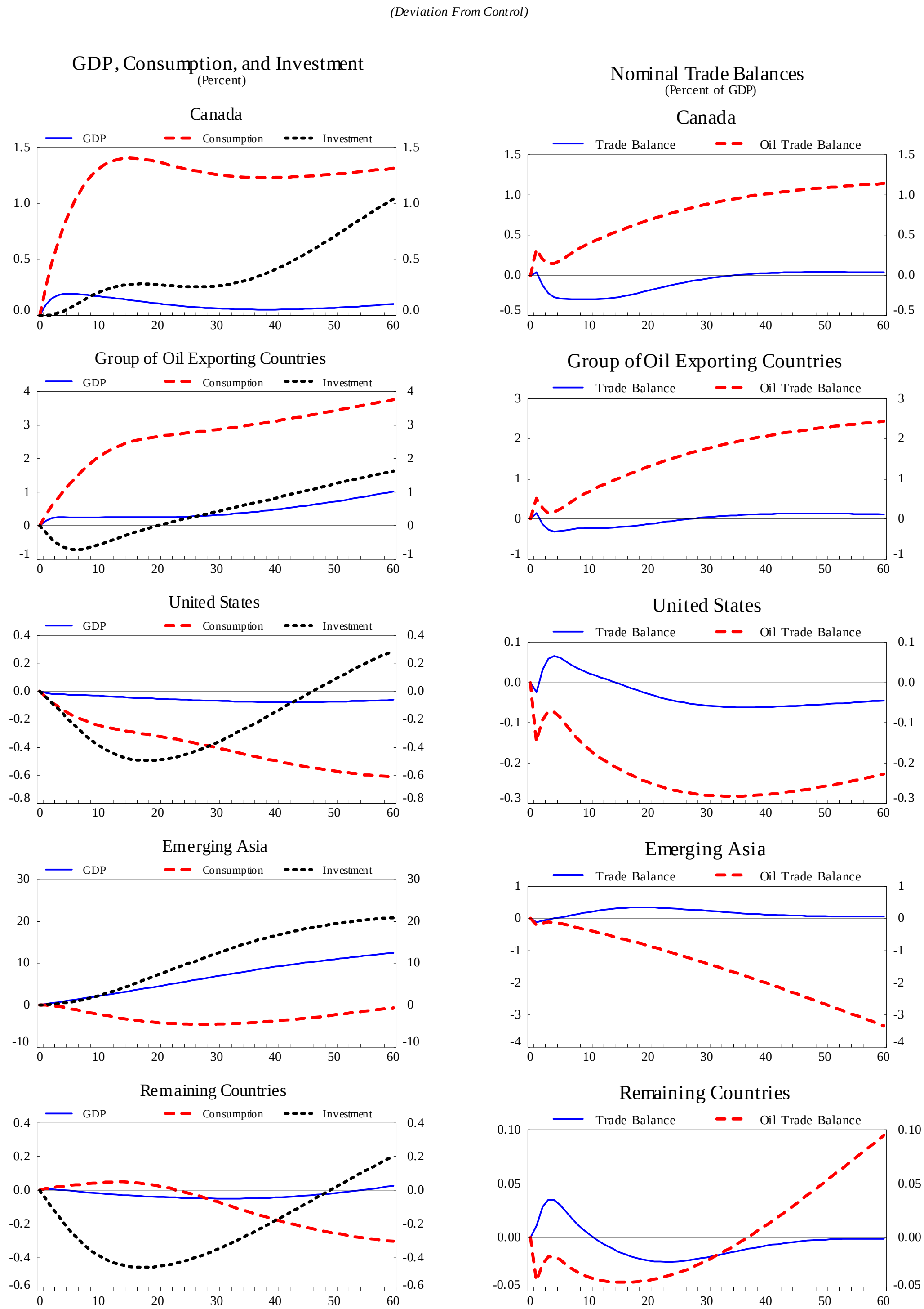


Figure 18: Increase in the Demand for Oil in Emerging Asia - Part II

(Deviation From Control)

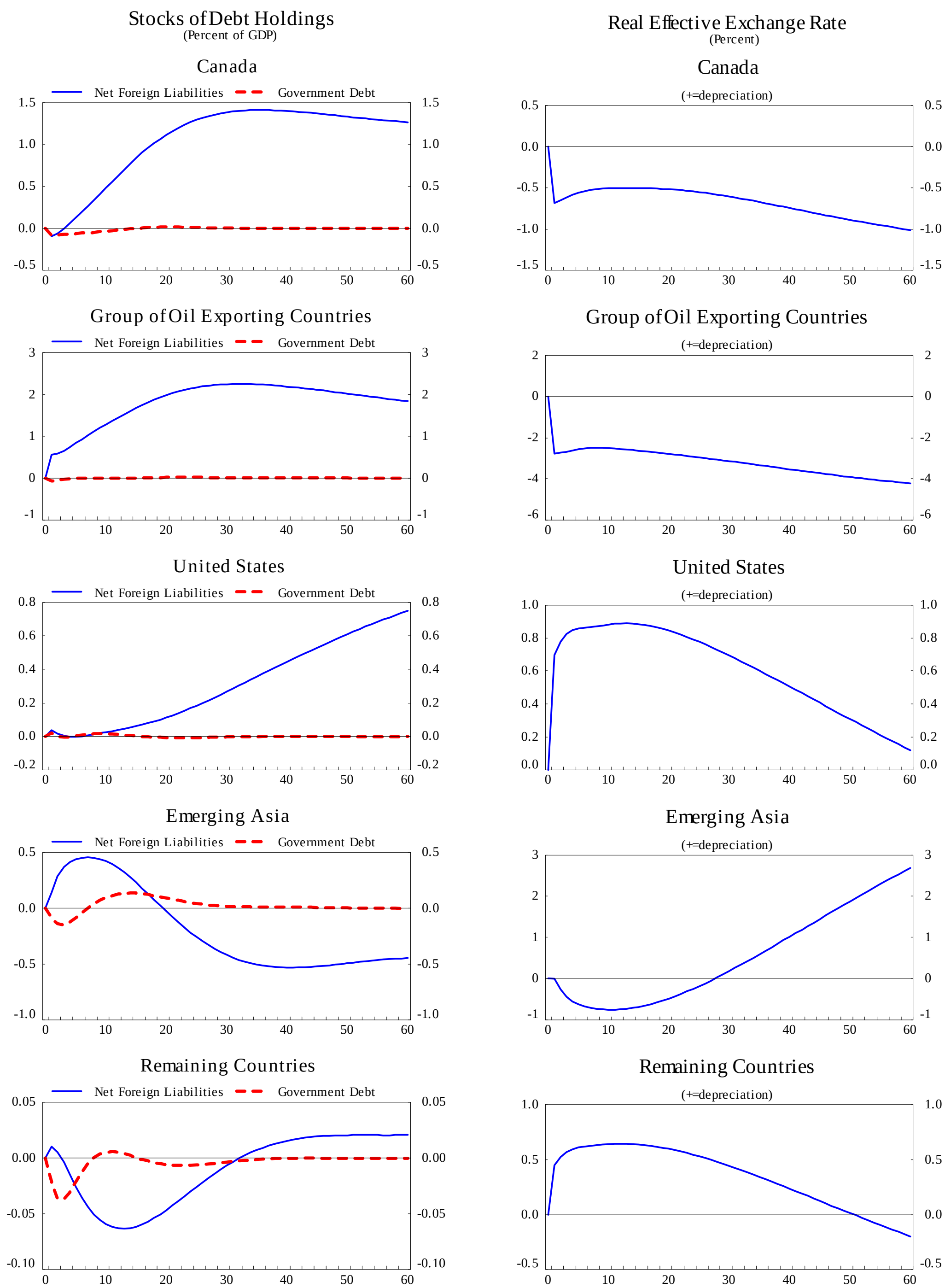


Figure 19: Increase in the Demand for Oil in Emerging Asia - Part III

(Deviation From Control)

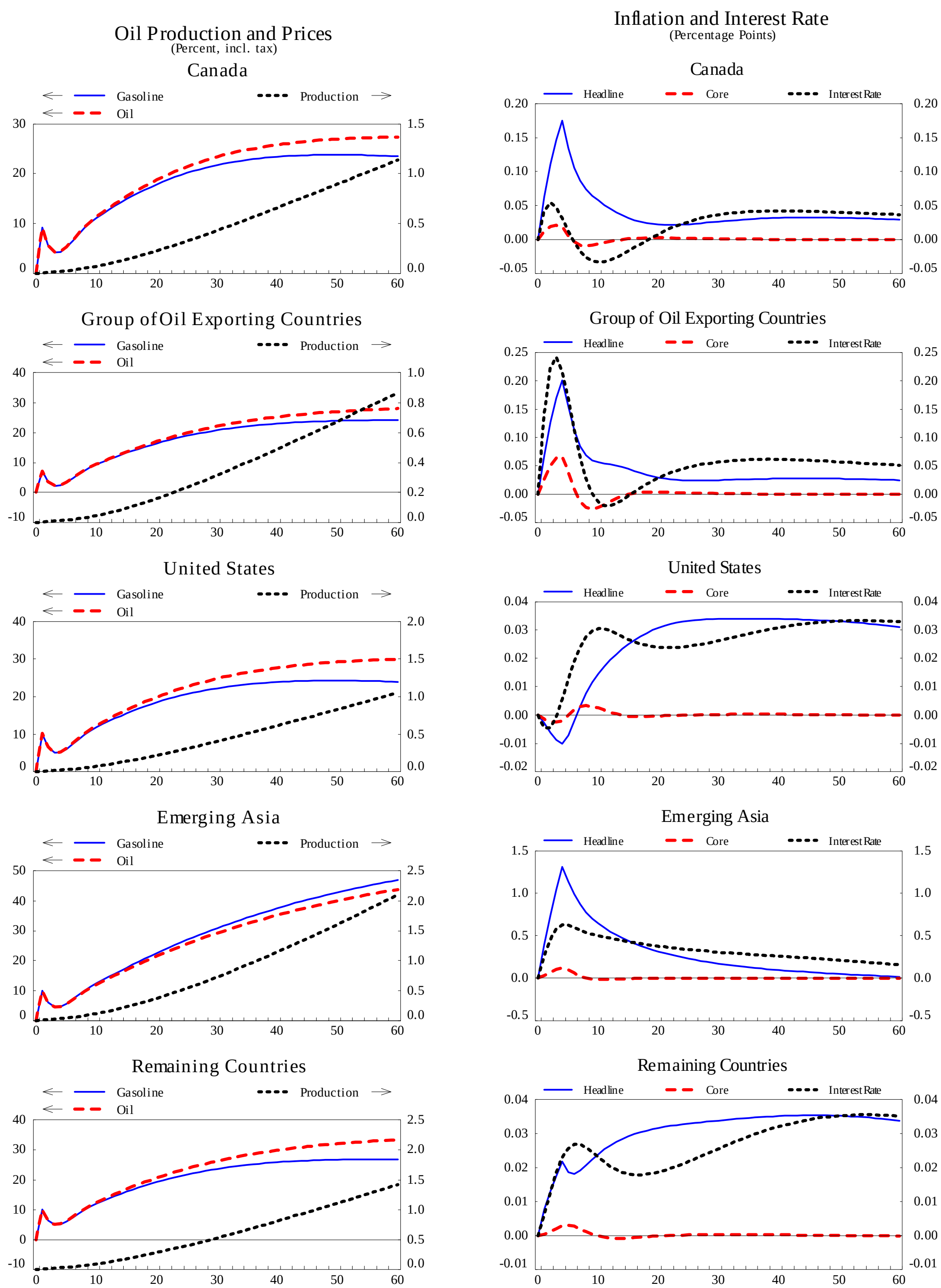


Figure 20: Higher Growth and Oil Intensity in Emerging Asia

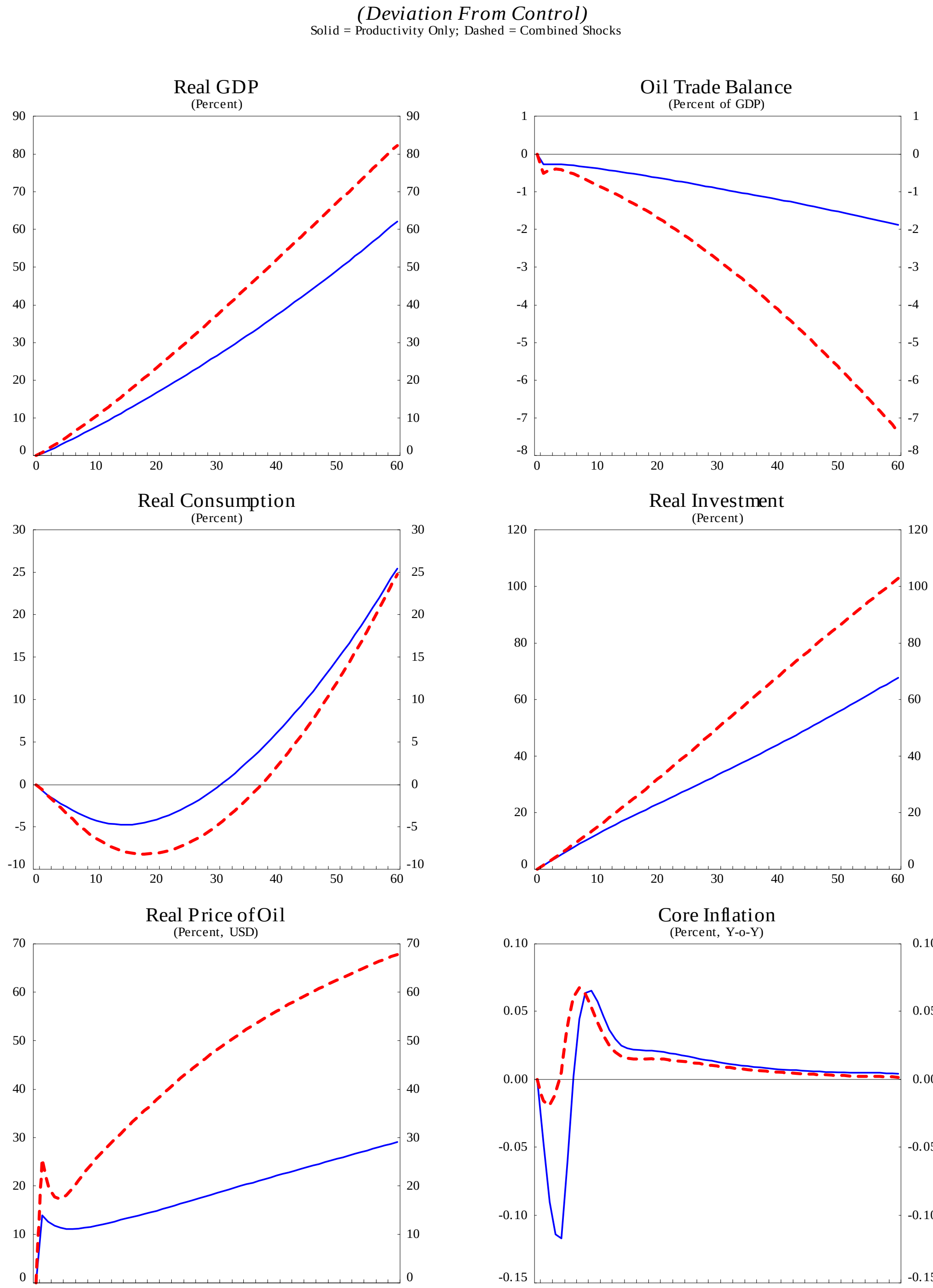


Figure 21: Supply-Induced Permanent Increase in Oil Prices - Part I

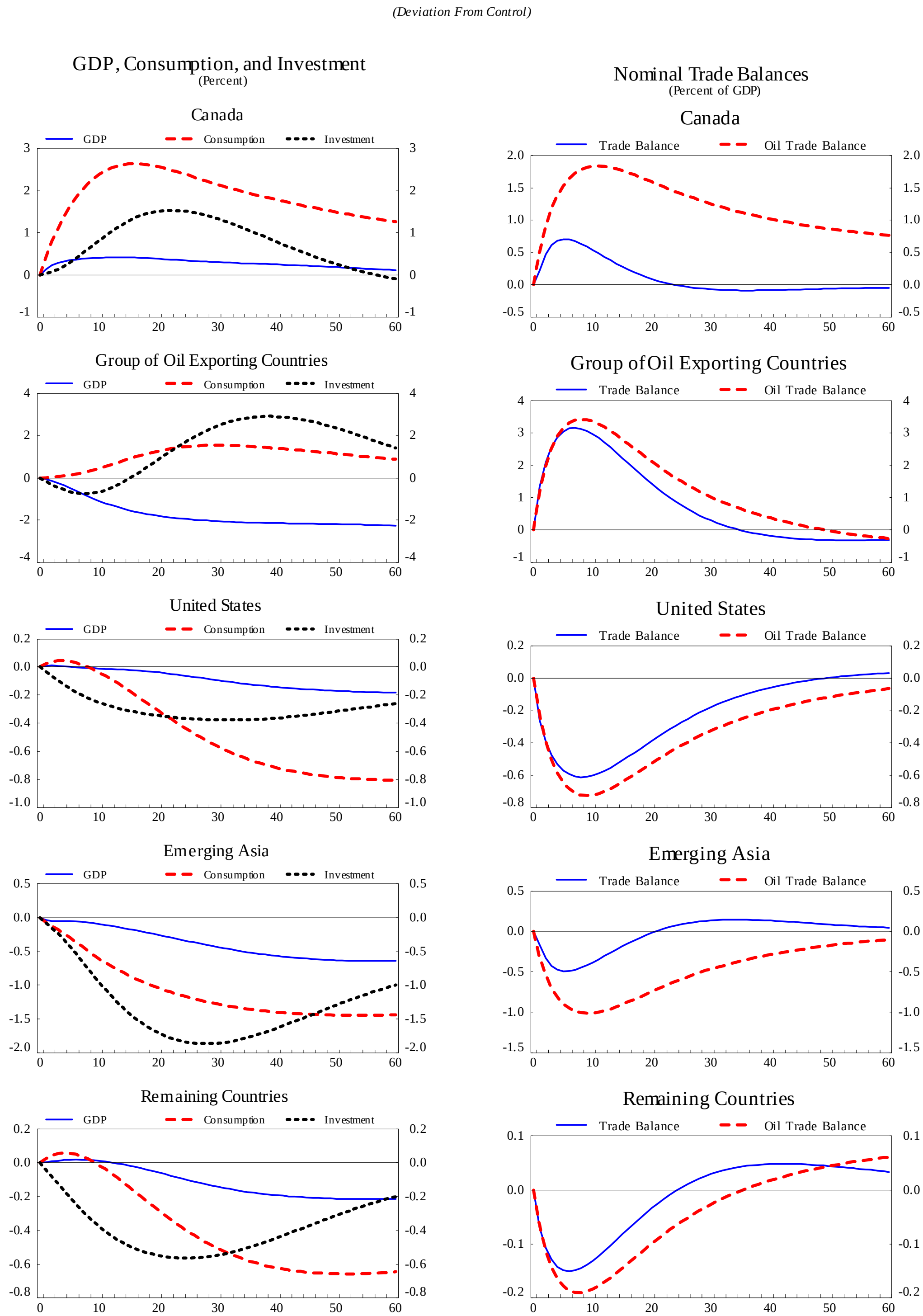


Figure 22: Supply-Induced Permanent Increase in Oil Prices - Part II

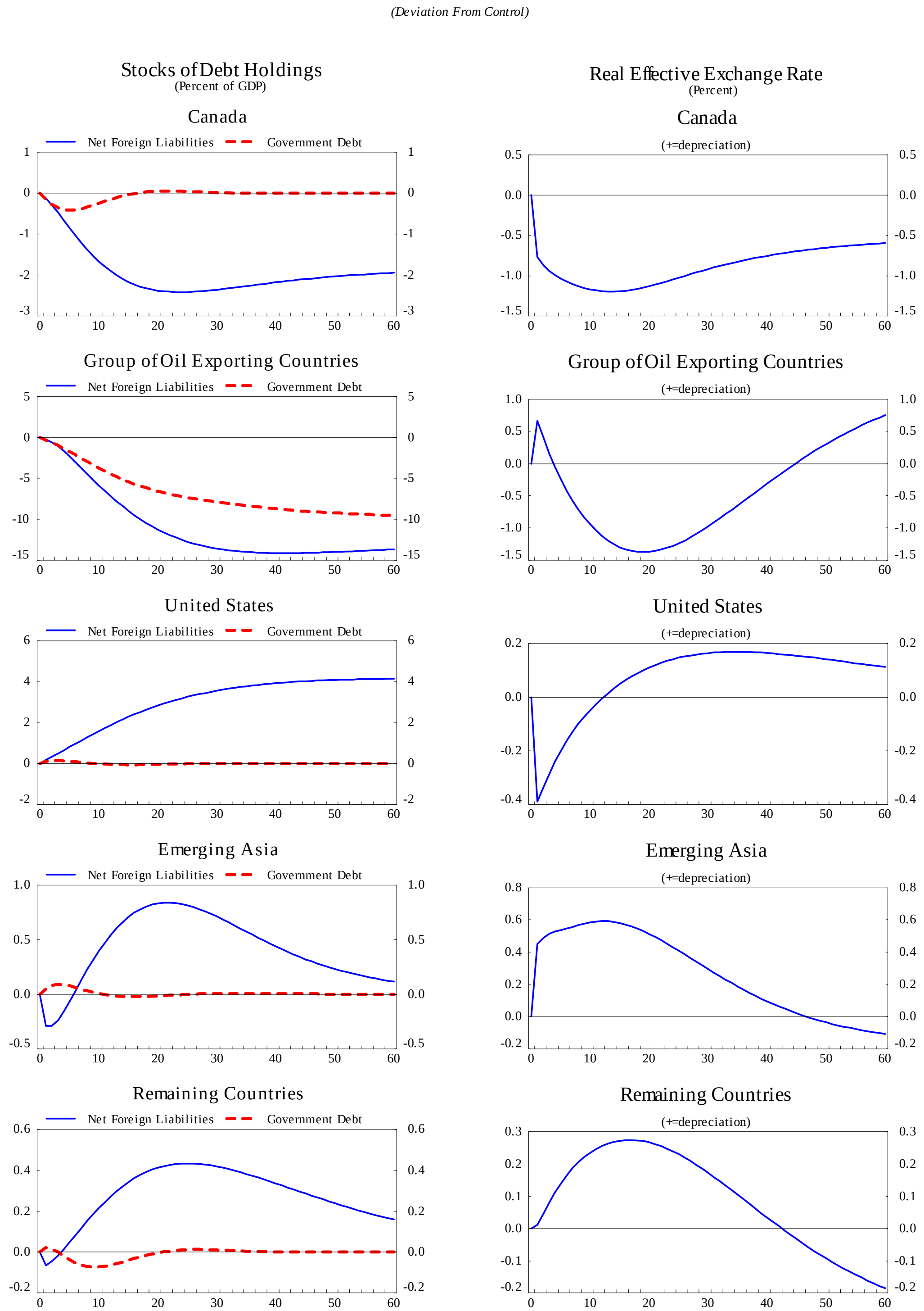


Figure 23: Supply-Induced Permanent Increase in Oil Prices - Part III

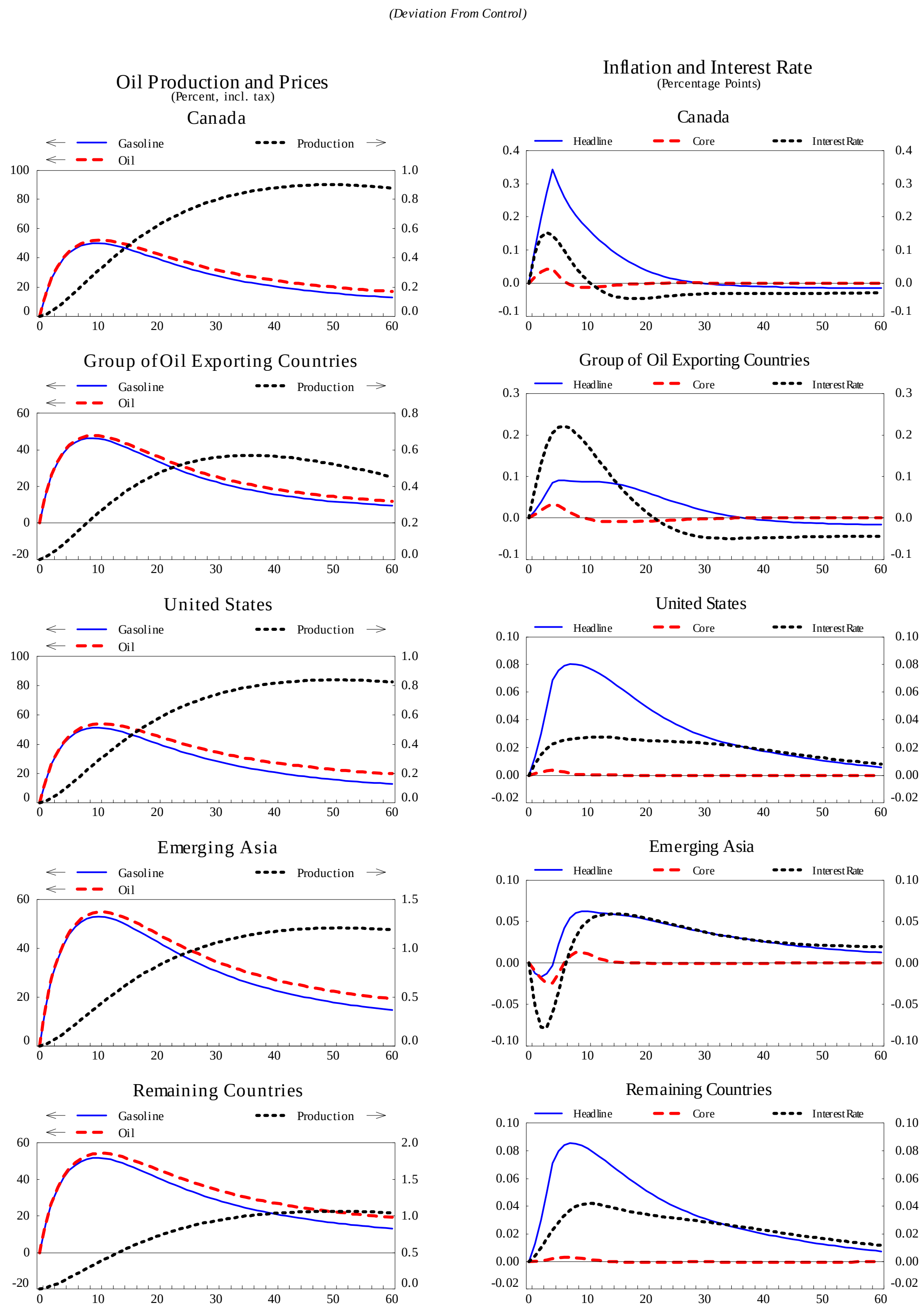


Figure 24: A Global Increase in Gasoline Tax Rates by 25 Percentage Points - Part I

(Deviation From Control)

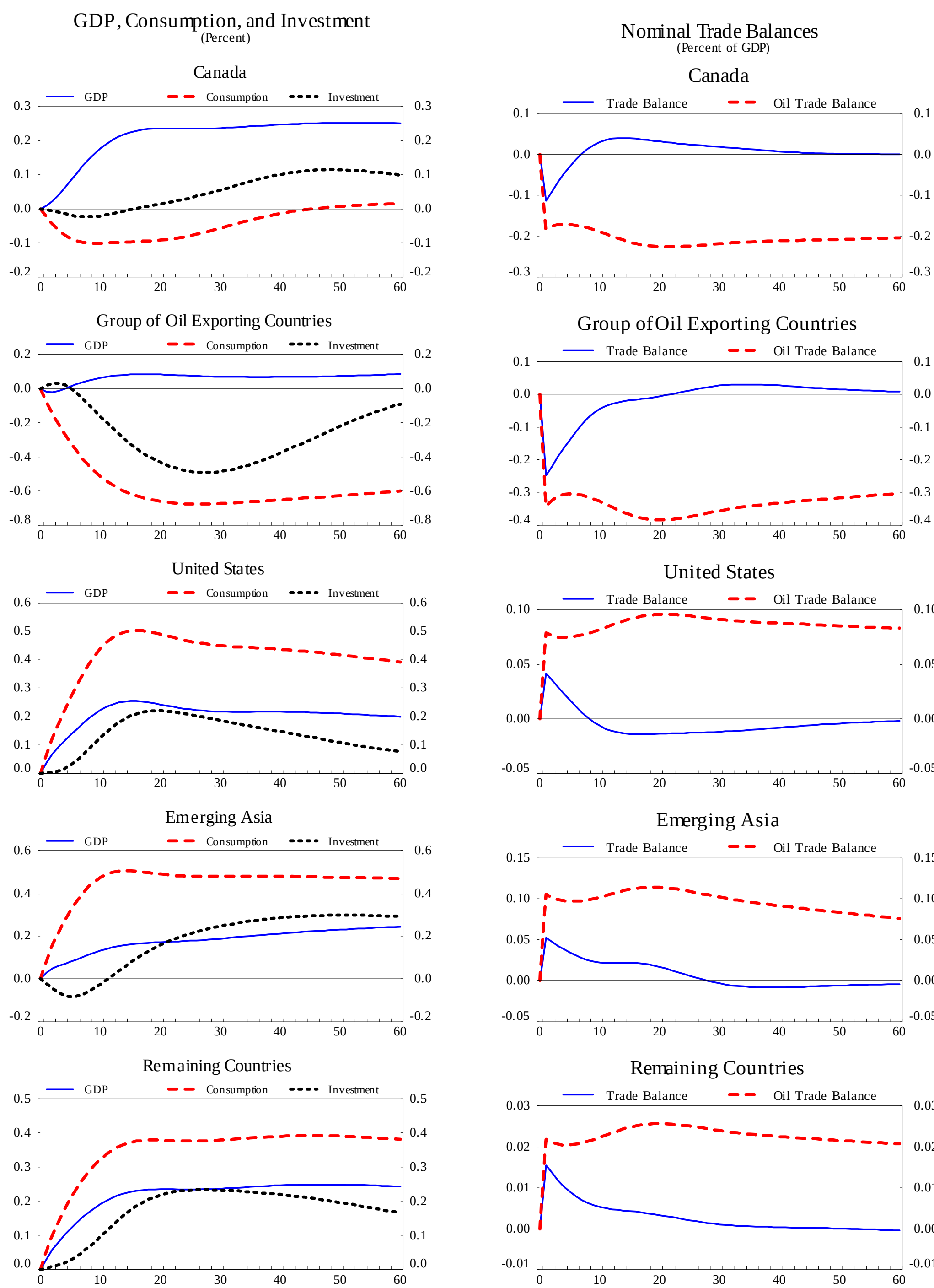


Figure 25: A Global Increase in Gasoline Tax Rates by 25 Percentage Points - Part II

(Deviation From Control)

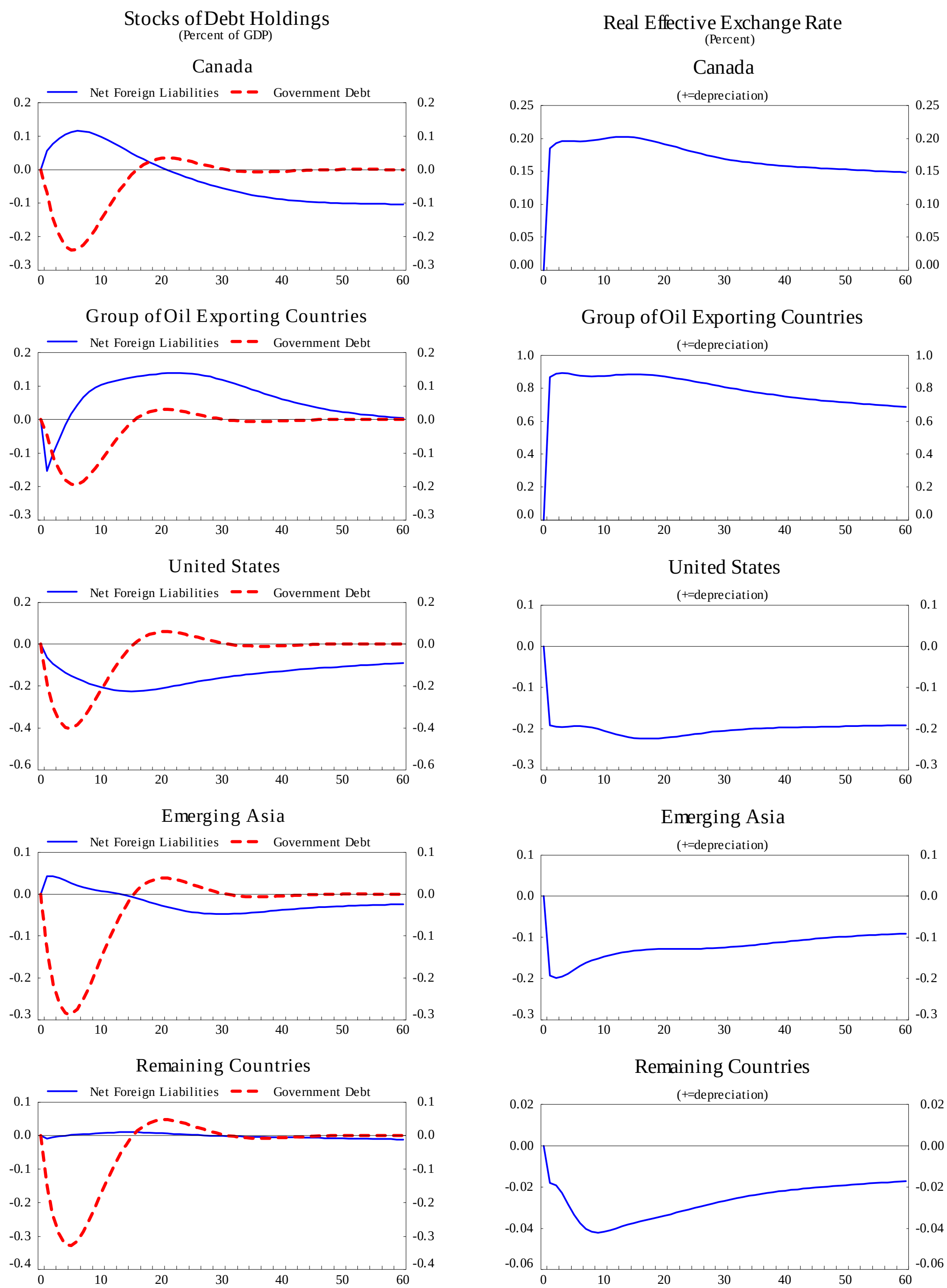


Figure 26: A Global Increase in Gasoline Tax Rates by 25 Percentage Points - Part III

(Deviation From Control)