

Government Investment and the Business Cycle in Oil-Exporting Countries[†]

JOB MARKET PAPER

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Abstract

How should governments that receive natural resource rents manage them so as to avoid inducing boom-bust cycles? This paper focuses on oil-exporting countries and argues that government investment of oil revenue, if not adequately smoothed over time, can propagate oil price shocks and exacerbate the business cycle. I use a structural vector autoregression to estimate the effects of an oil price shock on the Mexican economy and find that it generates a temporary expansion of government investment and a boom in private economic activity. In Norway, the government does not increase investment in response to a similar shock, and the economy expands modestly. I then develop a small open economy dynamic stochastic general equilibrium model that provides an explanation for the propagation mechanism. An expansionary response of government investment to a positive oil price shock raises the stock of public capital, which is an input in the production of goods and services. This increases the productivity of the private sector, triggering an expansion. Under a hypothetical prudent policy by which the government saves part of its oil revenue and smooths investment, the shock generates a milder and more long-lasting expansion. The paper, therefore, highlights the productivity-enhancing effect of public capital as a channel through which fiscal policy amplifies shocks.

JEL classification codes: E32, E62, F41, Q33.

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1 Introduction

How should governments that receive natural resource rents design fiscal policy? It has been recognized that these rents offer opportunities to accelerate economic development, but also that they pose challenges related to macroeconomic and political stability. This paper contributes to this policy question by arguing that the effects of government investment on the business cycle should receive an important consideration in the design of fiscal policy in oil-exporting countries. While government investment is typically seen as a tool that promotes long-run growth, I describe how it is also a channel through which fiscal policy can propagate shocks and exacerbate the cycle.

A substantial fraction of the revenue of many governments around the world is tied to the production and export of crude oil, which exposes their economies to the instability of international oil prices. For example, in Ecuador, Mexico, and Venezuela, oil revenue accounts for 25, 36, and 53 percent of total government revenue, respectively.¹ Thus, a sudden increase in the oil price will typically provide governments in these countries with a substantial revenue windfall. This paper argues that government investment of oil revenue, if not adequately smoothed over time, can propagate oil price shocks and exacerbate the business cycle.

I estimate the effects of an oil price shock on Mexico and Norway, two small open oil-exporting countries, by means of a structural vector autoregression. In Mexico, a positive oil price shock generates a temporary expansion of government revenue and investment, and a boom in private economic activity. The Norwegian economy responds very differently to a similar shock: the government does not increase government investment, and the economy expands modestly.

I develop a small open economy dynamic stochastic general equilibrium (DSGE) model that provides an explanation for the propagation mechanism. An expansionary response of government investment to a positive oil price shock raises the stock of public capital, which is an input in the production of goods and services. This increases the productivity of the private sector, triggering an expansion. Interestingly, the nonwasteful investment of oil revenue propagates the shock.

The DSGE model shows that under a prudent policy by which the government builds a sovereign wealth fund with oil revenue, as in Norway, and smooths investment, the shock generates a milder and more long-lasting expansion. The prudent policy protects the economy from the instability of oil prices.

¹Averages for the period 2005–2009. The source is [Villafuerte, López-Murphy, and Ossowski \(2013, p. 122\)](#).

To shed light into the role of government investment in the transmission of oil price shocks, I study the behavior of the DSGE model under two simple and extreme fiscal policy rules. Under the first rule, which resembles the behavior of Mexican fiscal policy in some respects, the government spends all of its revenue immediately, so that a positive oil price shock translates into a drastic scale-up of government investment. Under the second rule, which in some respects resembles the behavior of Norwegian policy, the government saves a substantial fraction of oil revenue, including all windfalls, in a sovereign wealth fund, so that investment is delinked from fluctuations in the oil price.

Under the first rule, the model economy's response to an oil price shock reproduces several features of the Mexican economy's response to the same shock, so the model offers an explanation for the propagation mechanism. In the model, public capital is an input in the production of tradable and nontradable goods. As the government scales investment up, adding to the stock of public capital in response to an oil price shock, it raises the productivity of private capital and labor, triggering an expansion. As the shock dies out, fiscal revenue drops, limiting the government's ability to sustain the stock of public capital, productivity decreases, and the private sector retreats. The second and more prudent fiscal rule shields the model economy from this effect, since oil revenue windfalls are saved in a sovereign wealth fund. I emphasize here that the two simple and extreme policy rules highlight different approaches to fiscal policy in oil-exporting countries, and should not be viewed as detailed and implementable rules.

But exactly how important are the oil sector and government investment in Mexico and Norway? Table 1 shows that the oil sector weights significantly on both economies, as it represents 9 percent and 28 percent of GDP in Mexico and Norway, respectively. I have mentioned that an oil price shock of similar size has a much stronger effect in Mexico than in Norway, but this is clearly not because oil is more important in Mexico's economy. Actually, the oil sector weights nearly 3 times more in Norway's economy. Similarly, oil exports represent 12 percent and 42 percent of total exports in Mexico and Norway, respectively. Oil contributes with a substantial fraction of government revenue in both countries: about a third in Mexico (31 percent) and a fifth in Norway (22 percent). Regarding government investment, the table shows it is a significant component of government spending, as it represents 17 percent and 8 percent of primary expenditures (total expenditures minus interest payments) in Mexico and Norway, respectively. Finally, government investment represents a larger fraction of GDP in Mexico (6 percent) than in Norway (3 percent).²

²The data in table 1 refer to the following samples: 1993:Q1–2014:Q1 for Mexico, and 1991:Q1–2014:Q1 for Norway. Government data refer to the federal government in Mexico and the central government in Norway, except for the ratio of government investment to GDP, which considers the general government; this level includes the federal (or central), state, and local governments.

Table 1: Oil and Government Investment in Mexico and Norway

Ratio	Mexico		Norway	
	Mean	St. dev.	Mean	St. dev.
Oil value added to GDP	0.09	0.01	0.28	0.05
Oil exports to total exports	0.12	0.03	0.42	0.07
Oil revenue to total gov. revenue	0.31	0.08	0.22	0.09
Gov. investment to primary exp. ^a	0.17	0.03	0.08	0.03
Gov. investment to GDP ^b	0.06	0.01	0.03	0.00

Samples are 1993:Q1–2014:Q4 and 1991:Q1–2014:Q4 for Mexico and Norway, respectively. Government data refer to the federal government, unless stated otherwise.

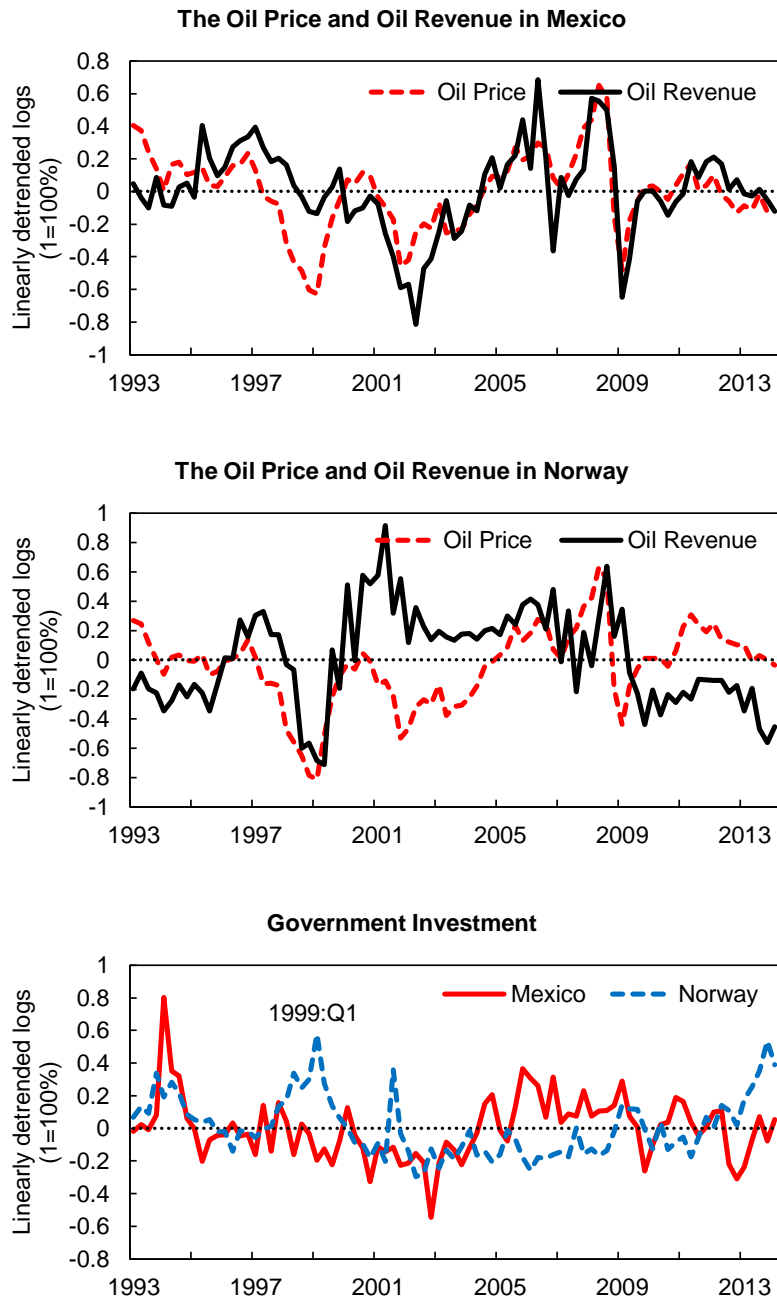
^aPrimary expenditures are total government expenditures minus interest payments.

^bRatio of investment by the *general government*, which includes state and local governments in addition to the federal or central government, to GDP.

Figure 1 shows the evolution of three important variables: the oil price, oil revenue, and government investment. In the top panel, we can see that the oil price and government revenue exhibit substantial fluctuations about their trends and are highly correlated in Mexico. The correlation coefficient between the two series is 0.63 between 1993:Q1 and 2014:Q1, but increases to 0.82 for the period 2000:Q1–2014:Q1, part of which was characterized by a spectacular expansion in the international price of oil and other commodities. The middle panel shows that in Norway, oil revenue does not follow the oil price as closely as in Mexico, which suggests that other factors, such as oil production and taxes on oil companies, are more relevant to oil revenue in Norway. Indeed, the correlation coefficient between the two series is only 0.15 in Norway, though we can see they appear to be synchronized when the oil price falls. The bottom panel shows that government investment also fluctuates considerably about its trend, with a standard deviation of 19 percent in both countries. In Mexico, however, government investment seems to respond more to the oil price. For example, between 2000 and 2002, just before the oil price took off, it is 17 percent below its trend, and by 2006–2008, a period of high oil prices, it climbs to 15 percent above trend. In Norway, we see government investment *increases* around 1999, a period of *decline* in the oil price. Something similar happens in 2013.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 provides empirical evidence on the effects of an oil price shock on several macroeconomic variables, including fiscal variables, in Mexico and Norway. Section 4 spells out a small open economy DSGE model that explains some features of the data and can be used as a laboratory to conduct policy experiments. Section 5 discusses the calibration of the

Figure 1: The Oil Price, Oil Revenue, and Government Investment



The reference price for Mexican oil is West Texas Intermediate. Norway's is Brent crude. Fiscal variables correspond to the federal government in the case of Mexico, and the central government in the case of Norway. Data are log deviations from linear trends. The sample is 1993:Q1–2014:Q1. See the data appendix for more details.

model. Section 6 puts the model to work; it studies the effects of an oil price shock under two different fiscal policy rules. Section 7 concludes.

2 Related Literature

This paper builds on the important work by [Pieschacón \(2012\)](#), who shows that in oil-exporting countries, fiscal policy can propagate oil price shocks or insulate the economy from them. She finds that the Mexican government eases fiscal policy after a positive oil price shock, while in Norway, another oil exporter, fiscal policy does not expand following oil price shocks. This is a consequence of the radically different fiscal institutions that prevail in these countries. The Mexican government enjoys ample discretion in the use of its oil revenue, while the Norwegian government saves its oil revenue in what has become the biggest sovereign wealth fund in the world; only the return from the fund is used to fund the budget.

As expected, a positive oil price shock generates a boom in Mexico, but not in Norway. [Pieschacón \(2012\)](#) establishes the importance of fiscal policy as a transmission mechanism by building a DSGE model that cannot explain this evidence unless it takes into account the observed response of fiscal policy. For example, the model calibrated to the Mexican economy cannot reproduce the response of Mexican variables when assuming fiscal policy responds as in Norway. The key features that propagate the shock in her DSGE model, however, are an expansionary response of *tax rates* (a reduction in tax rates), and the assumption that government purchases generate utility to households; government investment is absent. In my model, which uses the broad structure of that in [Pieschacón \(2012\)](#), the key feature is an expansionary response of government investment.

The transmission mechanisms that a fall in distortionary taxes and an increase in government investment bring about are related in the sense that both raise the marginal product of private capital and labor, all else equal. I focus on the role of government investment because it is directly observed in the data: an oil price shock generates an expansion of government investment. Data on tax rates are not readily available, so [Pieschacón \(2012\)](#) obtains the expansionary response of tax rates indirectly, by backing out the percent change in tax rates from the percent change in tax revenue and the tax base.³ Expansionary tax rates and government investment are, of course, not mutually exclusive propagation mechanisms. Both

³[Végh and Vuletin \(2012\)](#) have recently built what seems to be the first comprehensive dataset on tax rates for developed and developing countries. They find that tax rates in Mexico decrease in economic expansions, and vice versa. Tax rates are “procyclical” in their terminology. Since the Mexican business cycle seems to be positively correlated with oil prices, this finding lends support to the transmission mechanism emphasized by [Pieschacón \(2012\)](#).

may be at work in oil-exporting countries.

The DSGE model I develop borrows several features from a stream of recent papers that focus on the *long-term effects* of public investment in African resource-rich and low-income countries. [Melina, Yang, and Zanna \(2014\)](#), for example, study the choices available to the government of a low-income country faced with the prospect of a stream of resource revenue.⁴ How should it allocate this revenue between investment and saving in a sovereign wealth fund so as to maximize long-run growth and guarantee fiscal sustainability? To answer this question, the authors build a rich small open economy DSGE model in which public capital plays a key role. [Berg, Portillo, Yang, and Zanna \(2013\)](#) and [Richmond, Yackovlev, and Yang \(2013\)](#) pay some attention to cyclical considerations. When applying the model to Angola, they note that a smooth trajectory of government investment would result in greater macroeconomic stability. I obtain a similar result for Mexico, and give details on the mechanism that leads to this result. Finally, the models in this literature feature a representative household that behaves like a hand-to-mouth consumer, which may be an adequate approximation for studying low-income countries. Since I focus on an emerging economy, the representative household in my model has several options for intertemporal optimization.

My focus on government investment as a propagation mechanism, as opposed to other fiscal tools such as tax policy, finds further empirical support in research that reveals it fluctuates substantially in resource-rich countries whose governments rely on resource revenue. To motivate their explanation for fiscal procyclicality in developing countries, [Talvi and Végh \(2005\)](#) discuss cases in which governments that suddenly received huge revenue windfalls from oil or other natural resource expanded their spending drastically. In most cases, the biggest portion of the windfall was devoted to investment, as opposed to consumption or transfers.⁵ [Villafuerte, López-Murphy, and Ossowski \(2013, pp. 166-8\)](#) note that capital expenditure was the key driver of the procyclicality of fiscal policy in Latin American and Caribbean nonrenewable resource exporters between 2003 and 2008, a period characterized by a spectacular boom in commodity prices. Government investment is typically the largest component of government capital expenditure by far; the rest are purchases of financial assets. In Mexico, for example, the mean share of fixed investment in capital expenditure exceeds 90 percent between 1993:Q1 and 2014:Q1.

There is also evidence that government investment responds substantially to the business cycle. [Gavin and Perotti \(1997, p. 34\)](#), in a seminal paper on fiscal procyclicality in Latin

⁴See also [Berg, Portillo, Yang, and Zanna \(2013\)](#); [Araujo, Li, Poplawski-Ribeiro, and Zanna \(2013\)](#); and [Richmond, Yackovlev, and Yang \(2013\)](#).

⁵See also [Gelb \(1988\)](#) and [Little, Cooper, Corden, and Rajapatirana \(1993, pp. 40-9\)](#).

America, find that capital expenditure is the most procyclical component of government spending: a 1 percent increase in real GDP growth is associated with a 2.32 percent increase in capital expenditure. In recessions, this elasticity increases to 3.16 percent.⁶ [Ilzetzi and Végh \(2008, p. 19\)](#), for a sample of 81 developing countries, find that a 1 percent increase in real GDP growth is associated with a 1.31 percent increase in government investment.⁷ Quite possibly, causality runs in both directions, so that fluctuations in government investment have sizeable effects on the business cycle as well. After all, economists worry about fiscal procyclicality only because it might amplify the cycle.

This evidence, in addition to the empirical evidence I provide on the response of the Mexican and Norwegian economies to oil price shocks, suggests it is quite plausible that government investment is an important propagation mechanism of aggregate fluctuations. This possibility, however, has been largely neglected by the profession. To my knowledge, the only paper that considers the role of government investment in the business cycle is due to [Leeper, Walker, and Yang \(2010\)](#), who use a closed-economy DSGE model to study whether government investment could be a useful tool to fight recessions in the U.S.

Although the role of government investment has been neglected, a substantial literature highlights the role of fiscal policy, more generally defined, in the business cycle of developing countries or a subgroup of these. An empirical literature has established fiscal policy is procyclical in most developing countries, which suggests it might amplify the cycle. In addition to the work due to [Villafuerte, López-Murphy, and Ossowski \(2013\)](#); [Gavin and Perotti \(1997\)](#); and [Ilzetzi and Végh \(2008\)](#) that I have cited, papers by [Kaminsky, Reinhart, and Végh \(2004\)](#); and [Daude, Melguizo, and Neut \(2011\)](#) also belong to this group.⁸ Another literature uses DSGE models to confirm procyclical fiscal policy amplifies the cycle in resource-rich countries. It finds that if policy were acyclical or countercyclical, aggregate fluctuations would be much less volatile. Papers in this group include, for example, [Medina and Soto \(2007\)](#); [Snudden \(2013\)](#); and [Kumhof and Laxton \(2009\)](#).

More broadly, this paper belongs to the literature on the sources and propagation mechanisms of business cycles. I focus on oil-exporting countries, consider the importance of oil price shocks as a source of fluctuations, and the role of government investment as a propagation mechanism. Other external sources of business cycles considered by the literature, especially for emerging countries, are for example, shocks to the terms of trade, foreign in-

⁶Regressions consider 13 Latin American countries, including Mexico. The sample starts in the mid-1960s for most countries and ends in 1995. Although the regressions control for the terms of trade, [Kose \(2002\)](#) argues that world prices explain most of the fluctuations in the real GDP of small open developing countries.

⁷Panel regressions with country fixed effects and no additional control variables. The sample is 1961-2003.

⁸[Frankel, Végh, and Vuletin \(2013\)](#) point out that about a third of developing countries have “graduated” from fiscal procyclicality in the last decade.

terest rates, and foreign economic activity. Other propagation mechanisms include exchange rate and monetary policies, labor market flexibility, and trade linkages. On the role of several external factors, including commodity prices, see [Osterholm and Zettelmeyer \(2008\)](#) and [Izquierdo, Romero, and Talvi \(2008\)](#). On the role of terms-of-trade shocks and exchange rate policy, see [Mendoza \(1995\)](#), and [Broda \(2004\)](#). [Kose \(2002\)](#) finds that world prices, which include prices of capital, intermediate, and primary goods, and the world interest rate, account for 88 percent of aggregate output fluctuations in small open developing economies.

3 Empirical Evidence

In this section, I document the effects of an unexpected increase in the oil price on several domestic economic and policy variables. Following [Pieschacón \(2012\)](#), I study Mexico and Norway, two small open oil-exporting economies, by means of a structural vector autoregression (VAR).⁹ The structural VAR is given by:

$$\mathbf{A}_0 \mathbf{y}_t = \mathbf{A}_1 \mathbf{y}_{t-1} + \mathbf{A}_2 \mathbf{y}_{t-2} + \cdots + \mathbf{A}_q \mathbf{y}_{t-q} + \mathbf{u}_t^y, \quad (1)$$

where $\mathbf{y}_t \equiv [p_t^o; \mathbf{x}_t]'$. The scalar p_t^o is the oil price, and the vector $\mathbf{x}_t \equiv [T_t^{no}; T_t^o; G_t^C; G_t^I; Y_t^o; Y_t^N; Y_t^T; tb_t^{no}; C_t; I_t; p_t^N; S_t]'$ contains domestic economic and policy variables. These variables are, in order, government non-oil revenue (T_t^{no}), government oil revenue (T_t^o), government consumption (G_t^C), government investment (G_t^I), oil production (Y_t^o), nontradable production (Y_t^N), tradable production (Y_t^T), the non-oil trade balance (tb_t^{no}), private consumption (C_t), private investment (I_t), the price of nontradable goods relative to the CPI (p_t^N), and the real exchange rate (S_t).

The \mathbf{A}_i , $i = 1, 2, \dots, q$, are square matrices of coefficients, and \mathbf{u}_t^y is the vector of structural shocks, which has variance-covariance matrix $\text{Var}(\mathbf{u}_t^y) = \Omega$.

I am interested in identifying the effects of a shock to the oil price, u_t^o , on the domestic economy. A reduced-form VAR would fail at this, because a reduced-form shock to the oil price cannot be interpreted as a pure disturbance, and because it would not capture the contemporaneous effects of the oil price on domestic variables.

As in [Pieschacón \(2012\)](#), the mild assumption of exogeneity of the oil price is the key to identifying the structural oil price shock u_t^o .¹⁰ This assumption implies that developments in the Mexican or Norwegian economies do not affect the oil price, so that it is only affected by

⁹My sample is 1993:Q1–2014:Q1. [Pieschacón \(2012\)](#) studies the period from 1980:Q1 to 2006:Q4. Due to changes in the base year for national accounts, currently available time series start in 1993. However, the results I report are qualitatively similar to those in [Pieschacón \(2012, p. 258\)](#).

¹⁰In related research, [Broda \(2004\)](#) assumes the terms of trade are exogenous to identify terms-of-trade shocks.

its own lagged values and a shock. The exogeneity assumption implies that the first row of the 13×13 matrix \mathbf{A}_0 has a one followed by zeros. (This is true for the other \mathbf{A} matrices as well.) Additionally, assume the oil price is the only variable that can exert a contemporaneous effect on other variables, so that matrix \mathbf{A}_0 has ones in the main diagonal and zeros elsewhere, except the first column. With these constraints, the structural parameters can be recovered from the reduced-form VAR estimates, and the ordering of the variables in \mathbf{x}_t is irrelevant.

To clarify the implications of the identifying assumptions, equation (1) can be rewritten in two blocks, as follows:

$$\begin{aligned} p_t^o &= \alpha_1 p_{t-1}^o + \cdots + \alpha_q p_{t-q}^o + u_t^o, \\ \mathbf{x}_t &= \mathbf{B}_0 p_t^o + \mathbf{B}_1 p_{t-1}^o + \cdots + \mathbf{B}_q p_{t-q}^o + \mathbf{\Gamma}_1 \mathbf{x}_{t-1} + \cdots + \mathbf{\Gamma}_q \mathbf{x}_{t-q} + \mathbf{u}_t^x, \end{aligned} \tag{2}$$

where the α coefficients are scalars, and the \mathbf{B} and $\mathbf{\Gamma}$ are coefficient matrices.

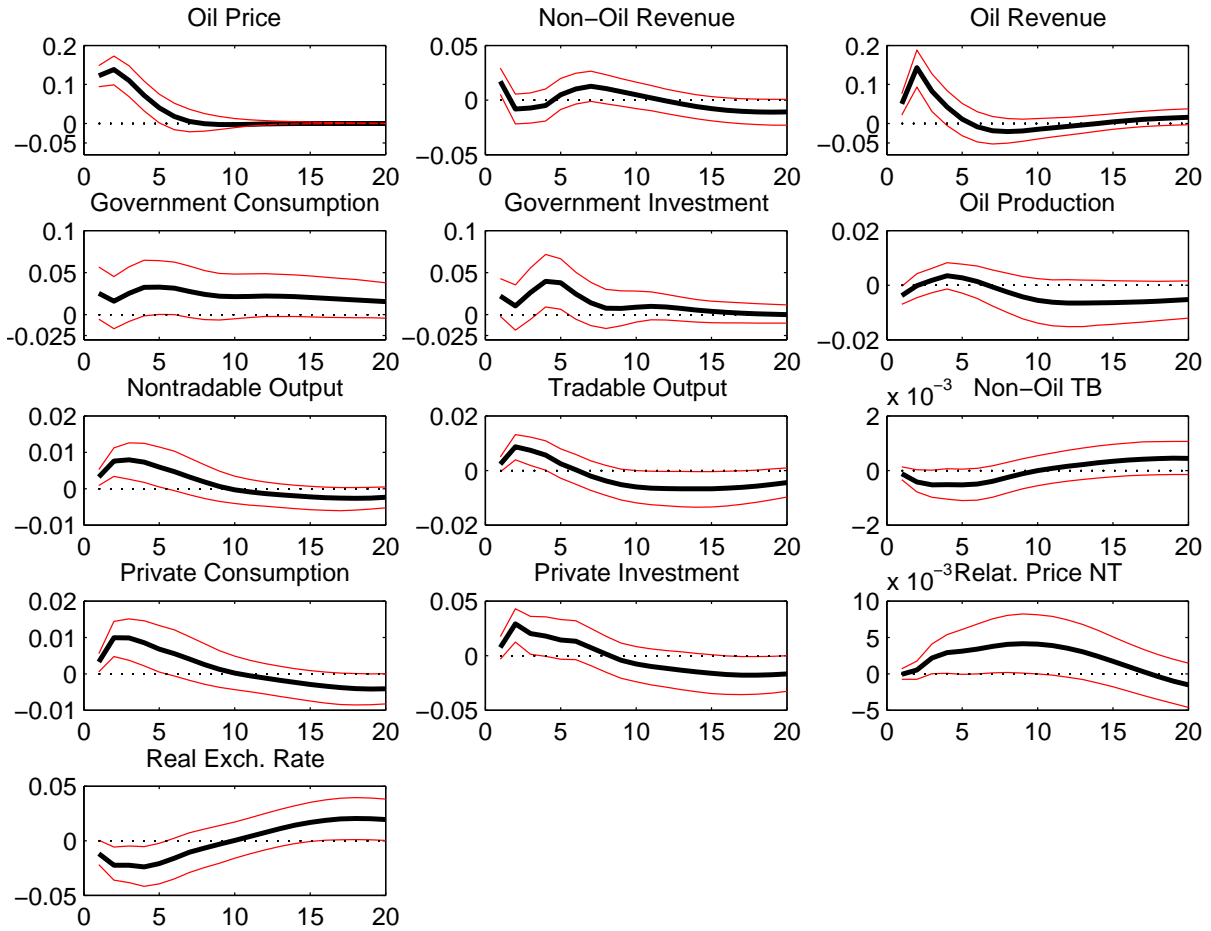
Figure 2 shows Mexico's impulse responses to a positive one-standard-deviation shock to the oil price. I set $q = 2$ based on the Akaike Information Criterion. Impulse responses can be interpreted as percent deviations from linear trends, except for the non-oil trade balance, which is expressed as a percent of trend GDP.¹¹ Appendix A contains details on data sources, definitions, and transformations.

The main features of the data are summarized as follows:

- A shock that raises the oil price 12.3 percent above its trend on impact (one standard deviation) generates a substantial windfall of oil revenue for the government. Non-oil revenue does not respond significantly.
- The oil price shock generates an expansion of government spending. Government investment, a key variable in this paper, peaks at 4 percent above trend one year after the shock hits the economy. Government consumption also seems to increase, although it is not statistically different from zero for most of the 20-quarter horizon.
- The shock generates an expansion in private economic activity. Nontradable and tradable output peak at 0.8 and 0.9 percent above trend, respectively, and return to trend between 6 and 9 quarters after the shock hits the economy.
- Oil production does not respond significantly to the shock.
- Private consumption and investment rise. The former reaches a peak of 1 percent above trend, while the latter peaks at 3 percent.

¹¹I remove a linear trend from the logarithm of the variables, as in [Pieschacón \(2012\)](#). In figure 2, thick black lines are estimated impulse responses, while thin red lines are 90 percent bootstrap confidence intervals. [Hamilton \(1994, pp. 337–8\)](#) and references therein discuss the computation of confidence intervals.

Figure 2: Mexico's Response to an Oil Price Shock (VAR)



Impulse responses to a one-standard-deviation shock to the price of West Texas Intermediate crude oil, the reference price for Mexican oil. Thick black lines are estimated responses. Thin red lines are 90 percent bootstrap confidence intervals. Responses are expressed as log deviations from a linear trend (1=100 percent), except for the non-oil trade balance, which is expressed as a percent of trend GDP. Horizontal axes represent quarters. Government variables refer to the federal government.

- The non-oil trade balance, which is measured in nominal terms as a percent of trend GDP, deteriorates, although the decline is not statistically significant by a small margin.
- The price of nontradables relative to the CPI increases. Finally, the CPI-based real exchange rate appreciates (decreases).¹²

Figure 3 shows how Norway responds to a one-standard-deviation shock to the oil price.¹³ As in Mexico, the shock generates a substantial oil revenue windfall for the government, but its spending response is very different than Mexico's. Government consumption and investment *decrease* significantly following an oil price shock. The latter reaches a trough of 3 percent below trend 3 quarters after the shock hits the economy. A possible explanation for this surprising result is that fiscal policy might be countercyclical in Norway, so that to prevent the shock from generating an economic boom, the government cuts consumption and investment. Whether this is the explanation or not, the shock generates a much more modest economic expansion in Norway; it is about half the size of Mexico's expansion. Nontradable and tradable output peak at 0.4 and 0.6 percent above trend, respectively. Private consumption and investment peak at 0.3 and 1.6 percent, respectively, and their responses are barely significant.

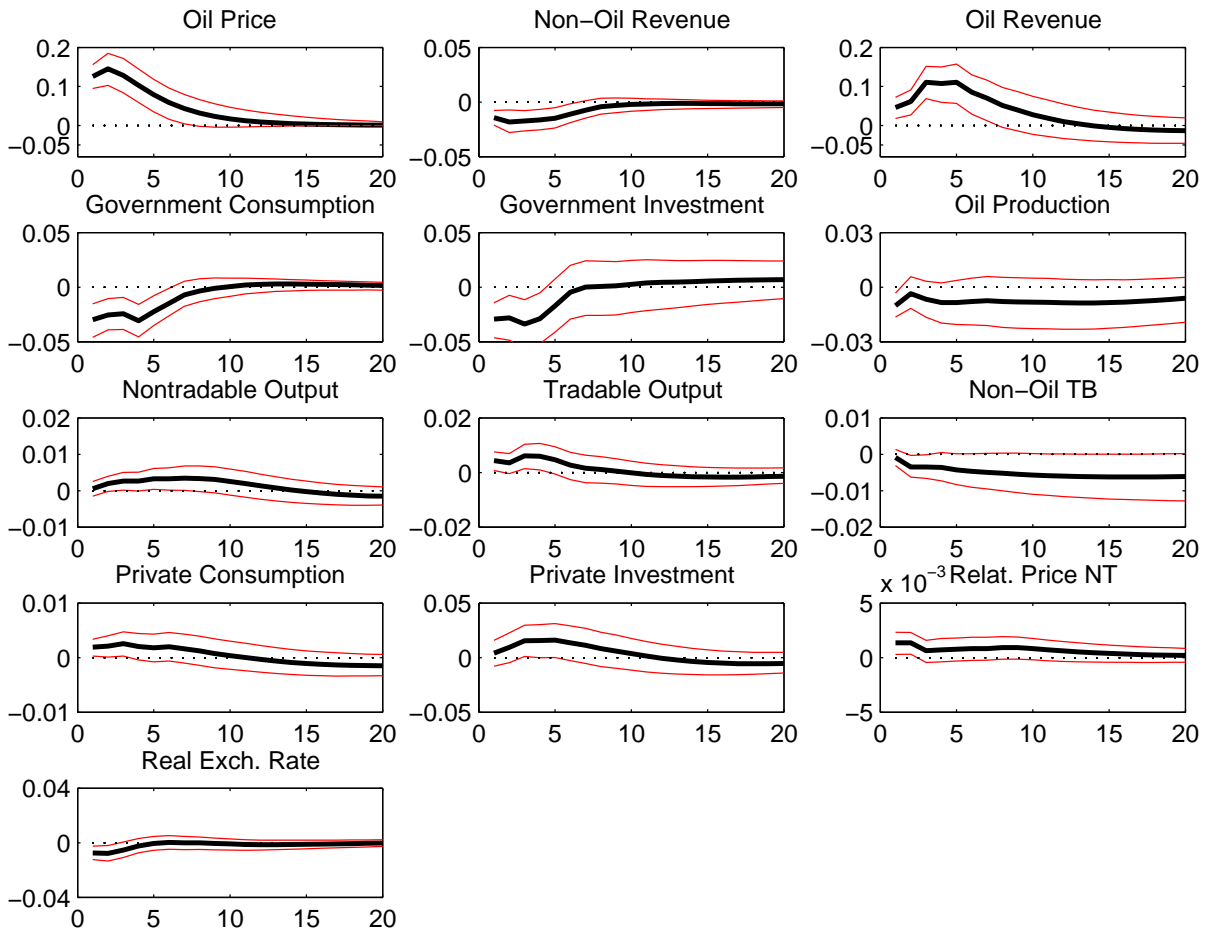
Qualitatively, these features are broadly robust to two variations. The baseline results use data for the federal and central governments in Mexico and Norway, respectively. The first robustness check considers consumption and investment by these countries' general governments, a level of government that includes state and local governments as well. In this exercise, the only important difference is that the expansion of Mexican government investment is milder and more persistent than in the baseline VAR, and the contraction of Norwegian government investment is also milder. The second robustness check consists of using an alternative detrending procedure, namely the HP filter, instead of removing a linear trend. The sign of the responses is the same, but as expected, their magnitude is smaller than in the baseline VAR. This is due to the fact that an HP trend follows the data more closely than a linear trend. Appendix B contains details on these robustness checks.

In the next section, I use a dynamic stochastic general equilibrium model to explain some of the evidence reported in this section. In the model, government investment is a key transmitter of oil price shocks to the economy.

¹²Excluding the real exchange rate from the VAR only reduces the statistical significance of the response of the non-oil trade balance and the price of nontradables. I note this because the DSGE model of section 4 abstracts from the real exchange rate.

¹³As for Mexico, I set $q = 2$. The AIC, however, favors one lag ($q = 1$) for Norway. A first-order VAR for Norway produces very similar results.

Figure 3: Norway's Response to an Oil Price Shock



Norwegian variables' impulse responses to a one-standard-deviation shock to the price of Dated Brent crude oil, the reference price for Norwegian oil. Thick black lines are estimated responses. Thin red lines are 90 percent bootstrap confidence intervals. Responses are expressed as log deviations from a linear trend (1=100 percent), except for the non-oil trade balance, which is expressed as a percent of trend GDP. Horizontal axes represent quarters. Government variables refer to the central government.

4 The Model

This section spells out a DSGE model that highlights the role of government investment in the transmission of oil price shocks. The structure of the model borrows several features from [Pieschacón \(2012\)](#), and the idea of comparing alternative government investment rules is related to the work of [Berg, Portillo, Yang, and Zanna \(2013\)](#).

Succinctly, the model is structured as follows. In a perfectly competitive small open economy, a representative household produces a tradable and a nontradable good using labor, private and public capital. The government consumes goods and services and invests in public capital. Government revenue comes from taxes on labor income and consumption, and from an oil endowment it receives every period, which is exported at an exogenous price.

4.1 Households

The representative household receives positive utility from a consumption bundle, C , and negative utility from labor; L denotes total hours worked. It seeks to maximize the present discounted value of lifetime utility:

$$\text{Max}_{C_t, L_t} \quad \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j u(C_{t+j}, L_{t+j}),$$

where utility in period t is given by a function that displays constant relative risk aversion, and as assumed by [Pieschacón \(2012\)](#), takes the form proposed by [Greenwood, Hercowitz, and Huffman \(1988\)](#):

$$u(C_t, L_t) = \frac{(C_t - \zeta L_t^\omega)^{1-\sigma}}{1-\sigma}.$$

$\sigma > 0$ is the coefficient of relative risk aversion, $\omega > 1$ governs the wage elasticity of labor supply, given by $(1/\omega - 1)$, and $\zeta > 0$. “GHH preferences” are widely used in the small open economy literature.¹⁴ They imply the marginal rate of substitution between consumption and leisure depends only on labor, i.e., there is no wealth effect on labor supply.

C_t is a basket of tradable and nontradable goods, denoted C_t^T and C_t^N , respectively:

$$C_t \equiv \left[\varphi^{\frac{1}{\chi}} (C_t^N)^{\frac{\chi-1}{\chi}} + (1-\varphi)^{\frac{1}{\chi}} (C_t^T)^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}, \quad (3)$$

where $\varphi \in (0, 1)$ is the degree of home bias, and $\chi > 0$ is the constant elasticity of substitution between tradable and nontradable goods. The price of this basket is given by:

¹⁴See, for example, [Correia, Neves, and Rebelo \(1995\)](#).

$$p_t = [\varphi(p_t^N)^{1-\chi} + (1-\varphi)(p_t^T)^{1-\chi}]^{\frac{1}{1-\chi}}, \quad (4)$$

where p_t^N and p_t^T are the retail prices of nontradable and tradable goods, respectively.¹⁵ The economy's numeraire is the *wholesale* price of tradable goods, which is assumed to obey the law of one price and to be constant at one dollar, as will be further explained below. Thus, all prices in the economy are also relative prices with respect to tradable goods at the wholesale level. This amounts to abstracting from fluctuations in the real exchange rate.

The household receives a wage in exchange for labor services, which are freely mobile across the two sectors; rents private capital, which is also freely mobile, to firms in both sectors; and has the ability to borrow from international financial markets. It consumes goods and services, invests in private capital, and pays interest on its foreign debt. There is no domestic debt in the model. Thus, the budget constraint is given by:

$$(1 + \tau^C)p_t C_t + I_t + (1 + R_t)D_t = (1 - \tau^L)W_t L_t + R_t^K K_t + D_{t+1}. \quad (5)$$

τ^C and τ^L are the consumption and labor income tax rates, respectively; I_t is gross investment in physical capital; D_t is the stock of one-period foreign debt at the beginning of period t ; its real interest rate is R_t ; W_t is the wage; and K_t is the stock of physical capital at the beginning of period t , which the household rents to firms at the rate R_t^K .

According to equation (5), the household receives income in the form of: *a*) wages, net of taxes; *b*) new foreign debt; and *c*) the return to its stock of capital. Expenditures are given by: *a*) consumption of tradable and nontradable goods, including taxes; *b*) investment in private physical capital; and *c*) interest payments on foreign debt.

To close the open economy, the interest rate on foreign debt is assumed to be debt-elastic; it is an increasing function of the economy's stock of debt relative to its steady state:¹⁶

$$R_t = R + \psi(e^{\tilde{D}_t - D} - 1), \quad (6)$$

where R is the world interest rate, $\psi > 0$ determines the sensitivity of the interest rate to deviations of debt from its steady state D , and \tilde{D}_t is the cross-sectional average of debt, which the household takes as exogenous. As foreign debt increases beyond its steady state, the real interest rate increases. When the economy's stock of foreign debt is at the steady

¹⁵The price index, along with the optimal demand schedules for tradable and nontradable goods can be obtained as solutions to the problem of consumption maximization subject to a given level of expenditures. Demands are given by $C_t^T = (1 - \varphi) \left(\frac{p_t^T}{p_t}\right)^{-\chi} C_t$, and $C_t^N = \varphi \left(\frac{p_t^N}{p_t}\right)^{-\chi} C_t$.

¹⁶This is one of the methods proposed by [Schmitt-Grohé and Uribe \(2003\)](#) to induce stationarity of the debt process in a small open economy model.

state, the second term on the right-hand side of equation (6) vanishes.

The accumulation of private capital follows the simple law of motion

$$K_{t+1} = (1 - \delta)K_t + I_t, \quad (7)$$

where δ is the depreciation rate. Capital is freely mobile across sectors, so that

$$K_t = K_t^N + K_t^T, \quad (8)$$

where K_t^i , $i = \{N, T\}$, is the stock of capital available to sector i in period t .

4.2 Firms

A competitive representative firm in each sector uses private inputs and public capital to maximize profits.

4.2.1 Nontradable Sector

The production function has the following Cobb-Douglas form:

$$Y_t^N = A^N (K_t^N)^\alpha (K_t^G)^\theta (L_t^N)^{1-\alpha}. \quad (9)$$

Y_t^N is nontradable output, A^N is a productivity index, K_t^G is the stock of public capital at the beginning of period t , and L_t^N is labor used in the production of nontradables. The production function exhibits constant returns to scale with respect to the private inputs K^N and L^N , and increasing returns with respect to K^G . This specification is common in studies that consider the role of public capital. For example, it is adopted by [Leeper, Walker, and Yang \(2010\)](#); [Berg, Portillo, Yang, and Zanna \(2013\)](#); and [Baxter and King \(1993\)](#).

The firm chooses private inputs to maximize profits:

$$\text{Max}_{K_t^N, L_t^N} p_t^N Y_t^N - W_t L_t^N - R_t^K K_t^N,$$

where p_t^N denotes the wholesale price of nontradable goods, which is assumed to be the same as its retail price.

4.2.2 Tradable Sector

The firm that produces tradable goods also seeks to maximize profits and uses the same production function as the firm in the nontradable sector:

$$Y_t^T = A^T (K_t^T)^\alpha (K_t^G)^\theta (L_t^T)^{1-\alpha}. \quad (10)$$

Y_t^T is tradable output, A^T is a productivity index, and L_t^T is labor in the tradable sector. I assume the elasticity of output with respect to inputs is constant across sectors.

As I mentioned, the wholesale price of tradable goods is constant at one dollar, and the law of one price holds at the wholesale level.

4.2.3 Distribution of Tradable Goods

The law of one price does not hold for tradable goods at the retail level, because a competitive retailer requires γ units of nontradable goods to take a unit of tradable goods to the final consumer. This implies:

$$p_t^T = 1 + \gamma p_t^N, \quad (11)$$

i.e., the retail price of tradable goods is equal to its marginal cost.

4.3 Government

The government purchases tradable and nontradable goods for two purposes: consumption, and investment in public capital. It levies taxes on labor income and private consumption, collects income from the export of a constant oil endowment it receives every period, and has access to a sovereign wealth fund that pays a constant return. Therefore, the government's budget constraint is given by:

$$p_t^G G_t + F_{t+1} = \tau^C p_t C_t + \tau^L W_t L_t + p_t^o Y^o + (1 + R^F) F_t, \quad (12)$$

$$G_t = G_t^C + G_t^I. \quad (13)$$

F_t is the stock of the sovereign wealth fund (SWF) at the beginning of period t ; it pays the constant return R^F . G_t^C is government consumption, while G_t^I is government investment. Y^o denotes the constant oil endowment the government receives every period, which is exported at an exogenous price p_t^o .¹⁷ The oil price follows a stationary AR(1) process:¹⁸

¹⁷By assuming a constant and exogenous oil endowment, I abstract from the possibility of technological spillovers from the oil sector to the rest of the economy, especially the sectors that provide services for oil production. [Bjornland and Thorsrud \(2014\)](#) study this channel in detail.

¹⁸It is common in the literature to assume stationarity of oil prices. This suits the model, as it abstracts from secular growth. Some authors, however, assume oil prices follow a random walk. See, for example, [Melina, Yang, and Zanna \(2014\)](#).

$$\ln(p_t^o) = \rho_o \ln(p_{t-1}^o) + \epsilon_t^o, \quad \rho_o \in (-1, 1), \quad \epsilon_t^o \sim \text{i.i.d.}(0, \sigma_o^2). \quad (14)$$

G_t is a CES basket of tradable and nontradable goods purchased by the government:

$$G_t \equiv \left[\nu^{\frac{1}{\chi}} (G_t^N)^{\frac{\chi-1}{\chi}} + (1-\nu)^{\frac{1}{\chi}} (G_t^T)^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}, \quad (15)$$

where $\nu \in (0, 1)$ is the degree of home bias in government purchases. I assume the elasticity of substitution between tradable and nontradable goods is the same as that for private consumption; it is given by χ . As in [Pieschacón \(2012\)](#), I assume the government purchases tradable goods at wholesale prices, so that the price of the basket purchased by the government is given by:

$$p_t^G = [\nu (p_t^N)^{1-\chi} + (1-\nu)]^{\frac{1}{1-\chi}}. \quad (16)$$

The government exhausts its purchases of tradable and nontradable goods in consumption and investment:

$$p_t^G (G_t^C + G_t^I) = G_t^T + p_t^N G_t^N. \quad (17)$$

Government investment adds to the stock of public capital, which evolves according to the simple law of motion

$$K_{t+1}^G = (1 - \delta_G) K_t^G + G_t^I, \quad (18)$$

where δ_G is the rate at which public capital depreciates.

I assume tax rates are fixed, so government policy is formulated in terms of the triplet $\{G_t^C, G_t^I, F_{t+1}\}$. Once policymakers determine consumption and investment, they take prices as given and purchase the combination of tradable and nontrable goods that minimizes expenditures.¹⁹

The government chooses between two radically different fiscal policy rules:

Policy A: Spend-as-you-go.²⁰ Under this policy, the government spends all of its oil revenue every period, investing part of it and consuming the rest. It consumes all of its tax

¹⁹Optimal demand for tradable and nontradable goods is given by $G_t^T = (1-\nu) \left(\frac{1}{p_t^G}\right)^{-\chi} G_t$, and $G_t^N = \nu \left(\frac{p_t^N}{p_t^G}\right)^{-\chi} G_t$, respectively.

²⁰I borrow terminology from [Melina, Yang, and Zanna \(2014\)](#) to name the two policies.

revenue, and does not use the SWF to save:

$$F_t = 0 \quad \forall t, \quad (19a)$$

$$p_t^G G_t^I = \phi p_t^o Y^o, \quad (19b)$$

$$p_t^G G_t^C = \tau^C p_t C_t + \tau^L W_t L_t + (1 - \phi) p_t^o Y^o, \quad (19c)$$

where $\phi \in (0, 1)$ is the fraction of oil revenue the government invests every period.

This balanced-budget policy transmits fluctuations in government revenue to purchases. I will show that this policy propagates oil price shocks in the model economy.

Policy B: Delinked investment. Under this policy, the government saves a fraction of its *steady-state oil revenue* in the SWF, and invests the rest. Oil revenue windfalls, i.e., oil revenue in excess of its steady-state level, are also saved in the SWF. The return from the fund is invested, while tax revenue is consumed:

$$F_{t+1} = (1 - \gamma_F) F_t + \gamma_o p^o Y^o + (p_t^o Y^o - p^o Y^o), \quad (20a)$$

$$p_t^G G_t^I = (1 - \gamma_o) p^o Y^o + R^F F_t, \quad (20b)$$

$$p_t^G G_t^C = \tau^C p_t C_t + \tau^L W_t L_t, \quad (20c)$$

where $\gamma_o \in (0, 1)$ is the fraction of steady-state oil revenue $p^o Y^o$ the government decides to save in the SWF every period. To ensure stationarity of the SWF, I assume the government transfers to households a fraction $\gamma_F \in (0, 1)$ of the fund in lump-sum fashion every period.

Under this policy, government investment is practically delinked from fluctuations in oil revenue. Swings in the oil price do not affect investment directly, though they do affect it indirectly, slightly, and gradually, through their effect on the SWF. I will show that this policy can go a long way toward protecting the economy from drastic swings in the oil price.

There are several types of sovereign wealth funds around the world. Although the SWF in policy B is admittedly highly stylized, it is similar to what the literature calls a “saving fund,” since it allows the investment of oil revenue in the future. Although it contributes to a smoother path of government investment, it is not a “stabilization fund,” because it does not guarantee that investment will stay constant when the oil price fluctuates. In fact, investment moves in the same direction of the oil price, albeit only slightly.²¹

²¹Ossowski, Villafuerte, Medas, and Thomas (2008) offer a detailed analysis of several types of sovereign wealth funds, as well as other fiscal institutions available to oil-exporting countries.

4.4 Market Clearing Conditions, Identities, and Equilibrium

The labor market clears every period:

$$L_t = L_t^N + L_t^T. \quad (21)$$

The market for nontradable goods also clears:

$$Y_t^N = C_t^N + G_t^N + \gamma C_t^T. \quad (22)$$

To ensure the budget constraints of the household and the government are satisfied, tradable goods and oil exports must satisfy the following condition:

$$Y_t^T + p_t^o Y^o + (R^F F_t - R_t D_t) = C_t^T + I_t + G_t^T + [(F_{t+1} - F_t) - (D_{t+1} - D_t)], \quad (23)$$

where I have used the zero-profit condition $W_t L_t + R_t^K K_t = Y_t^T + p_t^N Y_t^N$.

Definition. A competitive equilibrium is a set of processes $\{Y_t^T, Y_t^N, C_t, C_t^T, C_t^N, L_t, L_t^T, L_t^N, I_t, K_t, K_t^T, K_t^N, G_t^T, G_t^N, G_t^C, G_t^I, G_t, K_t^G, F_t, D_t, p_t^T, p_t^N, p_t, p_t^G, p_t^o\}$, such that the household's and firms' optimization problems are solved, and the markets for goods and private factors of production clear, given $p_0^o, D_0, F_0, K_0, K_0^G$, and the process $\{\epsilon_t^o\}$. This results in a system of expectational difference equations. Appendix C lists the equations that constitute the system and derives the deterministic steady state.

The equilibrium process of the trade balance, which I denote tb_t , can be constructed by noting gross domestic product $GDP_t \equiv Y_t^T + p_t^N Y_t^N + p_t^o Y^o$, and using the equilibrium processes for consumption and investment by the private and public sectors:

$$tb_t \equiv GDP_t - (p_t C_t + I_t + p_t^G G_t^C + p_t^G G_t^I). \quad (24)$$

Note that an increase in the oil price pushes the trade balance up, other things equal, since it raises the value of exports. Finally, the balance of payments identity holds, so the current account can also be constructed from the competitive equilibrium of the model economy:

$$\underbrace{[(F_{t+1} - F_t) - (D_{t+1} - D_t)]}_{\text{capital account}} = \underbrace{tb_t + R^F F_t - R_t D_t}_{\text{current account}}, \quad (25)$$

or in words, changes in the net foreign asset position must be equal to the trade balance plus net interest income on foreign assets.

I solve the model by linear approximation. Specifically, I take a first-order Taylor series expansion around the model’s deterministic steady state. In the steady state, the oil price shock is held at its mean value and variables are constant.

Before discussing the model’s calibration, I note that the assumption of an exogenous and constant oil endowment implies that increases in the oil price do not raise firms’ costs, which would contract output. This effect is present in models in which oil is an intermediate good, an input in the production of other goods. [Leduc and Sill \(2004\)](#), who study the interaction between oil price shocks and monetary policy in U.S. recessions, offer an example of such a model. I believe it is reasonable to ignore this input-cost channel because gasoline and other energy products are heavily subsidized by the Mexican government (and many governments in other developing oil-exporting countries). As a result of the subsidies, the price of domestic energy is substantially smoother than the international oil price.²²

5 Calibration

I calibrate the model to Mexico. I assign values found in the literature to a subset of model parameters and set others to match features of the Mexican economy. I calibrate the model so that the steady state under policy A is very similar to that under policy B. The only substantial difference is foreign debt: to sustain levels of consumption and investment similar to those under the spend-as-you-go policy A, the economy under the more prudent delinked-investment policy B holds a larger stock of foreign debt at the steady state. [Appendix C](#) provides a detailed derivation of the deterministic steady state.

[Table 2](#) summarizes the calibration. The unit of time is a quarter, so the world interest rate R is set to 0.01 and the discount factor $\beta = 0.99$. I use values commonly found in the small open economy literature for the coefficient of relative risk aversion, $\sigma = 2$; the rate of depreciation of private capital, $\delta = 0.025$; and the consumption and labor income tax rates, $\tau^C = 0.2$ and $\tau^L = 0.1$. Following [Schmitt-Grohé and Uribe \(2003\)](#), I set the parameter that governs the risk premium on foreign debt $\psi = 0.0007$. As in [Pieschacón \(2012\)](#), I set the parameter that governs the wage elasticity of labor supply $\omega = 3$, which implies a wage elasticity of 0.5. As in [Berg, Portillo, Yang, and Zanna \(2013\)](#), I set the elasticity of substitution between nontradable and tradable goods $\chi = 0.44$. Following [Leeper, Walker, and Yang \(2010\)](#); and [Berg, Portillo, Yang, and Zanna \(2013\)](#), I set the elasticity of output with respect to public capital $\theta = 0.1$. I set the return from the SWF $R^F = 0.0067$, so as to match the annual value in [Berg, Portillo, Yang, and Zanna \(2013\)](#).

²²The standard deviation of the international oil price is three times larger than that of domestic energy consumer prices. These data are available upon request.

Table 2: Calibration of the DSGE Model

Symbol	Definition	Value	Comments/Source
R	World interest rate	0.01	Schmitt-Grohé and Uribe (2003)
β	Discount factor.	0.99	Standard value
σ	Coefficient of relative risk aversion	2	Standard value
δ	Rate of depreciation of private capital	0.025	Standard value
τ^C, τ^L	Consumption and labor income tax rates	0.2, 0.1	Lim and McNelis (2008)
ψ	Risk premium parameter	0.0007	Schmitt-Grohé and Uribe (2003)
ω	Governs wage elasticity of labor supply	3	Pieschacón (2012)
χ	Elasticity of subst. between N and T goods	0.44	Berg, Portillo, Yang, and Zanna (2013)
θ	Elasticity of output with respect to public capital	0.1	Leeper, Walker, and Yang (2010)
R^F	Return from the sovereign wealth fund	0.0067	Set to match value in Berg, Portillo, Yang, and Zanna (2013)
δ_G	Rate of depreciation of public capital	0.016	Calibrated to match ratios
α	Elasticity of output with respect to private capital	0.38	Calibrated to match ratios
ζ	Governs disutility from labor	4.8	Calibrated to match ratios
φ, ν	Home bias in private and public consumption	0.9	Calibrated to match ratios
γ	Distribution cost parameter	0.75	Calibrated to match ratios
ϕ	Fraction of oil revenue gov invests (policy A)	0.6	Calibrated to match ratios
γ_o	Fraction of ss oil revenue gov saves in SWF (policy B)	0.5	Policy parameter
γ_F	Fraction of SWF lump-sum transferred (policy B)	0.037	Calibrated to match ratios
ρ_o	Persistence of shock to oil price	0.8	Serial correlation of linearly detrended oil price
σ_o	St. dev. of shock oil price	0.123	Vector autoregression. See section 3

Table 3: Restrictions for the Calibration of the DSGE Model

Symbol	Definition	Value
K/K^G	Ratio of private to public capital	3.1
S_{GI}	Share of gov. investment in GDP	0.05
S_I	Share of private investment in GDP	0.25
S_o	Share of oil production in GDP	0.09
S_{YN}	Share of nontradables in GDP	0.67
S_D	Distribution margin	0.43
tb/GDP	Trade balance-to-GDP ratio	0.015

I calibrate the remaining parameters to match the following features of the Mexican economy, which are summarized in table 3 (most are median values for the period 1993:Q1–2014:Q1): a ratio of private to public capital $K/K^G = 3.1$, as implied in Cubas (2010, p. 107); a share of government investment in GDP (S_{GI}) of 5.3 percent; a share of oil production in GDP (S_o) of 9 percent; a share of value added of nontradable goods and services in GDP (S_{YN}) of 67 percent; a distribution margin (S_D), defined as the fraction of the retail price of tradables that reflects distribution costs, of 43 percent, as in Pieschacón (2012); and a trade balance-to-GDP ratio (tb/GDP) of 1.5 percent. I also use the share of private investment in GDP, denoted S_I , which I set to 25 percent. I am not able to compute this value from the data, however, since the measure of private consumption I use includes durable and non-durable goods. In the model, all durable goods are part of the stock of private capital, so the consistent ratio must be greater than the 16 percent that results from following Mexican national accounting conventions. The model dynamics, however, are not sensitive to changes in this ratio.²³

The rate of depreciation of public capital consistent with these ratios is $\delta_G = 0.016$. The elasticity of output with respect to private capital $\alpha = 0.38$. The coefficient that modulates the disutility of labor $\zeta = 4.8$. I iterate on φ and ν , the degree of home bias in private consumption and government purchases, respectively, under the restriction that these parameters be equal, to match the size of the nontradable sector in GDP. This results in $\varphi = \nu = 0.9$. The value of the distribution parameter γ consistent with a distribution margin $S_D = 0.43$, which I obtain from Pieschacón (2012), is 0.75.

The derivation of the steady state implies that under policy A the fraction of oil revenue the government invests $\phi = 0.6$. Under policy B, the government chooses the fraction of oil

²³Fluctuations in response to oil price shocks are robust, and indeed, almost identical, when assuming ratios of private investment to GDP of 0.20 and 0.30.

revenue γ_o it saves in the SWF.²⁴ This choice then leads to consistent values for the size of the SWF at the steady state and for the fraction γ_F of the fund the government distributes in lump-sum fashion to the household. My baseline analysis assumes that under policy B, the government saves half of its oil revenue in the SWF every period ($\gamma_o = 0.5$). This value seems feasible for an emerging country such as Mexico. It is useful to note that Norway saves the totality of its oil revenue in a SWF, while [Berg, Portillo, Yang, and Zanna \(2013\)](#) consider cases in which African countries save a fraction of 20 and 50 percent of resource windfalls in sovereign wealth funds. My choice for γ_o then implies $\gamma_F = 0.037$.

Finally, I set the persistence of the oil price $\rho_o = 0.8$, so as to match the serial correlation of the oil price used in the empirical section, and the standard deviation of the oil price shock $\sigma_o = 0.123$ to match the standard deviation of the oil price residuals obtained in the VAR.

6 An Oil Price Shock in the Model Economy

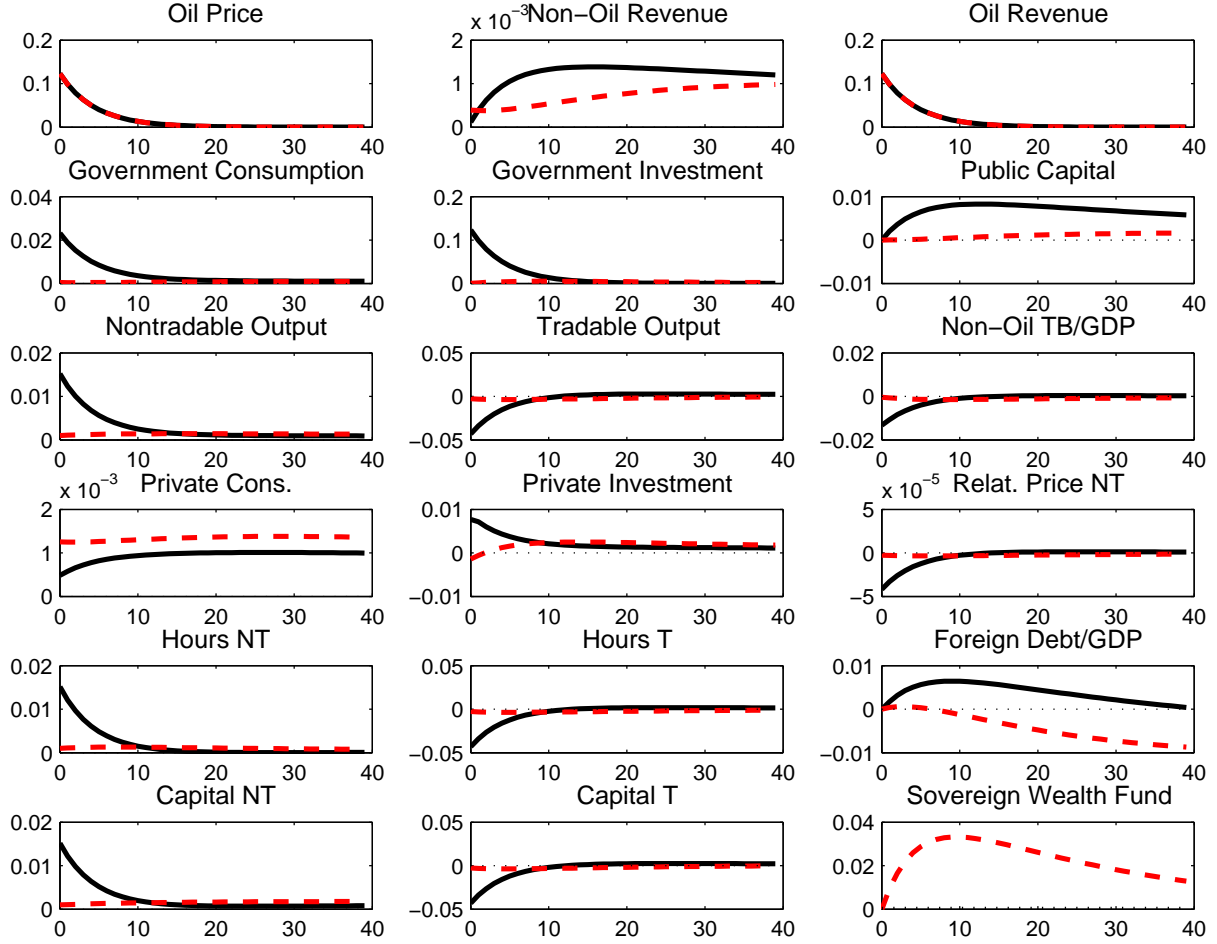
6.1 Baseline Results

Figure 4 shows impulse responses to a one-standard-deviation shock to the oil price. Solid black lines describe the model economy’s response under the spend-as-you-go policy A, by which the government exhausts its revenue every period; it invests a fraction $\phi = 0.6$ of its oil revenue and consumes the rest, along with all of the tax revenue it collects. Dashed red lines show the economy’s response under the more prudent delinked-investment policy B, by which the government saves every period a fraction $\gamma_o = 0.5$ of steady-state oil revenue, plus all windfalls, in a SWF, and invests the remaining fraction of its steady-state oil revenue plus the return from the fund. Vertical axes denote percent deviations from deterministic steady states (1=100 percent), except for the non-oil trade balance and foreign debt, which are expressed as ratios to GDP measured at constant prices.

The model economy’s response under policy A is qualitatively similar to that of the Mexican economy on several dimensions. The oil price shock induces an increase in government investment, proportionally equal to the increase in the oil price by construction, that triggers an economic expansion. The transmission mechanism works as follows. The expansionary response of fiscal policy raises the stock of public capital. This generates an increase in the productivity of private inputs, so private investment and total hours worked (not shown in the figure) rise. Both the government and households demand more tradable and nontradable goods for consumption and investment purposes. The private sector re-

²⁴This parameter must satisfy $\gamma_o > (1 - G^I/Y^o)$. See appendix C for details.

Figure 4: Impulse Responses to an Oil Price Shock (Model)



Impulse responses to a one-standard-deviation shock to the oil price. Solid black lines describe responses under policy A, by which the government consumes and invests all of its revenue every period. Dashed red lines describe responses under the more prudent policy B, by which the government saves a fraction $\gamma_o = 0.5$ of its steady-state oil revenue, plus all oil windfalls, in a sovereign wealth fund, and invests each period a fraction $(1 - \gamma_o)$ of steady-state oil revenue plus the return from the fund. Horizontal axes show quarters, while vertical axes describe percent deviations from steady state (1=100 percent), except for the non-oil trade balance, for which deviations are expressed in absolute values.

sponds by reallocating labor and capital to the nontradable sector, since tradable goods can be imported, leading to a deterioration of the non-oil trade balance.

Under policy A, the model reproduces the well-known countercyclicality of the trade balance (only the non-oil trade balance is shown in the figure).²⁵ Through the balance of payments identity, this results in an increase in foreign debt. Under policy A, the model economy suffers from what [Kaminsky, Reinhart, and Végh \(2004\)](#) call the when-it-rains-it-pours syndrome: macroeconomic policy and capital inflows are positively correlated. In this case, fiscal policy expands precisely when capital is flowing in, as is evident in the accumulation of foreign debt and in a deterioration of the trade balance.

The model under policy A does not capture some features of Mexico. Specifically, tradable output contracts substantially following an oil price shock, and the relative price of nontradables decreases slightly. The VAR showed these two variables increase following an oil price shock. The reason for this is that, in the model, private capital and labor are freely mobile across sectors. The reallocation of resources to the nontradable sector, an optimal response in the model, is so drastic that tradable production drops sharply. In turn, this means there is no temporary scarcity of nontradables, so their price does not increase. In fact, the price of nontradables falls, albeit very slightly. This limitation could be addressed by adding frictions to the mobility of labor and capital, which would limit the rapid sectoral reallocation. The counterfactual response of tradable output could also be explained if, in the data, oil price shocks are the result of higher global demand, fueled perhaps, by the growth of emerging economies such as China. Such a phenomenon would increase the demand for Mexico's exports, inducing it to expand the production of tradables.²⁶ In the model, however, the small open economy that faces a perfectly elastic demand for its exports, so it is irrelevant whether the oil price is demand-driven.

Figure 4 also shows, in dashed red lines, the response of the model economy under the more prudent policy B. The government saves each period a fraction $\gamma_o = 0.5$ of its steady-state oil revenue plus all oil windfalls in a SWF, and invests a fraction $(1 - \gamma_o)$ of steady-state oil revenue plus the return from the fund. Under this policy, government investment responds smoothly, unlike under policy A, and the economy displays a much milder and more prolonged expansion, almost imperceptible given the scale and the time horizon in the figure. Because oil revenue windfalls are saved in the SWF, the non-oil trade balance does not deteriorate. The behavior of the model under policy B bears resemblance to Norway in some respects. The SWF is a tool that helps the government avoid an expansionary fiscal

²⁵See, for example, [Neumeier and Perri \(2005\)](#); and [Schmitt-Grohé and Uribe \(2014\)](#).

²⁶[Bjornland and Thorsrud \(2014\)](#) use an empirical framework that is able to distinguish between changes in the oil price that are caused by global demand shocks from other oil price shocks, such as those caused by supply disruptions.

response to the shock. Government investment does not fall as in Norway, of course, because the model is not constructed to capture that response.

The difference in the model's performance under policies A and B suggests governments in oil-exporting countries would go a long way toward protecting their economies from the instability of oil prices by avoiding large and sudden expansionary responses to temporary increases in the oil price. Specifically, the results highlight the importance of delinking government investment from oil revenue. Unfortunately, Mexico has struggled to design stabilizing fiscal institutions. [Villafuerte, López-Murphy, and Ossowski \(2013, pp. 158-60\)](#) mention that legislation enacted in the 2000s has contributed to a procyclical fiscal policy and has not facilitated the accumulation of oil windfalls in funds. Indeed, Congress allowed the government to deplete a poorly designed oil fund in 2002.

6.2 Inspecting the Prudent Policy

What features of the prudent policy B, exactly, allow it to protect the economy from oil price shocks? In this subsection, I show that the key feature is not the SWF per se, but the fact that government investment is not linked directly to oil revenue (and the oil price). Consider a seemingly slight variation of policy B, and call it **policy C**:

$$F_{t+1} = (1 - \tilde{\gamma}_F)F_t + \tilde{\gamma}_o p_t^o Y^o, \quad (26a)$$

$$p_t^G G_t^I = (1 - \tilde{\gamma}_o) p_t^o Y^o + R^F F_t, \quad (26b)$$

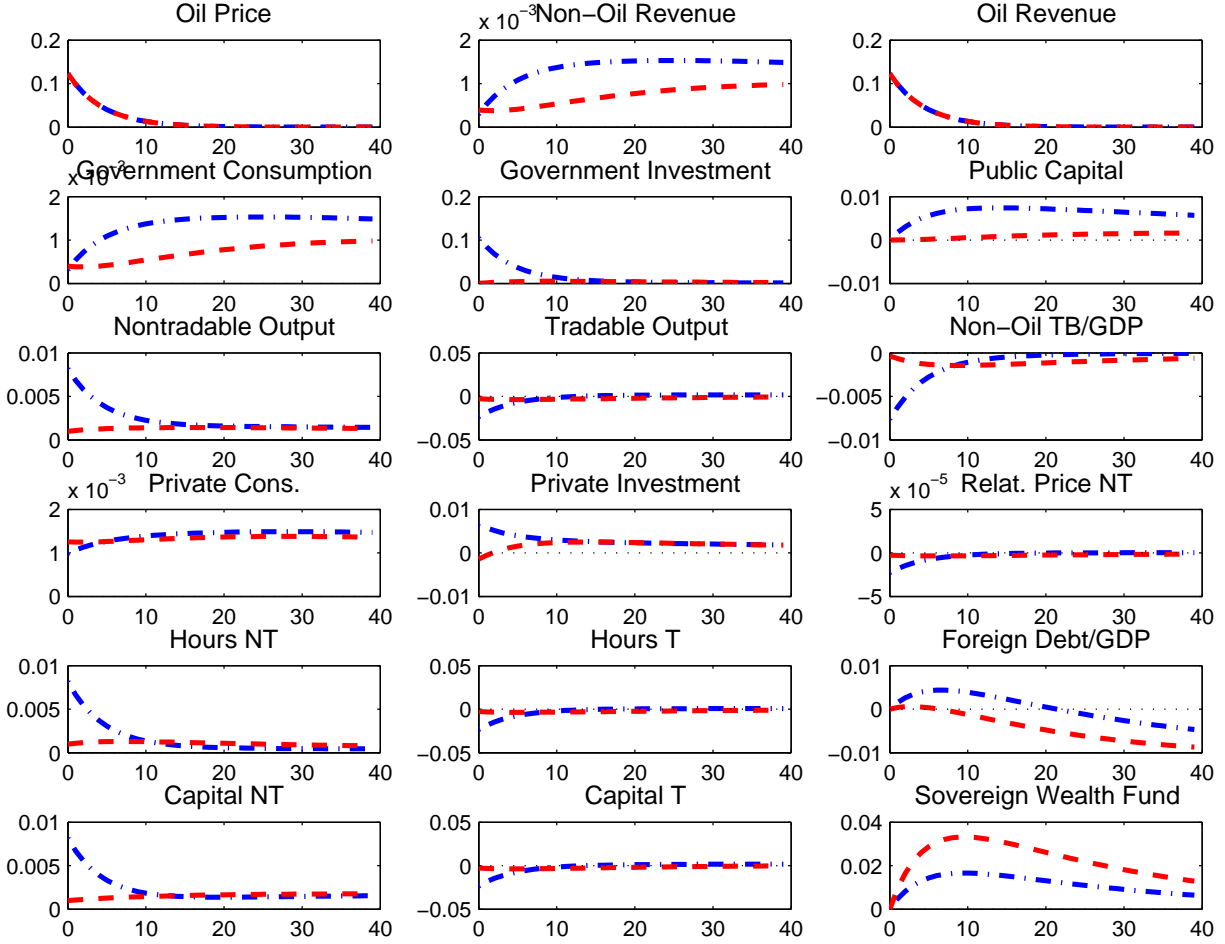
$$p_t^G G_t^C = \tau^C p_t C_t + \tau^L W_t L_t. \quad (26c)$$

Under this policy, the government saves each period a fraction $\tilde{\gamma}_o$ of its *current oil revenue*, as opposed to a fraction of its *steady-state oil revenue*. The government invests the rest of current oil revenue (a fraction $(1 - \tilde{\gamma}_o)$) plus the return from the fund. Consumption is the same as in policy B, and the steady state under policies B and C is identical.

Unlike policy B, policy C does not deal with the saving and investing of oil revenue in terms of its steady-state or long-term level, but in terms of its current level. This means that fluctuations in the oil price affect government investment directly under policy C. Oil windfalls (oil revenue in excess of steady state) are now split between saving and investment, while they are saved in their entirety under policy B. Government investment is, thus, *linked* to fluctuations in the oil price under policy C.

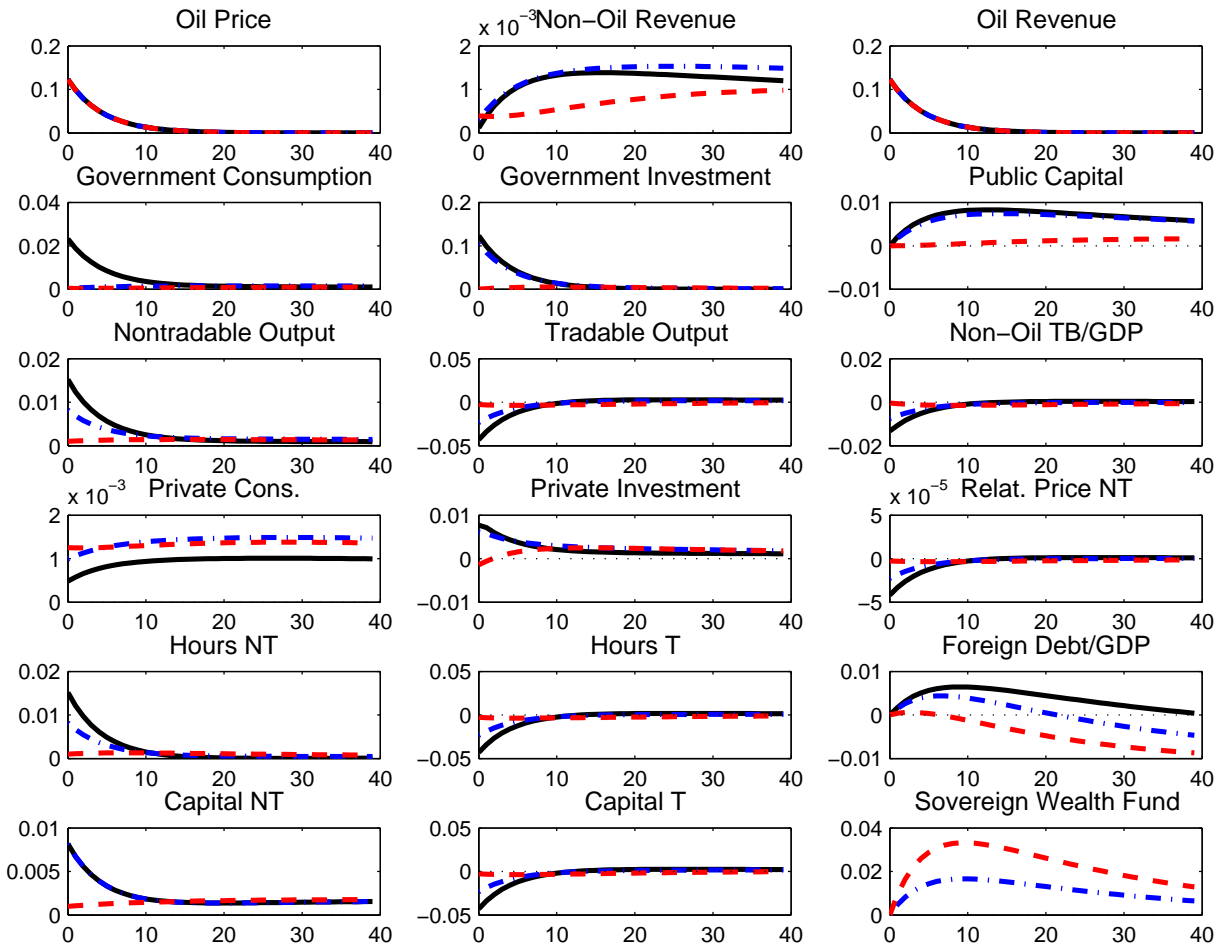
Impulse responses to an oil price shock are substantially different under policies B and C, as figure 5 shows. Dashed red lines reproduce the economy's response under policy B,

Figure 5: Impulse Responses to an Oil Price Shock (Policies B and C)



Impulse responses to a one-standard-deviation shock to the oil price. Dashed red lines describe responses under policy B, by which the government saves a fraction $\gamma_o = 0.5$ of its *steady-state oil revenue*, plus oil windfalls, in a sovereign wealth fund (SWF), and invests each period a fraction $(1 - \gamma_o)$ of steady-state oil revenue plus the return from the fund. Dash-and-dotted blue lines describe responses under policy C, by which the government saves a fraction $\tilde{\gamma}_o = 0.5$ of its *current oil revenue* in a SWF, and invests a fraction $(1 - \tilde{\gamma}_o)$ of current oil revenue plus the return from the fund. Horizontal axes show quarters, while vertical axes describe percent deviations from steady state (1=100 percent).

Figure 6: Impulse Responses to an Oil Price Shock (Policies A, B, and C)



Impulse responses to a one-standard-deviation shock to the oil price. Solid black lines describe responses under policy A, dashed red lines are responses under policy B, and dash-and-dotted blue lines are responses under policy C. Horizontal axes show quarters, while vertical axes describe percent deviations from steady state (1=100 percent).

while dash-and-dotted blue lines refer to policy C. I set $\gamma_o = \tilde{\gamma}_o = 0.5$, so that the steady state is identical. In particular, the level of the SWF at the steady state is identical under the two policies. We can see that policy C does not protect the economy from the volatility of the oil price. It allows government investment to rise about 10 percent above trend on impact, which triggers a response similar to that under the spend-as-you-go policy A. Policy B is successful because it delinks government investment from fluctuations in the oil prices, and not due to the mere existence of a sovereign wealth fund.

For completeness, figure 6 shows that the behavior of the model economy under policy C lies in the middle of the two extreme fiscal policy rules A and B.

7 Conclusion

This paper argues that government investment can play an important role in the propagation of oil price shocks in oil-exporting countries. A structural vector autoregression (VAR) applied to Mexico finds that a positive oil price shock generates a temporary expansion of government investment and a boom in private economic activity. In Norway, an oil price shock does not lead to an increase in government investment, and the economy expands modestly. A small open economy dynamic stochastic general equilibrium model points to the productivity-enhancing effect of public capital as the channel through which government investment transmits the oil price shock. The DSGE model shows that a prudent policy by which the government saves part of its oil revenue and smooths investment would protect the economy from the instability of oil prices.

The goal of the paper is not to offer a precise recipe to policymakers, but its results suggest that oil-exporting countries could limit large swings in economic activity by saving oil windfalls and delinking government investment from fluctuations in oil prices. Of course, this is easier said than done. As authors such as [Alesina, Campante, and Tabellini \(2008\)](#); and [Tornell and Lane \(1999\)](#) argue, there are strong political economy considerations that prevent developing countries from implementing sound fiscal policies. Countries that pass the political hurdle, however, can benefit from the theory and evidence on the effects of fiscal policy on the business cycle.²⁷

In the future, it would be useful to address certain limitations of the DSGE model. For instance, and in contrast to the empirical evidence, tradable output falls following a positive oil price shock. Features that might dampen this limitation include frictions in the mobility

²⁷See [Frankel \(2013\)](#) and the references therein for an analysis of the case of Chile, a copper producer that has succeeded at insulating its economy from the volatility of copper prices thanks to the implementation of adequate fiscal institutions.

of capital and labor, which would slow the reallocation of resources from the tradable to the nontradable sector. It would also be useful to strengthen the link between the DSGE model and the data. This could be achieved by calibrating the model to match stylized facts of the Mexican business cycle and/or the impulse responses from the VAR.

Finally, future research could provide policymakers in oil-exporting countries with a DSGE framework that would aid in understanding the role of several fiscal tools in the propagation of shocks. Policymakers would benefit from a model that considered, in addition to government investment, the role of other components of spending, such as consumption and transfers, of tax rates, and of debt instruments. Allowing for heterogeneity among households would capture the effects of schemes such as conditional cash transfer programs, while imposing collateral constraints on the government's ability to borrow from international capital markets would be useful in light of the evidence that finds that many countries' access to international financing drops precisely when their need for it increases.²⁸

²⁸See, for example, [Gavin and Perotti \(1997\)](#), and [Kaminsky, Reinhart, and Végh \(2004\)](#).

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Appendix

A Data Sources and Transformations

National accounts data come from Mexico’s National Statistics Institute (*Instituto Nacional de Estadística y Geografía*—INEGI).²⁹ As in Pieschacón (2012), traded output includes agriculture, non-oil mining, and manufactures. The source of data on federal government revenue and expenditure is the Mexican Treasury (*Secretaría de Hacienda y Crédito Público*—SHCP).³⁰ The oil price comes from the International Monetary Fund. It is the price of West Texas Intermediate crude oil, the reference price for Mexican oil. Finally, the CPI-based real exchange rate comes from Mexico’s central bank (*Banco de México*).

Norwegian data comes from Statistics Norway, except the price of Dated Brent crude oil, which comes from the International Monetary Fund, and the CPI-based real exchange rate, which comes from the Bank for International Settlements.

To maximize compatibility between the empirical analysis and the DSGE model of section 4, I define private investment as the sum of private fixed capital formation and the change in inventories.

The non-oil trade balance is expressed in nominal terms, and stationarity is obtained by dividing it by the log-linear trend of nominal GDP.

As a proxy of the relative price of nontradables relative to the CPI, I use the ratio of a consumer price index for *services* to the aggregate CPI.

Oil prices are deflated with the U.S. GDP deflator.

I deflate the data on government revenue and expenditure using the GDP deflator, and deseasonalize them with the X-12-ARIMA method.

To estimate the baseline VAR, I remove a linear trend from the logarithm of the variables,

²⁹In the Economic Information Databank (*Banco de Información Económica*), tables *Oferta y demanda global de bienes y servicios*, and *Producto interno bruto trimestral*.

³⁰The dataset is called *Situación Financiera del Gobierno Federal*.

as in [Pieschacón \(2012\)](#). I use the HP filter as a robustness check.

B Empirical Evidence: Robustness Checks (Not for publication)

The empirical evidence reported in section 3, based on VARs for Mexico and Norway, is qualitatively robust to two variations. Figures 7 and 8 show, in red lines, impulse responses to an oil price shock from VARs that consider consumption and investment by these countries' *general governments*. The baseline impulse responses, shown in black lines for comparison, are based on consumption and investment by the Mexican federal government and the Norwegian central government. The general government encompasses state and local governments as well. For both countries, the response of general government investment is milder and more persistent than that of its narrower counterpart.

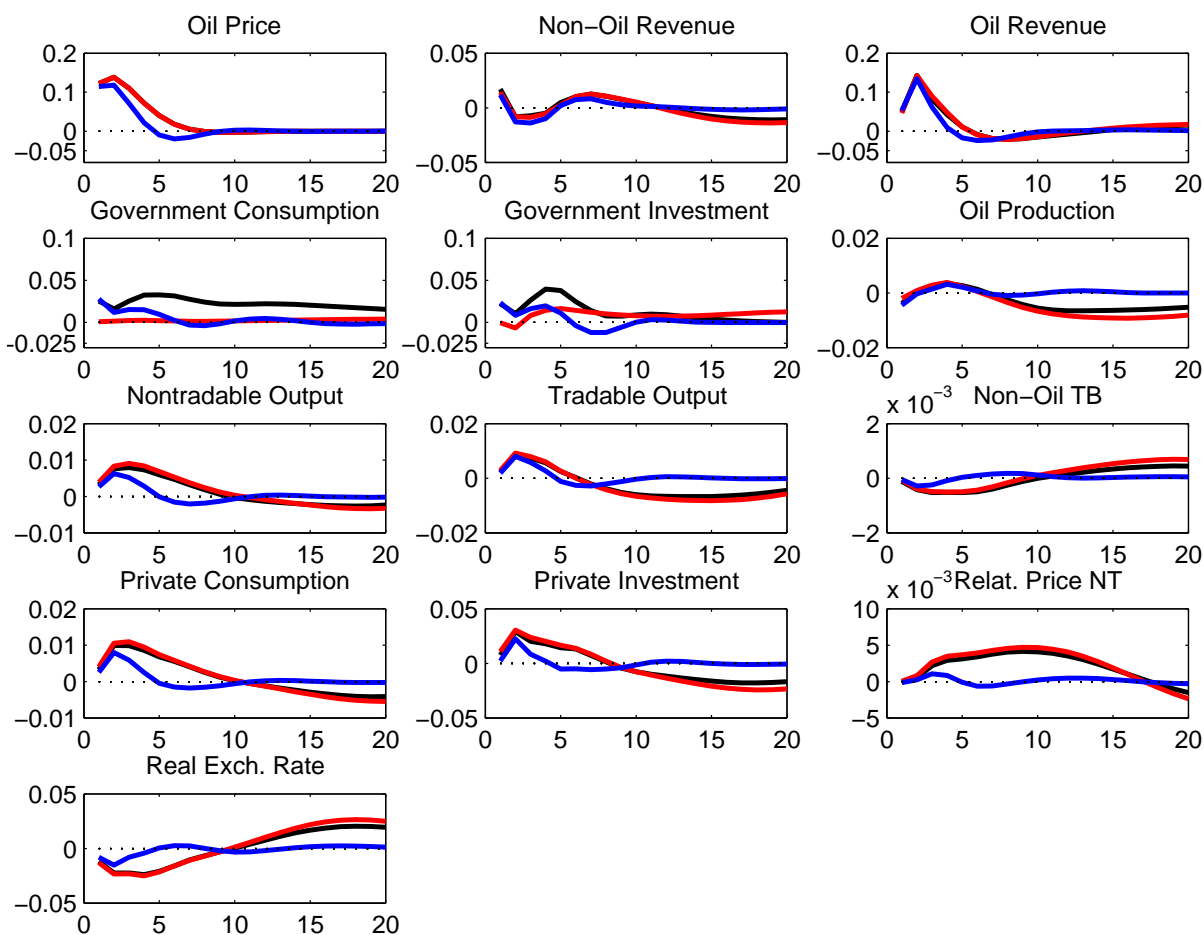
The empirical results are also qualitatively robust to a different detrending procedure. Blue lines show impulse responses from VARs based on time series expressed as log-deviations from HP trends (HP parameter $\lambda = 1600$).³¹ As expected, the magnitude of the responses is smaller than in the baseline VARs. This is due to the fact that the HP trend follows the data more closely than a linear trend. The amplitude of the resulting cyclical component is, thus, quite smaller.

C Model Equations and Derivation of the Steady State (Not for publication)

This appendix contains the first-order conditions from the household's and firms' optimization problems, lists the system of equations that describes the model's equilibrium dynamics,

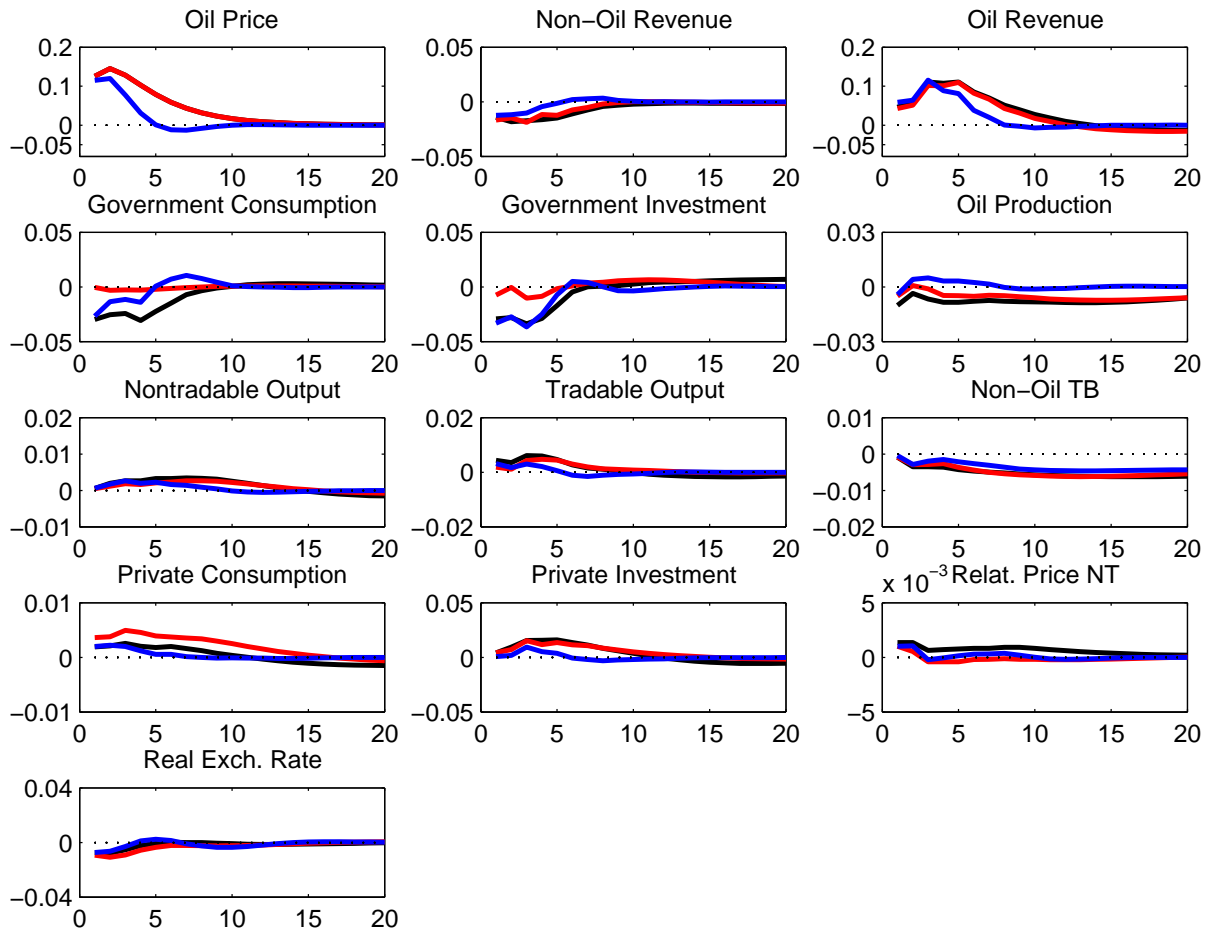
³¹The non-oil trade balance is an exception. As in the baseline VAR, it is expressed as a percent of trend GDP.

Figure 7: Mexico's Response to an Oil Price Shock: Robustness Checks



Mexican variable's impulse responses to a one-standard-deviation shock to the price of West Texas Intermediate crude oil, the reference price for Mexican oil. Black lines: baseline results; red lines: consumption and investment by the *general government* (federal, state, and local governments) replace consumption and investment by the federal government; blue lines: HP filtered data instead of linearly detrended data, except the non-oil trade balance, which is expressed as a percent of trend GDP. Vertical axes are percent deviations from trend (1=100 percent). Horizontal axes represent quarters.

Figure 8: Norway's Response to an Oil Price Shock: Robustness Checks



Norwegian variable's impulse responses to a one-standard-deviation shock to the price of Dated Brent crude oil, the reference price for Norwegian oil. Black lines: baseline results; red lines: consumption and investment by the *general government* (central and local governments) replace consumption and investment by the central government; blue lines: HP filtered data instead of linearly detrended data, except the non-oil trade balance, which is expressed as a percent of trend GDP. Vertical axes are percent deviations from trend (1=100 percent). Horizontal axes represent quarters.

and derives the model's deterministic steady state.

C.1 First Order Conditions and the System of Equations

Letting $u_C(\cdot)$ and $u_L(\cdot)$ denote the derivative of the utility function with respect to consumption and labor, respectively, the conditions for utility maximization by the household are:

$$\frac{(1 - \tau^L) W_t}{(1 + \tau^C) p_t} = - \frac{u_L(C_t, L_t)}{u_C(C_t, L_t)},$$

$$u_C(C_t, L_t) = \beta \mathbb{E}_t \left[u_C(C_{t+1}, L_{t+1}) \frac{p_t}{p_{t+1}} (1 + R_{t+1}) \right],$$

$$u_C(C_t, L_t) = \beta \mathbb{E}_t \left[u_C(C_{t+1}, L_{t+1}) \frac{p_t}{p_{t+1}} [R_{t+1}^K + (1 - \delta)] \right],$$

The conditions for profit maximization by firms in both sectors are:

$$R_t^K = \alpha p_t^N \frac{Y_t^N}{K_t^N},$$

$$W_t = (1 - \alpha) p_t^N \frac{Y_t^N}{L_t^N},$$

$$R_t^K = \alpha \frac{Y_t^T}{K_t^T},$$

$$W_t = (1 - \alpha) \frac{Y_t^T}{L_t^T}.$$

I now list the equations that form a system of expectational difference equations. They describe the equilibrium dynamics of the model. Equations (40a)–(40c) describe fiscal policy rule A, while equations (41a)–(41c) describe fiscal policy rule B.

$$\zeta\omega L_t^{\omega-1} = \left(\frac{1-\tau^L}{1+\tau^C}\right) (1-\alpha) \frac{p_t^N Y_t^N}{p_t L_t^N}, \quad (27)$$

$$\zeta\omega L_t^{\omega-1} = \left(\frac{1-\tau^L}{1+\tau^C}\right) (1-\alpha) \frac{1}{p_t} \frac{Y_t^T}{L_t^T}, \quad (28)$$

$$L_t = L_t^N + L_t^T, \quad (29)$$

$$(C_t - \zeta L_t^\omega)^{-\sigma} = \beta \mathbb{E}_t \left[(C_{t+1} - \zeta L_{t+1}^\omega)^{-\sigma} \frac{p_t}{p_{t+1}} \left[\alpha \frac{Y_{t+1}^T}{K_{t+1}^T} + (1-\delta) \right] \right], \quad (30)$$

$$(C_t - \zeta L_t^\omega)^{-\sigma} = \beta \mathbb{E}_t \left[(C_{t+1} - \zeta L_{t+1}^\omega)^{-\sigma} \frac{p_t}{p_{t+1}} \left[\alpha p_{t+1}^N \frac{Y_{t+1}^N}{K_{t+1}^N} + (1-\delta) \right] \right], \quad (31)$$

$$K_t = K_t^N + K_t^T, \quad (32)$$

$$K_{t+1} = (1-\delta)K_t + I_t, \quad (33)$$

$$(C_t - \zeta L_t^\omega)^{-\sigma} = \beta \mathbb{E}_t \left[(C_{t+1} - \zeta L_{t+1}^\omega)^{-\sigma} \frac{p_t}{p_{t+1}} [1 + R + \psi(e^{D_{t+1}-D} - 1)] \right], \quad (34)$$

$$Y_t^T = A^T (K_t^T)^\alpha (K_t^G)^\theta (L_t^T)^{1-\alpha}, \quad (35)$$

$$Y_t^N = A^N (K_t^N)^\alpha (K_t^G)^\theta (L_t^N)^{1-\alpha}, \quad (36)$$

$$Y_t^N = C_t^N + G_t^N + \gamma C_t^T, \quad (37)$$

$$Y_t^T + p_t^o Y^o + (R^F F_t - R_t D_t) = C_t^T + I_t + G_t^T + [(F_{t+1} - F_t) - (D_{t+1} - D_t)], \quad (38)$$

$$\ln(p_t^o) = \rho_o \ln(p_{t-1}^o) + \epsilon_t^o, \quad \rho_o \in (-1, 1), \quad \epsilon_t^o \sim \text{i.i.d.}(0, \sigma_o^2), \quad (39)$$

$$F_t = 0 \quad \forall t, \quad (40a)$$

$$p_t^G G_t^I = \phi p_t^o Y^o, \quad (40b)$$

$$p_t^G G_t^C = \tau^C [p_t^T C_t^T + p_t^N C_t^N] + \tau^L W_t L_t + (1 - \phi) p_t^o Y^o, \quad (40c)$$

$$F_{t+1} = (1 - \gamma_F) F_t + \gamma_o p^o Y^o + (p_t^o Y^o - p^o Y^o), \quad (41a)$$

$$p_t^G G_t^I = (1 - \gamma_o) p^o Y^o + R^F F_t, \quad (41b)$$

$$p_t^G G_t^C = \tau^C [p_t^T C_t^T + p_t^N C_t^N] + \tau^L W_t L_t, \quad (41c)$$

$$K_{t+1}^G = (1 - \delta_G) K_t^G + G_t^I, \quad (42)$$

$$C_t^T = (1 - \varphi) \left(\frac{p_t^T}{p_t} \right)^{-\chi} C_t, \quad (43)$$

$$C_t^N = \varphi \left(\frac{p_t^N}{p_t} \right)^{-\chi} C_t, \quad (44)$$

$$p_t = [\varphi(p_t^N)^{1-\chi} + (1-\varphi)(p_t^T)^{1-\chi}]^{\frac{1}{1-\chi}}, \quad (45)$$

$$p_t^G = [\nu(p_t^N)^{1-\chi} + (1-\nu)]^{\frac{1}{1-\chi}}, \quad (46)$$

$$p_t^G(G_t^C + G_t^I) = G_t^T + p_t^N G_t^N, \quad (47)$$

$$p_t^T = 1 + \gamma p_t^N, \quad (48)$$

$$G_t^T = (1-\nu) \left(\frac{1}{p_t^G} \right)^{-\chi} G_t, \quad (49)$$

$$G_t^N = \nu \left(\frac{p_t^N}{p_t^G} \right)^{-\chi} G_t, \quad (50)$$

C.2 Derivation of the Deterministic Steady State

To solve the DSGE model, I take a linear approximation around its deterministic steady state. Consider the system of expectational difference equations evaluated at the steady state. The oil price shock is held at its mean value and variables are constant. I remove time subscripts to denote a variable's steady state value.

From equation (39), note $p^{o*} = 1$. I also set the productivity indices $A^i = 1$, $i = \{N, T\}$.

At the steady state, the laws of motion of private and public capital reduce to $\delta K = I$, and $\delta_G K^G = G^I$, respectively. Dividing the steady state conditions for public and private capital by GDP , dividing the latter by the former, and rearranging results in:

$$\delta_G = \delta \frac{K}{K^G} \frac{S_{GI}}{S_I},$$

where $\frac{K}{K^G}$ is the ratio of private to public capital, which I obtain from Cubas (2010); $S_{GI} \equiv \frac{G^I}{GDP}$ is the share of government investment in GDP; and $S_I \equiv \frac{I}{GDP}$ is the share of private investment in GDP. I compute these ratios from the data.

Without loss of generality, assign a value to steady-state public capital, say $K^G = 10$. Then solve for government investment: $G^I = \delta_G K^G$; private capital: $K = (K/K^G)K^G$; private investment: $I = \delta K$; gross domestic product: $GDP = G^I/S_{GI}$; non-oil GDP: $Y = (1 - S_o)GDP$; and the oil endowment: $Y^o = GDP - Y$.

It can be shown that because the elasticity of output with respect to inputs is the same across sectors, relative prices in the two sectors are equal at the steady state: $p^N = 1$. This implies, from equation (46), that $p^G = 1$.

From equation (48):

$$p^T = 1 + \gamma.$$

Equation (45) implies:

$$p = [\varphi + (1 - \varphi)(p^T)^{1-\chi}]^{\frac{1}{1-\chi}}.$$

Combining the equilibrium conditions for debt and private capital, equations (34), (31), and (30), and rearranging results in:

$$\alpha = \frac{R + \delta}{\frac{Y^i}{K^i}},$$

$i = \{N, T\}$. Because input shares are constant across sectors, $(Y^N/K^N) = (Y^T/K^T) = (Y/K)$. Both Y and K are known, so α is now known.

With the value of α , it is possible to compute the capital-labor and output-labor ratios, which are the same across sectors and in the aggregate.

Non-oil output at the steady state is given by $Y = Y^N + Y^T$. Using the production functions, and the fact $(K^N/L^N) = (K^T/L^T) = (K/L)$, and $L = L^N + L^T$,

$$L = \frac{Y}{\left(\frac{K}{L}\right)^\alpha (K^G)^\theta}.$$

Use any of the two conditions for equilibrium in the labor market, equation (27) or (28), to calibrate ζ :

$$\zeta = \frac{\left(\frac{1-\tau^L}{1+\tau^C}\right) (1-\alpha)\frac{1}{p}\frac{Y}{L}}{\omega L^{\omega-1}}.$$

From this point, it is useful to separate the derivations for the model under policies A and B.

C.3 Policy A

The balance of payments identity, equation (25), gives foreign debt: $D = (tb/R)$. Multiplying and dividing the right-hand side by GDP results in:

$$D = \frac{tb/GDP}{R}GDP,$$

where tb/GDP is the trade balance-to-GDP ratio, which I obtain from Mexican data.

The fraction of oil revenue the government invests at the steady state results from equation (40b): $\phi = G^I/Y^o$.

Combine equations (37) and (38), and note $p^T C^T + C^N = pC$, $G^T + G^N = G = G^C + G^I$, to get:

$$Y + Y^o = pC + I + G^C + G^I + RD.$$

Plugging the expression for government consumption into this expression and solving for private consumption results in:

$$C = \frac{[1 - \tau^L(1 - \alpha)]Y - I - RD + (\phi Y^o - G^I)}{(1 + \tau^C)p},$$

where $(\phi Y^o - G^I) = 0$ by equation (40b). Government consumption is then given by $G^C = \tau^C pC + \tau^L(1 - \alpha)Y + (1 - \phi)Y^o$.

The trade balance is $tb = Y + Y^o - (pC + I + G^C + G^I)$, while the non-oil trade balance is given by $tb - Y^o$.

Using the demands for tradable and nontradable goods by the household and the government results in:

$$C^T = (1 - \varphi) \left(\frac{p^T}{p} \right)^{-\chi} C,$$

$$C^N = \varphi \left(\frac{1}{p} \right)^{-\chi} C,$$

and $G^T = (1 - \nu)G$; $G^N = \nu G$.

From equation (37), obtain nontradable output:

$$Y^N = C^N + G^N + \gamma C^T.$$

It follows that $Y^T = Y - Y^N$. Since the output-labor ratio is constant across sectors,

$$L^N = \frac{L}{1 + \frac{Y^T}{Y^N}}.$$

It follows that $L^T = L - L^N$. Since the output-capital ratio is constant across sectors,

$$K^N = \frac{K}{1 + \frac{Y^T}{Y^N}}.$$

It follows that $K^T = K - K^N$.

C.4 Policy B

Equation (41b) gives the SWF at the steady state:

$$F = \frac{G^I - (1 - \gamma_o Y^o)}{R^F}.$$

It follows that for $F > 0$, $\gamma_o > (1 - G^I/Y^o)$.

From equation (41a), compute the consistent fraction of the SWF the government transfers to the household in lump-sum fashion:

$$\gamma_F = \frac{\gamma_o Y^o}{F}.$$

Solving the balance of payments identity for foreign debt, and multiplying and dividing the right-hand side by GDP results in:

$$D = \frac{\frac{tb}{GDP} + R^F \frac{F}{GDP}}{R} GDP,$$

where, again, $\frac{tb}{GDP}$ is a ratio I obtain from the data.

A procedure analogous to that described in the derivation of the steady state under policy A results in private consumption:

$$C = \frac{[1 - \tau^L(1 - \alpha)]Y - I + R^F F - RD + Y^o - G^I}{(1 + \tau^C)p}.$$

Government consumption is given by $G^C = \tau^C pC + \tau^L(1 - \alpha)Y$.

The trade balance is $tb = Y + Y^o - pC - I - G^C - G^I$, and the steady state levels of the rest of the variables are derived exactly as under policy A.