

Government Investment and the Business Cycle in Oil-Exporting Countries

Juan F. Guerra-Salas[†]

Department of Economics

Fordham University

jguerrasalas@fordham.edu

<http://juanguerrasalas.com/>

March 2014

[PRELIMINARY AND INCOMPLETE. PLEASE DO NOT CITE WITHOUT PERMISSION.]

Abstract

In countries where the government relies heavily on oil revenue, the response of government investment to oil price fluctuations is a key transmission mechanism of oil price volatility. To show this, I provide evidence on the Mexican economy, where a positive oil price shock generates an expansion in consumption and investment by both the private and public sectors. I explain this with a small-open-economy dynamic stochastic general-equilibrium model in which the response of government investment to oil price fluctuations is a key transmission mechanism: when the government rapidly consumes and invests oil revenue windfalls, the increase in public capital raises the productivity of the private sector, triggering a considerable expansion. This contrasts with a hypothetical prudent policy by which the government saves its oil revenue in a sovereign wealth fund and invests each period only the return from the fund plus a small additional fraction. Under the prudent policy, the shock generates a milder and more long-lasting expansion, effectively insulating the economy from the volatility of oil prices.

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

Keywords: Government investment, oil price shock, fiscal policy, business cycle, small open economy.

[†]I thank Bart Moore, my advisor, for comments.

1 Introduction

Many governments rely heavily on oil revenue, which exposes their economies to the volatility of oil prices. For example, between 2005 and 2009, oil revenue represented, on average, 25 percent of total government revenue in Ecuador. This share reached 36 percent in Mexico, and 53 percent in Venezuela.¹ In this paper, I show that the response of *government investment* to oil price fluctuations is a key transmission mechanism of oil price volatility. First, I provide evidence on Mexico, an oil exporter where a positive oil price shock generates an expansion in consumption and investment by both the private and public sectors. Government investment expands about 6 percent above trend a few quarters after a 12 percent oil price shock hits the economy. I then use a small-open-economy dynamic stochastic general-equilibrium (DSGE) model to study how the response of government investment transmits the shock: when the government rapidly consumes and invests oil revenue windfalls, as in the data, the increase in public capital raises the productivity of labor and private capital, triggering a considerable expansion. Interestingly, the productive investment of oil revenue injects volatility to the economy if it responds “too quickly” to oil price fluctuations.

This outcome contrasts with the one produced by a hypothetical prudent policy by which the government saves its oil revenue in a sovereign wealth fund and invests each period only the return from the fund plus a small additional fraction. Under the prudent policy, the shock generates a milder and more long-lasting expansion, effectively insulating the economy from the volatility of oil prices.

Figure 1 gives an idea of the importance of oil revenue and public investment in Mexico’s budget. The top panel shows the oil price and investment by the Mexican federal government, expressed in percent deviations from their linear trends, move closely.² Between 1993:Q1 and 2013:Q3, the correlation coefficient between the two series is 0.4. This positive correlation is

¹The source of these figures is Villafuerte, López-Murphy, and Ossowski (2013, table 1).

²The oil price is the West Texas Intermediate deflated by the U.S. GDP deflator. Government investment is fixed investment by the federal government, deseasonalized and deflated by the GDP deflator. See the data appendix for details.

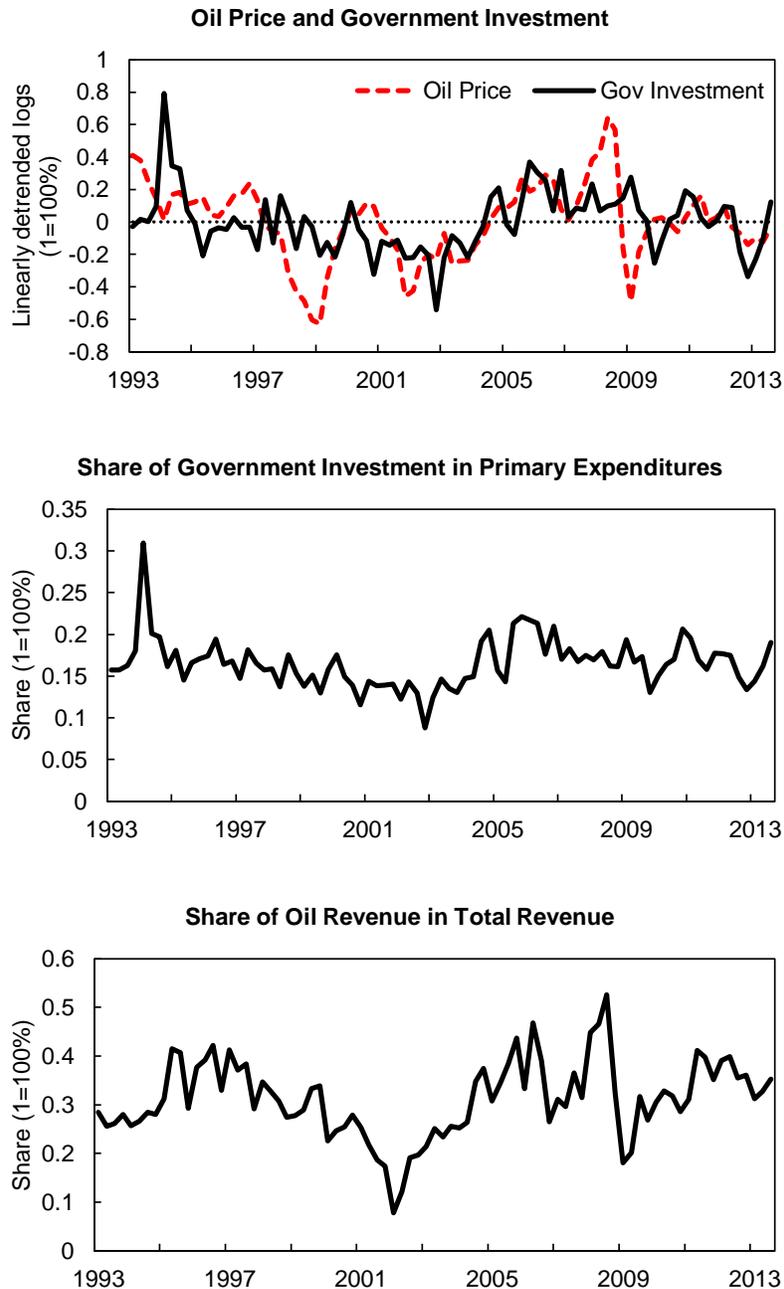
greater from about the year 2000: between 2000:Q1 and 2013:Q3, the coefficient is 0.5. At the beginning of the decade, the oil price and government investment are 20 to 40 percent below trend. They start climbing in 2003, and by 2006, they are about 30 percent above trend. Government investment decreases in the aftermath of the global financial crisis, as the oil price tumbles.

The middle panel shows government investment represents a significant share of primary expenditures (total expenditures minus interest payments). The mean and median shares for the period are about 16 percent. The bottom panel highlights the Mexican government's dependence on oil revenue. The mean and median shares of oil revenue in total revenue are about 30 percent, but with significant variation. The three panels paint the picture of a government that is highly dependent on oil revenue and lets its investment fluctuate substantially.

This paper builds on the important work by Pieschacón (2012), who shows that in oil-exporting countries, fiscal policy can transmit the volatility of oil prices or insulate the economy from oil price fluctuations. She finds that Mexico lets its fiscal policy expand after an oil price shock, while Norway, another oil exporter, does not. As expected, the 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 the evidence unless it takes into account the 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 consumption generates utility to households; public investment is absent. In my model, the key feature is an expansionary response of *government investment*. Furthermore, I do not assume government consumption generates private utility.

In Pieschacón (2012), expansionary tax policy following an oil price shock is important

Figure 1: Oil and Fiscal Policy in Mexico



Fiscal variables refer to the federal government. The top panel shows percent deviations of the price of West Texas Intermediate oil and federal government investment from their linear trends. Primary expenditures, a variable used in the computation of the series in the second panel, are total expenditures minus interest payments. The sample is 1993:Q1–2013:Q3. See the data appendix for details.

for obtaining impulse responses close to those of the data, but she justifies this without looking at data on tax rates, which are scarce. Instead, she backs out the percent change in tax rates generated by an oil price shock from the percent change in tax revenue and the tax base.³ My model emphasizes a transmission mechanism that is directly observed in the data: an oil price shock generates an expansion in government investment. Expansionary tax rates and government investment are, of course, not mutually exclusive transmission mechanisms. Both may be at work in oil-exporting countries.

My approach finds further empirical support in the work due to Villafuerte, López-Murphy, and Ossowski (2013). These authors find that during the boom years between 2003 and 2008, fiscal policy was procyclical in Latin American and Caribbean nonrenewable resource exporters, including Mexico. That is, these countries relaxed fiscal policy at a time when commodity prices, and the government revenue associated with it, expanded substantially.⁴ These results are similar to those I find in a vector autoregression (VAR). But most importantly, Villafuerte, López-Murphy, and Ossowski (2013, pp. 166–8) show that the key component behind the expansionary fiscal response in these countries is government *capital expenditure*, of which investment is typically the largest subcomponent by far. In Mexico, for the period 1993:Q1–2013:Q3, the mean share of fixed investment in capital expenditure is 90 percent, and the median is 94 percent.

This paper contributes to a literature concerned with the effects of external factors on the business cycle of emerging countries. A strand of empirical papers finds that factors such as commodity prices, terms of trade, external financial conditions, and foreign economic activity, account for a large fraction of business cycle volatility. For example, Osterholm and Zettelmeyer (2008) find that three types of external factors (foreign growth, external

³Végh 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 some support to the transmission mechanism emphasized by Pieschacón (2012).

⁴Daude, Melguizo, and Neut (2010) also find several Latin American countries, including Mexico, displayed expansionary fiscal policies in the 2000s.

financial conditions and commodity prices) explain about half of the forecast error variance of a Latin American GDP growth index.⁵ More specifically, they find that a 5.5 percent increase in commodity prices leads to a 0.4 percent increase in Latin American growth. I contribute to this literature by studying how a larger set of domestic variables is affected by one external factor, the oil price, in Mexico. Importantly, I consider how fiscal policy variables respond to fluctuations in the oil price. This facilitates my theoretical analysis of the transmission mechanism of oil price shocks to the economy.

My DSGE model uses many insights from a small literature that studies the effects of alternative government investment policies. Leeper, Walker, and Yang (2010) use a closed-economy DSGE model to study whether government investment could be a useful tool to fight recessions in the U.S. Berg, Portillo, Yang, and Zanna (2013) use an open-economy DSGE model to study how African governments could best use their abundant resource revenues. In particular, they are interested in the right mix between public investment and savings in a sovereign wealth fund.

The rest of the paper is organized as follows. Section 2 provides evidence on the effects of an oil price shock on several Mexican macroeconomic variables, including fiscal variables. Section 3 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 4 discusses the calibration of the structural and policy parameters of the model. Section 5 puts the model to work. It simulates the effects of an oil price shock under two fiscal policies. Under *policy A*, the government immediately consumes and invests all the oil windfall, while under *policy B*, the government saves its oil revenue in a sovereign wealth fund and invests each period only the return from the fund plus a small additional fraction. Section 6 concludes.

⁵See also Izquierdo, Romero, and Talvi (2008).

2 Empirical Evidence

In this section, I document the effects of an unexpected increase in the price of oil, denoted p_t^o , on several variables. Following Pieschacón (2012), I study the Mexican economy and use a vector autoregression (VAR). Due to data availability, however, I study a more recent period, from 1993:Q1 to 2013:Q3.⁶ The VAR is given by:

$$p_t^o = \mathbf{A}(L)p_{t-1}^o + u_t^o, \quad (1)$$

$$\mathbf{x}_t = \mathbf{H}(L)p_t^o + \mathbf{J}(L)\mathbf{x}_{t-1} + \mathbf{u}_t^x, \quad (2)$$

where $\mathbf{x}_t \equiv \{GDP_t, G_t^C, G_t^I, C_t, I_t\}$ is a vector of domestic variables that includes, in order, gross domestic product, federal government consumption of goods and services (except labor services), federal government investment, private consumption, and private investment. $\mathbf{A}(L)$, $\mathbf{H}(L)$, and $\mathbf{J}(L)$ contain polynomials in the lag operator. u_t^o is an oil price shock and \mathbf{u}_t^x is a vector of shocks to the variables in \mathbf{x}_t .

As in Pieschacón (2012), I assume the oil price is exogenous, so that it is only affected by its lagged values and a shock.⁷ The domestic variables in \mathbf{x}_t , on the contrary, are affected by lags of themselves and the oil price; they are also affected contemporaneously by the oil price, but because it is exogenous, endogeneity is not a problem. This implies the oil price shock u_t^o is identified, while the shocks in \mathbf{u}_t^x are not. I am only interested, however, in the economy's response to oil price shocks.

To keep the empirical exercise as close as possible to that in Pieschacón (2012), I use four lags in the VAR, and the logarithms of the variables are linearly detrended, so that impulse

⁶Pieschacón (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, fig. 2).

⁷More precisely, the oil price is assumed to be block-exogenous in the time series sense. See Hamilton (1994, p. 309).

responses can be interpreted as percent deviations from linear trends.⁸

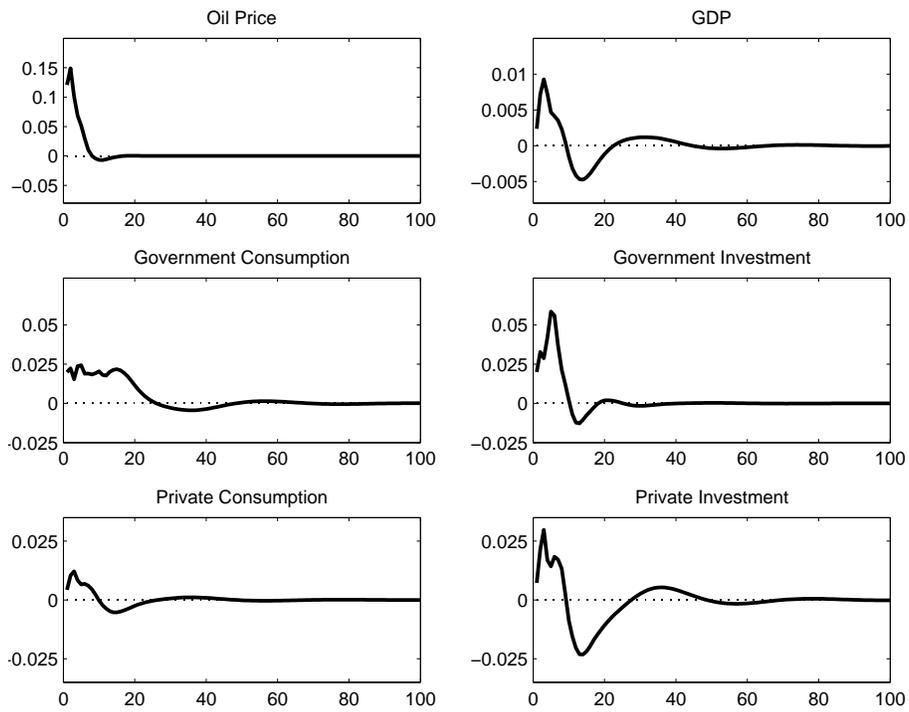
Figure 2 shows how the domestic variables in \mathbf{x} respond to a positive one-standard-deviation shock to the oil price. The main features of the data are summarized as follows: [Add confidence intervals and discuss significance.]

- A shock that raises the oil price 12.1 percent above its linear trend on impact generates a positive response of all the domestic variables: the oil price shock generates an expansion of government spending and a boom in the Mexican economy.
- GDP peaks at about 1 percent above trend a few quarters after the shock hits the economy.
- Government investment expands substantially more than government consumption. The former peaks at about 6 percent above trend, while the latter does not increase beyond 3 percent.
- Consumption and investment by the private sector expand initially. Investment peaks at 3 percent above trend, approximately, while consumption peaks at about 1 percent above trend.
- After the expansion generated by the oil price shock ends, about 10 quarters after it hits the economy, the domestic variables *contract* before returning to their trends. This feature is most obvious for private investment, which displays a contraction that, at its trough, is almost of the same magnitude as the peak of its initial expansion: about 3 percent with respect to trend.

The greater responsiveness of government investment relative to government consumption uncovered by the VAR bears some resemblance to the arguments in Arezki and Ismail (2013), who find, for a panel of oil-exporting countries that includes Mexico, that current government expenditures, which include consumption of goods and services and transfers, are downwardly

⁸The data appendix contains details on definitions, sources, and transformations.

Figure 2: Impulse Responses to an Oil Price Shock (VAR)



Impulse responses of Mexican variables to a one-standard-deviation shock to the oil price. Responses are expressed as log deviations from a linear trend (1=100 percent). Government variables refer to the federal government. [Add confidence intervals.]

rigid with respect to oil price changes. In contrast, capital expenditures, which are mostly investment, are not downwardly rigid. These authors suggest current spending might be “sticky” because it is more vulnerable to political pressures, as recipients of transfers and government employees are among those directly affected by its fluctuations. However, Arezki and Ismail (2013) also find that capital spending is not very responsive to *increases* in the oil price in the panel of countries they study. I do find an expansionary response of Mexican government investment to a rise in the oil price.

The impulse responses to an oil price shock support the hypothesis that fiscal policy, and government investment in particular, is a key transmitter of oil price volatility to the business cycle. In the next section, I explore this hypothesis in the context of a dynamic stochastic general-equilibrium (DSGE) model. As a model grounded in microeconomic optimization, it allows me to study the natural counterfactual: how would the economy respond to an oil price shock under an alternative fiscal policy?

But before proceeding with the model, I highlight a limitation of the empirical analysis: it does not distinguish between tradable (T) and nontradable (NT) production. Doing this would allow me to study whether the oil bonanza could be responsible for a “Dutch disease” effect, i.e., an expansion in the nontradable sector and a contraction in the tradable sector.⁹ Some evidence of this effect is implicit in Pieschacón (2012, fig. 2) for the period she studies. Distinguishing between T and NT production would shed light into the observed drop in GDP and other variables after the initial expansion: is this drop reflecting a contraction in the tradable sector only (Dutch disease) or an economy-wide contraction? The latter scenario would suggest that the economy as a whole adjusts painfully after the oil bonanza.

3 The Model

In a perfectly competitive small open economy, a representative household produces a single good using labor, private and public capital. The government is endowed with a commodity

⁹The classic paper on the Dutch disease is due to Corden and Neary (1982).

that can only be exported. The model abstracts from monetary policy.

3.1 Households

The representative household receives positive utility from consumption, C , and negative utility from labor; L denotes 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 uses the form proposed by Greenwood, Hercowitz, and Huffman (1988):

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

$\sigma > 0$ is the coefficient of relative risk aversion, $\omega > 1$ governs the wage elasticity of labor supply ($= 1/\omega - 1$), and $\zeta > 0$. “GHH preferences” are widely used in the small open economy literature; see, e.g., Correia, Neves, and Rebelo (1995). 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.

The household’s budget constraint, in real terms, is given by:

$$(1 + \tau^C)C_t + I_t + B_t + (1 + R_{t-1}^*)D_{t-1} = (1 - \tau^L)W_t L_t + D_t + R_t^K K_{t-1} + (1 + R_{t-1})B_{t-1} + Z_t. \quad (3)$$

τ^C and τ^L are the consumption and labor income tax rates, respectively, I_t is investment, B_t is the stock of one-period domestic bonds that mature at the end of period t and pay the real interest rate R_t , D_t is the stock of one-period foreign debt that matures at the end of period t and has a real interest rate R_t^* , W_t is the real wage, K_{t-1} is the stock of physical

capital at the end of period $t-1$ that offers a real return R_t^K in period t , and Z_t are lump-sum transfers from the government.

Equation (3) says that the household receives income from: *a*) the labor services it supplies, net of taxes; *b*) new foreign debt; *c*) the return to its stock of capital; *d*) the return to its stock of domestic bonds; and *e*) government transfers. Expenditures are given by: *a*) consumption, including taxes; *b*) investment in physical capital; *c*) purchases of domestic bonds; and *d*) interest payments on foreign debt.

To close the open economy, the interest rate on foreign debt is assumed to be debt-elastic:¹⁰

$$R_t^* = R^* + \psi(e^{\tilde{D}_t - D} - 1), \quad (4)$$

where R^* is the world real interest rate, $\psi > 0$ is a parameter, and D is foreign debt at the steady state. \tilde{D}_t is the cross-sectional average of debt, which the household takes as exogenous.

Private capital evolves according to the following law of motion:

$$K_t = (1 - \delta)K_{t-1} + I_t, \quad (5)$$

where δ is the depreciation rate.

The Lagrangean that describes the household's optimization problem is:

$$\begin{aligned} \mathcal{L} = \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \{ & U(C_{t+j}, L_{t+j}) + \Lambda_{t+j} [(1 - \tau^L)W_{t+j}L_{t+j} + D_{t+j} + [1 - \delta + R_{t+j}^K]K_{t+j-1} \\ & + (1 + R_{t+j-1})B_{t+j-1} + Z_{t+j} - (1 + \tau^C)C_{t+j} - K_{t+j} - B_{t+j} - (1 + R_{t+j-1}^*)D_{t+j-1}] \}, \end{aligned}$$

where Λ_t denotes the Lagrange multiplier at time t . Using U_C and U_L to denote the derivative

¹⁰This is one of the methods Schmitt-Grohé and Uribe (2003) propose to induce stationarity of the debt process in a small open economy model.

of the utility function with respect to consumption and labor, respectively, optimization results in the following conditions:

$$\frac{(1 - \tau^L)}{(1 + \tau^C)} W_t = - \frac{U_L(C_t, L_t)}{U_C(C_t, L_t)}, \quad (6)$$

$$U_C(C_t, L_t) = \beta E_t [U_C(C_{t+1}, L_{t+1})(1 - \delta + R_{t+1}^K)], \quad (7)$$

$$U_C(C_t, L_t) = \beta E_t [U_C(C_{t+1}, L_{t+1})(1 + R_t^*)], \quad (8)$$

$$U_C(C_t, L_t) = \beta E_t [U_C(C_{t+1}, L_{t+1})(1 + R_t)]. \quad (9)$$

Equation (6) is the intratemporal optimality condition; it says that the real wage, net of taxes, must be equal to the marginal rate of substitution. Equation (7) is the intertemporal optimality condition for private capital; it says that the marginal cost of saving must be equal to the marginal benefit of capital. Equation (8) is the intertemporal optimality condition for foreign debt; it says that the marginal benefit of debt must be equal to the marginal cost of paying it. Finally, equation (9) is the intertemporal optimality condition for domestic bonds; it says that the marginal cost of saving must be equal to the marginal benefit of holding domestic bonds.

3.2 Firms

The representative firm produces a single good according to the Cobb-Douglas production function

$$Y_t = AK_{t-1}^\alpha (K_{t-1}^G)^\theta L_t^{1-\alpha}, \quad (10)$$

where Y_t is output, A is a productivity index, and K_{t-1}^G is the stock of public capital at the

end of period $t - 1$. This is the functional form adopted by Leeper, Walker, and Yang (2010) and Berg, Portillo, Yang, and Zanna (2013). There are constant returns to scale with respect to the private inputs K and L and increasing returns with respect to K^G . The objective of the firm is to maximize profits

$$\text{Max}_{K_{t-1}, L_t} Y_t - W_t L_t - R_t^K K_{t-1},$$

which results in the following optimality conditions:

$$R_t^K = \alpha \frac{Y_t}{K_{t-1}}, \quad (11)$$

$$W_t = (1 - \alpha) \frac{Y_t}{L_t}. \quad (12)$$

In words, the real return to capital and the real wage must be equal to the marginal product of capital and labor, respectively.

3.3 Government

The government consumes non-durable goods and services (except labor services), invests in public capital, and distributes lump-sum transfers. It levies taxes from labor income and private consumption, receives income from the exports of an oil endowment it receives every period, issues domestic bonds, and has access to a sovereign wealth fund that pays a constant return. Therefore, the government's budget constraint is given by:

$$G_t^C + G_t^I + Z_t + (1 + R_{t-1})B_{t-1} + F_t = B_t + \tau_t^C C_t + \tau_t^L W_t L_t + p_t^o Y^o + (1 + R^F)F_{t-1}, \quad (13)$$

where G_t^C is government consumption, G_t^I is government investment, F_t is the stock of the sovereign wealth fund (SWF) at the end of period t that pays the constant return R^F , p_t^o is

the price of oil, and Y^o is a constant endowment of oil that can only be exported.

Like Pieschacón (2012), I assume the oil price is stationary and its log follows an AR(1) process:

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

The stock of public capital evolves according to the following law of motion:

$$K_t^G = (1 - \delta_G)K_{t-1}^G + G_t^I, \quad (15)$$

where δ_G is the rate at which public capital depreciates.

Government transfers adjust to stabilize government debt:

$$Z_t = \phi_Z(B_{t-1} - B), \quad \phi_Z < 0, \quad (16)$$

where B is the level of domestic bonds at the steady state.¹¹

The government chooses between two spending policies:

Policy A. The government immediately spends all oil windfalls (oil revenue in excess of its steady state level) and does not use the SWF:

$$G_t^C = G^C + \phi_C(p_t^o Y^o - p^o Y^o), \quad (17a)$$

$$G_t^I = G^I + \phi_I(p_t^o Y^o - p^o Y^o), \quad (17b)$$

$$F_t = 0 \quad \forall t, \quad (17c)$$

where $\phi_C > 0$ and $\phi_I > 0$ are policy parameters that satisfy $\phi_C + \phi_I = 1$.

Policy B. The government saves all the oil revenue in the SWF and invests its return plus

¹¹In Leeper, Walker, and Yang (2010), transfers adjust to stabilize the *debt-to-GDP ratio*. It would be straightforward to implement this in the model.

a fraction γ_F every period:

$$G_t^C = G^C, \quad (18a)$$

$$G_t^I = G^I + (\gamma_F + R^F)F_{t-1}, \quad (18b)$$

$$F_t = (1 - \gamma_F)F_{t-1} + p_t^o Y^o, \quad (18c)$$

where $\gamma_F \in (0, 1)$ is a policy parameter.¹²

3.4 Equilibrium

To obtain equilibrium in the labor market, combine labor demand and supply (equations (6) and (12)) to obtain:

$$L_t^\omega = \left(\frac{1 - \tau^L}{1 + \tau^c} \right) (1 - \alpha) Y_t. \quad (19)$$

Equilibrium in the market for private capital results from combining the household's relevant intertemporal optimality condition (equation (7)), with the firm's optimal demand for capital, (equation (11)). This results in:

$$(C_t - \zeta L_t^\omega)^{-\sigma} = \beta \mathbf{E}_t \left[(C_{t+1} - \zeta L_{t+1}^\omega)^{-\sigma} \left(1 - \delta + \alpha \frac{Y_{t+1}}{K_t} \right) \right]. \quad (20)$$

In equilibrium, the cross-sectional average of foreign debt is $\tilde{D}_t = D_t$, since all households are identical. Plugging this relation and the expression for the foreign interest rate (equation (4)) in the household's relevant intertemporal optimality condition (equation (8)), results in the equilibrium condition for foreign debt:

$$(C_t - \zeta L_t^\omega)^{-\sigma} = \beta \mathbf{E}_t \left[(C_{t+1} - \zeta L_{t+1}^\omega)^{-\sigma} [1 + R^* + \psi(e^{D_t - D} - 1)] \right]. \quad (21)$$

¹²Stationarity of the SWF requires $\gamma_F > 0$.

The household's optimality condition for bonds (equation (9)) describes the equilibrium process for the domestic interest rate:

$$(C_t - \zeta L_t^\omega)^{-\sigma} = \beta \mathbf{E}_t \left[(C_{t+1} - \zeta L_{t+1}^\omega)^{-\sigma} (1 + R_t) \right]. \quad (22)$$

The government budget constraint determines how domestic bonds evolve in equilibrium. Combining equations (13) and (12) results in:

$$B_t = G_t^C + G_t^I + Z_t + (1 + R_{t-1})B_{t-1} + F_t - [\tau^C C_t + \tau^L (1 - \alpha)Y_t + p_t^o Y^o + (1 + R^F)F_{t-1}]. \quad (23)$$

An economy-wide constraint results from combining the household's budget constraint with the government's budget constraint, and noting $Y_t = W_t L_t + R_t^K K_{t-1}$:

$$Y_t + p_t^o Y^o + (D_t - D_{t-1}) + R^F F_{t-1} = C_t + I_t + G_t^C + G_t^I + (F_t - F_{t-1}) + R_{t-1}^* D_{t-1}. \quad (24)$$

This equation says economy-wide income, which consists of output, the exports of the oil endowment, new foreign debt, and the return from the SWF, must be equal to economy-wide purchases and payments, which are given by consumption and investment by the private and public sectors, deposits in the SWF, and interest payments on foreign debt.

Government policy and the stochastic process for the oil price complete the description of the economy's equilibrium dynamics.

Definition. A competitive equilibrium is a set of processes $\{C_t, L_t, D_t, B_t, K_t, I_t, G_t^C, G_t^I, K_t^G, Y_t, R_t, F_t, Z_t, p_t^o\}$ satisfying equations (5), (10), and (14)–(24), given $p_0^o, D_{-1}, B_{-1}, F_{-1}, K_{-1}, K_{-1}^G$, and the process $\{\epsilon_t^o\}$.

The equilibrium process of the trade balance, denoted tb_t , results from noting gross domestic product $GDP_t \equiv Y_t + p_t^o Y^o$, and using the equilibrium processes for consumption

and investment by the private and public sectors:

$$tb_t \equiv Y_t + p_t^o Y^o - C_t - I_t - G_t^C - G_t^I. \quad (25)$$

Finally, the balance of payments identity holds, so the current account can also be constructed from the competitive equilibrium of the model economy:

$$\underbrace{(F_t - F_{t-1}) - (D_t - D_{t-1})}_{\text{capital account}} = \underbrace{tb_t + R^F F_{t-1} - R_{t-1}^* D_{t-1}}_{\text{current account}}, \quad (26)$$

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 take a linear approximation to the model. Specifically, I take a first-order Taylor series expansion around the model's deterministic steady state. In the deterministic steady state, shocks are held at their mean levels and variables are constant. With this approximation, variables are expressed as percent deviations from their steady state, except the real interest rate, which remains expressed in levels.

3.5 Deterministic Steady State

Variables without a time subscript denote their value at the deterministic steady state. I normalize $A = p^o = 1$, and set $Y^o = 0.5$, $G^I = 0.3$, and $Z = 0$ (I explain these choices below).

From the law of motion of public capital, $K^G = \frac{G^I}{\delta_G}$. A steady state in financial markets requires $R = R^*$. Combining the intertemporal equilibrium condition for private capital with the production function gives the capital-labor ratio $\frac{K}{L} = \left[\frac{\beta^{-1} - (1 - \delta)}{\alpha(K^G)^\theta} \right]^{\frac{1}{\alpha-1}}$. Using the equation that describes equilibrium in the labor market, $L = \left[\left(\frac{1 - \tau^L}{1 + \tau^C} \right) (1 - \alpha) \left(\frac{K}{L} \right)^\alpha (K^G)^\theta \right]^{\frac{1}{\omega-1}}$. Then, $K = \left(\frac{K}{L} \right) L$. Output at the steady state is given by $Y = K^\alpha (K^G)^\theta L^{1-\alpha}$. Private investment maintains the stock of capital constant: $I = \delta K$.

The steady-state SWF is $F = \frac{Y^o}{\gamma_F}$ when the government implements *policy B*; it is zero otherwise. Foreign debt at the steady state comes from the balance of payments identity: $D = \frac{tb + R^F F}{R^*}$. I use data on the average trade balance-to-GDP ratio to calibrate this value. Multiplying and dividing the right-hand side by GDP results in $D = \frac{tb/GDP + R^F F/GDP}{R^*} GDP$.

Government consumption at the steady state is given by $G^C = s_C GDP$, where s_C is the share of general government consumption in GDP. Solving the market-clearing condition for consumption gives $C = Y + p^o Y^o + R^F F - I - G^C - G^I - R^* D$. Finally, domestic bonds at the steady state are $B = \frac{\tau^C + \tau^L(1 - \alpha)Y + p^o Y^o + R^F F - G^C - G^I}{R}$.

4 Calibration

Table 1 shows the values I assign to the structural parameters of the model. The unit of time is a quarter. Most parameter values are standard in the small open economy literature: the coefficient of relative risk aversion, σ , is set equal to 2, the discount factor, β , is set equal to 0.99, the elasticity of output with respect to private capital, α , to 1/3, the depreciation of private capital, δ , to 0.025, the world interest rate, R^* , to 0.01, the parameter that governs the risk premium on foreign debt, ψ , to 0.0007, and the consumption and labor income tax rates, to 0.2 and 0.1, respectively.

As in Pieschacón (2012), I set ω , the parameter that governs the wage elasticity of labor supply, to 3, which implies a wage elasticity of 0.5. (I set $\zeta = 1$.) As in Leeper, Walker, and Yang (2010) and Berg, Portillo, Yang, and Zanna (2013), I set θ , the elasticity of output with respect to public capital, equal to 0.1. I leave the depreciation rate of public capital equal to that of private capital at 0.025. The quarterly return to the sovereign wealth fund, R^F , is equal to 0.005, which implies an annual return of 2 percent, a value close to that in Berg, Portillo, Yang, and Zanna (2013). I set the persistence of the oil price, ρ_o , equal to 0.8, the serial correlation of the oil price used in the empirical section. Finally, the standard

Table 1: Calibration of Structural Parameters

Parameter	Definition	Value	Comments/Source
ω	Determines wage elasticity of labor supply ($= 1/(\omega - 1)$).	3	Pieschacón (2012).
σ	Coefficient of relative risk aversion.	2	Standard value.
β	Household's discount factor.	0.99	Standard value.
α	Elasticity of output with respect to private capital.	1/3	Standard value.
θ	Elasticity of output with respect to public capital.	0.1	Berg, Portillo, Yang, and Zanna (2013), Leeper, Walker, and Yang (2010).
δ	Rate of depreciation of private capital.	0.025	Standard value.
δ_G	Rate of depreciation of public capital.	0.025	Close to value in Leeper, Walker, and Yang (2010); 0.02.
R^*	World interest rate.	0.01	Schmitt-Grohé and Uribe (2003).
R^F	Return to the sovereign wealth fund.	0.005	Close to the value in Berg, Portillo, Yang, and Zanna (2013).
ψ	Risk premium parameter.	0.0007	Schmitt-Grohé and Uribe (2003).
τ^C	Tax rate on consumption.	0.2	Lim and McNelis (2008).
τ^L	Tax rate on labor income.	0.1	Lim and McNelis (2008).
ρ_o	Persistence of shock to oil price.	0.8	Serial correlation of linearly detrended oil price.
σ_o	St. dev. of shock to oil price.	0.121	Vector autoregression. See section 2.

deviation of the oil price shock, σ_o , is set to match the standard deviation of the oil price shock obtained in the VAR.

Table 2 shows the calibration of the policy parameters. I set ϕ_Z , the reaction of transfers to the deviation of domestic bonds from steady state, to -0.5, which implies a fairly quick fiscal adjustment. I set the parameters that correspond to *policy A*, $\phi_C = \phi_I = 0.5$, so that the government consumes half of the oil revenue in excess of its steady state value and invests the other half. I set γ_F , the fraction of the SWF that, under *policy B*, the government invests in excess of its return, to 0.01 (1 percent of the fund each period).

The steady state value of government investment G^I is set at 0.3 so that its share in GDP is close to that in the data (6 percent). Finally, I set the constant oil endowment $Y^o = 0.5$ so that the share of oil revenue in total government revenue is close to the average ratio seen

Table 2: Calibration of Policy Parameters

Parameter	Definition	Value
ϕ_Z	Reaction of lump-sum transfers to deviation of bonds from steady state.	-0.5
ϕ_C	Reaction of gov. consumption to deviations of oil revenue from s.s.	0.5
ϕ_I	Reaction of gov. investment to deviations of oil revenue from s.s.	0.5
γ_F	Fraction of the SWF government invests in excess of its return.	0.01

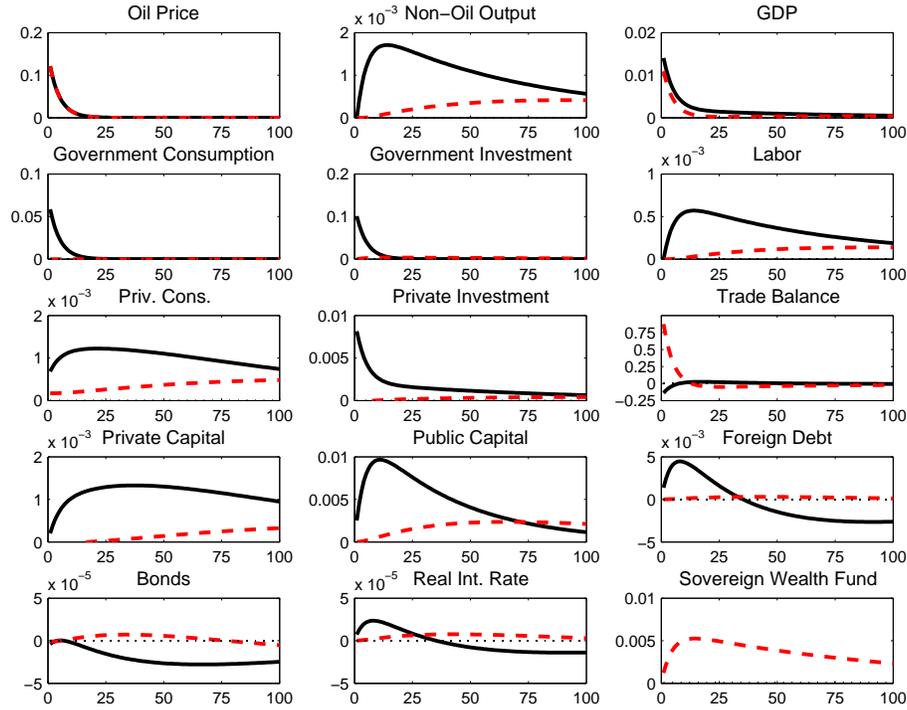
in the data (30 percent).

5 Simulation

Figure 3 shows impulse responses to a one-standard-deviation shock to the oil price. Black and solid lines describe the model economy's response under *policy A*, in which the government immediately spends all the oil revenue in excess of its steady state value. Red and dashed lines show how the economy responds under *policy B*, in which the government saves all the oil revenue in a sovereign wealth fund (SWF) and invests each period the return from the fund plus one percent of the stock of the fund. Vertical axes denote percent deviations from deterministic steady states (1=100 percent).

The economy's response under *policy A* reproduces several features of the data revealed by the VAR exercise in section 2. Government investment increases about twice as much as government consumption, for two reasons. First, under the calibration $\phi_C = \phi_I = 0.5$, the government splits oil windfalls evenly between consumption and investment, and second, at the steady-state, government consumption is about twice as large as government investment. The response of the government triggers an economic expansion: GDP, private consumption, and private investment, variables included in the VAR, initially increase about 1.5, 0.1, and 1 percent above trend, respectively. The expansionary fiscal policy raises the stock of public capital and the productivity of private inputs. This induces an increase in labor and private investment that translates into an increase in non-oil output. The model and calibration

Figure 3: Impulse Responses to an Oil Price Shock (Model)



Impulse responses to a one-standard-deviation shock to the oil price. Black and solid lines describe responses under *policy A*, in which the government immediately consumes and invests all the oil revenue in excess of its steady state value. Red and dashed lines describe responses under *policy B*, in which the government saves all the oil revenue in a sovereign wealth fund and invests each period the return of the fund plus 1 percent of the stock of the fund. Horizontal axes show quarters, while vertical axes describe percent deviations from steady state (1=100 percent).

under *policy A* reproduce the well-known countercyclicality of the trade balance;¹³ it deteriorates by about 14 percent on impact, although the scale of its graph makes it difficult to see this. The deterioration of the trade balance induces an increase in foreign debt through the balance of payments identity. Since the foreign interest rate (not shown in the figure) is debt elastic, it increases and, due to interest parity, the domestic interest rate also increases.

The simplicity of the model leads to its inability to match some features of the data. First, the expansion in the model economy is much more prolonged than in the data. In the VAR exercise (figure 2), the effects of the shock vanish completely between 40 and 50 quarters after it hits the economy, but in the model economy, the effects of the shock last

¹³See Schmitt-Grohé and Uribe (2014, ch. 1).

more than 100 quarters. The effects of the shock are so persistent in the model economy because public capital remains above trend for a long period of time. Since this holds productivity well above trend for a long time, labor and private investment follow the same path. This limitation could be solved by adding frictions to the formation of public capital that have been proposed in the related literature. For example, Berg, Portillo, Yang, and Zanna (2013) build a model with public capital in which a drastic scale-up of government investment triggers a decrease in the productivity of public capital. Frictions such as this would accelerate the return of public capital to its steady state following the oil price shock, pulling the rest of the model economy with it.

Another feature that the model fails to capture is the observed contraction that follows the boom generated by the oil price shock. As I previously mentioned, this could be due to the Dutch disease effect, which could be captured by a DSGE model with tradable and nontradable production.

Figure 3 also shows, in red and dashed lines, the response of the model economy under the more prudent *policy B*. When the government saves all the oil revenue in a sovereign wealth fund and invests each period the return of the fund plus a small additional fraction, the economy displays a much milder and more prolonged expansion. Because the majority of the revenue from oil exports is saved, the trade balance improves substantially. Such a policy effectively insulates the economy from the volatility of oil prices. This is related to the finding in Pieschacón (2012) that an oil price shock does not generate a boom in Norway. Not surprisingly, Norway saves part of its oil revenue in a sovereign wealth fund. The key message of figure 3 is that the Mexican government could protect its economy from oil price volatility by saving more and spending less of its oil revenue. Mexico has struggled to design stabilizing fiscal institutions. Villafuerte, López-Murphy, and Ossowski (2013, pp. 158-60) suggest legislation in the 2000s has contributed to a procyclical fiscal policy and has not facilitated the accumulation of oil windfalls in funds.

6 Concluding Remarks

This paper has shown that government investment is an important mechanism through which fiscal policy can transmit oil price shocks to the business cycle in oil-exporting countries. Focusing on Mexico, an oil exporter with a budget that is highly dependent on oil revenue, I used a vector autoregression (VAR) to document the response of key macroeconomic variables to an oil price shock. This exercise showed that from 1993:Q1 to 2013:Q3, a shock to the oil price generates an expansion in GDP, private consumption, private investment and, importantly, in government consumption and investment. Government investment peaks at about 6 percent above trend a few quarters after a 12 percent oil price shock hits the economy.

I then used a small-open-economy DSGE model to shed light into how an expansionary response from government investment transmits oil price shocks: the expansion of public capital raises the productivity of private factors of production, triggering a boom. I also used the DSGE model to study the effects of an oil price shock under a more prudent policy by which the government saves its oil revenue in a sovereign wealth fund and invests each period only the return from the fund plus a small additional fraction. As expected, this policy produces a much milder and more long-lasting expansion, effectively insulating the economy from the volatility of oil prices.

The results of the paper carry important implications for the formulation of fiscal policy in oil-exporting countries. These countries could prevent large swings in economic activity by saving oil windfalls and investing them gradually. Of course, this is easier said than done. As authors such as Alesina, Campante, and Tabellini (2008) have argued, there are strong political economy considerations that prevent developing countries from implementing sound fiscal policies. Nevertheless, once countries pass the political hurdle, they can greatly benefit from the theory and evidence on the effects of fiscal policy on the business cycle.¹⁴

¹⁴Frankel (2013) discusses the case of Chile, a copper producer that has managed to insulate its economy from the volatility of copper prices.

The paper has several limitations that I plan to address in future research. Perhaps the most important is related to the distinction between tradable and nontradable production, in both the empirical and theoretical aspects. This consideration would facilitate the study of the Dutch disease in Mexico. More importantly, it would make it possible to study how a more prudent response from government investment would mitigate the Dutch disease effect of oil price shocks. A limitation of the DSGE model is that it is too simple to capture several features of the data. As it stands, it delivers an expansion in response to oil price shocks that is much too persistent. This could be addressed by incorporating rigidities that have been proposed in the literature and would accelerate the return of public capital to its steady state after oil price shocks hit the model economy. Addressing these limitations would improve this framework's ability to serve as a tool for macroeconomic policy analysis in small open economies.

References

- Alesina, Alberto, Filipe R. Campante, and Guido Tabellini (2008), "Why is Fiscal Policy Often Procyclical?" *Journal of the European Economic Association*, 6, 1006–1036.
- Arezki, Rabah and Kareem Ismail (2013), "Boom-Bust Cycle, Asymmetrical Fiscal Response and the Dutch Disease." *Journal of Development Economics*, 101, 256–267.
- Berg, Andrew, Rafael Portillo, Shu-Chun S. Yang, and Luis-Felipe Zanna (2013), "Public Investment in Resource-Abundant Developing Countries." *IMF Economic Review*, 61, 92–129.
- Corden, W. Max and J. Peter Neary (1982), "Booming Sector and De-Industrialisation in a Small Open Economy." *The Economic Journal*, 92, 825–848.
- Correia, Isabel, João Neves, and Sergio Rebelo (1995), "Business Cycles in a Small Open Economy." *European Economic Review*, 39, 1089–1113.
- Daude, Christian, Ángel Melguizo, and Alejandro Neut (2010), "Fiscal Policy in Latin America: Countercyclical and Sustainable at Last?" OECD Development Centre Working Paper 291.
- Frankel, Jeffrey (2013), "A Solution to Fiscal Procyclicality: the Structural Budget Institutions Pioneered by Chile." In *Fiscal Policy and Macroeconomic Performance* (Luis Felipe Céspedes and Jordi Galí, eds.), 323–391, Central Bank of Chile, Santiago, Chile.

- Greenwood, Jeremy, Zvi Hercowitz, and Gregory W. Huffman (1988), “Investment, Capacity Utilization, and the Real Business Cycle.” *American Economic Review*, 78, 402–17.
- Hamilton, James D. (1994), *Time Series Analysis*. Princeton University Press.
- Izquierdo, Alejandro, Randall Romero, and Ernesto Talvi (2008), “Booms and Busts in Latin America: The Role of External Factors.” Inter-American Development Bank Research Department Working Paper 631.
- Leeper, Eric M., Todd B. Walker, and Shu-Chun S. Yang (2010), “Government Investment and Fiscal Stimulus.” *Journal of Monetary Economics*, 57, 1000–1012.
- Lim, G.C. and Paul D. McNelis (2008), *Computational Macroeconomics for the Open Economy*. The MIT Press.
- Osterholm, Par and Jeromin Zettelmeyer (2008), “The Effect of External Conditions on Growth in Latin America.” *IMF Staff Papers*, 55, 595–623.
- Pieschacón, Anamaría (2012), “The Value of Fiscal Discipline for Oil-Exporting Countries.” *Journal of Monetary Economics*, 59, 250–268.
- Schmitt-Grohé, Stephanie and Martín Uribe (2003), “Closing Small Open Economy Models.” *Journal of International Economics*, 61, 163–185.
- Schmitt-Grohé, Stephanie and Martín Uribe (2014), *Open Economy Macroeconomics*. Unpublished book manuscript.
- Végh, Carlos and Guillermo Vuletin (2012), “How is Tax Policy Conducted over the Business Cycle?” NBER Working Paper 17753.
- Villafuerte, Mauricio, Pablo López-Murphy, and Rolando Ossowski (2013), “Riding the Roller Coaster: Fiscal Policies of Nonrenewable Resource Exporters in Latin America and the Caribbean.” In *Fiscal Policy and Macroeconomic Performance* (Luis Felipe Céspedes and Jordi Galí, eds.), 117–173, Central Bank of Chile, Santiago, Chile.

Appendix

A Data Sources