Oil Price Shocks, Government Revenues, and Public Investment: The Case of Ecuador

Igor E. Díaz-Kovalenko[a], José L. Torres[b]

[a]*Faculty of Social Sciences, Commercial Education and Law, State University of Milagro, Ecuador*
[b]*Department of Economics, University of Malaga, Campus El Ejido s/n 29013, Malaga, Spain*

Abstract

This paper studies the macroeconomic consequences of oil price shocks for small oil-exporting countries as a function of the adopted specific fiscal policy rule related to oil revenues. We focus on the particular case of Ecuador, where a large fraction of government revenues depends on oil revenues and where a fiscal policy rule implemented in 2008 establishes that public investment is a function of oil revenues. The paper develops a simple two-sector model featuring some key characteristics of the Ecuadorian economy to study the effects of international oil price shocks on macroeconomic volatility and welfare. The paper investigates alternative simple and easy practical implementation of fiscal rules related to oil revenues and compares their effects on economic activity and welfare to the existing rule. We argue that a slight modification of the current fiscal rule, by linking public investment to all government revenues and not only to oil revenues, would significantly reduce the volatility of the Ecuadorian economy and cut the welfare cost of oil price shocks.

Keywords: Oil-exporting countries; Oil price shocks; Oil windfalls; Oil revenues fiscal rules; Public investment.

⋆Corresponding author: José L. Torres. e-mail: jtorres@uma.es. ORCID: 0000-0002-7469-5656.

1. Introduction

Oil price volatility has important macroeconomic consequences for both oil-importing and oil-exporting countries. Traditionally, it has been observed that in oil-importing countries, real output growth, employment, and inflation are very sensitive to fluctuation in the world price of oil; in these economies oil fuel represents a significant fraction of total energy consumption.[1] On the other hand, rich endowment of commodity resources can have both positive and negative consequences for the economy, particularly in relatively small countries.[2] Oil-exporting countries face a budget dependency on price shocks in international markets causing oil revenue windfalls, which are one source of procyclicality in fiscal policy and macroeconomic fluctuations. This is particularly important in small developing oil-exporting countries, where the public budget depends heavily on oil revenues, and the way in which oil windfalls are managed is a key transmission mechanism of oil price fluctuations (Mehara and Oskouri, 2007; Villafuerte et al., 2010; Erbil, 2011; Pieschacón, 2012; Arezki and Ismail, 2013; Hou et al., 2016; García-Albán et al., 2021). Importantly, the transmission mechanism from oil price shocks to the rest of the economy depends on how oil windfalls are managed by the government. Fiscal rules related to oil revenues and oil funds have been established by several oil exporting countries with two main objectives: saving a fraction of oil revenues for future generations and macroeconomic stabilization.

A number of works have studied the implications of alternative fiscal policies in commodity producing countries, focusing on the experiences of Norway, Chile, and Mexico, studying the effects of price fluctuations of international commodities on macroeconomic volatility and fiscal policy procyclicality (Schmitt-Grohé and Urible, 2007; García et al., 2011; Pieschacón, 2012; Kumhof and Laxton, 2013; Snudden, 2016). Talvi and Végh (2005) study a sample of 56 countries (both developed and developing) and find that whereas fiscal policy in the G7 countries appears to

[1]See, for instance, Barsky and Kilian (2004), Blanchard and Gali (2007), Kilian (2008), and Balke and Brown (2018).

[2]Natural resources can be a source of income and economic growth but also the opposite. This second phenomenon has been named by the literature as the resource curse, the paradox of plenty, or the Dutch disease (Corden and Neary, 1982; Arezki and Ismail, 2003, Mehara, 2009). Sach and Warner (1995) prove that economies with abundant natural resources have tended to grow less rapidly than those with scarce natural resources during the 1970s and 1980s.

be acyclical, fiscal policy is found to be procyclical in developing countries, mostly in economies with rich endowments of commodities. Frankel (2011) shows that procyclical fiscal policies have been a general problem in Latin American commodity-exporting countries. He studies the case of Chile, an economy very sensitive to fluctuations in the international price of cooper, where fiscal policy has been governed since 2000 by a structural budget rule that has succeeded in implementing countercyclical fiscal policies. Guerra-Salas (2014) studies the case of Mexico and compares a policy where the government consumes and invests all oil windfalls with a prudent policy based on a sovereign fund. He finds that a positive oil price shock generates an expansion in consumption and investment and that the prudent policy can isolate the economy from oil price volatility. Pieschacón (2012) demonstrates that fiscal policy design in oil-exporting countries is key in the transmission mechanism of oil price shocks to the economy, propagating or isolating the economy from oil price volatility. She compares fiscal policy in two oil-exporting countries, Mexico and Norway, with different fiscal policy schemes related to oil revenues, resulting in different outcomes depending on the scheme adopted for managing the oil revenues. Berg et al. (2013) study the role of fiscal policies in commodities exporting developing countries, comparing a public investment fiscal rule with a sovereign wealth fund in managing windfalls from exporting of resources. In particular, they study the cases of Angola and the CEMAC region (Central Africa Economic and Monetary Community), proposing a sustainable investing policy as a combination of investment with a resource fund to gain macroeconomic stability and accelerate economic development. Bergholt et al. (2019) quantify the importance of oil price shocks for Norway and find that oil price fluctuations are an important source of macroeconomic volatility and that the domestic oil industry supply chain is an important transmission mechanism for oil price movements. The fact that Norwegian fiscal authorities accumulate oil income in a sovereign wealth fund implies substantial protection against oil price shocks.

This paper studies the implications of oil price shocks for oil-exporting countries as a function of fiscal policy related to oil revenues, focusing on the case of Ecuador. Ecuador is an oil-producing economy featuring some particular characteristics that closely link the oil sector to the fiscal policy. The paper quantifies the impact on macroeconomic volatility and welfare from the fiscal policy related to oil revenues implemented by Ecuador, and contributes to the literature by comparing alternative rules for fiscal policy related to oil revenues and their implications for the transmission mechanism of oil price volatility in oil-exporting countries to macroeconomic fluctuations and welfare. While many oil-exporting countries (e.g., Mexico, Norway, and Middle Eastern countries) have adopted a wide range of public funds designed to stabilize the economy against oil price fluctuations, in the case of Ecuador this type of instrument was discarded due to an urgent need of the government to foster economic growth with expansive fiscal policies. Since 1998, a number of oil fund programs have been successively created in Ecuador for specific uses of oil revenues with little success. Generally, the creation of these oil programs was followed by a series of new fiscal rules, mainly aimed at controlling the fiscal deficit by introducing limitations on primary expenditure growth. The purpose of these funds was mainly to finance priority infrastructure, education and health projects, and they were also used to purchase public external debt. Nevertheless, with the 2008 Constitution and due to the excessive fiscal rigidity of the country, all oil funds were eliminated by means of the Law for the Recovery of the Public Use of the State's Oil Resources and Administrative Rationalization of the Indebtedness Processes. This new law establishes that all public resources coming from oil must enter the general budget as capital revenues and must be solely and exclusively used for investment purposes. This fiscal rule introduces a new transmission mechanism from oil price shocks to capital accumulation, as public investment is constrained by oil revenues. All these factors have contributed over time to increasing macroeconomic fluctuations and an excessive dependency of capital formation on the international oil barrel price.

First, we study the effects on the business cycle of an oil price shock given the current fiscal rule related to oil-revenues implemented by Ecuador. A positive oil price shock increases public revenues and, given the oil fiscal rule, also increases public investment. As a consequence, the shock increases total output but generates crowding-out effects on the non-oil sector. We compare the effects of the shock with three alternative fiscal rules: a fiscal rule where public investment is a function of total government revenues, a second fiscal rule where public investment is a function of permanent oil revenues, and a third fiscal rule where oil windfalls are not included in the public budget but accumulated into a fund. These alternative fiscal rules related to oil revenues only require a slight change to the current fiscal rule where public investment is a function of oil revenues. We find that the transmission mechanism from oil price shocks to macroeconomic fluctuations changes dramatically depending on the particular oil revenues fiscal rule. The model is simulated and some moments are used to investigate how oil price shocks generate volatility in the economy depending on the fiscal rule. We find that with the three proposed alternative rules, the transmission mechanism is significantly damped and macroeconomic fluctuations are significantly reduced compared to the current fiscal rule. Finally, we evaluate the welfare consequences of oil price shocks depending on the oil revenues fiscal rule implemented by the government. Welfare losses due to oil price fluctuations are high with the current fiscal rule. We show that the adoption of any of the three alternative fiscal rules, considerably reduces the welfare losses due to oil price shocks.

The structure of the rest of the paper is as follows. Section 2 presents a simple dynamic stochastic general equilibrium (DSGE) model describing the key features of the economy of Ecuador. Section 3 calibrates the parameters of the model according to key ratios for the Ecuadorian economy. Section 4 uses the calibrated model to assess the effects of a world oil price shock. Section 5 studies the transmission mechanism of an oil price shock depending on alternative fiscal rules related to oil revenues. Section 6 evaluates welfare under the alternative fiscal rules. Finally, Section 7 concludes.

2. A two-sector model for the Ecuadorian economy

We build a simple real business cycle-type DSGE model featuring some key characteristics of the economy of Ecuador: the existence of a state-owned oil production sector, where oil exploitation, extraction and export are done by the government with a technology using public capital and labor, a fiscal rule linking public investment to oil revenues, and no monetary policy. The model economy considers two sectors: a privately managed non-oil sector and a publicly managed oil sector. Non-oil sector technology uses labor, private capital and non-oil public capital as inputs. Labor and public capital inputs are distributed across the two sectors. The economy is populated by a representative household that has preferences regarding consumption and leisure. The government finances lump-sum transfers by collecting taxes and public investment using oil revenues. Finally, there is no monetary policy nor exchange rate changes as Ecuador has de facto no currency, and has instead been a dollarized economy since 2000.

2.1. Households

We consider an economy inhabited by an infinity-lived household. Households' maximize the expected discounted inter-temporal utility function defined over consumption, $\{C_t\}_{t=0}^{\infty}$, and labor, $\{L_t\}_{t=0}^{\infty}$. The following utility function accommodates these preferences,

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\log C_t - \phi \frac{L_t^{1+1/\upsilon}}{1 + 1/\upsilon} \right] \tag{1}$$

where β is the discount factor, E_0 is the conditional expectation operator evaluated at time 0, υ is the Frisch labor elasticity parameter, and $\phi > 0$ is a parameter representing the relative preference for leisure over consumption (household' willingness to work). Total labor is split between the two sectors: non-oil sector labor, $L_{s,t}$, and oil sector labor, $L_{o,t}$,

$$L_t = L_{s,t} + L_{o,t} \tag{2}$$

By renting labor and physical capital to the firms in the non-oil sector, households get labor and capital income. Additionally, they obtain labor income for devoting hours to the oil sector. The budget constraint is given by:

$$(1 + \tau_t^c)C_t + I_{s,t} = (1 - \tau_t^l)W_{s,t}L_{s,t} + (1 - \tau_t^l)W_{o,t}L_{o,t} + (1 - \tau_t^k)R_t K_{s,t} + Tr_t + (1 - \tau_t^\pi)\Pi_{s,t} \tag{3}$$

where $I_{s,t}$ denotes private investment, $K_{s,t}$ is the capital stock in the non-oil sector, $W_{s,t}$, and $W_{o,t}$ are the wages in the non-oil and oil sectors, respectively, R_t is the rental price of private capital, Tr_t is a lump-sum transfers, and $\Pi_{s,t}$ represents profits from the non-oil firms. The model includes four taxes: the consumption tax, τ_t^c, the labor income tax, τ_t^l, the capital income tax, τ_t^k, and a profits tax, τ_t^π. Private physical capital stock holdings evolve according to the following law of motion,

$$K_{s,t+1} = (1 - \delta_s)\, K_{s,t} + I_{s,t} \tag{4}$$

where $0 < \delta_s < 1$ is the fixed depreciation rate of physical capital in the non-oil sector.

Households maximize expression (1) subject to (2), (3), and (4). From the first order conditions, we obtain the following equilibrium conditions for labor supply and optimal investment choices,

$$\phi L_t^{1/\upsilon}(1+\tau_t^c)C_t = (1-\tau_t^l)W_{s,t} \tag{5}$$

$$\phi L_t^{1/\upsilon}(1+\tau_t^c)C_t = (1-\tau_t^l)W_{o,t} \tag{6}$$

$$\frac{(1+\tau_{t+1}^c)E_t C_{t+1}}{(1+\tau_t^c)C_t} = \beta E_t\left[(1-\tau_t^k)R_{t+1} + 1 - \delta_s\right] \tag{7}$$

Equilibrium conditions (5), (6) and (7) are necessary conditions for an optimal solution. Equation (5) is the optimal labor supply in the non-oil sector, equation (6) is the equivalent optimal condition for the oil sector, and equilibrium condition (7) is the optimal consumption path (Euler equation for the accumulation of private capital). These conditions, along with the accumulation equations, technology, resource constraint and transversality conditions, fully characterize the equilibrium of the model, given the price of productive factors, and taxes. Combining equilibrium conditions (5) and (6), we find that the household supply working time to each sector until $W_{s,t} = W_{o,t}$.

2.2. Non-oil sector firms

For simplicity, we assume a competitive environment for the non-oil sector. The problem for the firm is to find optimal values for the utilization of labor and capital given the technology. The production of final output, $Y_{s,t}$, requires labor services, $L_{s,t}$, private capital, $K_{s,t}$, and public capital, $K_{gs,t}$. The firm rents capital and hires labor from households and maximizes period-by-period profits, taking factor prices and public inputs as given. The technology exhibits a constant return to scale; hence the profits are positive equilibrium, as firms do not pay the cost of use of public capital. The Cobb-Douglas technology used by the firm is:

$$Y_{s,t} = A_t K_{s,t}^{\alpha} K_{gs,t}^{\gamma} L_{s,t}^{1-\alpha-\gamma} \tag{8}$$

where α is the capital share of output, γ is the output-public capital elasticity, and A_t is a measure of aggregate productivity. The problem for the firm is to maximize period-by-period profits:

$$\Pi_{s,t} = A_t K_{s,t}^{\alpha} K_{gs,t}^{\gamma} L_{s,t}^{1-\alpha-\gamma} - W_{s,t}L_{s,t} - R_t K_{s,t} \tag{9}$$

From the profit maximization problem we obtain the following two first order conditions:

$$W_{s,t} = (1 - \alpha - \gamma) A_t K_{s,t}^{\alpha} K_{gs,t}^{\gamma} L_{s,t}^{1-\alpha-\gamma} \tag{10}$$

$$R_t = \alpha A_t K_{s,t}^{\alpha-1} K_{gs,t}^{\gamma} L_{s,t}^{1-\alpha-\gamma} \tag{11}$$

Therefore, profits are positive and given by contribution of public capital to output,

$$\Pi_{s,t} = \gamma Y_{s,t} \tag{12}$$

The technology in the non-oil sector is assumed to follow a stochastic process given by,

$$\log A_t = (1 - \rho_A) \log A + \rho_A \log A_{t-1} + \varepsilon_t^A \tag{13}$$

where A is the steady-state value of the non-oil technology, ρ_A the persistence of the shock, and $\varepsilon_{A,t} \sim N(0, \sigma_A^2)$, is an independently and identically distributed random variable.

2.3. Oil sector

The oil sector is ownership by the government, and hence, all capital input used in oil production is provided by the government. The oil production function use a combination of labor and public capital into a Cobb-Douglas type production function,

$$Y_{o,t} = B_t K_{go,t}^{\eta} L_{o,t}^{1-\eta} \tag{14}$$

where η $(0 < \eta < 1)$ represents the oil output to oil capital elasticity, and B_t is a measure of aggregate productivity in the oil production. Profits for the oil-producing firm is defined as,

$$\Pi_{o,t} = P_{o,t} Y_{o,t} - W_{o,t} L_{o,t} \tag{15}$$

where $P_{o,t}$ is the price of oil and where the only production cost is labor cost. Contribution to oil production by capital is costless and transformed into profits. The oil sector firm maximize profits subject to the technological restriction. From this profit maximization process, we find that equilibrium wages in the oil sector is given by,

$$W_{o,t} = (1 - \eta) P_{o,t} B_t K_{go,t}^{\eta} L_{o,t}^{-\eta} \tag{16}$$

As the oil production firm uses public capital at no cost, profits are given by,

$$\Pi_{o,t} = \eta P_{o,t} Y_{o,t} \tag{17}$$

The technology in the oil sector is assumed to follow a similar stochastic process as in the non-oil sector, that is,

$$\log B_t = (1 - \rho_B) \log B + \rho_B \log B_{t-1} + \varepsilon_t^B \tag{18}$$

where B is the steady-state value of the oil technology, ρ_B the persistence of the shock, and $\varepsilon_{B,t} \sim N(0, \sigma_B^2)$ is an independently and identically distributed random variable. Finally, the price of oil is exogenously given to the economy. Ecuador is a small economy and its oil production is relative small to world oil production. Hence, oil production fluctuations in Ecuador has no impact on the world oil price. As it is standard in the literature, we assume that oil price follows a first order auto regressive process AR(1) as follows:

$$\log P_{o,t} = (1 - \rho_o) \log P_o + \rho_o \log P_{o,t-1} + \varepsilon_t^o \tag{19}$$

where $P_{o,t}$ is the steady-state value of oil price, ρ_o the persistence of the shock, and $\varepsilon_{o,t} \sim N(0, \sigma_o^2)$ is a stochastic component.

2.4. The Government

The government has an active role in the economy apart from taxing and spending, as the oil sector is public-owned. Public revenues comes from two sources: taxes and oil export revenues. Indeed, there are two separate government budgets, one of them specific to the oil sector. Total government revenues are defined as:

$$F_t = \tau_t^c C_t + \tau_t^l (W_{s,t} L_{s,t} + W_{o,t} L_{o,t}) + \tau_t^k R_t K_{s,t} + \tau_t^\pi \Pi_{s,t} + \Pi_{o,t} \tag{20}$$

where $\Pi_{o,t}$ are profits from the oil sector (oil revenues). On the expenditure side we consider two components: lump-sum transfers to the households, and public investment, $I_{g,t}$

$$G_t = Tr_t + I_{g,t} \tag{21}$$

imposing the following two additional restrictions according to the oil revenues-related fiscal rule used by the government:

$$T_t = \tau_t^c C_t + \tau_t^l (W_{s,t} L_{s,t} + W_{o,t} L_{o,t}) + \tau_t^k R_t K_{s,t} + \tau_t^\pi \Pi_{s,t} \quad (22)$$

$$I_{g,t} = \Pi_{o,t} \quad (23)$$

where T_t account for tax revenues, and where public investment is equal to oil revenues.

Given fiscal rules in the Ecuadorian economy, we assume that public budget is in equilibrium period-by-period. This balanced fiscal rule has been followed by the Ecuadorian fiscal authorities during the last decade, provoking dramatic changes in the public budget year to year. This is equivalent to assume that public deficit does not change in response to oil price shocks and instead government spending adjust to the new level of public revenues where oil windfalls are incorporated. The fiscal rule introduces a new transmission mechanism from oil price shocks to capital accumulation, as public investment is constrained by oil revenues.

Public investment transforms into public capital stock that is used as an input in both sectors, $I_{g,t} = I_{gs,t} + I_{go,t}$, according to the following law of motions:

$$K_{gs,t+1} = (1 - \delta_{gs}) K_{gs,t} + I_{gs,t} \quad (24)$$

$$K_{go,t+1} = (1 - \delta_{go}) K_{go,t} + I_{go,t} \quad (25)$$

where $K_{gs,t}$ is public capital in the non-oil sector and $K_{go,t}$ is public capital in the oil sector. Public investment is split between the two sectors according to the following exogenous rule:

$$I_{gs,t} = \theta I_{g,t} \quad (26)$$

$$I_{go,t} = (1 - \theta) I_{g,t} \quad (27)$$

where θ $(0 < \theta < 1)$ is the fraction of public investment allocated in the non-oil sector.

3. Calibration of the model

This section carefully calibrates the parameters of the model to a number of targets for the Ecuadorian economy, using data from the Central Bank of Ecuador, the World Bank, and the Penn

World Table. We use data starting in 2000, mostly due to restrictions on data availability and to the fact that the Ecuadorian economy was subject to a structural change in 1999 with a dollarization process, and the de facto loss of monetary policy and the adoption of a fixed exchange rate with the US. The baseline parameters values are shown in Table 1.

Table 1: Calibration of the parameters

Parameter	**Definition**	**Value**
β	Discount factor	0.99
ϕ	Willingness to work	6.54
υ	Frisch elasticity	0.72
α	Non-oil output-capital elasticity	0.35
γ	Non-oil output-public capital elasticity	0.10
η	Oil output-public capital elasticity	0.833
δ_s	Non-oil capital depreciation rate	0.03
δ_{gs}	Non-oil public capital depreciation rate	0.025
δ_{go}	Oil public capital depreciation rate	0.035
θ	Public investment fraction non-oil sector	0.8525
ρ_o	Persistence of shock to oil price	0.92
ρ_A	Persistence of shock to TFP in the non-oil sector	0.95
ρ_B	Persistence of shock to TFP in the oil sector	0.95
τ^c	Consumption tax rate	0.12
τ^k	Capital income tax rate	0.25
τ^l	Labor income tax rate	0.122
τ^π	Profits tax rate	0.25
P_o	Oil barrel price	0.56
σ_o	Deviation oil price	0.16
σ_A	Deviation TFP non-oil sector	0.01
σ_B	Deviation TFP oil sector	0.01

First, we use data for oil revenues as a fraction of GDP, Π_o/Y, as a target for the calibration of the technological parameters for oil capital in the oil production function. In the particular case of Ecuador, oil export revenues are a significant fraction of total exports (32%), total public revenues (28%), and account for about 12% of GDP. According to World Bank data, average public revenue from oil production as a percentage of GDP was 0.0996 in Ecuador for the period 1980-2017. This figure fluctuates year to year mainly depending on international oil prices, and is calculated as total revenues minus the production cost of oil as a percentage of GDP. On the other hand, oil output represents around 12% of total GDP in Ecuador. Using these figures, we find that $\eta = 0.0996/0.12 = 0.833$. This result in a high value for the elasticity of oil capital to oil production, indicating that 83.3% of total oil income correspond to capital, whereas the remaining 16,7% corresponds to labor, given the assumed Cobb-Douglas production function. The labor share is calculated using data from the Penn World Table, as the average for the period 2000-2019, resulting a value of 0.55. Hence, for the non-oil sector, the elasticity of output with respect to private capital is fixed to $\alpha = 0.35$, whereas the elasticity of output with respect to public capital elasticity is fixed to $\gamma = 0.1$. The household's discount factor, β is fixed to 0.99, which corresponds to an annual interest rate of around 4%. The public investment $I_g = (\Pi_o/Y) = 0.1$ and the proportion of public investment allocated to the non-oil sector is given by the parameter $\theta = 0.8525$.

The parameters driving labor supply are fixed as follows. First, for the Frisch elasticity of labor supply, υ, we use a value of 0.72 as proposed by Heathcote et al., (2010). Given this value, we use the fact that the average number of hours worked for the period 1995-2016 is 1,815 hours as a target. Assuming a total available time of 5,000 hours per year (considering 6 working days per week and a total of 16 hours available each day), the fraction of working hours over total hours is 0.363. Given this target, the willingness to work parameter is chosen internally just to produce that figure, resulting in a calibrated value for the parameter ϕ of 6.54. Depreciation rates are fixed at δ_s =0.03 for private capital, δ_{gs} =0.025 for public capital in the non-oil sector, and δ_{go} =0.035 for public capital in the oil sector.

For the parameters denoting tax rates $\tau^c, \tau^l, \tau^k, \tau^\Pi$ we use values which are consistent with the Ecuadorian Law known as the Internal Tax Regime (LORTI). The parameters for the oil price autoregressive process have been estimated using historical oil prices for the West Intermediate

Texas oil, resulting in an autoregressive parameter of $\rho_0 = 0.92$, and $\sigma_o = 0.16$. Autoregressive processes of aggregate productivity parameters are calibrated using standard values in the literature. The value of the steady-state oil price P_o was calculate as $P_o = \Pi_o/(\eta Y)$. Finally, steady-state values for A and B are normalized to 1.

4. Quantitative simulations: Oil price shock

The calibrated model is simulated to study the consequences of a positive oil price shock on the economy in the current scenario, given the fiscal rule implemented by Ecuador that links public investment to oil revenues. How this shock is transmitted to the whole economy, depends on how the government manages the additional oil revenues and how they affect the government budget. García-Albán et al. (2021) estimate a structural autoregressive model to study the effects of fiscal policy and oil revenues shocks in the Ecuadorian economy, and find that oil revenues shocks have been the most important force driving output growth.

Figure 1 plots the impulse-response of key variables of the model to a positive (one standard deviation) oil price shock under the fiscal rule implemented by Ecuador from the year 2008. As expected an international rise in the price of oil leads to an instantaneous increase in government oil revenue, which is fully expended in public capital formation. A fraction of this additional oil revenue is expended in public capital in the oil producing sector, while the remaining is transformed into public capital to be used by firms in the non-oil sector. This creates two channels of transmission of the shock to the economy. The first channel results from the higher capital input in the oil sector, leading to an instantaneous expansion of oil production. The second channel results from the higher level of public capital used in non-oil production activities, which increases the profits of private firms. However, the fiscal policy produces a crowding out effect on private activities. This crowding out effect is observed in both private investment and labor. The rise in public investment is accompanied by a decline in private investment during some periods, although after some time the response turns out to be positive, expanding private investment and hence, increasing private capital stock. On the other hand, the increase in working hours in the oil sector is accompanied by a decline in working hours in the rest of the economy, although total working hours remain almost constant.

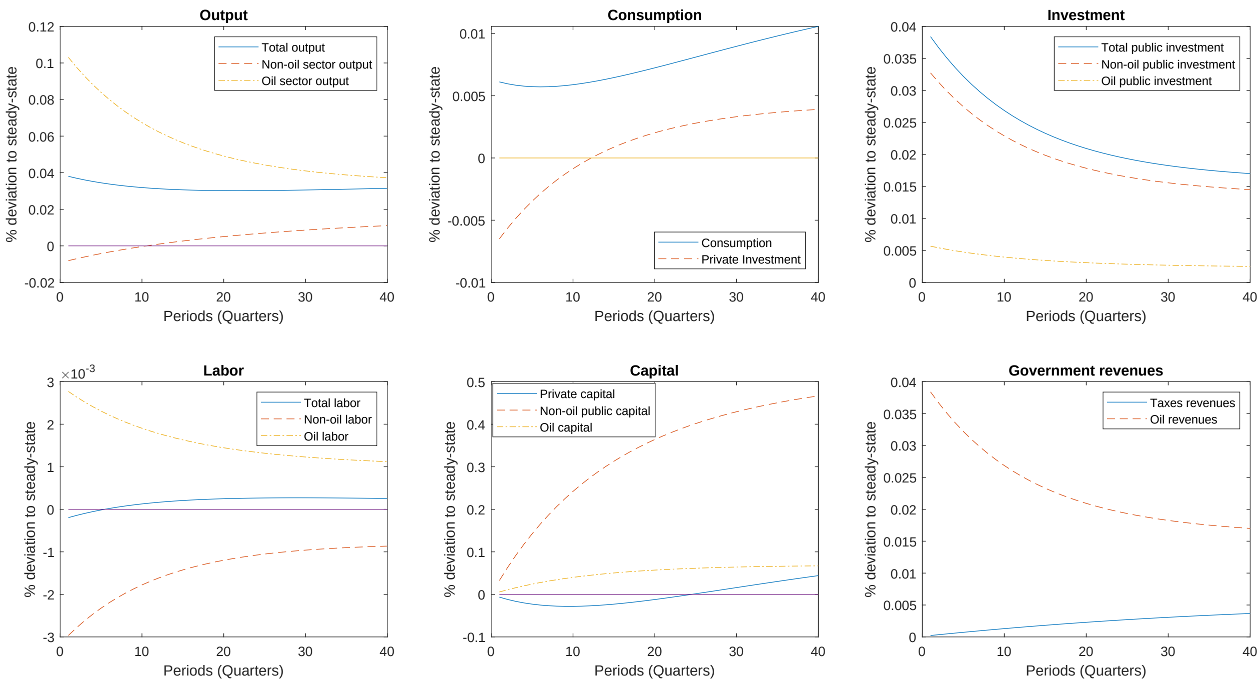

Figure 1: Impulse-response functions to a positive oil price shock.

The initial crowding out effect of fiscal policy has a negative impact on private output, although the total output of the economy expands thank to the increase in oil production. However, we observe a negative effect on private output in the first ten quarters, which becomes an expansion of private output in the following periods. Consumption expands mainly due to the crowding out effect that reduce private investment during the first quarters after the shock, where the substitution effect predominates. However, after some time, the income effect takes over, causing consumption to expand further. The expansion of the economy leads to a rise in taxes revenues which contribute to expanding the public budget, along with the higher oil revenues.

Finally, it is observed that the effects of the shock are highly persistent. This high persistence is explained not only by the persistence of the shock, but also by the initial crowding out effect of the shock, by the posterior positive effects once additional public capital has been built, and also by the high persistence induced by the fiscal rule, which causes accumulation of public capital. The fiscal rule related to oil revenues implemented by Ecuador not only directly translates any oil price shock to the economy, but also fosters its persistence through the accumulation of public capital.

5. Rethinking the oil-revenues fiscal rule

Fiscal rules by oil-producing countries can be classified into two types. In the first type, countries implement fiscal rules in which the government budget is a function of oil revenues. In this case, fiscal policy is linked to international oil price fluctuations, and hence, dependent on supply and demand shocks in the oil international market. This is the case for Ecuador and other developing oil producing economies (García-Albán et al. 2021). In the second type, fiscal policy is isolated from fluctuations in oil prices by collecting the oil revenues in an investment fund. This is the case for Norway (see Pieschacón, 2012; Tabarrei et al., 2018; Bergholt et al., 2019, among others).

This section explores alternative fiscal rules related to oil revenues and compares their consequences for the economy to the existing fiscal rule implemented since 2008 in Ecuador. We focus on simple rules that require only slight modifications of the current one and that are easy to implement and politically feasible. The proposed alternative fiscal rules are the following:

5.1. Fiscal rule A

First, we consider a slight modification in the public investment rule implemented by the government. This modification consists in linking public investment not only to oil revenues but to total government revenues, F_t, including both taxes levies and oil revenues. This new fiscal rule is defined as:

$$I_{g,t} = \mu F_t \tag{28}$$

where μ $(0 < \mu < 1)$ is the fraction of total public revenues devoted to public investment. This fiscal rule implies that oil windfalls are proportionally distributed among the different components of public spending, and hence, public investment depends not only on oil revenues, but also on tax revenues. We calibrate this fraction just to keep the public investment ratio constant at the value resulted from the benchmark public investment rule in steady state. Given that under the benchmark fiscal rule, public investment is equal to oil revenues ($\Pi_o = Ig$), which is, on average, a 10% of GDP ($Ig/Y = 0.1$), and given that the ratio of total government revenues to GDP has been

36% on average during the last 10 years, these figures results in a value of $\mu = 0.1/0.36 = 0.277$. This value is relatively high, indicating that close to 28% of total government revenues is devoted to capital formation, leaving the remaining 72% for transfers to households.

5.2. Fiscal rule B

This second alternative fiscal rule consists in linking public investment to permanent oil revenues. Oil revenues can be decomposed into a permanent component and a transitory one,

$$\Pi_{o,t} = \Pi_o + \Pi_{shock,t} \tag{29}$$

where Π_o is the long-run oil revenues for the equilibrium oil price, and $\Pi_{shock,t}$ are positive or negative oil windfalls depending on fluctuations in the international oil price. Formally, this fiscal rule can be defined as,

$$I_{g,t} = \Pi_o \tag{30}$$

$$Tr_t = T_t + \Pi_{shock,t} \tag{31}$$

Under this scenario, public investment is constant and equal to oil revenues in the long-run, and is hence isolated from changes in the international oil market. The positive or negative oil windfalls (as the deviation of the long-run value) are incorporated into the public budget and expended as lump-sum transfers to households.

5.3. Fiscal rule C

The last fiscal rule is similar to the previous one except for the fact that oil windfalls are not included in the public budget but accumulated in an investment fund. Formally, this fiscal rule can be defined as,

$$I_{g,t} = \Pi_o \tag{32}$$

$$Tr_t = T_t \tag{33}$$

where transfers are equal to taxes revenues and therefore, current public expenditures are not affected by oil price shocks. Likewise, public investment remains constant over the business cycle.

Figures 2 and 3 plot the impulse-response functions of the key variables following a positive oil price shock under the four alternative fiscal rules. Interestingly, the impulse-responses under fiscal rule A and C are very similar, indicating that both fiscal rules, although of very different nature, lead to a similar response of the economy to an oil price shock. The reason why rule B provokes a different behavior of the economy compared to rule C is that under the former, oil windfalls are included in the lump-sum transfers. Overall, we find that the deviations from equilibrium of the key variables provoked by the shocks are lower under the three alternative fiscal rules compared with the current public investment fiscal rule related to oil revenues.

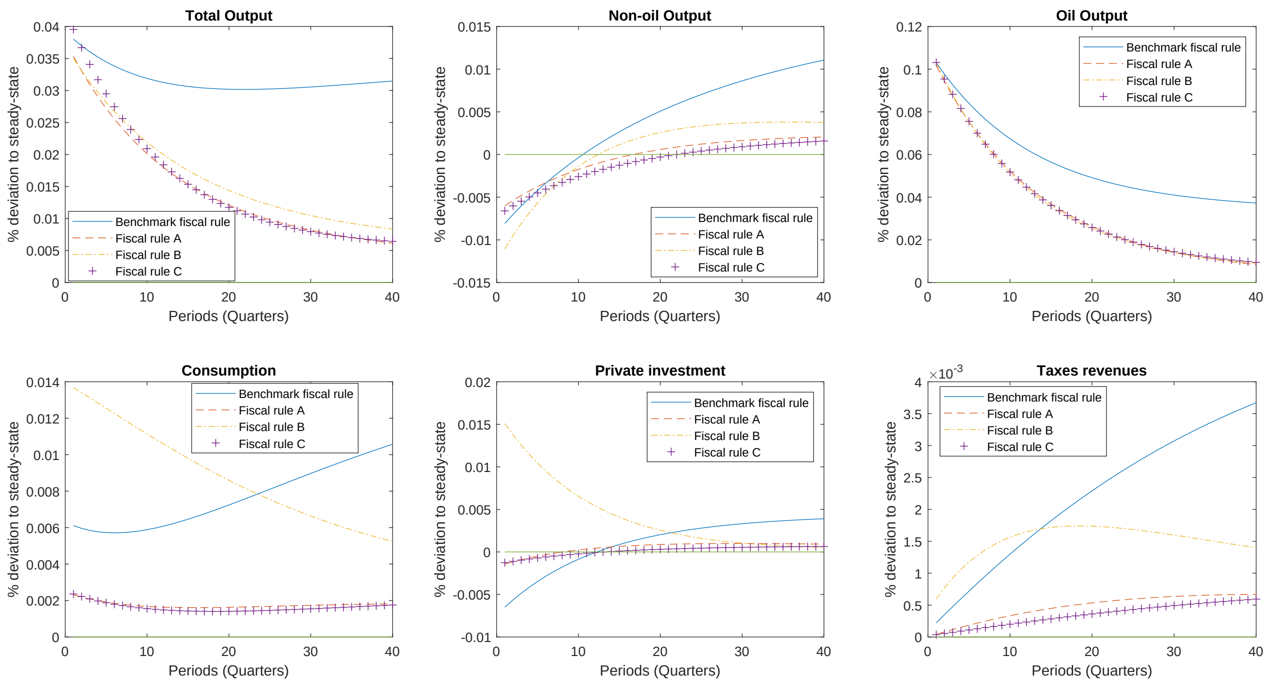

Figure 2: Impulse-response functions to a positive oil price shock under alternative oil revenues-related fiscal rules (I).

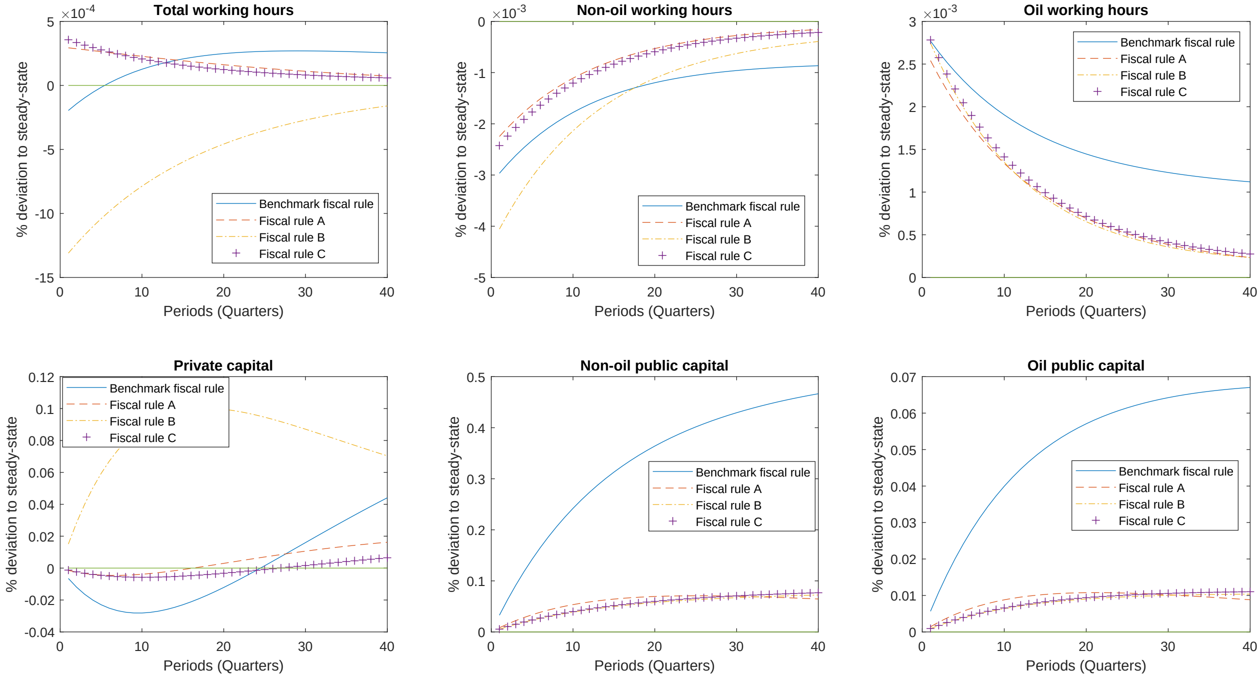

Figure 3: Impulse-response functions to a positive oil price shock under alternative oil revenues-related fiscal rules (II).

Table 2 shows some key moments (standard deviation and correlation to output) for the baseline and the alternative fiscal rules. The output standard deviation in the current scenario is dramatically high. This is a consequence of the high volatility shown by oil prices, volatility that is aggravated by the baseline fiscal rule, which is translated directly to the rest of the economy through the public capital formation process. This baseline fiscal rule not only translates any oil price variation to the rest of the economy and amplifies it, but also increases the persistence of the shock due to the designed public investment rule. Among the alternative fiscal rules proposed, rule A has better performance in terms of stabilization of the economy, reducing the volatility of the total output by a factor of five, the non-oil output by a factor of four, and the oil output and public investment by a factor of around 10. Hence, it is shown that when the oil output revenues are part of the government general budget instead of going directly into investment, the overall volatility of the economy decreased. Rules B and C have similar results each other, with both greatly reducing the volatility of the economy but in a lesser extent than rule A.

Table 2: Simulated moments from the model

	Benchmark rule		Fiscal rule A		Fiscal rule B		Fiscal rule C	
	S.D.	Corr.	S.D.	Corr.	S.D.	Corr.	S.D.	Corr.
Total output	41.69	1.00	7.94	1.00	10.52	1.00	10.67	1.00
Non-oil output	22.67	0.97	5.45	0.54	6.80	0.72	6.76	0.71
Oil output	173.85	0.99	16.41	0.78	33.86	0.84	35.83	0.85
Consumption	27.01	0.99	4.36	0.74	7.73	0.97	6.44	0.87
Private investment	23.52	0.91	10.18	0.57	13.87	0.81	11.13	0.62
Public investment	184.70	0.97	16.99	0.90	33.88	0.84	35.82	0.85
Labor	0.82	0.72	0.82	0.69	1.34	-0.23	0.82	0.58
Non-oil labor	5.91	-0.93	2.09	-0.51	3.53	-0.61	2.35	-0.61
Oil labor	158.10	0.96	52.70	0.74	56.08	0.77	58.78	0.78
Tax revenues	25.67	0.98	4.97	0.70	6.93	0.90	6.72	0.83
Government spending	72.15	0.99	7.04	0.99	13.93	0.92	14.24	0.91

To assess the relative importance of oil price shocks to the Ecuadorian economy under the current and alternative fiscal rules, we simulate the model considering aggregate productivity shocks to each of the two sectors of the economy in addition to the oil price shock. The variance decomposition results for the baseline rule and for the alternative fiscal rules A, B and C are shown in Table 3. It is important to notice how predominant the oil price shock is compared to the productivity shocks in explaining output volatility. This can be specially observed under the effects of the current fiscal rule related to oil revenues in Ecuador. By contrast, the estimated relative importance of oil price shocks in explaining macroeconomic volatility diminishes when the alternative fiscal rules are adopted, in particular, for rule A. Overall, we find that any of the three alternative fiscal rules reduces the volatility of key macroeconomic variables in both the non-oil and the oil sector, and also reduces the volatility of both government revenues and expenditures. Based on all these results, the preferred alternative is fiscal rule A if the objective is to minimize fluctuations due to international oil price shocks.

Table 3: Variance decomposition of shocks

	Benchmark rule			Fiscal rule A			Fiscal rule B			Fiscal rule C		
	ε_o	ε_a	ε_b	ε_o	ε_a	ε_b	ε_o	ε_a	ε_b	ε_o	ε_a	ε_b
Total output	97.93	1.10	0.97	63.53	36.03	0.45	66.85	17.60	15.55	67.83	17.08	15.09
Non-oil output	94.26	4.80	0.94	6.57	93.39	0.05	32.38	56.59	11.03	31.72	57.14	11.14
Oil output	98.82	0.10	1.08	90.33	2.40	7.27	68.55	2.63	28.82	71.91	2.35	25.74
Consumption	97.13	1.91	0.97	11.65	88.25	0.10	63.93	23.93	12.14	48.06	34.36	17.48
Private invest.	83.56	15.61	0.83	3.24	96.73	0.03	43.51	53.64	2.84	12.16	83.42	4.42
Public invest.	98.95	0.09	0.96	94.36	5.00	0.64	68.55	2.63	28.82	71.91	2.35	25.74
Labor	54.09	45.38	0.53	18.49	81.40	0.11	67.51	32.12	0.37	14.94	84.08	0.97
Non-oil labor	96.50	2.57	0.93	80.52	18.93	0.55	89.78	7.52	2.71	76.75	17.10	6.16
Oil labor	98.83	0.22	0.95	98.81	0.54	0.65	90.63	1.79	7.58	91.41	1.64	6.95
Taxes revenues	96.03	3.02	0.96	7.56	92.38	0.06	43.13	43.19	13.67	39.51	45.95	14.55
Public spending	98.82	0.21	0.97	59.21	40.37	0.42	67.98	5.71	26.31	69.39	5.46	25.15

6. The welfare cost of oil price shocks

Fluctuations in economic activity and macroeconomic aggregates cause welfare costs for households. These welfare costs could be even more significant for commodity-exporting developing countries, where international price shocks of commodities enter as an additional source of fluctuations. The question here is how business cycle fluctuation provoked by oil price shocks in combination with fiscal policies related to oil revenues affects welfare. For that, we compare households' utility in a situation with no fluctuations (the steady state), with their utility under a scenario with oil price and productivity shocks and alternative scenarios with fiscal policies related to oil revenues. Utility in the steady state is defined as,

$$\sum_{t=0}^{\infty} \beta^t U(C, L) = \frac{1}{1-\beta} U(C, L) \tag{34}$$

where C, and L represents steady-state values for consumption and labor, respectively. We measure the cost of oil price shocks in consumption equivalent variation, that is, we calculate by how many percentage points we would have to increase or decrease the consumption of a household living in the steady state, without any change in oil prices, so as to make the household as well off as a household living in a world with oil price shocks (scenario denoted by O). We do that by solving the following equation,

$$\frac{1}{1-\beta}U((1+\Delta^O)C, L) = \sum_{t=0}^{\infty}\beta^t U(C_t, L_t; O) \tag{35}$$

where $\Delta^O \lesseqgtr 0$, represents the change (positive or negative) in consumption for each fiscal policy rule related to oil revenues. Using a first-order Taylor expansion of the utility in the new steady state when the change in the fiscal policy rule takes place, the above equations can be written as,

$$U(C, L) + U_C(C, L)C\Delta^O = E_0\sum_{t=0}^{\infty}\beta^t U(C_t, L_t; O) \tag{36}$$

where $U_C(\cdot)$ represents the marginal utility of consumption in the steady-state. From the above expressions, the consumption equivalent variation can be calculated as,

$$\Delta^O \approx \frac{E_0\sum_{t=0}^{\infty}\beta^t U(C_t, L_t; O) - U(C, L)}{U_C(C, L)C} \tag{37}$$

For each fiscal policy rule we simulate the model and calculate the expected level of utility. We do that by calculating the average of all utility levels in each simulated period for the four alternative scenarios. Table 4 summarizes the estimated welfare cost of economic fluctuations depending on the specific fiscal policy rule related to oil revenues implemented by Ecuador. We calculate the welfare cost from an oil price shock and from all shocks for each fiscal rule. Under the current fiscal rule, welfare losses are significant with a welfare loss of 2.84% from oil price volatility with respect to the steady state, and an aggregate loss of 3.63% when all three shocks are considered. By contrast, the three alternative fiscal policy rules related to oil revenues strongly mitigate welfare losses, and even oil price shocks turn out to have no effects on welfare. Considering all three shock, welfare losses are 0.09% for rule A, -0.26% for rule B, and -0.17% for rule C, whereas the welfare losses from the oil price shock are close to zero for the three alternative fiscal rules related to oil revenues.

Table 4: Welfare analysis

Welfare losses (consumption equivalent variation)		
	All shocks	Oil price shock
Baseline Fiscal Policy	-3.6275	-2.8382
Alternative Policy A	-0.0902	0.0061
Alternative Policy B	-0.2628	0.0019
Alternative Policy C	-0.1706	0.0794

7. Conclusions and policy implications

This paper studies the transmission mechanism of oil price shocks to the rest of the economy in a small oil-exporting country depending on the fiscal rule related to oil revenues followed by the government. In particular, the paper focuses in the case of Ecuador, where the oil sector is government-ruled, oil revenues represent a significant fraction of the public budget, and the government implements a oil revenues fiscal rule that closely link public investment to oil revenues, separated from taxes revenues which are used for current spending.

The analysis done in this paper and the results therein have clear policy implications for the design of fiscal policies related to oil revenues in some developing economies where the use of an investment fund such as the scheme used by Norway is controversial and has little room for practical implementation due to institutional factors. We show that the fiscal rules followed by the Ecuadorian fiscal authorities, namely a budget equilibrium year by year, and a public investment rule where public investment is equal to oil revenues, reinforces the transmission mechanism from international oil price shocks to macroeconomic fluctuations, increasing the volatility of key macroeconomic variables and reducing welfare. However, the current scenario of high macroeconomic volatility and welfare cost could be reversed by introducing small and simple changes in the current public investment fiscal rule related to oil revenues.

We propose and evaluate three alternative fiscal rules that are simple and easy to implement practically and their economic consequences for macroeconomic fluctuations and welfare are compared to the current oil revenues-public investment fiscal rule. These alternative fiscal rules decouple public investment from oil windfalls and prove to be effective in reducing macroeconomic volatility provoked by international oil price shocks. The most adequate alternative seems to be a fiscal rule where public investment is a function of total public revenues, including both taxes and oil revenues. This alternative fiscal rule is simple and only requires a slight modification of the current fiscal rule with little political impact, by decoupling public investment from oil windfalls from international oil price fluctuations, as under this alternative rule public investment also depends on tax revenues. If Ecuador were to adopt this alternative fiscal rule, it would mitigate welfare losses due to oil price shocks and substantially reduce the volatility of the business cycle.

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