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Oil Price Effects on Colombia's Central Government Oil Revenues

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MINHACIENDA

Efectos de los precios del petróleo en los ingresos petroleros del Gobierno Nacional Central de Colombia

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Resumen

En este trabajo se estima la magnitud de los ingresos marginales del petróleo en Colombia entre 2002 y 2018. El ingreso marginal es el ingreso adicional para el Gobierno Nacional Central (GNC) cuando los precios del petróleo aumentan en 1 USD, y su relevancia está asociada a las estimaciones del ciclo minero energético de la Regla Fiscal de Colombia. Para ello, utilizamos dos aproximaciones: un análisis basado en un enfoque de hoja de balance y un modelo VAR con parámetros cambiantes en el tiempo y volatilidad estocástica (TVP-VAR-SV). En ambos casos, nuestros hallazgos sugieren que los ingresos marginales del petróleo son asimétricos, no constantes en el tiempo y no lineales. En el primer enfoque, encontramos que ante un aumento/caída de 1 USD en el precio del petróleo se incrementan/reducen los ingresos tributarios en una magnitud de 175 miles de millones de pesos (mm), en promedio, con una mayor magnitud en el efecto cuando los precios caen. En el segundo enfoque, se encuentra que el ingreso marginal es de 129 mm, en promedio, siendo la magnitud de este efecto mayor sobre niveles bajos de precios y menor sobre niveles altos de precios.

Jel Code: E62, H29, C11

Palabras clave: ingreso marginal**,** ingreso petrolero, Regla Fiscal

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Oil Price Effects on Colombia's Central Government Oil Revenues

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Abstract

In this study, we estimate the magnitude of the marginal oil revenues of the Colombian Central Government (CG) from 2002 to 2018. The marginal revenue is the CG's additional income when the oil prices climb by 1 USD, and its relevance is related to the estimations of the mining-energy cycle of the Colombian Fiscal Rule. Moreover, the marginal oil revenues were assessed over time to observe their specific effects when the prices rise or fall. The researchers employed two different approaches: (i) a balance sheet analysis and (ii) a time-varying VAR model with stochastic volatility (TVP-VAR-SV). Both suggested that the marginal oil revenues are asymmetric, nonlinear and non-constant over time. In particular, the findings of the first approach indicate that with an increase/decrease of 1 USD in oil prices, oil tax revenues increase/decrease by 175 COP billion, on average, such a figure being larger when the prices fall, and smaller when they rise. Through the second approach, we find that oil marginal revenue is 129 COP billion, on average, with larger impacts when prices increase on low price levels, in contrast to smaller impacts when prices increase on high price levels.

Jel Code: E62, H29, C11

Key Words: marginal revenue, oil revenue, Fiscal Rule.

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1. Introduction

The objective of this paper is to estimate the magnitude of the marginal oil revenues of the Colombian Central Government (CG) from 2002 to 2018. The marginal revenue is the CG's additional income when the oil prices climb by 1 USD, and its relevance is related to the estimations of the mining-energy cycle of the Colombian Fiscal Rule. The Fiscal Rule is a valuable mechanism to consolidate public financing, prevent macroeconomic volatility and guarantee fiscal sustainability.

Designing and implementing fiscal rules is of great importance within economies that depend largely on commodities for revenue collection. These economies tie their fiscal accounts to the uncertainty of commodity prices countercliclically, thereby decreasing their vulnerability to external price shocks, and protecting their macroeconomic stability in times of downward pricing.

In this vein, to adjust their fiscal programming to the price cycles of commodities, countries like Chile, Nigeria, and Mongolia include in their fiscal rules the prices of their economies' chief commodities. In these countries, the mining or fossil fuel industries explain an important part of their GDP and represent the main export goods. Moreover, their government expenditure displays a pro-cyclical behavior with respect to commodity prices, which increases economic exposure to the trends of natural resources.

Similarly, the Colombian Fiscal Rule seeks to ensure the country's long-term macroeconomic sustainability through a countercyclical fiscal policy. Therefore, it improves the coordination of the fiscal and monetary aspects of economic policymaking, sets boundaries to the fiscal deficit, and includes an oil-price element in the estimation of its mining-energy cycle[1]. Since its implementation in 2012, 15% of the total deficit has come from the oil cycle, which represents nearly 0.5% of the GDP in additional allowed deficit[2].

Given the weight of the oil cycle in the total fiscal deficit, we estimated the magnitude of the CG's marginal oil revenues through two different approaches: (i) a balance-sheet analysis and (ii) a time-varying VAR model with stochastic volatility (TVP-VAR-SV). Both suggested that the marginal oil revenues are asymmetric, nonlinear, and non-constant over time. In particular, the findings indicate that an increase/decrease of 1 USD in the oil prices increases/decreases tax revenues for the CG ranging from 129 COP billion and 175 COP billion, on average, such a figure being larger when the prices fall, and smaller when they

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[1] Also known as "Oil Cycle"

[2] These estimations are based on the values provided by the Ministry of Finance's Fiscal Rule reports to the Congress of the Republic from 2012 to 2017.

rise[3]. Moreover, we found that the impact of an oil-production shock in Colombia on CG's oil tax revenues represents 25% of the magnitude of an oil-price shock.

The rest of the discussion is structured as follows: the second section describes the importance of the mining-energy sector within Colombia's fiscal environment; the third section centers on the balance sheet approach and its results; the fourth and fifth sections, explain, respectively, the econometric methodology and its findings; and the last section provides some closing remarks.

2. The Mining-Energy Sector in Colombia's Fiscal Rule

In Colombia, the oil sector has been an important source of economic growth and external revenues for the CG. Currently, the country is producing, on average, 865 thousand barrels per day (KBPD)[4]- or less than 1% of the global oil production. The sector explains nearly 5% of the country's total GDP, and some 38.8%[5] of its total exports. Consequently, not only is oil production a key driver for economic growth, but it also serves as a mechanism to correct Colombia's current account deficit. Between 2002 and 2018, oil revenues represented, on average, 1.3% of GDP (**Figure 1**), and they explained 9% of the total CG revenues **(Figure 2**). In 2013, this income source amounted to 20% of the total CG revenues; however, by 2016, its share had fallen to 0.9%, forcing the economy to absorb a strong price shock.

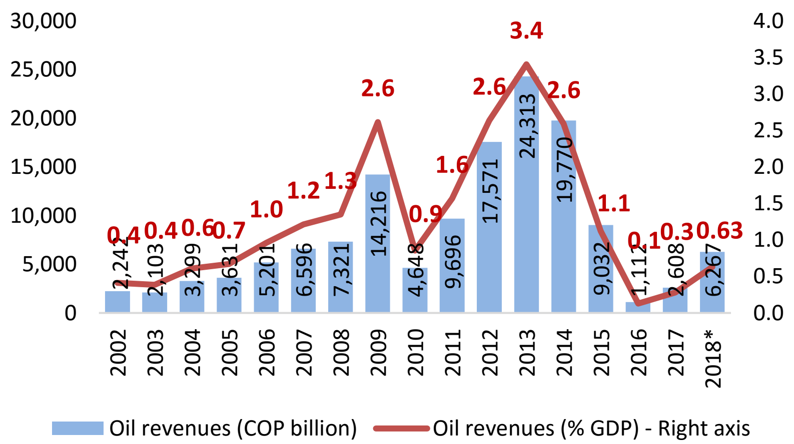

Figure 1. Oil revenues (COP billion & % of GDP). The blue bars represent the CG's total oil revenues in COP billion. The red line represents the CG's total oil revenues as a percentage of Colombia's GDP. Source: DIAN. Ecopetrol. Ministry of Finance estimations.

[3] The income from the oil and mining sector in Colombia includes capital and tax revenues. While the balance sheet approach analyzes both components, the econometric perspective focuses specifically on the tax component.
[4] 2018 average production.
[5] Includes oil and derivatives.

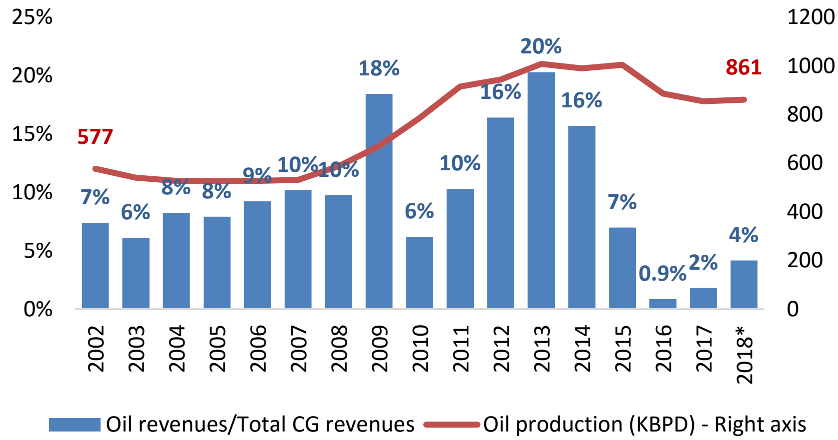

Figure 2. Share of oil revenues in total CG revenues (%) and oil production (KBPD). The blue bars represent the share of oil revenues in total CG revenue. The red line represents the country's annual average of daily oil production. Source: DIAN. Ecopetrol. Ministry of Finance estimations.

Given the importance of the mining-energy sector to Colombia's public finances, in 2012, a Fiscal Rule with a mining-energy component began to be implemented. Such a component was a stabilizing mechanism associated with the volatility of oil prices, which prescribed, from a countercyclical perspective, saving during oil-price booms and spending throughout low-price periods. Consequently, the oil cycle permits a wider fiscal deficit space when the oil spot prices fall below the long-term price; and the same logic applies otherwise, by narrowing the fiscal space when the oil prices exceed their long-term levels.

The oil cycle for the Colombian Fiscal Rule is:

$$Oil\ cycle_t = (P_{t-1} - \bar{P}_{t-1})(Marginal\ Revenue_{t-1})(EXR_{t-1}) \qquad [1]$$

Where:

$$\text{Marginal Revenue}_{\,t-1} = (\text{Revenue}_{t-1}^{\text{Long-term price+1USD}} - \text{Revenue}_{t-1}^{\text{Long-term price}})$$

$$\text{P}_t = \text{Colombian oil spot price}$$

$$\bar{\text{P}}_t = \text{Colombian oil long} - \text{term price}^6$$

$$\text{EXR}_t = \text{Exchange rate (COP for USD)}$$

Hence, the relationship between the oil cycle and the CG's fiscal deficit has several determinants:

[6] The Colombian oil long-term price is estimated as a moving average of order 9, which includes the average of oil prices in the previous 4 years, the expected average of the current year, and the estimated average for the 4 years ahead.

1. $(P_{t-1} - \bar{P}_{t-1})$: If the spot price is above the long-term price, there will be a positive oil cycle, enabling a lower fiscal deficit. If the spot price is below the long-term price, there will be a negative oil cycle, enabling a higher fiscal deficit.
2. $(Marginal\ Revenue_{t-1})$: The marginal revenue, measured in million dollars (MUSD), indicates the additional oil revenues gained if the long-term price level increases by 1 USD/barrel. If the marginal revenue increases/decreases, there will be a larger/smaller oil cycle and a higher/lower deficit will be enabled.
3. (EXR_{t-1}): An exchange rate depreciation/appreciation will generate a bigger/smaller deficit, either positive or negative.

Since the implementation of Colombia's Fiscal Rule in 2012, 15% of the total deficit has come from the oil cycle, representing about 0.5% of the GDP in additional allowed deficit[7]. Given the weight of the oil cycle in the total fiscal deficit, in the next section, we estimate the country's marginal oil revenues from 2002 to 2018, through a balance-sheet approach. Later in our discussion, through a structural analysis, we will explain how the oil-price fluctuations affect the CG's tax revenues coming from the mining-energy sector.

3. The Impact of Oil Prices on Colombia's Oil Revenues: A Balance-Sheet Analysis

As it has been mentioned, the marginal oil revenues are an additional income for the CG when the long-term prices of oil increase by 1 USD/barrel. Although they are included in the estimation of the oil cycle of the Colombian Fiscal Rule, they represent a calculation and do not come entirely from observed data[8]. In this section, we analyze the CG's observed oil revenues from 2002 to 2018 (**Figure 3**) and the observed oil prices during the same period, and how oil revenues have increased/decreased when oil prices increase/decrease by 1 USD/barrel.

[7] These estimations are based on the values provided by the Ministry of Finance's Fiscal Rule reports to the Congress of the Republic from 2012 to 2017.
[8] Taking into account that some of the data used to estimate the long-term prices corresponds to forecasts.

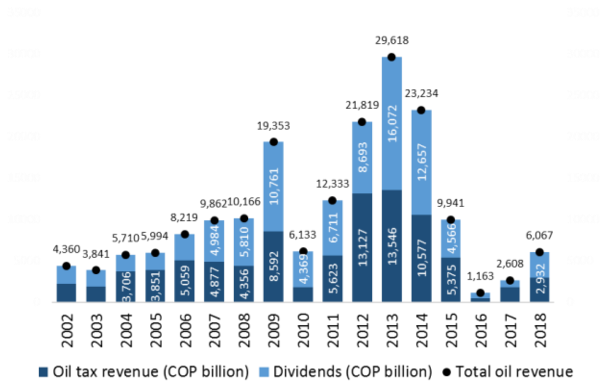

Figure 3. Total oil revenues in Colombia (COP billion) – 2017 constant prices. In the bars, the dark blue area represents tax revenues, and the light blue area represents the dividends from Ecopetrol (State oil company). Source: DIAN. Ecopetrol. Ministry of Finance estimations.

We began by estimating the absolute change in the Brent oil prices[9] from 2002 to 2018 (**Figure 4**), and the absolute change in oil revenues from taxes and dividends paid by Ecopetrol, the State oil company (**Figure 5**). Having both, the oil price change and the oil revenue change (including taxes and dividends), we then estimated the change in tax and dividend revenues for each USD increased or decreased in the oil prices, as follows:

$$Effect\ of\ 1\ additional\ USD\ on\ oil\ revenue_{it} = \frac{Change\ in\ revenue_{it}}{Change\ in\ Brent\ Price_{t}} \quad [2]$$

This is what we will refer to as the effect of an additional 1 USD on oil revenues, within the CG's total revenue.

[9] 2017 constant prices

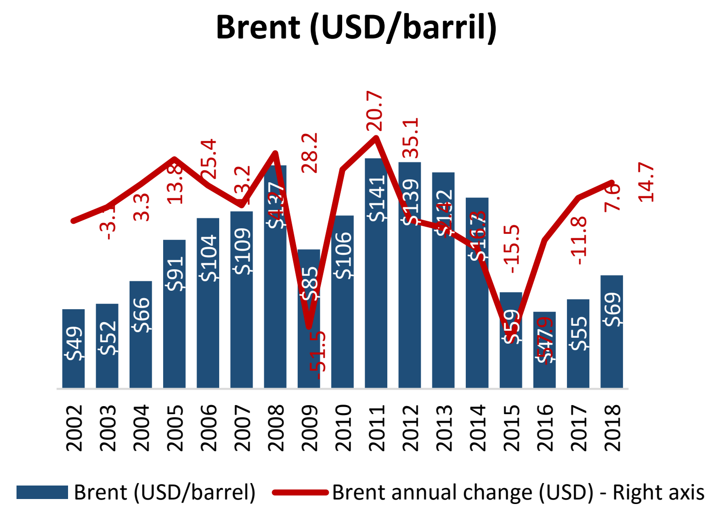

Figure 4. Brent Price (USD/barrel) - 2017 constant prices. The blue bars show the Brent price, and the red line shows the annual change of the Brent price in USD. Source: Bloomberg. Ministry of Finance estimations.

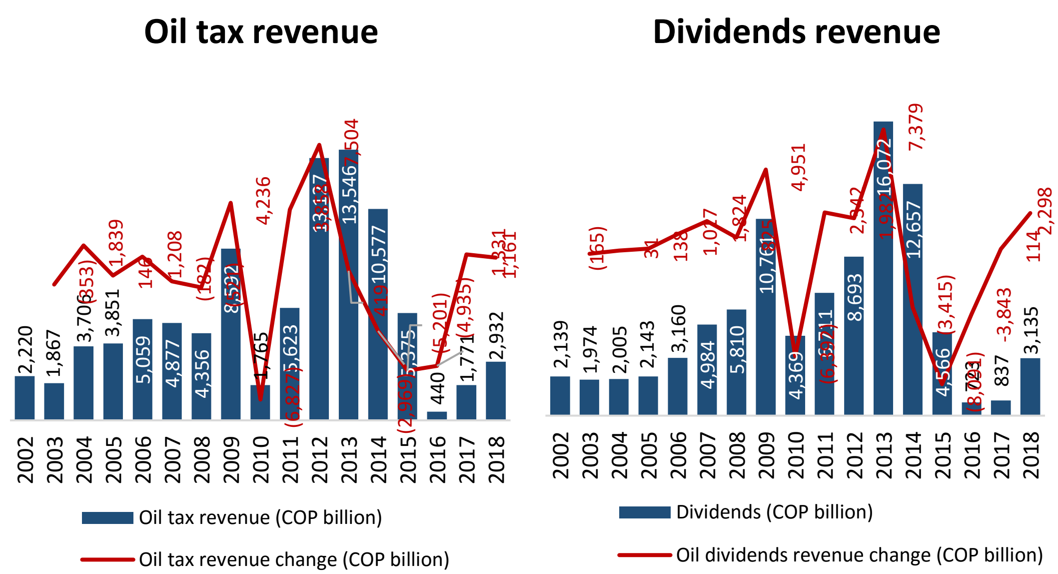

Figure 5. Oil tax revenue – 2017 constant prices. The blue bars show total oil (tax or dividends) revenues, and the red lines show the annual change of these revenues in COP billion. Source: Ministry of Finance estimations.

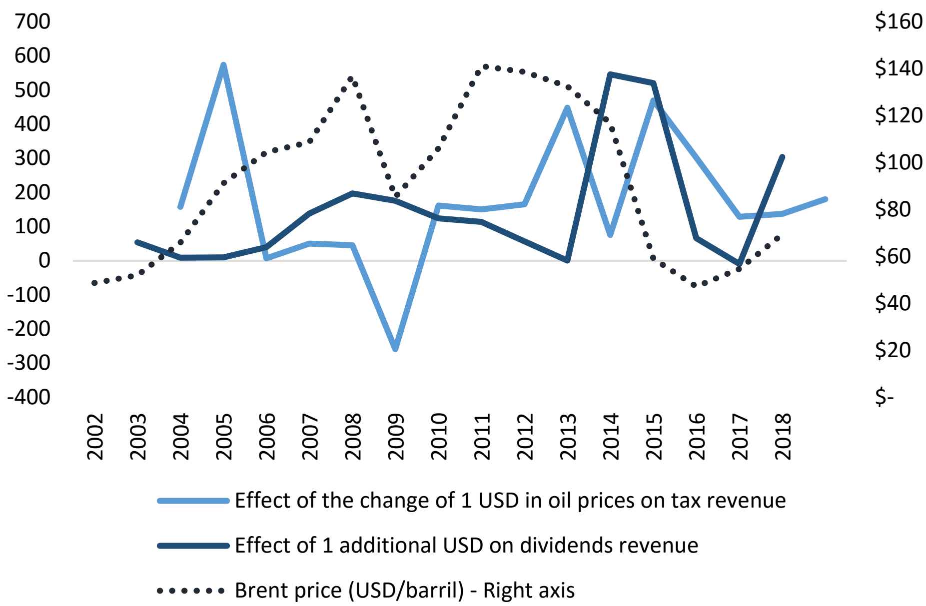

Figure 6 displays the effects of an additional 1 USD (in the oil prices) on the oil revenues (tax and dividends) between 2002 and 2018. The shape of the graph suggests that when prices are falling (specifically between 2008 and 2009 and between 2011 and 2016) the marginal oil revenue is larger than the magnitude of the effect when prices rise. Thus, when prices fall, the decrease in oil revenue is larger than the increase in oil revenue when prices rise. Thus, the graph indicates that this effect is not linear or symmetrical, suggesting that the average effect size is different when the prices rise than when they fall.

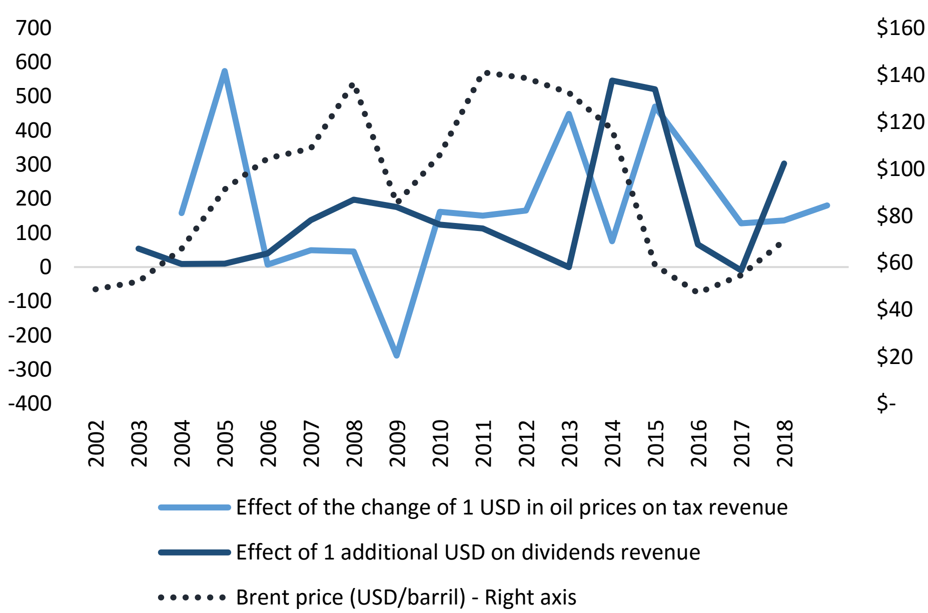

Figure 6. Effects of an additional 1 USD (in the oil prices) on the oil tax and dividend revenue – 2017 constant prices. The light-blue solid line shows the effect of that additional 1 USD on the tax revenues, and the dark-blue solid line shows the same effect on the dividend revenues.

Figure 7 shows the average effect of an additional 1 USD (in the oil prices) on the oil revenues (tax and dividends). From 2002 to 2018, the average effect of that additional 1 USD on the tax revenues was 175 COP billion; and on the dividends, it was 156 COP billion. Therefore, during that period, the overall average effect on the total oil revenues was 331 COP billion. By breaking down the effect, we found that when the prices increased, the effect on tax and dividend revenues of that additional 1 USD was additional revenues of 145 COP billion, and 116 COP billion, respectively. However, when the prices decreased, those effects are larger, causing a decrease of 212 COP billion for the tax revenues, and 217 COP billion for the dividend revenues. Consequently, we confirmed that this effect is not symmetrical and that its impact is greater when the oil prices fall.

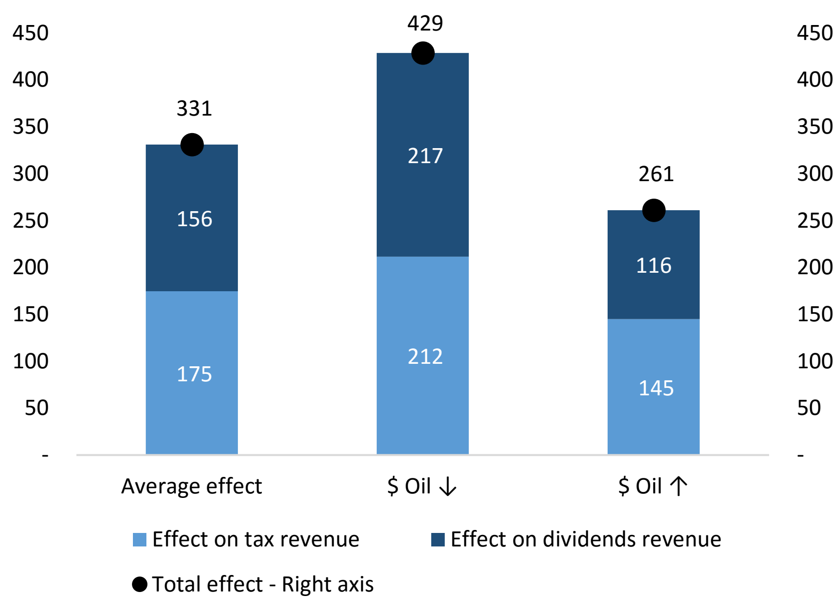

Figure 7. Effects of an additional 1 USD (in the oil prices) on the oil tax and dividend revenue – 2017 constant prices. The light-blue solid bars shows the average effect of that additional 1 USD on the tax revenues, and the dark-blue bar shows the same effect on the dividend revenues.

This asymmetry suggests that the impacts on oil revenue are larger when prices decrease– which may relate to the fact that, during downward price periods, oil companies react by closing some well operations once the prices plunge. Likewise, when the prices rise, there are clearer signals for the sector, and enhanced investment incentives. Moreover, in periods of fast price increases, the companies may be unable to react immediately and intensify their production, since the deployment of more well operations demands time. Indeed, increasing production requires careful planning, investment in –mostly imported– capital goods, and hiring labor, among other factors. In order to confirm that impacts are larger when the prices fall than when they mount, in the next section, we estimate how oil revenues respond to oil shocks at different price levels.

4. The Effects of Oil Prices and Oil Production on Colombia's Oil Tax Revenues: A Time-Varying VAR Approach

In section 3, we estimated the total marginal oil revenues observed during the period 2002-2018. Based on our results, we expect that the effects of oil-price changes on the CG's income will be asymmetric, non-linear, non-constant over time, and larger when the prices fall than when they rise. Franta et al. (2012) indicated various basic approaches to model, in applied work, changes in the transmission mechanisms (e.g., splitting the sample to recover possible coefficient changes over time). However, as they explained, these methods assume that the changes in economic transmissions are not gradual. In order to overcome this assumption, the time-varying parameter literature employs the Kalman filtering for the full sample –as opposed to the time-invariant studies, which employ the relevant information in the relevant subsample.

Moreover, according to Franta et al. (2012): "(…) even within explicit modeling of the evolution of parameters over time, there are several different approaches that can be used. For example, the Markov switching VAR model as employed by Sims & Zha (2006) might be considered. However, time-varying parameters VAR models have gained popularity. The reason for this popularity lies in the flexibility of this approach. For example, the system does not have to jump from one regime to another, as it is often the case with Markov switching VAR models."

In order to assess otherwise the effects of international oil-price shocks on the CG's tax revenues, we employed the Primicieri (2005) time-varying VAR model with stochastic volatility (TVP-VAR-SV). This approach allowed us to introduce a time variation in the variance-covariance matrix of innovations, thus permitting us to make structural interpretations of the system. Then, we defined the model for month periods, from 2002 to 2018, as follows:

$$y_t = B_{0,t} + B_{1,t}y_{t-1} + B_{2,t}\Delta y_{t-2} + u_t \quad [3]$$

Where y_t is a $n \times 1$ vector of endogenous variables, expressed in log terms, which are observable. $B_{i,t}, i = 0,1,2$ are $n \times n$ matrices of time-varying VAR coefficients, and u_t are unobservable shocks with a time-varying variance-covariance matrix Ω_t for $t = 1, \dots \dots \dots, T$.

And, in order to improve our structural analysis, we allowed a chage over time not only of the parameters, but also of the variances and covariances. Hence, we used a triangular reduction of Ω_t, such that:

$$\mathrm{A}_t \Omega_t A_t' = \Sigma_t \Sigma_t' \quad [4]$$

Or

$$\Omega_t = A_t^{-1} \Sigma_t \Sigma_t' (A_t^{-1})' \quad [5]$$

Where A_t is a lower triangular matrix:

$$A_t = \begin{bmatrix} 1 & \cdots & \cdots & \vdots \\ a_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{n1,t} & a_{n2,t} & \cdots & 1 \end{bmatrix} \quad [6]$$

And Σ_t is the diagonal matrix:

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sigma_{2,t} \end{bmatrix} \quad [7]$$

Then, the VAR process that will be estimated is:

$$y_t = B_{0,t} + B_{1,t} y_{t-1} + B_{2,t} y_{t-2} + A_t^{-1} \Sigma_t \varepsilon_t \quad [8]$$

Where ε_t are independent identically distributed errors with $var(\varepsilon_t) = I_n$.

We rewrote (8) by stacking all the right-hand-side coefficients in a vector B_t, to obtain:

$$y_t = X' B_t + A_t^{-1} \Sigma_t \varepsilon_t \quad [9]$$

Where $X' = I_n \otimes [I, y_{t-1}', y_{t-2}']$ and $\otimes$ refers to the Kronecker product.

Based on the literature related, the law of motion for the VAR parameter B_t and the elements of A_t were assumed to follow a random walk. For the variance of the shock Σ_t, a stochastic volatility framework was assumed as well as a geometric random walk for its elements. Formally, the parameters were described as follows:

$$B_t = B_{t-1} + v_t \quad [10]$$

$$\alpha_t = \alpha_{t-1} + \zeta_t \quad [11]$$

$$Log\sigma_t = Log\sigma_{t-1} + \eta_t \quad [12]$$

Our model to analyse the structural relation between the oil-price shocks and the CG's mining-energy tax revenues is a state space model, where equation [9] is the measurement equation, and the state equations are defined by [10], [11] and [12].

The innovation parameters (v_t, ζ_t, η_t) are assumed to be jointly normal with the variance-covariance matrix:

$$V = var\left[\begin{pmatrix} \varepsilon_t \\ v_t \\ \zeta_t \\ \eta_t \end{pmatrix}\right] = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix} \quad [13]$$

Where I_n is an n-dimensional identity matrix, and Q, S, and W are a positive definite matrix.

a. Priors and Structural Scheme

Usually, the estimation of VAR models requires a large amount of parameters, which can easily add up to a few hundred. Without prior information, it is almost impossible to obtain precise estimates (Arratibel & Henrike, 2014).

In order to specify the priors, we followed Arratibel & Henrike's (2014) strategy. Then, we used the whole sample 2002M1-2018m8, and run an OLS estimation on a fixed-coefficient VAR model to calibrate our priors**.** Under this scheme, the selected priors were:

From the time-invariant VAR:

$$B_0 \sim N(\hat{B}_{OLS}, (n+1) \cdot var(\hat{B}_{OLS})) \quad [14]$$

And the prior for A_t was obtained similarly:

$$A_0 \sim N(\hat{A}_{OLS}, (n+1) \cdot var(\hat{A}_{OLS})) \quad [15]$$

The prior for the variance of each endogenous variable, $Log\sigma_0$, was set to be the logarithm of the OLS estimate of the standard errors from the same time-invariant VAR, and the variance- covariance matrix was arbitrarily chosen to be proportional to the identity matrix:

$$Log\sigma_0 \sim N(Log\hat{\sigma}_{OLS}, I_n) \quad [16]$$

The priors for the hyperparameters were set as follows:

$$Q \sim IW\left(k_Q^2 \cdot \tau \cdot var(\hat{B}_{OLS}), \tau\right) \quad [17]$$

$$W \sim IG\left(k_W^2 \cdot (1+n) \cdot I_n, I_n \cdot (1+n)\right) \quad [18]$$

$$S_l \sim IW\left(k_S^2 \cdot (1+n) \cdot var\left(\hat{A}_{l,OLS}\right), n\right) \qquad [19]$$

Where τ is the size of the training sample, S_l denotes the corresponding block of S, and $\hat{A}_{l,OLS}$ is the corresponding block of $\hat{A}_{OLS}$. The parameters k_Q, k_w and k_s are specified below. The degrees of freedom of the hyperparameters were set to be n plus 1.

As for the structural shocks, we followed Primiceri (2005), and the identification was based on a triangular scheme.

b. Data and Estimation Strategy

We employed a time-varying VAR model with stochastic volatility (TVP-VAR-SV) to estimate the transmission of changes in international oil prices to the CG's tax revenues, coming from the mining-energy sector. We used monthly data from January 2002 until August 2018. The variables selected for the estimation were: 1) monthly revenue and complementary tax payments, 2) monthly average of daily Brent prices, and 3) monthly average of daily crude oil production in Colombia. We gathered this data from the DIAN (Colombia's Tax and Customs National Authority), Bloomberg, and the Colombian Ministry of Mining and Energy.

Because our main goal was to understand the effects of oil-price changes on tax revenues, our monthly variables were in logarithmic terms. In order to achieve a parsimonious estimation, we carried out a two-lag estimation, which increased our degrees of freedom and made programming easier –this was the case, given the evidence that VAR(2) specifications are in line with less parsimonious but real specification results (Jordà, 2005).

As described above, we used Bayesian methods given the number of unknown parameters that we needed to estimate. These methods allowed us to get individual estimates of parameters with independent algorithms, which helped us to calculate the whole model comprehensively.

5. Results of the Time-Varying Approach

Section (a.) below presents the volatilities estimated through the model previously described. Subsequently, sections (b.) and (c.) present the median impulse response functions to international oil-price shocks and Colombian oil-production shocks, respectively.

a. Volatility of International Oil Prices, Colombia's Oil Production and CG's Tax Revenues from the Mining-Energy Sector

By measuring the relative importance and changes of unexpected tax revenues from the mining-energy sector, through their time-varying standard deviation, any non-expected shocks become evident. **Figure 8** plots the posterior median and the 32^{nd} and 68^{th} percentiles, for one standard normal deviation, under a normality assumption of time-varying volatility, of Colombia's mining-energy-sector tax-revenue shocks from 2002 to 2018. The figure features some interesting findings. In panel (c), 2013 is the year with the lowest volatility and the highest tax-revenue levels; this is not surprising since its oil-production and price levels were the highest of the sample. However, the tax revenues from the mining-energy sector display a volatility pattern that cannot be explained by international prices or domestic production. This high-volatility levels usually occur in the second half of each year and are probably associated with increasing third-party withholdings due to the closings of investment contracts.

As for the volatility of international oil prices and oil production in Colombia, the effects were as expected. On the one hand, the international prices displayed their highest volatility levels in 2009 and 2014 –years affected by the 2008 international financial crisis and the 2014 oil-demand shocks. On the other hand, the volatility of domestic oil production was on the rise and reached a peak after 2012, when production levels hit their top values in a decade and a half.

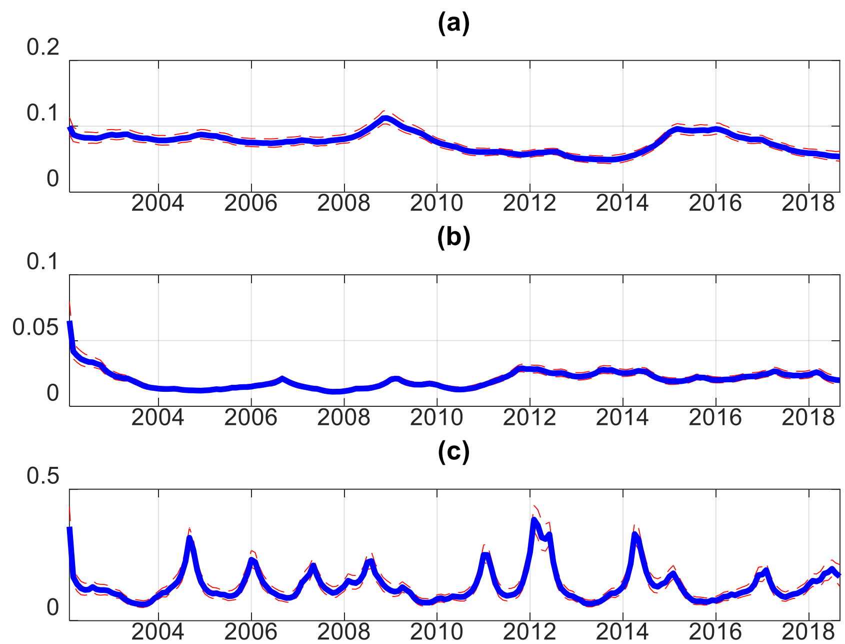

Figure 8. Posterior median, 32nd and 68th percentiles of the standard deviation of: (a) residuals of monthly log of international oil prices, (b) residuals of log of Colombia's oil production, and (c) residuals of log of revenues and complementary taxes from the mining-energy sector in Colombia.

b. Impulse Response Function to International Oil Prices

Figure 9 displays the median impulse responses (over 50 months: 2002:1-2018:8) to a one-standard- deviation oil-price increase. Such an oil-price shock has the expected impact on oil production in Colombia (↑) and its tax revenues from the mining-energy sector (↑).

It is evident that oil-price shocks have time-varying effects. For instance, the tax-revenue growth coming from the mining-energy sector was higher in 2008-2010 and 2014-2018 than in the rest of the period, and particularly than in the years 2011 to 2014. Based on information from the model, we also estimated the effects of an unexpected international oil-price shock on Colombia's oil production. We found a positive, though not very strong, effect –which is expectable given the difficulties of reopening oil wells.

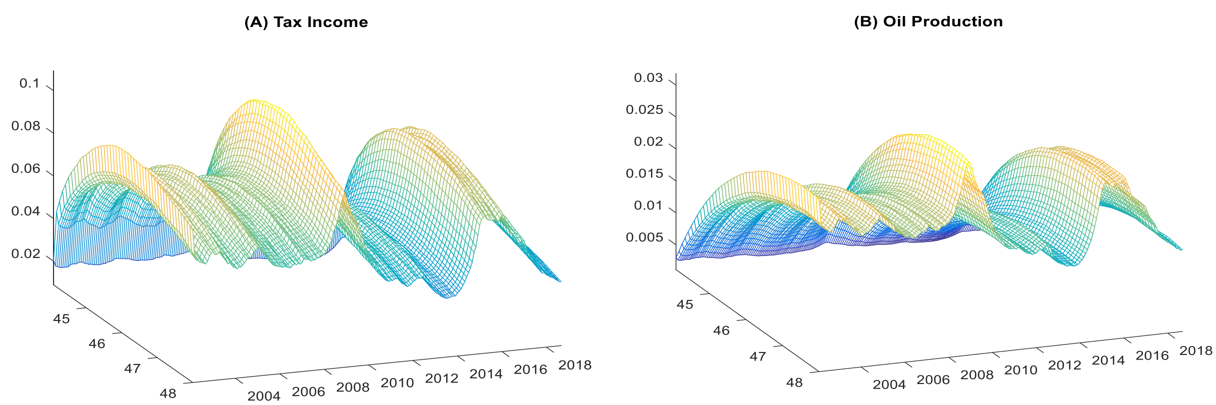

Figure 9. Posterior median of time-varying impulse responses to an oil-price shock. Panel (A) shows the monthly effect of a positive shock of one standard deviation of the international oil prices on the CG's tax revenues coming from the mining-energy sector in the period 2002-2018. Panel (B) displays the same monthly effect on Colombia's oil production during the same period.

In **Figure 10**, the peak of the cumulative effects of an oil-price shock on the mining-energy-sector tax revenues took place in 2008 –a year with the highest volatility level. A closer look to such cumulative effects reveals that the structural impact increased when the prices fell. Hence, the cumulative impact, after one year, of an unexpected shock of nearly 1 USD[10] in the oil prices, increased the monthly tax revenues by 6.12%, on average. This effect climbed to 7.19% when the prices were below 50 USD and fell to 5.65% when the prices were above 50 USD.

[10] The TVP-VAR-SV structure allows us to interpret the impulse response functions as how a shock of one standard deviation in the oil prices affects the percentage of oil production in Colombia and the tax revenues from the mining-energy sector. We estimated that an impact of one standard deviation in the oil price corresponds to an increase of 1.07 USD in such a price; for ease of interpretation, it is expressed as a price and not in standard deviations.

These results provide evidence that the effects of oil-price shocks are higher when price volatility soars –that is, during downward pricing. And conversely, those effects fall during periods of low price volatility –that is, when the prices rise. These interactions reveal the fact that at signals of high volatility, the sector reacts by narrowing down oil-well operations, which explains why oil production has the same dynamic response to oil-price shocks (figure 9 - panel B). Hence, when the oil prices and production fall, the sector's revenues also plunge. However, when the oil prices climb, the decision-making process on increasing production is not as immediate (as we mentioned in Section 3), and this may explain why the oil shocks during high-pricing levels have lower effects on the tax revenues than those of the shocks occurring during downward-pricing periods.

Figure 10. Cumulative effects of the impact of an international oil-price shock of one standard deviation on the tax revenues from the mining-energy sector. Month-0 is the cumulative impact in the first month; month-6 is the cumulative impact after 6 months of the shock; and month-12 is the cumulative impact after one year of the shock. Since tax revenues is a cumulative variable, the annualized effect must be interpreted with caution. For example, if the monthly tax revenues are 300,000 COP billion and the annual cumulative effect of the 1 USD increase in the oil price is 80%, this means that, on average, monthly revenues increase by 6.66% and total annual revenues by 240,000 COP million.

In order to find further evidence, we estimated the effect of a price increase of 1 additional USD/barrel on the tax revenues. **Figure 11** describes the marginal tax revenues generated by such an increase, since 2008. On average, the abovementioned impact increases the oil tax revenues by 129.1 COP billion per year. This effect climbs to an average of 137 COP billion per year when the prices are below 50 USD, and falls to an average of 127.5 COP billion when the prices exceed 50 USD.

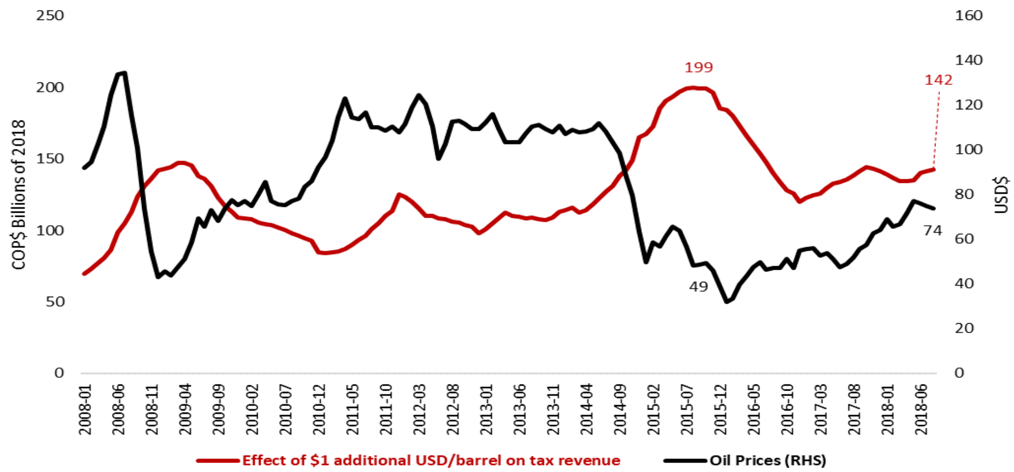

Figure 11. Annual marginal tax revenues generated by a positive oil-price shock of 1 USD (2008m1-2018m8). The red line represents the monthly average of such annual marginal revenues. The black line describes the monthly average of the international oil price from 2008 to 2018.

Concerning Colombia's oil production, the cumulative effects of an oil-price shock have a positive impact, which is higher as the oil prices fall (**Figure 12**). On average, a 1 USD positive shock on oil prices generates a monthly increase in oil production of 0.74%. This effect climbs to 0.86% when the oil price exceeds 50 USD per barrel, and falls to 0.69% when that price is below 50 USD.

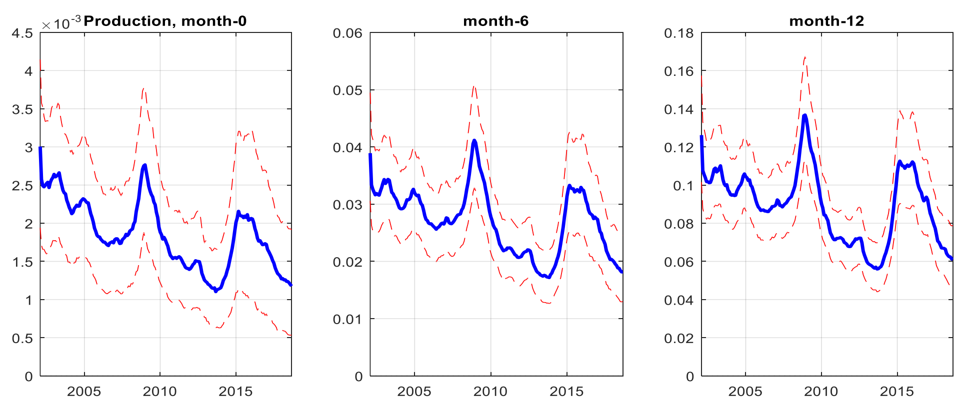

Figure 12. Cumulative effects on crude oil production of a shock of one standard deviation in the international oil price. Month-0 is the cumulative impact in the first month; month-6 is the cumulative impact after 6 months of the shock; and month-12 is the cumulative impact after one year of the shock. Since oil production is an estimate of daily barrel production, which is a non-cumulative variable, the interpretation of the accumulated annual effect must be made with caution. In this sense, if the accumulated impact is 12%, the average monthly impact would be an increase of 1.2%; therefore, if the average production amounts to 900,000 barrels per day, the effect of an unexpected increase of 1 USD in the price of oil would be of nearly 10,800 barrels per day.

When we translated this effect to increases in oil-barrel production per day, we determined that since 2008, an oil-price hike of 1 USD boosts the Colombian daily average oil production by 5.5 KBPD. However, this effect is higher when oil-barrel prices are below 50 USD –reaching 7.2 KBPD, and lower when those prices exceed 50 USD –reaching 5.2 KBPD (**Figure 13**).

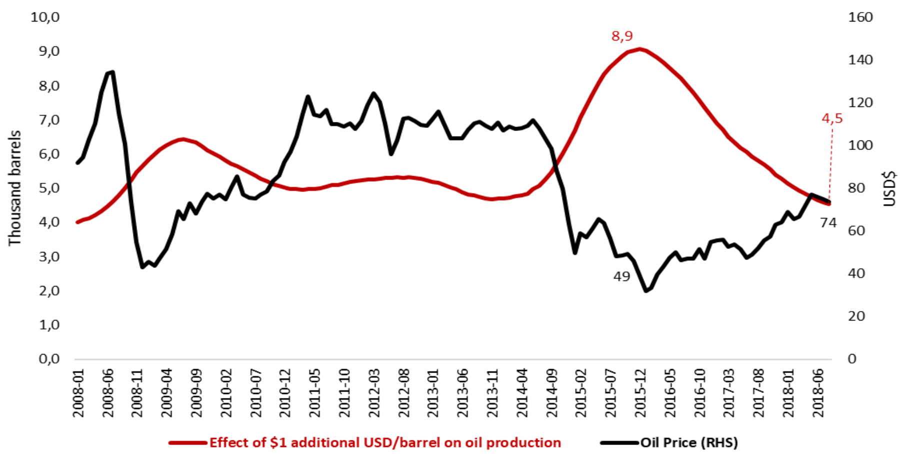

Figure 13. Colombia's daily oil-production increase caused by a positive oil-price shock of 1 USD (2008m1-2018m). The red line represents Colombia's oil production given a such a positive oil-price shock from 2008 to 2018. The black line describes the monthly average of the international oil prices from 2008 to 2018.

c. Impulse Response Function to Domestic Oil Production

Figure 14 displays the median impulse responses (over 50 months: 2002:1-2018:8) to a one standard deviation in Colombia's oil production. This oil-production shock has the expected impact on the tax revenues from the mining-energy sector (↑).

Figure 14. Posterior median of the time-varying impulse responses to an oil-production shock in Colombia. Panel (A) shows the monthly effect of a positive shock of one standard deviation in Colombia's oil production on the CG's tax revenues from the mining-energy sector in the period 2002-2018.

Figure 15 describes the cumulative effects of an unexpected shock in Colombia's oil production as well as some interesting findings: 1) As expected, as long as the oil production increases, its impact on the tax revenues will also increase. 2) While the domestic oil-production shocks also affect the tax revenues from the mining-energy sector, the impact of an increase of one standard deviation in that production only represents 25% of the impact of a similar unexpected oil-price shock of one standard deviation. On average, an unexpected oil-production positive shock implies a positive impact of 1.55% on the monthly tax revenues, while the same shock in oil prices implies a positive shock of 6.12% on those revenues. 3) Between 2011 and 2014, when Colombia's oil production reached its peak, an unexpected shock of one standard deviation in that production led to a 2.2% increase in the monthly tax revenues from the mining-energy sector; this represented more than 1.5 times its impact for the rest of the sampling period (1.4%).

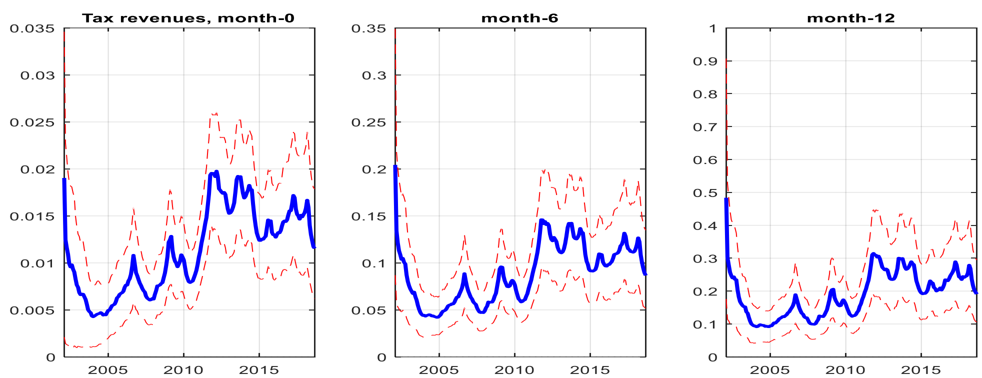

Figure 15. Cumulative effects of an impact of one standard deviation in the domestic oil production on the tax revenues from the mining-energy sector. Month-0 is the cumulative impact in the first month; month-6 is the cumulative impact after 6 months of the shock; and month-12 is the cumulative impact after one year of the shock.

6. Closing Remarks

Since 2002, the CG's revenues from the mining-energy sector have represented nearly 1.2% of the country's GDP –or an average of 9% of the total income of the CG. Given the high volatility of this type of revenues and their importance to public finances, the Colombian Fiscal Rule regards the oil cycle as a key factor to set the fiscal-deficit boundaries. Indeed, this mining-energy component of the Fiscal Rule acts as a stabilizing mechanism against oil-price volatility, prescribing –from a counter-cyclical perspective- saving during oil-price booms and spending throughout low-price periods. In other words, the oil cycle permits a larger fiscal deficit space when the oil-spot prices are below the long-term level, and a smaller fiscal deficit space when such spot prices rise above the long-term price levels.

The oil cycle mechanism of the Colombian Fiscal Rule has two leading components: first, the long-term and spot oil-price differential; and second, the marginal oil revenues, which represent the effect of one extra dollar in the oil prices on the CG's mining-energy sector revenues. Our study analyzed those marginal revenues through balance-sheet and time-varying VAR methodologies.

Our balance-sheet analysis, which employed observed data from 2002 to 2018, revealed that an increase of 1 USD/barrel in the oil price, over that period, rendered an average marginal oil revenue of COP 331 billion, of which 175 COP billion were tax revenues, and 156 COP billion were dividends. Moreover, we found that the magnitudes of this effect were not symmetric, since they were larger during periods of oil-price falls (leading to a larger decrease in oil revenues) than in times of soaring prices.

As for our time-varying VAR analysis, it addressed three goals: first, to estimate marginal tax revenues similar to those obtained through our balance-sheet calculations; second, to assess the structural effects of oil-price changes on Colombia's tax revenues; and third, to confirm whether the effects of oil-price changes on tax revenues differed when oil prices rise or fall.

Our time-varying VAR estimations showed that, between 2002 and 2018, an unexpected shock of 1 USD in the oil prices, increased the monthly revenues from the mining-energy sector by 6.12%, on average. This impact represents a marginal tax revenue of COP 129 billion, which is in line with that calculated through the balance-sheet approach (COP 164 billion). Furthermore, we confirmed that the effects of oil-price changes on the CG's revenues were asymmetric, non-linear, and non-constant over time, being larger when the prices fall than when they rise, and on low oil-price levels. For example, the abovementioned effect of 6.12% climbs to an average 7.19% when the prices are below 50 USD and falls to 5.65% when the prices exceed 50 USD.

The abovementioned asymmetry in the magnitude of effects –confirmed through both methodological approaches– indicates that the impacts of oil-price shocks are larger when price volatility is higher (i.e., at lower price levels) than when price volatility falls (i.e., at higher price levels). When the prices plunge, the oil industry faces increased uncertainty, and therefore, it adopts immediate measures to slow down oil well operations. However, when the prices soar, oil companies may not react as quickly to increase production. These dynamics explain why oil shocks that occur during high-price periods and when prices are rising (lower volatility), have smaller effects on tax revenues than those that occur when the prices are falling and on low-price periods (higher volatility).

Moreover, our estimations showed that domestic oil-production shocks also have an impact on the tax revenues from the mining-energy sector. However, the impact of an oil-production shock of one standard deviation on those revenues only represents 25% of the impact of an equal oil-price shock. On average, an unexpected positive oil-production shock implies a positive impact of 1.55% on the monthly tax revenues, while the positive impact of the same oil-price shock on those revenues amounts to 6.12%.

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NOTAS FISCALES

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