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Macroprudential Policies in a Commodity Exporting Economy*

Andrés González† Franz Hamann‡ Diego Rodríguez§

Abstract

Colombia is a small open and commodity exporter economy, sensitive to international commodity price fluctuations. During the surge in commodity prices, as income from the resource sector increases total credit expands, boosting demand for tradable and nontradable goods, appreciating the currency and shifting resources from the tradable sector to the nontradable. Although this adjustment is efficient, the presence of financial frictions in the economy exacerbates the resource allocation process through credit. In this phase, as total credit expands, the appreciation erodes the net worth of the tradable sector and boosts the nontradable one, and thus credit gets concentrated in that sector. A sudden reversal of commodity prices causes a rapid adjustment of resources in the opposite direction. However, the ability of the tradable sector to absorb the freed resources is limited by its financial capacity. In this scenario, macroprudential policies may help to restrain aggregate credit dynamics and thus prevent or act prudently in anticipation to the effects of large oil price shock reversals. In this work we write a model that accounts for these facts and quantify the role of three policy instruments: short term interest rate, FX intervention and financial regulation. We explore this issues in a DSGE model estimated for the Colombian economy and find that both FX intervention and regulation policies complement the short-term interest rates in smoothing the business cycle by restraining credit, raising market interest rates and smoothing economic activity. However, these additional instruments have undesirable sectoral implications. In particular, the use of these policies implies that credit to the tradable sector dries and becomes more expensive, weakening its financial position, which in turn implies a sharper fall of this sector during the price reversal and a longer recovery. These effects, nonetheless, appear to be quantitatively small according to the estimated model.

Keywords: credit, leverage, financial accelerator, business cycle, monetary policy, macro-prudential policies, Colombia
JEL Classification Codes: E3, E58.

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1 Introduction

Colombia, like many Emerging Market economies, is a small open and commodity exporter economy. The predominant type of the commodity exported has varied, from coffee in the past century to oil in the current one. Nonetheless the importance of the commodity exporting sectors for the Colombian business cycle is prominent. In the last 40 years, empirical evidence shows a strong and positive association between the cyclical component of the real price of Colombian exports and the cyclical component of real GDP. Periods of high export prices coincide with economic booms, while periods of lower than usual prices are associated with recessions. In addition, besides contributing significantly to the GDP cycle volatility, the effects of these shocks are widespread as they affect real variables, like consumption and investment, as well as other financial variables, like credit.

Figure 1 is clear that about the growing importance of oil for the Colombian economy. Colombia became an important net oil exporter by the mid 80's, but in the last decade, oil production increased from 6% of GDP to 10%; the share of oil export in GDP jumped from 4% in 2002 to 8% in 2012. In turn, fiscal revenues from oil (as a share from total public revenues) increased from under 10% in 2002 to close to 20% in 2011. Patterns like these were observed in the 80's and the 90's, but at significantly lower international real oil prices. While by the end of 1998 the nominal oil price was close to US$12 per barrel, by mid 2008 the price had multiplied by a factor of ten. Few quarters later the price dropped abruptly to US$30. Since then, the oil price has recover steadily to levels close to a US$100 per barrel.

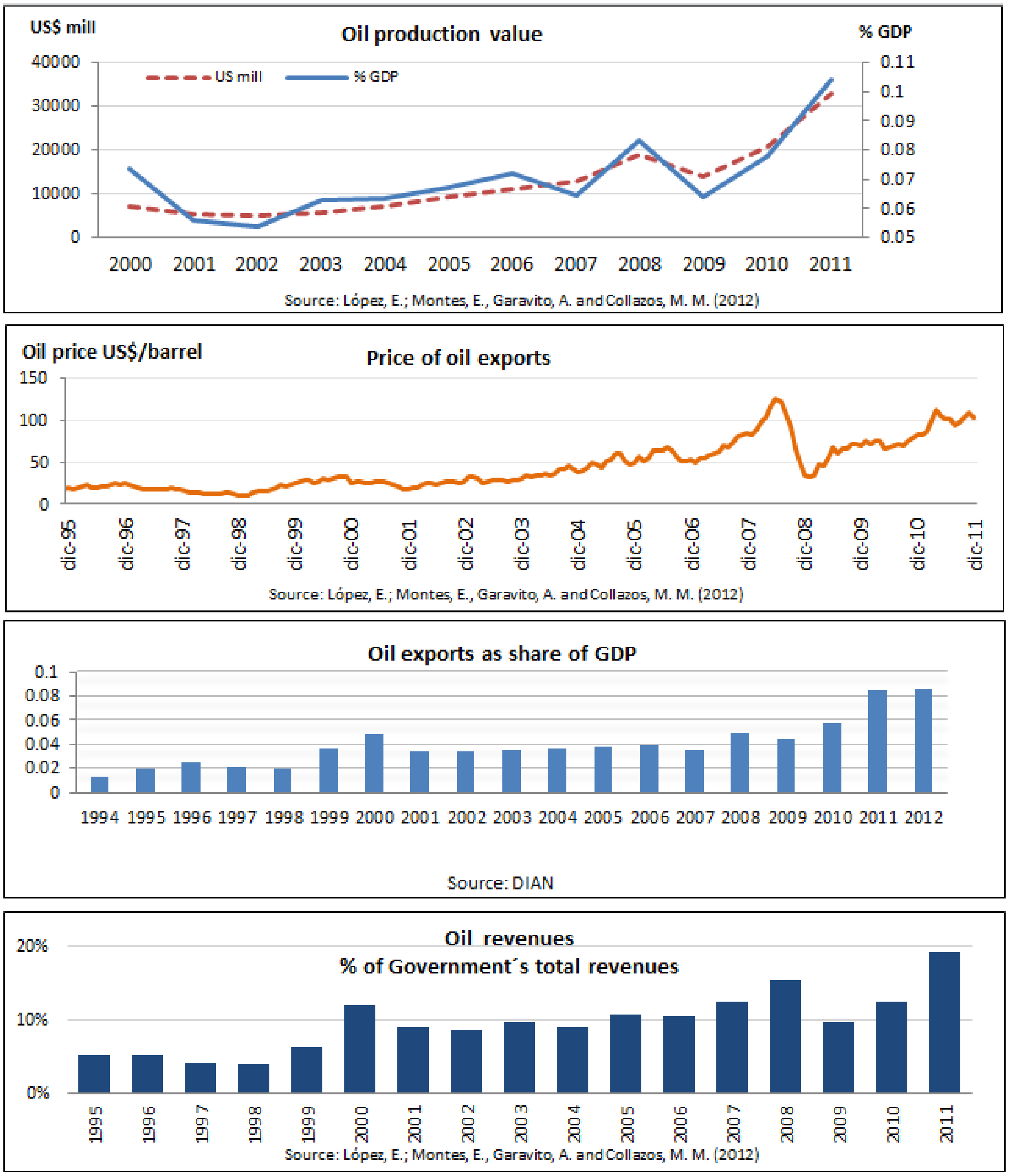
Because of their potentially significant macroeconomic consequences, commodity price shocks are relevant for monetary policy. There has been growing interest in understanding the consequences of commodity price shocks on small open economies, like Colombia. Gómez and Julio (2014) identify episodes of buoyancy and retrenchment in global risk and find that they were transmitted to Colombia's country risk premium being important drivers of Colombia's output and unemployment gaps. Furthermore, taking into account the interaction of foreign shocks and using a gap model of monetary policy for Colombia, they find that aggregate demand-related shocks are not important as drivers of Colombian non-core inflation. Nonetheless, they find that global risk was relevant at explaining Colombia's output gap, particularly during the global financial crisis.

Recently, Arango, Chavarro and González (2014) using a small-scale monetary policy model studied the impact of commodity price shocks on inflation, finding evidence of a positive albeit small impact from oil and food international prices shocks to inflation. The authors attribute the lack of effect from oil and energy price shocks to a substantial decrease in the pass-through from oil prices to headline inflation and to a monetary authority has faced correctly these shocks. In their view, inflation expectations emerge as the main determinant of inflation during the inflation targeting regime and commodity price movements are already part of the information set used by agents to form expectations. These results contrast with the empirical study of Arango, Chavarro and González (2013), which finds a positive and significant pass-through from food and oil international prices to the domestic prices of some selected, yet important, items of the CPI and PPI baskets. Moreover, Jalil and Tamayo (2011), using also an empirical model, estimated first and second round effects of food international prices on inflation of Brazil, Chile, Colombia, México and Peru, finding that, for Colombia, the effects of commodity price shocks imply an elasticity of 0.27 of domestic prices to the international prices, but these effects vanish after four months.

Despite the increased interest that has recently emerged among academics and policy makers about the impact of commodity prices and their interaction with monetary policy, there is still room to learn about how do these shocks transmit to the Colombian economy. Empirical models often fail to capture the interaction of these shocks to real, nominal and financial variables as well as the economic policy reaction functions and their feedback to the economy. Small scale models, on the other hand, are very useful to illustrate key mechanisms and ideas of the transmission of these shocks, but also fall short or being considered a sufficient description of a ample set of transmission channels, which may be relevant for policy makers.

In this study, we proceed in two stages. In the first one, we perform an oil price shock identification

Figure 1: Oil shock



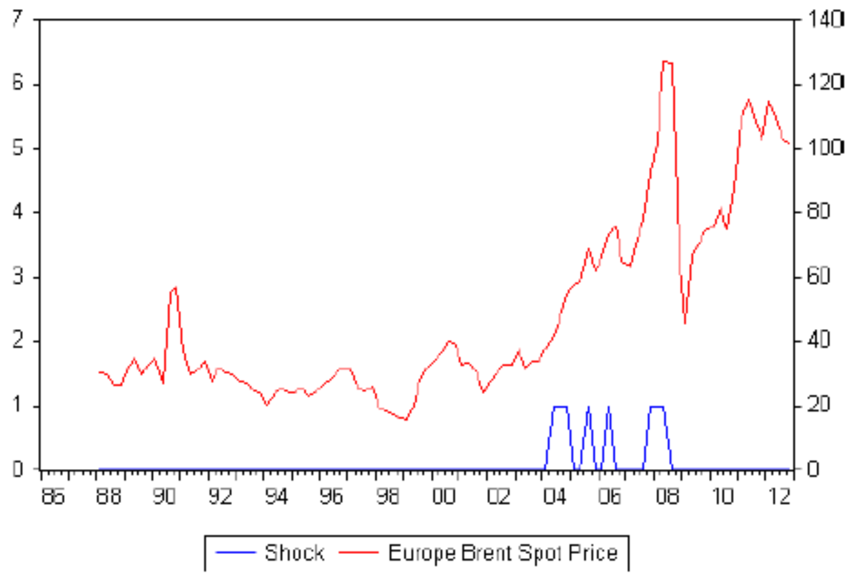
analysis in which we analyze how a key set of macroeconomic variables behave around these events. In particular, we are interested in studying large increases in international oil prices. Once we identify the shocks, we observe how country risk, GDP, private consumption, domestic credit, trade balance and the real exchange rate evolve during the commodity price surge as well as during its collapse. Our main findings are that before the peak of a large and steady oil price hikes, country risk falls, GDP rises, private consumption increases, domestic credit booms, trade balance improves and the real exchange rate appreciates. In general, after the sudden oil price reversal all these patterns shift back in the opposite direction.

These facts are consistent with the intuition shared by most economists who study small open economies in which resource sectors are important. As the oil price grows, income from the resource sector increases and risk premium falls with the improved overall creditworthiness, creating a surge in demand for tradable and nontradable goods, inducing a real exchange rate appreciation and a shift of economic resources from the tradable sector to the nontradable sector. Credit expands, especially in those favored sectors by the real appreciation. Overall economic activity and demand booms, in tandem with asset prices. However, sharp oil price reversals truncate this process and a rapid reallocation of resources happen together with a collapse in asset prices and the currency.

In the second stage, we write a large-scale dynamic stochastic general equilibrium model to account for these facts. The model captures some prominent features of the Colombian economy. We consider a three sector economy (resource, tradable and nontradable sectors) populated by households, entrepreneurs, monopolistically competitive retailers, capital producers, banks and the public sector (government and the central bank). Households enjoy the revenues from the windfall sector, consume and supply labor to firms. They can also save in the form of bank deposits. Monetary policy has real effects because there are nominal frictions in the nontradable sector. Entrepreneurs, both in the tradable and nontradable sectors face financial frictions and their external financing cost is decreasing in net worth, as in Bernanke Gertler and Gilchrist (BGG), 1999. Since we are interested in studying monetary and macroprudential policies, we consider a central bank with three policy instruments: the nominal interest rate, which adjust in response to inflation deviations, the sales/purchases of international reserves, which adjusts in response to real exchange rate misalignment, and finally, a financial regulation instrument, which enlarge or compress external financing depending on aggregate credit dynamics. Banks are key in the transmission of shocks to the rest of the economy. They give commercial loans to entrepreneurs, purchase sterilization bonds and finance their operations by deposits from households and borrowing abroad in the form of foreign debt. The external interest rate is increasing in the ratio of aggregate external debt to the outstanding value of the stock of oil. This last mechanism captures the spirit of Kiyotaki's role of collateral: the stock oil can be thought as an asset which reduces the risk premium of the external interest rate of the economy.

We estimate the model to use it for monetary policy analysis. Our aim is to assess the benefits and the costs of conventional and unconventional instruments in the face of a sudden reversal of high international oil prices. The model shows that, even though the adjustment of the economy is efficient, it can be also be a source of financial and macroeconomic instability. The source of these instabilities can be associated with the fact that when commodity shocks are persistent but end up abruptly, the presence of financial frictions exacerbates the resource reallocation process through the credit process. In particular, with a financial friction as in BGG, a persistent appreciation erodes the net worth of the tradable sector and boosts the nontradable one, redirecting not only labor and capital to the nontradable sector but also credit. The collapse of the commodity price after a prolonged period of high prices, triggers a rapid adjustment of resources between sectors. However, the ability of the tradable sector to absorb the freed resources is limited by its financial capacity. However, despite that macroprudential policies are able to restrain aggregate credit dynamics and thus prevent or act prudently in anticipation to the effects of large oil price shock reversals, they intensify the credit allocation from the affected (tradable) sectors towards those who are the beneficiaries of the appreciation (the nontradable sector).

Figure 2: Price of oil and the oil shocks



2 Macroeconomic impact of large oil shocks: an event-study analysis.

In this section we perform an event-study to analyze how key macroeconomic variables behave around oil price shocks. In particular, we are interested in studying the effect of large and persistent increases in international oil prices. We observe how domestic output, consumption, investment, trade balance, the country risk premium, credit and the real exchange rate evolve during the commodity price surge as well as during its collapse.

Our sample runs from 1988 to 2012. The event analysis is carried out at quarterly frequency. However not all variables are available for the full sample neither are observed at same frequency. In particular, we take monthly data for the oil price and the country risk measured by EMBI-Colombia. Our measure of oil prices is the Europe Brent Spot Price FOB (Dollars per Barrel) 1988m1 to 2012m12 adjusted using the United States' CPI. The remaining variables are quarterly and taken from the national accounts and the balance of payments statistics. The observed sample for these last variables is 1999Q2 to 2012Q4.

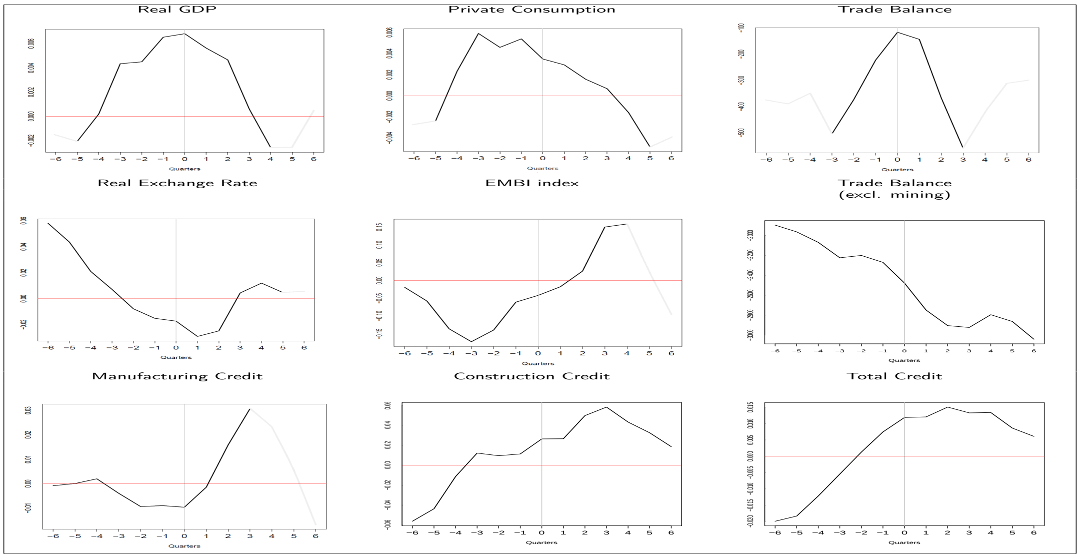
We follow Hamilton (2003) to find the quarters during which there were oil price shocks. Hamilton defines an oil shock as a large increase in the oil price. Specifically, an oil shock is the maximum value of the oil price during the last 36 months. An oil shock event occurs when the oil shock is larger than two standard deviations[1]. At the quarterly frequency there is an event if at least one monthly shock event occurs. Figure 2 shows the oil price and its shocks for the Europe Brent Spot Price. As can be seeing from the figure, oil shock have become larger and more frequent in the last 10 years.

Figure 3 reports the average evolution of the cyclical component of each variable six quarters before and after the oil shock.[2] The value of zero in the horizontal axis represents the date of the oil price

[1]This leaves us with a set of special or singular events, not just noise. We believe that given the special nature of these events and given the dates at which these events were identified, it is unlikely that they will coincide with other special or prominent events (other shocks In Hamilton's sense) that may have hit Colombia at the same time. Additionally, using average in the macroeconomic series identifies shocks since the average responses are integrated over other shocks present.

[2]We take the average across events. We do not compute the cyclical component for the trade balance.

Figure 3: Macroeconomic effects of oil shock an event-study analysis



shock event. Our main findings are[3]:

1. Country risk premium falls and stays below normal levels while the oil price increase and jumps right after the fall in the price.

2. Real GDP and private consumption increase above trend during oil price hikes and fall back after the price reversal.

3. Total real credit to the private sector expands above normal as oil prices increase, and scales back down about two quarters after the price shock vanishes. Credit to tradable sector contracts and credit to nontradable sector expands during the booming phase. This credit allocation process reverses during the collapse.

4. The peso appreciates steadily in real terms against the US dollar during the oil price boom and depreciates sharply thereafter.

5. The total trade balance improves during three quarters before oil price peak, and deteriorates after the price collapse. The non-oil trade balance deteriorates during the boom and also after the price collapse.

In the next section we write a model to account for these facts.

3 The Model

Our baseline model is a three sector economy (resource, tradable and nontradable sectors) populated by households, entrepreneurs, retailers, capital producers, private banks, the government and the central bank. Households receive the revenues from the resource sector, supply labor to firms and consume final goods and save in the form of bank deposits. Output is produced in several stages,

[3]The nature of the oil shock (supply or demand) may have different effects on macroeconomic variables, nevertheless, our objective in the paper is not to identify the nature of the shocks, instead we focus on a small open economy being hit by international oil price spikes (unusual price movements), which the economy takes as given, regardless of the nature of these price movements.

including a monopolistic competitive nontradable sector with nominal rigidities. Entrepreneurs, both in the tradable and nontradable sector face financial frictions and their external financing cost is decreasing in their net worth, as in BGG. In the baseline specification of the model, the central bank sets the nominal interest rate using a monetary policy rule. We also enhanced further the model to consider exchange rate and credit policies. We model the first as the sales/purchases of international reserves, which adjusts in response to real exchange rate misalignment, and the second as any financial regulation instrument, which respond to aggregate credit dynamics by enlarging or compressing the external financing premium in the economy. We report the complete set of equations in Appendix 1.

3.1 Households

The economy is populated by households who discount the future at the factor $\beta \in (0,1)$ and choose consumption, c_t, labor supply, h_t, and deposits, d_t, to maximize expected lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[z_t^u \frac{c_t^{1-\sigma}}{1-\sigma} - \chi \frac{h_t^{1+\eta}}{1+\eta} \right]$$

where z_t^u is an exogenous preference shock, which evolves according to

$$z_t^u = \rho_{z^u} \, z_{t-1}^u + (1-\rho_{z^u}) \log(\bar{z}^u) + \varepsilon_t^{z^u}. \tag{1}$$

The representative household budget constraint is

$$c_t + d_t = (1-\zeta)\, q_t oil_t + \tau_t + \xi_t^N + w_t^h h_t + (1+r_{t-1})\, d_{t-1} \tag{2}$$

where w_t^h is the real wage, r_t denote the real deposit interest rate, q_t is the real exchange rate, ξ_t^N are the profits of the producers of nontradable goods, τ_t are lump-sum transfers from the government to households and $(1-\zeta)\, oil_t$ is the fraction of oil revenues earned by households. Households also allocate labor between tradable and nontradable sector, thus the time constraint is $h_t = h_t^{Nh} + h_t^{Th}$. The consumption bundle for household is defined as

$$c_t = \left(\gamma^{\frac{1}{\omega}} \left(c_t^N\right)^{\frac{\omega-1}{\omega}} + (1-\gamma)^{\frac{1}{\omega}} \left(c_t^T\right)^{\frac{\omega-1}{\omega}} \right)^{\frac{\omega}{\omega-1}} \tag{3}$$

where c_t^T and c_t^N is the consumption of tradable and nontradables, ω is a parameter that determines the elasticity of substitution between tradable and nontradable goods and γ determines the household's importance of nontradable goods. Under these assumptions, the optimal household choices of consumption, labor supply and deposits are:

$$z_t^u c_t^{-\sigma} = \lambda_t \tag{4}$$

$$\chi h_t^{\eta} = w_t^h \lambda_t \tag{5}$$

$$\lambda_t = \beta \mathbb{E}_t \left[\lambda_{t+1} (1+r_t) \right] \tag{6}$$

$$c_t^N = \gamma \left(p_t^N\right)^{-\omega} c_t \tag{7}$$

$$c_t^T = (1-\gamma) \left(p_t^T\right)^{-\omega} c_t \tag{8}$$

where λ_t is the lagrange multiplier of the budget constraint and p_t^T and p_t^N are the relative prices of tradable and nontradable goods.

The relationship between the real and nominal rates in the economy is determined by the Fisher equation, $(1 + r_t) = \frac{(1+i_t)}{\left(1+\pi_{t+1}^C\right)}$, and by $\frac{(1+\partial_t)}{\left(1+\pi_t^C\right)} = \frac{q_t}{q_{t-1}}$ in the case of the exchange rates, where ∂_t is the nominal depreciation rate. Also, as there are two goods their inflation rates are:

$$\frac{\left(1+\pi_t^N\right)}{\left(1+\pi_t^C\right)} = \frac{p_t^N}{p_{t-1}^N} \tag{9}$$

and

$$\frac{\left(1+\pi_t^T\right)}{\left(1+\pi_t^C\right)} = \frac{p_t^T}{p_{t-1}^T}. \tag{10}$$

3.2 Capital Good Producers

In both tradable and nontradable sectors, there is a representative capital good producer acting in a perfectly competitive environment. Every period both producers buy x_t^T and x_t^N of final goods and old capital net of depreciation, $(1-\delta)\, k_{t-1}^T$ and $(1-\delta)\, k_{t-1}^N$, and transform these into new capital at a quadratic cost. Thus, the technology to produce each type of capital is

$$k_t^T = z_t^{xT} x_t^T + (1-\delta_T)\, k_{t-1}^T - \frac{\psi_T}{2}\left(\frac{x_t^T}{k_{t-1}^T} - \delta_T\right)^2 k_{t-1}^T \tag{11}$$

$$k_t^N = z_t^{xN} x_t^N + (1-\delta_N)\, k_{t-1}^N - \frac{\psi_N}{2}\left(\frac{x_t^N}{k_{t-1}^N} - \delta_N\right)^2 k_{t-1}^N. \tag{12}$$

Both z_t^{xT} and z_t^{xN} are exogenous investment effciency shocks which evolve according to

$$z_t^{xT} = \rho_{z^{xT}}\, z_{t-1}^{xT} + (1-\rho_{z^{xT}}) \log\left(\bar{z}^{xT}\right) + \varepsilon_t^{z^{xT}} \tag{13}$$

$$z_t^{xN} = \rho_{z^{xN}}\, z_{t-1}^{xN} + (1-\rho_{z^{xN}}) \log\left(\bar{z}^{xN}\right) + \varepsilon_t^{z^{xN}} \tag{14}$$

Under these assumptions the tradable and nontradable capital prices are:

$$p_t^{kT}\left(z_t^{xT} - \psi_T\left(\frac{x_t^T}{k_{t-1}^T} - \delta_T\right)\right) = p_t^T \tag{15}$$

$$p_t^{kN}\left(z_t^{xN} - \psi_N\left(\frac{x_t^N}{k_{t-1}^N} - \delta_N\right)\right) = p_t^N. \tag{16}$$

3.3 Entrepreneurs

Entrepreneurs produce an homogeneous good in both tradable and nontradable sectors. In the production process, the entrepreneurs buy capital from the capital producer firm and finance these payments by their own funds and taking loans from banks. Additionally, they work for the firm and hire labor from households. Once the production is made, entrepreneurs sell back the (depreciated) capital to the capital producer firm. During the production process, each entrepreneur is subject to an idiosyncratic shock that affects the productivity of its capital. While the tradable good is sold at international (given) prices, the non tradable homogeneous output is sold to a retail firm that differentiates the product and sells it to households. Thus, during the period t, this process can be characterized by the following technologies

$$y_t^N = z_t^N \left(\alpha_N^{\frac{1}{\omega_N}} \left(h_t^N\right)^{\frac{\omega_N - 1}{\omega_N}} + (1-\alpha_N)^{\frac{1}{\omega_N}} \left(k_{t-1}^N\right)^{\frac{\omega_N - 1}{\omega_N}} \right)^{\frac{\omega_N}{\omega_N - 1}} \tag{17}$$

$$y_t^T = z_t^T \left(\alpha_T^{\frac{1}{\omega_T}} \left(h_t^T\right)^{\frac{\omega_T - 1}{\omega_T}} + (1-\alpha_T)^{\frac{1}{\omega_T}} \left(k_{t-1}^T\right)^{\frac{\omega_T - 1}{\omega_T}} \right)^{\frac{\omega_T}{\omega_T - 1}} \tag{18}$$

where $h_t^N = \left(h_t^{Nh}\right)^{\Omega_N} \left(h^{Ne}\right)^{1-\Omega_N}$ and $h_t^T = \left(h_t^{Th}\right)^{\Omega_T} \left(h^{Te}\right)^{1-\Omega_T}$. Both z_t^T and z_t^N are exogenous technology shocks which evolve according to

$$z_t^T = \rho_{z^T} z_{t-1}^T + (1-\rho_{z^T}) \log\left(\bar{z}^T\right) + \varepsilon_t^{z^T} \tag{19}$$

$$z_t^N = \rho_{z^T} z_{t-1}^N + (1-\rho_{z^T}) \log\left(\bar{z}^N\right) + \varepsilon_t^{z^N} \tag{20}$$

The optimal allocation of labor services implies that in the nontradable sector

$$w_t^h = p_t^W \Omega_N z_t^N \left(\alpha_N \frac{y_t^N}{z_t^N h_t^N} \right)^{\frac{1}{\omega_N}} \frac{h_t^N}{h_t^{Nh}} \tag{21}$$

$$w_t^{Ne} = p_t^W \left(1-\Omega_N\right) z_t^N \left(\alpha_N \frac{y_t^N}{z_t^N h_t^N} \right)^{\frac{1}{\omega_N}} \frac{h_t^N}{h^{Ne}} \tag{22}$$

and in the tradable sector

$$w_t^h = p_t^T \Omega_T z_t^T \left(\alpha_T \frac{y_t^T}{z_t^T h_t^T} \right)^{\frac{1}{\omega_T}} \frac{h_t^T}{h_t^{Th}} \tag{23}$$

$$w_t^{Te} = p_t^T \left(1-\Omega_T\right) z_t^T \left(\alpha_T \frac{y_t^T}{z_t^T h_t^T} \right)^{\frac{1}{\omega_T}} \frac{h_t^T}{h^{Te}}. \tag{24}$$

The optimal allocation of capital depends on the expected return of one unit of capital.

$$\mathbb{E}_t r_{t+1}^{kN} = \mathbb{E}_t \left[\frac{p_{t+1}^W z_{t+1}^N \left((1-\alpha_N) \frac{y_{t+1}^N}{z_{t+1}^N k_t^N} \right)^{\frac{1}{\omega_N}} + (1-\delta_N) p_{t+1}^{kN}}{p_t^{kN}} \right] \tag{25}$$

$$\mathbb{E}_t r_{t+1}^{kT} = \mathbb{E}_t \left[\frac{p_{t+1}^T z_{t+1}^T \left((1-\alpha_T) \frac{y_{t+1}^T}{z_{t+1}^T k_t^T} \right)^{\frac{1}{\omega_T}} + (1-\delta_T) p_{t+1}^{kT}}{p_t^{kT}} . \right] \tag{26}$$

Given that entrepreneurs do not have enough resources to finance their total capital expenses, then their borrowing, $b_t^N$and b_t^T, is given by:

$$b_t^N = p_t^{kN} k_t^N - n_t^N \tag{27}$$

$$b_t^T = p_t^{kT} k_t^T - n_t^T. \tag{28}$$

which in turn depends on the net worth of the firm, n_t^N and n_t^T, which evolves in time according to:

$$n_t^N = \phi_N v_t^N + w_t^{Ne} h^{Ne} \tag{29}$$

$$n_t^T = \phi_T v_t^T + w_t^{Te} h^{Te}. \tag{30}$$

where

$$v_t^N = r_t^{kN} p_{t-1}^{kN} k_{t-1}^N - \mathbb{E}_{t-1}\left[r_t^{kN}\right] b_{t-1}^N \tag{31}$$

$$v_t^T = r_t^{kT} p_{t-1}^{kT} k_{t-1}^T - \mathbb{E}_{t-1}\left[r_t^{kT}\right] b_{t-1}^T, \tag{32}$$

are the proceeds per unit of capital acquired, net of the financing cost. Finally, entrepreneurs consume $p_t^N c_t^{Ne} = (1-\phi_N) v_t^N$ and $p_t^T c_t^{Te} = (1-\phi_T) v_t^T$.

3.4 Retailers

Retailers operate in a monopolistic competition environment, buy the homogeneous nontradable goods from the nontradable entrepreneurs at a wholesale price, p_t^W, differentiate it at no cost and sell it to households and to the capital producer firms at the retail price, p_t^N. There are nominal price rigidities in the nontradable sector, as each firm maximizes profits under costly price changes as in Rottemberg (1982). Thus, the optimal price set is

$$\begin{aligned} 0 \;=\; & (1-\theta_t) p_t^N y_t^N + \theta_t p_t^W y_t^N - p_t^N \kappa \left(\frac{(1+\pi_t^N)}{\left(1+\pi_{t-1}^N\right)^{\iota} (1+\bar{\pi})^{1-\iota}}\right)\left(\frac{(1+\pi_t^N)}{\left(1+\pi_{t-1}^N\right)^{\iota} (1+\bar{\pi})^{1-\iota}} - 1\right) \\ & + \mathbb{E}_t\left[\beta \frac{\lambda_{t+1}}{\lambda_t} p_{t+1}^N \kappa \left(\frac{(1+\pi_{t+1}^N)}{(1+\bar{\pi})^{1-\iota}\left(1+\pi_t^N\right)^{\iota}}\right)\left(\frac{(1+\pi_{t+1}^N)}{(1+\bar{\pi})^{1-\iota}\left(1+\pi_t^N\right)^{\iota}} - 1\right)\right] \end{aligned} \tag{33}$$

where θ_t is an exogenous markup shock, which evolves according to

$$\theta_t = \rho_\theta \, \theta_{t-1} + (1-\rho_\theta) \log\left(\bar{\theta}\right) + \varepsilon_t^\theta. \tag{34}$$

The retailers' profits are

$$\xi_t^N = p_t^N y_t^N - p_t^W y_t^N - p_t^N \frac{\kappa}{2}\left(\frac{(1+\pi_t^N)}{\left(1+\pi_{t-1}^N\right)^{\iota}(1+\bar{\pi})^{1-\iota}} - 1\right)^2 \tag{35}$$

where $\kappa = \frac{\epsilon}{(1-\epsilon)(1-\epsilon\beta)}(\theta_t - 1)$ is a parameter that determines the slope of the Phillips curve in the nontradable sector.

3.5 Banks

The banking sector operates under perfect competition and each bank is owned by households. Banks can make commercial loans to entrepreneurs by taking deposits from households and borrowing b_t^* from international financial markets at the interest rate, r_t^*. This financial intermediation process is subject to frictions, in particular a costly state verification problem on the side of the asset side of the banks, which shows up in loan interest rates in the form of spreads. In addition, banks can also purchase sterilization bonds, b_t, from the central bank. The rate of return of these bonds is r_t. Thus, the balance sheet of the banks is $b_t + b_t^N + b_t^T = d_t + q_t b_t^*$. Therefore, interest rates are related by the following conditions

$$1 + r_t = \mathbb{E}_t\left[\frac{q_{t+1}}{q_t}\left(1 + r_t^*\right)\right] \tag{36}$$

$$\mathbb{E}_t\left[r_{t+1}^{kN}\right] = \left(\frac{n_t^N}{p_t^{kN} k_t^N}\right)^{-\nu_t^N} (1+r_t)(rp_t) \tag{37}$$

$$\mathbb{E}_t\left[r_{t+1}^{kT}\right] = \left(\frac{n_t^T}{p_t^{kT} k_t^T}\right)^{-\nu_t^T} (1+r_t)(rp_t). \tag{38}$$

Both ν_t^T and ν_t^N are exogenous spread shocks which evolve according to

$$\nu_t^T = \rho_{\nu^T} \nu_{t-1}^T + (1 - \rho_{\nu^T}) \log \left(\overline{\nu}^T\right) + \varepsilon_t^{\nu^T} \tag{39}$$

$$\nu_t^N = \rho_{\nu^N} \nu_{t-1}^N + (1 - \rho_{\nu^N}) \log \left(\overline{\nu}^N\right) + \varepsilon_t^{\nu^N} \tag{40}$$

Equations (37) and (38) state that real interest rates of commercial loans are a decreasing function of the net worth (relative to capital) in each of the sectors. This function is equivalent to a more detailed description of the BGG financial accelerator with one exception, the term rp_t, which introduces a "regulation premium". This premium captures the essence of the role of regulation on interest rate spreads. It enlarges the interest rate spreads in response to rapid aggregate credit growth, for instance. The precise mechanism by which this happens is not explicit in our paper, but we believe this term could represent any regulation measure, like countercyclical buffers, capital requirements, reserve requirements, or any mechanism which makes private credit more costly.

3.6 Government and Central Bank

We characterize the government and the central bank as a set of policy rules:

a monetary policy rule, that responds to deviations of inflation relative to the target $\overline{\pi}$,

$$i_t = i_{t-1}^{\rho_i} \left(\bar{i} \left(\frac{\pi_t}{\overline{\pi}} \right)^{\varphi_\pi} \right) \exp\left(\varepsilon_t^{\mu}\right) \tag{41}$$

a FX intervention rule, which responds to real exchange rate deviations from its steady state value,

$$q_t r i_t^* = \bar{ri}^* - \Psi_q \left(\frac{q_t}{\bar{q}} - 1 \right) \tag{42}$$

a regulation premium rule, which responds to total credit deviations from its steady state value,

$$rp_t = \exp\left(\mu_{rp} \left(\frac{credit}{\overline{credit}} - 1 \right) \right) \tag{43}$$

and a set of accounting equations that have to be satisfied every period:

$$q_t r i_t^* = b_t \tag{44}$$

$$\tau_t = b_{t-1} + q_t \left(1 + r_{t-1}^*\right) r i_{t-1}^* - \left((1 + r_{t-1})\, b_{t-1} + q_t r i_{t-1}^* \right). \tag{45}$$

The first equation is the balance sheet of the central bank: on the left hand side appears the value of the international reserves (in real terms of local currency) and on the right hand side the bonds issued to perform sterilized operations. The second equation states that the proceeds of the central bank operations are the result of bond sales and FX purchases (both net of interest payments). These proceeds are transferred back to households in a lump-sum way.

3.7 Oil sector

One key aspect of the model is the role of oil. The value of oil activities (in units of the final composite goods) in the economy evolves exogenously according a process[4]:

$$oil_t = \rho_{z^{oil}} oil_{t-1} + (1 - \rho_{z^{oil}}) \log \left(\overline{oil}\right) + \varepsilon_t^{oil}. \tag{46}$$

[4]We assume that oil shocks are exógenous to the small open economy and we do not diferenciate the nature of the oil shok, this involves modeling a global block in which the dynamics of the oil price is endogenous and depends on the overall activity.

The revenues from oil activities are transferred to households. Thus changes in these revenues affect the households budget constraint. In addition to this effect, we model the role of oil as affecting the interest rate premium that the economy faces when borrowing or lending abroad.

$$(1+i_t^*) = (1+\bar{r}^*)\,(1+\pi_t^*)\, z_t^{i^*} \frac{\exp\left(\nu_{b^*}\left(\frac{q_t b_t^*}{GDP_t} - \bar{b}^*\right)\right)}{\exp\left(\nu_{oil}\left(oil_t - \overline{oil}\right)\right)} \tag{47}$$

where $GDP_t = q_t\,(1-\zeta)\,oil_t + p_t^N y_t^N + p_t^T y_t^T$ and

$$z_t^{i^*} = \rho_{z^{i^*}}\, z_{t-1}^{i^*} + (1-\rho_{z^{i^*}})\log\left(\bar{z}^{i^*}\right) + \varepsilon_t^{z^{i^*}}$$

$$\pi_t^* = \rho_{\pi^*}\,\pi_{t-1}^* + (1-\rho_{\pi^*})\log\left(\overline{\pi}^*\right) + \varepsilon_t^{\pi^*}$$

are exogenous external shocks. This equation states that the interest rate at which the economy borrows abroad grows as the stock of external debt increases but falls with the value of the stock of oil in the economy. Besides helping to close the small open economy model, this device is a simple way to capture the idea that an economy which discovers new oil or enjoys higher oil prices, not only relaxes the households budget constraint but also makes the economy more credit-worthy and reduces its "risk premium". Although this is an *ad-hoc* device, we believe it captures the idea that a real asset, like the stock of oil available for extraction, influences the external borrowing premium. For instance, a country like Venezuela with a large stockpile of oil, faces a lower external premium when compared to other countries with fewer oil reserves.

4 Estimation

There are two types of parameters in the model. One type of parameters are calibrated and the other type are estimated.

The set of calibrated parameters are those that affected the steady state of the model and therefore are chosen in order to match the long run relations observed in the data. Table (1) shows the values of the calibrated parameters.

We begin by discussing the parameters that affect the utility function. The discount factor β is set in order to obtain a real interest rate of 2.5% in the long run. The risk aversion coefficient σ is set to one, implying a logarithmic utility function in consumption. The parameter η is also set to one, therefore the labor supply elasticity is unitary. And finally, as is standard in the literature, the parameter χ is chosen in order to obtain an average supply of hours of $1/3$. The external real interest rate, $\overline{r}^\star$, is also set to 2.5% and the domestic and external inflation targets, $\overline{\pi}$ and $\overline{\pi}^\star$, are set to 3%. This implies a long run real depreciation in the model equal to zero.

The consumption bundle in the model is composed by nontradable and tradable goods, we are assuming an almost unitary elasticity of substitution, ω, between these two goods and since γ affects the share of nontradable consumption in the bundle, the parameter is chosen to match the long run share of nontradable consumption.

The nontradable technology in the model includes labor and capital, the elasticity of substitution between them, ω_N, is set near to one and the share of labor in the production function, α^N , implies a labor intensive technology. The total amount of labor used in the production combines labor supplied by the household and supplied inelastically by the entrepreneurs h^{Ne}. The share of household labor relative to total labor, Ω^N, is set to 0.95, in line with the share of business owners in the total labor workforce as reported in Mejia (2009).

Another parameters that affect production are those related with the capital demand from the entrepreneurs. In this case, the external finance premium depends on $\overline{\nu}^N$, depends also on the parameter

Table 1: Parameter Calibration

Parameter	Description	value
β	Discount Factor	0.9938
σ	Risk aversion	1.0000
η	Inverse of labor supply	1.0000
χ	Scale parameter	6.2574
$\overline{r}^{\star}$	External real interest rate	1.0062
$\overline{\pi}$	Inflation Target	1.0074
$\overline{\pi}^{\star}$	External inflation target	1.0074
ω	Elasticity of substitution b/w T and NT	0.9000
γ	Share in consumption bundle b/w T and NT	0.7000
ω_N	Elasticity of substitution b/w Labor and Capital	0.9000
α_N	Share of labor in the production	0.6000
Ω^N	Share of household labor in total labor	0.9000
$\overline{\nu}^N$	External finance premium parameter	0.0100
ϕ_N	Share of net worth consumed by entrepreneur	0.9000
δ_N	Depreciation rate	0.0250
h^{Ne}	Entrepreneur labor supply	0.0100
$\overline{\theta}$	Elasticity of substitution b/w intermediate goods	5.0000
ω_T	Elasticity of substitution b/w Labor and Capital	0.9000
α_T	Share of labor in the production	0.6000
Ω^T	Share of household labor in total labor	0.9000
$\overline{\nu}^T$	External finance premium parameter	0.0100
ϕ_T	Share of net worth consumed by entrepreneur	0.9000
δ_T	Depreciation rate	0.0250
h^{Te}	Entrepreneur labor supply	0.0100
$\overline{b}^{\star}$	Stock of net foreign assets	1.2000
$\overline{ri}^{\star}$	Stock of international reserves	0.1000
$\overline{oil}$	Stock of oil reserves	5.1812
ζ	Extraction rate	0.9500
$\overline{z}^T$	Mean exogenous technological process	1.0000
$\overline{z}^N$	Mean exogenous technological process	1.0000
$\overline{z}^{i^{\star}}$	Mean exogenous external interest rate process	1.0000
$\overline{z}^u$	Mean exogenous preferences process	1.0000
$\overline{z}^{x^T}$	Mean exogenous investment process	1.0000
$\overline{z}^{x^N}$	Mean exogenous investment process	1.0000

Table 2: Long run relations

Relations	Model	Data
labor	32.21%	28.58%
Real interest rate	2.47%	2.50%
Inflation rate	2.96%	3.00%
Nominal interest rate	5.43%	6.07%
Nominal nontradable loan rate	10.05%	13.86%
Nominal Tradable loan rate	9.95%	10.24%
Consumption / GDP	73.67%	82.34%
Consumption nontradable / Consumption	62.99%	87.32%
Consumption tradable / Consumption	38.56%	12.82%
Investment / GDP	11.37%	21.22%
Investment nontradable / Investment	60.95%	59.95%
Investment tradable / Investment	41.59%	40.20%
nontradable output/ GDP	64.77%	59.03%
Tradable output/ GDP	24.22%	33.76%
Oil production/ GDP	11.00%	7.21%
Stock of oil / Annual GDP	55.02%	64.63%
Net foreign assets / Annual GDP	30.00%	28.29%
International reserves/ Annual GDP	10.00%	13.13%
Credit / Annual GDP	96.48%	28.02%

ϕ_N which defines the consumption for the entrepreneurs and depends on the depreciation rate, δ^N. All these parameters are chosen in order to fix observed long run value of the interest rate spread. In addition, the model assumes imperfect competition in the nontradable sector. The elasticity of substitution between the differentiated nontradable goods $\overline{\theta}$, implies a mark up of 25%. This value is taken from previous studies for Colombia (Restrepo (2005) and Perez (2005)).

The same arguments are used to pick the parameters for the tradable sector, the only difference arises because in this sector there is perfect competition and therefore there is no mark up.

The parameter $\bar{b}^*$ determines ratio of net foreign assets to GDP, $\overline{ri}^*$ determines the ratio of international reserves to GDP, $\overline{oil}$ the stock of oil reserves relative to GDP and ζ the extraction rate of the oil reserves. Finally, the mean for all exogenous process are set equal to one. The table (2) shows the long run relations obtained from the calibrated parameters and their empirical counterparts.

The second set of parameters are estimated using Bayesian techniques. These parameters mainly affect the dynamic behavior of the model and are related with investment adjustment costs, nominal rigidities, interest rate spreads, the policy rule coefficients and the parameters for the exogenous process. During the estimation the parameters that determine the FX intervention Ψ_q and the macroprudencial regulation μ_{rp} are set equal to zero. The parameter Table (3) shows their prior-posterior distributions.

The data used in the estimation is expressed in quarterly growth rates and is assumed to have a measurement error. We included output in tradable, nontradable and mining sectors, total consumption (public and private), total investment, commercial loans for tradable and nontradable and saving deposits. Additionally we included tradable and non tradable inflation, nominal devaluation, interbank

Table 3: Estimation results

	Prior Mean			Posterior Mean	
	distribution	Mean	Var	Mean	std
parameters					
ρ_i	beta	0.5000	0.0225	0.4587	0.0859
φ_π	gamma	1.5000	0.2500	1.0206	0.0138
ϵ	beta	0.5000	0.0225	0.1582	0.0537
ι	beta	0.5000	0.0225	0.4798	0.1746
ρ_{z^T}	beta	0.5000	0.0225	0.9112	0.0305
ρ_{z^N}	beta	0.5000	0.0225	0.3277	0.1270
$\rho_{i^\star}$	beta	0.5000	0.0225	0.6159	0.1919
$\rho_{\pi^\star}$	beta	0.5000	0.0225	0.6329	0.1079
$\rho_{z^{oil_1}}$	beta	0.5000	0.0225	0.9196	0.0189
ρ_θ	beta	0.5000	0.0225	0.4951	0.1756
ρ_{z^u}	beta	0.5000	0.0225	0.9826	0.0072
$\rho_{z^{xN}}$	beta	0.5000	0.0225	0.2919	0.0972
$\rho_{z^{xT}}$	beta	0.5000	0.0225	0.7623	0.0683
ρ_{ν^T}	beta	0.5000	0.0225	0.2281	0.0710
ρ_{ν^N}	beta	0.5000	0.0225	0.1364	0.0507
ψ_N	gamma	1.0000	0.2500	3.1358	0.8659
ψ_T	gamma	1.0000	0.2500	6.8434	1.0891
ν_{b^*}	gamma	0.0100	0.0003	0.0041	0.0016
ν_{oil}	gamma	0.0100	0.0003	0.0136	0.0029
variances					
ε^{z^T}	inv_gamma	0.0125	Inf	0.0093	0.0011
ε^{z^N}	inv_gamma	0.0125	Inf	0.0055	0.0008
$\varepsilon^{z^{i^\star}}$	inv_gamma	0.0125	Inf	0.0032	0.0005
ε^{oil}	inv_gamma	0.0125	Inf	0.0347	0.0057
$\varepsilon^{\pi^\star}$	inv_gamma	0.0125	Inf	0.0045	0.0008
ε^{μ}	inv_gamma	0.0125	Inf	0.0028	0.0003
ε^{θ}	inv_gamma	0.0125	Inf	0.0111	0.0023
ε^{z^u}	inv_gamma	0.0125	Inf	0.0126	0.0028
$\varepsilon^{z^{xT}}$	inv_gamma	0.0125	Inf	0.0456	0.0084
$\varepsilon^{z^{xN}}$	inv_gamma	0.0125	Inf	0.0203	0.0034
ε^{ν^T}	inv_gamma	0.0125	Inf	0.0627	0.0174
ε^{ν^N}	inv_gamma	0.0125	Inf	0.0579	0.0194

lending rate and a measure of external interest rate augment with risk premium. In appendix B there is detailed description of the database used for the estimation of the model.

5 Macro Policy in Response to Oil Shocks

We use the estimated model to perform several quantitative exercises. First, we compute the shock decomposition analysis. We quantify the historical importance of external and domestic shocks in the colombian data. Although our focus is commodity export shocks, we also study the relative importance of the remaining ones. Second, we compute the Bayesian impulse-response functions. The objective is to visualize in more detail the macroeconomic impact of one-off commodity shocks and the policy response of the central bank. The third exercise is a counterfactual experiment to assess the effects of an unexpected reversal of a commodity shock. There, agents take decisions based on the idea that the value of commodity production will increase persistently for several quarters. However, they do not anticipate the possibility of a sudden reversal. Our interest is to use the model to analyze the role of conventional monetary policy and macro-prudential policies when the sudden commodity collapse takes agents by surprise.

5.1 Shock decomposition

Our first quantitative experiment is a shock decomposition analysis. The model considers 12 shocks. We label three of them as external and the rest as domestic. The external shocks are: one to the external interest rate spread that the economy faces when borrowing abroad, another is a foreign inflation shock and the third is a shock to commodity exports. It can be either commodity prices or quantities. The domestic ones are shocks to productivity, investment and interest rate spreads all to both sectors (tradable and nontradable), markup as well as a monetary policy shock. Our aim is to gauge the estimated contribution of the considered shocks on the observed movements of tradable and nontradable output and credit, aggregate consumption, inflation, the real exchange rate and nominal interest rates. Figure (4) reports the evolution of these variables (solid black line) from the second quarter of 2000 to the first quarter of 2013. The colored bars represent the shock contributions.

The shock decomposition of these time series confirms a conventional finding in many of the models used in the international macro literature. The role of foreign interest rate spread shocks appear to be small. Also the role of foreign inflation shocks is negligible. Most of the importance of foreign shocks in the Colombian macro series stems from commodity export movements, as we suspected by the documented evidence in the first part of the paper.

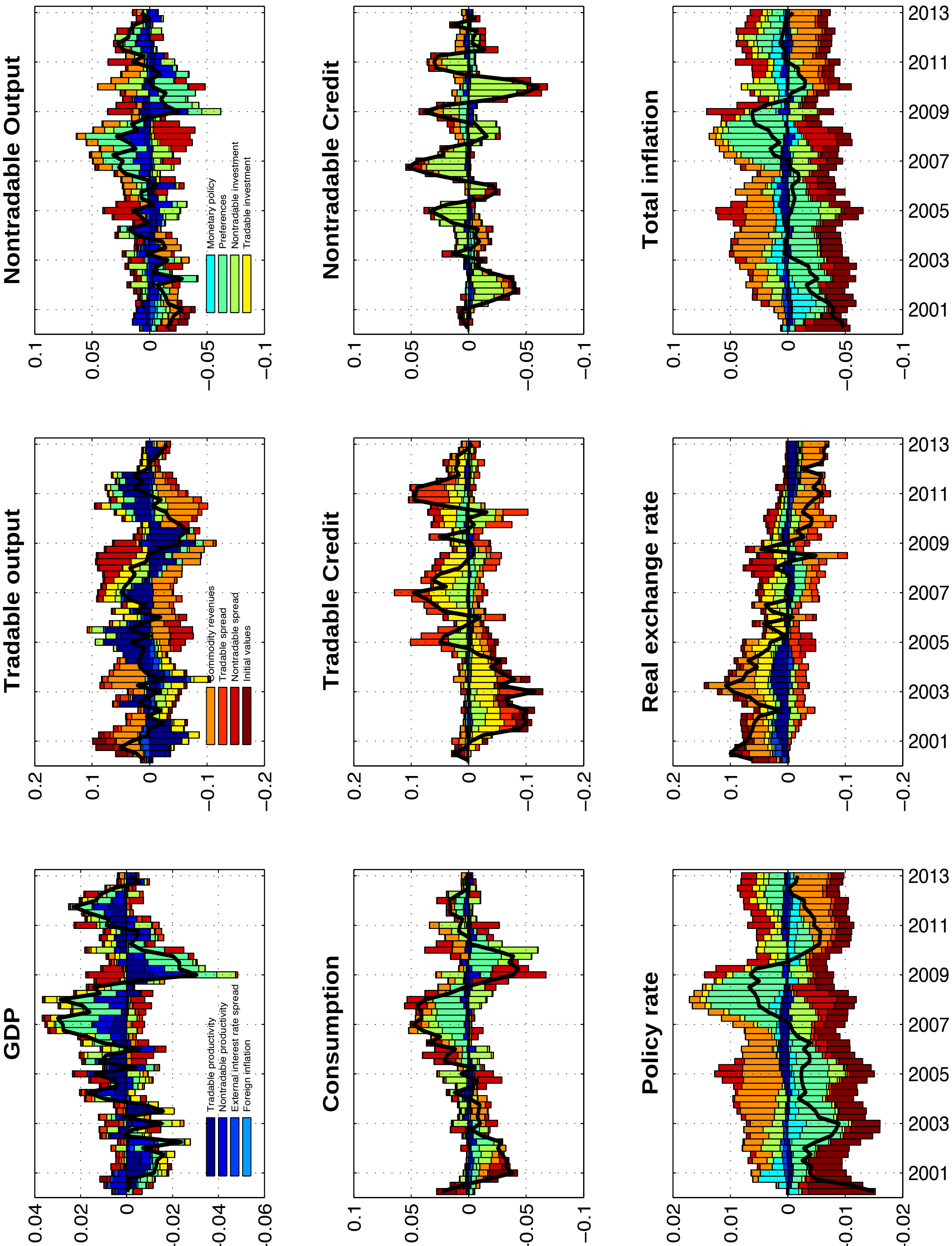
The mechanism through which this shock transmit to the economy is not apparent at first sight. The decomposition of output reveals that both tradable and nontradable productivity as well as preference shocks explain most of the observed output fluctuations in Colombia. The contribution of commodity export shocks to the aggregate output cycle is small. This is not surprising as the share of those exports on GDP is small.

However, a deeper inspection by sectors reveals a clearer picture of the role of commodities in the economy: the largest contribution of such shocks is to tradable and nontradable output, the real exchange rate, inflation and policy rates. In the last ten years commodity export shocks have been an important drag on tradable output and a booster to nontradable production.

This contribution is also evident on relative prices as commodity exports have been a major source of real exchange rate appreciation. This fact implies that tradable inflation is also affected by commodity shocks. From 2000 up to the first half of 2008 these shocks were an important source of inflationary pressures. This conditions have reversed since then. Now commodity shocks are helping to ease inflation. As the central bank sets its policy rate focusing mainly on inflation, interest rate movements reveal essentially the same shocks which impact inflation.

Despite these large real effects on sectoral output and relative prices, commodity export shocks have a smaller contribution to tradable and nontradable credit and consumption.Credit fluctuations

Figure 4: Historical Shock decomposition



are mostly dominated by investment specific shocks, specially in the case of nontradable credit. The inter-sectoral effects of specific shocks go from nontradable credit shocks to tradable credit, but not the other way around. More precisely, tradable investment shocks have no impact on nontradable credit, while nontradable investment shocks spillover to tradable credit. This type of credit is much more responsive to interest rate credit spread shocks than nontradable credit. Thus, based on these findings, we are inclined to conclude that the importance of commodity export shocks appears to lie more on its sectoral effects than on its impact on aggregate activity. GDP fluctuations may mask the reallocation effects that commodity export shocks entail.

Preference shocks appear to be an important source of macroeconomic fluctuations, as they affect GDP through nontradable output, consumption, inflation and the policy rate. However, they do not affect both types of credit. Their contribution to real exchange rate and tradable output fluctuations has also been small. Put together, these results suggest that credit cycles in Colombia does not appear to be driven by aggregate domestic shocks, nor by foreign shocks but mostly by sectoral specific shocks and their interaction.

5.2 Impulse response

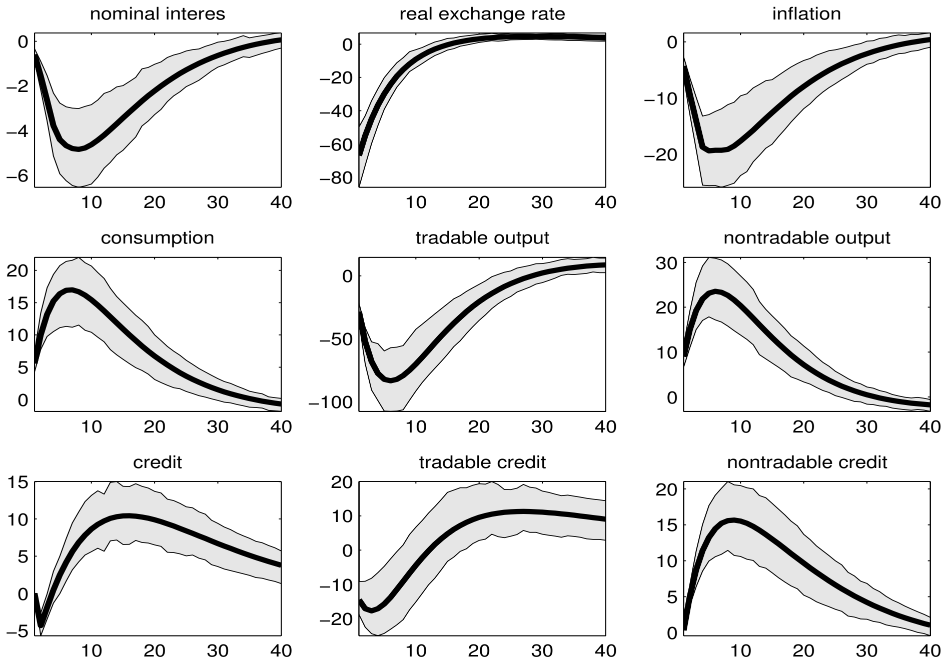
The model can be used to explain the dynamics of the economy after a commodity exports shock. There are several reasons that induced us to think that understanding the effects of these types of shocks is important. First, there is the documented evidence in the first part of this paper. Second, even if we disregard it, there is large body of literature in the international macroeconomics field that studies sectoral reallocation after such shocks. We have set up a model in which we assume that the nontradable sector in aggregate operates in domestically shielded final output markets and faces little direct competition from abroad. Also, nontradable sectors import a significant amount of their inputs. These two facts have been documented in Echavarría, González and Mahadeva (2013).

The mechanism that we have in mind to explain the response of the economy to a commodity boom, illustrated in Figure (5), is as follows: assume that many retail products are originally produced abroad. Given the relative shelter from foreign competition and the importance of imported inputs for nontradable sectors, the exchange rate appreciation lowers the cost of nontradable sectors' inputs without lowering their domestic output price. This boosts the nontradable sectors' value-added incomes and permits an expansion in the scale of production. Finally, another favorable impulse to the nontradable sector arises through the reaction of the consumer to the lower exchange rate. In the Dutch Disease literature, this was called the spending effect. In Colombia, an important share of imported goods goes into household consumption. Thus, the real exchange rate appreciation raises the real value of household income. In aggregate, this offsets the loss of income from those consumers who work in the tradable sectors. The rise in consumers´ income leads them to demand more. As most of domestic demand is supplied by the nontradable sector, this represents another channel through which the oil price rise benefits the nontradable sectors. Circumstancial evidence suggests that the combination of all these effects can be powerful, but especially when a boom in bank credit is also triggered by the appreciation.

In our model, when there is a positive commodity exports shock, households experience an increase in their income and wealth and therefore raise their spending. This implies a greater demand for both tradable and nontradable goods. The fall in the external risk premium associated with the improved net foreign debt to real assets position generates an appreciation of the real exchange rate as well as the increased demand of nontradable consumption. The increased demand for tradable goods is met by a greater share of imported goods than previously. The demand surge after the oil price shock also drives entrepreneurs to increase their demand for loans. This type of adjustment is conventional in a tradable-nontradable model.

However, in our model a key mechanism works through the external interest rate risk-premium. This premium has an endogenous component, which depends not only on net external debt but also on the stock of the real commodity resource. A commodity price shock raises the value of this real asset lowering the risk premium that the economy faces in international financial markets. Thus, the income

Figure 5: Impulse response to a commodity exports shock



effect on households budget constraint may be small but the wealth effect, specially since overall the economy has a negative net foreign asset position, may be large. Without this mechanism, the effects of a commodity boom on the real exchange rate in a three sector model would be smaller.

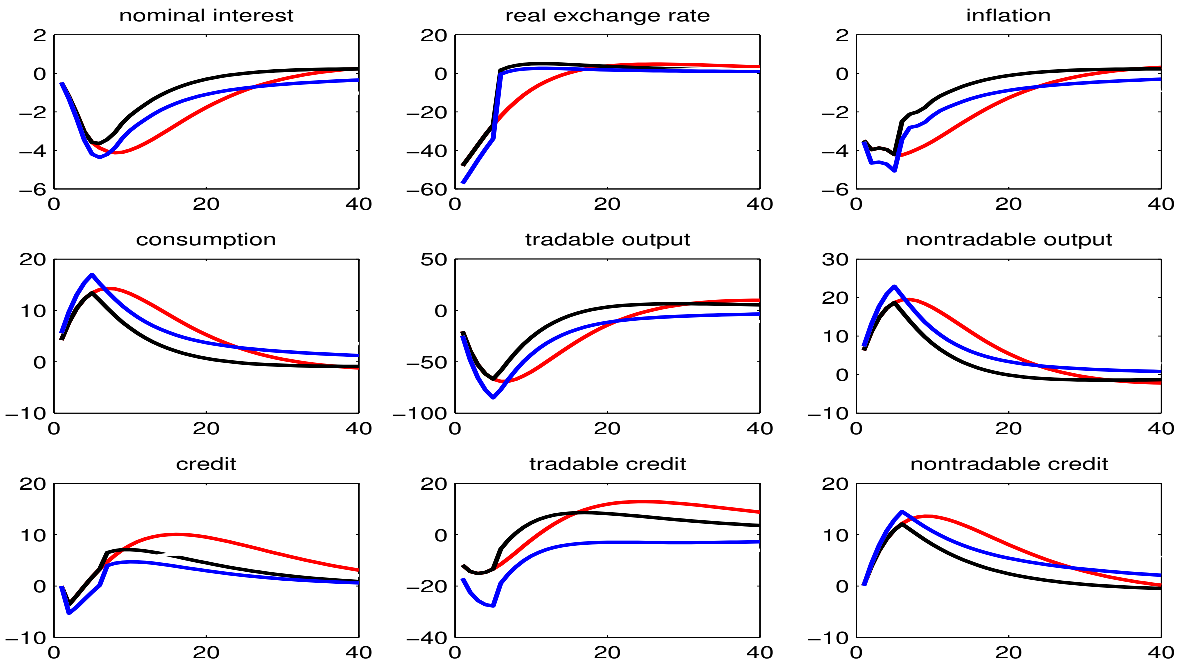
There is an additional channel in our model induced by the presence of the sectoral financial accelerator. The appreciation of the exchange rate also leads to a fall in the value of the assets of the tradable sector, lowering the value of its collateral and consequently, rising the external financing premium that tradable firms pay to commercial banks. This increase in financing costs coupled with the lower demand of domestically produced tradable goods drives further down employment in this sector. In contrast, the nontradable sectors benefit from an exchange rate appreciation. This channel is present in the model but it is quantitatively small in the Colombian data, as the shock decomposition has already revealed.

5.3 Unexpected commodity exports reversal

The adjustment of the economy described by the impulse response functions reflects the best reactions of economic actors, given the financial restrictions they face, and, also crucially, under the assumption that they expect that the commodity boom will not be reversed. However, in practice, agents may fail to appreciate that commodity prices are notoriously volatile. During the boom, the economy's aggregate debt and private credit are higher and also the "size" of the tradable sector is lower. Thus, this sectors' ability to absorb nontradable sector employees is limited by its capital stock. This creates a form of "vulnerability" and a prudent policy maker may consider the use of alternative policy instruments, like regulation policies aimed to contain aggregate credit. Our question is to determine quantitatively if alternative policies have different effects at the macro level and/or at the sectoral level.

The first and conventional option is to adjust the central bank reference rate in response to total inflation. In this case, the bank controls both the expansion of aggregate demand and credit. A second policy option is to combine the policy rate adjustment with macro-prudential policies, which respond to credit expansion. For instance, economic authorities have implemented policies to increase interest rates on commercial loans. To capture the idea of a macro-prudential policy in our model, we added

Figure 6: Effects of macroprudencial policy



Black: There is a unexpected commodity price reversal and monetary policy is conducted in a conventional way.
Blue: There is a unexpected commodity price reversal and conventional monetary policy is complemented with a macro-prudential policy on credit.
Red: There is no commodity price reversal and monetary policy is conventional.

a "regulation premium" to the lending rates in both sectors. This premium increases when domestic credit exceeds its steady state value and it can be set independently from the policy rate. For further details on this type of policy rule, see Unsal (2013).

Now, to mimic the dynamic pattern of a typical commodity shock, we simulate it as an AR(2) process. So, we replace the AR(1) process used for estimation, with the AR(2). The rest of the parameters of the model remain intact and those of the AR(2) process are configured in such a way that after an initial increase in the price of oil agents can expect additional increases in the future (tracing a hump shape). This type of pattern cannot be reproduced using an AR(1). We are aware that by changing the commodity shock process we would obtain possibly different policy rules and parameter estimates. However, we do so just to perform a counterfactual experiment to capture the idea of a sudden reversal in commodity prices. Thus, an unexpected negative shock is added six quarters after the initial commodity price hike.

Figure (6) depicts the response of the economy after a commodity shock under three scenarios. The red line shows the case in which there is no sudden unexpected commodity price reversal and monetary policy is conducted as the estimated Taylor rule. The black and blue lines show what happens when there is a reversal. The difference between the black and the blue lines is that, in the latter, conventional monetary policy is complemented with a macro-prudential policy.

We start considering the red line. It describes the scenario of a long lasting rise in the commodity export value. Initially there is a shock of 25 bps which does not reverse immediately but rises to 60 bps six quarters ahead. Thus, according to the estimated parameter values, the rise in commodity exports lead to an immediate significant appreciation of the exchange rate of 50 bps, which is unwound slowly thereafter.[5] The RER appreciation lowers tradable sector output initially by 20 bps. Tradable output gradually returns to its former level, as the exchange depreciates back slowly. Monetary policy

[5]The real exchange rate is shown as dollars per peso so that a fall is an appreciation.

is adjusted to keep inflation under control. As there is no macroprudential objective or instrument, private credit is allowed to increase, and, indeed, its level rises to reach 10bps at its peak. Thus, if commodity exports rise and are not expected to be reversed, monetary policy would have to be tightened to deal with non tradable inflation (not shown).

In reality, there is not much certainty that any commodity boom will be sustained. For instance, commodity prices are affected by supply and demand shocks and the possibility of storage implies that the price is sensitive to future prospects. Agents would do well to incorporate the sudden reversal risk in their actions. In our exercise, they fail to do so. However, to analyze the role of macro-prudential policies, we consider the case in which the central bank (for some unexplained reason) implements a regulation to tackle the commercial credit expansion.

The necessary adjustment of the economy after a sudden commodity boom reversal can be seen by comparing the red and black lines. As before, only monetary policy is active. Figure (6) reveals that at the time of the reversal, there is a sharp real depreciation together with a fall in aggregate consumption. Nontradable sector debt also contracts. This reflects the sudden realization that past investments in the sector will not be justified. Moreover, nontradable inflation (not shown) declines strongly at the time of the reversal. Inflation falls because of the labor market adjustment. In particular, real wages fall due to several factors. First, the real exchange rate depreciation triggers a flow of employment from the nontradable to the tradable sector causing an excess supply in the tradable sector. Second, labor demand in the tradable sector is lowered because there is shortage of domestic demand for these goods. Third, the tradable sector's ability to "absorb" the greater labor supply at any given wage is limited by its capital stock which had decreased in the booming phase. Note, however, that investment in the tradable sector increases upon the commodity reversal and the consequent depreciation. To some extent, credit returns to this sector and output recovers. Thus, the sectoral asymmetries linked to the exchange rate movement are also present in the case of a reversal.

The use of macro-prudential policies has important macroeconomic implications. First, commercial credit is stabilized as the policies are designed to do. Note that this happens even with a looser monetary policy. Exchange rate pass-through lowers tradable inflation and dominates the nontradable inflation pick-up. However, this macro-prudential policy has sectoral consequences. Credit to tradable sector falls even further during the boom, and credit to nontradable sector expands more rapidly. As a result, there is a sharper real exchange rate appreciation. This exacerbates the type of vulnerability that we have stressed. Note also that the sectoral effects are so strong that the fall in tradable sector credit overshadows the nontradable one, leading to a fall in commercial credit. Consequently, once the commodity boom reverses, total commercial credit reacts less, nontradable credit contracts less and tradable credit reacts more slowly.

These results illustrate that macro-prudential policy can be an effective complementary tool in stabilizing credit. However, in the presence of sectoral financial accelerators it can exacerbate the reallocation process. The tradable sector faces a higher interest rate because of macro-prudential policy and, additionally, suffers from the devaluation of its collateral; a reflection of the real exchange rate appreciation, which leads to higher external finance premium for those companies. As a result, investment in the tradable sector falls more when macro-prudential policy is employed than without it. Therefore, the adjustment of tradable sector after commodity price reversal takes longer. While the macroprudential policy limits the buildup of debt, our simulations illustrate that it also is likely to boost further the nontradable sector and hamper the tradable one.

6 Final Remarks

In the last four decades empirical evidence shows a strong and positive association between the cyclical component of the real price of Colombian exports and the cyclical component of real GDP. Periods of high export prices coincide with economic booms, while periods of lower than usual prices are associated with recessions. In addition, besides contributing significantly to the GDP cycle volatility, the effects of these shocks are widespread as they affect real and nominal variables, like consumption, investment and inflation, as well as other financial variables, like credit. In this study we performed an oil price shock identification analysis in which we analyzed how a key set of macroeconomic variables have behaved around oil price booms and busts. Following Hamilton (2003) we found the quarters during which there were oil price shocks and found that before the peak of large and steady oil price hikes, country risk falls, output rises, private consumption increases, domestic credit booms, trade balance improves, credit to tradable sector contracts while credit to nontradable sector expands and the real exchange rate appreciates. In general, after the sudden oil price reversal all these patterns shift in the opposite direction.

To explain these facts, we used Bayesian techniques to estimate a New-Keynesian-DSGE model for financial policy analysis that takes into account key features of the Colombian economy. We modeled the economy as a commodity-driven transfer problem, in which high oil prices increase export revenues and cause higher demand for tradable and nontradable goods. The model included three sectors (an exogenous commodity enclave, nontradable and tradable sectors) and used the Bernanke, Gertler and Girlchrist setup to introduce an external financing premium relating net worth of entrepreneurs in the tradable and nontradable sectors to their financing costs, and it also modeled separately the central bank and commercial banks. We stressed the role of sectoral financial frictions and their interplay with nominal rigidities as well as monetary policy. A key aspect of the model is that it was solved by approximation techniques and the economy's long-run net foreign assets was pinned down by assuming that the external interest rate was an exogenous, increasing function of the ratio of external debt to the stock of oil.

The economic structure model allowed us to conclude that the dynamics of the proposed transfer problem can be the efficient response of the economy to exogenous terms-of-trade shocks. However, the adjustment is inefficient because the equilibrium is distorted by financial frictions. In the commodity boom phase, credit growth and real appreciation transferred net worth from the tradable to the nontradable sector, which enhanced borrowing capacity in the latter, and then a sudden reversal in commodity prices caused a reallocation back to the tradable sector and caused the nontradable sector to experience a credit crunch. Moreover, a pecuniary externality was also at work in the process, because in the Bernanke, Gertler and Girlchrist financing premium the value of net worth depends on equilibrium sectoral relative price movements that individual agents do not internalize when they make borrowing decisions. The presence of the financial inefficiency gives a rationale for policy intervention.

Under the assumption that the policy maker has only a limited set of imperfect instruments, we enhanced the model to account for the role of macroprudential policy. In the baseline specification of the model, the central bank set the nominal interest rate using a monetary policy rule, but we also considered exchange rate and credit policy rules. These rules, although *ad-hoc*, made an interesting contribution because they were formulated as functions of the deviations of the real exchange rate from its long-run target (for the foreign exchange intervention rule) or the private sector credit from its steady state value (for the regulatory premium). Hence, these rules tried to approximate the prudential nature of the policy because by construction they induce larger adjustments in the policy instruments in boom times (i.e. when the real exchange rate and/or credit exceed their long run levels), and converge to turning off both instruments in the long run, when their driving variables settle at their steady state values.

The effectiveness of the macroprudential policy was evaluated by studying the response of the economy to an oil price hike lasting six quarters, followed by an unexpected reversal, differs with and without the macroprudential policy rules. In the case without the rules, the only policy rule at play was a Taylor rule. The results showed only small differences with or without the policy rules governing currency intervention and the regulatory premium. These results could be interpreted as indicating that the model's financial frictions are not the empirically relevant ones, but they may also suggest that the perturbation approach to smooth the convex borrowing costs implied by the financial frictions is weakening their real effects. The results also suggest that it would be useful to explore the implications of varying the values of the parameters that characterize the elasticities of the macroprudential policy instruments to their corresponding determinants. Intuitively, it seems that in the limit if the elasticities were very high, the financial sector could have strong real effects because of large changes in financing costs via the regulatory premium, and large adjustments in the central bank's balance sheet via the foreign exchange interventions.

In our work we also quantified the historical importance of external and domestic shocks in the Colombian data. Although our focus was on commodity export shocks, it was also interesting to assess the relative importance of other shocks. Our shock decomposition of the Colombian time series confirmed a conventional finding in many of the models used in the international macro literature. The role of foreign interest rate spread shocks appear to be small. Also the role of foreign inflation shocks is negligible. Preference shocks appear to be an important source of macroeconomic fluctuations, as they affect GDP through nontradable output, consumption, inflation and the policy rate. However, they do not affect both types of commercial credit. We also found that their contribution to real exchange rate and tradable output fluctuations was quantitatively small. Most of the importance of foreign shocks in the Colombian macro series came from commodity export movements, as we suspected by the documented evidence in the first part of the paper. However, the shock decomposition analysis also revealed that despite these large real effects on *sectoral* output, their overall quantitive significance was relatively small. The importance of commodity export shocks appears to lie more on its reallocation effects than on its impact on *aggregate* activity. GDP fluctuations masked the efficient reallocation effects that commodity export shocks entailed.

Our quantitative model could be extended along several dimensions. A promising one could be to consider the case of an endogenous oil extraction process in which oil producers respond to economic incentives, like price changes, interest rates swings, discovery shocks, to name a few. In turn, oil extraction and reserve accumulation may affect the country risk in non trivial ways. For instance, oil price shifts may affect the valuation of oil reserves in the short term, but their endogenous response may mitigate partially these shocks reducing the country risk premium in the future. A net debtor country may even experience a fall on its debt to output ratio again affecting spreads in the near and longer terms. Studying deeper and quantitatively these effects and their monetary policy implications are of central interest to central banks and the design of monetary policy.

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A Appendix: The Complete Model

$$c_t + d_t = (1-\zeta)\, q_t oil_t + \tau_t + \xi_t^N + w_t^h h_t + (1+r_{t-1})\, d_{t-1} \tag{48}$$

$$c_t^{-\sigma} = \lambda_t \tag{49}$$

$$\chi h_t^{\eta} = w_t^h \lambda_t \tag{50}$$

$$\lambda_t = \beta \mathbb{E}_t \left[\lambda_{t+1} (1+r_t)\right] \tag{51}$$

$$q_t \lambda_t = \beta \mathbb{E}_t \left[\lambda_{t+1} q_{t+1} (1+r_t^*)\right] \tag{52}$$

$$c_t = \left(\gamma^{\frac{1}{\omega}} \left(c_t^N\right)^{\frac{\omega-1}{\omega}} + (1-\gamma)^{\frac{1}{\omega}} \left(c_t^T\right)^{\frac{\omega-1}{\omega}}\right)^{\frac{\omega}{\omega-1}} \tag{53}$$

$$c_t^N = \gamma \left(p_t^N\right)^{-\omega} c_t \tag{54}$$

$$c_t^T = (1-\gamma) \left(p_t^T\right)^{-\omega} c_t \tag{55}$$

$$k_t^N = x_t^N + (1-\delta_N)\, k_{t-1}^N - \frac{\psi_N}{2} \left(\frac{x_t^N}{k_{t-1}^N} - \delta_N\right)^2 k_{t-1}^N \tag{56}$$

$$p_t^{kN} \left(1 - \psi_N \left(\frac{x_t^N}{k_{t-1}^N} - \delta_N\right)\right) = p_t^N \tag{57}$$

$$k_t^T = x_t^T + (1-\delta_T)\, k_{t-1}^T - \frac{\psi_T}{2} \left(\frac{x_t^T}{k_{t-1}^T} - \delta_T\right)^2 k_{t-1}^T \tag{58}$$

$$p_t^{kT} \left(1 - \psi_T \left(\frac{x_t^T}{k_{t-1}^T} - \delta_T\right)\right) = p_t^T \tag{59}$$

$$y_t^N = z_t^N \left(\alpha_N^{\frac{1}{\omega_N}} \left(h_t^N\right)^{\frac{\omega_N-1}{\omega_N}} + (1-\alpha_N)^{\frac{1}{\omega_N}} \left(k_{t-1}^N\right)^{\frac{\omega_N-1}{\omega_N}}\right)^{\frac{\omega_N}{\omega_N-1}} \tag{60}$$

$$h_t^N = \left(h_t^{Nh}\right)^{\Omega_N} \left(h^{Ne}\right)^{1-\Omega_N} \tag{61}$$

$$w_t^h = p_t^W \Omega_N z_t^N \left(\alpha_N \frac{y_t^N}{z_t^N h_t^N}\right)^{\frac{1}{\omega_N}} \frac{h_t^N}{h_t^{Nh}} \tag{62}$$

$$w_t^{Ne} = p_t^W (1-\Omega_N)\, z_t^N \left(\alpha_N \frac{y_t^N}{z_t^N h_t^N}\right)^{\frac{1}{\omega_N}} \frac{h_t^N}{h^{Ne}} \tag{63}$$

$$r_t^{kN} = \frac{p_t^W z_t^N \left((1-\alpha_N) \frac{y_t^N}{z_t^N k_{t-1}^N}\right)^{\frac{1}{\omega_N}} + (1-\delta_N)\, p_t^{kN}}{p_{t-1}^{kN}} \tag{64}$$

$$r_{t+1}^{kN} = \left(\frac{n_t^N}{p_t^{kN} k_t^N}\right)^{-\nu_N} (1+r_t)\, (rp_t) \tag{65}$$

$$v_t^N = r_t^{kN} p_{t-1}^{kN} k_{t-1}^N - \mathbb{E}_{t-1}\left[r_t^{kN}\right] b_{t-1}^N \tag{66}$$

$$n_t^N = \phi_N v_t^N + w_t^{Ne} h^{Ne} \tag{67}$$

$$n_t^N = p_t^{kN} k_t^N - b_t^N \tag{68}$$

$$p_t^N c_t^{Ne} = (1-\phi_N) v_t^N \tag{69}$$

$$\begin{aligned} 0 \quad = \quad & (1-\theta) p_t^N y_t^N + \theta p_t^W y_t^N - p_t^N \kappa \left(\frac{(1+\pi_t^N)}{\left(1+\pi_{t-1}^N\right)^{\iota} (1+\bar{\pi})^{1-\iota}} \right) \left(\frac{(1+\pi_t^N)}{\left(1+\pi_{t-1}^N\right)^{\iota} (1+\bar{\pi})^{1-\iota}} - 1 \right) \\ & + \mathbb{E}_t \left[\beta \frac{\lambda_{t+1}}{\lambda_t} p_{t+1}^N \kappa \left(\frac{(1+\pi_{t+1}^N)}{(1+\bar{\pi})^{1-\iota} \left(1+\pi_t^N\right)^{\iota}} \right) \left(\frac{(1+\pi_{t+1}^N)}{(1+\bar{\pi})^{1-\iota} \left(1+\pi_t^N\right)^{\iota}} - 1 \right) \right] \end{aligned} \tag{70}$$

$$\xi_t^N = p_t^N y_t^N - p_t^W y_t^N - p_t^N \frac{\kappa}{2} \left(\frac{(1+\pi_t^N)}{\left(1+\pi_{t-1}^N\right)^{\iota} (1+\bar{\pi})^{1-\iota}} - 1 \right)^2 \tag{71}$$

$$y_t^T = z_t^T \left(\alpha_T^{\frac{1}{\omega_T}} \left(h_t^T\right)^{\frac{\omega_T-1}{\omega_T}} + (1-\alpha_T)^{\frac{1}{\omega_T}} \left(k_{t-1}^T\right)^{\frac{\omega_T-1}{\omega_T}} \right)^{\frac{\omega_T}{\omega_T-1}} \tag{72}$$

$$h_t^T = \left(h_t^{Th}\right)^{\Omega_T} \left(h^{Te}\right)^{1-\Omega_T} \tag{73}$$

$$w_t^h = p_t^T \Omega_T z_t^T \left(\alpha_T \frac{y_t^T}{z_t^T h_t^T} \right)^{\frac{1}{\omega_T}} \frac{h_t^T}{h_t^{Th}} \tag{74}$$

$$w_t^{Te} = p_t^T (1-\Omega_T) z_t^T \left(\alpha_T \frac{y_t^T}{z_t^T h_t^T} \right)^{\frac{1}{\omega_T}} \frac{h_t^T}{h^{Te}} \tag{75}$$

$$r_t^{kT} = \frac{p_t^T z_t^T \left((1-\alpha_T) \frac{y_t^T}{z_t^T k_{t-1}^T} \right)^{\frac{1}{\omega_T}} + (1-\delta_T) p_t^{kT}}{p_{t-1}^{kT}} \tag{76}$$

$$r_{t+1}^{kT} = \left(\frac{n_t^T}{p_t^{kT} k_t^T} \right)^{-\nu_T} (1+r_t)(rp_t) \tag{77}$$

$$v_t^T = r_t^{kT} p_{t-1}^{kT} k_{t-1}^T - \mathbb{E}_{t-1}\left[r_t^{kT}\right] b_{t-1}^T \tag{78}$$

$$n_t^T = \phi_T v_t^T + w_t^{Te} h^{Te} \tag{79}$$

$$n_t^T = p_t^{kT} k_t^T - b_t^T \tag{80}$$

$$p_t^T c_t^{Te} = (1-\phi_T) v_t^T \tag{81}$$

$$(1+r_t) = \frac{(1+i_t)}{\left(1+\pi_{t+1}^C\right)} \tag{82}$$

$$p_t^T = q_t \tag{83}$$

$$(1+r_t^*) = (1+\bar{r}^*)\, z_t^{i^*} \frac{\exp\left(\nu_{b^*}\left(\frac{q_t b_t^*}{GDP_t} - \bar{b}^*\right)\right)}{\exp\left(\nu_{oil}\left(oil_t - \bar{oil}\right)\right)} \tag{84}$$

$$h_t = h_t^{Nh} + h_t^{Th} \tag{85}$$

$$y_t^N = c_t^{Ne} + c_t^N + x_t^N + \frac{\kappa}{2}\left(\frac{(1+\pi_t^N)}{(1+\pi_{t-1}^N)^{\iota}(1+\bar{\pi})^{1-\iota}} - 1\right)^2 \tag{86}$$

$$GDP_t = q_t (1-\zeta)\, oil_t + p_t^N y_t^N + p_t^T y_t^T \tag{87}$$

$$\frac{(1+\pi_t^N)}{(1+\pi_t^C)} = \frac{p_t^N}{p_{t-1}^N} \tag{88}$$

$$\frac{(1+\pi_t^T)}{(1+\pi_t^C)} = \frac{p_t^T}{p_{t-1}^T} \tag{89}$$

$$b_t + b_t^N + b_t^T = d_t + q_t b_t^* \tag{90}$$

$$(1+r_t) = \mathbb{E}_t\left[\frac{q_{t+1}}{q_t}(1+r_t^*)\right] \tag{91}$$

$$i_t \quad = \quad i_{t-1}^{\rho_i}\left(\bar{i}\left(\frac{\pi_t}{\bar{\pi}}\right)^{\varphi_\pi}\right)\exp\left(\varepsilon_t^{\mu}\right) \tag{92}$$

$$rp_t = \exp\left(\mu_{rp}\left(\frac{d_{t-1}}{\bar{d}} - 1\right)\right) \tag{93}$$

$$q_t ri_t^* = b_t \tag{94}$$

$$q_t ri_t^* = \overline{ri}^* - \Psi_q\left(\frac{q_t}{\bar{q}} - 1\right) \tag{95}$$

$$\tau_t = b_{t-1} + q_t\left(1+r_{t-1}^*\right) ri_{t-1}^* - \left((1+r_{t-1})\, b_{t-1} + q_t ri_{t-1}^*\right) \tag{96}$$

$$\frac{(1+\partial_t)}{(1+\pi_t^C)} = \frac{q_t}{q_{t-1}} \tag{97}$$

$$z_t^T = \rho_{z^T} z_{t-1}^T + (1-\rho_{z^T})\log\left(\bar{z}^T\right) + \varepsilon_t^{z^T} \tag{98}$$

$$z_t^N = \rho_{z^T} z_{t-1}^N + (1-\rho_{z^T})\log\left(\bar{z}^N\right) + \varepsilon_t^{z^N} \tag{99}$$

$$z_t^{i^*} = \rho_{z^{i^*}} z_{t-1}^{i^*} + (1-\rho_{z^{i^*}})\log\left(\bar{z}^{i^*}\right) + \varepsilon_t^{z^{i^*}} \tag{100}$$

$$oil_t = \rho_{z^{oil_1}} oil_{t-1} + \rho_{z^{oil_2}} oil_{t-2} + (1-\rho_{z^{oil_1}} - \rho_{z^{oil_2}})\log\left(\bar{oil}\right) + \varepsilon_t^{oil} \tag{101}$$

B Data set

Commercial debt portfolio: We took the commercial monthly real debt portfolio of the Colombian financial sector and converted it to quarterly frequency using the value for the last month in the quarter. This data is available from 1998Q4 to 2013Q2.

Sectoral commercial debt portfolio: We built a tradable and non tradable commercial debt portfolio measure by adding up sectoral data. In particular, for the tradable measure, we take the commercial debt portafolio of the agriculture, fishing, mining, manufacture and wholesale and retail commerce sectors. For the non tradable sector, we take the hotel and restaurant, transportation, financial intermediation, real estate, public administration, education, health, other social services, households with domestic service and extraterristorial organs sectors. These measure are then deflacted using the CPI and seasonally adjusted using Census x12. This data is available from 1999Q1 to 2013Q2.

Oil Production: We took the monthly average of the daily crude oil production (in barrels) and averaged it for each quarter. This data is available from 1993Q1 to 2013Q2.

Consumption: We took disaggregated quarterly data of total private consumption from 2000Q1 to 2013Q2. In particular, this disaggregation divides consumption in non durable, durable and semi durable goods, and services. We then approximate tradable consumption as the sum between consumption in durable and semidurable goods, and non tradable consumption as the sum between consumption non durable goods and services.

Gross fixed capital formation: We took disaggregated quarterly data of total gross fixed capital formation from 2000Q1 to 2013Q2. In particular, this disaggregation divides fixed capital formation by sector: agricultural, machinery, transportation, construction, civil project building and services. We then approximate tradable fixed capital formation as the sum of this among the following sectors: agricultural, machinery and transportation. We approximate non tradable fixed capital formation as the sum of this among the following sectors: construction, civil project building and services.

GDP: We build a measure of tradable and non tradable GDP using sectoral data. Specifically, tradable GDP is approximated using the sum between agriculture, silviculture, hunting and fishing, mining, manufacture, air transportation, supplementary transportation services, mail and communication services, financial services to firms (excluding real estate) and total taxes. Non tradable GDP is then computed as the difference between total and tradable GDP. We also compute a measure of tradable GDP excluding the mining sector. This data is available from 2000Q1 to 2013Q2.

Inflation: We build a measure of tradable and non tradable inflation based on the CPI of the same sectoral data as that of the GDP. These CPI measures (tradable and non tradable) are then seasonally adjusted using Census x12 and then turned to quarterly frequency by taking the value for the last month in the quarter. This CPI data is then used to compute quarterly inflation. These inflation measures are available from 1999Q2 to 2013Q2.

Deposits: We took the quarterly savings' account data starting in 1984Q1 and ending in 2013Q2. We then seasonally adjust this measure using Census x12.

Interest rates: We took the monthly data for inter-bank interest rate, home building interest rate (different from social housing) and corporate commercial interest rate and converted them to quarterly frequency using the value for the last month in the quarter. A measure for tradable interest rate is then approximated using the corporate commercial interest rate. On the other hand, the non tradable interest rate is approximated using the home building interest rate. This data is available from 2002Q2 to 2013Q2.