The Effect of Monetary Policy on Commodity Prices: Disentangling the Evidence for Individual Prices

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THE EFFECT OF MONETARY POLICY ON COMMODITY PRICES: DISENTANGLING THE EVIDENCE FOR INDIVIDUAL PRICES*

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ABSTRACT. In this paper we study the effect of monetary policy shocks on commodity prices. While most of the literature has found that expansionary shocks have a positive effect on aggregate price indices, we study the effect on individual prices of a sample of four commodities. This set of commodity prices is essential to understand the dynamics of the balance of payments in Colombia. The analysis is based on structural VAR models, we identify monetary policy shocks following [Kim, 1999, 2003] upon quarterly data for commodity prices and their fundamentals for the period 1980q1 to 2010q3. Our results show that commodity prices overshoot their long run equilibrium in response to a contractionary shock in the US monetary policy and, in contrast with literature, the response of the individual prices considered is stronger than what has been found in aggregate indices. Additionally, it is found that the monetary policy explains a substantial share of the fluctuations in prices.

Key words: Commodity prices, monetary policy, Overshooting
JEL codes: E31, E52, F42, Q17, Q43.

1. INTRODUCTION

The evolution of commodity prices has been one of the major sources of concern for policy makers during the past decades. From emerging countries to developed markets around the world, commodity prices have a great influence on the dynamics of economic activity, their international trade represents one quarter of the world's merchandise exchange (Cashin et al. [2000]), and a large share of developing world's GDP comes from commodity related activities. Hence, both long-term

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trends and short-term fluctuations in commodity prices are key determinants of exchange rates, prices, national income and the balance of payments.

Commodity markets are characterized by spreading shocks between markets, they connect commodity-importing countries, usually developed economies, with emerging exporter countries, see Borensztein and Reinhart [1994]. Therefore, learning about long-term trends and short-term fluctuations in prices of basic goods is crucial for understanding developments in the global economy. On the supply side, many developing countries are highly dependent on commodity exports income, and on the demand side, commodity markets play an important role as they transmit shocks from the world economic cycle to inflation in most economies. Additionally, in countries with low monetary policy credibility and where the share of commodities in the consumption basket is large, food and fuel price shocks might also raise expectations of larger inflation in the future and might thereby raise pass-through to headline inflation. Moreover, booms and slumps in commodity prices have strong impact on poorly diversified production structures.

Unlike manufactured goods, primary products have flexible prices which respond very quickly to macroeconomic fundamentals and other international finance concepts (Frankel [1985a]), the reason is that commodities are homogeneous and storable goods traded in competitive markets through auctions. Therefore, some macroeconomic concepts can be used in their analysis, for example, the neutrality of money, the interest rate parity, rational expectations and particularly Dornbusch [1976] overshooting model [1].

During the recent surge on commodity prices, some authors argue the loose monetary policy and persistently low interest rates could have partly fuelled the price increase (see Hamilton [2009] and Anzuini et al. [2010]). If that is the case it becomes relevant to understand to what extent the recent US monetary policy easing (or a future pull back of it) affects developments on commodity prices. For countries like Colombia, commodity exports represent a significant share of total exports. In 2010, for example, oil, coal, ferronickel and gold exports accounted for 64% of total exports. Additionally, their impact on tax collection and national income is not negligible.

In this paper we study the effect of monetary policy shocks on commodity prices focusing on individual products mentioned in the previous paragraph that are essential for understanding the dynamics of the balance of payments in Colombia. The analysis is based on structural VAR models following Kim [1999] and Kim [2003] monetary policy shocks identification strategy. The model is estimated with quarterly data for these prices and their fundamentals for the period 1980q1 to

[1] Given that commodity prices behave similarly to financial assets, they may be good predictors of future changes in aggregate price levels and production. Therefore, they can be used as a leading indicator for economic activity. For further discussion on the features of commodity prices see Frankel [2006] and Flórez [2010].

2010q3. Our results suggest that there is an overshooting behaviour of the commodity prices. Nevertheless, in contrast with the literature, the response of the individual prices considered is stronger than what has been found in aggregate indices.

This document consists of five sections including this introduction. The second section provides a brief literature review that shows different empirical approaches to the relationship between commodity prices and its fundamentals with an emphasis on monetary policy. The third section presents the theoretical model and the econometric strategy. The fourth section describes the results and finally, the fifth section concludes.

2. Literature review

2.1. **A summary of the theoretical approaches.** The first approaches of literature that tried to explain the behaviour of commodity prices relied exclusively on demand factors. In this line of research, it was found that the economic cycle and the real exchange rate of the United States accounted for most of the movements in the international prices of primary goods. The evolution of economic activity drives the demand for commodity products and it is, therefore, a critical determinant of its price. Similarly, the exchange rate is a variable that influences the price of commodities since it affects the competitiveness of producers and the purchasing power of consumers. Thus exchange rate fluctuations affect both the supply and the demand side of such basic goods.

However, when only demand-side determinants were used, prices forecasts showed positive biases in their estimations and current fundamentals could not explain the low prices observed in the nineties. A closer look at the information showed that while commodity prices fell down, imports from developed countries grew strongly, and it was found that in the mid-eighties the global supply of basic goods grew at an annual rate of 13%. This growth was driven by technological innovation and by higher trade openness in developing countries. Economists, therefore, realized the importance of analysing supply-side variables. Borensztein and Reinhart [1994] survey related literature on these approaches.

While supply and demand can in general explain a large share of commodity prices fluctuations, other forces might play an important role (Anzuini et al. [2010] and Hamilton [2009]). In his seminal contribution, Frankel [1985b] argues that monetary policy and in particular interest rates are key determinants of developments in commodity prices. This author extends Dornbusch [1976] exchange rate overshooting model to the case of commodity prices and using no arbitrage conditions explains the link between these two variables. Given commodity prices flexibility, the effect of monetary policy should be almost instantaneous and occur with an overshooting behaviour which is reversed in later periods. Frankel claims that an increase in nominal money supply must be matched by a proportional change in the general price level. However, since a proportion of prices are sticky in the short run, there is a short-term decline in real interest rates. This decrease leads to an increase in commodity prices through the following channels:

1. On the supply side, a decline in real interest rates generates incentives to delay the extraction of raw materials, as the cost of holding inventories in the ground also decreases.

2. Additionally, it provides incentives for carrying inventories, due to the lower implied opportunity cost of storage.

3. Furthermore, it encourages investors to buy contracts of futures and other derivatives related to commodity prices, increasing their demand for such products.

An additional channel, identified by Arango et al. [2008], is related to how low interest rates increase demand for capital goods which use commodities as inputs pushing basic goods prices up.

The fact that commodity prices respond more than proportionally to movements in the monetary policy rate, is explained following Dornbusch's overshooting model once is replaced the real exchange rate for commodity prices. The basic idea of this approach is that commodity prices will overshoot their equilibrium levels in response to a monetary policy shock. Therefore, a decline in real interest rates increases commodity prices above their equilibrium in the short-run. As a result, firms build up inventories and new investment projects become profitable, thus increasing commodity supply while simultaneously demand for commodity futures decreases as investors believe the price is above equilibrium. In consequence, prices tend smoothly to their new equilibrium (like the rest of sticky prices in the economy), the real interest rate returns to its initial level and the price level returns to a level expected by money neutrality. During this correction, the aggregate price level moves in the same direction as the movement in commodity prices.

In summary, the literature has identified three fundamental determinants of commodity prices. First, since many commodities are inputs in the production process, both demand and prices usually increase with global economic activity. The second factor is the exchange rate since commodity prices are denominated mostly in US dollars and commodity exporters have an incentive to stabilize their income and raise prices when the dollar is weak. Furthermore, a depreciation of the dollar means lower commodity prices in local currency and a consequent increase in the demand of such goods which pushes up prices. The third factor is the monetary policy and its effect on prices. Lower interest rates decrease the incentive to extract today, increase the incentives to maintain inventories and stimulate the demand for commodity derivatives, all of which raise the prices of basic products.

2.2. **Empirical results in literature.** This subsection reviews recent empirical literature on the relationship between interest rates and commodity prices. According to Frankel [2006], there is a negative relationship between real interest rate and real commodity prices. In particular, if the interest rate increases by 100 basis points, commodity prices drop 6% [2].

According to Akram [2009], an explanation for the possible weakness in the relationship may be the need to control for macroeconomic variables like real exchange rate and economic activity when analyzing the relationship between commodities and interest rates. This author argues that the solution to the problem is to carry out an analysis which includes the monetary policy endogenously (see also Flórez [2010]). There is an endogeneity in the relationship between commodity prices and interest rates, because low interest rates mean higher commodity prices and high commodity prices can lead to future increases in aggregate price indices and a contractionary monetary policy. Hence it is considered more appropriate to develop a multivariate analysis to capture this and other endogenous relationships. In this sense, Flórez [2010] introduces a Taylor rule in Frankel's approach and using an SVAR, finds that for a 1% increase in interest rate, commodity prices fall between 2.8% and 5.9%. In the opposite direction, an increase in commodity prices of 1% leads to higher interest rates from 0.2% to 0.5%. Furthermore, Flórez finds that in recent years the effect on commodity prices has a lag.

In the same direction, Akram [2009] conducted a VAR in which, besides the price of commodities and interest rates, he includes the real exchange rate and a variable of economic activity. This study highlights some important features of the determinants of commodity prices. Particularly, Akram argues that in addition to the transmission mechanisms explained by Frankel, there is an indirect channel from which the interest rate affects the price of commodities through the exchange rate. According to uncovered interest parity, the exchange rate variation depends on the interest rate differential between an economy and its international benchmark. Thus, the interest rate affects the exchange rate and the exchange rate in turn has an effect on the price of commodities. Akram [2009] conducts and impulse-response analysis which shows overshooting of commodity prices to interest rate shocks. Additionally the author performs a variance decomposition from which he concludes that from direct and indirect channels, the interest rate and exchange rate, explain approximately 70% of fluctuations in commodity prices.

While Frankel uses arbitrage conditions to develop his model, Browne and Cronin [2010] examine the relationship between commodity prices, consumer goods prices and the money supply in a pure-exchange economy framework. This paper examines whether an exogenous change in money supply causes price disequilibrium in both commodity and consumer goods markets and how measures of both of these

[2]This evidence holds for the three commodity-price measures that Frankel study: CRB, Dow Jones and Moody's.

disequilibria can predict future changes in CPI inflation. With this characterization, a simple two-good, two-period model is used to show that a flexible commodity price overshoots its new long run equilibrium value in the first period following an exogenous change in the money supply, doing so to ensure equilibrium in the overall system of money and prices. The extent of this overshooting acts to predict subsequent changes in the price of the other good, whose price is unchanged in the first period.

Browne and Cronin [2010], find that commodity and consumer prices are cointegrated with the money stock and move proportionally to it in the long run. Additionally, they find that commodity prices overshoot their new equilibrium level in response to a money shock, while consumer prices adjust more slowly and do not overshoot. Finally, the deviation of commodity prices from their long-run values has explanatory power for subsequent CPI inflation.

Similar findings are reported by Anzuini et al. [2010]. These authors perform a structural VAR estimation (SVAR) which allows identifying monetary policy shocks by assuming structural restrictions on their contemporaneous impact on the system. Their results show that the monetary effects on aggregate commodity prices are significant and that the short-run response usually has an overshooting during the first year after the shock. This paper also finds that the main transmission channel is the effect of the shock on inflation and growth expectations. We follow this paper and related literature on the procedure to identify monetary policy shocks.

On the other hand, Lombardi et al. [2010] estimate a VAR augmented by factors (FAVAR), in which the factors are two common trends in prices of commodities particularly food and metals. With this structure they study the impulse response between the price of commodities, the common trends, the exchange rate, the economic activity, oil prices and interest rates. According to the authors, the exchange rate, economic activity and the common trends have a major impact on commodity prices. However, it is not found any significant relation between oil prices and interest rates, this result contradicts the hypothesis of Frankel.

A similar result is found in Frankel and Rose [2010]. These authors estimate panel-data regressions of several individual commodity prices which are explained by both macroeconomic and microeconomic determinants. These micro determinants include measures of volatility, spot-future spreads and inventory levels. While inventory indicators and global GDP are found to be important determinants, the effect of the real interest rate is found non-significant. These estimations are based on a theoretical model which is an extension of the model presented in Frankel [2006].

Overall, the literature has several studies that try to empirically verify the hypothesis of Frankel [1985b]. These papers have usually applied multivariate methods such as vector autoregressive models (VAR) or vector error correction models (VEC) in presence of cointegrating relationships, or the imposition of structural restrictions (SVAR, SVEC). However, there is still no consensus in the literature about empirical relevance of Frankel's hypothesis. The purpose of this paper is to provide some evidence on the relationship of commodity prices and monetary policy for individual prices.

3. THEORETICAL MODEL AND ECONOMETRIC APPROACH

3.1. **Basic model.** Frankel's theory builds on the work of Dornbusch [1976] overshooting model, but substituting the exchange rate by commodity prices. The reason for the overshooting is that basic product prices adjust rapidly, while most other prices do it slowly. This model implies a negative relationship between the real interest rate and the difference between the spot price of a commodity and its expected equilibrium price over time.

Assume s is the log-spot price of a commodity, $\bar{s}$ is the long-term equilibrium price, p is the log-price level of the economy, $q \equiv s-p$ is the real commodity prices, $\bar{q}$ is the real long term equilibrium of commodity prices. When market participants note that the real price of commodities is above or below its long-term perceived value, they expect it to fall back to it's equilibrium, at a rate proportional to this gap:

$$E\left[\Delta(s-p)\right] \equiv E[\Delta q] = -\theta(q-\bar{q}) \tag{1}$$

$$E(\Delta s) = -\,\theta(q-\bar{q}) + E(\Delta p) \tag{2}$$

On the other hand, agents face the decision to hold the product for another period (without extracting or harvesting it or keeping it in inventory), or sell it at today's prices and deposit the money in the bank to earn interest. The arbitrage condition arise when the expected rate of return to these two alternatives is the same:

$$\begin{aligned} E\left[\Delta s\right] + c &= i \qquad (3) \\ c &\equiv cy - sc - rp \end{aligned}$$

Where c is the net profit from holding an inventory of the product, cy is the convenience yield from holding the stock (eg gold), sc is the storage cost, and rp is the risk premium .

By combining equations (2) and (3) we obtain:

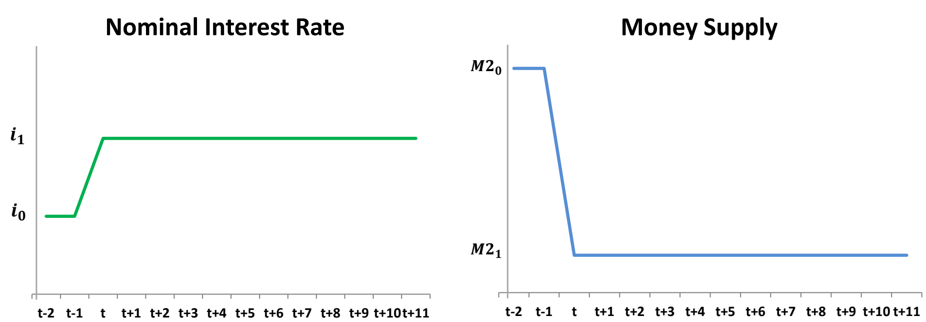
$$-\theta(q-\bar{q}) + E(\Delta p) + c = i \tag{4}$$

$$q-\bar{q} = -\left(\frac{1}{\theta}\right)(i - E(\Delta p) - c) \tag{5}$$

According to equation (5) real commodity prices (measured in relation to its long-run equilibrium) are inversely proportional to the real interest rate (measured against a constant term that depends on c). When the real interest rate is high, as in the 1980's, money flows outside the commodity sector in the form of foreign currency, emerging markets assets and other securities. Only when commodity prices are perceived to be sufficiently below the equilibrium the arbitrage condition is fulfilled. By contrast, when the real interest rate is low, as in 2001-04, money flows into the commodity market. Similarly, in this case, only when the prices of these alternative assets are perceived sufficiently above its equilibrium, the arbitrage condition is fulfilled.

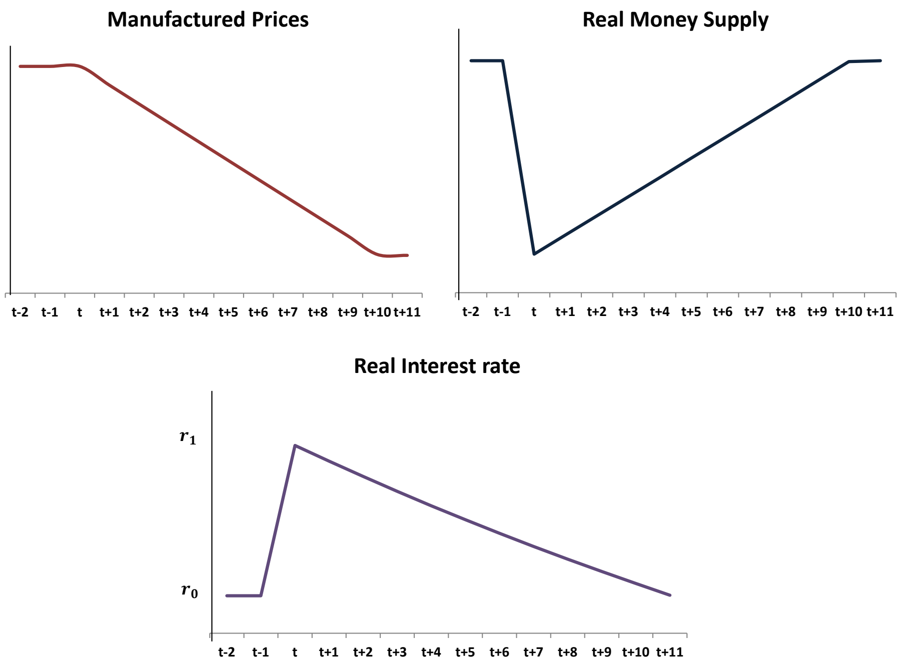
3.2. **The effect of monetary policy on commodity prices.** Frankel [1985b] explains the overshooting model as follows: Suppose an increase in the nominal interest rate or an equivalent drop in money supply which is expected to be permanent (see Graph 1).

GRAPH 1. Frankel effect example (a)



Then in the long run all prices should fall in the same magnitude. However given that in the short run manufacture prices are fixed, the rise in the nominal interest rate generates a reduction in real money supply. To equilibrate the money demand, real interest rate has to decrease (see Graph 2 and Flórez [2010]).

GRAPH 2. Frankel effect example (b)



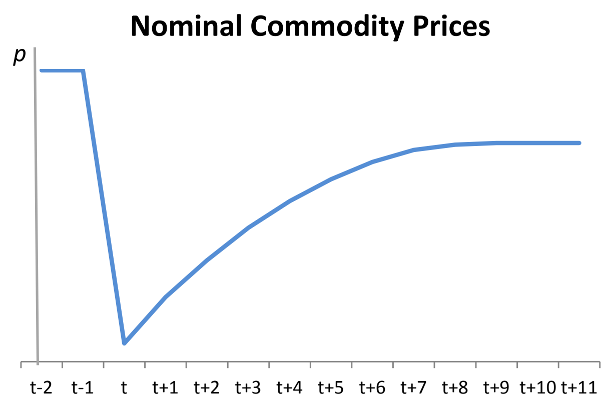
Now, since commodity goods are storable, they should follow the arbitrage condition (the rate of return on Treasury bills can be no greater than the expected rate of increase of commodity prices, minus the storage cost). Then commodity prices must fall today by more than the contraction in money supply (Flórez [2010]). This fall in commodity prices is such that it generates expectations of future appreciation that incentive firms to hold inventories despite the high storage cost.

"In the long run, the general price level adjusts to the change in money supply. As a result, the real money supply, real interest rate, and real commodity prices eventually return to where they were", Frankel [2006] p. 5.

The reason for the overshooting in commodity prices is their rapid adjustment, while most other prices adjust slowly (Graph 3), see Bordo [1980] and Frankel [1985a] for further discussion.

Within this framework, we estimate a structural VAR model (SVAR) which captures the relationship between the price of oil, gold, coal, and nickel with their macroeconomic determinants. Structural restrictions on the contemporaneous effects of innovations are used to identify monetary policy shocks using information from the interest rate and from the monetary aggregate of the US. Our identification

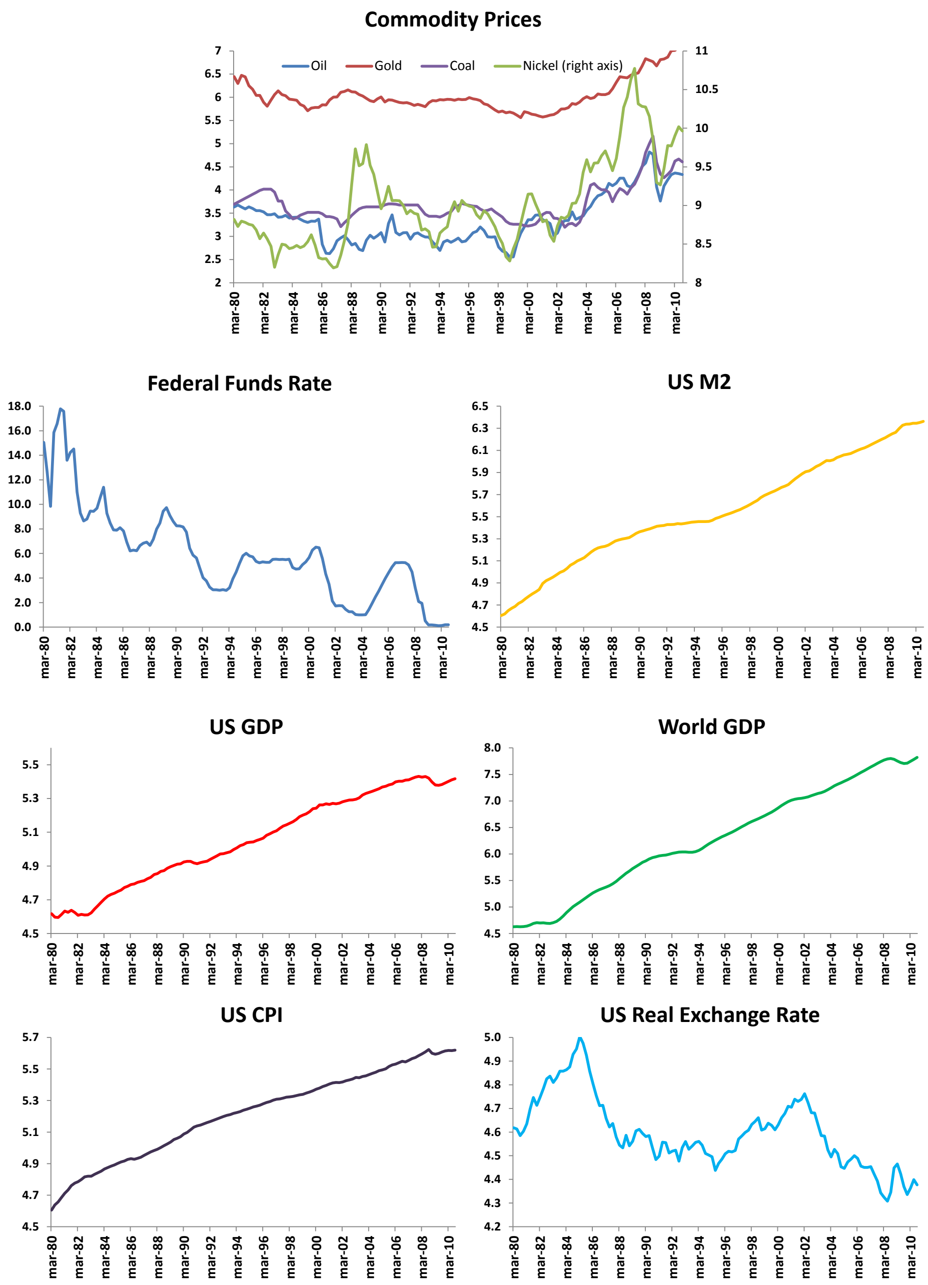
GRAPH 3. Frankel effect example (c)



strategy follows [Kim, 1999, 2003]. The remaining determinants are the real exchange rate of the US, the consumer price index for the US and a global economic activity index. Our objective is to study the effects of monetary policy shocks in commodity prices by simulating a transitory 100-basis-point increase of the nominal interest rate and analyzing its impulse-response functions. The advantage of using a SVAR framework with both interest rates and M2 is that this strategy takes in account the endogenous response of monetary policy to general developments in the economy. These endogenous responses can amplify the initial policy movement.

3.3. **Data.** We use quarterly data from 1980Q1-2010Q3. The international prices of oil, coal, gold and nickel are retrieved from the IMF commodity database, we also use Commodity Research Bureau aggregate price index. Given that we do not have a global monetary policy measure, we use nominal M2 from the United States and the Federal Funds Rate simultaneously. For the global economic activity variable we use quarterly GDP data from IMF between 2000 and 2010. For the 1980-2000 period we construct a moving weighted average of the annual GDP growth of the world major economies; the United States, the Eurozone, Japan, UK, China and India (These economies together account for 65% of world GDP). We also use the US GDP from the Bureau of Economic Activity. Finally, we use the logarithm of the real exchange rate against U.S. trading partners. Figure 5 shows the series in the database.

GRAPH 4. Data Series considered in the models



Source: IMF

3.4. **Econometric Approach.** In order to model the dynamic relations between the macroeconomic variables and commodity prices, we start with a reduced form VAR representation:

$$X_t = \sum_{t=1}^{P} A_i X_{t-i} + u_t \tag{6}$$

The Wold MA representation of (6) is given by,

$$X_t = u_t + \Phi_1 u_{t-1} + \Phi_2 u_{t-2} + \dots \tag{7}$$

Here,

$$\Phi_s = \sum_{j=1}^{s} \Phi_{s-j} A_j \qquad \Phi_0 = I_k \tag{8}$$

In (8) the elements of Φ_j matrices represent the forecast error impulse responses that are useful to determine the dynamic response of the system of variables. Unfortunately, these responses may not be correctly specified because the components of u_t could be contemporaneusly correlated. This can be fixed by estimating a model with orthogonalized impulses, for example, using a Cholesky decomposition. However, unless there is some special reason to consider a recursive structure in the innovations, this may be arbitrary and unsatisfactory (Lütkepohl [2005]).

One way to overcome this flaw and obtain instantaneously uncorrelated residuals is to model the contemporaneus relations between the variables directly. This could be done through a proper specification of a structural VAR model:

$$\mathrm{A}X_t = A_1^* X_{t-1} + A_2^* X_{t-2} + \dots + A_p^* X_{t-p} + \varepsilon_t \tag{9}$$

With $A_j^* = \mathrm{A}A_j,\ j = 1, \dots, p$ and $\varepsilon_t = \mathrm{A}u_t \sim (0, \Sigma_\varepsilon = \mathrm{A}\Sigma_u \mathrm{A}')$

In (9), Σ_ε has a diagonal covariance matrix with the advantage to model the economic contemporaneous relationships in X_t.

Following Kim [2003] and Anzuini et al. [2010], in our first group of estimations, we take X_t and A as follows:

$$X_t = \begin{bmatrix} FFR_t \\ M2_t \\ CPI_t^{us} \\ GDP_t^{us} \\ P_t^{com} \end{bmatrix}, \qquad A = \begin{bmatrix} 1 & a_{12} & 0 & 0 & a_{15} \\ a_{21} & 1 & a_{23} & a_{24} & 0 \\ 0 & 0 & 1 & a_{34} & 0 \\ 0 & 0 & 0 & 1 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 \end{bmatrix} \tag{10}$$

Where FFR is the federal funds rate, $M2$ is the US monetary aggregate, CPI^{us} is the US consumer price index, GDP^{us} is the US gross domestic product and P^{com} corresponds to the commodity price considered that is replaced in each estimation by oil, gold, coal and nickel prices respectively. All variables except FFR are taken in logarithms.

According to Anzuini et al. [2010], the first row of matrix A is a money supply equation modelled as a reaction function of the monetary authority. Here is assumed that, due to an informational delay, the current level of prices and production are not available to the monetary authorities. The second row is a money demand equation. The demand for money is a function of real income, the opportunity cost of holding money and the nominal interest rate. The third and fourth row encapsulate the hypothesis of price stickiness and adjustment costs; real activity is assumed to respond only with a lag to innovations on the system of variables. Finally, the last equation is and arbitrage equation which describes equilibrium in the commodity market as a financial market equilibrium. The commodity price is affected contemporaneously by all variables.

Our second group of estimations considers an extended system of variables given as follows:

$$X_t = \begin{bmatrix} FFR_t \\ M2_t \\ CPI_t^{us} \\ GDP_t^{tot} \\ RER_t^{us} \\ P_t^{com} \end{bmatrix}, \qquad A = \begin{bmatrix} 1 & a_{12} & 0 & 0 & 0 & a_{15} \\ a_{21} & 1 & a_{23} & a_{24} & 0 & 0 \\ 0 & 0 & 1 & a_{34} & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 \end{bmatrix} \tag{11}$$

The analysis is extended to include the rest of the world GDP and RER_{us}, in the first place, world economic growth, with a substantial contribution from emerging economies in recent years, is the main determinant of commodity demand and therefore of their price. Second, as many commodities are priced in dollars in international markets, a fall in the value of the dollar may raise the purchasing power and commodity demand of foreign consumers, while reducing the returns of foreign commodity suppliers and potentially their supply (Akram [2009]). In this case, We model contemporaneous relationships between the variables based in Kim [2003]. This approach has similar structure to the matrices used in the model with US data.

The new variables are in the fourth and fifth row of A in (11). The assumptions on the rest of the system are the same as in (10). On the other hand we assume that all currently available information on the real economy and on the monetary policy stance affects the real exchange rate instantaneously.

To compare the results with the literature, we also compute an estimation with a system in which $X_t[6,1]$ corresponds to the CRB index. Further analysis is discussed in next section.

3.4.1. *Impulse Response Functions and Forecast Error Variance Decomposition.* Within the estimation of the SVAR, it is possible to analyse the impulse response functions, compute the relevant multipliers and then interpret the dynamic effects in the variables of an isolated and independent shock.

These functions can be expressed in terms of the MA representation of the SVAR equation (in this case (9)) as follows,

$$X_t = \sum_{i=0}^{\infty} \Theta_i \varepsilon_{t-i} \tag{12}$$

Where $\Theta_i = \phi_i \mathbf{A} - 1$ and $\varepsilon_t = \mathrm{A}u_t$.

In (12), $\Theta_{jk,i}$ represents the effect of a variable j innovation in the variable k i periods after the shock. This effect allows us to determine if there exists a significant relationship among the considered variables and if there is an overshooting behaviour in commodity prices in the system.

Furthermore, in section 4 it is also shown the forecast error variance decomposition of the model. This approach is also developed from equation (12), where the forecast error h steps ahead is provided by,

$$X_{t+h} - X_{t(h)} = \sum_{i=0}^{h-1} \Theta_i \varepsilon_{t+h-i} \tag{13}$$

Where $X_t(h)$ is the forecast h steps ahead, conditional to information in t. Let $\theta_{mn,i}$ be the mn-th element of Θ_i, the h - step forecast error of the j-th element of X_t is given as follows,

$$\begin{aligned} x_{j,t+h} - x_{j,t}(h) &= \sum_{i=0}^{h-1} (\theta_{j1,i}\varepsilon_{1,t+h-i} + \ldots + \theta_{jK,i}\varepsilon_{K,t+h-i}) \qquad (14) \\ &= \sum_{k=1}^{K-1} \left(\theta_{jk,0}\varepsilon_{k,t+h} + \ldots + \theta_{jk,h-1}\varepsilon_{k,t+1}\right) \end{aligned}$$

Then, if coefficients are significant, the forecast error of the j-th component depends upon all innovations[3] in the system. Thus from (14) it is possible to obtain the proportion of the h-step forecast error variance of j accounted for by ε_{kt} innovations, such concept helps to build an idea of the most relevant variables among the system with respect to another j variable. This procedure is done with all the variables of the system regarding the prices of each commodity and the results are shown in the next section.

4. RESULTS

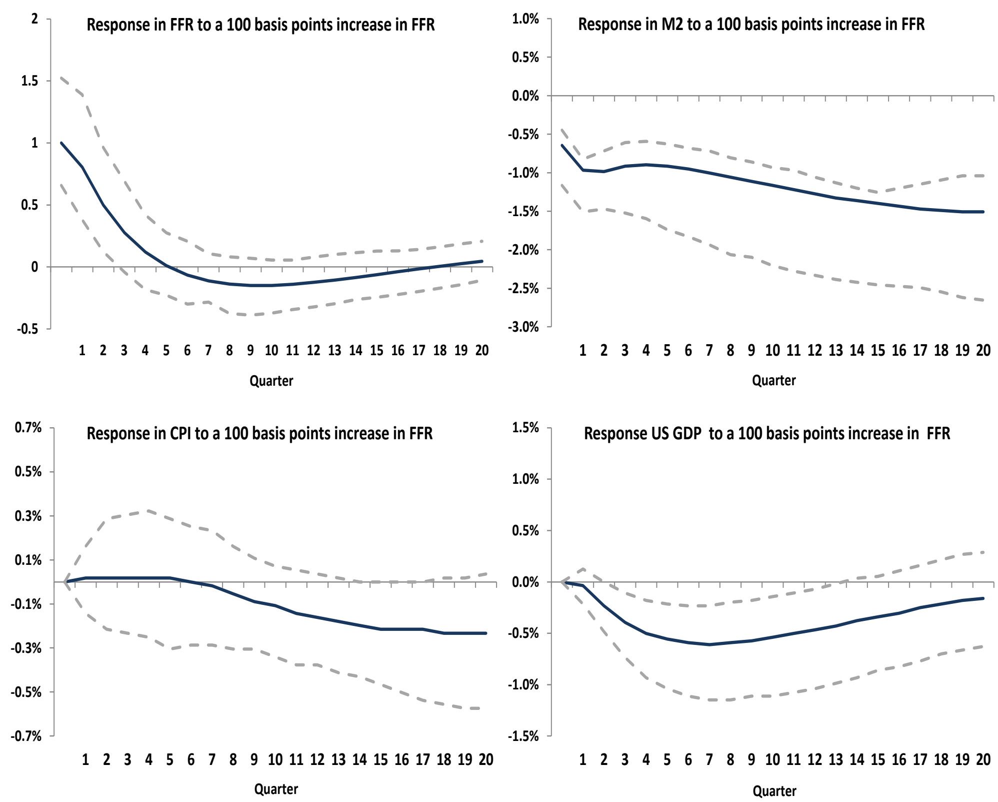
Several unit root test statistics (Ng - Perron, KPSS, ERS) were computed to each of the variables considered. The results (see Table 1 in Appendix A) show no evidence against the hypothesis that there is a unit root in the variables in levels [4]. Using Akaike, Schwarz, Hanna-Quin and Final Prediction Error information criteria, and considering the presence of autocorrelation we chose VAR(2) models for every specification (see Table 2, Table 3 and Table 6).

[3]This significance is also related to the Granger and instantaneous causality among the variables.

[4]Johansen's cointegration trace test statistic indicates the presence of cointegration among the variables in all the models estimated (See Table 4 and Table 5).

4.1. **Structural VAR estimation with US data.** In this section we analyse impulse response functions based on estimations of (10) with 95% confidence intervals following Hall [1992] approach. Graph 5 shows the dynamic response to a 100 basis points increase in the Federal Funds Rate for the system that considers oil price. All responses have the expected signs, a contractionary shock in the interest rate reduces the monetary aggregate, has a negative and significant impact on prices after the first year and with a lag of three periods decreases US GDP for nine quarters.

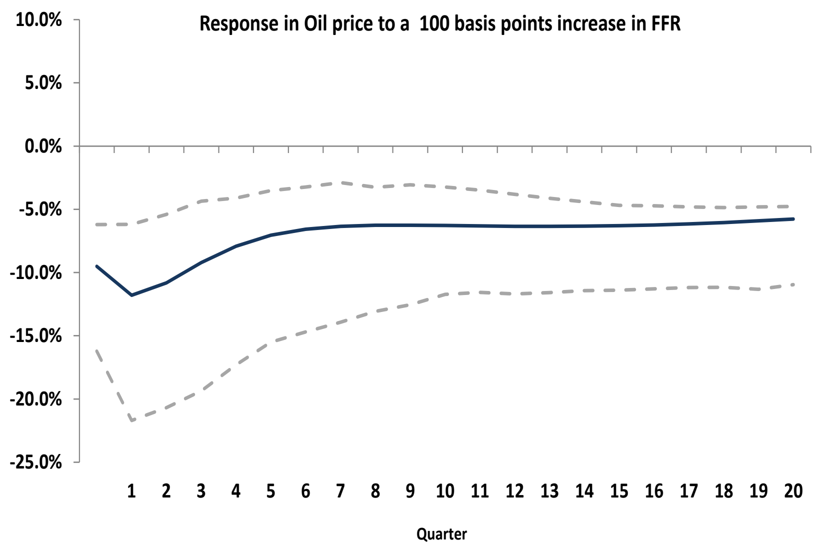
GRAPH 5. Impulse Response Functions of the system of variables to a shock in the FFR



Source: Authors' calculations

In response to a shock in FFR, oil price displays a negative and strong reaction. Our results support an overshooting behaviour of oil price, the response reaches its peak in the second quarter (-11.8%), and in the long run the effect slowly converges to -5.7%. As the effect on oil price is negative and significant on impact and the CPI responds with a lag, there is a significant effect of monetary policy on relative prices. However this effect is reabsorbed in the medium term when CPI decreases and the fall in oil prices converges to lower levels.

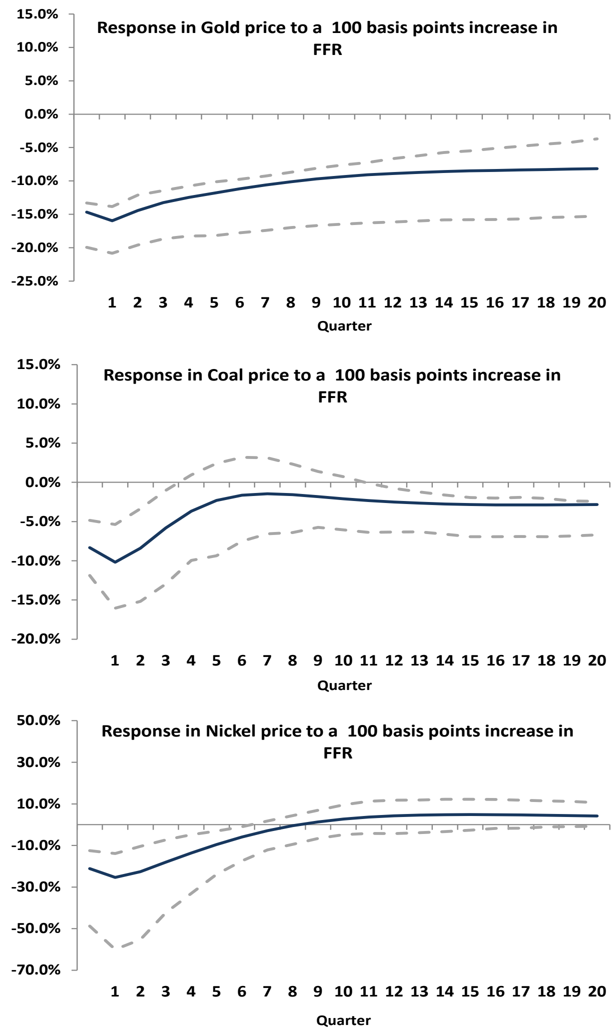
GRAPH 6. Oil impulse response to a shock in FFR



Source: Authors' calculations

The following impulse response functions correspond to the system of variables in (10), where in each case commodity price is replaced by gold, coal and nickel prices respectively. The results for the three models display a strong and negative impulse response to a shock in FFR as predicted by theory. All prices have an overshooting behaviour and their strongest response is observed after the first quarter. Gold price exhibit a significant and persistent fall with a maximum of -16% in the short run and of 8% in the long run. With respect to coal price, the response peaked to -10% and displays the less persistent behaviour returning to zero after the first year. In the case of nickel price, the response reaches a minimum of 25%, the effect is significant and takes two years to converge back to the baseline. Finally the response of the rest of variables is largely the same as in Graph 5 and is generally consistent with the theory.

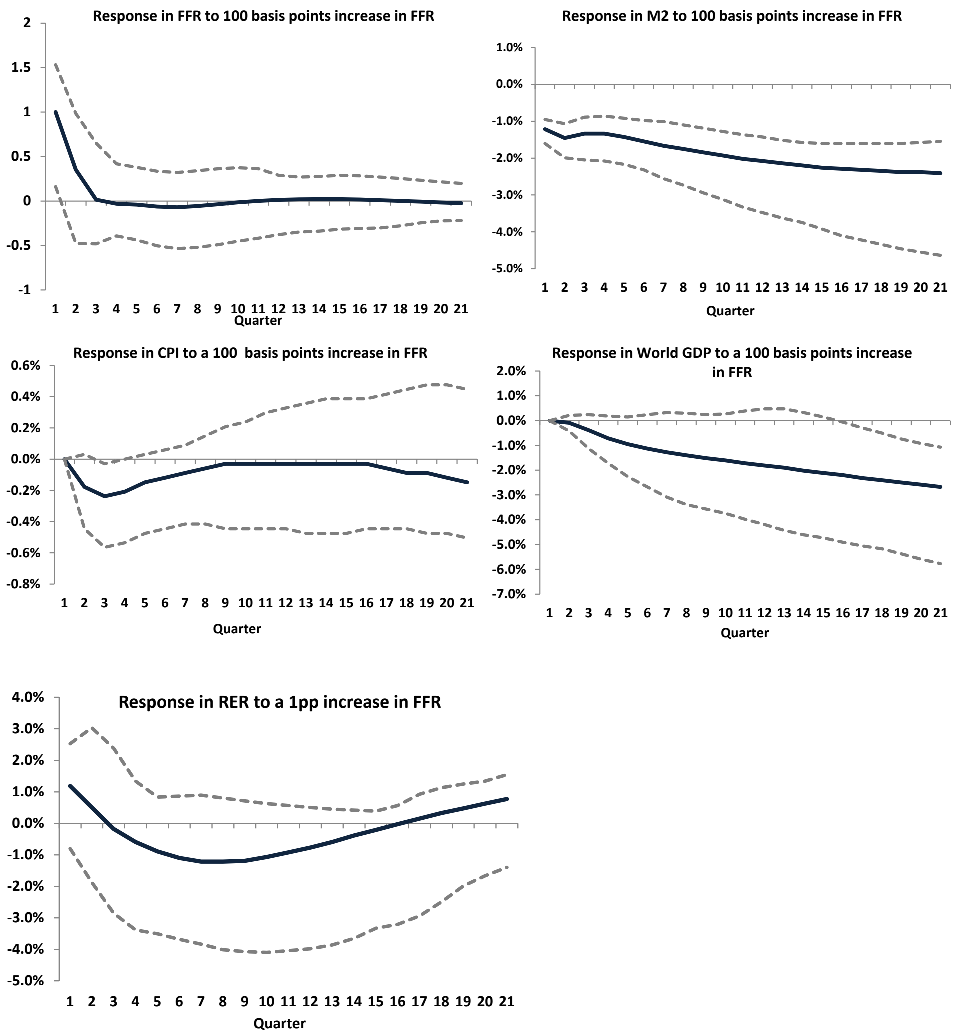
GRAPH 7. Response of individual prices



Source: Authors' calculations

4.2. **Structural VAR estimation with Augmented Model.** In this section the model is extended to include the effects of global output and the real exchange rate in the (11). As can be seen Graph 8 all responses have the expected signs. First, a contractionary shock in the interest rate implies a significant reduction in the monetary aggregate. In contrast to the previous model, the impact on prices is significant only around one year after the shock and the effect on World GDP is significant after 16 quarters. Finally the impact on RER_{us} has the correct sign but is not statistically different from zero.

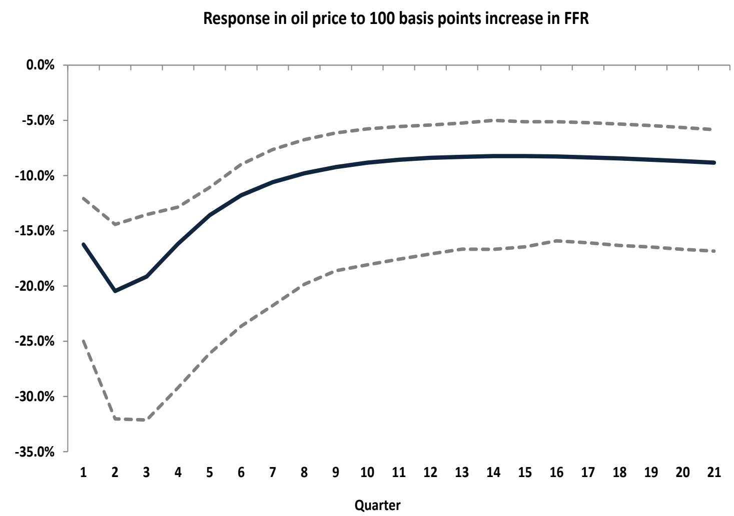
GRAPH 8. Impulse Response Functions of the system or variables to a shock in the FFR (Amplified model)



Source: Authors' calculations

Similarly to the results in the basic model, in response to a shock in FFR, oil price displays a negative and strong reaction. There is also evidence of overshooting behaviour as the response reaches its peak in the second quarter (-20,4%), and in the long run the effect slowly converges to approximately -8,8%. Notice that in the extended model the estimated effects on oil price are even stronger than in the basic model. The reason for this result is the reinforcing effect of the presence of the real exchange rate in the VAR system.

GRAPH 9. Oil impulse response to a shock in FFR

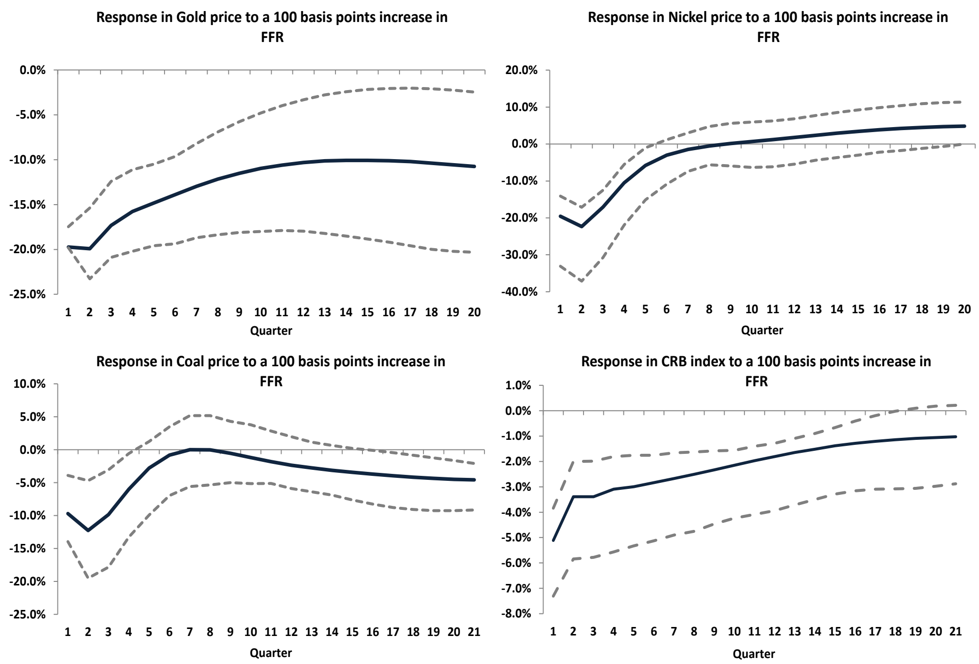


Source: Authors' calculations

Graph 10 shows the responses of the commodity price in each model (gold, coal and nickel). The results for the three models display negative impulse responses to shocks in FFR which are slightly stronger than those in the basic model. The price of gold exhibits a significant and persistent fall with a maximum of -20% in the short run which seems to converge to -10%, approximately, in the long run. The response of the price of coal peaks at -13% and displays the low persistence since it returns to zero right after the first year. In the case of the nickel price, the response reaches a peak of around -22% in the second quarter, the effect is significant and takes almost two years to converge back. The response of the remaining variables is mostly the same and is generally consistent with the theory.

We also include a commodity-price index in our analysis in order to compare our results with related literature. The estimated response of the CRB price index to shocks in the FFR is also consistent with theory and peaks at -5,3% in the first quarter and thereafter it converges slowly to zero around the fourth year. A qualitatively similar effect on the aggregate commodity price index was found by Anzuini, Lombardi and Pagano (2010) although the real exchange rate was not included in the system that they estimated.

GRAPH 10. Response of individual prices and CRB index (Amplified model)



Source: Authors' calculations

4.3. **Variance Decomposition.** We analyse forecast error variance decompositions of our set of commodity prices over a 20 quarter forecasting horizons. It displays percentages of the variance of the prediction error made in forecasting a variable at a given horizon due to the six structural shocks which are identified in the structural restrictions described in Equation (11).

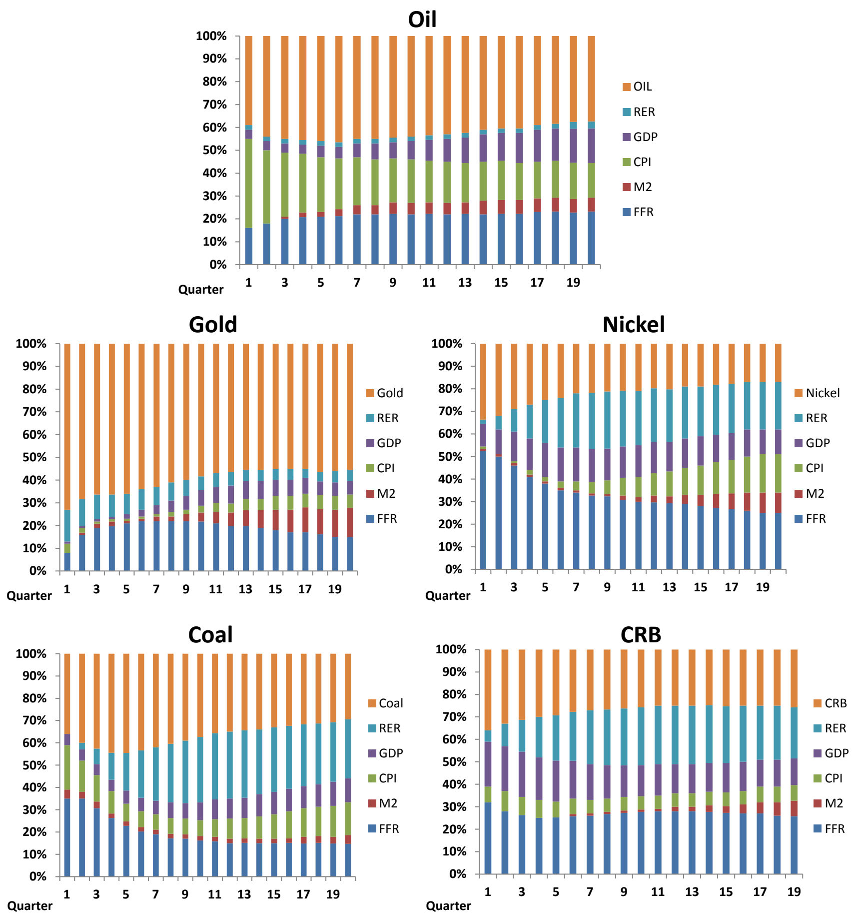
Graph 11 shows the important contribution of the structural disturbance related to monetary policy (FFR) shocks in explaining the fluctuations of commodity prices. These contributions vary, in the 20th quarter, from about 15% for gold and coal to 20% for oil and around 25% for nickel and the CRB index. The second most important determinant of commodity price fluctuations, different from the price itself, also varies across commodities. It is the real exchange rate for coal, nickel and the CRB[5]. It is money-demand shocks (M2) in the case of gold. Finally, it is

[5]Indeed, in the case of coal, the real exchange rate is the most important determinant of volatility apart from the price itself.

consumer-price stickiness (CPI) in the case of oil.

From this exercise, we can conclude that overall, structural monetary policy shocks are very important determinants of commodity price fluctuations. The real exchange rates is also important to explain fluctuations in the aggregate commodity price index.

GRAPH 11. Forecast Error Variance Decomposition for the SVAR models (Amplified system)



Source: Authors' calculations

5. CONCLUSION

Numerous countries are frequently exposed to macroeconomic adjustment in response to the behavior of commodity prices. This process is generally exacerbated by the low degree of export diversification. In Colombia, oil, coal, nickel and gold exports accounted for 64% of 2010 exports, therefore understanding the behavior of commodity prices and their determinants is crucial for the analysis of economic activity.

This paper constitutes an econometric approach to the theoretical result which states that monetary policy has an impact on commodity prices, as proposed by Frankel [1985a]. Our analysis is based on structural VAR models, using [Kim, 1999, 2003] monetary policy shocks identification scheme. Our main finding supports this theoretical argument and in contrast with the results of Anzuini et al. [2010] we found that shocks in US monetary policy has a significant and large effect on Colombian export commodity prices (oil, coal, gold and nickel).

In this document we perform two exercises, in the first one, following Anzuini et al (2010) the model consists of US FFR, M2, CPI and GDP. In the second one, we extend the analysis to include other commodity prices determinants such as US real exchange rate and the rest of the world GDP. In general, both result are supportive of each other, however, in the extended model prices response to monetary policy shock increased.

Our evidence suggests that shocks on US monetary policy contribute significantly to movements in commodity prices. A 100 basis points rise in FFR decreases oil price by 20.4%, gold price by 19.9%, coal price by 12.2%, nickel price by 22.4% and CRB index by 5.1% in the short run. In contrast to the instantaneous reaction of the CRB index, Colombian exported commodities reach their maximum response to the shock on FFR with a lag of one trimester. In the same line, oil, coal, gold and nickel price have a stronger overall response to monetary policy than what is found for aggregate indices (Anzuini et al. [2010], Akram [2009] and Flórez [2010] among others).

We have also found that monetary policy variables account for substantial shares of fluctuations in oil, coal, gold and nickel prices at all horizons.

In summary, we found two results that we would like to highlight. First, the response in prices to a shock in FFR is negative in all the cases and there is strong evidence of an overshooting as Frankel [2006] suggests. Second, in average Colombian exported commodity price display a stronger response to changes in US monetary policy

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APPENDIX A. COINTEGRATION AND RESIDUAL TESTS

This appendix contains the figures related to the selection of the VEC and VAR models considered, as well as the Residual tests of those estimations.

TABLE 1. Unit Root Tests

Variable	**ERS**	**KPSS**	**Ng Perron**	**Model**
Federal Funds Rate	I(1)	I(1)	I(1)	Constant and trend
Real exchange rate	I(1)	I(1)	I(1)	Constant
World GDP	I(1)	I(1)	I(1)	Constant
US GDP	I(1)	I(1)	I(1)	Constant and trend
M2	I(1)	I(1)	I(1)	Constant
Coal Price	I(1)	I(1)	I(1)	Constant
Nickel Price	I(0) (I(1) with 1%)	I(1)	I(1)	Constant and trend
Oil Price	I(1)	I(1)	I(1)	Constant and trend
Gold Price	I(1)	I(1)	I(1)	Constant and trend
CRB index	I(1)	I(1)	I(1)	Constant and trend
US CPI	I(1)	I(1)	I(1)	Constant and trend

TABLE 2. Information Criteria for SVAR models

Optimal endogenous lags from information criteria					
VEC Models	**FPE**	**AIC**	**SC**	**HQ**	**No. of lags chosen**
Oil	10	10	2	3	2
Gold	10	10	2	2	2
Coal	10	10	2	2	2
Nickel	10	10	2	2	2

TABLE 3. Information Criteria for SVAR models (Amplified system)

Optimal endogenous lags from information criteria					
Var Models	**FPE**	**AIC**	**SC**	**HQ**	**No. of lags chosen**
Oil (and average)	10	10	2	2	2
Gold	10	10	2	2	2
Coal	10	10	2	2	2
Nickel	10	10	2	2	2
CRB	10	10	2	2	2

TABLE 4. Cointegration trace test

Cointegration Analysis: Trace Test					
VEC Models	**r=0**	**r=1**	**r=2**	**r=3**	**r=4**
Oil	0,000	0,009	0,077	0,199	0,885
Gold	0,010	0,906	0,006	0,083	0,466
Coal	0,000	0,025	0,013	0,210	0,746
Nickel	0,000	0,070	0,001	0,064	0,182

TABLE 5. Cointegration trace test (Amplified system of variables)

Cointegration Analysis: Trace Test						
VAR Models	**r=0**	**r=1**	**r=2**	**r=3**	**r=4**	**r=5**
Oil	0,000	0,000	0,000	0,003	0,036	0,814
Gold	0,000	0,000	0,000	0,005	0,040	0,115
Coal	0,000	0,000	0,000	0,001	0,057	0,920
Nickel	0,000	0,000	0,001	0,013	0,108	0,753
CRB	0,000	0,000	0,004	0,050	0,180	0,627

TABLE 6. Residual tests

Autocorrelation Pormanteu test (16 lags)		
Model	**Statistic**	**P-value**
Oil	347,90	0,522
Gold	375,23	0,563
Coal	378,45	0,169
Nickel	345,14	0,142
Var Models	**Statistic**	**P-value**
Oil	536,30	0,154
Gold	545,35	0,099
Coal	538,71	0,138
Nickel	544,04	0,105
CRB	563,795	0,033