Optimal macroeconomic stabilization policy of food, metal, and energy price cycles in small open economies

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Abstract

This paper proposes an optimal strategy for stabilizing macroeconomic policy to address jointly the effects of changes in the prices of food, minerals and energy (oil). Our approach differs from the general literature, which analyzes the effects of a commodity boom and therefore the solutions in terms of economic policy separately, that is, by type of commodity. The stabilization strategy that we propose considers a key fact affecting many small open economies, namely, that they not only are affected by increases in commodity prices, but also benefit from them. Consequently, we use a DSGE model for a small open economy with restricted households to show that welfare could be improved with a fiscal rule incorporating transfers to stabilize household consumption. This strategy noticeably dominates an aggressive monetary policy focused only on stabilizing inflation and a fiscal policy that has an excessive bias toward saving income from exports.

Keywords: commodity price boom, optimal fiscal and monetary policy, DSGE models

JEL: E31, E32, E52, E62, E63, F1, F41.

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1. Introduction

This paper proposes an optimal strategy for macroeconomic policy stabilization that deals simultaneously with the effects of changes in the prices of food, minerals, and energy on the economy. We show that this strategy consists of a proper coordination between monetary and fiscal policy. The proposed strategy is valid for small open economies, especially developing and emerging economies that not only import raw materials, but also export commodities.

The literature examines the effects and therefore the solutions depending on the type of commodity. In this paper, we emphasize a feasible macroeconomic policy that stabilizes the economy as a whole in the short term against simultaneous fluctuations in different commodity prices.

First, several authors note the new characteristics of commodity price changes in the recent years. For example, Timmer (2010) shows that the global food crises caused by high food prices are no longer rare events, and he suggests that cyclical fluctuations could explain these crises. Lustig (2009) indicates that the introduction of biofuels can cause food prices to behave more like the prices of industrial commodities, although this phenomenon has not yet materialized according to empirical evidence found by Jacks, O'Rourke, and Williamson (2011).

On the other hand, Gilbert (2010) notes that food price booms in 1972–74 and 2006–08 cannot be explained by idiosyncratic shocks, since many of the price increases were caused by a common trend. Mitchell (2008) provides evidence that the high correlation between the prices of oil and food, both in levels and changes, is the result of a common trend, but there is no Granger causality between the two prices. Finally, Sugdden (2009) indicates that commodity prices should again grow strongly once the international economy recovers from the 2008 recession.

Second, the causes of the increase in commodity prices are varied. Headey and Shenggen (2008) analyze the strengths and weaknesses of a long list of factors that have been used to explain the increase in food prices. These include several macroeconomic shocks such as the increase in oil prices (and hence the demand for biofuels),[2] the depreciation of the dollar,[3] the growth of China and India,[4] financial

[2] For example, Schnepf (2008), Lipsky (2008), and Collins (2008) consider the demand for biofuels to be an important element in explaining the price of grains. Yang and others (2008) test this hypothesis using a global CGE model, while Mitchell (2008) finds that there is causality between oil and food prices.

[3] Awokuse (2005) provides evidence that monetary policy in the United States affects agricultural prices through the exchange rate. According to Abbott, Hurt, and Tyner (2008), the relationship between dollar depreciation and higher food prices stems from the fact that most of these products are priced in dollars (especially grains and oilseeds). Gilbert (2010) finds that global growth in conjunction with monetary expansions

speculation in favor of commodities following the collapse of the stock and the real estate markets,[5] and excess international liquidity (low interest rate).[6] Similar factors have been given to explain increases in both oil and metal prices.[7] In addition, Headey and Shenggen (2008) also mention restrictions on international trade, climate shocks[8], and a decrease in productivity and food stocks[9] to explain the increase in food prices.

Third, solutions for dealing with commodity price increases are also diverse and complex. In the case of food prices, several authors indicate that an important part of the problem can be solved by reducing restrictions on foreign trade (Sugden, 2009). For example, Headey (2011) and Martin and Anderson (2011) find evidence that restrictions on exports of rice from India and Vietnam caused an increase in the price of this product. Mitra and Josling (2009) show that both short-term and long-term export restrictions worsen the welfare of the countries that impose the measures and the rest of the world.

Nevertheless, not all researchers agree that eliminating trade barriers is the solution. For example, Gouel and Jean (2012) show that for a self-sufficient country, an optimal trade policy in the presence of risk aversion should include both subsidies on imports and taxes on exports in periods of high prices. In fact, some countries have followed this practice, according to the International Monetary Fund (IMF, 2008).

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and changes in the exchange rate cause food prices. Mitchell (2008) proposes an elasticity of 0.75 between depreciation of the dollar and food prices.

[4] Timmer (2008) identifies increased demand from China and India as a factor in the increase in food prices in 2006. However, while these two countries are self-sufficient in the production of rice and wheat, they could still affect food prices through their oil demand (Hamilton 2009), which would also affect biofuel prices.

[5] For example, Caballero, Farhi, and Gourinchas (2008) argue that persistent global imbalances, the subprime mortgage crisis, and rising oil prices are closely interconnected based on the tight supply of safe financial assets.

[6] Belke, Bordon, and Volz (2012) find evidence that while food prices and international liquidity are cointegrated, international liquidity would Granger cause food prices. Frankel (1984) provides an explanation for this phenomenon, proposing that a lower interest rate increases the demand for storable commodities.

[7] Hamilton (2009) summarizes the factors behind the rise in oil prices in 2007–08, emphasizing the high demand from China and the stagnant supply of Saudi Arabia. In contrast, Caballero, Farhi, and Gourinchas (2008) highlight financial speculation to explain the oil price shock. With regard to metals, Humphreys (2010) notes that the price boom can be explained largely by increased demand from China and emerging economies and supply lags. Moreover, the boom has coincided with a fall in the cost of manufactured goods, but with increased costs of minerals.

[8] Kang, Khan, and Maa. (2009).

[9] Kappel, Pfeiffer, and Werner (2010) argue that fundamental market forces of demand and supply were the main drivers of this development. Deficits in global food supply and declining inventories pushed prices upwards and led to expectations of further imbalances.

In practice, it is difficult to implement policies to eliminate or introduce trade barriers, especially in the short term, due to the redistribution of welfare between the different agents in the economy. Consequently, trade policies cannot stabilize the economy in the very short term. This paper therefore concentrates on monetary, exchange rate, and fiscal policies as tools to handle fluctuations in commodity prices.

Another way to address the problem of rising food prices is to help the poorest segment of the population directly with fiscal policies (Sugden, 2009; Timmer, 2010).[10] Ivanic and Martin (2008) point out that the recent increase in food prices could substantially increase poverty in low-income countries. Dawe (2008) finds that in Asian countries, the increases in prices are passing through quickly from farmers to consumers. According to the World Bank (2008), one of the most important policy options is direct transfers to the most vulnerable groups. Similarly, the IMF (2008) notes that the most vulnerable groups of the population in low-income countries should be protected from these increased prices.

Fourth, rising food prices are having an impact on the inflation rate, especially in developing countries. Walsh (2011) argues that the increase in the price of food has been so sharp that measures of inflation that exclude food inflation are not correct measures for policy purposes. Peeters and Strahilov (2008) find that the food inflation has been driving inflation in Algeria, Belarus, Egypt, Georgia, Israel, Jordan, Moldova, Russia, Saudi Arabia, Tunisia, and Ukraine. Further, Albers and Peeters (2011) show that the increase in the prices of food and energy were important elements in the revolts in the countries of North Africa at the end of 2010. This evidence is not definitive, however, especially for more developed economies and for some emerging economies. Cecchetti and Moessner (2008) point out that while food price increases have been important in this type of economy, such increases do not have had second-round effects on inflation.

Given the similarity of the effects of oil and food prices on inflation, some researchers have proposed a similar monetary policy to stabilize both kinds of shocks. Aoki (2001) shows that the optimal monetary policy under inflation targeting only has to respond to price inflation in the sector of the economy in which firms set their prices.[11] Huang and Liu (2004) extend the analysis by introducing two sectors with rigid prices: namely, the

[10] The economic logic behind this type of solution to the problem of rising food prices can be found in the classic paper by Newbery (1989): selling rations at a fixed price that is below the normal price is effective if coverage is wide and intervention is modest. In other conditions, price stabilization can be more effectively achieved through food storage.

[11] This monetary regime is particularly interesting for our study, De Mello and Moccero (2011) find that countries like Chile, Brazil, Colombia and Mexico once have adopted inflation targeting regime with flexible exchange rates have responded in varying degrees to the expected inflation.

final and intermediate goods sectors. In this case, monetary policy that responds to both the consumer price index (CPI) and the producer price index (PPI) is closest to the optimum. Catao and Chang (2010) explicitly incorporate food prices into a dynamic stochastic general equilibrium (DSGE) model for an open economy. They find that for different calibrations of the model, a rule that responds to the CPI (that is, including food prices) improves welfare when the variance of the price of food is similar to the observed data. Ben Aissa and Rebei (2012) find similar results when they estimate a DSGE model for a large number of countries using Bayesian methods.

However, if a tight monetary policy is implemented to stabilize the impact of food prices on the economy, as in case of the oil price, the economy will contract. Leduc and Sill (2004) and Carlström and Fuerst (2006) argue that the optimal monetary policy for dealing with an oil price shock is to stabilize inflation. This policy recommendation depends on the assumption about real wages, however: if real wages are rigid, the contraction of output is not optimal (Blanchard and Galí, 2007; Kormilitsina, 2010). Independent of whether an output contraction is optimal, an oil price increase has led many of the recessions. For instance, in many episodes in the United States, the oil price increased first, and then the U.S. Federal Reserve decided to increase the federal funds rate (Bernanke, Gertler, and Watson, 1997).[12]

Fifth, the boom in metal and oil prices has led several researches to suggest that export countries should save the revenues from these products. For example, countries like Chile and the Netherlands have created stabilization funds to spend the revenues from their natural resources over time[13]. García, Restrepo, and Tanner (2011) prove that in a small open economy with restricted consumers, the fiscal rule that replicates the saving decision of Ricardian agents to smooth consumption is closer to the optimal fiscal rule than the balanced-budget rule. In contrast, the available evidence suggests that fiscal policy is procyclical in most emerging and developing economies (Kaminsky, Reinhart, and Végh, 2005). Talvi and Végh (2005) show that in many countries where tax revenues are linked to the export of a commodity (such as oil or minerals), it is optimal for politicians to boost spending when the commodity price is high. In this way, the fiscal authority amplifies (rather than attenuates) macroeconomic volatility.

[12] The argument that a monetary policy contraction occurs after an oil price shock is originally from Bohi (1989) and was later developed by Bernanke, Gertler, and Watson, (1997). A critical view of this argument is in Hamilton and Herrera (2004) are critical of this argument, however: they find that oil shocks alone are strong enough to produce a contraction of the economy, independent of monetary policy.

[13] From the point of view of monetary policy, Frankel and Saiki (2002) propose linking the exchange rate to the price of the main export commodity. According to these authors, a country with such a strategy can thus combine a nominal anchor for monetary policy with the automatic accommodation of the terms of trade provided by a flexible exchange rate.

In this paper, we develop a DSGE[14] model to propose a macroeconomic policy that helps stabilize the effects of booms and busts of commodity prices. The stabilization strategy considers an important stylized fact that affects many developing economies and some emerging economies. These economies are not only affected by commodity price increases, but also favored by them. This supports a fiscal policy that transfers part of the revenues from the exports to the poorest segments of society. In other words, many economies can take advantage of the boom in commodity prices because they face not only “bad” prices that affect the production cost of firms or reduce the budget of consumers, but also “good” prices that increase fiscal revenues and can be used in transfers. Of course, this strategy is feasible if and only if the government decides to save part of the revenues from exports when prices are high, to be used in periods when prices fall.

We show that a fiscal policy of transfers can be implemented without a tight monetary policy, as the previous literature finds. Even more, the combination of fiscal transfers and a moderate monetary policy obtains a higher level of welfare than a fiscal policy focused excessively on saving income from exports combined with an aggressive monetary policy.

This important result is based on our assumption of two types of agents: Ricardian and restricted consumers. An aggressive monetary policy can greatly hurt the restricted agents, who are not able to smooth their consumption like optimizing agents who have plenty of access to international debt markets. In other words, in a small open economy, the central bank can only reduce the inflation rate by putting most the burden of adjustment on restricted households, which must reduce their consumption.

The above result contradicts some policy recommendations for closed economies. For instance, Galí (2008) and other authors demonstrate that sticky prices are an important distortion in a closed economy in the short run, and they argue that the central banks should therefore stabilize inflation to avoid the suboptimal position of firms and the subsequent welfare losses of Ricardian agents, who are the owners of the firms. This is not completely valid in our model, however, where the welfare losses of the poorest households in response to an aggressive monetary policy are higher than welfare losses caused by sticky prices.

The article is organized as follows. The second section summarizes the evidence on the boom in commodities in recent years. The third section presents the DSGE model in

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[14] Several authors build DSGE models to analyze macroeconomic policies in open economies. For instance, the structure of our model is similar to the one proposed by Laxton and Pesenti (2003).

detail. The fourth section presents the results and policy implications of our model. Our conclusions are presented in the fifth section.

2. Evidence and motivation

Developing countries and open economies face the dilemma of dealing with the growing trend in the prices of various commodities, including energy, food, and metals. Figures 1, 2, and 3 show this particular situation for the period 2000–10. Table 1 presents the correlation between different types of commodities. Most of the correlations are significant and indicate that commodity prices move together. Table 2 shows that the prices of these products are also highly persistent over time.

Insert Figures 1,2 , and 3
Insert Tables 1and 2

The boom in commodities can present not only problems, but also opportunities for some countries when designing fiscal and monetary policy. Many small open economies are both exporters and importers of these products. Consequently, the price fluctuations both hurt their terms of trade (a situation we term bad prices) and at the same time improve the terms of trade (good prices) during this period. In table 3, we show exports and imports for a group of countries relative to their gross domestic product (GDP). We highlight the fact that if a country is a net exporter of energy and minerals, it is a net importer of food, and vice versa.

Insert Table 3

This evidence further clarifies our hypothesis. The simultaneous and persistent increase in many commodity prices can be a sign of macroeconomic destabilization. A high pass-through of the commodity price hikes to domestic prices represents a complex problem for monetary policy. This reflects the fact that the share of food and transport in the consumption basket used to calculate the CPI is over 30 percent in many open economies (see table 4). In addition, very expansionary fiscal policy during an export boom may exacerbate the cycle of these open economies. One solution would be to address this phenomenon through a two-pronged approach: first, design an aggressive monetary policy to address the problem of inflation; second, and independently of monetary policy, implement a fiscal policy of accumulating assets for the future. We show that this strategy is not optimal and is dominated by an economic policy that considers the empirical fact that these economies are facing both good and bad prices, a fact that can improve the interaction between fiscal and monetary policy. Taking this interaction into account improves the country's welfare, especially for the most vulnerable groups in society.

Insert Table 4

In this paper, we show that a very aggressive monetary policy only worsens the situation of the most vulnerable groups of the population, and the losses incurred by these people are not compensated by rapid inflation stabilization. The resources generated in an export boom can be exploited to soften these losses without the need for a drastic reduction of inflation.

3. The Model

We assume a continuum of infinitely lived households indexed by $i \in$ [0, 1]. Following Galí, López-Salido, and Vallés (2007), a fraction of households λ consume their current labor income; they do not have access to capital markets and hence neither save nor borrow. Such agents are termed restricted consumers. The remainder, $1-\lambda$, save, have access to capital markets, and are able to smooth consumption. Therefore, their intertemporal allocation between consumption and savings is optimal (that is, they are Ricardian or optimizing consumers). Both segments optimize on the intratemporal margin in labor markets.

3.1 Consumption by Ricardian households

The representative household maximizes expected utility

$$E_o \sum_{t=0}^{\infty} \beta^t U\left(C_t^o(i), N_t^o(i)\right), \quad (1)$$

subject to the budget constraint

$$P_t C_t^o(i) \le W_t(i) N_t^o(i) + B_t^o(i) - S_t B_t^{o*}(i) + D_t^o(i) - P_t T_t$$
$$- R_t^{-1} B_{t+1}^o(i) + S_t (\Phi(b_{t+1}^*) R_t^*)^{-1} B_{t+1}^{o*}(i), \quad (2)$$

where $C_t^o(i)$ is consumption, $D_t^o(i)$ are dividends from ownership of firms, $\Phi(b_{t+1}^*)$ is the country risk premium,[15] S_t, is the nominal exchange rate, $B_t^{o*}(i)$ denotes private net foreign assets (with a positive value of $B_t^{o*}(i)$ defined as debt), $W_t(i)$, is the nominal wage, $N_t^o(i)$ is the number of hours of work, $B_t^o(i)$ is government debt held by households, R_t and R_t^* are the gross nominal returns on domestic and foreign assets (where $R_t = 1 + i_t$ and $R_t^* = 1 + i_t^*$), and T_t are lump-sum taxes.

Our utility function (Correia, Neves, and Rebelo, 1995) yields realistic values for consumption volatility:

$$U(C,N) = \frac{(C - \psi N^{\varphi})^{1-\sigma} - 1}{1-\sigma}, \quad (3)$$

where $1/\sigma$ is the intertemporal elasticity of substitution in consumption and $1/(\varphi - 1)$ is the elasticity of labor supply to wages. The value of ψ is calibrated to obtain a realistic fraction of steady-state hours worked.

The first-order condition for consumption (that is, the Euler equation for consumption) is[16]

[15] The domestic debt in the risk premium is in real terms and corresponds to the aggregate level, that is, it includes external government debt. We explain each transformation in detail below.

[16] Equation (4) is obtained by using the following transformation of domestic debt in real terms: $B_t^o / P_t = b_t^o$ and $R_t^{-1} B_{t+1}^o(i) = R_t^{-1} \left(P_{t+1} / P_t \right) b_{t+1}^o(i)$.

The first-order condition for utility maximization is obtained with respect to $b_{t+1}^o(i)$.

$$1 = E_t\left(\frac{\left(C_{t+1}^0(i) - \psi N_{t+1}{}^0(i)^{\varphi}\right)^{-\sigma}\beta}{\left(C_t^0(i) - \psi N_t{}^0(i)^{\varphi}\right)^{-\sigma}} R_t\left(\frac{P_t}{P_{t+1}}\right)\right). \quad (4)$$

From the first-order condition, it is also possible to derive the interest parity condition, where $Q_t^* = S_t P_t^* / P_t$.[17]

$$1 = E_t\left(\frac{\left(C_{t+1}^0(i) - \psi N_{t+1}{}^0(i)^{\varphi}\right)^{-\sigma}\beta}{\left(C_{t+1}^0(i) - \psi N_{t+1}{}^0(i)^{\varphi}\right)^{-\sigma}} \Phi\left(B_{t+1}^*\right) R_t^*\left(\frac{Q_{t+1}}{Q_t}\right)\right). \quad (5)$$

3.2 Consumption by restricted households

We assume that these households do not save or borrow (Mankiw, 2000). As a result, their level of consumption is given by their disposable income plus government transfers, equal to:

$$\theta\left(\frac{P_t^F}{P_t}\right)\left(\overline{C}^{F,R} - C_t^{F,R}\right) = \theta\left(\frac{P_t^F}{P_t}\right)(1-\gamma_c)\left(\frac{P_t^F}{P_t}\right)^{-\eta_C}\left(\overline{C}^R - C_t^R\right) = \theta(1-\gamma_c)\left(\frac{P_t^F}{P_t}\right)^{1-\eta_C}\left(\overline{C}^R - C_t^R\right). \quad (6)$$

The variable $C_t^{F,R}$ is the consumption of imported goods by restricted consumers. We have modeled the transfer in this way because we assume for simplicity that the only shock in the model is to commodity prices. The government then tries to stabilize only the restricted consumption of imported goods around its steady-state value. This

[17] The real exchange rate is obtained from equation (2) by using the following transformation of the external debt in domestic real terms: $S_t B_t^{o*} / P_t = b_t^{o*}$ and

$$S_t\left\{\Phi\left(b_{t+1}^*\right)R_t^*\right\}^{-1} B_{t+1}^{o*}(i) = \left(Q_t^* / Q_{t+1}^*\right)\left\{\Phi\left(b_{t+1}^*\right)R_t^*\right\}^{-1}\left(P_{t+1}^* / P_t^*\right) b_{t+1}^{o*}(i).$$

The first-order condition for utility maximization is obtained with respect to $b_{t+1}^{o*}(i)$.

stabilization depends on the value of the parameter $\theta \in [0,1]$. For example, if the parameter θ is zero, there is no stabilization, whereas if the parameter θ is one, the stabilization is complete. Thus, the consumption of the restricted households is equal to

$$P_t C_t^r(i) = W_t(i) N_t^r(i) - P_t T_t. + \theta(1-\gamma_c)\left(\frac{P_t^F}{P_t}\right)^{-\eta_C}\left(\overline{C}^R - C_t^R\right) \quad (7)$$

3.3 Labor Supply

Symmetric with the goods markets (discussed below), the continuum of monopolistically competitive households supply a differentiated labor service to the intermediate-goods-producing sector, and a labor aggregator combines as much household labor as is demanded by firms with a constant-returns technology. The aggregate labor index has the constant elasticity of substitution (CES) form:

$$N_t = \left[\int_0^1 N_t(i)^{\frac{1}{1+\theta_\omega}} di\right]^{1+\theta_w}, \quad (8)$$

where $N_t(i)$ is the quantity of labor used from each household. The representative labor aggregator minimizes the cost of producing a chosen amount of the aggregate labor index, given each household's wage rate $W_t(i)$. Labor index units are then sold to the production sector at their unit cost W_t (with no profit):

$$W_t = \left[\int_0^1 W_t(i)^{-\frac{1}{\theta_\omega}} di\right]^{-\theta_\omega}. \quad (9)$$

While prices are sticky, wages are completely flexible. Nominal wages are set by households so as to maximize their intertemporal objective function (1), subject to the intertemporal budget constraint (2). Thus the labor supply is equal to:

$$W_t(i) = \left(1+\theta_w\right)\varphi\psi N_t\,(i)^{\varphi-1}, \tag{11}$$

where the expression $\left(1+\theta_w\right)$ is a wedge between the wage and the ratio of the marginal disutility of labor to the marginal utility of consumption. We further assume that restricted families use the same condition to decide their labor supply.

3.4 Demand for domestic and imported consumption goods

Consumption is a CES aggregate of domestic goods $C_t^D(i)$ and imported goods $C_t^F(i)$, where η_C is the elasticity of substitution between domestic and foreign goods and α_C is the steady-state share of imported goods in total consumption:

$$C_t = \left(\alpha_c^{\frac{1}{\eta_C}}\left(C_t^D\right)^{\frac{\eta_C-1}{\eta_C}} + (1-\alpha_c)^{\frac{1}{\eta_C}}(C_t^F)^{\frac{\eta_C-1}{\eta_C}}\right)^{\frac{\eta_C}{\eta_C-1}}. \tag{12}$$

From the intra-minimization problem, we get the price for aggregate consumption:

$$P_t = \left(\alpha_c\,\left(P_t^D\right)^{1-\eta_c} + (1-\alpha_c)(P_t^F)^{1-\eta_c}\right)^{\frac{1}{1-\eta_C}}. \tag{13}$$

3.5 Domestic intermediate goods firms

We assume a continuum of monopolistically competitive firms, indexed by $j \in [0,1]$, which produce differentiated intermediate goods. The production function of the representative intermediate goods firm, indexed by (j), corresponds to a CES combination of capital $K_t\,(j)$ and labor $N_t\,(j)$, to produce $Y_t^D(j)$. It is is given by

$$Y_t^D(j) = A_t\left[\alpha K_t(j)_t^{\frac{\sigma_s-1}{\sigma_s}} + (1-\alpha)N_t^{\frac{\sigma_s-1}{\sigma_s}}(j)\right]^{\frac{\sigma_s}{\sigma_s-1}} , \tag{14}$$

where A_t is the technology parameter and σ_s is the elasticity of substitution between capital and labor, with both greater than zero. Firms minimize costs, taking as given the rental price of capital R_t^k, and wage W_t, subject to the production function.

The demand for factors arising from the first-order condition is given by

$$\frac{R_t^k}{W_t} = \left(\frac{\alpha}{1-\alpha}\right)\left(\frac{N_t(j)}{K_t(j)}\right)^{\frac{1}{\sigma_s}} . \tag{15}$$

Thus the marginal cost is given by

$$MC^D = \frac{1}{A_t}\left[\alpha^{\sigma_s}(R_t^k)^{1-\sigma_s} + (1-\alpha)^{\sigma_s}(W_t)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}} . \tag{16}$$

When firm (j) receives a signal to optimally set a new price à la Calvo (1983), it maximizes the discounted value of its profits, conditional on the new price:

$$\max \sum_{k=0}^{\infty} \theta_D^k E_t\left\{\Lambda_{t,t+k} Y_{t+k}^D(j)(P_t^{D*}(j) - MC_{t+k}^D)\right\} \tag{17}$$

subject to

$$Y_{t+k}^D(j) \leq \left(\frac{P_t^{D*}(j)}{P_{t+k}^D}\right)^{-\varepsilon_D} Y_{t+k}^D , \tag{18}$$

where the probability that a given price can be reoptimized in any particular period is constant and is given by $(1-\theta_D)$ and where ε_D is the elasticity of substitution between any two differentiated goods. The stochastic discount factor is $\Lambda_{t,t+k}$. = $\beta^k \left(\frac{C^0_{t+k} - \psi N^{0\ \varphi}_{t+k}}{C^0_t - \psi N^{0\varphi}_t} \right)^{-\sigma} \left(\frac{P_t}{P_{t+k}} \right)$.

The optimal price P_t^{D*} is obtained from the first-order condition:

$$\sum_{k=0}^{\infty} \theta_D^k E_t \left\{ \Lambda_{t,t+k} Y_{t+k}^D(j) \left(P_t^{D*}(j) - \frac{\varepsilon_D}{\varepsilon_D - 1} MC_{t+k}^D \right) \right\} = 0 \tag{16}$$

Firms that did not receive the signal will not adjust their prices. Those who do reoptimize choose a common price, $P_t^{D\tilde{*}}$ Finally, the dynamics of the domestic price index P_t^D. are described by the following equation:

$$P_t^D = \left[\theta_D (P_{t-1}^D)^{1-\varepsilon_D} + (1-\theta_D)(P_t^{D*})^{1-\varepsilon_D} \right]^{\frac{1}{1-\varepsilon_D}} . \tag{17}$$

3.6 Importing firms

We assume that the import sector also set prices à la Calvo. In other words, firms import in dollars and then set the price in domestic currency. For example, the prices of food and energy imports (oil) are set in domestic currency. Therefore, we assume that there is some degree of market power in the import sector. The variables $(1-\theta_F)$ and ε_F have the same definition as before, so the price of imports is given by

$$P_t^F = \left[\theta_F (P_{t-1}^F)^{1-\varepsilon_F} + (1-\theta_F)(S_t P_t^{F*})^{1-\varepsilon_F} \right]^{\frac{1}{1-\varepsilon_F}} . \tag{18}$$

3.7 Final goods distribution

Total final output is expressed with a CES aggregator function (across firms). There is a perfectly competitive aggregator, which distributes the final good using a constant return to scale (CRS) technology. It is valid for both K = D (domestic) and F (imported) goods:

$$Y_t^K = \left(\int_0^1 Y_t^K(j)^{\frac{\varepsilon_K - 1}{\varepsilon_K}} dj \right)^{\frac{\varepsilon_K}{\varepsilon_K - 1}} , \qquad (19)$$

where $Y_t^K(j)$ is the quantity of the intermediate good (domestic or imported) included in the bundle that minimizes the cost of any amount of output Y_t. The aggregator sells the final good at its unit cost P_t with no profit:

$$P_t^K = \left(\int_0^1 P_t^K(j)^{1-\varepsilon_K} dj \right)^{\frac{1}{1-\varepsilon_K}} , \qquad (20)$$

where P_t is the aggregate price index. Finally, demand for any good $Y_t^K(j)$ depends on its price $P(j)$, which is taken as given, relative to the aggregate price level P_t:

$$Y_t^K(j) = \left(\frac{P(j)}{P_t} \right)^{-\varepsilon_K} Y_t^K . \qquad (21)$$

3.8 Optimizing investment firms and Tobin's Q

There are firms that produce homogenous capital goods and rent them to the intermediate goods firms. Firms are owned exclusively by Ricardian households. Firms invest the amount so as to maximize firm value:

$$V^t(K_t^o) = R_t^k K_t^o - P_t^I I_t^o + E_t \Lambda_{t,t+1}(V^{t+1}(K_{t+1}^o)) \ , \tag{22}$$

subject to a capital accumulation constraint that includes an adjustment cost function ϕ (.):

$$K_{t+1}^o = (1-\delta)K_t^o + \phi\left(\frac{I_t^o}{K_t^o}\right)K_t^o \ . \tag{23}$$

3.9 Demand for investment goods

Overall investment is equal to a CES aggregate of domestic and imported goods:

$$I_t = \left(\alpha_I^{\frac{1}{\eta_I}}(I_t^D)^{\frac{\eta_I-1}{\eta_I}} + (1-\alpha_I)^{\frac{1}{\eta_I}}(I_t^F)^{\frac{\eta_I-1}{\eta_I}}\right)^{\frac{\eta_I}{\eta_I-1}} \tag{24}$$

where η_I is the elasticity of substitution between domestic and foreign goods and α_I is the steady-state share of domestic goods in total investment.

3.10 Exports

On the one hand, the demand for total domestic (non-commodity) exports from foreign countries is

$$X_t^D = \left(\int_0^1 X_t^D(j)^{\frac{\varepsilon_D-1}{\varepsilon_D}} dj\right)^{\frac{\varepsilon_D}{\varepsilon_D-1}} \tag{25}$$

Exports of good (j) depend on its own relative price:

$$X_t^D(j) = \left(\frac{P_t^D(j)}{P_t^D} \right)^{-\varepsilon_D} X_t^D \tag{26}$$

There is a demand for each set of differentiated domestic goods, which in turn depends on both total consumption abroad and the home price of domestic goods (relative to prices in the foreign country):

$$X_t^D = \left[\left(\frac{P_t^D}{S_t P_t^{D*}} \right) \right]^{-\eta*} C_t^{D*} \tag{27}$$

On the other hand, we assume that the price of the exported commodity varies exogenously according to $P_t^{cu} = \overline{P^{cu}}(1+\varepsilon_t)$, where ε_t is a shock with a normal distribution. By contrast, the quantity of the commodity is assumed constant: $Q_t^{cu} = \overline{Q^{cu}}$. We are thinking here of a natural resource that is exported at a price given on international commodity markets.

3.11 Monetary policy

We assume that the central bank follows a simple Taylor rule to stabilize inflation:

$$R_t = \overline{R} \left(\left(\frac{\Pi_t}{\overline{\Pi}} \right)^{\phi_\pi} \left(\frac{YR_t}{\overline{YR_t}} \right)^{\phi_y} \right), \tag{28}$$

where $\overline{R}$ is the steady-state nominal interest rate, Π_t is total inflation, $\overline{\Pi}$ is steady-state total inflation (assumed to be zero), YR_t is GDP excluding natural resources, and $\overline{YR}$ is the steady-state value of GDP excluding natural resources.

3.12 Fiscal policy and export commodities

The government budget constraint is

$$IT_t + R_t^{-1} B_{t+1}^G + S_t (\Phi(B_{t+1}^*) R_t^*)^{-1} B_{t+1}^{G*}$$
$$= B_t^G + S_t B_t^{G*} + P_t^G G_t + \lambda\theta(1-\gamma_c)\left(\frac{P_t^F}{P_t}\right)^{1-\eta_c}\left(\overline{C}^R - C_t^R\right) \qquad , \qquad .(29)$$

where IT_t is total revenue (including copper), B_t^G is domestic public debt, $S_t B_t^{G*} = v_b B_t^G$ is public foreign debt (a fixed proportion of domestic public debt), and $P_t^G G_t$ is public spending.

An important feature of open developing economies is that revenues from commodity exports are collected through direct taxes or simply through government ownership of some of these resources. For the sake of simplicity and to avoid introducing distortionary taxes in the model, we assume that the government owns a constant percentage of the exported commodity.

There are two sources of revenue: a domestic (non-commodity) lump-sum tax, $P_t T_t = \overline{PT}, \forall t$, which is assumed to always be in steady state; and a commodity revenue, which varies each period and is defined as $\tau_{cu}(S_t P_t^{cu} Q^{cu})$, where τ_{cu} is the share of the natural resource (commodity) owned by the government, P_t^{cu} is the world price of the commodity, and Q^{cu} is the quantity supplied.

Since constrained households are not able to smooth their consumption over time, we assume that the government tries to do this for these households. Restricted households thus receive a government transfer equal to $\lambda\theta(1-\gamma_c)\left(\frac{P_t^F}{P_t}\right)^{1-\eta_c}\left(\overline{C}^R - C_t^R\right)$.

The exact amount of resources transferred by the government to restricted consumers is determined by the parameter θ. For instance, when $\theta = 1$, the transfer of resource is complete.

3.13 A simple fiscal rule

Commodity revenue is essentially manna from heaven. The government purchases goods and services with this manna. A fiscal rule determines the intertemporal allocation of such spending. In this regard, we follow the work of García, Restrepo, and Tanner (2011), who propose that the rule should be transparent and easily understood (as emphasized by Kydland and Prescott, 1977) and that the government's net asset position—debtor or creditor—must be bounded. Neither net debt nor assets may grow without limit.

García, Restrepo, and Tanner (2011) propose the following rule to distribute the proceeds of export earnings of nonrenewable raw materials such as copper (for Chile) and oil (for Norway):

$$P_t^G G_t = \overline{IT} - [\tilde{r}_t + \mu_x] B_t^G + \alpha_r (IT_t - \overline{IT}), \qquad (30)$$

where $\tilde{r}_t$ is a weighted average (effective) interest rate on total debt (domestic plus foreign), namely,

$$\tilde{r}_t \equiv \frac{\tilde{R}_t - 1}{\tilde{R}_t} \equiv \left[\frac{R_t - 1}{R_t} + \frac{R_t^* \Phi(B_{t+1}^*) - 1}{R_t^* \Phi(B_{t+1}^*)} v_b \right] . \qquad .(31)$$

Thus, if $\alpha_\gamma = 1, \mu_x = 0$, then the fiscal rule collapses to a balanced budget regime; whereas for an acyclical regime, $\alpha_\gamma = 0$, and $0 < \mu_x < R^{-1}$,that for small values of $\tilde{r}$ this is a necessary and sufficient condition for non-explosive debt dynamics. For other intermediate rules, $0 < \alpha_\gamma < 1$, and $0 < \mu_x < R^{-1}$. We can thus use alternative pairings of $[\alpha_\gamma, \mu_x]$ to introduce both the mean and variance of government spending in a continuous fashion.

3.14 The interaction between the fiscal rule and monetary policy

In the context of our DSGE model, it is possible to complement monetary policy with fiscal policy if the economy faces active commodity shocks. Suppose that the economy faces two simultaneous shocks: an increase in the price of imported goods, such as food, and an increase in the price of commodity exports, such as oil.

First, assuming sticky prices, monetary policy could be contractionary (Galí, 2008).[18] This is because an increase in the price of imported goods in dollars, that is, a marginal increase in the cost of importing, creates a suboptimal situation for firms that sell imported goods at prices fixed in domestic currency. For example, the prices of rice, wheat, and dairy products are set in the domestic currency, but these products are imported in dollars. Thus, monetary policy is contractionary because lower earnings among importing firms have a negative effect on the consumption of Ricardian households, since these agents are the owners of these firms in this economy.

A contractionary monetary policy in our model means a rise in the interest rate and a reduction in domestic demand, as in a Keynesian DSGE model of a closed economy. This increase in the interest rate causes a fall in output and inflation. It is also standard in these models for the increase in the interest rate to generate a fall in the exchange rate, which negatively affects intermediate goods exports, reinforcing the contractionary effect on demand (García and Gonzalez, 2013).

Second, the imported price shock can be smoothed by Ricardian agents, since they have direct access to external borrowing in international markets (in contrast to a closed economy). However, restricted households cannot smooth their consumption in response to the shock because they have not access to these markets.

Third, the government could try to subsidize imported goods prices to mitigate the impact on restricted consumers. This policy will also benefit Ricardian agents that could deal with the shock on their own, according to our model, through the external capital market. We do not treat this case explicitly in the model, although clearly this filtration reduces the resources available to the government for stabilizing restricted households.

Fourth, as an alternative to subsidies, the government can make direct transfers to restricted agents from the additional tax revenues stemming from the rising price of the export commodity. For example, the government may decide to implement acyclical spending $P_t^G G_t$, i.e., $\alpha_\gamma = 0,$ and $0 < \mu_x < \tilde{R}^{-1}$, while simultaneously giving

[18] We are assuming flexible wages, otherwise this recommendation is not already correct, for example see Blanchard and Galí (2007).

$\lambda(1-\gamma_c)\left(\frac{P_t^F}{P_t}\right)^{1-\eta_c}\left(\overline{C}^R - C_t^R\right)$ to restricted households out of fiscal resources from commodity exports, with a parameter $\theta=1$. In other words, the government decides to save less and, therefore, accumulate fewer assets for the future.

Fifth, providing direct transfers to restricted consumers is equivalent to a countercyclical fiscal policy. This is possible because in our model, total government expenditure is the sum of $P_t^G G_t$ and the direct transfer to restricted households. Indeed, fiscal policy is only completely acyclical when $\alpha_\gamma = 0, \quad 0 < \mu_x < \tilde{R}^{-1}$, and $\theta=0$, because there are no transfers. However, in the case $\theta=1$, the government spends $(1-\gamma_c)\left(\frac{P_t^F}{P_t}\right)^{1-\eta_c}\left(\overline{C}^R - C_t^R\right)$ of its revenues from commodity exports on transfers to restricted households. This should produce a positive impact on the economy if we assume all other elements of the model constant.

3.15 Aggregation

Total consumption is a weighted sum of consumption by Ricardian and rule-of-thumb agents:

$$C_t = \lambda C_t^r + (1-\lambda)C_t^o = \int_0^\lambda C_t^r(i)di + \int_\lambda^1 C_t^o(i)di \quad . \qquad (32)$$

Since only Ricardian households invest and accumulate capital, total investment is equal to $(1-\lambda)$ times optimizing investment:

$$I_t = (1-\lambda)(I_t^o) \qquad .(33)$$

Likewise, the aggregate capital stock is

$$K_t = (1-\lambda)(K_t^o) \qquad ..(34)$$

Again, only optimizing households hold financial assets:

$$B_t = (1-\lambda)(B_t^o) \qquad .(35)$$

Foreign assets (or debt) include fiscal assets B_t^{G*}. and privately held assets B_t^{o*}:

$$B_t^* = B_t^{G*} + (1-\lambda)B_t^{o*} \qquad .(36)$$

Hours worked are given by a weighted average of labor supplied by each type of consumer:

$$N_t = \lambda N_t^r + (1-\lambda)N_t^o \,. \qquad .(37)$$

Finally, in equilibrium each type of consumer works the same number of hours:

$$N_t = N_t^r = N_t^o \qquad .(38)$$

3.16 Market-Clearing Conditions

The factor-market-clearing conditions are total employment by all firms (j),

$$N_t = \int_0^1 N_t(j)dj \quad , \qquad (39)$$

and full capital utilization,

$$K_t = \int_0^1 K_t(j)dj \quad . \tag{40}$$

In the goods market, the market-clearing condition is

$$Y_t^D = (C_t^D + I_t^D + G_t^D + X_t^D) \quad , \tag{41}$$

Where the total supply of domestic goods equals total demand for the domestically produced good for consumption, investment, government spending, and exports. Finally, the economy-wide budget identity can be expressed as follows:

$$\begin{aligned} P_t C_t = & -P_t^G G_t - P_t^I I_t + P_t^D Y_t^D + (P_t^F Y_t^F - S_t P_t^{*F} Y_t^F) + \\ & S_t \left(\Phi\left(b_{t+1}^*\right) R_t^* \right)^{-1} B_{t+1}^* - S_t B_t^* + \\ & \tau_{cu} (S_t P_t^{cu} Q^{cu}) \end{aligned} \tag{42}$$

Equation (43) has an intuitive interpretation. First, GDP is the (approximate) sum of the domestically produced goods, value added on the distribution of imports, and copper exports: [19]

$$P_t Y_t = P_t^D Y_t^D + (P_t^F Y_t^F - S_t P_t^{*F} Y_t^F) + (S_t P_t^{cu} Q^{cu}) \quad . \tag{43}$$

Thus, according to the national income accounting identity, consumption must equal GDP minus investment (I) and government expenditures (G) plus foreign debt (positive values of B_t^*), which is written

$$S_t \left(\Phi\left(b_{t+1}^*\right) R_t^* \right)^{-1} B_{t+1}^* - S_t B_t^* \quad . \tag{44}$$

The risk premium ensures that the economy returns to the steady state.[20] This variable therefore increases with the foreign debt.

[19] We assume for simplicity that there are no private commodity exports; we treat them as if they were transfers from abroad.

4. Results

First, we present the results in terms of impulse response functions to a **one unit** composite shock, which we define as a simultaneous shock to the prices of the exported commodity and imported goods. This assumption is consistent with the evidence presented in the second section, where we show the high correlation between different prices of commodities: oil, food, and minerals. For example, this shock could be a simultaneous increase in the price of foods (imports) and the price of metals or energy (exports).

Our goal with the impulse responses in this section is two-fold. First, we analyze how this compound shock may cause more inflation in the small open economy. Second, we explain how consumption in both types of households is affected by different monetary and fiscal policy alternatives for stabilizing inflation and the economy, and use simulations from the DSGE model to measure the effects on welfare of the different policies in response to the composite shock. We use this latter exercise to establish a ranking of the different policies based on the level of welfare.

To adequately measure welfare, we solve the model with a second-order approximation (Schmitt-Grohé and Uribe, 2004). The simulations cover 1,000 periods and are repeated 50 times. We then calibrate the model using the same parameters as proposed by García, Restrepo, and Tanner (2011), which are presented in the appendix.

Finally, to measure the sensitivity of the results to the proposed changes in the calibration, we consider two alternative values for a key parameter, namely, the elasticity of substitution between the consumption of domestic and imported goods. Imported products such as oil or food such as rice or wheat should have a low elasticity. The model is calibrated for two values of the elasticity of substitution: a low elasticity of $\eta_c = 0.2$ and a higher elasticity of close to one, $\eta_c = 0.8$.

4.1 Impulse responses

We analyze two cases in this section. The first case explores what would happen in our model if the only policy target was to stabilize inflation as quickly as possible. We thus assume a composite shock that is clearly inflationary under standard parameters (see

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[20] See Schmitt-Grohé and Uribe (2004).

the appendix). This case corresponds to an aggressive monetary policy, that is, with an inflation rate coefficient of $\varphi_{\pi} = 3$ in the Taylor rule, almost twice the value considered standard in the literature ($\varphi_{\pi} = 1.5$) (Woodford, 2003; Galí, 2008). In this first case, we also consider a fiscal policy that is mostly acyclical, that is, the fiscal rule parameter that measures the transfer is equal to zero ($\theta = 0$). This first case thus represents a mix of a conservative central bank and an especially prudent government. As we show below, under this mix of parameters, the final effect of the compound shock on the economy is similar to a supply shock.

Figure 4 shows the response of the economy to a composite shock in the commodity price for the first case. This shock increases inflation (*inft*) in the first period. The central bank responds by increasing the nominal interest rate (*int*) to stabilize inflation. This reaction by the central bank is consistent with evidence from several empirical studies that measure monetary policy in small open economies[21].

As expected, in a DSGE model with rigid prices, a higher real interest rate depresses consumption and private investment; the consequent fall in aggregate demand in turn reduces production. In other words, the compound shock affects the economy as a supply shock. Monetary policy achieves its goal of stabilizing inflation, because the drop in production translates into less demand for labor (n) and lower real wages (w_p). As a final result of this chain of events, the fall in marginal costs (*cm_e*) ends by pushing down the inflation rate. For simplicity, we define all these events as the first-round effect of the monetary policy response to a compound commodity shock. This first-round effect is the typical mechanism in a model with sticky prices for a closed economy, whose explanation is based on Euler equations for consumption and investment.

The exchange rate response in the model helps stabilize the inflation rate. The increase in the interest rate causes the real exchange rate (*e_p*) to drop because of the inflows of international assets. This drop in the real exchange rate simultaneously affects both the cost of imported inputs and the external demand for intermediate goods. Both effects push down marginal costs and therefore the inflation rate. The lower real exchange rate also reduces the resources from commodity exports in domestic currency, which is an extra pressure against the inflation rate. Again for presentation purposes, we define all these events as the second-round effect of the monetary policy response to a compound commodity shock, because it does not work directly through the real interest rate, but indirectly through the real exchange rate. This is the typical mechanism in a

[21] Several authors estimate DSGE models to measure the impact of monetary policy in small open economies, including Adolfson and others (2007), Castillo, Montoro, and Tuesta (2006), Caputo, Liendo, and Medina (2006), Cook (2004), Devereux, Lane, and Xu (2006), Elekdag, Justiniano, and. Tchakarov (2006), García and González (2012), Hamann, Pérez, and Rodríguez (2006), Medina and Soto (2007), and Tovar (2006).

model with sticky prices for an open economy, whose explanation is based on interest parity conditions and elasticities for the foreign sector (exports and imports).

In short, the central bank's reaction stabilizes the initial inflationary shock by increasing the real interest rate. This result is not only expected, but also desired. From a welfare perspective, the stabilization of inflation should be a natural result, because in our DSGE model, all intermediate firms have sticky prices á la Calvo (1983). A shock that accelerates inflation leaves the group of firms that do not receive the signal to change their prices (Galí, 2008) in a suboptimal position.

However, figure 4 also indicates that the adjustment is based primarily on the decrease in consumption by restricted agents. These agents do not have the option of smoothing their consumption, which Ricardian households are able to do in a small open economy. Although we have considered a risk premium on borrowing abroad that increases with the external debt, our model parameterization allows Ricardian agents to smooth private consumption by accessing not only the domestic credit market, but also the external market.

In other words, both of the mechanisms related to monetary policy—that is, the first- and second-round effects—are able to decrease aggregate demand because they can reduce consumption by restricted households without affecting Ricardian households. Both mechanisms cause firms to lower production and therefore to demand fewer workers. In the labor market, the lower demand for workers ultimately translates into lower real wages. Less employment and lower real wages produce a direct impact on the disposable income of restricted households. Since they are unable to smooth their consumption, they must reduce their expenditure.

The second case analyzes what would happen if the policy aims not only to reduce inflation, but also to stabilize restricted households' consumption through fiscal transfers. As shown in figure 5, this second case assumes a standard monetary policy with an inflation coefficient of the 1.5 in the Taylor rule, but we now consider a more active, countercyclical fiscal policy, with a fiscal rule parameter equal to one ($\theta=1$). In this second case, the big difference is clearly the response of consumption by restricted agents. Since fiscal policy now seeks to stabilize these families around their steady-state consumption (see equations 6 and 7), the drop in consumption by restricted households is much lower.

However, the cost of implementing a more active fiscal policy is higher inflation. The countercyclical policy thus presents a clear trade-off: while restricted households are affected by only a minor contraction in their consumption thanks to fiscal transfers, Ricardian households are more disadvantaged because their firms cannot change their prices. These firms are not maximizing benefits after the shock, so Ricardian households earn less profits.

4.2 Welfare

What is the best choice of economic policy? To answer this question, we must measure the welfare obtained under the two cases that presented above. We measure welfare for each type of family by the present value of utility:

$$V_t = U\left(C_t^j(i), N_t^j(i)\right) + \beta E_t\left(V_{t+1}\right), \quad j = o, r \, .$$

Table 5 displays the results for simulations with our DSGE model. The results presented in the table are averages of 50,000 simulations. The average welfare of the simulations is

$$\bar{V} = \frac{U\left(\bar{C}^j(i), \bar{N}^j(i)\right)}{1-\beta}, \quad j = o, r \, .$$

In Table 5, we compare the average welfare, expressed as a percentage, of the two cases, that is, an aggressive monetary policy with a cautious fiscal policy versus a standard monetary policy with a more countercyclical fiscal policy. The results indicate that the difference of the welfare gains of the Ricardian household is marginal between the two cases. This result is consistent with the fact that these families are able to smooth their consumption through access to the international credit market.

In other words, the standard mechanism for a closed economy that was described above is weaker in our model than in the canonical model with sticky prices for a closed economy. This occurs because the Ricandian households have the possibility of borrowing abroad, which helps them cope with the central bank’s reaction of increasing interest rates to stabilize inflation.

However, restricted households are more favored when policymakers decide to deliver fiscal transfers financed by the resources from commodity exports. Since the calibration assumes that 50 percent of consumers are restricted, the second case (that is, a more cyclical fiscal policy combined with a standard monetary policy) is preferred to the first case, in which policymakers have a bias in favor of stabilizing inflation and saving resources from the export sector.

This last result confirms our earlier explanation of the impulse response functions. In an open economy with restricted households, economic stabilization puts the burden of adjustment on these families. This occurs because the mechanism identified in the last section for a closed economy is weaker in our model DSGE than in the canonical model for a closed economy. Therefore, the central bank's attempt to stabilize the economy will further depressing the consumption of restricted families.

The results in table 5 also indicate that if the elasticity of substitution between domestic and imported consumer goods falls, the benefits to restricted households are higher. For example, if the exported commodity is metal or oil, and if the imported good is difficult to substitute with domestic goods, the welfare gains of restricted households are larger if fiscal policy has a contercyclical component that helps stabilize the consumption of these households.

Insert Table 5

5. Conclusions

In this article, we have analyzed the effects of stabilizing shocks to commodity prices. First, we presented empirical evidence that many open developing economies face composite shocks, in that they are favored by increases in the price of their main export, such as metals or petroleum, but they are disadvantaged by increase in the prices of imported products such as food.

Second, using a highly stylized DSGE model with a standard calibration, we showed that a composite shock in commodity prices is inflationary. Since we use a DSGE model with rigid prices, it is natural to think that it is desirable to stabilize inflation, since firms that cannot change their prices are in a suboptimal position.

Third, however, our model indicates that the above statement depends on the existence of households that have restricted access to the capital market (the poorest households), especially the external market. In a context of a small open economy, optimizing agents can smooth their consumption more than in the case of a closed economy because the can borrow abroad, an option that is not available to restricted agents. Therefore, when the central bank reduces the inflation rate in a small open economy, most the burden of adjustment falls to restricted households, which must reduce their consumption.

Fourth, welfare analysis with the DSGE indicates that the losses to the restricted households can be avoided if the central bank pursues a less aggressive monetary policy against inflation. This should be complemented by a fiscal policy that allocates part of the resources from the export sector, which is favored by the external shock, to these restricted households.

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Appendix: CALIBRATION OF THE MODEL

We calibrate the model taking sensible values from different studies (see Table A.1).[22] For example, the discount factor β is 0.99, which is close to the values found elsewhere in the literature. The risk aversion coefficient σ is greater than one (2.0), as the evidence indicates for small open economies.[23]

The elasticity of substitution across intermediate goods, ε_D and ε_F, is 6, in order to have a markup of 20 percent; the fraction of firms that keep their prices unchanged each period, θ_D and θ_F, is 0.75; and the depreciation rate δ is 0.025. All these values are standard in the literature on New Keynesian models (Woodford, 2003; Galí and Monacelli, 2005; Galí, López-Salido, and Vallés, 2007).

For the labor market, we assume the same markup as in the goods market, with θ_w equal to 0.2. The value of φ (=1.7) is from Correia, Neves, and Rebelo (1995), who introduced a Greenwood-Hercowitz-Huffman (GHH) utility function into real business cycle (RBC) models for small open economies to explain the higher volatility of the consumption observed in these countries. We also follow these authors in choosing a value for ψ (=7.02) to ensure that hours worked in steady state coincide with actual data in our benchmark country. The value of the investment adjustment cost ϕ is 1/15, which is half of the value of Correia, Neves, and Rebelo (1995). Half of households are hand-to-mouth (that is, λ is 0.5), which is within the range of values considered in other studies (Mankiw, 2000; Galí, López-Salido, and Vallés, 2007). We assume that government spending is heavily biased toward domestic goods, so we set the share of domestic goods in the government consumption basket α_G at 0.99.

This allows us to replicate a stylized fact: in many commodity-exporting countries, increases in government spending cause real appreciations (Edwards, 1989). We do not have information about the values of the elasticity of substitution between domestic and foreign goods (η_C, η_I, and η_G), so we assume values close to one (following Galí and Monacelli, 2005). For the same reason, we choose values for α_C and α_I close to 0.5 (also following Galí and Monacelli, 2005) as a measure of openness.

We assume public debt is zero in steady state as García, Restrepo, and Tanner (2011). We also assume that 21 percent of public debt is held by foreigners (v_b = 0.21). In our baseline simulation, the coefficient in the monetary rule with respect to inflation ϕ_π is 1.5, which is standard for Taylor rules. The interest rate response with respect to the output gap ϕ_{yr} is assumed to be zero. Likewise, the elasticity of substitution between capital and labor σ_S is 1.0. Thus, α is the capital share and is assumed to be 0.4. The elasticity of domestic exports to the real exchange rate η^* is 1.0, in line with estimations for developing countries (Ghei and Pritchett, 1999).

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[22] We assume that each period corresponds to one quarter.

[23] See Agénor and Montiel (1996, table 1, p. 353).

The autoregressive coefficient for the real price of the commodities ρ is 0.8. We choose small values for the debt weight (μ_X = 0.01) in the acyclical rule, as well as for the elasticity of the interest rate to external debt (0.001). Both coefficients ensure the stability of the model. The first makes public debt a stationary variable, while the second forces the current account and net foreign assets to be stationary.

Insert Table A.1

Tables

Table 1. Pearson coefficient

		Petroleum Crude	Coal (1)	Natural gas (2)			Coffee (3)		Soybean (4)			Maize		Rice Thai (5)			Wheat (6)			Sugar (7)	Al	Cu	Ni	Zn	Au	Ag
			A	US	E	(L), J	Ar	Ro	S	O	M			5%	25%	A.1.	C	US, SRW	US, HRW	World						
Petroleum Crude			6.18	1.31	9.42	7.03	4.09	9.78	4.55	5.54	3.35	4.89	4.38	4.67	3.25	5.40	5.47	5.10	5.24	2.32	3.39	8.16	3.20	2.67	4.11	5.50
Coal (1)	A			0.68	5.25	####	3.37	4.59	7.36	7.84	5.27	7.29	5.57	6.35	3.01	11.55	7.34	4.96	4.94	2.05	1.66	3.56	1.62	1.09	4.17	4.45
Natural gas (2)	US				1.33	0.40	0.03	0.97	0.29	0.62	-0.25	0.12	0.21	0.23	-0.38	0.44	0.66	0.59	0.78	-0.89	1.93	0.82	1.25	0.84	-0.40	-0.10
	E					6.45	2.74	8.92	4.02	4.59	3.34	4.66	4.56	5.24	2.61	5.04	6.11	4.09	5.91	1.97	3.00	4.92	2.41	2.30	3.03	3.69
	(L), J						4.28	6.02	6.57	6.72	5.62	8.35	5.98	8.65	3.70	13.18	7.67	4.78	4.98	2.96	1.72	4.13	1.62	1.39	5.52	5.88
Coffee (3)	Ar							3.43	3.16	2.73	3.15	2.81	2.14	3.49	5.96	3.35	2.37	2.37	1.88	5.30	1.45	4.24	1.83	1.78	7.19	7.96
	Ro								4.57	5.12	3.70	5.44	5.19	4.62	3.02	4.89	6.01	5.41	6.20	2.04	3.19	6.34	3.43	2.83	3.67	4.80
Soybean (4)	S									11.63	11.62	9.22	6.19	7.35	4.03	8.92	7.38	5.68	5.14	1.99	1.07	3.07	1.64	0.90	5.06	4.58
	O										5.82	12.15	9.01	5.42	3.03	8.83	###	9.93	7.72	1.65	1.61	3.59	2.06	1.21	4.25	4.33
	M											6.76	4.88	8.12	4.70	6.57	5.37	3.88	3.84	2.40	0.59	2.45	1.15	0.64	5.24	4.28
Maize													0.00	6.10	3.07	9.82	###	8.73	8.18	1.97	1.51	3.45	1.82	1.24	4.55	4.67
Rice Thai (5)	5%														4.57	9.33	6.46	3.47	4.23	2.79	1.00	2.91	1.09	0.89	4.85	4.31
	25%															3.24	2.56	2.40	2.16	5.25	0.78	3.33	1.48	1.37	9.09	6.51
	A.1.																###	5.07	5.31	2.14	1.28	3.07	1.30	0.86	4.47	4.32
Wheat (6)	C																	7.52	11.61	1.51	1.69	3.18	1.76	1.17	3.35	3.52
	US, SRW																		9.64	1.35	2.24	4.08	2.99	1.80	3.48	4.02
	US, HRW																			1.21	2.32	3.65	2.50	1.75	2.80	3.21
Sugar (7)	World																				0.79	2.81	0.91	1.49	5.47	4.85
Al																						4.38	5.51	6.42	1.14	1.90
Cu																							4.94	4.77	4.23	6.64
Ni																								6.33	1.73	2.53
Zn																									1.54	2.33
Au																										####
Ag																										

(1) A: Australian
(2) US: EEUU; **E:** Europe; (L), **J:** Liquefied natural gas, Japan
(3) Ar: Arabica; **Ro:** Robusta
(4) S: Soybeans; **O:**Oil; **M:** Meal
(5) 5%: broken; **25%:** broken; **A1:** Super
(6) C: Canadian; **US, SRW:** Soft Red winter; **US, HRW:** Hard Red Winter

Al: Aluminum
Cu: Cooper
Ni: Nickel
Zn: Zinc
Au: Gold
Ag: Silver

Source: The Word Bank website (Data & Research, Commodity Markets) and authors´ calculations. .

Table 2. Correlation coefficients

	Petroleum Crude (*)	Coal (1) (*)	Natural gas(2)			Coffee (3) (*)		Soybean (4) (*)			Maize (*)	Rice Thai(5) (*)				Wheat (6) (*)			Sugar		Al (*)	Cu (*)	Ni (*)	Zn (*)	Au (*)	Ag (*)
		A	US	E (*)	(L), J	Ar	Ro	S	O	M		5%	25%	A.1.	C	US, SRW	US, HRW	EU	US	World (*)						
Correlation Coefficient	0.89	0.90	0.40	0.95	-0.03	0.81	0.96	0.83	0.88	0.74	0.85	0.84	0.73	0.87	0.88	0.86	0.87	-0.35	-0.01	0.61	0.75	0.94	0.70	0.66	0.81	0.76

(1) A: Australian
(2) US: EEUU; **E:** Europe; (L), **J:** Liquefied natural gas, Japan
(3) Ar: Arabica; **Ro:** Robusta
(4) S: Soybeans; **O:**Oil; **M:** Meal
(5) 5%: broken; **25%:** broken; **A1:** Super
(6) C: Canadian; **US, SRW:** Soft Red winter; **US, HRW:** Hard Red Winter

Al: Aluminum
Cu: Cooper
Ni: Nickel
Zn: Zinc
Au: Gold
Ag: Silver

Source: The Word Bank website (Data & Research, Commodity Markets) and authors´ calculations. .

Table 3. Average commodity exports and imports to GDP
Percent.

	PERU		COLOMBIA		CHILE		VENEZUELA		ANGOLA		NIGERIA	
	Mining and petroleum products exports	Food Imports	Export Cofee and Petroleum	Food Imports	Copper exports	Food Imports	Petroleum exports	Food Imports	Diamonds and petroleum exports	Current good consume imports	Gas and Petroleum exports	Rice exports
2000-2010	12.57	1.02	4.61	0.33	15.65	0.85	25.57	1.42	0.05	13.89	39.14	3.15
2000-2005	9.16	0.94	4.05	0.36	11.77	0.54	25.60	1.11	0.03	NA	48.41	4.36
2006-2010	16.66	1.16	5.28	0.28	20.31	1.23	25.53	1.79	0.07	13.89	37.28	1.69

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	ARGENTINA		NEW ZEALAND		AUSTRALIA		THAILAND		PHILIPPINES	
	Wheat and Soy exports	Petroleum imports	Milk products exports	Petroleum imports	Milk products exports	Petroleum imports	Rice exports	Petroleum imports	Food exports	Mineral fuel imports
2000-2010	4.86	0.20	2.04	23.71	0.45	2.37	1.53	7.06	0.04	0.09
2000-2005	4.57	0.37	2.00	24.66	0.70	2.19	1.38	5.93	0.04	0.09
2006-2010	5.29	0.00	2.10	22.58	0.16	2.60	1.70	8.42	NA	NA

Source: Banco Central de Perú, Banco Central de Colombia, Banco Central de Colombia, FAO, Banco Central de Chile, Banco Central de Venezuela, INE Venezuela, Banco Nacional de Angola, Central Bank of Nigeria, INDEC Argentina, Statistics New Zealand Tatauranga Aotearoa, FAO, Bangco Sentral NG Philipinas, Australian Bureau Statistics, FAO, and International Monetary Fund.

Table 4. Share of food items and transport in the consumption basket (CPI) Percent

Groups	Argentina	Australia	Chile	Colombia	Nigeria	New Zealand	Peru	Philippines	Thailand	Venezuela	Zambia
FOOD AND NON-ALCOHOLIC BEVERAGES	37.87	16.80	18.90	28.21		17.38	**25.12**	46.6	33.0	32.20	
FOOD ONLY					50.70						
FOOD INCL. ALCOHOLIC BEVERAGES & TOBACCO											57.10
TRANSPORT	12.77	11.60	19.28	15.19	NA	17.24	**12.62**	NA	NA	10.80	NA

Country	Base Year	Source
Argentina	2008	INDEC
Australia	2011	Australian Bureau of Statistics
Chile	2009	INE
Colombia	2012	DANE
Nigeria	2009	FAO
New Zealand	2006	Statistics New Zealand Tatauranga Aotearoa
Peru	2009	INE
Philippines	NA	Asia Development Bank (2011)
Thailand	NA	Asia Development Bank (2011)
Zambia	1994	FAO
Venezuela	2007	INE

Table 5. Welfare comparision[1]

	Consumption		Employment	Real Wage	Government	Real Exchange	Investment	Real Interest	PIB	Inflation	Welfare	
	Ricardian	Hand-to-Mouth			Spending	Rate		Rate		Rate	Ricardian	Hand-to-Mouth
(1) η_c=.8,$\phi\pi$=3,ξ=0	-0,006%	-0,175%	-0,039%	-0,028%	0,050%	0,008%	-0,137%	0,000%	0,012%	-0,043%	-1,168%	-0,003%
(2) η_c=.8,$\phi\pi$=1.5,ξ=1.0	-0,053%	1,586%	0,102%	0,072%	-0,056%	0,055%	-0,314%	0,002%	0,038%	0,000%	0,030%	13,671%
(1)-(2)	**-0,047%**	**1,760%**	**0,141%**	**0,099%**	**-0,107%**	**0,047%**	**-0,177%**	**0,002%**	**0,025%**	**0,044%**	**0,033%**	**14,830%**
(3) η_c=.2,$\phi\pi$=3,ξ=0	-0,099%	-0,676%	-0,019%	-0,017%	0,140%	0,062%	-0,417%	0,003%	0,042%	-0,036%	-6,204%	0,058%
(4) η_c=.2,$\phi\pi$=1.5,ξ=1.0	-0,188%	4,099%	0,020%	0,016%	-0,089%	0,021%	-0,394%	0,000%	-0,045%	-0,002%	0,126%	40,370%
(3)-(4)	**-0,089%**	**4,776%**	**0,040%**	**0,034%**	**-0,229%**	**-0,041%**	**0,023%**	**-0,003%**	**-0,087%**	**0,033%**	**0,068%**	**46,719%**

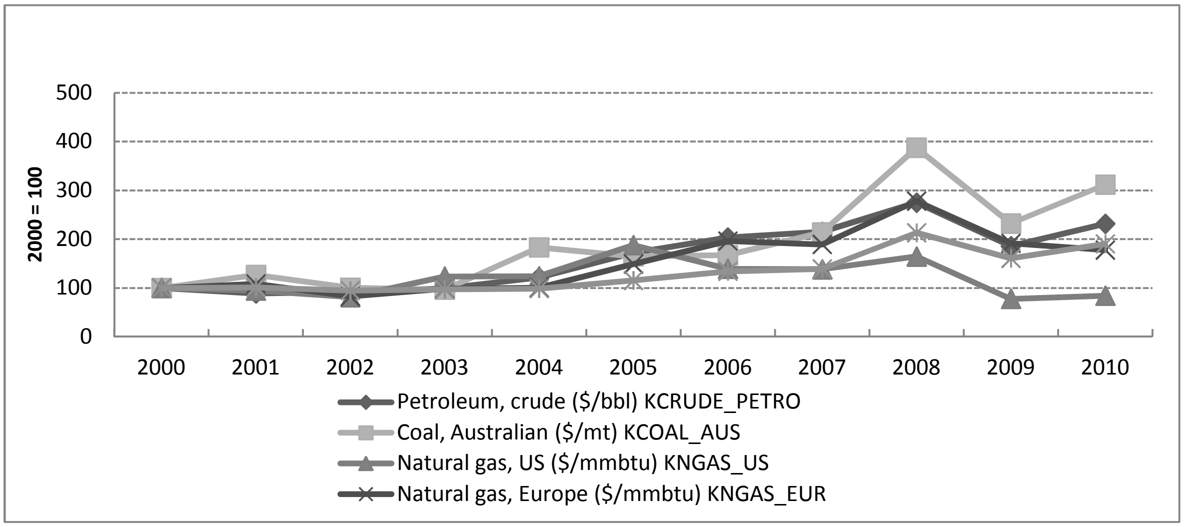
Notes: [1] The calculations of this table were made with 50000 draws

Source: authors´ calculations with the DSGE model.

Table A.1. Baseline parameters	
Discount factor (β)	0.99
Risk aversion coefficient (σ)	2.00
Disutility parameters, worked hours (N)	
φ	1.70
ψ	7.02
Weight of rule-of-thumb consumers (λ)	0.50
Rate of depreciation (δ)	0.025
Investment adjustment cost ϕ	1/15
Elasticity of substitution across intermediate goods (ε_D, ε_F)	6.00
Parameter of CES production function (α)	0.40
Fraction of firms that keep their prices unchanged (θ_D, θ_F)	0.75
Real wage mark-up ($1+\theta_W$)	1.20
Elasticity of substitution between capital and labor (σ_S)	1.00
Response of monetary authority to inflation (ϕ_π)	1.50
Response of monetary authority to output (ϕ_{yr})	0.00
Autoregressive coefficient of commodity price	0.80
Share of the production of the natural resource owned by the government (τ_{cu})	0.50
Amount produced of the natural resource (Q^{cu})	0.45
Weight of domestic good in consumption (α_C)	0.60
Weight of domestic good in investment (α_I)	0.50
Weight of domestic good in government expenditure (α_G)	0.99
Foreign-domestic good (consumption) elasticity of substitution (η_C)	0.99
Foreign-domestic good (investment) elasticity of substitution (η_I)	0.99
Foreign-domestic good (government) elasticity of substitution (η_G)	0.99
Acyclical rule, debt weight (μ_X)	0.01
The share of external public debt over total public debt ν_b	0.21
Elasticity of interest rate to external debt	0.001
Elasticity of domestic export to real exchange rate (η^*)	1.00

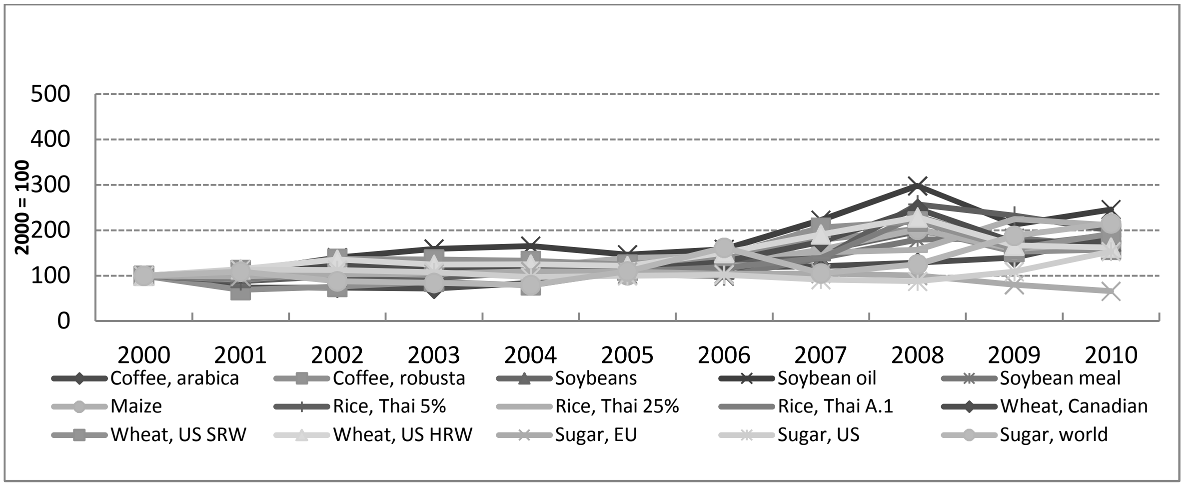
Figures

Figure 1. Energy Prices



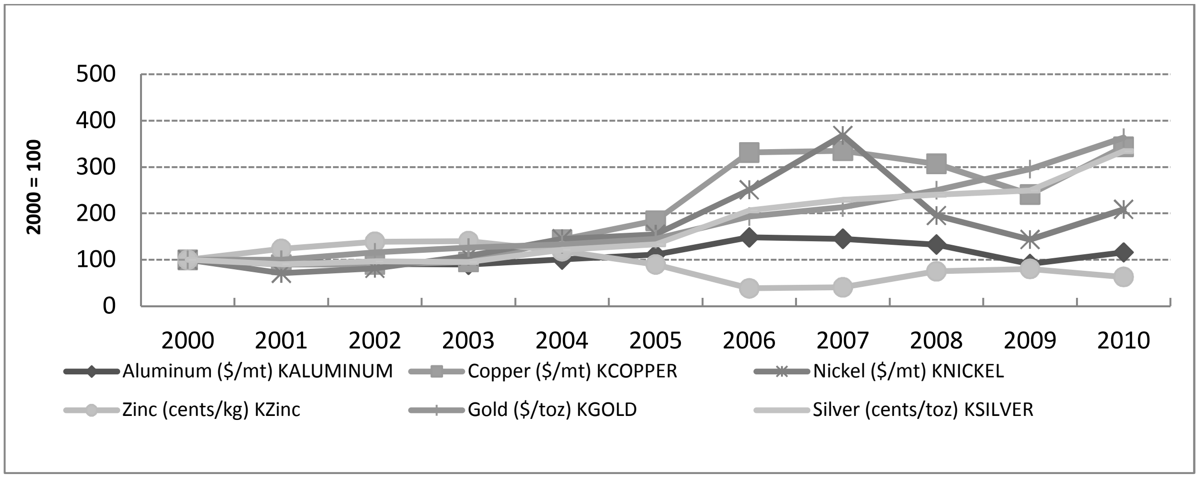
Source: The Word Bank website (Data & Research, Commodity Markets) and IMF (2012).

Figure 2. Food Prices



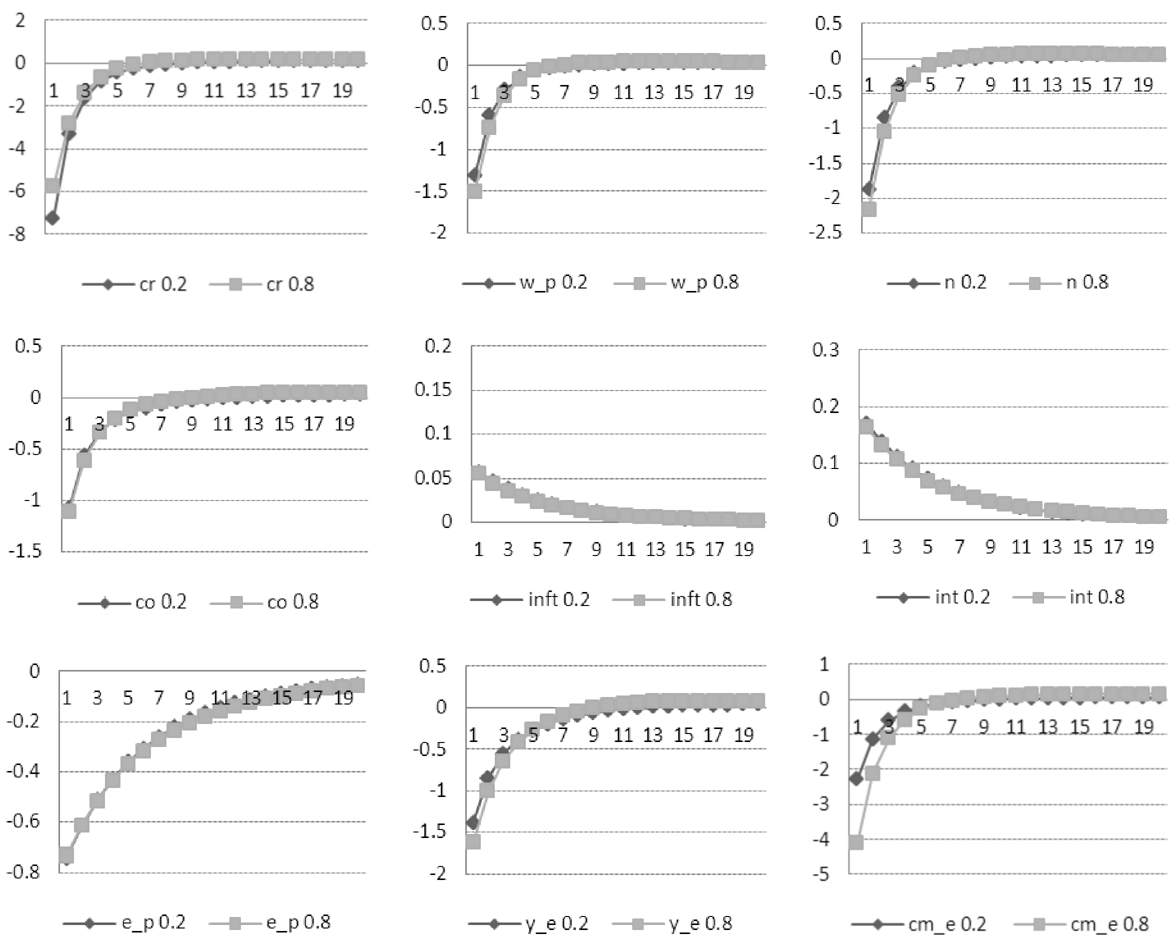
Source: The Word Bank website (Data & Research, Commodity Markets) and IMF (2012)

Figure 3. Metal Prices



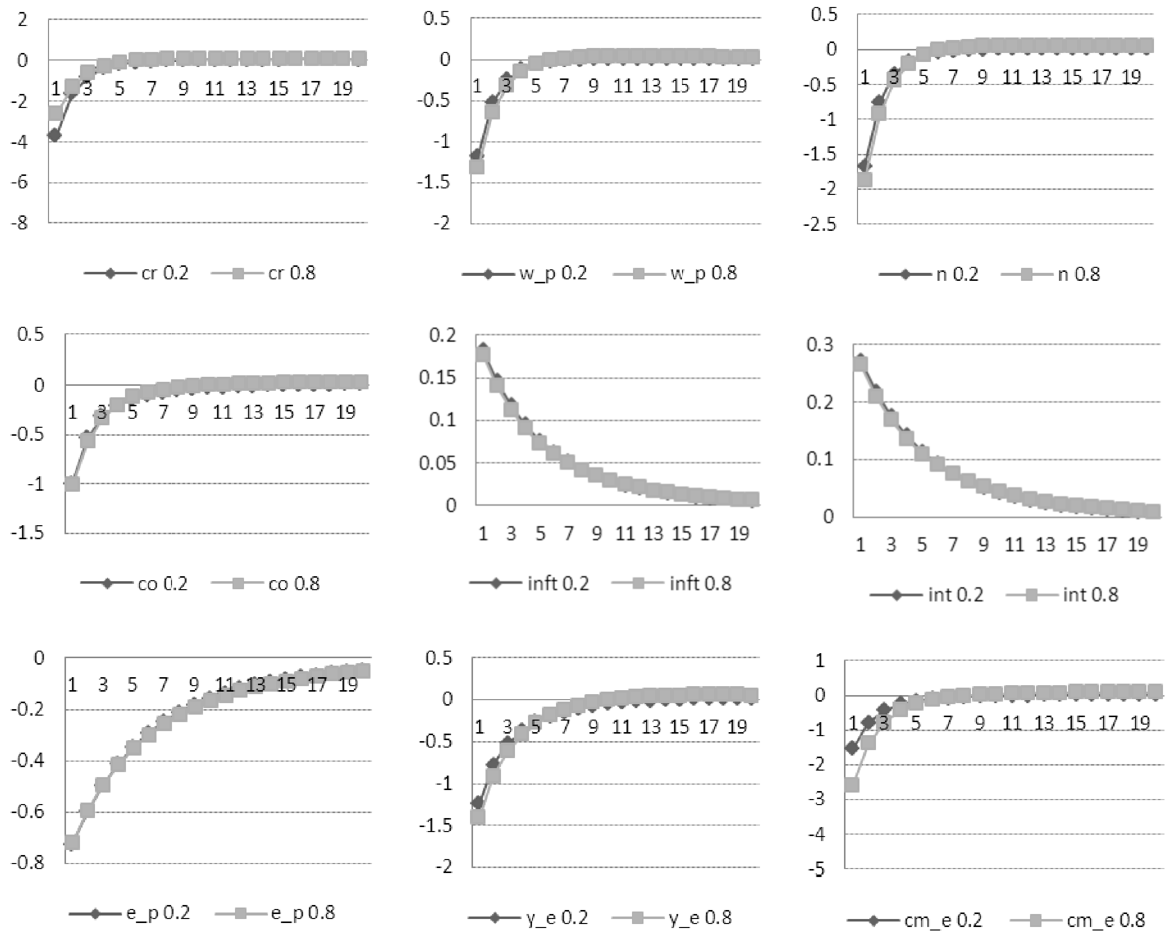
Source: The Word Bank website (Data & Research, Commodity Markets) and IMF (2012)

Figure 4. Impulse Response: $\eta c=\{0.2,0.8\},\phi\pi=3,\xi=0$



Source: authors´ calculations with the DSGE model.

Figure 5. Impulse Response: $\eta c=\{0.2,0.8\},\phi\pi=1.5,\xi=1.0$



Source: authors´ calculations with the DSGE model.