Macroeconomic adjustment in commodity producing countries with limited access to financial markets: the role of storage

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Abstract

Macroeconomic volatility is a fundamental concern for developing countries, in particular for commodity exporters. In this paper we look at the macroeconomic adjustments of small open economies that produce a storable commodity to changes in the foreign interest rate. When a commodity is storable a shock in international financial markets not only has an impact via the interest rate channel but also via the price of the commodity. This additional channel comes from the fact that storable commodity prices react to changes in world interest rates as a result of investment decisions in international financial markets. We extend the previous literature by including the storage mechanism in a standard model for a small African primary-exporter economy. We show that when commodity prices are allowed to respond endogenously to muted investment situations, the dynamics of the economy are importantly impacted. Therefore the extended model provides new insights on the macroeconomic adjustments of primary-exporting economies and calls for a reassessment of the corresponding policy prescriptions.

Keywords: Storable commodity, International financial shock, Low-income economies

JEL Classification: C32, C33, E31, F32, 011.

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1 Introduction

It is well established that the business cycle of developing countries differs from the one of developed economies. Developing countries’ business cycles are more volatile and driven both by world factors and by country-specific dynamics (Kose et al. (2003)). Among the world factors the literature has highlighted the role of terms-of-trade shocks (Mendoza (1995); Schmitt-Grohé and Uribe (2018)), world price shocks (Kose (2002)); foreign interest rates (Neumeyer and Perri (2005)) and country risk premium dynamics (Uribe and Yue (2006)). More recently the increase in commodity price fluctuations has fostered studies showing the key role of commodity price shocks for developing economies that are commodity exporters (Kose and Riezman (2001); Drechsel and Tenreyro (2018); Fernández et al. (2017, 2018)).

In this paper we reconsider the impact of foreign interest rate shocks for the volatility of developing economies. In particular we focus on low income countries that are producers of storable commodities.

According to theory, foreign interest rate shocks may affect small open economies through several channels. First, as shown by the standard Mundell-Fleming model, foreign interest rate shocks may lead to changes in the level of domestic interest rates -following international capital flows adjustments- and impact the dynamics of credit. Second, foreign interest rate shocks also affect real exchange rates and therefore the import-export dynamics of the developing economy. Third, foreign interest rate shocks may also affect the net revenue that the country can get on its net international financial position. For instance, after an increase in the foreign interest rate, interest charges on external debt raise as well as interest payments received on foreign claims.

If the small country produces and exports a storable commodity, the price of the commodity is an additional channel through which world interest rate shocks may affect the economy, as shown by Frankel (1986) in a partial equilibrium setup. This channel comes from the fact that world interest rates affect the international investors’ decision of holding the commodity. By arbitrage on efficient markets, the expected return from investing in a storable commodity should be equal to the return from investing in an other financial asset, net of costs. Following the seminal work of Kaldor (1939); Working (1949), the theory of storage stresses the timing option of investors in holding a storable commodity. The holder can choose to consume the commodity or store it for future consumption giving rise to a convenience yield for holding the commodity. The choice is determined by variations in commodity prices, physical costs of storage and in the opportunity cost that is represented by the possibility of investing in alternative assets. Therefore, when asset returns change, investors reallocate their financial positions determining variations in commodity holdings (and the corresponding inventory level) and in commodity prices.

There is evidence suggesting that shocks to the reference US interest rate account for a substantial share of world commodity price fluctuations. Akram (2009) shows for instance that the reduction in U.S. real interest rates led, at least partially, to the increase of commodity prices over the period 1990-2007. Carter et al. (2011) (p. 105) further suggests that the collapse of all commodity prices through much of the 1980s-90s was the consequence of the tight U.S. monetary policy that was implemented at the end of the 1970s.

In models of small open economies, even those which are concerned with the case of a primary exporting developing country (see for instance Khan and Montiel (1987); Dagher et al. (2012)), the relationship between commodity prices and interest rates is not considered as these models impose the international law of one price for the primary commodity, whose international price is set as exogenous. To provide a comprehensive representation of the dynamics that small countries that are producers of storable commodities face, we extend the standard small open economy framework of Agenor (1998) by allowing for commodity storage.

We are not the first to embed the commodity storage mechanism in a general equilibrium setup. Arseneau and Leduc (2013) compare the impact of storage in partial and general equilibrium highlighting
the amplification effect that is generated in the second case by the endogenous behaviour of interest rates after a commodity price shock. Unalmis et al. (2012) study the role of storage in the US oil market, and show that disregarding the storage facility in the model causes an upward bias in the estimated role of oil supply shocks in driving oil price fluctuations. Tumen et al. (2016) analyze -for the same market- the optimal policy mix necessary to stabilize the economy and they stress the need to redesign the environmental tax policy that can account for the impact of speculation on fossil fuel prices. However, all the previous models study developed economies.

We focus instead on a small African primary-exporting country that relies completely on commodity exports and that is not fully integrated in international capital markets. We show that adding the storage mechanism has important implications for the reaction of the economy. In our extended model, the macroeconomic volatility after a world interest rate shocks is higher than what is observed in standard small open economy models. The commodity price channel amplifies in a significant way the standard effects of world interest rate shocks providing new insights on the adjustment of these economies and calling for a reassessment of the necessary stabilization policies.

2 Model

We develop a model of a small open developing country that produces two goods: a non-tradable good which is only used for final domestic consumption and an exportable primary commodity. Additionally, the country is shut out of international capital markets. Labor and the capital stock are assumed to be fixed within the time-frame considered. Labor is homogeneous and perfectly mobile between the non tradable sector and the commodity producing sector. This benchmark model builds on Agenor (1998).

We additionally study the impact of the storage market for commodities. When a commodity is storable its international price is determined by a financial arbitrage condition. Therefore, foreign interest rates do affect -indirectly- the domestic economy through their impact on the commodity price.

2.1 Firms

The economy produces two goods: a home good ($Y_N$) that is only used for final domestic consumption and a primary commodity ($Y_X$) that is exported.

We assume that the production of the two goods only requires labor which is assumed to be perfectly mobile across the two sectors. The production function of the two goods exhibits decreasing returns to labour:

$$ Y_i = L_i^{\alpha_i} \tag{1} $$

where $L_i$ is the quantity of labor employed in sector $i = N, X$ and $0 < \alpha_i < 1$.

From the first-order conditions for profit maximization, we get:

$$ w_i = \alpha_i L_i^{(\alpha_i - 1)} \tag{2} $$

where $w_i = \frac{W}{P_i}$. $P_X$ is the commodity price in domestic currency, $P_N$ is the price of the home good and $W$ is the nominal wage rate, which is the same for both sector as we assume that labor is perfectly mobile across the two sectors.
2.2 Households

Households supply a fixed quantity of labor, $\bar{L}$ and consumes two goods: the home good ($C_N$) and an imported good ($C_T$). They may hold two assets: domestic money (which bears no interest), $M$, and a domestic government bond, $D$.

The representative household maximizes its discounted utility function:

$$\sum_{t=0}^{\infty} \beta^t u\left\{ C_t, \frac{M_{t+1}}{P_t} \right\}$$

(3)

where $M_{t+1}$ denotes the quantity of nominal balances accumulated during period $t$ and carried over into period $t+1$ and $C_t$ is a composite consumption index defined as:

$$C_t = \frac{C_N^\delta C_T^T (1-\delta)}{\delta (1-\delta)^{(1-\delta)}}$$

(4)

The corresponding consumer price index (CPI) is $P_t = P_N^\delta P_T^{(1-\delta)}$ where $P_T$ is the price of the tradable good. The optimal allocation of expenditures between non-tradable and tradable goods is given by:

$$C_{N,t} = \delta Z_t^{(1-\delta)} C_t ; \quad C_{T,t} = (1-\delta) Z_t^{-1} C_t$$

(5)

where $Z_t = \frac{E_t}{P_{N,t}}$ is the relative price between the imported good and the home good under the assumption that the domestic currency price of the imported good is set by the international law of one price $P_T = E_t P_T^* + \frac{1}{E_t}$ and $E_t$ is the nominal exchange rate. Combining all previous results, we can write total consumption expenditure as $P_t C_t = P_N^t C_{N,t} + P_T C_{T,t}$.

Thus households maximize equation (3) subject to the following budget constraint:

$$D_{t+1} + \frac{M_{t+1}}{P_t} + C_t = (1 + r_t) D_t + \frac{M_t}{P_t} + Y_t - T_t$$

(6)

where $D_{t+1}$ denotes the household holdings of domestic bonds (denominated in output), that are carried over into period $t+1$, $r$ is the real interest rate, $Y$ is household total real income, $C$ is total real consumption, $T$ are real government transfers, and $P$ is the price of the domestic consumption basket. All real variables are expressed in terms of the price of the domestic consumption basket.

In what follows we assume that the household utility has the following form:

$$u\left\{ C_t, \frac{M_{t+1}}{P_t} \right\} = C_t^{1-\sigma} + \psi \frac{(M_{t+1})^{1-\sigma}}{1-\sigma}$$

(7)

The corresponding optimality conditions read:

$$\psi \frac{(M_{t+1})^{1-\sigma}}{(P_t)^{1-\sigma}} = C_t^{1-\sigma} - \beta C_{t+1}^{1-\sigma} \left( \frac{P_t}{P_{t+1}} \right)$$

(8)

To simplify the notation $P_T^*$ is normalized to 1.
\[ C_t^{-\sigma} = \beta C_{t+1}^{-\sigma}(1 + r_{t+1}) \]  

Combining equations (8) to (9) and using the following definition of the real interest rate  
\[(1 + r_{t+1}) = (1 + i_{t+1})(\frac{P_t}{P_{t+1}}),\]  
with \(i\) being the nominal interest rate, we obtain:

\[ \frac{M_{t+1}}{P_t} = \psi \frac{1}{\sigma} \left[ 1 + \frac{1}{i_{t+1}} \right]^{\frac{1}{\sigma}} C_t \]  

(10)

### 2.3 Government and the Central Bank

There are no commercial banks in the economy. We also assume that the nominal exchange rate is fixed  
and there is no domestic credit. It then follows that the domestic money stock is equal the domestic  
currency value of the stock of net foreign assets held by the central bank:

\[ M_{t+1} = E_t R^*_t \]  

(11)

where \(E_t = \bar{E}\) is the nominal exchange rate, expressed as the price of one unit of foreign currency in  
terms of units of the domestic currency, and \(R^*\) is the central bank’s stock of net foreign assets, measured  
in foreign currency terms.

The government consumes both the home good and the imported good. It has to pay interest on its  
domestic debt. It is also assumed that it has to pay interest on a foreign debt that it has accumulated in  
the past and which is assumed to be constant as the government can no longer issue new foreign debt.  
On the revenue side, the government levies lump-sum taxes on households. It is also assumed that the  
central bank transfers to the government the interest income that it receives on its stock of net foreign  
assets. Finally, the government finances its budget deficit by issuing domestic bonds. In real terms, the  
government budget constraint is therefore expressed as follows:

\[ D_{t+1} - D_t = G_t - T_t + r_tD_t + i^*_t \frac{E_t}{P_t} B^* - i_t \frac{E_t}{P_t} R^*_t \]  

(12)

where \(G\) denotes total real government consumption expenditures, \(B^*\) is the government constant  
level of foreign debt, expressed in foreign currency terms, and \(i^*\) is the nominal foreign interest rate.

Real government consumption expenditures are defined as \(G_t = (\frac{P_t}{P_{t+1}})G_{N,t} + (\frac{P_t}{P_{t+1}})G_{T,t}\) where \(G_{N,t}\) and \(G_{T,t}\) denote the quantity of the home good and the imported good that is purchased by the government.

### 2.4 Market clearing conditions

There are three market clearing conditions:

\[ Y_N = C_N + G_N \]  

(13)

\[ \bar{L} = L_N + L_X \]  

(14)

\[ \frac{M_{t+1}}{P_t} = \left( \frac{E_t}{P_t} \right) R^*_t \]  

(15)

Equation (13) specifies the home market equilibrium, which determines \(P_N\), the price of the home
good. Equation (14) specifies the labor market equilibrium that determines, as a result, $W$, the nominal wage rate. Finally, equation (15) represents the money market equilibrium that determines the domestic nominal interest rate, $i$.

**Consolidated budget constraint**

The budget constraint of the representative household (Equation 6), the government (Equation 12) and the central bank (Equation 11) can be consolidated into a single expression:

$$R^*_t + 1 - R^*_t = Y_t - C_t - G_t + i^*_t (R^*_t - B^*)$$

$$= P^*_X Y_{X,t} - C_{T,t} - G_{T,t} + i^*_t (R^*_t - B^*) \quad (16)$$

This expression is the balance-of-payments identity, expressed in foreign currency terms. The right-hand side represents the current account balance of the economy while the left-hand side is the net accumulation of foreign assets by the central bank: if the current account is in surplus, the central bank accumulates foreign reserves while it loses reserves if there is a current account deficit.

### 2.5 The commodity-inventory market

In this section we explain how we model the international price of the commodity.

We build on Pindyck (2001) that firstly showed that for a primary commodity that is storable the expected rate of increase of its price over a specified period, minus storage costs, is equal to the interest rate prevailing on a bond with the same maturity as the holding period of the commodity.

As in Unalmis et al. (2012) we consider a competitive investor, competitive speculator, that has the choice between the following investment strategies. (1) It can either buy at time $t$ one unit of the commodity with spot price $P^*_X$, holds it until period $t + 1$, and sell it at time $t + 1$ at the price $P^*_X(1 + \Phi(I_t))$.

In this case, the expected return from its investment is:

$$(E_t P^*_X(1 + \Phi(I_t))) \quad (17)$$

where $\Phi(I_t) = \kappa + \frac{\Psi}{2} I_t$ is the physical cost of storing a unit of the commodity during period $t$ with $\Phi > 0$ and $\kappa < 0$ being the convenience yield. The convenience yield is the benefit that one can obtain from holding the commodity (e.g., assurance of supply as needed, ease of scheduling, pleasure of holding the commodity (gold)). (2) Alternatively, the investor can choose to invest the amount $P^*_X$ in a one-period risk-free foreign bond with the interest rate $i^*_t$, in which case its (risk-free) return is:

$$i^*_t P^*_X \quad (18)$$

Investors are risk neutral and they maximize expected profits:

$$\frac{E_t P^*_X(I_t)}{i^*_t} = P^*_X(1 + \Phi(I_t)) \quad (19)$$

given the cost of storage and the non-negativity constraint on aggregate storage: $I_t \geq 0$.

If storers are price takers, the following arbitrage relationship holds (FOC wrt $I_t$):

$$E_t P^*_X = i^*_t P^*_X \quad (20)$$

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2 Remind that, for convenience, $P^*_T$ has been set equal to 1.
Equation (20) states that given $E_t P^*_t X_{t+1}, \Psi$, and $\kappa_t$, there is a negative relationship between $i^*_t$ and $P^*_X t$.

Finally, the inventory level of the commodity evolves over time according to variations in the aggregate production and demand of the commodity:

$$I_t = I_{t-1} + Y^\text{all}_{X,t} - X^*_t$$

(21)

where $Y^\text{all}_{X,t}$ denotes the supply and $X^*$ the demand of the commodity from the rest of the world. The demand is a negative function of the price of the commodity:

$$X^*_t = \mu - \theta_x P^*_X,t$$

(22)

Whereas the supply is a combined function of the small economy production and the one of the rest of the world:

$$Y^\text{all}_{X,t} = Y_{X,t} + \bar{Y}_{row_{X}} + \theta_y P^*_X,t$$

(23)

where $1/\chi$ denotes the relative weight of the small economy supply in world commodity production.

2.6 Shocks

A standard shock in the literature of SOE is a foreign interest rate shock:

$$i^*_t = \rho_i i^*_{t-1} + (1 - \rho_i) \bar{i} + \epsilon_{i,t}$$

(24)

2.7 Policy stabilization

In a first exercise we assume that the nominal exchange rate is fixed and there is no stabilization at play on this side. In a second moment we will test the proposal of Frankel (2003) to stabilize the economy by targeting exchange rate to the commodity price.

3 Calibration

In this section we explain the benchmark calibration of the economy. Time is discrete and one period represents one quarter. Table 1 presents an overview of the parameters.

In the benchmark calibration we assume that the quantity of labour employed in the non-tradable sector is equal to the one employed in the tradable sector: $\alpha_i = 0.6$ consistently with Agenor (2016). Households are assumed to consume more of the non-tradable good than the imported one ($\delta=0.55>0.5$) consistent with Agenor (2016) and standard assumption in NOEM literature. Households are risk averse in this economy with a concavity of the utility function governed by the parameter $\sigma=2.4$, that is in line with the estimate of Ostry and Reinhart (1992) for African countries. The discount factor, $\beta$, is set to 0.99 in order to match a steady state annualized interest rate of 4%. We consider as the world interest rate the LIBOR (London Interbank Offer Rate) as in Kose and Riezman (2001) and we calibrate accordingly the corresponding shock. Finally, we set the utility parameter for money holdings, $\psi$, to 0.5 in order to match the level of reserves at steady state. The level of foreign indebtedness in the economy is set to different values in order to distinguish two cases: i) when foreign indebtedness is smaller than reserves, $R^*/B^* = 1.1$, the economy is a net creditor whereas ii) when indebtedness is bigger than reserves the economy is a net debtor $R^*/B^* = 0.9$. 

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha_N$</td>
<td>0.6</td>
<td>Share of labour in production of the non-tradable good</td>
</tr>
<tr>
<td>$\alpha_X$</td>
<td>0.6</td>
<td>Share of labour in production of the commodity good</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>Discount factor</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.55</td>
<td>Home bias in consumption of the non-tradable good</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>2.4</td>
<td>Inverse of inter-temporal elasticity of substitution in consumption</td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.5</td>
<td>Weight of real money balances in utility</td>
</tr>
<tr>
<td>Extension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\kappa$</td>
<td>-0.04</td>
<td>convenience yield</td>
</tr>
<tr>
<td>$\Psi$</td>
<td>9.6</td>
<td>sensitivity of the cost of storage to inventories</td>
</tr>
<tr>
<td>$I/Y^{all}$</td>
<td>0.2</td>
<td>ratio of commodity stock of storage to overall supply</td>
</tr>
<tr>
<td>$\mu$</td>
<td>2.4</td>
<td>level of foreign demand for commodities</td>
</tr>
<tr>
<td>$\theta_x$</td>
<td>0.2</td>
<td>foreign demand elasticity to commodity prices</td>
</tr>
<tr>
<td>$\theta_y$</td>
<td>0.2</td>
<td>world supply elasticity to commodity prices</td>
</tr>
<tr>
<td>$y_{xSOE}/Y_x$</td>
<td>5</td>
<td>size of world commodity production wrt the SOE commodity production</td>
</tr>
<tr>
<td>Shocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma_i$</td>
<td>0.01</td>
<td>standard deviation of the foreign interest rate shock</td>
</tr>
<tr>
<td>$\rho_i$</td>
<td>0.34</td>
<td>persistence of the foreign interest rate shock</td>
</tr>
</tbody>
</table>
Regarding prices we assume $p^*_T$ to be normalized to 1, as we also assume that $E$ is fixed and equal to 1, $P_T$ also equals 1. In steady state this implies a value for $\bar{P}$ and $\bar{p}^*_N$ of 1. Where the upper-script bar defines the steady state values. Finally, the foreign commodity price is also set to 1 implying a steady state value of $\bar{p}^*_X = 1$ both in the baseline and in the extension.

The commodity storage block is calibrated based on the papers of Knittel and Pindyck (2016) and Unalmis et al. (2012). We consider the world commodity demand and supply as characterized by the US. The reason being that there is a rich literature for commodities for the US -encouraged by data availability-, and the fact that the US is one of the big players in all the commodities markets being a good proxy for world demand. Therefore, we set the supply commodity price elasticity according to the estimates of Knittel and Pindyck (2016) to 0.2; as in Unalmis et al. (2012) we set the steady state of the convenience yield to 0.04.

$I/Y\hat{=} 0.20$...explain and replace the previous part:

We set the steady state ratio of inventories to commodity production, for the US, to be $\bar{I}/\bar{Y}_X = 0.61$ consistent with Unalmis et al. (2012). This pins down the sensitivity of the storage cost to the level of inventories, $\Psi$, to be around 5. Finally, in steady state, the market for commodities clears, $\bar{X}^* = \bar{Y}^{all}_X$, and this pins down a corresponding value of $\mu$.

4 Results

In what follows we compare two specifications of the model: i) a baseline where commodity prices are fixed and determined abroad and ii) an extension where we allow the commodity to be storable and commodity prices to be endogenous.

Baseline

A increase in the world interest rate shock has a differentiated impact on the country depending on whether the country is a net debtor or a net creditor.

If the country is a net creditor, the increase in the foreign interest rate determines a amelioration in the external balance of payments, impacting positively reserves (Figure 1, solid lines). As reserves increase the money supply augments as well, followed by an increase in households’ consumption. As demand is increased, production raises in the non-tradable sector together with labour and prices in the same sector. As workers are perfectly mobile, they move from the commodity to the non-tradable sector and in this process wages adjust to clear the labour market. These adjustments depress labour in the commodity sector and production decreases, prices do not move as they are exogenously given. At the aggregate level the impact on global production is null as the effects in the two sectors cancel each other out. Finally, the overall level of prices follows the non-tradable price behaviour and the CPI index increases, determining a real exchange rate appreciation.

If the economy is a net borrower (Figure 2, solid lines), the impact of an increase in the interest rates is reversed. As now foreign debt to be repaid is more costly, the domestic economy is dampened. Reserves decrease, followed by money and consumption. Demand falls dampening the non-tradable sector whose resources are now transferred to the commodity sector. The overall level of prices decreases and the exchange rate depreciates.

\footnote{Unalmis et al. (2012) consider fuel for the US. If we take data on different commodities, the ratio of commodities to production (in the US) ranges from 0.1 to 1.3. 0.6 is therefore a good approximation of the average value. In section 5 we provide a sensitivity analysis on this parameter.}
Figure 1: Net creditor IRFs: increase in the world interest rate

Notes. Solid line: Benchmark simulation. Dotted line: Extension. The shock is a 1std increase in the world interest rate. The results which deviate from the steady state are expressed respectively in percentage points for rates, and in percentages for the remaining variables.
Extension

Let us now turn to the extension. When commodities are storable and subject to international investor decisions, changes to the foreign interest rate affect commodity prices. An increase in the foreign interest rate makes storers sell commodities and decrease inventories as the opportunity cost of other investments has increased. The commodities’ price therefore decreases. With a lower commodity price, producers in the small economy decrease production in the commodity sector determining a shift of resources across sectors. The corresponding increase in the non-tradable sector production determines a decline in non-tradable prices. Finally, a decrease in the commodity price and commodity production also impacts the external balance of payments in a negative way: reserves fall.

In the case of a net creditor economy, the decrease in commodity prices (and production) amplifies the production switching towards the non-tradable sector. As the decrease in commodity production is sizable it determines an overall decrease in aggregate output. Reserves now decrease because the effect of lower commodity revenues counteracts the initial positive effect of an increase in the foreign interest rate driving a decrease in money supply and consumption. As non-tradable prices are lower because of the strong production switching effect, consumption falls more on tradable than non-tradable goods. As the CPI falls, the real exchange rate depreciates.

In the case of a net debtor economy, the commodity price effect amplifies the decrease in reserves, determining a stronger decrease in money supply and consumption. As the price of commodities drops, there is a production switching from the commodity to the non-tradable sector that makes non-tradable goods’ prices fall. Overall production and CPI fall and the real exchange rate depreciates.

In both cases, the introduction of the endogenous commodity channel amplifies considerably the dynamics and in certain cases it qualitatively changes the responses of variables to the shock (in the creditor case reserves, real exchange rate, non-tradable prices; in the debtor case commodity and non-tradable production). This is the case because allowing commodities prices to adjust endogenously in the model, affects production and expenditure decisions -with a switch in favour of the non-tradable sector- at the same time. In both cases, overall output falls and the real exchange rate depreciates.

We have shown that the introduction of the commodity storage channel has non negligible effects on the dynamics of the small open economy. As all the amplified dynamics are driven by the reaction of commodity prices, in section 5 we will do a sensitivity analysis on the parameters governing the extension block. In section 6 we will study the stabilizing power of pegging the export price in such a framework.

5 Sensitivity

In this section we study the sensitivity of the results to a different calibration of the commodity extension. The new mechanism we focus on is driven by three parameters: $\theta_x$, $\theta_y$ and $\Psi$. The first two are commodity demand and supply elasticities to the world commodity price. When performing a sensitivity analysis for different values estimated in the literature, we find that results are very robust. The $\Psi$ parameter governs the cost of storage and it is key for the dynamics.

As we can see in Figure 3, when $\Psi$ is low, dynamics are amplified as the reaction of the commodity price is more important. A low $\Psi$ implies low storage costs, therefore inventories adjust quickly reflecting

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4 Another transmission channel for the SOE economy could be trough the risk premium channel -as highlighted by Neumeyer and Perri (2005); Uribe and Yue (2006)- that can be a positive function of $B^*R_t$ and a negative function of $P_x$. Adding this channel would reinforce the effect of the foreign interest rate shock as an increase in $i_f$ drives an increase in $i_O$, $om_O$ and it decreases $P_x$; a decrease in $P_x$ increases the risk premium and so, further increase $i_O$.

5 We show these sensitivity results in appendix B.

6 This parameter depends on changes on the assumption on $\frac{1}{\Psi} = \frac{1}{\Psi} + \frac{\Psi}{2}$ that we variate from almost zero (implying a value of $\Psi = 3$) to 0.61 (implying a value of $\Psi = 193$) as suggested in Unalmis et al. (2012). A low value of the commodity stock to production implies a very high value of the parameter and vice-versa.
Figure 2: Net debtor IRFs: increase in the world interest rate

*Notes.* Solid line: Benchmark simulation. Dotted line: Extension. The shock is a 1std increase in the world interest rate. The results which deviate from the steady state are expressed respectively in percentage points for rates, and in percentages for the remaining variables.
changes in demand and supply driven by strong changes in $P_x$. With a low storage costs investors have an incentive to enter the storage market: hold a commodity and sell it in a future date. With a high $\Psi$, the cost of storing the commodity is very high so the speculator does not hold inventories ($I_s$ is zero) and does not enter the storage-market speculation strategy. As a consequence the price of the commodity does not vary.

Another way to look at this cost is to say that international bonds and commodities are not perfect substitutable assets because of the existence of adjustment costs. This cost determines the degree of substitutability across the assets. The stronger the cost, the lower the substitutions and therefore the impact on commodity prices.

6 Policy implications

We study the implications of a nominal exchange regime pegging the export price (PEP). The export price targeting was firstly proposed by Frankel (2003) and put forward as a solution to terms of trade changes. The advantage of this targeting is to deliver at the same time a nominal anchor and an automatic
adjustment in the face of fluctuations in world prices of the countries’ exports.

For the economies we are considering the export price is the one associated with commodities. Therefore, we define the nominal exchange rate as:

$$E_t = \frac{1}{P_x^t}$$

In such a way, the domestic price of the commodity is fully stabilized as

$$P_x^t = E_t P_{x^*}^t.$$

Figure 4 shows the stabilization dynamics of this policy. When the nominal exchange rate targets the foreign commodity price ($P_{x^*}^t$), it automatically fixes the local commodity price ($P_x^t$). After an increase in the foreign exchange rate, $P_{x^*}^t$ falls thus increasing the nominal exchange rate. As $P_x^t$ is unchanged, the production switching effect from the commodity to the non-tradable sector is dampened. The aim of the policy of stabilizing the commodity sector is achieved although not perfectly. When the nominal exchange rate moves, it changes the price of imported goods. As they become more expensive, their consumption decreases bringing to an expenditure switch in favour of the non-tradable good and, therefore, at the expenses of the production of the commodity sector. Although this reallocation of resources in terms of quantities is reduced with respect to the case without policy, the impact on prices is more important determining a strong fluctuation of consumption and output in real terms. The aim of Frankel (2003)’s proposal was to give a nominal anchor, PEP in this case stabilizes the domestic commodity sector but not the rest of the economy that presents even stronger fluctuations. This is due to the fact that $E_t$ depreciates bringing to an adjustment in CPI and consumption that is stronger than in the case without policy stabilization.

More importantly, the implementation of this policy requires a strong depletion of reserves that could drive itself a currency crisis even without "sudden stops" as the economy is not perfectly integrated in international financial markets. So while the commodity production is stabilized, the overall economy faces even stronger fluctuations with the PEP.\footnote{Appendix C shows the effect of the PEP policy in the case of an economy that is a net creditor. The qualitative results are the same as the case of a net debtor.}

7 Conclusions

Future research could focus on other policies answering the concerns about fiscal stability of commodity producers countries.
Figure 4: Net debtor IRFs: increase in the world interest rate and policy stabilization

Notes. Solid line: Benchmark simulation. Dotted line: Extension. Dashed-dotted line: Extension + policy. The shock is a 1std increase in the world interest rate. Dashed line: Extension plus policy reaction. The results which deviate from the steady state are expressed respectively in percentage points for rates, and in percentages for the remaining variables.
References


### A Model

The complete model is composed by the following equations retrieved from the codes Dynare:

\[
\frac{w_t}{p_n_t} = \alpha_N L_{n_t}^{\alpha_N - 1} \tag{A.1}
\]

\[
\frac{w_t}{p_x_t} = \alpha_X L_{x_t}^{\alpha_X - 1} \tag{A.2}
\]

\[
Y_{n,t} = L_{n_t}^{\alpha_N} \tag{A.3}
\]

\[
Y_{X,t} = L_{x_t}^{\alpha_X} \tag{A.4}
\]

\[
Y_t = Y_{n,t} \frac{p_{n,t}}{P_t} + Y_{X,t} \frac{p_{x,t}}{P_t} \tag{A.5}
\]

\[
C_{n,t} = \delta p_{n,t}^{\delta - 1} E_t^{1 - \delta} C_t \tag{A.6}
\]

\[
C_{t} = (1 - \delta) p_{n,t}^{\delta} E_t^{(\delta)} C_t \tag{A.7}
\]

\[
P_t = E_t^{1 - \delta} p_{n,t}^{\delta} \tag{A.8}
\]
\[ C_t^{(-\sigma)} = \psi \left( \frac{M_t}{P_t} \right)^{(-\sigma)} + \frac{\beta C_{t+1}^{(-\sigma)}}{P_{t+1}} \]  
(A.9)

\[ C_t^{(-\sigma)} = \beta C_{t+1}^{(-\sigma)} (1 + r_{t+1}) \]  
(A.10)

\[ 1 + r_t = \frac{(1 + i_t) P_{t-1}}{P_t} \]  
(A.11)

\[ \frac{M_t}{P_t} = \frac{E_t \text{Res}_t}{P_t} \]  
(A.12)

\[ Y_{nt} = Cn_t + Gn \]  
(A.13)

\[ \bar{L} = Ln_t + Lx_t \]  
(A.14)

\[ C_t + \frac{M_t}{P_t} + D_t = Y_t + \frac{M_{t-1}}{P_t} + (1 + r_t) D_{t-1} - \bar{T} \]  
(A.15)

\[ D_t - D_{t-1} = r_t D_{t-1} + \bar{G} - \bar{T} + \frac{E_t v^*_t}{P_t} (B - \text{Res}_{t-1}) \]  
(A.16)

\[ px_{t+1}^* = i_t^* px_t^* \ (1 + cyield + \gamma I_t) \]  
(A.17)

\[ \text{cost}_t = px_t^* (cyield + \gamma I_t) \]  
(A.18)

\[ I_t = I_{t-1} + Y_{\text{all}t} - X_t^* \]  
(A.19)

\[ Y_{xt}^{\text{all}} = Y_{X,t} + Y_{X}^{\text{low}} + \theta_g px_t^* \]  
(A.20)

\[ X_t^* = \mu - \theta_x \bar{px}_t^* \]  
(A.21)

\[ i_t^* = \rho_i i_{t-1}^* + (1 - \rho_i) \bar{i}^* + \epsilon_{i,t} \]  
(A.22)

\[ \text{RER}_t = \frac{E_t}{P_t} \]  
(A.23)

\[ px_t = E_t px_t^* \]  
(A.24)
The exchange rate is fixed in the extension $E_t = 1$ or it follows the policy:

$$E_t = \frac{1}{p_t x_t^2}$$  \hspace{1cm} (A.25)

B Sensitivity

Figure 1: Net creditor IRFs: increase in the world interest rate - sensitivity

Notes. Solid line: Extension simulation. Dotted-dashed line: Extension with low $Ψ$. "o" line: Extension with high $Ψ$. The shock is a 1std increase in the world interest rate. The results which deviate from the steady state are expressed respectively in percentage points for rates, and in percentages for the remaining variables.
C Policy

Figure 2: Net creditor IRFs: increase in the world interest rate and policy stabilization

Notes. Solid line: Benchmark simulation. Dotted line: Extension. Dashed-dotted line: Extension + policy. The shock is a 1std increase in the world interest rate. Dashed line: Extension plus policy reaction. The results which deviate from the steady state are expressed respectively in percentage points for rates, and in percentages for the remaining variables.