International monetary policy spillovers: the role of commodity prices

Vincent Bodart* Erica Perego†

November 1, 2019

Abstract

With the financialization of commodity markets, international interest rates are now considered as being a key determinant of commodity prices. With this evidence in mind, this paper reconsiders the macroeconomic adjustment of small open commodity exporting countries to international monetary shocks. We proceed by building a model of a small open economy that produces a non-tradable good and a storable tradable commodity. The difference with standard models of small open economies lies in the endogenous response of commodity prices which, due to commodity storage, adjust to variations in international interest rates. We find that the endogenous response of commodity prices amplifies the response of commodity exporting countries to international monetary shocks. This suggests that commodity exporting countries are more vulnerable to unfavourable international monetary disturbances than other small open economies. In particular, because of the existence of the commodity price channel, even those small open commodity exporting economies that are disconnected from international financial markets can be affected by international financial shocks.

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

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

*Université Catholique de Louvain, IRES, B-1348 Louvain-La-Neuve, Belgium.
†CEPII, Paris, France.

1 Introduction

As many commodities are both storable and relatively homogeneous, they have become a popular asset class and they are now largely traded on financial markets just like stocks and bonds ((CFTC, 2008), Cheng and Xiong (2014)).[1] With this so-called "financialization" of commodity markets, interest rates and monetary policy are increasingly viewed as a driver of commodity prices, as shown empirically by several papers (Akram (2009), Anzuini et al. (2013); Scrimgeour (2014); Frankel (2014))[2]. With this evidence in mind, we reconsider in this paper how world interest rate shocks impact small open economies. More precisely, we explore whether, because of the financialization of commodities, commodity exporting countries are more affected by international monetary policy shocks than other small open economies.

Understanding how interest rate shocks are transmitted from one country to other economies is a major topic in the literature on international macroeconomics. From a conceptual point of view, this literature has identified three main transmission channels. First, the trade channel: higher interest rate in a country (the U.S., for instance) leads to a contraction of domestic expenditures, which then entails a lower demand for imports. Second, the exchange rate - competitiveness channel: higher US interest rates cause the dollar exchange rate to appreciate, which makes the production abroad more competitive. Third, the financial channel: through international portfolio rebalancing, higher US interest rates leads to higher interest rates abroad. Another dimension of the financial channel operates through the valuation effects due to exchange rate fluctuations.

We argue in this paper that commodity prices are an additional channel through which interest rate shocks are transmitted internationally and that disregarding this channel brings to a partial evaluation of the effect of foreign monetary policy shocks on small open economies that are commodity exporting countries.

From a theoretical point of view, foundations of the commodity price channel are given by the theory of storage, which states that, under risk neutral arbitrage, storable commodities are subject to the condition that their expected return, minus storage costs (net of the convenience yield), must be equal to the risk-free interest rate (Kaldor (1939); Working (1949), Frankel (1986)). It follows from that condition that commodity prices are negatively related to interest rates. An alternative explanation of this negative relationship rests on the idea that interest rates are the opportunity cost of holding inventories. According to this view, higher interest rates drive commodity price down because higher interest rates raise the cost of holding inventories, which leads to a lower demand for inventories that contribute to reduce the total demand of the commodities.

To explore the role of commodity prices in the international transmission of foreign interest rate shocks, we build a model of a small open economy which produces two goods, a non-tradable good and a storable tradable good. Our model has many of the characteristics of standard models of small open economies. However, our model differs from standard models of small open economies by including a competitive storage mechanism. The main implication of this new feature is that the price of the tradable good in foreign currency is determined endogenously, rather than being exogenously given as it is the case in standard models of small open economies, even those which treat of primary exporting countries (see for instance Khan and Montiel (1987); Dagher et al. (2012)). In particular, storage implies that variations in interest rates lead to instantaneous endogenous changes in the price of the tradable good.

We are not the first to embed a commodity storage mechanism in a general equilibrium setup. Arseneau and Leduc (2013) compare the impact of storage in partial and general equilibrium highlighting

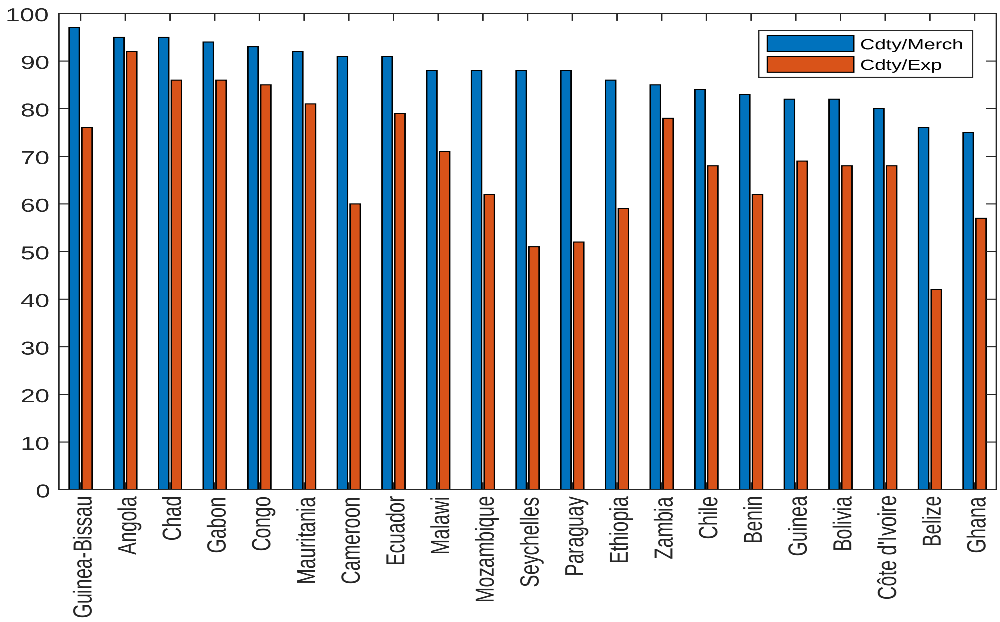
[1] The emergence of commodities as a new asset class dates back to the early 2000s. This process, usually referred to as the financialization of commodities in the literature, has been accentuated after 2004 with the entrance in the market of institutional investors.

[2] 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. Anzuini et al. (2013); Scrimgeour (2014); Frankel (2014) estimate that a 100 basis points increase in the US interest rate has a negative impact on commodity prices ranging between 3 and 7%.

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) analyse -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 are concerned with developed economies, and the US in the specific.

We focus instead on a small primary-exporting country that relies completely on the production and export of a commodities. To highlight the importance of the commodity price channel in the transmission of world interest rate shocks, we assume that this country has no access to international capital markets. While this assumption may appear rather extreme, it is however the reality of many low-income countries like sub-Saharan African countries (Fostel and Kaminsky (2008), IMF (2014)). It also turns out that these low-income countries represent the majority of commodity producers' countries with the highest dependence to the sector (see evidence on Figure 1 and table 1 in appendix A).

Figure 1: Commodity dependence



Note: "Cdty/Merch" (left bars) is the percentage ratio of commodity exports (in value) in total exports of merchandises; "Cdty/Exp" (right bars) is the percentage ratio of total commodity exports (in value) in total exports of goods and services. Both measures are computed as an average over the period 1995-2015.
Source: Bodart and Carpantier (2019).

To preview our results, we show that the spillover effects of foreign interest rate shocks are more pronounced in our model with commodity storage than what they are in standard small open economy models. This result holds whether the exchange rate is fixed, perfectly flexible, or adjusted to keep constant the domestic price of their commodity as firstly proposed by Frankel (2003). The higher magnitude of the spillovers comes from the fact that the commodity price channel amplifies the impact of interest rate shocks. Additionally, our results suggest that the degree of commodity dependence matters and that commodity exporting countries can be hurt by foreign monetary disturbances even when they are disconnected form international financial markets. It appears in particular that, if their exchange rate is fixed, they are more prone to an exchange rate crisis than countries that are not commodity dependent. This is also the case if they peg the domestic price of their commodity.

The paper is organized as follows. Section 2 presents the model, section 3 the calibration; section

4 the results; in section 4.3 the policy implications; in section 5 we present a sensitivity analysis, and section 7 concludes.

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.[3] 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 Households

Households supply a fixed quantity of labour, $\bar{L}$ 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:

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

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

$$C_t = \frac{C_{N,t}^{\delta} C_{T,t}{}^{(1-\delta)}}{\delta^{\delta}(1-\delta)^{(1-\delta)}} \tag{2}$$

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

$$C_{N,t} = \delta Z_t^{(1-\delta)} C_t \qquad ; \qquad C_{T,t} = (1-\delta) Z_t^{-\delta} C_t \tag{3}$$

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 $P_T = E_t P_T^*$ [4] and E_t is the nominal exchange rate. Combining all previous results, we can write total consumption expenditure as $P_t C_t = P_{N,t} C_{N,t} + P_{T,t} C_{T,t}$.

[3]There is indeed evidence showing that low-income countries have a limited access to international financial markets. Olabisi and Stein (2015) reveal that, excluding South-Africa, only 13 African countries have issued international sovereign bonds between 2006 and 2014: Ivory Coast (2 issuing), Congo (1), Ethiopia (1), Gabon (2), Ghana (3), Kenya (2), Namibia (1), Nigeria (3), Rwanda (1), Senegal (3), Seychelles (2), Tanzania (1), Zambia (2). Fostel and Kaminsky (2008) find that a few Latin American countries (Haiti, Nicaragua, Paraguay) had no access to international capital markets between 1980 and 2005 and that the access was limited for a larger group of countries including Bolivia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Jamaica, Panama, Peru, and Uruguay.

[4]To simplify the notation P_T^* is normalized to 1.

Thus households maximize equation (1) subject to the following budget constraint:

$$D_{t+1} + \frac{M_{t+1}}{P_t} + C_t = (1 + r_t)D_t + \frac{M_t}{P_t} + Y_t - T_t \tag{4}$$

where D_{t+1} denotes the household holdings of domestic bonds, 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:

$$u\Big\{C_t, \frac{M_{t+1}}{P_t}\Big\} = \frac{{C_t}^{1-\sigma}}{1-\sigma} + \psi\frac{(\frac{M_{t+1}}{P_t})^{1-\sigma}}{1-\sigma} \tag{5}$$

The corresponding optimality conditions read:

$$\psi\Big(\frac{M_{t+1}}{P_t}\Big)^{-\sigma} = {C_t}^{-\sigma} - \beta {C_{t+1}}^{-\sigma}\Big(\frac{P_t}{P_{t+1}}\Big) \tag{6}$$

$${C_t}^{-\sigma} = \beta {C_{t+1}}^{-\sigma}(1 + r_{t+1}) \tag{7}$$

Combining equations (6) to (7) 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:

$$\frac{M_{t+1}}{P_t} = \psi^{\frac{1}{\sigma}}\Big[1 + \frac{1}{i_{t+1}}\Big]^{\frac{1}{\sigma}} C_t \tag{8}$$

2.2 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 labour which is assumed to be perfectly mobile across the two sectors. The production function of the two goods exhibits decreasing returns to labour:

$$Y_i = {L_i}^{\alpha_i} \tag{9}$$

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:

$$w_i = \alpha_i {L_i}^{(\alpha_i - 1)} \tag{10}$$

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 sectors as we assume that labor is perfectly mobile across the two sectors.

2.3 The commodity-inventory market

In this section we explain how we model the international market for commodities.

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 $P^*_{X,t}$, hold it until period $t+1$, and sell it at time $t+1$ at the price $P^*_{X,t+1}$. In this case, the expected return from its investment is:

$$E_t P^*_{X,t+1} - P^*_{X,t}(1 + \Phi(I_t)) \tag{11}$$

where $\Phi(I_t) = \kappa + \frac{\Psi}{2} I_t$ is the physical and financial 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:

$$i^*_t P^*_{X,t} \tag{12}$$

Investors are risk neutral and they maximize expected profits:

$$\frac{E_t P^*_{X,t+1}\, I_t}{i^*_t} - P^*_{X,t}\, I_t (1 + \Phi(I_t)) \tag{13}$$

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 with respect to I_t):

$$E_t P^*_{X,t+1} = i^*_t P^*_{X,t}(1 + \kappa + \Psi\, I_t) \tag{14}$$

Equation (14) states that given $E_t P^*_{X,t+1}$, Ψ, and κ_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:

$$I_t = I_{t-1} + Y^{all}_{X,t} - X^*_t \tag{15}$$

where $Y^{all}_{X,t}$ 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:

$$X^*_t = \mu - \theta_x P^*_{X,t} \tag{16}$$

Whereas the supply is a combined function of the small economy production and the one of the rest of the world and it depends positively on the price of the commodity:[5]

$$Y^{all}_{X,t} = Y_{X,t} + Y^{\bar{row}}_X + \theta_y P^*_{X,t}. \tag{17}$$

[5]The representation of world supply and demand for commodities follows tight the specification in Knittel and Pindyck (2016). Accordingly, we will calibrate price elasticities on the basis of their estimates.

2.4 Government and the Central Bank

There are no commercial banks in the economy nor 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:

$$M_{t+1} = E_t R^*_{t+1} \tag{18}$$

where E_t 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:

$$D_{t+1} - D_t = G_t - T_t + r_t D_t + i^*_t \frac{E_t}{P_t} B^* - i^*_t \frac{E_t}{P_t} R^*_t \tag{19}$$

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 spendings are defined as $G_t = (\frac{P_{N,t}}{P_t})G_{N,t} + (\frac{P_{T,t}}{P_t})G_{T,t}$ 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.

2.5 Policy stabilization and exchange rate regimes

We will study the response of the model dynamics with fix and flexible exchange rate regimes. Under the fix exchange rate regime $E_t = \bar{E} = 1$ and the monetary authority becomes like a currency board changing the money supply to sustain the accumulation/depletion of reserves needed to sustain the fixed exchange rate. Under flexible exchange rates, reserves are constant as all the adjustment needed by the economy is absorbed by nominal exchange rate fluctuations.

Finally, in section 4.3, we will test the proposal of Frankel (2003) to stabilize the economy through nominal exchange rates pegging the export price, namely the commodity price.

2.6 Market clearing conditions

There are three market clearing conditions:

$$Y_N = C_N + G_N \tag{20}$$

$$\bar{L} = L_N + L_X \tag{21}$$

$$\frac{M_{t+1}}{P_t} = \left(\frac{E_t}{P_t}\right) R^*_{t+1} \tag{22}$$

Equation (20) specifies the home market equilibrium, which determines P_N, the price of the home good. Equation (21) specifies the labor market equilibrium that determines, as a result, W, the nominal wage rate. Finally, equation (22) represents the money market equilibrium that determines the domestic nominal interest rate, i.

Consolidated budget constraint

The budget constraint of the representative household (Equation 4), the government (Equation 19) and the central bank (Equation 18) can be consolidated into a single expression:

$$E_t\, R^*_{t+1} - E_{t-1}\, R^*_t = P_t\Big(Y_t - C_t - G_t\Big) + i^*_t\, E_t\Big(R^*_t - B^*\Big) \tag{23}$$

This expression is the balance-of-payments identity, expressed in foreign currency terms[6]. 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.

2.7 Shocks

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

$$i^*_t = \rho_i\, i^*_{t-1} + (1-\rho_i)\,\bar{i} + \epsilon_{i,t} \tag{24}$$

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 (δ=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 σ=2.4, that is in line with the estimate of Ostry and Reinhart (1992) for African and Latin American countries. The discount factor, β, 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).Finally, we set the utility parameter for money holdings, ψ, to 0.37 in order to match the ratio of reserves to external debt at steady state. We set external debt to GDP to 0.5 and total reserves to total external debt, R^*/B^*, to 0.6. These ratios are computed on the average of low-income commodity producer's countries on the sample period 2010-2014[7].

Regarding prices we assume P^*_T to be normalized to 1, as we also assume that the steady state level of the nominal exchange rate $\bar{E}$ to be 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, $\bar{P_X}^*$ is also set to 1 implying a steady state value of $\bar{P_X} = 1$ both in the baseline and in the extension.

[6]Remind that, for convenience, P^*_T has been set equal to 1.

[7]World Bank, International Debt Statistics, External debt stocks (% of GNI) and World Bank, International Debt Statistics, Total reserves (% of total external debt). The countries considered are those in table 1 in appendix A excluding developed economies. The data horizon chosen is consistent with the rest of steady state data availability.

Table 1: Parameter values

Parameter	Value	Description
Baseline		
α_N	0.6	Share of labor in production of the non-tradable good
α_X	0.6	Share of labor in production of the commodity good
β	0.99	Discount factor
δ	0.55	Home bias in consumption of the non-tradable good
σ	2.4	Inverse of inter-temporal elasticity of substitution in consumption
ψ	0.37	Weight of real money balances in utility
Extension		
κ	-0.1	convenience yield
Ψ	0.01	sensitivity of the cost of storage to inventories
$\bar{I}/\bar{Y^{all}}$	0.2	ratio of commodity stock of storage to overall supply
μ	4.3	level of foreign demand for commodities
θ_x	0.2	foreign demand elasticity to commodity prices
θ_y	0.2	world supply elasticity to commodity prices
$y_x^{\bar{row}}/\bar{Y_x}$	5	size of world commodity production wrt the SOE commodity production
Shocks		
σ_i	0.007	standard deviation of the foreign interest rate shock
ρ_i	0.8	persistence of the foreign interest rate shock

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 commodity markets being a good proxy for world demand. Therefore, we set the world supply and demand commodity price elasticity according to the estimates of Knittel and Pindyck (2016) to 0.2. Regarding the inventory-production commodity ratio, its value may actually vary a lot from commodity to commodity. For instance, according to the OECD-FAO Agricultural Outlook 2019[8], over the period 2011-2013, this ratio was on average equal to about 0.4 for sugar, 0.1 for oilseeds, 0.3 for wheat, and 0.6 for cotton. According to data from the US Department of Agriculture, in 2014, the world inventory-production ratio was about 0.2 for barley, for corn and for rice, 0.3 for wheat, 0.6 for soybeans, and 0.9 for cotton. For minerals, data from US Geological Survey show that the US inventory-commodity ratio amounted over the period 2010-2014 to about 0.1 for iron ore, 0.3 for nickel and for copper, 0.5 for zinc and 0.6 for aluminium. Following this evidence, we set the steady state value of the inventory-production commodity ratio to 0.2. We set the steady state of the convenience yield to -0.1 implying a sensitivity of the storage cost to the level of inventories, Ψ, to be around 0.01. In section 5, we provide a sensitivity analysis on this parameter. In steady state, the market for commodities clears, $\bar{X^*} = \bar{Y_X^{all}}$, and this pins down a corresponding value of μ.

Finally, the foreign interest rate shock process is calibrated following Neumeyer and Perri (2005); Uribe and Yue (2006) assigning 0.8 to the autoregressive coefficient and 0.007 to the standard deviation.

[8] OECD/FAO (2019).

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.

We do so under three different exchange rate regimes. We start with the case of a fixed exchange rate, then examine what happens when the exchange rate is flexible and, finally, following a proposal from Frankel (2003), we study an alternative exchange rate regime where the nominal exchange rate adjusts as to maintain constant the domestic currency value of the commodity price.

4.1 Fixed exchange rate

Baseline

The economy we consider is a net borrower. The reaction of the main variables of the economy to the increase of world interest rates is presented on Figure 2 (solid lines). As the interest rate increase makes external debt more costly, the current account deteriorates and external reserves decline. Given that external reserves decrease, the domestic money supply decreases as well, followed by aggregate consumption. The consequence of the contraction of consumption is a fall of the demand for the non-tradable good, whose price is declining. This leads to a switch of production from the non-tradable sector to the commodity producing sector. The demand for the imported good also declines. As the nominal exchange rate and the international price of the commodity are fixed, the domestic currency value of the commodity is unchanged. Given that the price of the non-tradable good has fallen, the overall price level also falls. Consequently, the real exchange rate depreciates. We can further notice that despite the increase in the production of the commodity, external reserves keep on falling after the shock. This is due to the fact that interest revenues on external reserves declines, which reinforces the initial deterioration of the current account.

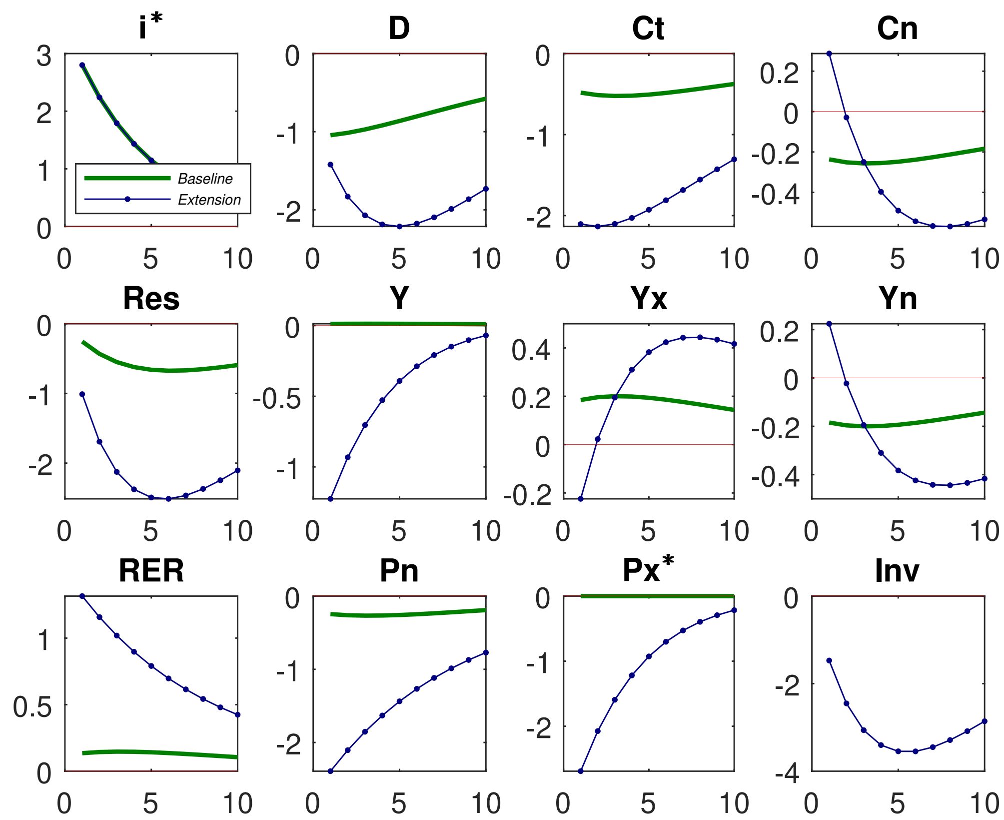
Extension

Let us now turn to the extension (see Figure 2, thin lines)-. Given that commodities are now subject to international investor arbitrage decisions, changes to the foreign interest rate now affect the world price of the commodity, which declines sharply. With a lower commodity price, the domestic production of the commodity declines. Labour then moves from the commodity sector to the non-tradable sector, whose production increases. Aggregate output however falls. Jointly, the increase of the word interest rate, the fall of the commodity price and the contraction of commodity production leads to a sharp deterioration of the external current account. There is therefore a strong decrease of external reserves and, consequently, of aggregate consumption. Despite the contraction of aggregate consumption, the demand of the non-tradable good increases. This comes from the fact that the increase in the production of the non-tradable good leads to a fall of the price of that good, which triggers a switch of consumption expenditures from the imported good to the non-tradable good.

These results suggest that the impact of world interest rate shocks on small open commodity dependent countries may differ significantly from what happens to small open economies that are not commodity dependent. As we can see on Figure 2, there are two main differences. First, commodity price effects amplifies the impact response of several variables. It appears in particular that commodity dependent countries suffer from a larger fall of external reserves and, therefore, of aggregate consumption. The decline of the domestic price level and, consequently, the depreciation of the real exchange rate are also more pronounced if the small open economy is commodity dependent than if it is not. Second, the direction of the impact response of some important variables differs strongly between commodity dependent countries and not commodity dependent countries. A major difference is about the sectoral effect of the shocks. It appears indeed that, when the country is commodity dependent, the production and the demand for the non-tradable good increase, and the production of the tradable good (commodity) declines while the effects are opposite when the tradable good is not a commodity. One can further notice that real GDP declines when the country is commodity dependent while it remains constant when the country is not commodity dependent.

We have shown that the introduction of the commodity storage channel has non negligible effects on the dynamics of the small open economy.[9] As what differs between commodity dependent and non-commodity countries is driven by the reaction of commodity prices, in section 5 we will do a sensitivity analysis on the parameters governing the extension block.

Figure 2: Fixed exchange rate IRFs: increase in the world interest rate



Notes. Solid line: Baseline 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.

4.2 Flexible exchange rate

Baseline

The response of the small open economy to the international interest rate shock hen the exchange rate is flexible is given on Figure 3. It so appears that the nominal exchange rate appreciates on impact in response to the increase of the world interest rate. This result differs strongly from what we usually

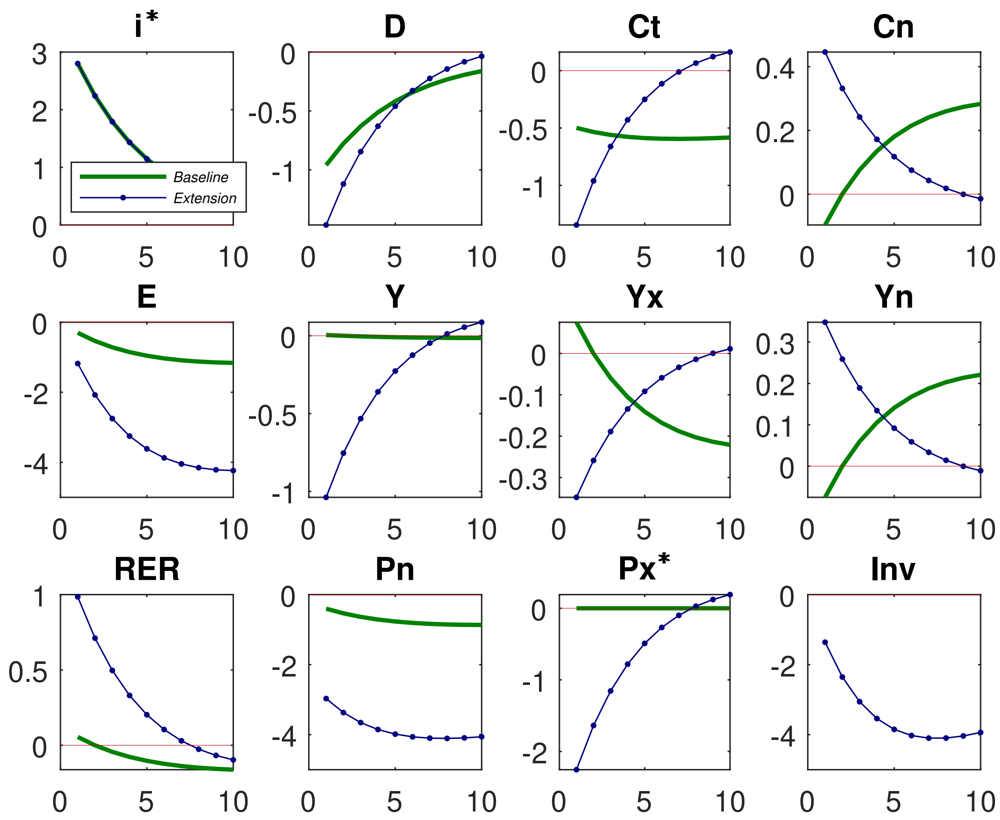
[9]Another transmission channel for the SOE economy could be trough the risk premium channel -as highlighted by Neumeyer and Perri (2005); Uribe and Yue (2006)- that can be a positive function of $\frac{B*}{R^*_t}$ and a negative function of Px. Adding this channel would reinforce the effect of the foreign interest rate shock as an increase in i^* drives an increase in i_{SOE} and it decreases Px; a decrease in Px increases the risk premium and so, further increase i_{nom}.

obtain with standard models of small open economies, where the nominal exchange rate depreciates following a rise of world interest rates. The origin of this difference is that our small open economy has zero international capital flows, which implies that its external current account must be balanced at every period. On impact, the appreciation of the nominal rate generates positive valuation effects, that offset the increase in the cost of servicing the external debt and so keep balanced the external current account. Following the appreciation of the nominal exchange rate, the domestic money stock declines and, accordingly, aggregate consumption. There is then a contraction in the demand for both the non-tradable good and the imported good. This leads to a fall in the price of the non-tradable good, which triggers a shift of production from the non-tradable sector to the commodity producing sector. There is also a decline in the overall consumer price level, which dominates the appreciation of the nominal exchange rate and therefore causes the real exchange rate to depreciate.

Extension

When international commodity prices are endogenous, they decline in response to the increase of the world interest rate. This commodity effect, jointly with the appreciation of the nominal exchange rate, leads to a contraction of the commodity production. Labor then moves from the commodity producing sector to the non-tradable sector, whose production increases. The price of the non-tradable good then falls, which leads to a switch of consumer expenditures from the imported good to the non-tradable good. Aggregate consumption increases, but aggregate output declines. While the nominal exchange rate appreciates, the real exchange rate depreciates, thanks to a fall in the domestic price level.

Figure 3: Flexible exchange rate IRFs: increase in the world interest rate



Notes. Solid line: Baseline 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.

These results show that, when the exchange rate is flexible, the introduction of the commodity storage channel has also non negligible effects on the dynamics of the small open economy. It so appears that commodity dependent countries react more strongly to world interest rate shocks than countries which are not specialized in the export of commodities. Our analysis also shows that the response of the non-tradable sector and the tradable sector is different whether the main export of the country is a commodity or not. When the country is commodity dependent, the production (demand) of the non-tradable good increases and the production of the tradable good falls, while the sectoral production effects are opposite when the country is not a commodity exporter. We also find that aggregate consumption increases when the country is a commodity exporter while it declines when its main export is not a commodity.

4.3 Pegging the export price policy

We now study the implications of an alternative nominal exchange rate regime that pegs export price (PEP) in terms of the domestic currency. The export price targeting was firstly proposed by Frankel (2003) for countries that are specialized in the export of a particular commodity and are, for that reason, subject to volatile terms of trade. 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 that we are considering, the export price is the one associated with commodities. Therefore, the PEP regime implies that:

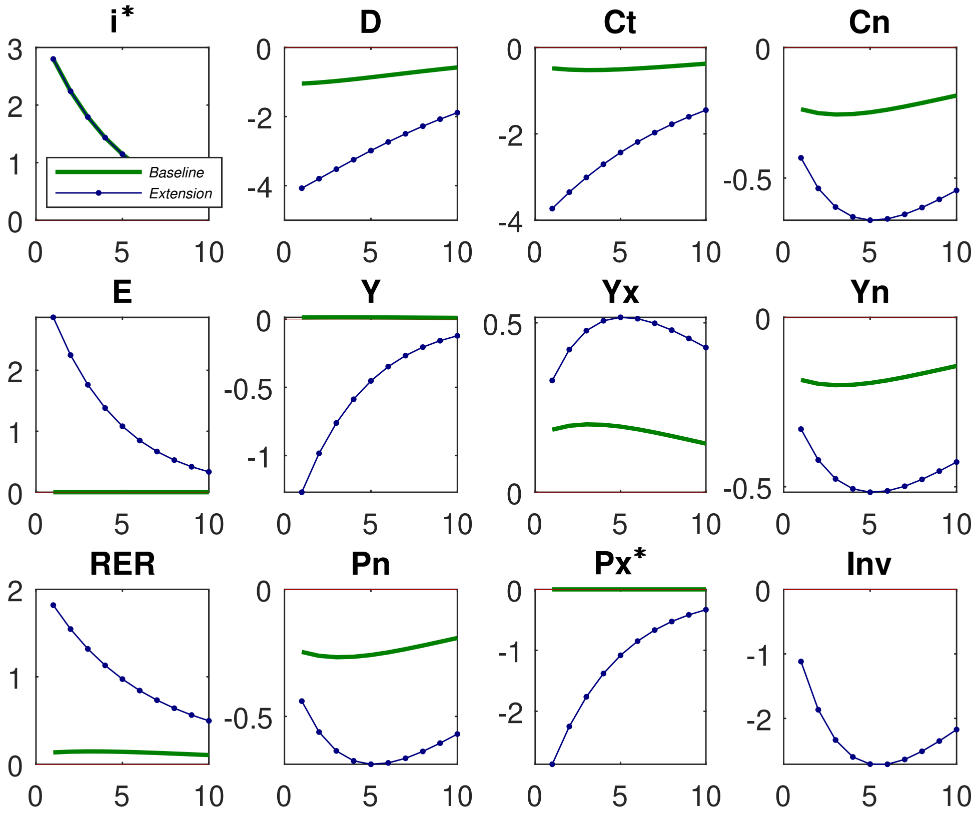
$$E_t = \frac{1}{Px_t^*}$$

In such a way that the price of the commodity in terms of the local currency is kept constant to $Px_t = E_t Px_t^*$.

Figure 4 shows the reaction of the small open economy to the foreign interest rate shock under a PEP regime. Notice that when the small economy is not a commodity exporter, which implies that the price of its exported good is fixed in foreign currency (baseline case), what happens in response to the foreign interest rate shock is similar to the case of the fixed exchange rate regime. For convenience, the response of the economy is however reproduced on Figure 6 (thick line). What happens when the small open economy is a commodity exporter, with the world price of the commodity being endogenously determined, is given by the thin lines on Figure 6. When the nominal exchange rate targets the foreign commodity price (Px_t^*), it automatically stabilizes the price of the commodity in local currency (Px_t). Therefore, given that the price of the commodity in foreign currency (Px_t^*) falls instantaneously in response to the increase in the foreign interest rate, the nominal exchange rate depreciates instantaneously. Due to the rise of the world interest rate and the depreciation of the nominal exchange rate, the cost of servicing the external increases strongly. The external current account then deteriorates, external reservers fall and aggregate consumption declines. The demand for both the tradable and the non-tradable declines. However, given the depreciation of the nominal exchange, there is a switch of expenditures from the imported good to the non-tradable good, which explains why the demand for the imported good declines more strongly than the demand for the non-tradable good. Following the contraction of the demand for the non-tradable good, the relative price between the non-tradable good and the commodity falls, which triggers a reallocation of production from the non-tradable sector to the (tradable) commodity sector. Finally, due to the nominal exchange rate depreciation and the fall of the domestic price level, there is a sharp depreciation of the real exchange rate.

These results indicate that, with a PEP exchange rate regime regime, the reaction of a commodity exporting country is qualitatively similar to that of non-commodity exporting one. On impact, as Px_t is unchanged, the production switching effect from the commodity to the non-tradable sector is however

Figure 4: Pegging the export price IRFs: increase in the world interest rate



Notes. Solid line: Baseline 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.

dampened, but the production of the commodity sector is not totally insulated from the foreign shock. Conversely, the response of aggregate production and consumption, of the domestic price level, and the real exchange rate are more pronounced on impact for commodity exporting countries. So, while the PEP exchange rate regime allows to dampen on impact the sectoral production effects in commodity exporting countries, it however leads to stronger fluctuations in the rest of the economy. In particular, the sharp reaction of the domestic price level suggests that, despite the presumption of Frankel (2003), the PEP exchange rate regime does not provide a proper nominal anchor for commodity exporting countries. Furthermore, our results suggest that, over time, the sectoral production effects are stronger when the country is a commodity exporter. This comes from the fact that, for commodity exporting countries, the PEP exchange rate regime implies that the increase in the foreign interest is followed instantaneously by a depreciation of the nominal exchange rate. More importantly, it appears that, with a PEP regime, the increase of the foreign interest rate leads to a strong depletion of external reserves when the country is a commodity exporter. Because of this impact on the external reserves, the commodity exporting country could be the victim of a currency crisis even though there is no "sudden stops" as the economy is not integrated in international financial markets.

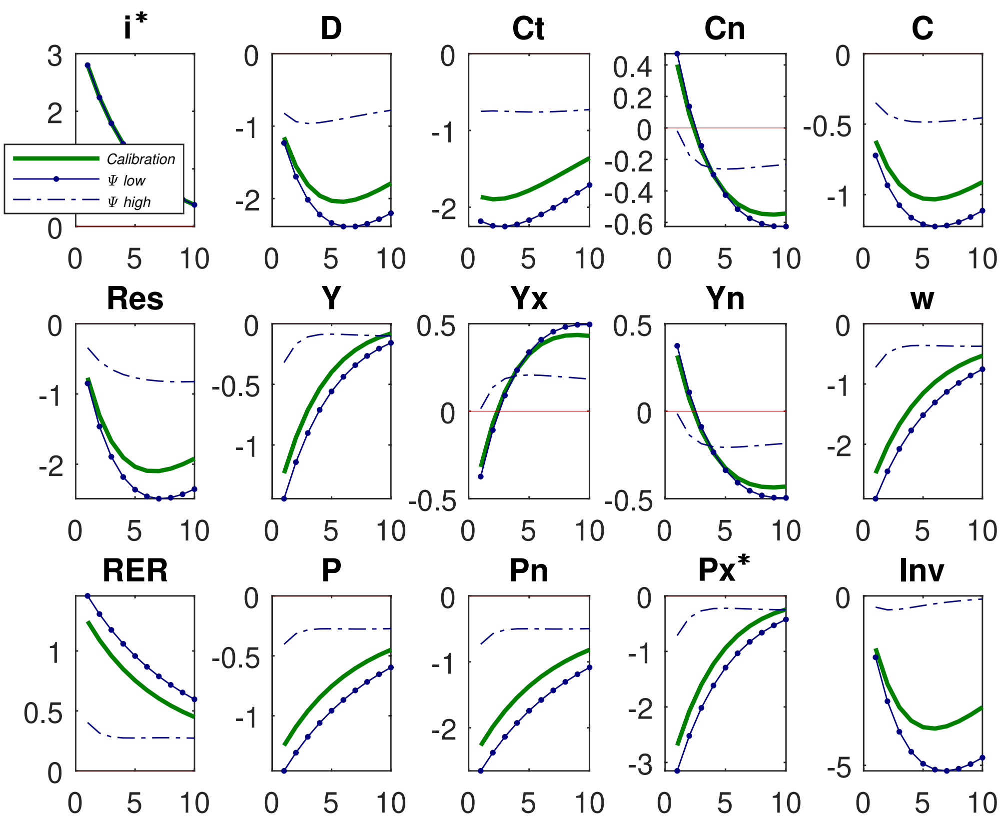
5 Sensitivity

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: θ_x, θ_y and Ψ. 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 the results are very robust.[10] The Ψ parameter governs the cost of storage and it is key for the dynamics.

As we can see in Figure 5, when Ψ is low, dynamics are amplified as the reaction of the commodity price is more important. A low Ψ implies low storage costs, therefore inventories adjust quickly reflecting changes in demand and supply driven by strong changes in Px. With a low storage cost investors have an incentive to enter the storage market: hold a commodity and sell it in a future date. With a very high Ψ, the cost of storing the commodity is also high, therefore the speculator does not hold inventories and does not enter the storage-market speculation strategy. As a consequence the price of the commodity would not vary, and the dynamics are as in the baseline case.

If we consider the cost of storage as both a financial and a physical cost, the increase in the volume of the commodity future market could have coincided with an important decrease in the cost to access financial markets. This could have been the consequence of the standardization and increased transparency in futures contracts, spurring a reduction in information costs. More confidence in the market could have pushed more traders to enter decreasing the liquidity and transaction costs. As long as this cost decreases, the commodity price channel takes more and more importance.

Figure 5: Fixed exchange rate IRFs: increase in the world interest rate - sensitivity to Ψ -



Notes. Solid line: Extension simulation. Dotted-dashed line: Extension with low Ψ = 0.000001. "o" line: Extension with high Ψ = 0.1. 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.

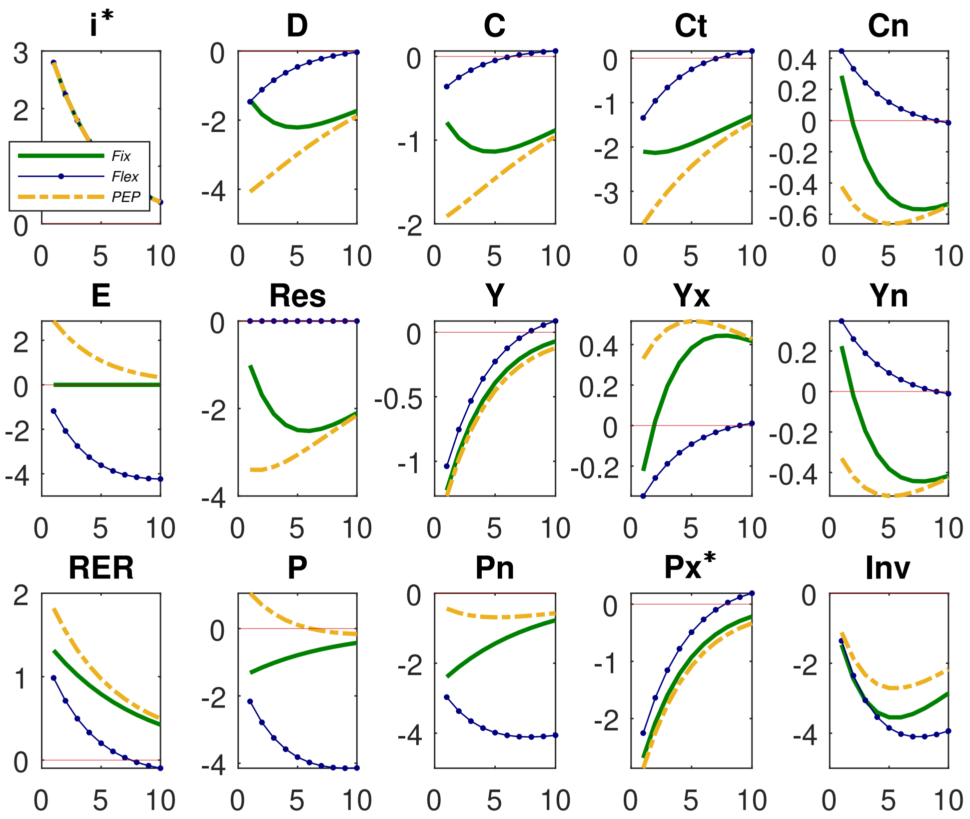
[10]We show these sensitivity results in appendix C.

6 Summary results and policy implications

The main insight from our analysis is to show that small open developing countries that are commodity dependent react differently to foreign interest rate shocks than small open developing countries whose main export is not a commodity. There are two main differences.

First, it appears that the foreign interest rates shock leads to stronger fluctuations in commodity dependent countries. Given the endogeneity of commodity prices, commodity dependent countries are hit simultaneously by an adverse international financial shock and an adverse international commodity price shock, while non-commodity dependent countries are only subject to the international financial shock. For instance, we have shown that when the exchange rate is fixed, there is a drop of external reserves in bth commodity and non-commodity dependent countries but the drop is larger in the former. When the exchange rate is flexible, the adjustment of the nominal exchange rate in response to the shock is more pronounced for commodity dependent countries than it is for countries that are not commodity dependent countries. This also holds for the reaction of the real exchange rate, whatever the exchange rate regime. Commodity dependent countries also suffer from a larger decline of total real output.

Figure 6: IRFs after an increase in the world interest rate with different exchange regimes



Notes. Solid line: Extension model under fixed exchange rate. Dotted line: Extension model under a flexible exchange rate. Dashed-dotted line: Extension model + PEP policy. 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.

Second, the sectoral production effects caused by the international interest rate shock are different whether the country is commodity dependent or not. If the main export is not a commodity, it appears that there is reallocation of production from the export sector to the non-tradable sector. Conversely, if the main export is a commodity, production is switching from the commodity sector to the non-tradable sector when the exchange rate is fixed or flexible. The export sector is thus booming when the exported good is not a commodity while it is contracting sharply when the exported good is a commodity. The contraction of the commodity sector does not happen if the country operates a PEP exchange rate regime.

Another important insight of our analysis is the findings that commodity dependent countries are vulnerable to international financial shocks even if they are disconnected from international financial markets. Figure 6 compares the three exchange rate regimes with an active commodity price channel. Whatever the exchange rate regime, real GDP declines strongly following the shock. It also appears that, when the exchange rate is fixed or there is a PEP, the countries face a large drop of reserves and are thus more exposed to exchange rate crisis, which is in line with Bodart and Carpantier (2019) findings.

7 Conclusions

With the financialization of commodity markets, international interest rates are increasingly viewed as a key determinant of commodity prices. With this evidence in mind, this paper explores the role of commodity prices in the transmission of international monetary shocks to small open commodity exporting countries. We do so by building a model of a small open economy which produces two goods, a non-tradable good and a storable tradable good. The key difference with standard models of small open economies lies in the endogenous response of commodity prices which, due to competitive commodity storage, adjust instantaneously to variations in interest rates.

The main insight of our analysis is to show that commodity exporting countries are exposed to international financial disturbances, even when they are disconnected from international financial markets. This comes from the endogenous response of commodity prices, which amplifies the international transmission of world interest rate shocks. It appears therefore that the business cycle of commodity dependent countries is more impacted by world interest rate shocks than what it is for non-commodity dependent countries. We find for instance that the response of prices, real GDP, exchange rates or external reserves are more pronounced when the country is commodity dependent. We also find that the sectoral production effects are different whether the country is commodity dependent or not. It appears notably that, after a rise of world interest rates, the exporting sector is contracting sharply when the country is a commodity exporter while it is booming when the traded good is not a commodity.

Our results offer a new perspective on the drivers of the business cycle of commodity producers developing countries. Future research could study stabilization policies for these countries making a distinction between commodity dependent and non-commodity dependent economies.

References

Agenor, P.-R. (1998). Capital inflows, external shocks, and the real exchange rate. *Journal of International Money and Finance*, 17(5):713–740.

Agenor, P.-R. (2016). Optimal fiscal management of commodity price shocks. *Journal of Development Economics*, 122(C):183–196.

Akram, Q. F. (2009). Commodity prices, interest rates and the dollar. *Energy Economics*, 31:838–851.

Anzuini, A., Lombardi, M. J., and Pagano, P. (2013). The impact of monetary policy shocks on commodity prices. *International Journal of Central Banking*, 9(3):125–150.

Arseneau, D. M. and Leduc, S. (2013). Commodity price movements in a general equilibrium model of storage. *IMF Economic Review*, 61(1):199–224.

Bodart, V. and Carpantier, J.-F. (2019). Currency collapses and output dynamics in commodity dependent countries. IRES Discussion Paper 2019-11, UCLouvain.

CFTC (2008). Staff report on commodity swap dealers and index traders with commission recommendations.

Chari, V. and Christiano, L. (2017). Financialization in commodity markets. NBER Working Papers 23766, National Bureau of Economic Research, Inc.

Cheng, I. and Xiong, W. (2014). The financialization of commodity markets. *Annual Review of Financial Economics*, 6:419–441.

Dagher, J., Gottschalk, J., and Portillo, R. (2012). The short-run impact of oil windfalls in low-income countries: A dsge approach. *Journal of African Economics*, 21(3):343–372.

Fostel, A. and Kaminsky, G. L. (2008). Latin america's access to international capital markets: Good behavior or global liquidity? In Cowan, K., Edwards, S., Valdés, R. O., Editor), N. L. S., and Schmidt, K., editors, *Current Account and External Financing*, volume 12 of *Central Banking, Analysis, and Economic Policies Book Series*, chapter 4, pages 117–158. Central Bank of Chile.

Frankel, J. (1986). Expectations and commodity price dynamics: The overshooting model. *American Journal of Agricultural Economics*, 68(2):344–348.

Frankel, J. (2003). A Proposed Monetary Regime for Small Commodity Exporters: Peg the Export Price ('PEP'). *International Finance*, 6(1):61–88.

Frankel, J. (2014). Effects of speculation and interest rates in a "carry trade" model of commodity prices. *Journal of International Money and Finance*, 42:88–112.

IMF (2014). Issuing international sovereign bonds. opportunities and challenges for sub-saharan africa. Technical report, International Monetary Fund, African Department, Washington D.C.

Kaldor, N. (1939). Speculation and economic stability. *The Review of Economic Studies*, 7(1):1–27.

Khan, M. S. and Montiel, P. J. (1987). Real exchange rate dynamics on a small, primary-exporting country. *Staff Papers (International Monetary Fund)*, 34(4):681–710.

Knittel, C. and Pindyck, R. (2016). The simple economics of commodity price speculation. *American Economic Journal: Macroeconomics*, 8(2):85–110.

Kose, M. A. (2002). Explaining business cycles in small open economies: 'How much do world prices matter?'. *Journal of International Economics*, 56(2):299–327.

Kose, M. A., Otrok, C., and Whiteman, C. H. (2003). International business cycles: World, region, and country-specific factors. *American Economic Review*, 93(4):1216–1239.

Kose, M. A. and Riezman, R. (2001). Trade shocks and macroeconomic fluctuations in africa. *Journal of Development Economics*, 65:55–80.

Mendoza, E. (1995). The terms of trade, the real exchange rate, and economic fluctuations. *Journal of Moneratary Economics*, 36(1):101–137.

Neumeyer, P. A. and Perri, F. (2005). Business cycles in emerging economies: the role of interest rates. *Journal of Monetary Economics*, 52(2):345–380.

OECD/FAO (2019). OECD-FAO Agricultural outlook 2019-2028. Technical report, OECD Publishing, Paris/Food andAgriculture Organization of the United Nations, Rome.

Olabisi, M. and Stein, H. (2015). Sovereign bond issues: Do african countries pay more to borrow? *Journal of African Trade*, 2(1):87 – 109.

Ostry, J. D. and Reinhart, C. M. (1992). Private saving and terms of trade shocks: Evidence from developing countries. *Staff Papers (International Monetary Fund)*, 39(3):495–517.

Pindyck, R. (2001). The dynamics of commodity spot and futures markets: A primer. *The Energy Journal*, 22(3):1–29.

Schmitt-Grohé, S. and Uribe, M. (2018). How important are terms-of-trade shocks? *International Economic Review*, 59(1):85–111.

Scrimgeour, D. (2014). Commodity Price Responses to Monetary Policy Surprises. *American Journal of Agricultural Economics*, 97(1):88–102.

Tumen, S., Unalmis, D., Unalmis, I., and Unsa, D. F. (2016). Taxing fossil fuels under speculative storage. *Energy Economics*, 53(C):64–75.

Unalmis, D., Unalmis, I., and Unsal, D. F. (2012). On oil price shocks: The role of storage. *IMF Economic Review*, 60(4):505–532.

Uribe, M. and Yue, V. (2006). Country spreads and emerging countries: Who drives whom? *Journal of International Economics*, 69(1):6–36.

Working, H. (1949). The theory of price of storage. *The American Economic Review*, 39(6):1254–1262.

A Commodity dependence

Table 1 presents the degree of commodity dependence of different countries in Africa, South America and in developed countries. The data show that many small open African and Latin American countries are highly commodity dependent as commodities are the main source of export revenues.

Table 1: Commodity dependence and Export Values

Countries	Cdty/Merch	Cdty/Exp	Cdty/GDP	Cdty1	Cdty2	Cdty3
Angola	95	92	63	Crude oil	Natural gas	Crustaceans
Gabon	94	86	49	Crude oil	Wood	Coffee
Congo	93	85	66	Crude oil	Wood	Copper
Chad	95	86	27	Crude oil	Cotton	Tobacco
Mauritania	92	81	32	Iron	Fish	Crustaceans
Zambia	85	78	25	Copper	Tobacco	Sugar
Ivory Coast	80	68	31	Cocoa	Crude oil	Fruits
Guinea-Bissau	97	76	15	Fruits	Crude oil	Crustaceans
Malawi	88	71	17	Tobacco	Sugar	Tea
Guinea	82	69	21	Aluminium	Crude oil	Natural gas
Cameroon	91	60	16	Crude oil	Wood	Cocoa
Mozambique	88	62	16	Aluminium	Crustaceans	Tobacco
Zimbabwe	71	61	22	Tobacco	Nickel	Cotton
Seychelles	88	51	30	Fish	Crude oil	Crustaceans
Benin	83	62	15	Cotton	Uranium	Fruits
Ghana	75	57	20	Cocoa	Crude oil	Wood
Ethiopia	86	59	6	Coffee	Oil seeds	Meat
Congo Rep.	62	43	13	Crude oil	Wood	Copper
Niger	65	57	11	Uranium	Crude oil	Meat
Burkina Faso	71	60	8	Cotton	Oil seeds	Fruits
Togo	62	50	18	Phosphate	Cotton	Crude oil
Uganda	77	48	7	Coffee	Fish	Tobacco
Kenya	69	42	10	Tea	Crude oil	Coffee
Mali	51	41	10	Cotton	Meat	Crude oil
Tanzania	68	38	7	Fish	Tobacco	Coffee
Rwanda	87	45	5	Coffee	Crude oil	Tea
Senegal	66	44	12	Crude oil	Fish	Crustaceans
Burundi	69	50	4	Coffee	Tea	Sugar
Ecuador	91	79	21	Crude oil	Fruits	Crustaceans
Chile	84	68	24	Copper	Fruits	Wood
Bolivia	82	68	23	Natural gas	FeedAnimals	Crude oil
Paraguay	88	52	27	Oliseeds	Meat	FeedAnimals
Belize	76	42	23	Sugar	Fruits	Juices
Peru	68	57	13	Copper	FeedAnimals	Crude oil
Colombia	68	56	9	Crude oil	Coal	Coffee
Uruguay	68	44	11	Meat	Rice	Oil seeds
Honduras	45	42	21	Coffee	Fruits	Crustaceans
Nicaragua	59	50	14	Coffee	Meat	Crustaceans
Guatemala	55	42	10	Coffee	Fruits	Wood
Costa Rica	36	29	11	Bananas	Coffee	Fish
Australia	70	56	11	Coal	Iron	Crude oil
Canada	38	32	11	Softwood sawn	Aluminum	Wheat
New-Zealand	69	49	15	Meat	Wood	Fruits
South-Africa	45	34	10	Gold	Coal	Iron
Norway	75	57	24	Crude oil	Natural gas	Fish
Russia	70	61	19	Crude oil	Natural gas	Aluminium
Argentina	66	57	10	Feed animals	Crude oil	Vegetable oils
Brazil	51	43	5	Iron	Meat	Oil seeds

Note: "Cdty/Merch" is the percentage ratio of commodity exports (in value) in total exports of merchandises; "Cdty/Exp" is the percentage ratio of total commodity exports (in value) in total exports of goods and services. "Cdty/GDP" is the percentage ratio of commodity exports (in value) in GDP. All the measures are computed as an average over the period 1995-2015. Cdty1, Cdty2, Cdty3 are respectively the first, second and third main commodity exported by the country.

Source: Bodart and Carpantier (2019).

B Model

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

$$\frac{w_t}{pn_t} = \alpha_N \, {Ln_t}^{\alpha_N - 1} \tag{A.1}$$

$$\frac{w_t}{px_t} = \alpha_X \, {Lx_t}^{\alpha_X - 1} \tag{A.2}$$

$$Yn_t = {Ln_t}^{\alpha_N} \tag{A.3}$$

$$Y_{X,t} = {Lx_t}^{\alpha_X} \tag{A.4}$$

$$Y_t = Yn_t \, \frac{pn_t}{P_t} + Y_{X,t} \, \frac{px_t}{P_t} \tag{A.5}$$

$$Cn_t = \delta \, {pn_t}^{\delta - 1} \, {E_t}^{1-\delta} \, C_t \tag{A.6}$$

$$Ct_t = (1 - \delta) \, {pn_t}^{\delta} \, {E_t}^{(-\delta)} \, C_t \tag{A.7}$$

$$P_t = {E_t}^{1-\delta} \, {pn_t}^{\delta} \tag{A.8}$$

$${C_t}^{(-\sigma)} = \psi \left(\frac{M_t}{P_t}\right)^{(-\sigma)} + \frac{\beta \, {C_{t+1}}^{(-\sigma)}}{\frac{P_{t+1}}{P_t}} \tag{A.9}$$

$${C_t}^{(-\sigma)} = \beta \, {C_{t+1}}^{(-\sigma)} \, (1 + r_{t+1}) \tag{A.10}$$

$$1 + r_t = \frac{(1 + i_t) \, P_{t-1}}{P_t} \tag{A.11}$$

$$\frac{M_t}{P_t} = \frac{E_t \, Res_t}{P_t} \tag{A.12}$$

$$Yn_t = Cn_t + \bar{Gn} \tag{A.13}$$

$$\bar{L} = Ln_t + Lx_t \tag{A.14}$$

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

$$D_t - D_{t-1} = r_t\, D_{t-1} + \bar{G} - \bar{T} + \frac{E_t\, i_t^*}{P_t}\, \left(\bar{B} - Res_{t-1}\right) \tag{A.16}$$

$$px_{t+1}^* = i_t^*\, px_t^*\, \left(1 + cyield + \gamma\, I_t\right) \tag{A.17}$$

$$cost_t = px_t^*\, \left(cyield + \gamma\, I_t\right) \tag{A.18}$$

$$I_t = I_{t-1} + Yall_t - X_t^* \tag{A.19}$$

$$Y_{x,t}^{all} = Y_{X,t} + Y_X^{\bar{r}ow} + \theta_y\, px_t^* \tag{A.20}$$

$$X_t^* = \mu - \theta_x\, px_t^* \tag{A.21}$$

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

$$RER_t = \frac{E_t}{P_t} \tag{A.23}$$

$$px_t = E_t\, px_t^* \tag{A.24}$$

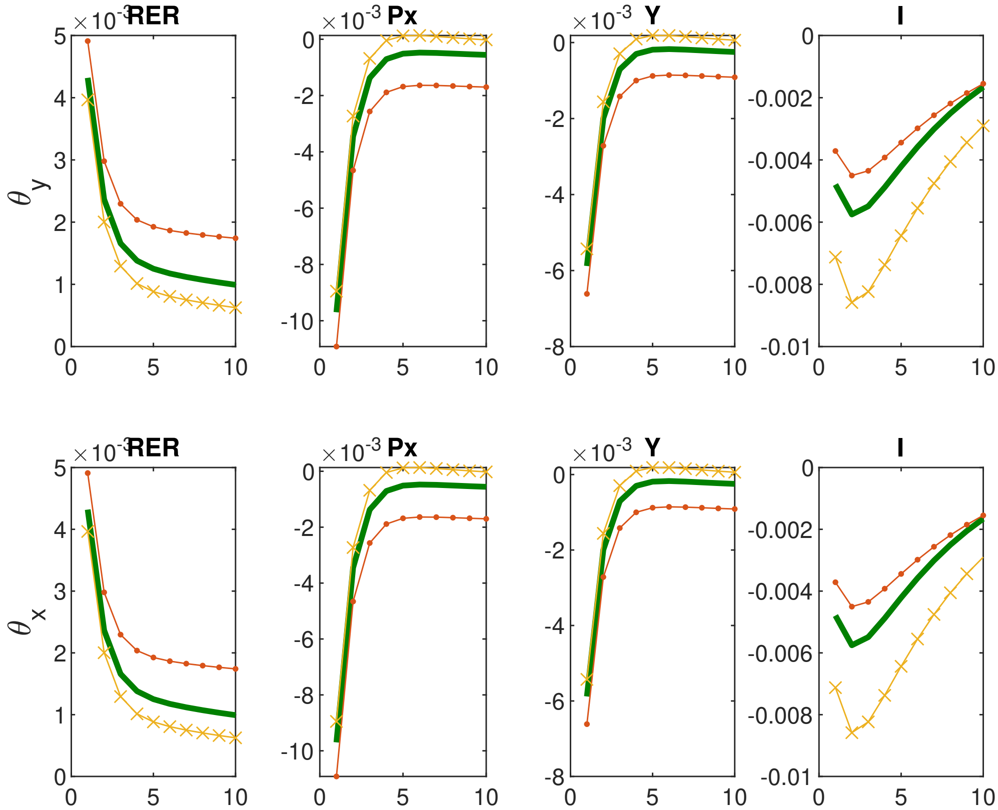
The exchange rate can be fixed $E_t = 1$, flexible (with $Res_t = \bar{Res}$) or it can follow the policy:

$$E_t = \frac{1}{px_t^*} \tag{A.25}$$

C Sensitivity

We compute the sensitivity of the world demand and supply elasticity to commodity prices. For both parameters we perform a sensitivity between the values $0.05 < \theta < 0.51$ and we present the results for the highest and lowest values. As we can see in figure 1, the higher is the θ the stronger is the reaction of commodity price and therefore the amplification to the rest of the economy. However, the quantitative impact of changing these parameters is not key to the behavior of the model.

Figure 1: Fixed exchange rate IRFs: increase in the world interest rate - sensitivity to commodity price elasticities -



Notes. Solid line: Extension model simulation. Dotted line: Extension model with high θ. "x" line: Extension model with low θ. The top line presents the sensitivity to the demand elasticity, θ_y; the bottom panel to the supply elasticity, θ_x. 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.