WORLD INTEREST RATES AND MACROECONOMIC ADJUSTMENTS IN DEVELOPING COMMODITY PRODUCING COUNTRIES

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World interest rates and macroeconomic adjustments in developing commodity producing countries *

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Abstract

With commodities becoming international financial securities, commodity prices are affected by the international financial cycle. With this evidence in mind, this paper reconsiders the macroeconomic adjustment of developing commodity-exporting countries to changes in world interest rates. 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 reaction 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, through the commodity price channel, even those small open commodity-exporting economies that are disconnected from international financial markets can be affected by the international financial cycle.

Keywords: Storable commodity, International financial shock, Developing economies

JEL Classification: E32, F41, G15, 011, Q02.

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1 Introduction

Commodities have become a popular asset class and they are now largely traded on financial markets just like stocks and bonds (CFTC, 2008; Tang and Xiong, 2012; Cheng and Xiong, 2014; Henderson et al., 2014).[1] Because of the new role of commodities as international financial securities, commodity prices are affected by the international financial cycle, whose most influential variable is the US monetary policy interest rate.[2] A growing empirical evidence attests a causal negative relationship between the US monetary policy interest rates and commodity prices (Akram (2009), Anzuini et al. (2013); Byrne et al. (2013); Frankel (2008, 2014); Rosa (2014); Scrimgeour (2014)).[3] With this evidence in mind, in this paper we reconsider how world interest rates impact small open economies that are commodity producers.

Understanding how interest rate changes are transmitted from one country to other economies is a major topic in international macroeconomics. From a conceptual point of view, the literature has identified three main transmission channels. First, the trade channel: higher interest rates in a country (the U.S., for instance) lead 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 lead to higher interest rates abroad. Another dimension of the financial channel operates through valuation effects due to exchange rate fluctuations.

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

The foundations of the "commodity price channel" explored in this paper are based on the theory of storage. According to it, the holder of a commodity can choose either to sell it now or to store it and sell it in the future. Under risk neutral arbitrage, the expected return of storing a commodity—net of storage costs—must be equal to the risk-free interest rate (Kaldor (1939); Working (1949); Frankel (1986, 2008) among others). It follows from this condition that commodity prices are negatively related to interest rates. Higher interest rates raise the opportunity cost of holding inventories leading to a lower demand for inventories, that contributes to reducing the total demand of commodities and driving commodities' prices down.

To explore the role of commodity prices in the international transmission of world interest rate shocks, we build a model of a small open economy which produces two goods, a non-tradable good and a storable tradable commodity. The modelling framework is in the same spirit of reference models for developing countries such as Mendoza (1995); Kose (2002); Neumeyer and Perri (2005); Uribe and Yue (2006); Schmitt-Grohé and Uribe (2018). In particular, we relate closely to those models that study developing economies that are commodity exporters (Kose and Riezman, 2001; Drechsel and Tenreyro, 2018; Fernández et al., 2018). However, our model differs from them because of the inclusion of i) the competitive storage mechanism ii) in international financial markets. The first feature implies that the price of the tradable commodity is determined endogenously in the model—rather than being exogenously imposed—, the second feature implies that the opportunity cost considered in the optimal storage decision is the risk-

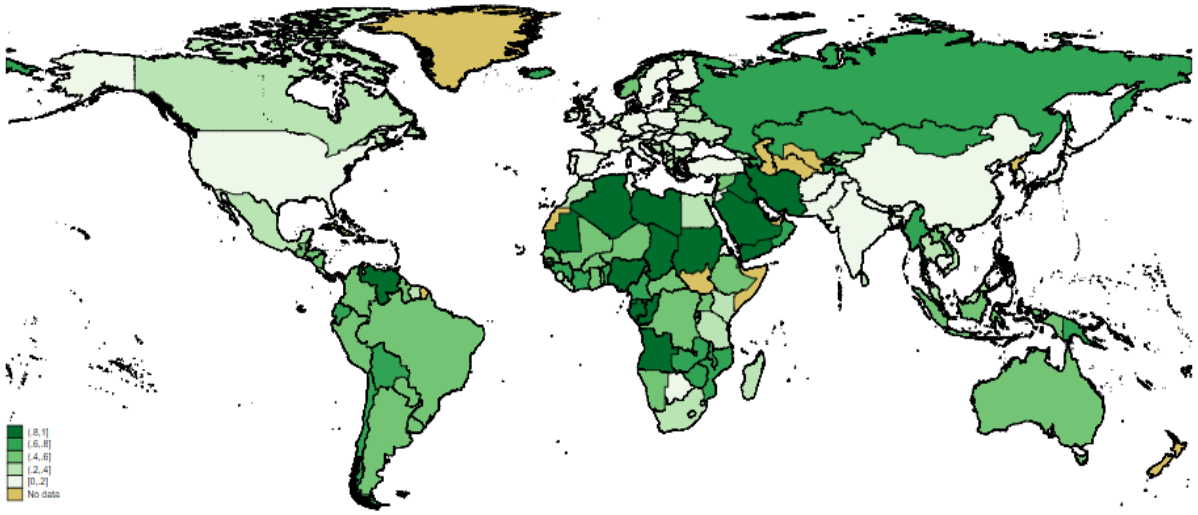
[1] The emergence of commodities as a new asset class dates back to the early 2000s. This process, usually referred to in the literature as the financialization of commodities, has been accentuated after 2004 with the entrance in the market of institutional investors. For a detailed description of the functioning of the commodity market and its evolution see Valiante and Egenhofer (2013).

[2] Miranda-Agrippino and Rey (2020) show that US monetary policy shocks induce comovements in international financial variables characterizing the "Global Financial Cycle". Byrne et al. (2013) provide significant evidence of co-movements in commodity prices driven by the US real interest rate as the common factor (together with risk).

[3] Akram (2009) shows 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); Frankel (2014); Rosa (2014); Scrimgeour (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%. Byrne et al. (2013) also find a significant negative impact of US real interest rate shocks on commodity prices.

free rate leading the global financial cycle. Therefore, in our model, through the commodity price channel, variations in world interest rates lead to endogenous changes in the price of the tradable commodity of the small open economy.

Figure 1: Commodity dependence



Note: The figure presents the degree of commodity dependence defined as the percentage ratio of total commodity exports (in value) in total exports of goods and services. The measure is computed as an average over the period 1995-2015.

Source: Bodart and Carpantier (2020).

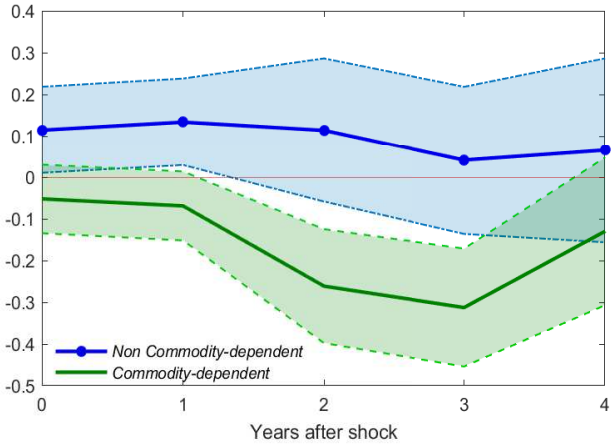
We are not the first to embed a commodity storage mechanism in a general equilibrium setup. Arseneau and Leduc (2013) compare the impact of storage in partial and general equilibrium frameworks highlighting the amplification effect that is generated in the second case by the endogenous behaviour of interest 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) 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 commodity-exporting developing country that relies completely on the production and export of a commodity. It turns out that developing (middle and) low-income countries represent the majority of commodity producers' countries with the highest dependence to the sector (see the evidence in Figure 1 and table A.1 in Appendix A). Based on this evidence, and in order to highlight the importance of the commodity price channel, we consider the representative country to have a limited access to international capital markets as in a "semi-open" economy à la Bacchetta et al. (2013, 2014).[4] While the 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), Olabisi and Stein (2015)).[5] Studying these countries is key because, through the commodity price channel, they can be affected by the international financial cycle even if they are shut-out of international financial markets.

[4]In a semi-open economy the private sector has no access to international financial markets; the central bank does not issue foreign debt but there are net capital outflows through the accumulation of international reserves. Notice that commodity storage is conducted by international investors at the world level, and so it does not depend on the degree of financial openness of the commodity-producing country.

[5]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

Figure 2: IRFs of GDP growth after an increase in the US monetary policy interest rate.



Note: The figure presents the impulse response functions of low and middle income countries' GDP to a 1% increase in the US real Fed Funds rate computed using the local projection method developed by Jordà (2005). GDP is in percent deviation from steady state. This baseline estimation controls for global demand (as a proxy for the trade channel) and the degree of financial openness (as a proxy for the financial channel). The shaded areas denote 68% confidence intervals.

Source: Authors' calculation, see Appendix A.

Supportive evidence of the commodity price channel shows that changes in the US interest rate do have a differentiated impact on the GDP growth of developing economies depending on their degree of commodity dependence. That is what we can see on Figure 2 which depicts the impact of a US interest rate change on the GDP growth of commodity-dependent versus non commodity-dependent low and middle-income countries, after controlling for global demand (as a proxy for the trade channel) and for the degree of financial openness (as a proxy for the financial channel). Commodity-dependent countries are clearly—additionally—negatively affected with respect to non commodity-dependent countries for which there seems to be no significant effect above the one of the traditional channels. The evidence of a differentiated impact on the two groups of countries remains valid regardless of the exchange rate regime (see Figure A.1 in Appendix A).

In this paper we provide a model able to rationalize the mechanisms behind these empirical findings. In line with the supportive evidence of Figure 2, our theoretical model shows that the spillover effects of a world interest rate shock on small open commodity producing countries are more pronounced when it is allowed for commodity storage and endogenous commodity prices. For instance, in response to a 300 basis points increase of the world interest rate, aggregate output of our representative small open economy is almost unchanged (slightly increasing) when the commodity price channel is ignored, while it declines by about 1% when commodity prices are endogenous. The higher magnitude of the spillovers comes from the endogenous reaction of commodity prices which amplifies the interest rate shock through external trade valuation effects and pro-cyclical commodity production adjustments. With a lower commodity price, the domestic commodity production declines affecting negatively domestic output. Additionally, both the fall in commodity prices and the contraction of commodity production lead to a sharp deterioration of the external current account which ultimately impacts negatively aggregate consumption and output. With exogenous commodity prices, as in standard models of small open economies, relative price movements are smaller, reducing the volatility of exchange rates and, consequently, of other variables like consumption. Our results thus show that the degree of commodity dependence matters and suggest that commodity exporting countries can be hurt by the international financial cycle even when they are disconnected from

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.

international financial markets. This result holds whether the exchange rate is fixed, perfectly flexible, or adjusted to keep constant the domestic price of the commodity as firstly proposed by Frankel (2003).

The paper is organized as follows. Section 2 presents the model, Section 3 the calibration, Section 4 the results and Section 5 a sensitivity analysis. Section 6 summarizes the main results 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, we assume that the country has a limited access to international capital markets as in "semi-open" economies à la Bacchetta et al. (2013, 2014): the private sector has no access to international financial markets; the public sector does not issue foreign debt anymore but the central bank can increase or reduce its stock of net foreign assets. 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 mainly builds on Agenor (1998). The novel feature of the model is the existence of commodity storage. This feature implies that the international price of the commodity is endogenously determined by a financial arbitrage condition. Therefore, world interest rates do affect—indirectly—the domestic economy through their impact on the commodity price.

2.1 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:

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

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 tradable good price. The optimal allocation of expenditures between non-tradable and tradable goods is given by:

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

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 $P_T = E_t P_T^*$ [6], and 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). Combining all previous results, we can write total consumption expenditure as $P_t C_t = P_{N,t} C_{N,t} + P_{T,t} C_{T,t}$.

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

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

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

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_t is household total real income, C_t is total real consumption, $\bar{T}$ are taxes expressed in real terms and assumed to be exogenous, and P_t 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 labor which is assumed to be perfectly mobile across the two sectors. The production function exhibits decreasing returns to labour:

$$Y_{i,t} = {L_{i,t}}^{\alpha_i} \tag{9}$$

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:

$$w_{i,t} = \alpha_i {L_{i,t}}^{(\alpha_i - 1)} \tag{10}$$

where $w_{i,t} = \frac{W_t}{P_{i,t}}$. $P_{X,t}$ is the commodity price in domestic currency, $P_{N,t}$ is the price of the home good and W_t 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.

The novelty—with respect to standard models of small open economies—is to recognize that commodity prices are not exogenously set but that they are related to international market dynamics through the actions of international investors.[7] Therefore, as in Unalmis et al. (2012) and Arseneau and Leduc (2013), we consider a competitive investor who compares the expected return that he can get by buying at time t one unit of the commodity with spot price $P^*_{X,t}$, store it until period $t+1$, and sell it at time $t+1$ at the expected price $P^*_{X,t+1}$, to the return that he gets by investing the amount P^*_X in a one-period risk-free foreign bond with the interest rate i^*_t.

The international commodity investor is risk-neutral, and chooses the optimal amount of storage, I_t, by maximizing expected profits:

$$\frac{\mathbb{E}_t\, P^*_{X,t+1}\, I_t}{1+i^*_t} - P^*_{X,t}\, I_t(1+\Phi(I_t)) \tag{11}$$

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

$\Phi(I_t) = \kappa + \frac{\Psi}{2} I_t$ is the physical and financial cost of storing a unit of the commodity during period t with $\Psi > 0$ 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)).

If storers are price takers, maximizing with respect to I_t yields the following arbitrage relationship:

$$\mathbb{E}_t\, P^*_{X,t+1} = (1+i^*_t) P^*_{X,t}(1+\kappa+\Psi\, I_t). \tag{12}$$

Equation (12) states that given $\mathbb{E}_t\, P^*_{X,t+1}$, Ψ, κ, 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:

$$I_t = I_{t-1} + Y^{all}_{X,t} - X^*_t, \tag{13}$$

where $Y^{all}_{X,t}$ denotes the global supply of the commodity and X^* the demand of the commodity from the rest of the world.

The global supply of the commodity is just the sum of the small economy production and the one of the rest of the world which depends positively on the price of the commodity:[8]

$$Y^{all}_{X,t} = Y_{X,t} + (\bar{Y^{row}_X} + \theta_y P^*_{X,t}). \tag{14}$$

Regarding the world demand for the commodity, it is simply modeled as a negative function of the price of the commodity:

$$X^*_t = \mu - \theta_x P^*_{X,t}. \tag{15}$$

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 to the domestic currency value of the stock of net foreign assets held by the central bank:

$$M_{t+1} = E_t R^*_{t+1} \tag{16}$$

[7] See Valiante and Egenhofer (2013) to know more about the functioning of commodity markets.

[8] 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.

where E_t is the nominal exchange rate and R_t^* 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:

$$D_{t+1} - D_t = \bar{G} - \bar{T} + r_t D_t + i_t^* \frac{E_t}{P_t} \bar{B}^* - i_t^* \frac{E_t}{P_t} R_t^* \tag{17}$$

where $\bar{G}$ denotes the steady state level of total real government consumption expenditures, $\bar{B}^*$ is the government constant level of foreign debt, expressed in foreign currency terms, and i^* is the nominal world interest rate.

2.5 Market clearing conditions

There are three market clearing conditions:

$$Y_{N,t} = C_{N,t} + \bar{G}_N \tag{18}$$

$$\bar{L} = L_{N,t} + L_{X,t} \tag{19}$$

$$\frac{M_{t+1}}{P_t} = \Big(\frac{E_t}{P_t}\Big) R_{t+1}^* \tag{20}$$

Equation (18) specifies the home market equilibrium, which determines P_N, the price of the home good, and where $\bar{G}_N$ denotes the quantity of the home good that is purchased by the government. Equation (19) specifies the labor market equilibrium that determines, as a result, W, the nominal wage rate. Finally, equation (20) represents the money market equilibrium that determines the domestic nominal interest rate, i.

2.6 Consolidated budget constraint

The budget constraint of the representative household (Equation 4), the government (Equation 17) and the central bank (Equation 16) can be consolidated into a single expression:

$$E_t\, R_{t+1}^* - E_{t-1}\, R_t^* = P_t\Big(Y_t - C_t - \bar{G}\Big) + i_t^*\, E_t\Big(R_t^* - \bar{B}^*\Big). \tag{21}$$

This expression is the balance-of-payments identity, expressed in foreign currency terms[9]. 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.

[9]Remind that, for convenience, P_T^* has been set equal to 1.

2.7 Shocks

We consider a world interest rate shock in line with the literature on small open economies:

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

where $\bar{i}^*$ is the steady state value of the world interest rate and $\epsilon_{i,t}$ is a normally distributed independent innovation with zero mean and standard deviation σ_i.

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 share of labor in the production, α_i, is the same in the non-tradable sector and in the tradable sector. It is set equal to 0.6 consistently with Agenor (2016). As standard in the New Open Economy Macroeconomics literature, households are assumed to consume more of the non-tradable good than the imported one. Then, following again Agenor (2016), δ is set equal to 0.55. 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% in line with the value of the Federal Funds rate over the period 1985–2014. Finally, we set the utility parameter for money holdings, ψ, to 0.04 in order to match the ratio of reserves to external debt at steady state. We set external debt to GDP to 0.55 and total reserves to total external debt, R^*/B^*, to 0.7. These ratios are computed on the average of low-income commodity dependent countries on the sample period 1995-2014[10].

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 $\bar{E}$ is equal to 1, P_T also equals 1. In steady state, this implies a value of 1 for $\bar{P}$ and $\bar{p_N}$, 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 $\bar{P_X} = 1$.

The commodity storage block is calibrated based on the papers of Knittel and Pindyck (2016) and Unalmis et al. (2012). Parameters of the world commodity demand and supply are set with US data. This is motivated by the fact that the US is one of the big players in all the commodity markets and that, thanks to data availability, there is a rich literature on commodities for the US. Therefore, according to the estimates of Knittel and Pindyck (2016), we set the world supply and demand commodity price elasticity 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[11], 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 -0.01, implying

[10] 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 A.1 in Appendix A. Additionally, domestic debt to gdp is set to 0.6 and public expenditures to 0.2.

[11] OECD/FAO (2019).

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	0.04	Weight of real money balances in utility
Extension		
κ	-0.01	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
$\bar{y_x^{row}}/\bar{Y_x}$	5	size of world commodity production wrt the SOE commodity production
Shocks		
σ_i	0.007	standard deviation of the world interest rate shock
ρ_i	0.8	persistence of the world interest rate shock

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 world 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.

4 Results

In this section, we explore the reaction of the economy to an exogenous increase in world interest rates. The economy considered is a net external borrower, which is a characteristic of many developing countries. Formally, we thus have that $B^* > R^*$ at the initial steady state. The case of a net creditor country is illustrated in Appendix D.

Two specifications of the model are used : i) a baseline where international commodity prices are exogenously fixed as in standard models of small open economies and ii) an extension where, due to competitive storage, they are endogenously determined. By comparing the results of the two specifications, we will see clearly in what respects the endogeneity of the price of the traded good brings new insights regarding the impact of world interest rates on small open developing countries. In this regard, the baseline specification can be viewed as a representation of small open developing economies that are not commodity-dependent. The price of their main exports is exogenously fixed in foreign currency and not affected by the commodity-price channel. Conversely, we view the extension specification as represen-

tative of small open developing countries that are commodity-dependent, thereby exporting goods whose price is sensitive to changes in world interest rates.

We conduct our analysis for 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 regime where the nominal exchange rate is adjusted as to maintain constant the domestic currency value of the commodity price.

4.1 Fixed exchange rate

Under the fixed exchange rate regime, $E_t = \bar{E} = 1$, the monetary authority behaves like a currency board, changing the money supply to sustain the accumulation/depletion of reserves needed to keep the exchange rate fixed.

Baseline

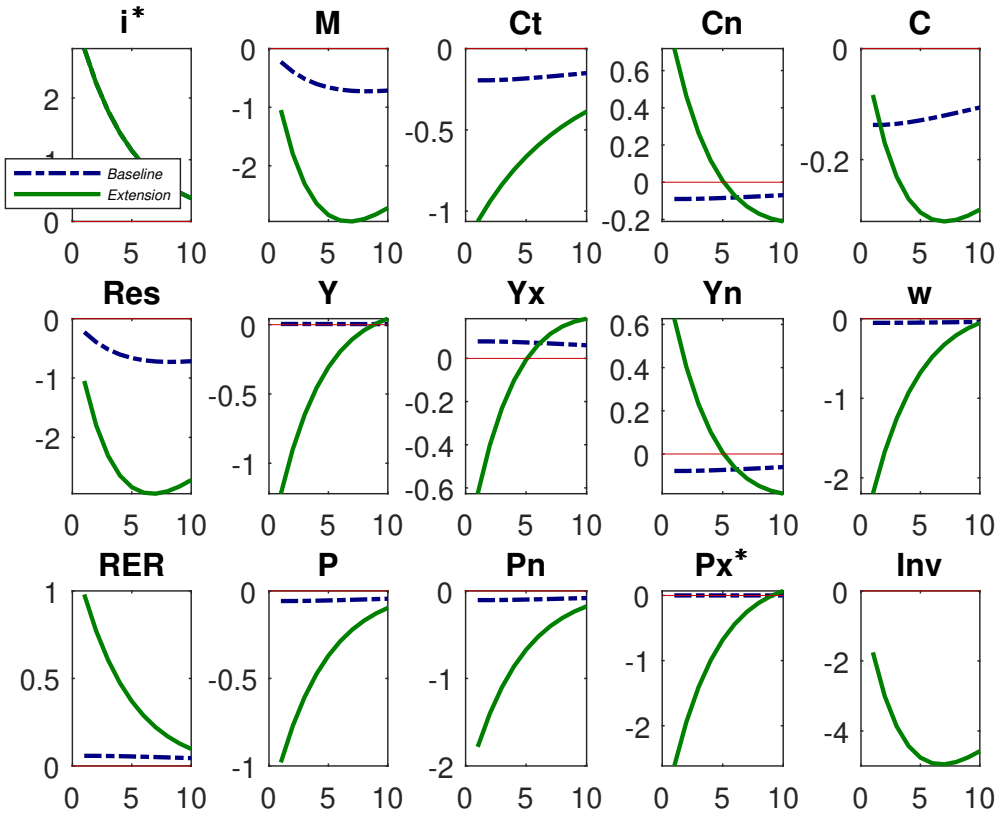
The reaction of the main variables of the economy to the increase of world interest rates is presented in Figure 3 (dotted lines). As the interest rate increase makes external debt more costly, the current account deteriorates and external reserves decline. Given that external reserves decrease, the 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 decline, which reinforces the initial deterioration of the current account.

Extension

Let us now turn to the extension with commodity storage (see Figure 3, solid lines). Given that commodities are now subject to international investor' arbitrage decisions, changes to the world 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. Labor 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 lead 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 in Figure 3, there are two main differences. First, commodity price effects amplify 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,

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



Notes. Dotted line: Baseline simulation. Solid 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.

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 shock. 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.

4.2 Flexible exchange rate

It is here assumed that the nominal exchange rate is perfectly flexible. As reserves are constant and the economy is shut out of international capital markets, the exchange rate adjusts so as to keep balanced the external current account.

Baseline

The response of the small open economy to the international interest rate shock when the exchange rate is flexible is given in Figure 4. The nominal exchange rate appreciates on impact in response to the increase in the world interest rate. This result differs strongly from what we usually obtain with standard models of small open economies, where the nominal exchange rate usually depreciates following a rise of world interest rates. The origin of this difference is that our small open economy has zero international

capital flows: in order to keep balanced the external current account, the appreciation of the nominal rate generates on impact positive valuation effects that offset the increase in the cost of servicing the external debt. 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 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. Labour 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 however declines, as well as aggregate output. While the nominal exchange rate appreciates, the real exchange rate depreciates, due to a fall in the domestic price level.

These results show that, when the exchange rate is flexible, the introduction of the commodity storage channel has again 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.

4.3 PEP: Pegging the Export Price

We now examine the reaction of the economy when the nominal exchange rate adjusts continuously such as to keep constant the domestic currency value of the commodity price. This targeting scheme 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 purpose of this targeting scheme 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' main exports.

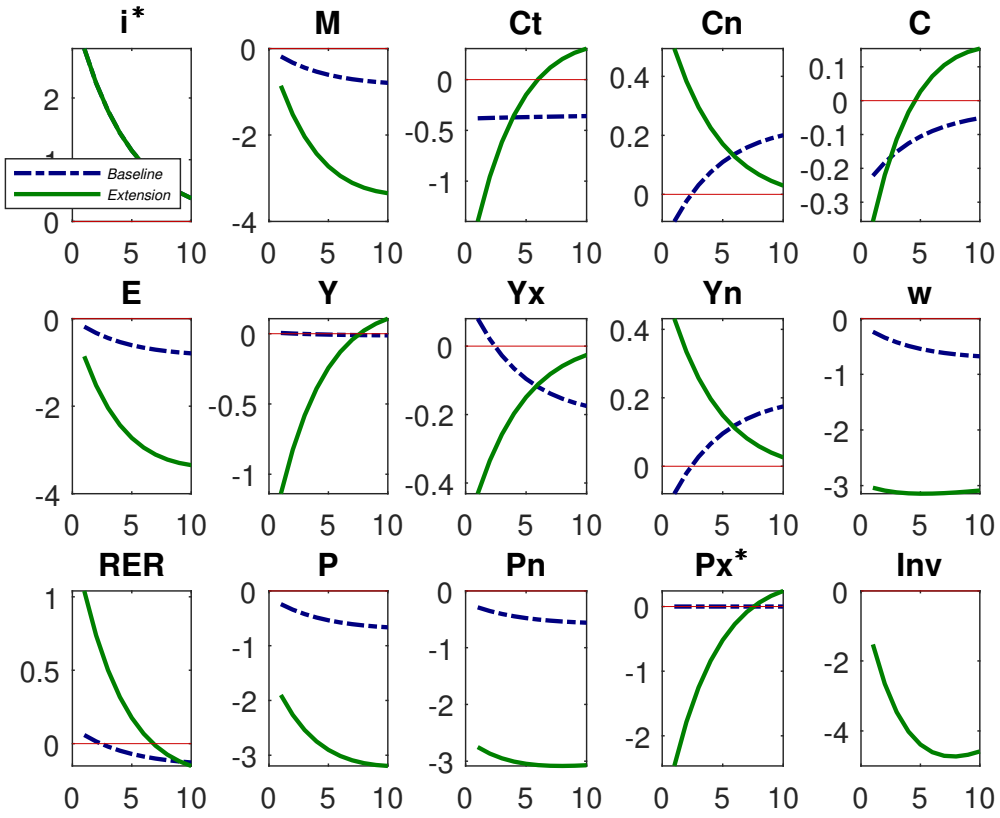
Formally, the Frankel (2003) targeting scheme is described as follows:

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

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

Figure 5 shows the reaction of the small open economy to the world interest rate shock under a PEP exchange rate 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), the response to the world interest rate shock is similar to the case of the fixed exchange rate regime. For convenience, the response of the economy is however shown in Figure 5, dotted lines. The reaction of the small open economy-commodity exporter when the world price of the commodity is endogenous is given by the solid lines in Figure 5. As the price of the commodity in foreign currency (Px_t^*) falls instantaneously in response

Figure 4: Flexible exchange rate IRFs: increase in the world interest rate

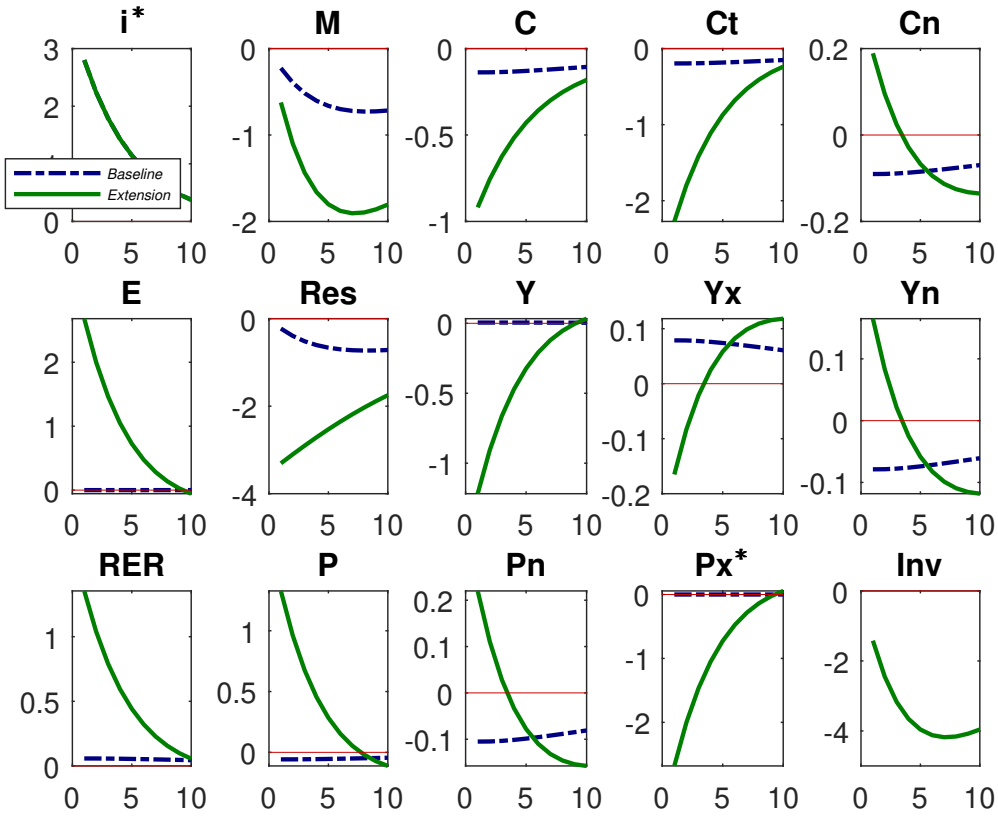


Notes. Dotted line: Baseline simulation. Solid line: Extension. The shock is a 1std increase in the world interest rate. The results which deviate from the steady state are expressed respectively in percentage points for rates, and in percentages for the remaining variables.

to the increase in the world interest rate, the nominal exchange rate depreciates instantaneously as to automatically stabilize the price of the commodity in local currency (Px_t). Due to the rise of the world interest rate and the depreciation of the nominal exchange rate, the cost of servicing the external debt increases strongly. The external current account then deteriorates, external reserves fall and so does money supply driving a decrease in aggregate demand and, therefore, aggregate consumption declines. 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 whereas the demand for the non-tradable good increases. The price of the non-tradable good then increases, which triggers a reallocation of production from the (tradable) commodity sector to the non-tradable sector and so, there is a rise of the production of non-tradables. Finally, despite the increase in the domestic price level, the sharp nominal exchange rate depreciation determines the depreciation of the real exchange rate.

These results indicate that, even under a PEP exchange rate regime regime, there is a reallocation of resources from the commodity exporting sector to the non-tradable sector (although of smaller magnitude, see Section 6). The reaction of the overall economy is also more pronounced with respect to the benchmark case. For instance, real GDP and real aggregate consumption contract more sharply. It also appears that commodity exporting countries experience a larger loss of external reserves, which implies a high risk of an exchange rate crisis. It must also be noticed—from the reaction of prices—that, despite the presumption of Frankel (2003), the PEP exchange rate regime does not provide a proper nominal anchor for commodity exporting countries.

Figure 5: Pegging the commodity price IRFs: increase in the world interest rate



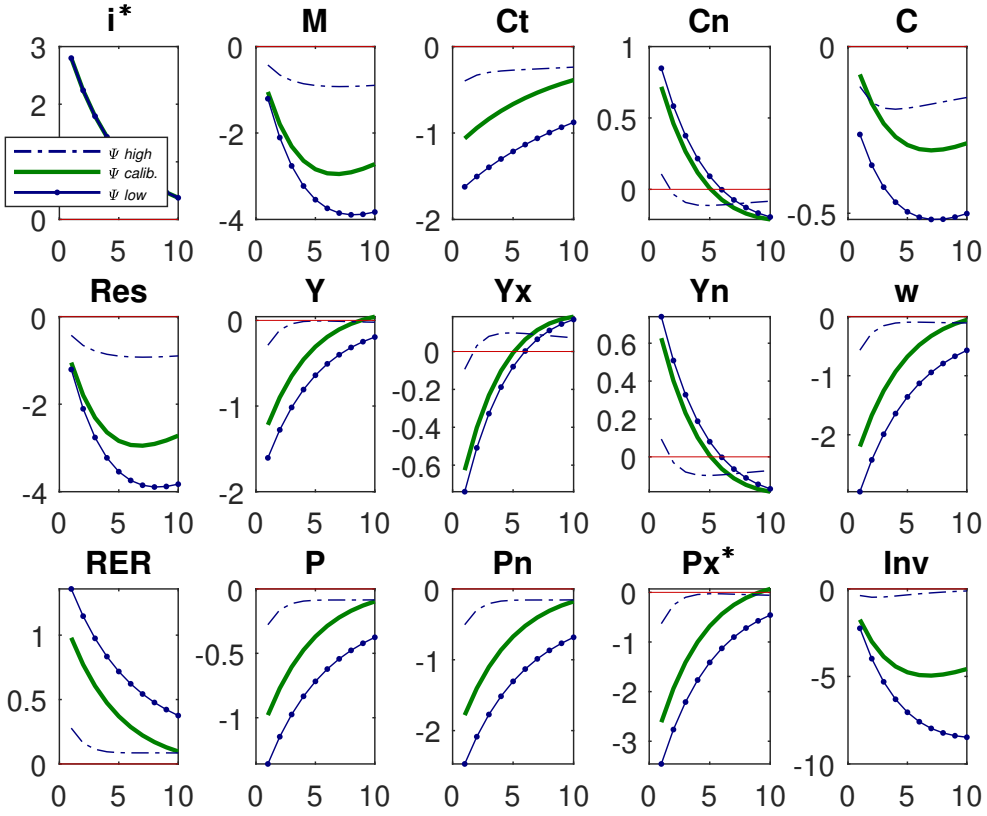
Notes. Dotted line: Baseline simulation. Solid line: Extension. The shock is a 1std increase in the world interest rate. The results which deviate from the steady state are expressed respectively in percentage points for rates, and in percentages for the remaining variables.

5 Sensitivity

In this section, we study the sensitivity of the results to a different calibration of the commodity block. The key parameters of the storage mechanism we focus on are: θ_x, θ_y and Ψ. The first two are the commodity demand and supply elasticities to the world commodity price. When performing a sensitivity analysis on these parameters using different values estimated in the literature, we find that the results are very robust.[12] The Ψ parameter governs the cost of storage. For reasons of space, we only report here the sensitivity results obtained for the fixed exchange rate regime. Similar conclusions are obtained with the other exchange rate regimes[13]. As we can see in Figure 6, the macroeconomic adjustment of the commodity exporting countries is qualitatively unchanged but is magnified when Ψ is low. The amplification effect is due to a more important reaction of the world commodity price: a low Ψ implies low storage costs, investors are therefore more inclined to store the commodity and, consequently, commodity prices are more sensitive to variations in the world interest rate. Conversely, when Ψ is high,investors are reluctant to hold inventories and do not enter the storage-market speculation strategy. As a consequence, the price of the commodity does not vary when world interest rates move and, so, the adjustment of the economy is similar to the baseline case.

[12] We show these sensitivity results in Appendix C.
[13] Results are available upon request from the authors.

Figure 6: Fixed exchange rate IRFs: increase in the world interest rate - sensitivity to Ψ -



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

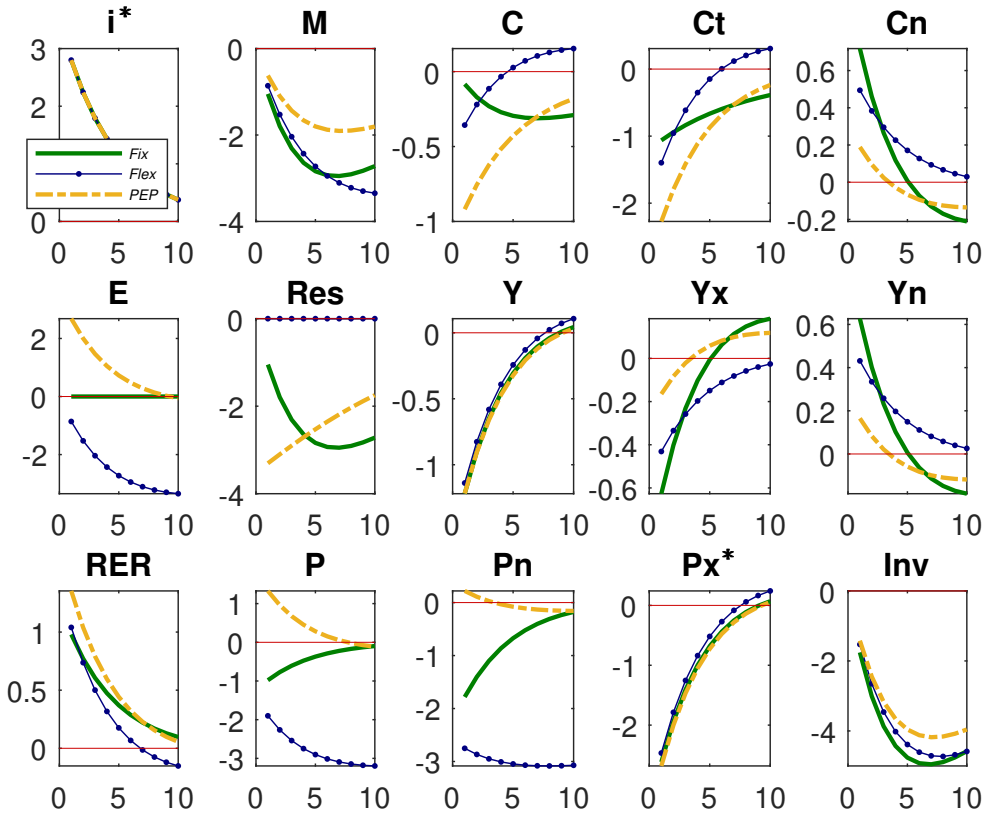
6 Summary results and policy implications

The main insight from our analysis is to show that small open developing countries that are specialized in commodity exports react differently to world interest rate shocks than small open developing countries that are not commodity-dependent. There are two main differences.

First, it appears that the world interest rate shock leads to stronger macroeconomic fluctuations in commodity-dependent countries. For these countries, higher interest rates raise the opportunity cost of holding inventories leading to a lower demand for inventories and commodities, and driving commodities' prices down. Given the endogeneity of commodity prices, commodity-dependent countries are hit simultaneously by an adverse international financial shock and an international commodity price decrease, while non commodity-dependent countries are only subject to the first shock. For instance, we have shown that when the exchange rate is fixed, there is a drop of external reserves in both commodity and non commodity-dependent countries but the drop is larger in the former. When the exchange rate is flexible, the nominal exchange rate adjustment—in response to the shock—is more pronounced for commodity-dependent countries than it is for non 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 aggregate output and aggregate consumption.

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

Figure 7: 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.

that there is reallocation of production from the non-tradable sector to the export 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 boosted when the exported good is not a commodity while it is contracting sharply when the exported good is a commodity. This divergence is clearly the consequence of the endogenous response of international commodity prices to the world interest rate shock. The contraction of the commodity sector happens even if the country operates a PEP exchange rate regime, although it is of a smaller magnitude.

Another important insight of our analysis is the finding that commodity-dependent countries are vulnerable to international financial shocks even if they are disconnected from international financial markets. Figure 7 compares the three exchange rate regimes when the commodity price channel is active. 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, countries face a large drop of external reserves. They are therefore more exposed to an exchange rate crisis, which is in line with the empirical evidence of Bodart and Carpantier (2020). So, for countries that are frequently and mainly hit by international financial shocks, a fixed exchange rate or a PEP exchange rate are not strongly sustainable. One can also notice that the PEP exchange rate regime helps preventing a strong contraction of the commodity sector when world interest rates increase, but this is achieved at the expense of a higher volatility of the rest of the economy. The response of aggregate consumption and aggregate output is reduced when the exchange rate is flexible but, conversely, the expenditure switching effects are large due to prices' adjustments.

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 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 through external trade valuation effects and pro-cyclical commodity production adjustments. 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 according to the degree of commodity dependence. 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 boosted when the traded good is not a commodity.

By showing the role of commodity prices in the international transmission of monetary shocks, our analysis offers a new perspective on the impact of world interest rate shock on small open developing countries. It suggests that the degree of commodity dependence is a key country characteristic that determines how strong is the transmission of the shock. In this respect, an interesting avenue for future research would be to study stabilization policies for these countries, making a distinction between commodity-dependent and non commodity-dependent economies.

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A Commodity dependence and Local Projections

A.1 Data

We use a panel of country-specific GDP data. The data are annual and cover the period 1962-2016 for 62 countries. Our sample only includes "Low and middle income" countries selected according to the 2019 World bank classification[14]. The list of countries is provided in Table A.1. Data sources are discussed in this section.

1. **GDP**. GDP data are retrieved from the World Bank's World Development Indicator (WDI) database. Data are in US$ at constant 2010 prices. GDP data are collected at the country level. Data on world GDP are also recovered. They will be used in our regressions to control for the world demand of goods produced by low and middle income countries.

2. **Commodity Dependence**.Table A.1 presents the degree of commodity dependence of the 62 countries used in this study. The dataset is taken from Bodart and Carpantier (2020). As in their work, commodity dependence is measured by the percentage ratio of total commodity exports (in value) in total exports of goods and services. Using this ratio, we follow the IMF (IMF, 2015) and classify a country as commodity-dependent if the share of its commodity exports in total exports is equal or higher than 35%.

3. **FFR**. The annual real interest rate is the effective Federal Funds Rate minus US inflation, which is itself measured as the percentage annual change of the consumer prices index.

4. **Exchange Rate Regime**. Exchange rate regimes are taken from the widely used classification provided by Ilzetzki et al. (2019) (IRR thereafter). The IRR classification is a de facto classification based on market determined exchange rates. It provides monthly and annual classifications over the period 1940-2016. Classifications by 6 and 15 categories are available. In our study, we classify the exchange rate regime in only two categories: fixed and not-fixed. We consider as fixed the exchange rate regime of a country that is classified as "No separate legal tender", "Pre announced peg or currency board arrangement", "Pre announced horizontal band that is narrower than or equal to +/-2%", "De facto peg" or "Pre announced crawling peg" in the Ilzetzki et al. (2019) 15 categories classification. It corresponds to the first category in the 6 categories IRR classification. The regimes vary across countries and over time. Table A.3 reports the number of years that each country has spent in every category.

5. **Financial Openness**. We use the Chinn-Ito index (KAOPEN) to control for the country's degree of capital account openness. KAOPEN is based on the IMF's Annual Report on Exchange Arrangements and Exchange Re-strictions (AREAER). Therefore, this index is a de jure measure of financial openness. In our sample, the values of KAOPEN range between about -1.9 and 2.3. These values are not of a cardinal nature, however, the higher KAOPEN the more financially open a country is. We classify the countries in 2 categories: closed and open. We follow Beine et al. (2012) and Bodart et al. (2015) by categorizing countries in the closed category if the value of the KAOPEN index is below -1.1. Table A.3 reports the number of years that each country has spent in every category.

[14] https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries

Table A.1: Commodity dependence and Export Values

Commodity-dependent countries							
Algeria	94	Chad	95	Honduras	56	Peru	59
Argentina	56	Colombia	57	Indonesia	48	Rwanda	44
Belize	41	Congo	86	Iran	81	Senegal	44
Benin	65	Côte d'Ivoire	68	Kenya	39	Sudan	80
Bolivia	75	Dem. Rep. Congo	52	Malawi	76	Togo	49
Brazil	45	Ecuador	78	Mauritania	90	Venezuela	82
Burkina Faso	51	Gabon	86	Nicaragua	54	Zambia	75
Burundi	51	Ghana	59	Niger	57	Zimbabwe	61
Cameroon	61	Guatemala	43	Nigeria	99		
Centr. African Rep.	60	Guyana	46	Paraguay	52		
Non-Commodity-dependent countries							
Bangladesh	6	El Salvador	29	Malaysia	24	South Africa	34
Botswana	14	Fiji	31	Mexico	20	Sri Lanka	21
China	10	Haiti	7	Nepal	13	Suriname	31
Costa Rica	30	India	19	Pakistan	16	Thailand	20
Dominican Rep.	16	Lesotho	7	Philippines	13	Tunisia	17
Egypt	24	Liberia	23	Sierra Leone	26	Turkey	12

Note: the numbers represent the measure of commodity dependence: the percentage ratio of total commodity exports (in value) in total exports of goods and services.

Source: Bodart and Carpantier (2020).

A.2 Local Projections

We study the impulse response functions of GDP in low and middle income countries to changes in the U.S. interest rates with the local projections method (LPM) developed by Jordà (2005) and further developped by Teulings and Zubanov (2014).

Formally, we estimate the following equation using data from 1962 to 2016:

$$\begin{aligned} y_{i,t+h} - y_{i,t-1} \quad = \quad & \alpha_i^h + \gamma_t^h + \beta_1^h \Delta r_t + \sum_{j=1}^{h-1} \beta_{2,j}^h \Delta r_{t+h-j} + \sum_{j=1}^{p} \beta_{3,j}^h \Delta r_{i,t-p} + \beta_4^h \Delta r_t Cdty_i + \\ & \sum_{j=1}^{h-1} \beta_{5,j}^h \Delta r_{t+h-j} Cdty_i + \sum_{j=1}^{p} \beta_{6,j}^h \Delta r_{i,t-p} Cdty_i + \sum_{j=1}^{p} \theta_{1,j}^h \Delta y_{i,t-p} + \\ & \sum_{j=0}^{p} \theta_{2,j}^h Z_{i,t-p} + \sum_{j=1}^{h-1} \theta_{3,j}^h Z_{i,t+h-j} + \lambda_1 \epsilon_{i,t+h-1} + \epsilon_{i,t+h} \end{aligned} \tag{A.1}$$

where h = 0,1,2...H is the forecast horizon (5 years) and p is the maximum number of lags for each variable. As in Teulings and Zubanov (2014), we initially set p equal to 4. As it turned out that lags 3 and 4 were generally not significant, we restricted the lag order to 2. $y_{i,t}$ is the log GDP of country i in year t, α_i^h is a country-specific fixed effect, γ_t^h is a time fixed-effect and $Cdty_i$ is a dummy variable which takes the value 1 when a country i is classified as commodity-dependent (see Table A.1). Δr_t measures the change in the US real interest rate, while $\Delta y_{i,t}$ measures the growth rate of GDP of country i. For each country i, we include a set of controls $Z_{i,t}$ which include the growth rate of world GDP and the

transformed KAOPEN variable. Finally, an additional control includes the residuals of the regression at the preceding forecast horizon ϵ_{t+h-1}. Adding this new variable enables us to control for possible not modeled explanatory variables.

From the above specification, the impact of Δr_t on Δy_{t+h} will differ between commodity-dependent and commodity non-dependent countries if β_4^h is significantly different than zero. Accordingly, β_1^h (resp. $\beta_1^h + \beta_4^h$) measures the average response of output across countries to a 1 percentage point increase in the US real interest rate for commodity non-dependent (dependent) countries. Table A.2 provides the estimates of β_4^h over a forecast horizon h of 5 years. It appears that an increase in the real Fed Funds rate by 1 percentage point reduces GDP growth rate after two years by an additional 0.5 percentage point for countries that are commodity-dependent. This implies, as shown by Figure 2 in the introduction, that following an increase in the US policy rate, GDP growth declines in commodity-dependent countries whereas it increases in non-commodity-dependent countries.

Table A.2: Local projection results

$\beta_{4,t+h}$	**Pooled OLS**		**Fixed Effects**	
h				
0	-.21	-.21	-.21	-.17
1	-.29**	-.28**	-.28**	-.20
2	-.47**	-.46**	-.46**	-.35*
3	-.49**	-.47**	-.46**	-.35*
4	-.41	-.37	-.36	-.19
5	-.45	-.41	-.37	-.08
KAOPEN	No	Yes	No	Yes
World GDP	Yes	Yes	Yes	Yes

Note: Estimates significant at 1%, 5% and 10% levels are marked ***, ** and *, respectively.

We also looked at what happens to the above results when we control for the exchange rate regime. We do so by estimating separately for commodity-dependent countries and commodity non-dependent countries the following equation:

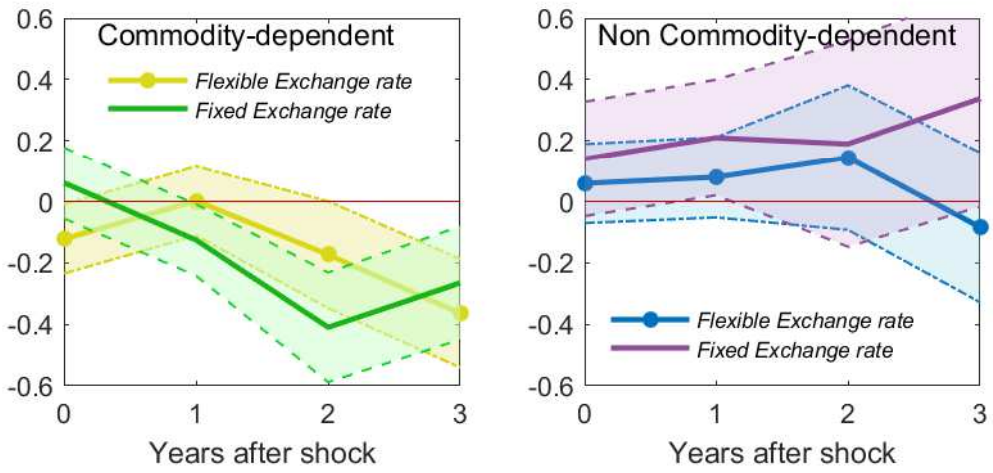
$$\begin{aligned} y_{i,t+h} - y_{i,t-1} \quad = \quad & \alpha_i^h + \gamma_t^h + \beta_1^h \Delta r_t + \sum_{j=1}^{h-1} \beta_{2,j}^h \Delta r_{t+h-j} + \sum_{j=1}^{p} \beta_{3,j}^h \Delta r_{i,t-p} + \beta_4^h \Delta r_t E_{i,t} + \\ & \sum_{j=1}^{h-1} \beta_{5,j}^h \Delta r_{t+h-j} E_{i,t} + \sum_{j=1}^{p} \beta_{6,j}^h \Delta r_{i,t-p} E_{i,t} + \sum_{j=1}^{p} \theta_{1,j}^h \Delta y_{i,t-p} + \\ & \sum_{j=0}^{p} \theta_{2,j}^h Z_{i,t-p} + \sum_{j=1}^{h-1} \theta_{3,j}^h Z_{i,t+h-j} + \lambda_1 \epsilon_{i,t+h-1} + \epsilon_{i,t+h} \end{aligned} \tag{A.2}$$

The regression equation is the same as above but we replaced the dummy variable about commodity dependence by a dummy variable $E_{i,t}$ that takes the value 1 when a country has a fixed exchange rate regime and 0 otherwise. As explained in the data section, the exchange rate regime classification follows Ilzetzki et al. (2019). The dummy is interacted with the variable of interest Δr_t.

As we can see in Figure A.1, controlling for the exchange rate regime does not wash out the previous evidence, the response of GDP growth to US monetary policy changes remaining stronger for commodity-dependent countries than for commodity non-dependent countries. It further appears that the fall in GDP is stronger for countries with a fixed exchange rate regime, what may be explained by the fact that fixed

exchange rate countries have less degree of freedom to respond to international financial shocks.

Figure A.1: IRFs of GDP growth after an increase in the US monetary policy interest rate.



Note: The figure presents the impulse response functions of low and middle income countries' GDP to a 1% increase in the US real Fed Funds rate computed using the local projection method developed by Jordà (2005). GDP is in percent deviation from steady state. The estimations control for global demand (as a proxy for the trade channel) and financial openness (as a proxy for the financial channel)—as in Figure 2 in Section 1— and further control for the exchange rate regime (proxy for the exchange rate channel). The shaded areas denote 68% confidence intervals.

Source: Authors' calculation.

Table A.3: Data summary

Country	**Exchange Rate Regime**			**Financial Openness**		
	Fixed	Not-fixed	Total	Closed	Open	Total
Algeria	7	48	55	47	0	47
Argentina	19	36	55	24	23	47
Bangladesh	18	37	55	39	2	41
Belize	55	0	55	21	11	32
Benin	55	0	55	21	17	38
Bolivia	4	51	55	3	44	47
Botswana	23	32	55	10	35	45
Brazil	0	55	55	34	13	47
Burkina Faso	55	0	55	21	8	29
Burundi	28	27	55	47	0	47
Cameroon	55	0	55	28	19	47
Centr. African Rep.	55	0	55	35	12	47
Chad	55	0	55	36	11	47
China	12	43	55	33	0	33
Colombia	0	55	55	34	13	47
Congo	55	0	55	39	8	47

(Continued)

Country	Exchange Rate Regime			Financial Openness		
	Fixed	Not-fixed	Total	Closed	Open	Total
Costa Rica	14	41	55	13	34	47
Côte d'Ivoire	55	0	55	28	19	47
Dem. Rep. Congo	2	53	55	38	5	43
Dominican Republic	3	52	55	32	15	47
Ecuador	23	32	55	4	43	47
Egypt	11	44	55	28	19	47
El Salvador	26	29	55	23	24	47
Fiji	18	37	55	25	17	42
Gabon	55	0	55	22	25	47
Ghana	15	40	55	45	2	47
Guatemala	28	27	55	8	39	47
Guyana	27	28	55	23	24	47
Haiti	28	27	55	0	40	40
Honduras	34	21	55	16	31	47
India	23	32	55	47	0	47
Indonesia	1	54	55	0	47	47
Iran	17	38	55	26	21	47
Kenya	30	25	55	26	21	47
Lesotho	55	0	55	21	24	45
Liberia	31	24	55	0	47	47
Malawi	20	35	55	46	1	47
Malaysia	26	29	55	4	43	47
Mauritania	17	38	55	45	2	47
Mexico	26	29	55	4	43	47
Nepal	22	33	55	46	1	47
Nicaragua	18	37	55	14	33	47
Niger	55	0	55	27	20	47
Nigeria	15	40	55	26	21	47
Pakistan	12	43	55	47	0	47
Paraguay	3	52	55	18	29	47
Peru	9	46	55	14	33	47
Philippines	12	43	55	22	25	47
Rwanda	18	37	55	38	9	47
Senegal	55	0	55	21	26	47
Sierra Leone	17	38	55	39	8	47
South Africa	16	39	55	38	9	47
Sri Lanka	12	43	55	24	23	47
Sudan	15	40	55	33	13	46
Suriname	29	26	55	34	6	40
Thailand	34	21	55	9	38	47
Togo	55	0	55	39	8	47
Tunisia	15	40	55	43	4	47
Turkey	1	54	55	31	16	47
Venezuela	35	20	55	17	30	47
Zambia	15	40	55	26	21	47
Zimbabwe	26	29	55	28	5	33
Total	1,840	1,570	3,410	1,630	1,180	2,810

Note: Currency regime is a de facto classification into two categories: Fixed and Not-Fixed. Since a country currency regime can change over time, figures correspond to the number of years in each regime.Financial openness, based on Kaopen index, is classified into two categories: Closed and Open. Since financial openness can change over time, figures correspond to the number of years in each regime.

B Model

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

$$\frac{w_t}{pn_t} = \alpha_N \, {Ln_t}^{\alpha_N - 1} \tag{A.3}$$

$$\frac{w_t}{px_t} = \alpha_X \, {Lx_t}^{\alpha_X - 1} \tag{A.4}$$

$$Yn_t = {Ln_t}^{\alpha_N} \tag{A.5}$$

$$Y_{X,t} = {Lx_t}^{\alpha_X} \tag{A.6}$$

$$Y_t = Yn_t \, \frac{pn_t}{P_t} + Y_{X,t} \, \frac{px_t}{P_t} \tag{A.7}$$

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

$$Ct_t = (1 - \delta) \; {pn_t}^{\delta} \, {E_t}^{(-\delta)} \, C_t \tag{A.9}$$

$$P_t = {E_t}^{1-\delta} \, {pn_t}^{\delta} \tag{A.10}$$

$${C_t}^{(-\sigma)} = \psi \left(\frac{M_t}{P_t} \right)^{(-\sigma)} + \frac{\beta \, {C_{t+1}}^{(-\sigma)}}{\frac{P_{t+1}}{P_t}} \tag{A.11}$$

$${C_t}^{(-\sigma)} = \beta \, {C_{t+1}}^{(-\sigma)} \; (1 + r_{t+1}) \tag{A.12}$$

$$1 + r_t = \frac{(1 + i_t) \; P_{t-1}}{P_t} \tag{A.13}$$

$$\frac{M_t}{P_t} = \frac{E_t \, Res_t}{P_t} \tag{A.14}$$

$$Yn_t = Cn_t + \bar{G}n \tag{A.15}$$

$$\bar{L} = Ln_t + Lx_t \tag{A.16}$$

$$C_t + \frac{M_t}{P_t} + D_t = Y_t + \frac{M_{t-1}}{P_t} + (1 + r_t) \; D_{t-1} - \bar{T} \tag{A.17}$$

$$D_t - D_{t-1} = r_t\, D_{t-1} + \bar{G} - \bar{T} + \frac{E_t\, i_t^*}{P_t}\, \left(\bar{B} - Res_{t-1}\right) \tag{A.18}$$

$$px_{t+1}^* = (1 + i_t^*)\, px_t^*\, (1 + cyield + \gamma\, I_t) \tag{A.19}$$

$$cost_t = px_t^*\, (cyield + \gamma\, I_t) \tag{A.20}$$

$$I_t = I_{t-1} + Yall_t - X_t^* \tag{A.21}$$

$$Y_{x,t}^{all} = Y_{X,t} + Y_X^{\bar{r}ow} + \theta_y\, px_t^* \tag{A.22}$$

$$X_t^* = \mu - \theta_x\, px_t^* \tag{A.23}$$

$$i_t^* = \rho_i\, i_{t-1}^* + (1 - \rho_i)\, \bar{i}^* + \epsilon_{i,t} \tag{A.24}$$

$$RER_t = \frac{E_t}{P_t} \tag{A.25}$$

$$px_t = E_t\, px_t^* \tag{A.26}$$

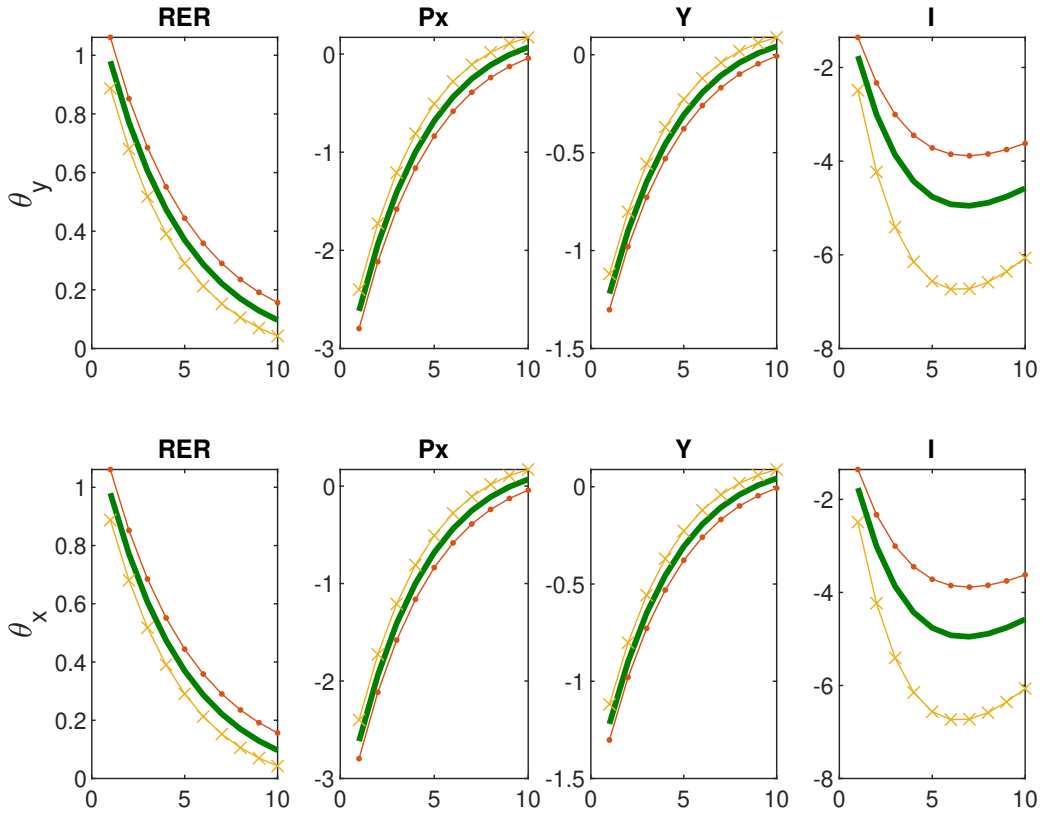
The exchange rate can be fixed $E_t = 1$, flexible (with $Res_t = \bar{Res}$) or it can follow the policy:

$$E_t = \frac{1}{px_t^*} \tag{A.27}$$

C Sensitivity

In this section, we explore the robustness of our results to different values of the world demand and supply elasticities with respect to commodity prices (θ_x, θ_y). The sensitivity analysis is performed using values in the following range: $0.05 < \theta < 0.51$. Results for the highest ($\theta = 0.51$) and lowest ($\theta = 0.05$) values are presented. To save space, results are presented for only a subset of the variables and for the fixed exchange rate regime. As we can see in figure C.1, the higher is θ, the stronger is the reaction of commodity prices and, therefore, the amplification to the rest of the economy. However, the quantitative impact of changing these parameters is small and not determinant for the behavior of the model.

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



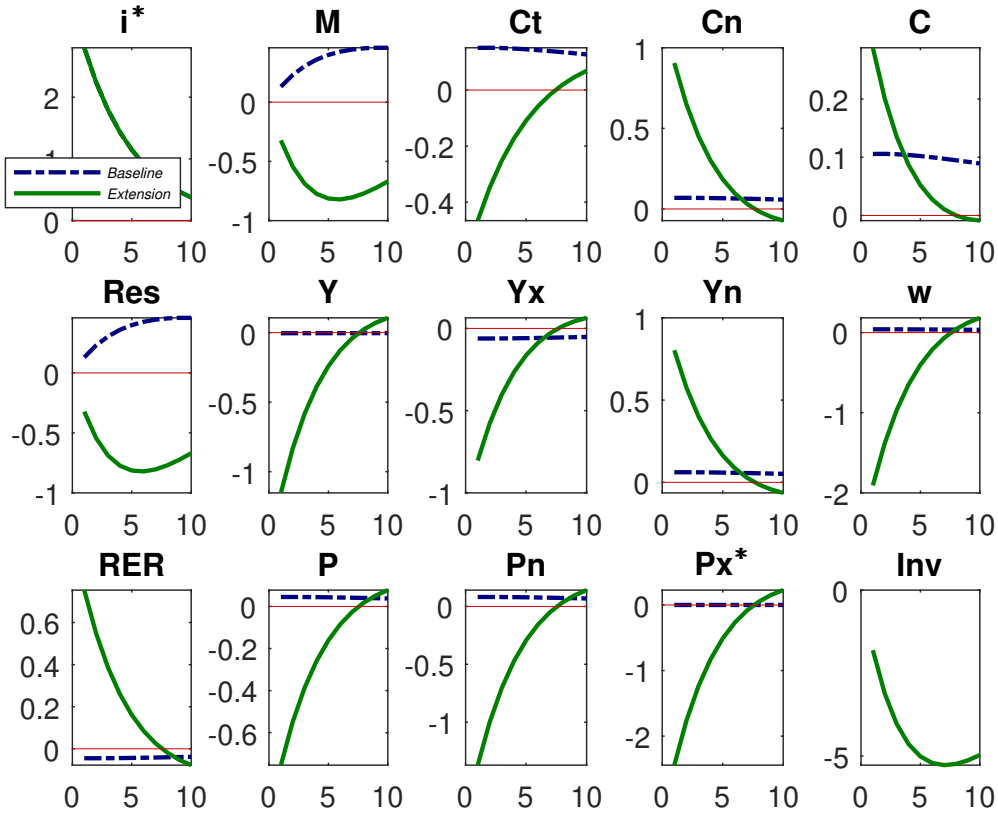
Notes. Solid line: Extension model simulation. Dotted line: Extension model with high θ. "x" line: Extension model with low θ. The upper panel presents the sensitivity to the supply elasticity, θ_y; the bottom panel to the demand elasticity, θ_x. The shock is a 1std increase in the world interest rate. The results which deviate from the steady state are expressed respectively in percentage points for rates, and in percentages for the remaining variables.

D Creditor case

In this appendix, we illustrate the reaction of the economy to an increase of world interest rates when the country is a net creditor. The illustration is provided for an economy with a fixed exchange rate. The increase in the world interest rate brings to an improvement in the external financial position. There is then an increase in external reserves, that drives an increase in the domestic money supply and therefore in real aggregate consumption. In the baseline model, the commodity price does not change. As the demand for both tradable and non-tradable goods increases, the price of the non-tradable good rises with respect to the price of the commodity and there is a production switch in favor of the non-tradable sector. In the extension, the rise in the world interest rate determines a fall in commodity prices, which amplifies the switch of production in favor of the non-tradable sector. Because of the stronger increase in the production of the non-tradable good, the price of the non-tradable good now decreases. This stimulates the demand for the non-tradable good, while the demand for the imported good now declines. The fall in the production and the price of the commodity has a negative effect on the external current account, which overcomes the positive effect of the interest rate increase. Consequently, external reserves now decline.

With respect to the debtor case, the response of most variables is qualitatively similar, with the notable exception of real aggregate consumption. It also appears that the reaction of external reserves, real aggregate output, the real exchange rate and prices is dampened. Conversely, the production switching effect and the increase in the demand for the non-tradable good are stronger.

Figure D.1: Fixed exchange rate IRFs: increase in the world interest rate



Notes. Dotted line: Baseline simulation. Solid 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.

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