Optimal monetary policy and exchange rate regimes in commodity-exposed economies *

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Abstract

Is the inflation targeting framework suitable for an environment with commodity price swings? Are there circumstances in which a fixed exchange rate could be beneficial? We study these perennial questions from the perspective of economies that have different exposures to commodity trade. We develop a flexible but tractable model for an economy that imports and/or exports commodities; moreover, in line with empirical evidence, we allow international borrowing conditions to vary endogenously with the commodity cycle, which gives rise to additional costs and benefits of active exchange rate management. By varying the economy's commodity exposure along these dimensions, we analyze the implied volatility of inflation and activity under different policy rules and derive the optimal monetary policy. We find that the desirability of different policy configurations critically depends on the economy's specific commodity exposure. Nonetheless, some form of inflation targeting tends to perform well in a relatively wide range of macroeconomic environments.

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1 Introduction

The recent surge and reversion in global energy prices has revived the question of how monetary policy should be conducted in the face of drastic commodity price swings. The prospect of more frequent shocks caused by geopolitical or climate-related events has also raised questions about the appropriate monetary policy and exchange rate framework for commodity-exposed economies across the globe.[1]

Building on the new open macroeconomics tradition launched by Obstfeld and Rogoff (1995), a number of studies have found that inflation targeting (whether domestic or CPI inflation targeting), supported by a freely floating exchange rate, is the optimal policy in a New Keynesian setting subject to both demand and productivity shocks (Svensson, 2000; Gali and Monacelli, 2005; Benigno and Benigno, 2006).[2] However, these findings have also come under scrutiny, as they are in stark contrast with the observation that many countries, especially emerging and developing economies, exhibit a 'fear of floating' (Calvo and Reinhart, 2002; Bianchi and Coulibaly, 2023).

This paper revisits these findings by studying how monetary policy should be conducted in commodity-exposed economies. We generalize the models presented in Drechsel and Tenreyro (2018) and Drechsel, McLeay, and Tenreyro (2019) along various dimensions, while retaining the simplicity of a New Keynesian open economy framework à la Gali and Monacelli (2005). The model is tractable, but flexible enough to be configured to represent different types of commodity-exposed economies: net commodity importers and exporters, as well as emerging and advanced economies facing different constraints in global financial markets, with risk premia on external debt potentially depending on swings in international commodity prices. The applicability of our framework to a range of economies is a key contribution to the existing macroeconomic literature on commodities, which has typically focused on either emerging economies that export commodities, or advanced economies that import commodities.[3]

[1] For evidence on the quantitative importance of commodity shocks, see, e.g., Schmitt-Grohe and Uribe (2017), Giovannini et al. (2019), Drechsel and Tenreyro (2018), and references therein.

[2] See also Kollmann (2001), De Paoli (2009), and a comprehensive survey by Corsetti et al. (2010).

[3] A review of that literature is provided in Drechsel, McLeay, and Tenreyro (2019). Hevia and Nicolini (2013) study a model with two types of commodities, one produced by the home economy, the other one imported; a key difference is that they do not consider the connection between risk premia and commodity prices, which is how we distinguish advanced and emerging/developing economies; moreover, their analysis assumes perfect international risk sharing, an assumption that

Obstfeld (2020) summarizes and critiques several 'newer objections' to flexible exchange rates. Those objections relate to the implications of (i) the global financial cycle; (ii) global value chains; (iii) dominant currency pricing; and (iv) the zero lower bound on nominal interest rates. Our model incorporates elements that capture the first three of these elements. We thus allow for a rich set of potential benefits of a fixed-exchange rate regime or managed float in our model.

Specifically, the literature on the global financial cycle (Rey, 2013) provides evidence of a close connection between US monetary policy and financial conditions, particularly in emerging markets. These effects are potentially difficult for floating exchange rates to offset. In our model, we capture these channels in a tractable way, by using an imperfect risk sharing setup with a quantitatively meaningful endogenous risk premium on emerging markets' foreign currency debt. The quantitative sensitivity of this risk premium is one key difference between advanced and emerging economies in our framework.

We also closely link emerging market financial conditions to the commodity cycle, consistent with the findings of Miranda-Agrippino and Rey (2020).[4] In line with empirical evidence (Drechsel and Tenreyro, 2018), we postulate that the risk premium faced by developing or emerging commodity exporters is negatively related to the prices of those commodities. For commodity or energy importers, instead, we postulate a positive relationship.

Imported commodities in our model are used in the production process and their prices are exogenous from the point of view of the economy we study, as they are determined in global markets. These can also be interpreted as imported non-commodity intermediates, allowing our model to speak, at least to a simplified degree, to the relevance of global value chains for monetary policy.

Exports of commodities are also priced in global markets but are subject to distinct price developments. This assumption captures that countries might import and export different types of commodities with different prices. Meanwhile, exports are priced in dollars, as in dominant currency pricing models formulated by Gopinath et al. (2020). However, differently from the dominant-currency pricing models, exports are also priced flexibly and in a competitive market, leading to the

we relax in our framework. See also Guerrieri et al. (2024) and Auclert et al. (2024) for more recent contributions on the impact of energy prices in commodity-importing countries, and Mendoza (1995) for a rich business cycle model with terms of trade shocks.

[4] Juvenal and Petrella (2024) also document a connection between the global financial cycle and commodity price swings.

standard allocative effects of flexible exchange rates on exports, in line with the arguments set out in McLeay and Tenreyro (2024).

We use our model to compare the performance of different monetary policy and exchange rate frameworks in response to commodity price shocks. Specifically, after setting out the model, we characterize the behavior of different types of economies when the policymaker seeks to implement a fixed exchange rate. We compare the volatility and performance of the economy under different inflation-targeting Taylor rules, and to the benchmark of the social planner's optimal policy.

We carry out our model experiments in a set of alternative calibrations which allow us to differentiate between: advanced economies that are commodity exporters, such as Australia, Norway, Canada; emerging and developing economies that are commodity exporters, such as Argentina, Chile, and Ghana; advanced economies that are commodity importers, such as Germany, Italy, and Japan; as well as emerging and developing economies that are commodity importers, such as India, Vietnam, Turkey, Eastern European countries.

We find that the desirability of alternative policy configurations critically depends on the economy's specific commodity exposure. Nonetheless, some form of inflation targeting is desirable over alternative policies in response to both commodity import and export price shocks, and for different model configurations. In some cases, a strong monetary policy response is of limited benefit overall or faces significant trade-offs. Depending on policymakers' preferences and comparing across the class of simple policy rules, there are some circumstances and types of external shocks where more active exchange rate management could be beneficial.

More specifically, our results suggest that for advanced, emerging or developing economy commodity *exporters*, facing commodity price shocks, exchange rate pegs create enormous volatility in inflation and output. A fall in commodity prices necessitates a domestic currency depreciation, and an exchange rate peg would sacrifice efficient internal adjustment for the sake of exchange rate stability. For emerging or developing economies, this volatility is amplified by an endogenous tightening of financial conditions in response to lower export prices, which leads to further pressure to loosen and depreciate.

For advanced economies facing a shock to the *import* price of commodities, which we also describe as energy in the context of recent geopolitical developments, there is far smaller differentiation between the various policies. The optimal response involves little change in employment or value added, with higher energy prices leading to lower energy import volumes, and lower consumption of both energy and other goods, to the extent that these use energy in production. The exchange rate peg implements a looser monetary stance, limiting some of this efficient consumption volatility, as well as the exchange-rate related volatility in import prices. It does so at the cost of greater volatility in the output gap and domestic inflation, so that on net it is neither strongly desirable nor strongly detrimental relative to alternative policies.

When emerging economies face commodity (or energy) import price shocks, there are more distinct advantages to the exchange rate peg. A rise in the risk premium in response to an increase in the price of the imported commodity leads to a more depreciated currency under inflation targeting rules, which the exchange rate peg prevents. By doing so, it can limit the volatility in both domestic and CPI inflation, relative to Taylor rules targeting these variables, and get closer to the optimal policy, which involves a small appreciation. Thus, across the range of configurations we study, the benefits of pegging appear to be most pronounced for emerging economy commodity importers, a case that has not received much focus by the existing literature, and a result we think deserves further attention in future research.

Finally, given the relevance of the risk premium for our results, we explore its role in more detail. Recent work (Itskhoki and Mukhin, 2021; Fukui, Nakamura, and Steinsson, 2023) has revived the importance more broadly of financial shocks in explaining exchange rate dynamics, as highlighted in early work by Kollmann (2001). Unsurprisingly, we find that for an emerging economy facing a pure risk premium shock, exchange rate pegs do relatively well at stabilizing CPI inflation, since the volatility comes largely via the exchange rate. There is a trade-off, however, as in our framework, this is at the expense of greater volatility in the real economy. Overall, our results are consistent with active exchange rate management being particularly costly in response to fundamentals-driven movements, but with some countervailing benefits for volatility driven exclusively by financial channels (see also Kalemli-Özcan (2019) for further discussions in this direction).

2 Model

This section presents our model for studying monetary policy and exchange rate dynamics following commodity import or export price fluctuations, with the risk premium on external borrowing being sensitive to commodity price developments.

2.1 Households

Households maximize expected lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \tag{1}$$

by choosing a sequence of consumption, labor supply and asset positions $\{C_t, N_t, D_{t+1}, B_{t+1}\}_{t=0}^{\infty}$, subject to the sequence of budget constraints

$$P_t C_t + Q_{t,t+1} D_{t+1} + Q^*_{t,t+1} \mathcal{E}_t B_{t+1} = W_t N_t + D_t + \mathcal{E}_t B_t \Phi(B_t, P^*_{\tilde{c},t-1}, P^*_{c,t-1}) + \Psi_t, \tag{2}$$

where $Q_{t,t+1}$ denotes the price of a domestic security, D_{t+1}; $Q^*_{t,t+1}$ is the price of an internationally traded bond, B_{t+1}; W_t is the wage rate and Ψ_t is a rebate of profits. The parameters β, σ and φ capture the discount factor, the inverse intertemporal elasticity of substitution, and the inverse Frisch elasticity.

While households have access to a complete set of *domestic* state-contingent securities, there is imperfect international risk sharing, with access only to an international bond priced in foreign currency. This bond is subject to a risk premium $\Phi(B_t, P^*_{\tilde{c},t-1}, P^*_{c,t-1})$, over the risk-free global interest rate, which depends on the level of external debt, as in Schmitt-Grohe and Uribe (2003), and potentially also on global commodity prices $P^*_{\tilde{c},t}$ and $P^*_{c,t}$. P^*_c is the price of exported commodities, which may differ from that of imported commodities, $P^*_{\tilde{c}}$. These global commodity prices will be defined in more detail below. The timing convention is such that there is uncertainty on the next period risk premium. The risk premium is normalized to one in steady state and households do not internalize that the level of bond holdings affects it. The risk premium increases in the price of the imported commodity and decreases in the price of the exported commodity and the level of bond holdings.

Total consumption is a CES aggregate of domestic and foreign goods,

$$C_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}} C_{h,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{f,t}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}. \tag{3}$$

$C_{h,t}$ is a bundle of consumption goods produced in the domestic economy ('home'), given by

$$C_{h,t} \equiv \left(\int_0^1 C_{h,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right)^{\frac{\epsilon}{\epsilon-1}}, \tag{4}$$

where ϵ is the elasticity of substitution. The price index for home goods is given by $P_{h,t} \equiv \left(\int_0^1 P_{h,t}(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}$.

$C_{f,t}$ is a bundle of goods produced abroad ('foreign'), which can be split into commodity and non-commodity goods:

$$C_{f,t} \equiv \left[(1-\alpha_{\tilde{c}})^{\frac{1}{\vartheta}} C_{nc,t}^{\frac{\vartheta-1}{\vartheta}} + \alpha_{\tilde{c}}^{\frac{1}{\vartheta}} C_{\tilde{c},t}^{\frac{\vartheta-1}{\vartheta}}\right]^{\frac{\vartheta}{\vartheta-1}}, \tag{5}$$

where $C_{\tilde{c},t}$ and $C_{nc,t}$ denote respectively consumption of commodity and non-commodity foreign goods, and ϑ is the elasticity of substitution.

The term α captures a preference weight on $C_{f,t}$ and $1-\alpha$ is the 'home bias' of the economy; $\alpha_{\tilde{c}}$ is the preference weight on commodities relative to non-commodity foreign goods. An analogous set of preferences apply to the foreign economy, with C_t^* representing total foreign consumption, $C_{h,t}^*$ foreign consumption of the home good, and $(1-\alpha^*)$ home bias, the preference weight on foreign goods.

We study Cole-Obstfeld preferences where $\sigma = \eta = \vartheta = 1$.[5] This gives log utility in consumption,

$$C_t \equiv \frac{C_{h,t}^{1-\alpha} C_{f,t}^{\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}, \tag{6}$$

and

$$C_{f,t} \equiv \frac{C_{nc,t}^{1-\alpha_{\tilde{c}}} C_{\tilde{c},t}^{\alpha_{\tilde{c}}}}{\alpha_{\tilde{c}}^{\alpha_{\tilde{c}}}(1-\alpha_{\tilde{c}})^{1-\alpha_{\tilde{c}}}}, \tag{7}$$

so that $P_{f,t} \equiv P_{nc,t}^{1-\alpha_{\tilde{c}}} P_{\tilde{c},t}^{\alpha_{\tilde{c}}}$, with the home economy CPI given by

[5] Both in the home country and the rest of the world, so $\sigma^* = \eta^* = \vartheta^* = 1$.

$$P_t \equiv P_{h,t}^{1-\alpha} P_{nc,t}^{\alpha(1-\alpha_{\tilde{c}})} P_{\tilde{c},t}^{\alpha\alpha_{\tilde{c}}}. \tag{8}$$

We denote by $\mathcal{T}_t$ the price of imports in terms of the price of domestic goods:

$$\mathcal{T}_t \equiv \frac{P_{f,t}}{P_{h,t}}, \tag{9}$$

which gives the relations to relative prices $\mathcal{T}_t^{-\alpha} = P_{h,t}/P_t$ and $\mathcal{T}_t^{1-\alpha} = P_{f,t}/P_t$. We let asterisks indicate prices and quantities abroad and define $\mathcal{E}_t$ as the nominal exchange rate.

The demand functions for the home and foreign good bundles can be derived from the usual expenditure minimization problems as

$$C_{h,t} = (1-\alpha)\left(\frac{P_t}{P_{h,t}}\right) C_t = (1-\alpha)\mathcal{T}_t^{\alpha} C_t \tag{10}$$

$$C_{f,t} = \alpha\left(\frac{P_t}{P_{f,t}}\right) C_t = \alpha\mathcal{T}_t^{\alpha-1} C_t, \tag{11}$$

where the second equalities use the relation between $\mathcal{T}_t$ and relative prices derived above. Demand for foreign goods can be split into the two subcategories as:

$$C_{nc,t} = (1-\alpha_{\tilde{c}})\left(\frac{P_{f,t}}{P_{nc,t}}\right) C_{f,t} \tag{12}$$

$$C_{\tilde{c},t} = \alpha_{\tilde{c}}\left(\frac{P_{f,t}}{P_{\tilde{c},t}}\right) C_{f,t}, \tag{13}$$

Finally, the demand for an individual home good is given by

$$C_{h,t}(i) = \left(\frac{P_{h,t}(i)}{P_{h,t}}\right)^{-\epsilon} C_{h,t}. \tag{14}$$

The law of one price requires that $P_{\tilde{c},t} = \mathcal{E}_t P^*_{\tilde{c},t}$, $P_{nc,t} = \mathcal{E}_t P^*_{nc,t}$ and $P_{h,t} = \mathcal{E}_t P^*_{h,t}$, and the same at the variety level. For our small open economy, we take the limit where $\alpha^* \to 0$ (though $\alpha^* C^*_t > 0$). We also assume that the foreign price basket includes only the non-commodity good ($\alpha^*_{\tilde{c}} = 0$), following Catão and Chang (2015). The foreign price level is therefore $P^*_t = P^*_{nc,t}$, and the real exchange rate is given by

$$S_t \equiv \frac{\mathcal{E}_t P^*_t}{P_t} = \frac{\mathcal{E}_t P^*_{nc,t}}{P_t} = \mathcal{T}_t^{1-\alpha}\left(\frac{P^*_{nc,t}}{P^*_{\tilde{c},t}}\right)^{\alpha_{\tilde{c}}}. \tag{15}$$

An analogous set of conditions can then be derived for foreign consumers, including foreign demand for the home good, given by:

$$C^*_{h,t} = \alpha^* \mathcal{T}_t \left(\frac{P^*_{nc,t}}{P^*_{\tilde{c},t}} \right)^{\alpha_{\tilde{c}}} C^*_t \ ; \tag{16}$$

for tractability (and using a symmetric set of preferences) we will assume that different varieties of the home good are demanded according to the same aggregator as for home households, so that

$$C^*_{h,t}(i) = \left(\frac{P^*_{h,t}(i)}{P^*_{h,t}} \right)^{-\epsilon} C^*_{h,t} = \left(\frac{P_{h,t}(i)}{P_{h,t}} \right)^{-\epsilon} C^*_{h,t} \ . \tag{17}$$

The household's optimality condition for labor gives the labor supply relation

$$N_t^{\varphi} C_t = \frac{W_t}{P_t}. \tag{18}$$

The first order condition for D_{t+1} gives the Euler equation

$$Q_{t,t+1} = \mathbb{E}_t \left[\beta \frac{1}{\Pi_{t+1}} \frac{C_t}{C_{t+1}} \right] \tag{19}$$

where $\Pi_{t+1} \equiv \frac{P_{t+1}}{P_t}$ denotes gross CPI inflation. This can be combined with the first order condition for B_{t+1} to give the uncovered interest parity (UIP) condition:

$$\frac{1}{Q_{t,t+1}} \mathbb{E}_t \left[\frac{1}{\Pi_{t+1}} \frac{C_t}{C_{t+1}} \right] = \frac{\Phi\left(B_{t+1}, P^*_{\tilde{c},t}, P^*_{c,t}\right)}{Q^*_{t,t+1}} \mathbb{E}_t \left[\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \frac{1}{\Pi_{t+1}} \frac{C_t}{C_{t+1}} \right] \ . \tag{20}$$

2.2 Domestic good sector

Firms produce with labor $N_t(i)$, and imported commodities $X_{\tilde{c},t}(i)$, paying the wage rate W_t, and the commodity price $P_{\tilde{c},t}$, both of which they take as given. They are monopolistically competitive and prices are staggered. Profits are rebated to households. Technology of firm i is given by the CRS production function

$$Y_{h,t}(i) = A_{h,t} N_t(i)^{1-\mu} X_{\tilde{c},t}(i)^{\mu} \ , \tag{21}$$

while demand is given by

$$Y_{h,t}(i) = \left(\frac{P_{h,t}(i)}{P_{h,t}}\right)^{-\epsilon} Y_{h,t} \ . \tag{22}$$

This follows from the consumer problem in the home country and abroad and from the demand from the commodity exporting sector described below.

The first order condition of firm i is

$$\mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \theta^\tau Q_{t,t+\tau} Y_{h,t,t+\tau}(i) \left(P_{h,t}(i) - \frac{\epsilon}{\epsilon - 1} MC_{t+\tau}(i)\right)\right] = 0. \tag{23}$$

where θ captures the probability of not being able to re-set the price in a given period, and $MC_t(i)$ are the firm's marginal costs of production in period t, and we define $Y_{h,t,t+\tau}(i) = \left(\frac{P^*_{h,t}(i)}{P_{h,t+\tau}}\right)^{-\epsilon} Y_{h,t+\tau}$, sales of the firm at time $t+\tau$ is the firm has been unable to reset the price before then. In the absence of nominal rigidities prices are set as a markup $\mathcal{M} = \frac{\epsilon}{\epsilon-1}$ over marginal costs every period. Cost minimization in this case implies that marginal costs are equal across firms and given by:

$$MC_t(i) = \frac{1}{1+\varsigma} \frac{N_t(i) W_t}{(1-\mu) Y_{h,t}(i)}, \tag{24}$$

where ς is a production subsidy given by the government, as well as

$$MC_t(i) = \frac{1}{1+\varsigma} \frac{X_{\tilde{c},t}(i) P_{\tilde{c},t}}{\mu Y_{h,t}(i)}, \tag{25}$$

and combining with (21):

$$MC_t = \frac{1}{1+\varsigma} \frac{W_t^{(1-\mu)} P_{\tilde{c},t}^{\mu}}{(1-\mu)^{(1-\mu)} \mu^\mu A_{h,t}}. \tag{26}$$

The equality of marginal costs implies that all firms resetting prices at time t choose the same price, and hence the same level of production and inputs.

The aggregate production function is given by

$$Y_{h,t} = \frac{A_{h,t} N_t^{(1-\mu)} X_{\tilde{c},t}^{\mu}}{\Delta_t}, \tag{27}$$

where $N_t = \int_0^1 N_t(i) di$, $X_{\tilde{c},t} = \int_0^1 X_{\tilde{c},t}(i) di$ and Δ_t denotes the familiar domestic price dispersion term of NK models with Calvo pricing

$$\Delta_t = \int_0^1 \left(\frac{P_{h,t}(i)}{P_{h,t}}\right)^{-\epsilon} di \ . \tag{28}$$

2.3 Commodity export sector

The commodity export sector is competitive, taking prices as given. We assume that the dynamics in the international price of commodities $P^*_{c,t}$ are driven by developments in world markets and are thus taken as an exogenous variable by the small open economy. Firms in the commodity sector require a quantity $M_{h,t}$ of domestic goods as intermediate input, taking their price $P_{h,t}$ as given. The production function is

$$Y_{c,t} = A_{c,t} M^{\nu}_{h,t}, \tag{29}$$

where $0 < \nu < 1$ reflects the presence of decreasing returns in the sector. This structure closely follows Drechsel, McLeay, and Tenreyro (2019). Profits from the commodity sector are rebated as a lump sum payment to the household. The real commodity price can be rewritten as a function of the real foreign currency commodity price:

$$\frac{P_{c,t}}{P_t} = \frac{\mathcal{E}_t P^*_{c,t}}{P_t} = \frac{P^*_{c,t}}{P^*_t}\mathcal{T}_t^{1-\alpha}\left(\frac{P^*_{nc,t}}{P^*_{\tilde{c},t}}\right)^{\alpha_{\tilde{c}}} = \mathcal{T}_t^{1-\alpha}\frac{P^*_{c,t}}{(P^*_{nc,t})^{1-\alpha_{\tilde{c}}}(P^*_{\tilde{c},t})^{\alpha_{\tilde{c}}}} \ . \tag{30}$$

Profit maximization gives

$$P_{c,t}\nu A_{c,t} M^{\nu-1}_{h,t} = P_{h,t}. \tag{31}$$

Rearranging (31), and using (30) as well as $P_{h,t}/P_t = \mathcal{T}_t^{-\alpha}$ gives

$$M_{h,t} = \left(\nu\frac{P_{c,t}}{P_{h,t}}A_{c,t}\right)^{\frac{1}{1-\nu}} = \left(\nu A_{c,t}\mathcal{T}_t^{\alpha}S_t\frac{P^*_{c,t}}{P^*_{nc,t}}\right)^{\frac{1}{1-\nu}} = \left(\nu A_{c,t}\mathcal{T}_t\frac{P^*_{c,t}}{(P^*_{nc,t})^{1-\alpha_{\tilde{c}}}(P^*_{\tilde{c},t})^{\alpha_{\tilde{c}}}}\right)^{\frac{1}{1-\nu}} \ . \tag{32}$$

Different varieties of final goods are used and demanded according to the same CES aggregator as for consumption:

$$M_{h,t}(i) = \left(\frac{P_{h,t}(i)}{P_{h,t}}\right)^{-\epsilon} M_{h,t} \ . \tag{33}$$

2.4 Market clearing and equilibrium

Aggregate domestic goods market clearing gives

$$C_{h,t} + C^*_{h,t} = Y_{h,t} - M_{h,t} \ , \tag{34}$$

for all t, while at the firm level market clearing implies for all $i \in [0,1]$

$$C_{h,t}(i) + C^*_{h,t}(i) = Y_{h,t}(i) - M_{h,t}(i) \ . \tag{35}$$

We close the model using four alternative monetary policies: a domestic inflation targeting Taylor rules; a CPI targeting Taylor rule; and an exchange rate peg; and the benchmark optimal commitment policy plan.

Given monetary policy determining i_t, and commodity prices $P^*_{c,t}$, $P^*_{\tilde{c},t}$ and $P^*_{nc,t}$, foreign interest rate $Q^*_{t,t+1}$ and aggregate consumption C^*_t, TFP in the final good $A_{h,t}$ and commodity exporting sector $A_{c,t}$, initial conditions on price dispersion and asset holdings, an equilibrium is given by a sequence of aggregate quantities

$$\{C_t, C_{h,t}, C^*_{h,t}, C_{f,t}, C_{\tilde{c},t}, C_{nc,t}, N_t, D_{t+1}, B_{t+1}, Y_{h,t}, X_{\tilde{c},t}, Y_{c,t}, M_{h,t}, \Psi_t\}_{t=0}^{\infty} \ , \tag{36}$$

firm-level quantities

$$\{[C_{h,t}(i), C^*_{h,t}(i), N_{h,t}(i), Y_{h,t}(i), X_{\tilde{c},t}(i), M_{h,t}(i)]_{i\in[0,1]}\}_{t=0}^{\infty} \ , \tag{37}$$

and prices

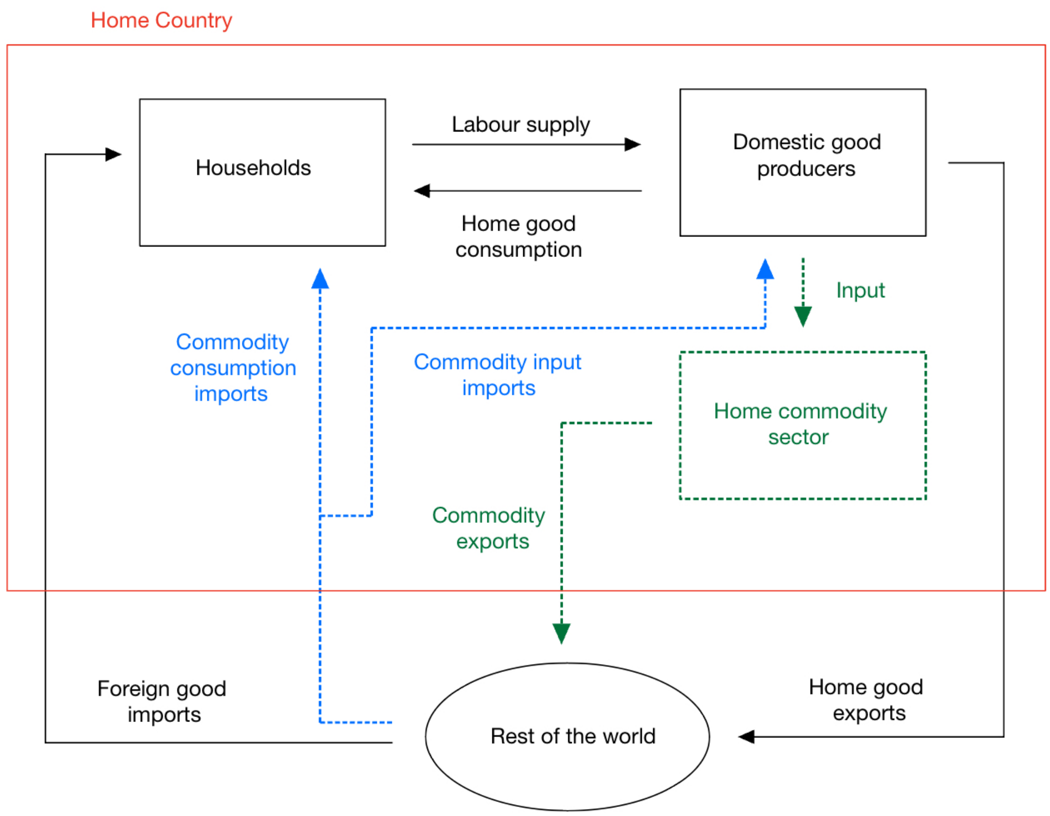
$$\{P_t, P_{h,t}, P^*_{h,t}, [P_{h,t}(i)]_{i\in[0,1]}, [P^*_{h,t}(i)]_{i\in[0,1]}, P_{f,t}, P_{\tilde{c},t}, P_{nc,t}, W_t, Q_{t,t+1}, P_{c,t}, \mathcal{T}_t, S_t, \mathcal{E}_t, \Delta_t\}_{t=0}^{\infty} \tag{38}$$

so that agents maximize their objectives and markets clear.

2.5 Graphical overview

We conclude the description of the model with a graphical depiction of the productive structure in Figure 1.

Figure 1: MODEL OVERVIEW



3 Model intuition and application

3.1 Intuition

In this section, we highlight some of the intuition underlying our model mechanism and results. We log-linearize the model around an efficient steady state with relative prices normalized to 1, and a zero initial net foreign asset position. The full model equations are listed in Appendix B.

Trade balance. The linearized trade balance[6] can be written as:

[6]In a steady state with zero bond holdings, the trade balance is equal to zero. We define the deviations $\hat{tb}_t$ as trade balance at time t divided by steady state value of home final good production, $\hat{tb}_t = \frac{TB_t}{P_h^* Y_h}$ (here we define the trade balanced in terms of foreign prices), where values in capital letters without time subscripts denote steady state values.

$$
\begin{aligned}
\hat{tb}_t =& \frac{s_{m,ss}}{\nu} \frac{\alpha s_{c,ss}}{\alpha s_{c,ss} + s_{c^*,ss}} (\hat{y}_{c,t} + \hat{p}^*_{c,t}) + s_{c^*,ss} \hat{c}^*_t \\
& - \mu \frac{\alpha s_{c,ss}}{\alpha s_{c,ss} + s_{c^*,ss}} (\hat{x}_{\tilde{c},t} + \hat{p}^*_{\tilde{c},t}) - \frac{\alpha s_{c,ss}}{1-\alpha} (\hat{c}_{f,t} + \alpha_{\tilde{c}} \hat{p}^*_{\tilde{c},t}),
\end{aligned} \tag{39}
$$

where lowercase letters with hat notation represent percentage deviations from steady state. The parameter $s_{m,ss}$ denotes the steady state share of home production used as materials in commodity production; $s_{c*,ss}$ denotes the share exported directly to foreign consumers; and $s_{c,ss}$ denotes the share consumed by home consumers.

This equation highlights several effects of a shock that raises commodity prices:

1. For a commodity exporter, increases in $\hat{p}^*_{c,t}$ increase profits for a given amount of production, generating a **windfall income channel**.
2. Given higher profit margins, competitive commodity exporting firms are incentivized to expand output ($\hat{y}_{c,t}$) until (upward sloping) marginal cost equals the new, higher price, via an **export supply channel**;
3. For a commodity importer, when $\hat{p}^*_{\tilde{c},t}$ increases, a given amount of production becomes more costly via a **domestic production channel**;
4. There is also a **direct consumption channel**, whereby the value of the same import basket increases by $\alpha_{\tilde{c}} \hat{p}^*_{\tilde{c},t}$, scaled up by steady state consumption of foreign good, worsening the trade balance.

Emerging economies' commodity exports are priced in a global, dominant currency (e.g. the dollar), in line with evidence in Gopinath et al. (2020). But as in McLeay and Tenreyro (2024), these exports are competitive, with high demand elasticities and flexible prices, so exports are also sensitive to the currency.

For our advanced economy, $s_{c^*,ss} > 0$: it also exports monopolistic, sticky price goods priced in domestic (producer) currency. For advanced economies there is also a **global demand channel**, captured by $\hat{c}^*_t$, independent of the commodity cycle.

Consumption. The full general equilibrium effects of commodity price increases also depend on the responses of the endogenous variables, including to changes in the risk premium. We can characterize consumption by solving forward households' Euler equation, and using the UIP condition, to give:

$$\hat{c}_t = \hat{s}_t - \mathbb{E}_t \sum_{i=0}^{\infty} (\hat{\phi}_{t+i} + \hat{r}^*_{t+i}) = -\mathbb{E}_t \sum_{i=0}^{\infty} \hat{r}_{t+i}. \tag{40}$$

Consumption depends on the current real exchange rate $\hat{s}_t$, but also on the expected future path of the risk premium. Given an increase in the risk premium, policymakers are presented with a choice. They must either increase the real interest rate, reducing consumption, or allow a real depreciation. This is the situation for emerging market commodity exporters following a commodity price fall, and importers after a commodity price increase. The opposite effect occurs when the price changes are reversed.

Inflation. CPI inflation is given by:

$$\hat{\pi}_t = \frac{\alpha}{1-\alpha} \Delta \hat{s}_t + \frac{\alpha \alpha_{\tilde{c}}}{1-\alpha} \Delta \hat{p}^*_{\tilde{c},t} + \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \hat{mc}_{t+i}, \tag{41}$$
$$\hat{mc}_t = (1-\mu)(\hat{c}_t + \varphi \hat{n}_t) + \mu(\hat{p}^*_{\tilde{c},t} + \hat{s}_t) - \hat{a}_{h,t}$$

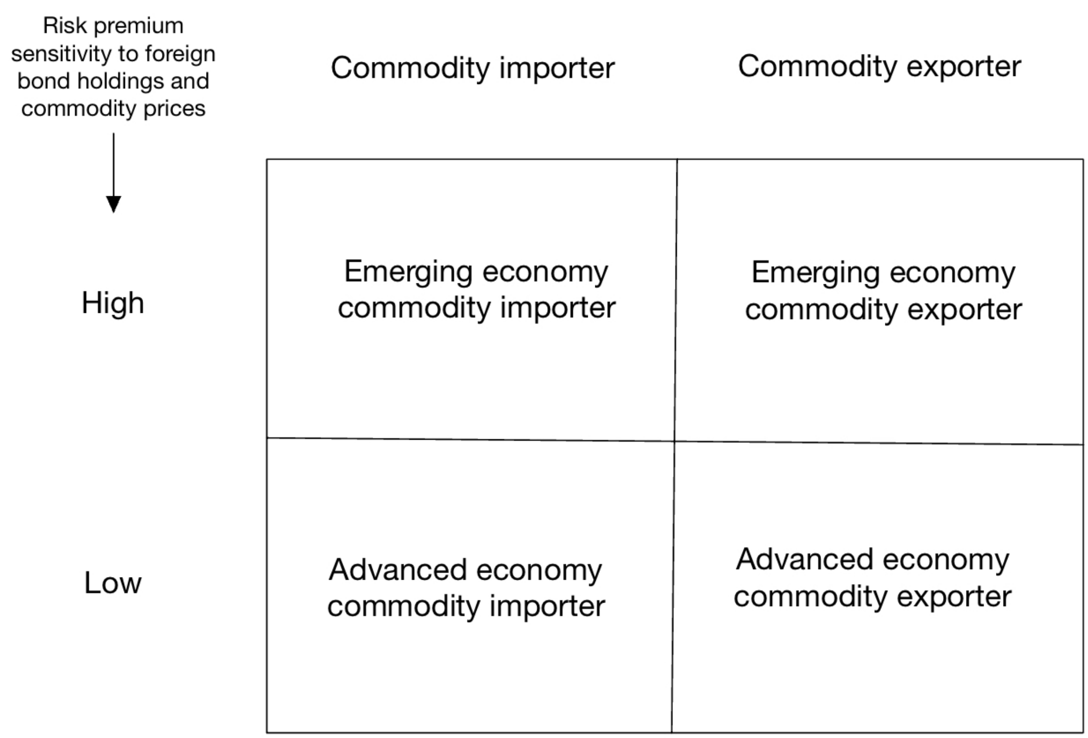
This equation, combined with the determinants of consumption, highlights the channels through which commodity prices, the exchange rate, and the risk premium affect inflation:

1. For a commodity importer, there is a **direct CPI impact** on the inflation basket, given by $\frac{\alpha \alpha_{\tilde{c}}}{1-\alpha} \Delta \hat{p}^*_{\tilde{c},t}$.
2. There is also **domestic production channel**, as a higher path for $\mu \hat{p}^*_{\tilde{c},t}$ increases domestic inflation via higher real marginal costs.
3. For both commodity importers and exporters, there is an **exchange rate impact**, whereby a depreciation increases import-price inflation.
4. In emerging markets, a higher risk premium for commodity importers drives a wedge between domestic and CPI inflation. It either depreciates the currency, leading to higher import price inflation; or reduces consumption, leading to lower domestic price inflation via a **labor market channel**.

3.2 Calibration: parameters for different types of economies

Our model is parsimonious enough that we can distinguish between four different types of economies: advanced economies that are commodity exporters, such as Australia, Norway, Canada; emerging and developing economies that are commodity exporters, such as Argentina, Chile, and Ghana; advanced economies that are commodity importers, such as Germany, Italy, and Japan; as well as emerging and developing economies that are commodity importers, such as India, Vietnam, Turkey, Eastern European countries.

Figure 2: TYPES OF ECONOMIES CONSIDERED



We distinguish between these alternative cases by just varying a few key parameters, which we summarize in Table 1. Figure 2 provides a stylized overview of the cases we consider.

For advanced economies, the risk premium sensitivity is set to a low level, as is common in the small open economy literature, as discussed in Schmitt-Grohe and Uribe (2003). For emerging economies, the elasticity with respect to the net asset position and commodity exports is set to match the evidence in Drechsel and Tenreyro (2018). The parameter for commodity imports is set to the same value.

Emerging economies are assumed to export only competitive commodities, or commodity-like goods, with flexible dollar prices that they take as given in global

Table 1: MODEL CALIBRATION: DIFFERENT PARAMETERS

Parameter	Description	Advanced econ.	Emerging econ.
ϕ_c	Elast. risk pr. to comm. exp.	0.0002	0.2
$\phi_{\tilde{c}}$	Elast. risk pr. to comm. imp.	0.0002	0.2
ϕ_b	Elast. risk pr. to asset position	0.0028	2.8
$s_{c*,ss}$	Output share of monop. exports	0.3	0.0003
		Comm. exporter	**Comm. importer**
μ	Input share of imp comm.	0.001	0.2
$\alpha_{\tilde{c}}$	Consumption share of imp comm.	0.001	0.25

markets. This is in line with the discussion in McLeay and Tenreyro (2024). The output share of monopolistic, sticky price export goods (i.e. $\frac{\alpha^* C^*}{Y_h}$) is set to a very low level. For advanced economies, this is set to 0.3, which ensures that around three-quarters of steady-state exports are monopolistic domestic goods.

For commodity exporters, we switch off commodity imports by setting the parameters governing these, μ and $\alpha_{\tilde{c}}$, to a low level. For commodity importers, these are set so that in steady state, 20% of intermediate inputs and 10% of direct consumption are of the imported commodity. .

3.3 Calibration: common parameters

The remaining, common parameters are given in Table 2 and take standard values used in the literature.

Table 2: MODEL CALIBRATION: COMMON PARAMETERS

Parameter	Description	Value	Calibration target/source
$1-\alpha$	Home bias	0.6	Gali and Monacelli (2005)
φ	Inverse Frisch elasticity	3	Gali and Monacelli (2005)
β	Discount factor	0.996	SS interest rate $\approx 1.5\%$
$1-\theta$	Price re-set probability	0.25	Standard Calvo value
ϵ	Elasticity of substitution	6	Gives markup of 20%
ν	Returns of scale in comm. prod.	0.6	Gives $s_{m,ss} = 0.4$ in Emerg.

4 Welfare

In this section of the paper we examine the welfare-optimal responses to commodity price shocks in our different economies. We first explore the efficient allocation that would obtain under a benevolent social planner. We then derive a quadratic second-order approximation to the representative household's utility. We use this to calculate the welfare-optimal commitment policy in each economy.

4.1 Social planner's allocation

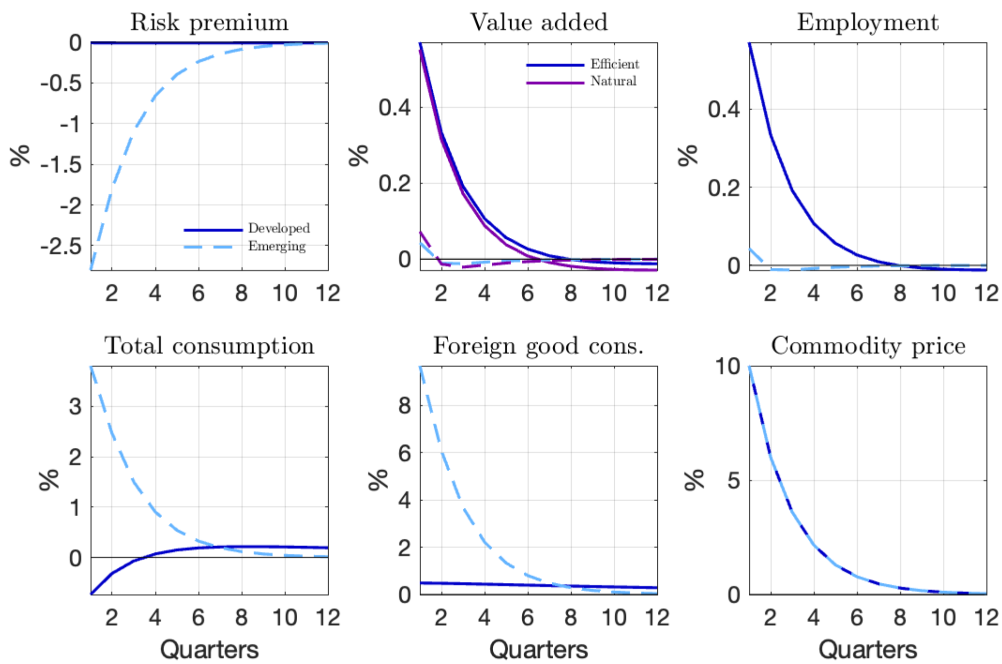
We first calculate the social planner's solution in the relevant small open economy. We assume that the planner maximizes household utility taking production, resource constraints and international prices as given. The solution is sketched in Appendix A. Importantly, the planner is also a price taker with respect to the exogenous parts of the international borrowing premium, although the planner does internalize the impact of asset holdings on the premium. To build intuition, we discuss these benchmark allocations in each case.

Commodity exporter. Figure 3 shows (blue lines) the responses of the planner's efficient allocation in our commodity exporter setup, faced with a 10% increase in commodity prices. The solid lines show the advanced economy calibration, and the dashed lines show the emerging market. For output, we also show (purple lines) the equivalent natural allocations that would be achieved in a competitive equilibrium if all prices were fully flexible.

For both advanced and emerging commodity exporters, a rise in commodity prices is equivalent to a positive productivity shock for its commodity output. At a given exchange rate, households can transform their labor into a greater amount of (foreign) consumption than before. With temporarily higher commodity prices (or productivity), it would be efficient for the economy to save more at unchanged international interest rates. The efficient response differs markedly between advanced and emerging economies, however, since the financial friction leads to different interest rates in each case.

In the **advanced economy**, the world interest rate is little changed. The planner therefore finds it optimal for agents to work more (to increase commodity production), so employment increases. Consumption temporarily falls slightly, as

Figure 3: SOCIAL PLANNER RESPONSE TO COMMODITY EXPORT PRICE SHOCK FOR COMMODITY EXPORTER



Note: IRFs to a 10% positive commodity export price shock with efficient or natural response. The results are generated under the calibration shown for a commodity exporter in Tables 1 and 2.

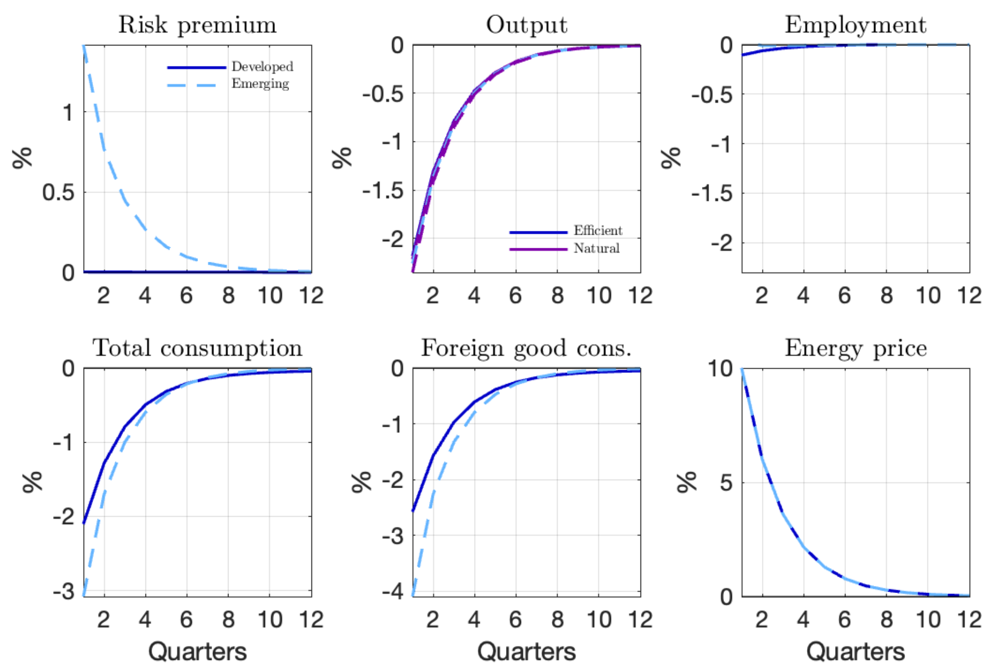
home goods are diverted into commodity production. Agents reap the benefits of this in future periods, as higher savings are used to fund greater foreign consumption (and reduced labour input).

In our **emerging economy**, in contrast, the risk premium co-moves strongly with the commodity price. With higher commodity prices, the risk premium faced by the small open economy falls sharply. From the planner's perspective, they face a lower effective path of interest rates. As a result it is efficient for agents to save less: employment and output are little changed, and it is efficient for some of the windfall income to be spent on greater consumption of foreign exports.

In both cases, the efficient allocation is quantitatively close to the natural equilibrium. Even though the planner internalizes the impact of greater savings on the risk premium, unlike in the competitive natural equilibrium this does not have much quantitative impact on the efficient policy.

Commodity importer. Figure 4 shows the equivalent efficient responses in our commodity importing economies. In these cases, given unit elasticities of substitution, the planner's solution involves little change to employment or value-added production (not shown). Instead, commodity imports are cut such that expenditure on the commodity is unchanged. Given its dual use as a consumption good and intermediate input, this leads to falls in gross output and home good consumption, as well as to foreign good consumption imports.

Figure 4: SOCIAL PLANNER RESPONSE TO COMMODITY/ENERGY IMPORT PRICE SHOCK FOR COMMODITY IMPORTER



Note: IRFs to a 10% positive commodity import price shock with efficient or natural response. The results are generated under the calibration shown for a commodity importer in Tables 1 and 2.

The size of the consumption response differs in each economy type, again owing to the financial friction. In the **advanced economy**, with an unchanged world interest rate, the planner requires consumption to fall by around 2% in response to a 10% commodity price increase. In the **emerging economy**, there is also a rise in the risk premium. Facing a higher effective interest rate, it is efficient for the emerging economy to cut consumption by more – around 3%. This extra saving also has the benefit of reducing the rise in the risk premium. Again, the natural allocation is almost identical to the efficient one, so the planner's solution is very similar to the one that would obtain in a competitive equilibrium with flexible prices.

Discussion. A key feature of these results concerns the cyclical behavior of consumption. Strikingly, in emerging economies, it is efficient for consumption to respond significantly more pro-cyclically than in advanced economies in response to energy shocks, whether an importer or an exporter. Our model therefore rationalizes part of the observed consumption volatility in emerging economies as the efficient response of the economies to commodity price shocks. Crucial to this result is that our small open economy planner takes the financial friction as exogenous. When faced with higher commodity import prices/lower commodity export prices, the planner cannot offset the exogenous part of the risk premium increase, and therefore the economy responds via a reduction in consumption.

4.2 Optimal monetary policy

We next derive the optimal monetary policy under commitment using the linear-quadratic approximation method in Benigno and Woodford (2012). To do so, we first carry out a second-order approximation of utility, and then derive a quadratic expression with no linear terms that is equivalent to the second-order approximation of utility at the efficient level, under the constraints of the model.

The second order approximation of utility under Cole-Obstfeld preferences is

$$\sum_{t=0}^{\infty}\beta^t\left(\hat{c}_t - N^{1+\varphi}\left(\hat{n}_t + \frac{1+\varphi}{2}\hat{n}_t^2\right)\right) + t.i.p. + o(|\xi|^2) \tag{42}$$

where $N^{1+\varphi} = \frac{(1-\mu)(1-\alpha)}{1-s_{m,ss}}$ is the steady state value of labor supply, $t.i.p.$ denotes terms that are independent of policy, and ξ is vector of shocks.

As discussed by Benigno and Woodford (2012), maximizing the above expression subject to first-order log-linear approximations of the model equations leads to an incorrect solution. Before maximizing welfare, it is necessary to use the second-order approximations of model equations to substitute out the linear part of approximation to welfare, as we describe in the remainder of this section. Notice that all our model equations are exactly log linear (and hence exact to any order) apart from four key equations: the home good market clearing (aggregate demand), the aggregate production equation (because of the presence of price dispersion), the current account, and the New Keynesian Phillips curve.

Since all but four of our equations are exact to the second order, we can express all real variables in our model in terms of four variables of our choice,

$$\mathbf{Y}_t = (\hat{y}_{h,t}, \hat{\tau}_t, \hat{c}_t, \hat{n}_t)' \ , \tag{43}$$

while shocks are collected in the vector

$$\xi_t = (\hat{p}^*_{c,t}, \hat{p}^*_{\tilde{c},t}, \hat{p}^*_{nc,t}, \hat{a}_{h,t}, \hat{a}_{c,t}, \hat{c}^*_t)' \ . \tag{44}$$

With this notation, we can rewrite the second-order approximation in matrix notation as follows

$$\sum_{t=0}^{\infty} \beta^t \{ w'_{\mathbf{Y}} \mathbf{Y}_t + \frac{1}{2} \mathbf{Y}'_t W_{\mathbf{Y}} \mathbf{Y}_t \} + t.i.p. + o(|\xi|^2) \tag{45}$$

where

$$w'_{\mathbf{Y}} = \begin{pmatrix} 0, 0, 1, -N^{1+\varphi} \end{pmatrix} \ , \tag{46}$$

$$W_{\mathbf{Y}} = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -N^{1+\varphi}(1+\varphi) \end{pmatrix} \ . \tag{47}$$

We then express the four equations that need to be approximated to the second order in the matrix form

$$\sum_{t=0}^{\infty} \beta^t \{ f^{i\prime}_{\mathbf{Y}} \mathbf{Y}_t + \frac{1}{2} \mathbf{Y}'_t F^i_{\mathbf{Y}} \mathbf{Y}_t + \mathbf{Y}'_t F^i_{\xi} \xi_t + f^i_{\pi} \pi^2_{h,t} \} + t.i.p. + o(|\xi|^2) = 0 \ , \tag{48}$$

for $i \in \{AD, AS, CA, NK\!-\!PC\}$, where $f^i_{\mathbf{Y}} \in \mathbb{R}^4$ is a column vector of dimension four representing the linear part of the equation, $F^i_{\mathbf{Y}} \in \mathbb{R}^{4,4}$ is a four-by-four matrix for the quadratic part and $F^i_{\xi} \in \mathbb{R}^{4,6}$ captures interactions between endogenous variables and shocks.

We solve for $L \in \mathbb{R}^4$ such that

$$\left(f_{\mathbf{Y}}^{AD} \mid f_{\mathbf{Y}}^{AS} \mid f_{\mathbf{Y}}^{CA} \mid f_{\mathbf{Y}}^{NK-PC}\right) L = w_{\mathbf{Y}} \Longrightarrow L = \left(f_{\mathbf{Y}}^{AD} \mid f_{\mathbf{Y}}^{AS} \mid f_{\mathbf{Y}}^{CA} \mid f_{\mathbf{Y}}^{NK-PC}\right)^{-1} w_{\mathbf{Y}} \,, \tag{49}$$

and express welfare as

$$\sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{2} \mathbf{Y}_t' \left(W_{\mathbf{Y}} - \sum_i L_i F_{\mathbf{Y}}^i \right) \mathbf{Y}_t - \mathbf{Y}_t' \sum_i L_i F_\xi^i \xi_t - \sum_i L_i f_\pi^i w_\pi \pi_{h,t}^2 \right\} + t.i.p. + o(|\xi|^2) \tag{50}$$

which we maximize subject to the model equations approximated to first order. In particular, we can again reduce the number of constraints to the four equations that are not exactly log-linear and UIP, all expressed as a function of $\mathbf{Y}_t$ plus $\hat{b}_t$ and $\pi_{h,t}$.[7]

In general, it is not possible to substitute out the Lagrange multipliers of the constraints. Thus, we code them as additional variables (there are five of them) and add the six first-order conditions to the model simulations. Since in total we are adding one equation, this closes the model.

5 Commodity price shocks

In this section we use our model to compare the performance of different exchange rate and monetary policy frameworks in response to commodity price shocks. We aim to understand the behavior of four different types of economies, in response to different shocks.

We examine the four cases set out in the previous section. First, we study the macroeconomic response of an advanced-economy commodity exporter in response to an increase in the prices of those commodities. Second, we examine the response of an emerging or developing economy commodity exporter, where we allow the risk premium to decrease in response to an increase in commodity prices. We assume that commodity exports are the only source of exports for the emerging economy, unlike our advanced-economy commodity exporter, which still exports mainly monopolistic goods.

[7] We could also reduce the number of constraints further since both aggregate demand and aggregate supply are intratemporal conditions, and express the problem in terms of $(\hat{y}_{h,t}, \hat{\tau}_t, \hat{b}_t, \pi_{h,t})$, of which b_t does not appear in the second-order approximation of welfare. However, we cannot express welfare as a function of output gap and inflation only, since the current account equation and the UIP equation are two additional intertemporal constraints.

We next turn to the case of an increase in commodity or energy prices for net importers of energy, before switching to an emerging or developing economy. For both, energy is used both as input in production, and directly consumed by households. The emerging economy additionally faces a borrowing risk premium sensitive to energy prices and the economy's net asset position.

For each case, we examine four types of monetary policy settings. As our benchmark, we examine the optimal commitment policy derived in the previous section. In our economy with Cole-Obstfeld preferences, this policy closely resembles a strict domestic price level/inflation target. While a useful benchmark, this policy is one that may be challenging for policymakers to implement in practice. It is not time consistent, so may not be credible. It may also require complex or extreme instrument reactions to achieve, which again, may not be credible (nor robust to uncertainty about the transmission mechanism).

We therefore compare our benchmark to three alternative simple policy rules, which approximate well the type of policy behaviors attempted by different central bank policymakers. Specifically, we study the economy when the policymaker seeks to implement a fixed exchange rate - a common strategy in many emerging and developing economies. We compare the volatility and performance of key variables with two inflation-targeting Taylor rules. The first focuses only on CPI inflation, with $i_t = 1.5\hat{\pi}_t$, similar to most inflation-targeting central bank operational targets. The second focuses on domestic inflation, with $i_t = 1.5\hat{\pi}_{h,t}$. This second rule approximates a common strategy for flexible inflation targeting central banks – which is to 'look through' the direct impact of energy-price shocks on CPI, while responding to their 'second-round' effects on domestic inflation.

Our main findings are that some form of inflation targeting with flexible exchange rates still performs better than a fixed exchange-rate regime in response to most shocks, and for different model configurations. But depending on policymakers' preferences, and comparing across the class of simple policy rules, there are some cases and shocks where more active exchange-rate management can be helpful.

Another key feature of our results is that it is optimal for all of our small open economies to appreciate their exchange rates, both in nominal and in real terms. Clearly, this could not occur in all countries at the same time. The model is therefore consistent with the idea that our small open economy commodity importers and exporters are trading with a large economy such as the United States, which does not significantly export or import our commodities. If all countries did try to appreciate simultaneously, this would trigger a rise in the global real interest rate, the effects of which we illustrate in Appendix C.

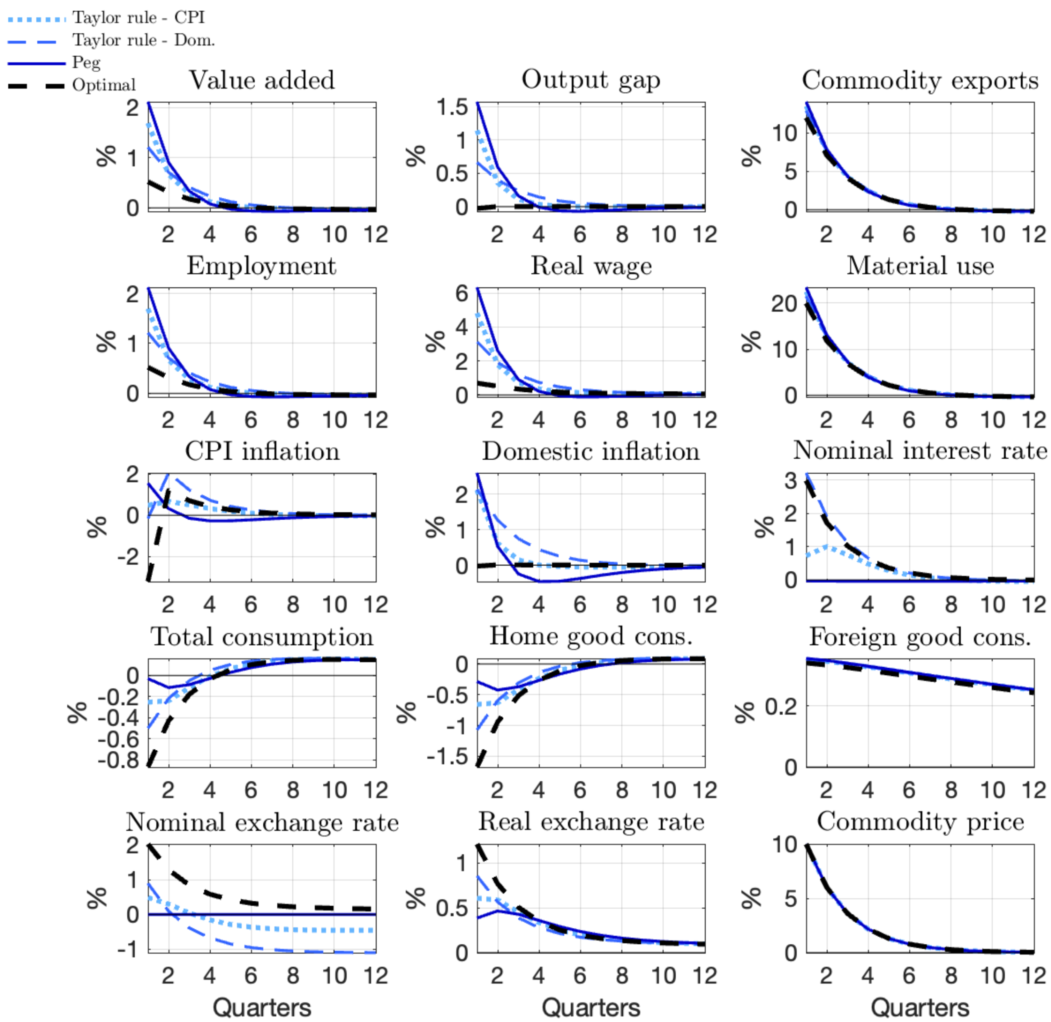
5.1 Advanced economy commodity exporters

Figure 5 shows the economy's response to a 10% increase in commodity export prices in an advanced economy under different monetary rules. In line with the efficient responses discussed in the previous section, the optimal response (black dashed lines) to the temporary increase in commodity prices is to increase commodity export production. This is achieved through a combination of higher employment and, since some home goods are substituted into commodity production, lower consumption. To achieve this, the real exchange rate needs to appreciate. On the nominal side, it is optimal to do this through an appreciation of the exchange rate (and a fall in import prices), keeping domestic inflation constant.

Comparing across simple policy rules, exchange-rate targeting creates more output gap and domestic inflation volatility than either inflation-targeting Taylor rule (Table 3). Rather than tightening policy to appreciate the nominal exchange rate, the peg requires keeping policy suboptimally loose, such that the commodity price rise increases demand for domestic goods, leading to an inefficiently large boom in employment and a positive output gap. It also bids up their price, creating domestic (and CPI) inflation. A smaller real appreciation occurs, owing solely to the price rise, rather than a nominal appreciation.

The responses of the domestic and CPI inflation targeting rules are between that of the exchange-rate peg and the optimal policy. The Taylor rules are not responsive enough to completely stabilize the target variables - they induce a smaller and more temporary appreciation. Moreover, since the shock is persistent, and the Taylor rules are not responsive enough in future either, higher inflation expectations also feed into further domestic inflation today. Interestingly, the domestic inflation-based Taylor rule actually brings inflation back to 0 more slowly than the exchange-rate peg, as the peg is able to commit to running negative inflation in future, which reduces inflation more quickly today. Bringing inflation back to 0 earlier is not beneficial, however. Table 3 shows that the exchange-rate peg leads to greater volatility in both domestic inflation and the output gap.

Figure 5: IRFS TO COMMODITY EXPORT PRICE SHOCK IN DEVELOPED ECONOMY COMMODITY EXPORTER



Note: IRFs to a 10% positive commodity export price shock under alternative policy rules. The results are generated under the calibration shown in Tables 1 and 2. Inflation is shown in annualized percent. The nominal exchange rate is plotted as $-\hat{e}_t$ so that an increase corresponds to an appreciation.

5.2 Emerging and developing economy commodity exporters

For *emerging or developing* economy commodity exporters, facing the same commodity price shock, the welfare ranking of different policies is even more clear-cut (Table 4). Figure 6 shows that exchange-rate pegs create an enormous amount

Table 3: IMPLIED STANDARD DEVIATIONS ACROSS POLICIES - DEVELOPED COMMODITY EXPORTER, CONDITIONAL ON COMMODITY EXPORT PRICE SHOCK

	CPI inf. target	**Dom. inf. target**	**Nominal peg**
CPI inflation	0.26	0.63	0.42
Domestic inflation	0.55	0.66	0.69
Efficient output gap	1.20	0.83	1.70

of inefficient volatility, by preventing the large required movements in the exchange rate. In the presence of an endogenous risk premium, the increase in commodity export prices relaxes the financial friction and reduces the risk premium. As a result, a much larger real appreciation is required, even to deliver a rise in consumption, rather than a fall. This is optimally achieved through a large nominal appreciation of almost 10%.

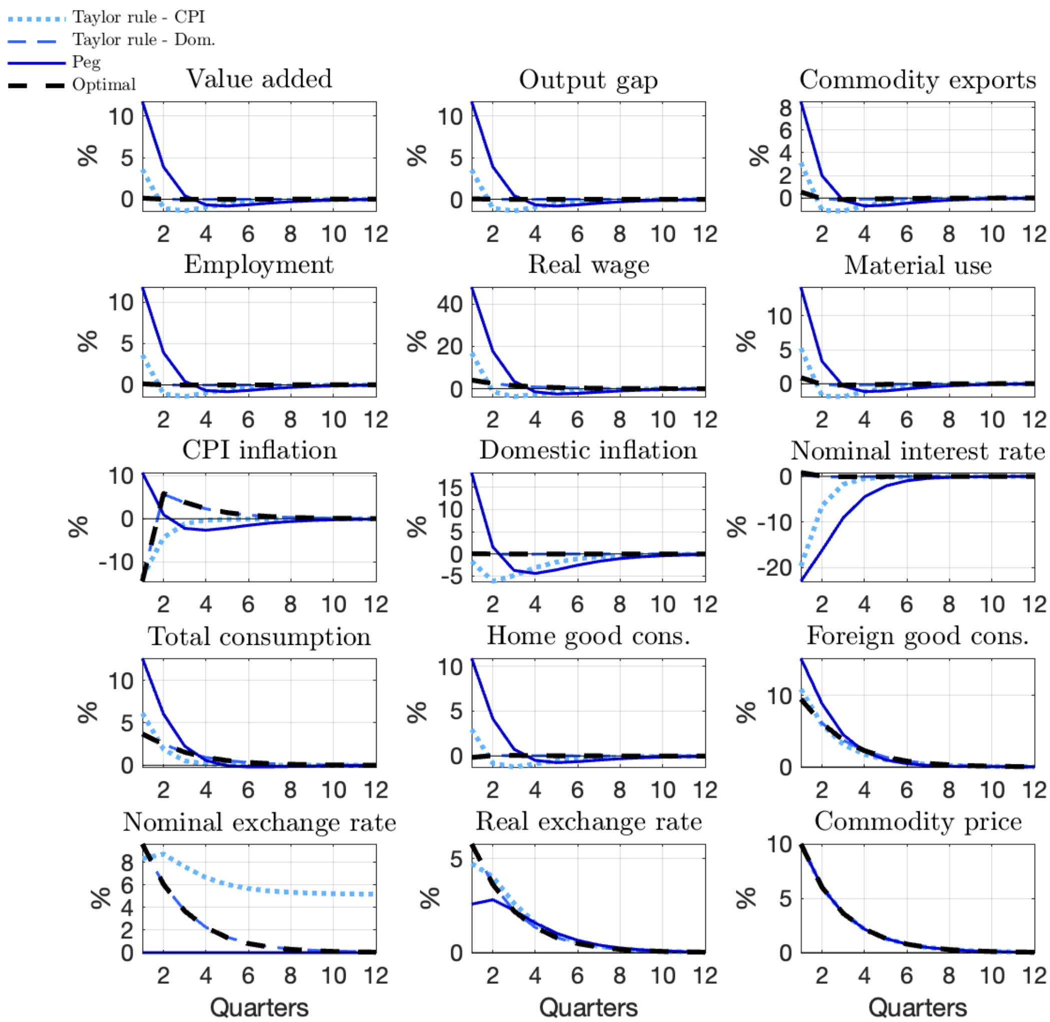
Table 4: IMPLIED STANDARD DEVIATIONS ACROSS POLICIES - EMERGING COMMODITY EXPORTER, CONDITIONAL ON COMMODITY EXPORT PRICE SHOCK

	CPI inf. target	**Dom. inf. target**	**Nominal peg**
CPI inflation	3.75	4.20	2.83
Domestic inflation	2.26	0.06	4.71
Efficient output gap	4.13	0.20	12.50

Given the much larger required appreciation, the exchange-rate peg creates extreme volatility. To keep the exchange rate stable requires a large loosening in monetary policy, leading to an extremely large inefficient boom in employment, the output gap and the real wage. In the face of a similarly sized fall in commodity prices, the enormous recession would make the peg difficult to maintain. In contrast, a domestic inflation targeting Taylor rule is very close to welfare-optimal. The CPI targeting rule is between the two, loosening policy in response to the fall in CPI inflation, though quickly reversing this, as the one-off effect of the exchange-rate appreciation on CPI inflation unwinds.

Given these results, how can we explain that many commodity-exporting emerging and developing economies do adopt exchange-rate pegs? One possible answer lies in the behavior of CPI inflation. By stabilizing the exchange rate, the peg avoids the volatility in import prices induced by the optimal appreciation. This

Figure 6: IRFS TO COMMODITY EXPORT PRICE SHOCK IN EMERGING MARKET COMMODITY EXPORTER

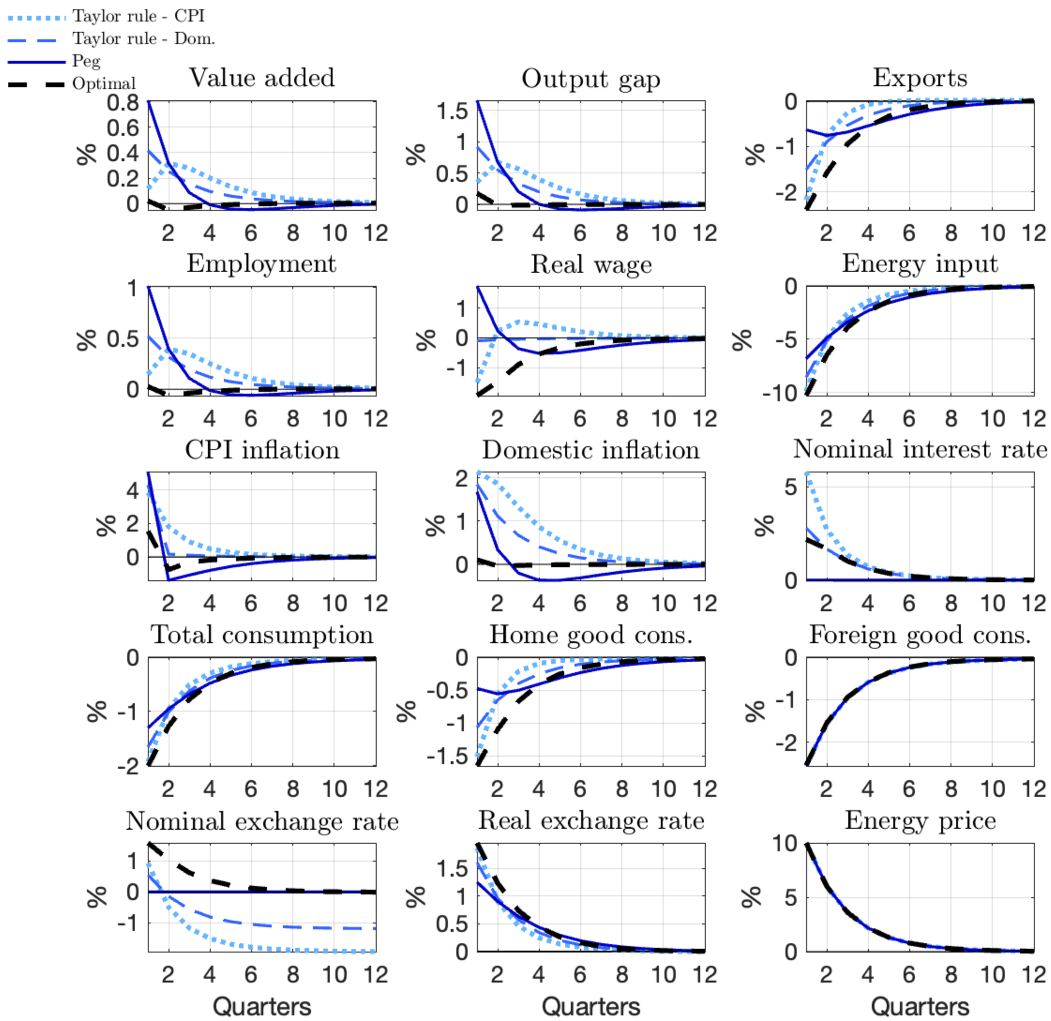


Note: IRFs to a 10% positive commodity export price shock under alternative policy rules. The results are generated under the calibration shown in Tables 1 and 2. Inflation is shown in annualized percent. The nominal exchange rates is plotted as $-\hat{e}_t$ so that an increase corresponds to an appreciation.

leads to somewhat lower (though still significant) volatility in CPI inflation than the domestic inflation-targeting Taylor rule, and even than the CPI-based one. If policymakers' remits are set as CPI targets, or if agents' expectations are formed based on CPI inflation, then the peg could still offer some benefits to policymakers.

5.3 Advanced economy energy importers

Figure 7: IRFS TO ENERGY IMPORT PRICE SHOCK IN ADVANCED ECONOMY



Note: IRFs to a 10% positive commodity/energy import price shock under alternative policy rules. The results are generated under the calibration shown in Tables 1 and 2. Inflation and interest rates are shown in annualized percent. The nominal and real exchange rates are plotted as $-\hat{e}_t$ and $-\hat{s}_t$ so that an increase corresponds to an appreciation.

We next examine the case of an advanced economy commodity/energy *importer*, facing a 10% positive energy price shock. The responses are displayed in Figure 7. The benchmark optimal adjustment involves little change in employment or value-added production, with almost all of the adjustment coming via a reduction in the energy input. This leads to an optimal fall in each of exports, home and foreign good consumption, which have respective energy intensities of 20%, 20% and 25%. The fall in consumption is optimally delivered via a policy tightening that appreciates the real exchange rate. Given the direct impact of higher (relative) energy prices on the CPI, this only needs a small nominal appreciation and nominal interest rate rise.

Comparing the outcomes from the simple policy rules, there is only a slight differentiation between them. All implement a looser than optimal policy, leading to inefficient increases in employment and value-added, with the positive output gap causing positive domestic inflation, and a larger increase in CPI inflation. The exchange rate peg initially implements the loosest monetary stance, limiting the efficient fall in imported energy, and its effects through the supply chain.

Table 5: IMPLIED STANDARD DEVIATIONS ACROSS POLICIES - DEVELOPED COMMODITY IMPORTER, CONDITIONAL ON COMMODITY (ENERGY) IMPORT PRICE SHOCK

	CPI inf. target	**Dom. inf. target**	**Nominal peg**
CPI inflation	1.08	1.06	1.36
Domestic inflation	0.83	0.58	0.46
Efficient output gap	1.08	1.45	1.81

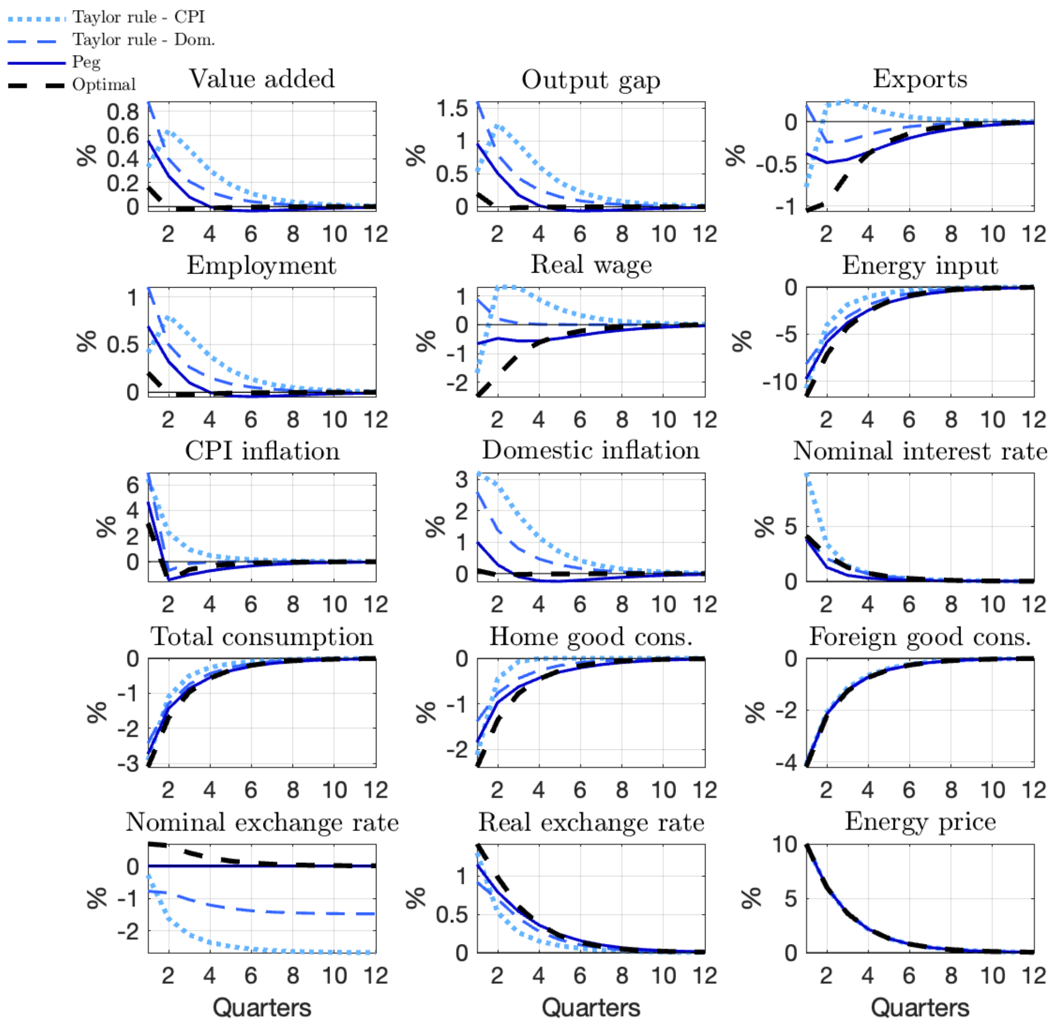
As with the commodity exporter, the exchange-rate peg is able to bring domestic inflation back to target more quickly than the two inflation-based Taylor rules. It is again able to commit to negative future inflation, and therefore greater stability in the price level. In this case, this actually leads to a better performance in minimizing domestic inflation volatility. But this comes at the cost of greater volatility in the efficient output gap 5.

5.4 Emerging and developing economy energy importers

When emerging economies face the same energy price shock, there are some more distinct advantages to the exchange rate peg. The optimal response is similar to the advanced economy's, but with the rise in the risk premium requiring a greater pro-cyclical fall in consumption, achieved with a smaller appreciation of the real and nominal exchange rate (Figure 8).

Unlike for emerging and developing commodity exporters, the risk premium for

Figure 8: IRFS TO ENERGY IMPORT PRICE SHOCK IN EMERGING MARKET COMMODITY IMPORTER



Note: IRFs to a 10% positive commodity/energy import price shock under alternative policy rules. The results are generated under the calibration shown in Tables 1 and 2. Inflation and interest rates are shown in annualized percent. The nominal and real exchange rates are plotted as $-\hat{e}_t$ and $\hat{s}_t$ so that an increase corresponds to an appreciation.

energy importers moves the exchange rate in a suboptimal direction – depreciating the currency, despite an optimal appreciation. A credible peg guards against this risk premium movement, keeping the exchange rate stable, and closer to the optimal policy. By doing so, Table 6 shows it is able to limit the volatility in both domestic and CPI inflation, even relative to Taylor rules targeting those variables. [8]

Table 6: IMPLIED STANDARD DEVIATIONS ACROSS POLICIES - EMERGING COMMODITY IMPORTER, CONDITIONAL ON COMMODITY (ENERGY) IMPORT PRICE SHOCK

	CPI inf. target	**Dom. inf. target**	**Nominal peg**
CPI inflation	1.70	1.71	1.26
Domestic inflation	1.21	0.77	0.29
Efficient output gap	1.83	1.87	1.11

5.5 The role of financial conditions

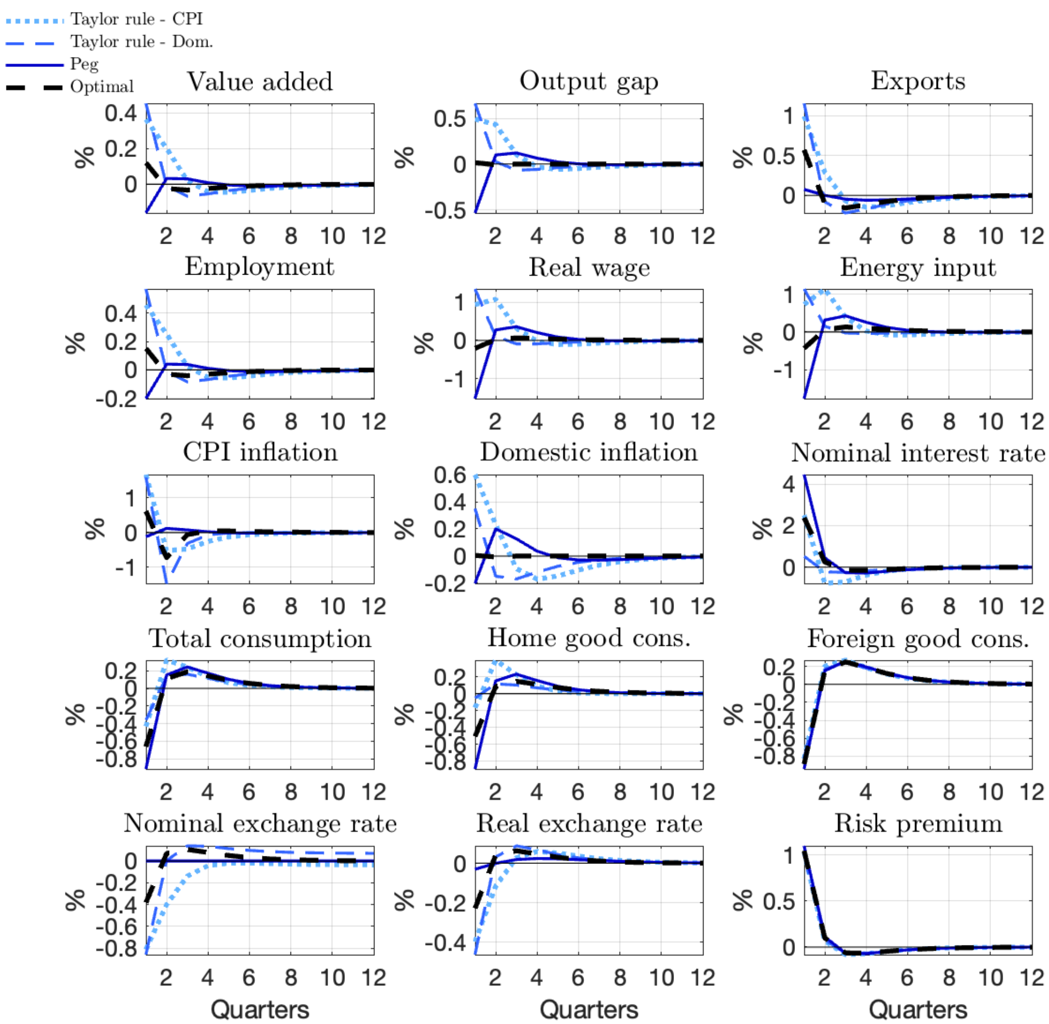
Given its importance to our results, Figure 9 explores the role of the risk premium and financial conditions in more detail. This also relates to early work by Kollmann (2001) and more recent contributions by Itskhoki and Mukhin (2021) and Fukui et al. (2023) stressing the role of financial volatility in driving exchange rate dynamics.

The figure shows how for an emerging economy facing a pure risk premium shock, exchange-rate pegs do relatively well at stabilizing CPI inflation, since the volatility comes largely via the exchange rate.

There is a trade-off, however, as inflation stabilization comes at the expense of greater volatility in the real economy. This result is consistent with active exchange-rate management being particularly costly in response to fundamentals-driven movements, but with some countervailing benefits for volatility driven by financial channels.

[8] The results rely on the credibility and sustainability of the peg, which might not be granted in emerging economies. See for example, Mendoza and Uribe (2000).

Figure 9: IRFS TO RISK PREMIUM SHOCK IN EMERGING ECONOMY



Note: IRFs to a 3.3pp positive shock to the risk premium under alternative policy rules. The results are generated under the calibration shown in Tables 1 and 2. Inflation and interest rates are shown in annualized percent. The nominal exchange rate is plotted as $\hat{e}_t^{-1}$ so that an increase corresponds to an appreciation.

6 Conclusions

We develop a small open economy New Keynesian setting with commodity exports and imports to compare the performance of different monetary policy and exchange-rate frameworks in response to commodity-price shocks. To capture the marked procyclicality of credit in emerging and developing economies, we allow the risk premium faced by these economies to vary with commodity prices. After setting out the model, we characterize the behavior of different types of economies when the policymaker seeks to implement a fixed exchange rate. We compare the volatility and performance of the economy under different inflation-targeting Taylor rules, and to the benchmark of the welfare-optimal policy.

We find that for advanced economies that are commodity exporters, inflation-targeting policies consistently dominate over a peg, leading to lower volatility in the output gap and inflation. The advantages of inflation targeting over pegs are more striking in the case of commodity-exporting emerging or developing economies: in the face of commodity price shocks, exchange rate pegs create enormous volatility in inflation and output. A fall in commodity prices necessitates a domestic currency depreciation, and the peg sacrifices efficient internal adjustment for the sake of exchange-rate stability. This volatility is amplified by an endogenous tightening of financial conditions, which leads to further pressure to loosen and depreciate.

For advanced economies that are commodity importers, there is less differentiation between inflation targeting and the peg. The optimal response involves little change in employment or value-added production, with higher energy prices leading to lower import volumes, exports and consumption of energy-intensive goods. The exchange-rate peg implements a looser monetary stance initially and a tighter stance thereafter, reducing some of the exchange-rate related volatility in import prices and CPI inflation, and bringing domestic inflation back to target more quickly. But it does so at the cost of greater volatility in the output gap and domestic inflation. When emerging economies face the same energy-price shock, there are some more distinct advantages to the exchange-rate peg. A rise in the risk premium leads to a more depreciated currency under inflation targeting rules, which the peg prevents. By doing so, the peg is able to limit the volatility in both domestic and CPI inflation, relative to Taylor rules targeting those variables. Further exploring the role of borrowing costs, we find that for an emerging economy, facing a pure risk premium shock, exchange-rate pegs do relatively well at stabilizing CPI inflation, since the volatility comes largely via the exchange rate. There is a trade-off, however, as the stabilization of CPI inflation comes at the expense of greater volatility in the real economy. Overall, our results are consistent with active exchange rate management being particularly costly in response to fundamentals-driven movements, but with some countervailing benefits for volatility driven exclusively by financial channels.

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APPENDIX TO

Commodity shocks with diverse impacts: how can different central banks tailor their policies?

by Thomas Drechsel, Michael McLeay, Silvana Tenreyro and Enrico Turri

A Social planner

The social planner maximizes household utility taking production, resource constraints and international prices as given.

We can write it as

$$\max_{\left\{\substack{C_{h,t},C_{f,t},N_t,\\ M_{h,t},X_{\tilde{c},t},B_{t+1}}\right\}_{t=0}^{\infty}} \quad \sum_{t=0}^{\infty} \beta^t \left((1-\alpha)\log C_{h,t} + \alpha \log C_{f,t} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \tag{51}$$

$$s.t. \quad A_{h,t} N_t^{1-\mu} X_{\tilde{c},t}^{\mu} = C_{h,t} + C_{h,t}^* + M_{h,t} \tag{52}$$

$$P_{f,t}^* C_{f,t} = P_{c,t}^* A_{c,t} M_{h,t}^{\nu} + P_{h,t}^* C_{h,t}^* - P_{\tilde{c},t}^* X_{\tilde{c},t} + B_t \Phi_{t-1}(B_t) - Q_{t,t+1}^* B_{t+1} \tag{53}$$

$$C_{h,t}^* = \alpha^* C_t^* \frac{\alpha C_{h,t}}{(1-\alpha) C_{f,t}} \left(\frac{P_{nc}^*}{P_{\tilde{c}}^*} \right)^{\alpha_{\tilde{c}}} \tag{54}$$

Noticing that $P_{h,t}^* C_{h,t}^* = \alpha^* C_t^* P_{nc,t}^*$, we can then write the current-value Lagrangian

$$\begin{aligned}\mathcal{L} = \sum_{t=0}^{\infty} \beta^t & \left((1-\alpha)\log C_{h,t} + \alpha \log C_{f,t} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \\ & + \beta^t \lambda_t \Big(-C_{h,t} - \alpha^* C_t^* \frac{\alpha C_{h,t}}{(1-\alpha) C_{f,t}} \left(\frac{P_{nc}^*}{P_{\tilde{c}}^*} \right)^{\alpha_{\tilde{c}}} - M_{h,t} + A_{h,t} N_t^{1-\mu} X_{\tilde{c},t}^{\mu}\Big) \\ & + \beta^t \xi_t \left(-P_{f,t}^* C_{f,t} + P_{c,t}^* A_{c,t} M_{h,t}^{\nu} + P_{nc,t}^* \alpha^* C_t^* - P_{\tilde{c},t}^* X_{\tilde{c},t} + B_t \Phi_{t-1}(B_t) - Q_{t,t+1}^* B_{t+1} \right)\end{aligned} \tag{55}$$

The system of first order conditions and constraints is

$$\frac{1-\alpha}{C_{h,t}} - \lambda_t(1 + \frac{\alpha\alpha^* C_t^*}{(1-\alpha)C_{f,t}} \left(\frac{P_{nc}^*}{P_{\tilde{c}}^*}\right)^{\alpha_{\tilde{c}}}) = 0 \quad (56)$$

$$\frac{\alpha}{C_{f,t}} - \xi_t P_{f,t}^* + \lambda_t(\frac{\alpha\alpha^* C_t^* C_{h,t}}{(1-\alpha)C_{f,t}^2} \left(\frac{P_{nc}^*}{P_{\tilde{c}}^*}\right)^{\alpha_{\tilde{c}}}) = 0 \quad (57)$$

$$-N_t^{\varphi} + \lambda_t(1-\mu)\frac{A_{h,t}N_t^{1-\mu}X_{\tilde{c},t}^{\mu}}{N_t} = 0 \quad (58)$$

$$-\lambda_t + \xi_t \nu P_{c,t}^* A_{c,t} M_{h,t}^{\nu-1} = 0 \quad (59)$$

$$+\lambda_t \mu \frac{A_{h,t}N_t^{1-\mu}X_{\tilde{c},t}^{\mu}}{X_{\tilde{c},t}} - \xi_t P_{\tilde{c},t}^* = 0 \quad (60)$$

$$-\xi_t Q_{t,t+1}^* + \beta\xi_{t+1}(\Phi_t(B_{t+1}) + B_{t+1}\partial_B\Phi_t(B_{t+1})) = 0 \quad (61)$$

$$A_{h,t}N_t^{1-\mu}X_{\tilde{c},t}^{\mu} = C_{h,t} + C_{h,t}^* + M_{h,t} \quad (62)$$

$$P_{f,t}^* C_{f,t} = P_{c,t}^* A_{c,t} M_{h,t}^{\nu} + P_{nc,t}^* \alpha^* C_t^* - P_{\tilde{c},t}^* X_{\tilde{c},t} + B_t\Phi_{t-1}(B_t) - Q_{t,t+1}^* B_{t+1} \quad (63)$$

We linearize the model around the steady state that satisfies these conditions and with relative prices normalized to one. Substituting out the multipliers and letting capital letters without time subscripts denote steady state values, we have the following system.

$$N^{1+\varphi} = \frac{1-\alpha}{C_h}\frac{1}{1+\alpha^* C^* \frac{\alpha}{1-\alpha}\frac{1}{C_f}}(1-\mu)A_h N^{1-\mu}X^{\mu} \quad (64)$$

$$\frac{1-\alpha}{C_h}\mu\frac{A_h N^{1-\mu}X^{\mu}}{X} = \frac{1}{C_f}\left[\alpha + \alpha^* C^* \frac{\alpha}{1-\alpha}\frac{1}{C_f}\right] \quad (65)$$

$$\frac{1-\alpha}{C_h} = \frac{1}{C_f}\left[\alpha + \alpha^* C^* \frac{\alpha}{1-\alpha}\frac{1}{C_f}\right]\nu A_c M^{\nu-1} \quad (66)$$

$$A_h N^{1-\mu}X^{\mu} = C_h + M_h + \alpha^* C^* \frac{\alpha}{1-\alpha}\frac{C_h}{C_f} \quad (67)$$

$$C_f + X = A_c M_h^{\nu} + \alpha^* C^* + B(\Phi(B) - Q^*) \quad (68)$$

$$\frac{Q^*}{\beta} = \Phi(B) + B\partial_B\Phi(B) \quad (69)$$

We choose an initial steady state with zero net asset positions. With $Q^* = \beta$ this implies the normalization that the risk premium at the steady state level of bond holdings (zero) equals one. Once the level of bond holdings is set to zero, we are left with a model with seven parameters, $\alpha, \varphi, \alpha^* C^*, \mu, \nu, A_h, A_c$. However, since we are interested in the behavior of the model in percentage terms, we can normalize $A_h = 1$ and introduce share parameters that denote the steady state allocation of final good production in commodity production, consumption and exports,

$$s_{m,ss} = \frac{M_h}{Y_h} \ , \quad s_{c,ss} = \frac{C_h}{Y_h} \ , \quad s_{c^*,ss} = \frac{C_h^*}{Y_h} \ . \tag{70}$$

These substitute the parameter A_c, so only one of these can be a free parameter, and we choose $s_{c^*,ss}$. The other two steady state shares are determined by

$$s_{m,ss} + s_{c,ss} + s_{c^*,ss} = 1 \tag{71}$$

$$s_{c,ss}^2 - s_{c,ss}\left[\frac{(1-\mu\nu)(1-\alpha)}{1-\alpha(1-\nu)} - s_{c^*,ss}\right] - \frac{1-\alpha}{\alpha}\frac{\nu}{1-\alpha(1-\nu)}s_{c^*,ss}^2 = 0 \tag{72}$$

where for the second equation the unique positive solution for $s_{c,ss}$ is considered.

At steady state it is also true that

$$N^{1+\varphi} = \frac{(1-\alpha)(1-\mu)}{1-s_{m,ss}} \ . \tag{73}$$

which for $s_{c^*,ss} = \mu = 0$ gives the same level of employment as the autarky economy with commodity exports in Drechsel et al. (2019).

Finally, the steady state currency values are

$$\frac{P_h^* C_h^*}{P_h^* Y_h^*} = s_c^* \ , \quad \frac{P_f^* C_f^*}{P_h^* Y_h^*} = \frac{\alpha}{1-\alpha} s_c \ , \quad \frac{P_{\tilde{c}}^* X_{\tilde{c}}}{P_h^* Y_h^*} = \mu \frac{\alpha s_c}{\alpha s_c + s_c^*} \ , \quad \frac{P_c^* Y_c}{P_h^* Y_h^*} = \frac{s_m}{\nu} \frac{\alpha s_c}{\alpha s_c + s_c^*} \tag{74}$$

that are used in the expression of the trade balance and the current account.

B Full linearized model

Relative price relations and resource constraint.

$$\hat{p}_t = \alpha \hat{p}_{f,t} + (1-\alpha)\hat{p}_{h,t} \tag{75}$$

$$\hat{p}_{f,t} = \alpha_{\tilde{c}} \hat{p}_{\tilde{c},t} + (1-\alpha_{\tilde{c}})\hat{p}_{nc,t} \tag{76}$$

$$\hat{p}_{\tilde{c},t} = \hat{e}_t + \hat{p}^*_{\tilde{c},t}\,, \quad \hat{p}_{nc,t} = \hat{e}_t + \hat{p}^*_{nc,t}\,, \quad \hat{p}_{c,t} = \hat{e}_t + \hat{p}^*_{c,t}\,, \quad \hat{p}_{h,t} = \hat{e}_t + \hat{p}^*_{h,t} \tag{77}$$

$$\hat{p}^*_t = \hat{p}^*_{nc,t} \tag{78}$$

$$\hat{\tau}_t = \hat{p}_{f,t} - \hat{p}_{h,t} \tag{79}$$

$$\hat{s}_t = \hat{e}_t + \hat{p}^*_t - \hat{p}_t = (1-\alpha)\hat{\tau}_t + \alpha_{\tilde{c}}(\hat{p}^*_{nc,t} - \hat{p}^*_{\tilde{c},t}) \tag{80}$$

$$\hat{y}_{h,t} = s_{c,ss}\hat{c}_{h,t} + s_{c^*,ss}\hat{c}^*_{h,t} + s_{m,ss}\hat{m}_{h,t} \tag{81}$$

$$\hat{\pi}_{t+1} = \hat{p}_{t+1} - \hat{p}_t\,, \quad \hat{\pi}_{h,t+1} = \hat{p}_{h,t+1} - \hat{p}_{h,t}\,, \quad \hat{\pi}^*_{t+1} = \hat{p}^*_{t+1} - \hat{p}^*_t \tag{82}$$

Households.

$$\hat{c}_{h,t} = \hat{p}_t - \hat{p}_{h,t} + \hat{c}_t = \alpha\hat{\tau}_t + \hat{c}_t \tag{83}$$

$$\hat{c}_{f,t} = \hat{p}_t - \hat{p}_{f,t} + \hat{c}_t = (\alpha-1)\hat{\tau}_t + \hat{c}_t \tag{84}$$

$$\hat{c}^*_{h,t} = \hat{p}^*_t - \hat{p}^*_{h,t} + \hat{c}^*_t \tag{85}$$

$$\hat{c}_{nc,t} = \hat{p}_{f,t} - \hat{p}_{nc,t} + \hat{c}_{f,t} \tag{86}$$

$$\hat{c}_{\tilde{c},t} = \hat{p}_{f,t} - \hat{p}_{\tilde{c},t} + \hat{c}_{f,t} \tag{87}$$

$$\varphi\hat{n}_t + \hat{c}_t = \hat{w}_t - \hat{p}_t \tag{88}$$

$$\hat{c}_t = -(i_t - \mathbb{E}_t\hat{\pi}_{t+1}) + \mathbb{E}_t\hat{c}_{t+1} \tag{89}$$

$$i_t - \mathbb{E}_t\hat{\pi}_{t+1} = i^*_t - \mathbb{E}_t\hat{\pi}^*_{t+1} + \mathbb{E}_t\hat{s}_{t+1} - \hat{s}_t + \hat{\phi}_t \tag{90}$$

$$\hat{\phi}_t = \phi_{\tilde{c}}\hat{p}^*_{\tilde{c},t} - \phi_c\hat{p}^*_{c,t} - \phi_B\hat{b}_t \tag{91}$$

$$\beta\hat{b}_t - \hat{b}_{t-1} = \frac{s_{m,ss}}{\nu}\frac{\alpha s_c}{\alpha s_c + s^*_c}(\hat{y}_{c,t} + \hat{p}^*_{c,t}) + s_{c^*,ss}(\hat{c}^*_{h,t} + \hat{p}^*_{h,t}) + \tag{92}$$

$$-\mu\frac{\alpha s_c}{\alpha s_c + s^*_c}(\hat{x}_{\tilde{c},t} + \hat{p}^*_{\tilde{c},t}) - \frac{\alpha s_{c,ss}}{1-\alpha}(\hat{c}_{f,t} + \hat{p}^*_{f,t}) \tag{93}$$

Domestic goods sector.

$$\begin{aligned}
\hat{y}_{h,t} &= \hat{a}_{h,t} + (1-\mu)\hat{n}_t + \mu\hat{x}_{\tilde{c},t} && (94)\\
\hat{\pi}_{h,t} &= \kappa \hat{mc}_t^r + \beta \mathbb{E}_t \hat{\pi}_{h,t+1} && (95)\\
\hat{mc}_t^r &= (1-\mu)\hat{w}_t + \mu \hat{p}_{\tilde{c},t} - \hat{a}_{h,t} - \hat{p}_{h,t} && (96)\\
\hat{x}_{\tilde{c},t} + \hat{p}_{\tilde{c},t} &= \hat{n}_t + \hat{w}_t && (97)
\end{aligned}$$

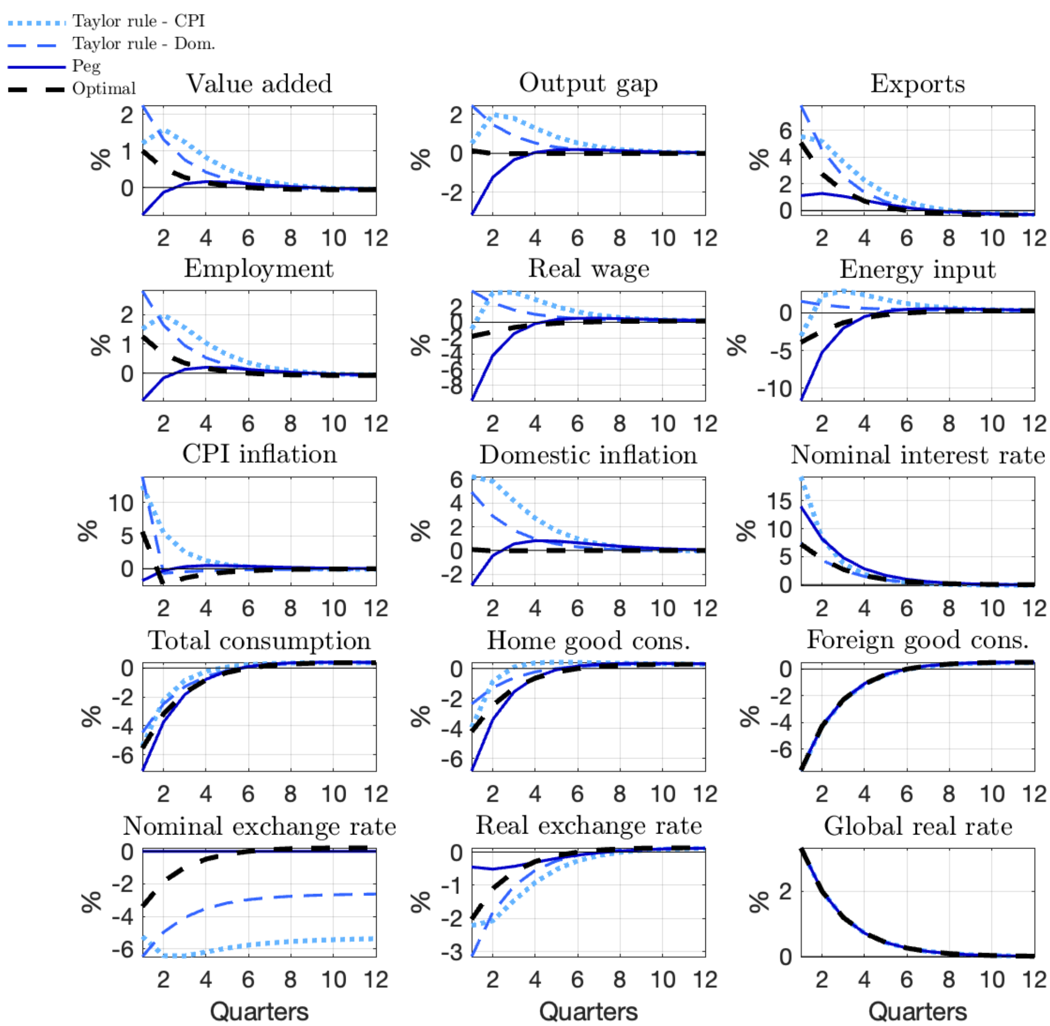
Commodity export sector.

$$\begin{aligned}
\hat{y}_{c,t} &= \hat{a}_{c,t} + \nu \hat{m}_{h,t} && (98)\\
(1-\nu)\hat{m}_{h,t} &= \hat{a}_{c,t} + \hat{p}_{c,t} - \hat{p}_{h,t} && (99)
\end{aligned}$$

All hat variables are log deviations from steady state, except $\hat{b}_t \equiv \frac{B_{t+1}}{P_h^* Y_h}$, which denotes foreign bond holdings as a share of the value of home output in foreign prices, and the prices $\hat{p}^*_{c,t} \equiv \frac{\frac{P^*_{c,t}}{P^*_t} - \frac{P^*_c}{P^*}}{\frac{P^*_c}{P^*}}$, $\hat{p}^*_{\tilde{c},t} \equiv \frac{\frac{P^*_{\tilde{c},t}}{P^*_t} - \frac{P^*_{\tilde{c}}}{P^*}}{\frac{P^*_{\tilde{c}}}{P^*}}$. As usual, $\kappa = \frac{(1-\beta\theta)(1-\theta)}{\theta}$.

C Additional figure: Interest rate shock AE

Figure C.1: IRFS TO GLOBAL INTEREST RATE SHOCK IN ADVANCED ECONOMY



Note: IRFs to a 3.3pp positive shock to the world interest rate under alternative policy rules. The results are generated under the calibration shown in Tables 1 and 2. Inflation and interest rates are shown in annualized percent. The nominal and real exchange rates are plotted as $-\hat{e}_t$ and $-\hat{s}_t$ so that an increase corresponds to an appreciation.