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Jakub Mistak, F. Gulcin Ozkan

Asymmetric monetary policy spillovers: the role of supply chains, credit networks and fear of floating

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Abstract

This paper examines the asymmetry in global spillovers from Fed policy across tightening versus easing episodes several examples of which have been on display since the global financial crisis (GFC). We build a dynamic general equilibrium model featuring: (i) occasionally binding collateral constraints in the financial sector with significant cross-border exposure; and (ii) global supply chains, allowing us to match the asymmetry of spillovers across contractionary versus expansionary monetary policy shocks. We find clear asymmetries in the transmission of US monetary policy, with significantly larger spillovers during contractionary episodes under both conventional and unconventional monetary policy changes. Our results also reveal that the greater the size of international credit and supply chain networks and the policymakers' aversion to exchange rate fluctuations in the rest of the world, the greater the spillover effects of US monetary policy shocks.

JEL codes: E52, F41, E44

Keywords: supply chains, capital flows, spillovers, monetary policy, emerging markets

Non-technical summary

The US monetary policy changes have been a major source of fluctuations in much of the rest of the world, particularly since the global financial crisis (GFC) in 2008-09. This has been due to (i) the significant variation in the US monetary policy over this period through both conventional and unconventional tools; (ii) the Fed's central position in the global financial system generating substantial spillovers from US monetary policy to economic activity in other countries. Emerging economies with strong trade and financial linkages with the rest of the global economy have been particularly impacted.

Existing work points to several asymmetries in the transmission of US monetary policy across policy tools, episodes, transmission channels, and recipient country characteristics. This paper, however, shifts the focus to the asymmetrical global spillover effects during tightening versus easing periods, prevalent since the GFC. In doing so, we build a dynamic general equilibrium model featuring: (i) financial frictions in the form of occasionally binding collateral constraints in the financial sector; (ii) cross-border loans extended to intermediate goods producers for purchases of physical capital; and (iii) global supply chains allowing for imported intermediate inputs to be a core part of the production process. By utilizing this framework, we examine spillovers from US monetary policy shocks to a small open economy - calibrated on a sample of emerging economies - across three distinct scenarios mapping to three versions of our model: (i) international trade in final consumer goods only; (ii) trade in final consumer goods and intermediate inputs representing supply chains; and (iii) trade in final goods, supply chains, and credit networks between the two countries.

Our analysis uncovers significant asymmetries in the effects of monetary policy shocks across tightening versus loosening episodes. At the heart of this asymmetry is occasionally binding constraints facing the banking sector. When these balance sheet constraints bind, associated with tightening policy episodes, reduced liquidity magnifies the detrimental impact of monetary contraction, generating a more sizable negative effect on outcomes. In contrast, periods of monetary expansion coincide with loose balance sheet constraints resulting in a moderate impact from expansionary monetary policy changes. Interestingly, the asymmetry in the impact of the expansionary versus contractionary US monetary policy does not only spill across borders, it also magnifies. This is because the balance sheet constraints in the rest of the world aggravate the unfavorable spillover effects from US monetary tightening, further worsening domestic outcomes in these countries. The policy asymmetry across monetary contractions versus expansions prevails under both conventional and unconventional monetary policy changes in the US. We also show that both supply chains and credit networks contribute significantly to the asymmetry in spillovers.

Importantly, our results also reveal that emerging market policymaker's aversion to exchange rate fluctuations plays a major role in aggravating the detrimental effects of US monetary tightening, thus magnifying the asymmetric effects of global monetary policy shocks. We also find that the spillovers are greater (i) the greater the size of financial frictions; (ii) the greater the elasticity of substitution between the domestic and foreign capital; (iii) the greater the substitutability of domestic and foreign inputs; and (iv) the greater the inflation aversion of policymakers in both countries.

Overall, our findings point to the substantial spillovers from US monetary policy shocks to the rest of the world, that are significantly larger in contractionary episodes. Given that extensive global value chains and deepening cross-country financial linkages are key features of the current global economic landscape, the strength of such spillovers is likely to persist. We argue that our model with its detailed specification of both trade and financial linkages as well as a realistic depiction of financial frictions provides a suitable framework for policy analysis for small open economies highly vulnerable to global disturbances.

1 Introduction

The US monetary policy, particularly since the global financial crisis (GFC), has exerted sizable spillover effects on other countries. Given the Fed's central role in the global financial system and its substantial monetary policy response to the two unprecedented crises over this period – GFC and the COVID-19 pandemic – this is not surprising. In the wake of the GFC, the Fed cut interest rates promptly to near zero levels and adopted a host of by-then 'unconventional' monetary policy tools, which were also utilized in responding to the COVID-19 pandemic. More recently, when inflation hit record levels due to post-pandemic pressures and the energy price shocks, the Fed reversed its stance sharply using both conventional and unconventional tools. News about such variation in the US monetary policy is closely followed by policymakers in other countries in anticipation of significant cross-border effects spilling onto the rest of the world.

There are other important factors underlying the size and the significance of global spillovers from the US monetary policy, closely linked to the profound transformation in the global economy in recent decades. Indeed, the emergence of global value chains and deepening cross-country financial connections have fundamentally reshaped the global economic system. One clear implication of this extensive interconnectedness across countries is that any policy shock in systemically important countries reverberates across the global economy. Consequently, spillover effects originating from shocks in central economies such as the US and the eurozone have assumed a central role in shaping domestic dynamics in the rest of the world.

A substantial part of the work on the US monetary policy since the global financial crisis has focused on the size and the shape of its global spillovers, pointing to several asymmetries. For example, stark differences have been observed in the effect of the Fed's and the ECB's policy actions, where the former is significantly greater than the latter (see, for example, Miranda-Agrippino and Nenova, 2022 and Ca'Zorzi et al., 2023). It has also been shown that the effects of US monetary policy have varied across conventional versus unconventional policy actions (Bauer and Neely, 2014; Kolasa and Wesołowski, 2020); announcements versus actual policy changes (Fratzscher et al., 2016); across different policy episodes (Fratzscher et al., 2016); and in advanced versus emerging economies (Georgiadis, 2016; Arezki and Liu, 2020).

Significant attention has also been paid to the characteristics of individual economies exposed to the US-originated monetary policy shocks. Existing empirical evidence points to the variation in trade and financial openness (Georgiadis, 2016; Buch et al., 2019; Degasperi et al., 2020);

exchange rate regimes (Georgiadis, 2016; Degasperi et al., 2020); and frictions in the banking sector (Buch et al., 2019) as sources of that asymmetry in the global effects of US monetary policy.

In this paper, we uncover a different kind of asymmetry in the global spillovers of US monetary policy by examining the transmission of tightening versus easing monetary action by the Fed. Given the several rate cuts and hikes episodes of the Fed since the GFC, combined with the significant exposure to changes in the US monetary policy in the rest of the world, understanding the global effects of both policy stances, in themselves and against each other, is of crucial relevance to policymakers across the globe.[1] As yet, there is very limited empirical evidence on the asymmetry in the spillover effects of monetary policy across expansionary versus contractionary episodes, and what exists reveals mixed findings. For example, while Caggiano et al. (2020) and Tillmann et al. (2019) discover more sizable spillover effects from US policy in contractions relative to expansions, on the outcomes in Canada and a sample of emerging economies, respectively, Eterovic et al. (2022) find larger effects in emerging economies in periods of US rate reductions. To the best of our knowledge, our paper is the first that documents the asymmetry of spillovers across the cycle using a general equilibrium framework.

In doing so, we build a non-linear two-country dynamic stochastic general equilibrium model that incorporates two key components to mirror the current scale and nature of global interconnectedness. The first is international credit networks which we formalize by cross-border loans extended by foreign banks to local intermediate goods producers for purchases of physical capital. This results in financial intermediaries holding assets backed by foreign physical capital, exposing them to fluctuations in foreign asset prices, the return on foreign capital, and the exchange rates. A core feature of the financial sector in the two countries is occasionally binding balance sheet constraints that are tied to banks' leverage levels along the lines of Karadi and Nakov (2021). When bank leverage is below its maximum threshold constraints become non-binding. In this scenario, financial conditions within banks remain loose, rendering unconventional monetary policy through asset purchases (quantitative easing, QE) and sales

[1] Most of the existing empirical work on the effects of monetary policy across easing versus tightening episodes focuses on domestic effects, revealing larger effects during contractionary episodes relative to expansionary ones (see Barnichon and Matthes (2018), Angrist et al. (2018) and Kurt (2024) for evidence from the US and Cloyne and Hürtgen (2016) and Stenner (2022) from the UK for conventional monetary policy shocks). Evidence on the domestic effects of unconventional monetary policy throughout the economic cycle also indicates a greater impact during contractionary periods compared to expansionary ones (see, for example, Rogers et al. (2014) and Lloyd and Ostry (2024), both based on US data).

(quantitative tightening, QT) ineffective. In contrast, when bank leverage reaches its maximum level, the incentive constraint becomes binding, resulting in positive excess returns in equilibrium. In such circumstances, the use of QE and QT alters the degree of slack in financial markets and impacts the pattern of aggregate fluctuations.

Second, our model features a trade network that allows for domestically produced and imported intermediate inputs to be combined with labor and physical capital in the production process in both countries. Cross-border trade in inputs that are used in multiple stages of production represents the global supply chains, which now make up more than 70 percent of global trade (OECD, 2020). Such intensity of cross-border trade linkages is likely to shape the form of global spillovers from monetary policy given the latter's role in exchange rate movements, a key determinant of global trade flows. While the impact of international financial linkages on global monetary policy spillovers has been extensively studied, the role of supply chains in such spillovers is largely ignored in formal work (on the former see, for example, Devereux and Yetman, 2010, Kamber and Thoenissen, 2013, Banerjee et al., 2016, Dedola et al., 2017, Ozkan and Unsal, 2017, Miranda-Agrippino et al., 2020, Kolasa and Wesołowski, 2023 among many others).[2] Our framework with its direct consideration of cross-border input-output linkages allows us to trace the role of supply chain networks in the global transmission of US monetary policy explicitly.[3]

In investigating the global effects of US monetary policy shocks, we specifically focus on the case of emerging market economies (EMs). Underlying this choice is the fact that global shocks are a major source of fluctuations in these economies, often resulting in sudden and significant shifts in cross-country capital and trade flows. Given their high degree of trade openness and significant reliance on external finance EMs are especially exposed to policy shocks in systemically important countries such as the US and the euro area (see, for example, Lane and Milesi-Ferretti, 2012, Akinci, 2013, Chang and Fernández, 2013, Banerjee et al., 2016, Rey, 2016, Tillmann, 2016 among many others). The substantial body of empirical work studying the effects of US monetary policy changes on EMs has considered; channels of transmission (Bruno

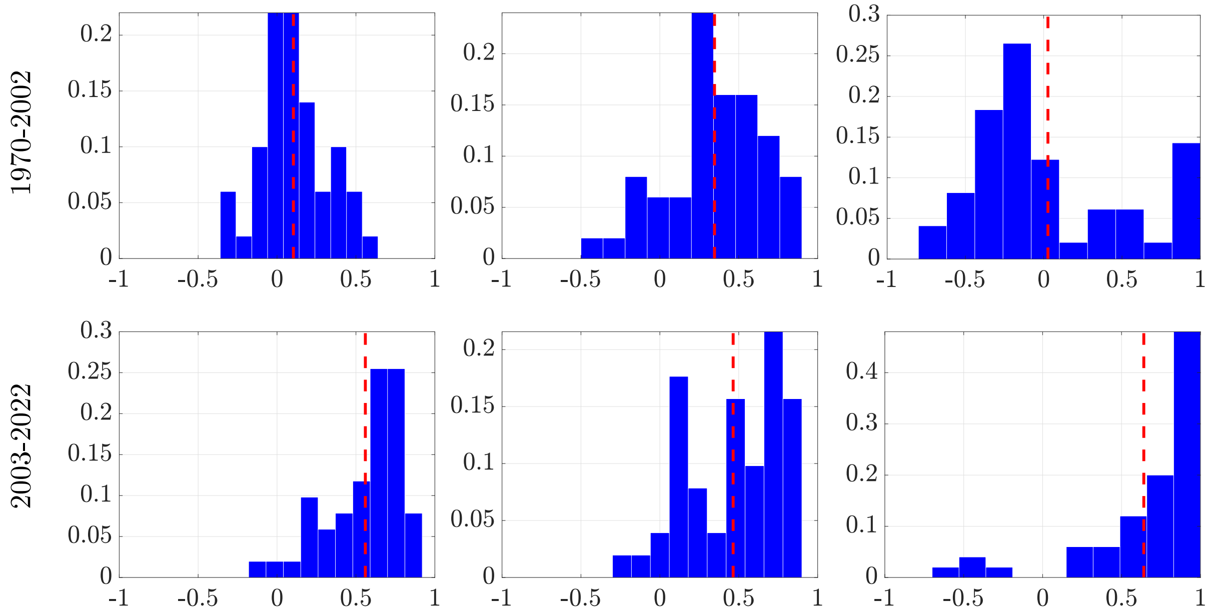
[2]This is in contrast to the mounting empirical evidence on the role of supply chains in the global monetary policy spillovers (see, for example, Auer et al., 2017, Kolasa and Wesołowski, 2020, Miranda-Agrippino and Rey, 2020 and Di Giovanni and Hale, 2022 among others).

[3]The two existing studies that examine the implications of global supply chains for optimal monetary policy analyse the case of domestic monetary policy not its international spillovers. It is shown that in the presence of strong supply chains, it is welfare-improving to follow PPI-based Taylor rules especially when the supply chains are long and the price stickiness in the intermediate goods sector is high (Gong et al., 2016 and Wei and Xie, 2020).

and Shin, 2015, Anaya et al., 2017, Fratzscher et al., 2018); endogeneity of policy (Tillmann, 2016); asymmetry in effects in the domestic (US) economy versus on the rest of the world (Georgiadis, 2016); effects of conventional versus unconventional US monetary policy changes (Kolasa and Wesołowski, 2023); and effects of conventional monetary policy tightening shocks and their spillovers in the presence of occasionally-bonding financial constraints (Caldara et al., 2024).

The interconnectedness between US and EMs is portrayed in Figure 1 in the form of bilateral correlations in GDP growth, inflation, and bank deposits across a group of 51 emerging economies and the US over 1970-2022, organized over two sample periods with mean correlations denoted by the dashed red line.

Figure 1: Distribution of cross-country correlations of GDP growth, inflation, and bank deposits.



(i) GDP growth (ii) Inflation (iii) Bank deposits

Source: World Development Indicators, Global Financial Development.

Comparing the two periods, 1970-2002 as displayed in the first row with 2003-2022 in the second row, points to a sharp rise in cross-country correlations across all three outcomes between the two periods. For example, the mean correlation of 0.1 in GDP growth in the earlier period, as is seen in the top left panel of Figure 1, sharply contrasts with the substantially higher 0.56 in the latter period in the bottom left panel. The surge in the correlation in bank deposits is even more stark; with a drastic rise from 0.03 to 0.64 between the two periods. While larger and more frequent common shocks in the later period may offer some explanation, the greater spillovers from country-specific shocks and the associated systematic responses by central banks in systemic economies could play a non-trivial role in shaping these dynamics.

We therefore calibrate our model using data from the US and a sample of emerging economies, ensuring a clear distinction between the two model blocks. Of particular significance is the EM's greater reliance on imported capital, a major source of exposure to variation in the exchange rate, foreign prices of capital, and financial conditions abroad. We also explicitly consider the EM policymakers' well-documented aversion towards exchange rate fluctuations. To capture this, we employ a modified Taylor rule that responds to changes in the nominal exchange rate, as suggested by Garcia et al. (2011) and Ghosh et al. (2016), among others. We then formally examine the global effects of equal-sized monetary policy tightening and expansion in the US by tracing the impact of each policy shock on the outcomes in the domestic emerging economy.

Our analysis yields a number of findings with important policy implications in an increasingly interconnected world. First, we show that there are significant asymmetries in the international spillovers from interest rate hikes versus interest rate cuts in the US. A US monetary contraction delivers a significantly larger deterioration in emerging economies relative to the improvement from a monetary expansion of the same size. Such an asymmetry in the impact of US monetary policy arises from the occasionally binding constraints facing banks in the two countries which are slack during expansions, leading to a smaller effect from any policy action. In contrast, during contractions, binding collateral constraints exacerbate the negative impact of policy on the aggregate demand and output in the US, with subsequent detrimental effects on other countries. Moreover, given that the financial sector in the emerging economy also faces binding constraints their policymakers face a double whammy during contractions working through both trade and financial channels. EM real activity contracts as a result of (i) lower demand for EM exports owing to the fall in US output; (ii) a drop in US bank credits resulting in lower EM capital. Importantly, the policy asymmetry across monetary contractions versus expansions prevails under both conventional and unconventional monetary policy changes in the US. We also show that both supply chains and credit networks contribute significantly to the asymmetry in spillovers.

Interestingly, our results also reveal that EM policymaker's aversion to exchange rate fluctuations - widely referred to as fear of floating - plays a major role in aggravating the negative effects of US monetary contractions, thus magnifying the asymmetric effects of global effects of monetary policy. This is because the appreciation (depreciation) of the US dollar (EM currencies) following a US rate hike improves the competitiveness of the EM economy and works towards partially compensating the unfavorable effects of the US monetary contraction. However, when the EM policymakers raise their interest rates to limit the loss in the value of the domestic currency this channel is muted, worsening the effects of US interest rate hikes on EM outcomes.

The remainder of this paper is structured as follows: Section 2 presents the two-country model with supply chain and financial linkages between countries. Section 3 outlines a detailed parametrization of the model. Section 4 explores the effects of both contractionary and expansionary US monetary policy shocks under the following three scenarios building up our two-country setting iteratively: (i) trade in final consumer goods only; (ii) trade in both consumer goods and intermediate inputs; and (iii) trade in both final and intermediate goods and cross-border financial credit networks. Section 4 also includes an explicit consideration of EM policymakers' aversion to exchange rate fluctuations and how this shapes the global monetary policy spillovers. In Section 5 we subject our results to a battery of sensitivity and robustness checks. Finally, Section 6 provides concluding remarks.

2 The model economy

We build a two-country model with significant interconnectedness between the two economies, developing our framework in two blocks; one for each country. Of the two, the first - domestic - is modeled as a small open emerging economy; and the second one - foreign - exemplifies the US as a large country with a dominant role in both global trade and finance.

Each economy is populated by households, competitive retailers, monopolistically competitive intermediate goods producers, capital goods producers, banks, and a government implementing monetary and fiscal policies. We incorporate nominal rigidities along the lines of Calvo (1983) by allowing intermediate goods producers to adjust prices in a staggered manner. We build on Garcia-Lazaro et al. (2021) and introduce financial frictions of the type used by Karadi and Nakov (2021) wherein financial markets are frictionless under loose credit conditions that prevail when the banks' leverage remains below its maximum. Once the leverage ratio reaches its maximum level, the constraint becomes binding, resulting in the emergence of positive excess returns on corporate and government bonds. Banks hold deposits and, akin to households, purchase long-term bonds from the local government. We also explicitly account for cross-border capital flows allowing banks to purchase corporate long-term bonds from both domestic and foreign intermediate goods producers.

In what follows, we provide a detailed description of the model for the domestic economy where we use asterisk for variables associated with the foreign country, when necessary. Unless otherwise specified, the model structures of the two countries mirror each other. Details of the optimization problems and supplementary material are provided in Appendix A.

2.1 Households

Households derive utility from consumption C_t and disutility from hours worked H_t, as given by:

$$\max_{C_t, H_t, B_t, B_{h,t}} \mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \left[log\left(C_{t+k} - hC_{t+k-1}\right) - \vartheta \frac{{H_{t+k}}^{1+\varphi_h}}{1+\varphi_h} \right] \tag{1}$$

where $0 < \beta < 1$ is the discount factor, h the habit persistence parameter, $\vartheta > 0$ the disutility from supplying labor to intermediate goods producers, $\varphi_h > 0$ the inverse of the Frisch elasticity of labor supply, and $\mathbb{E}_t$ denotes the expectations operator.

Households' utility maximization, as defined by equation (1), is subject to a sequence of intertemporal budget constraints in the following form:

$$C_t + B_t + B_{h,t} = W_t H_t + R_{b,t} B_{h,t-1} - \frac{1}{2}\kappa \left(B_{h,t} - \bar{B}_h\right)^2 + R_t B_{t-1} + \Pi_t \tag{2}$$

where B_t denotes government-issued short-term bonds and bank deposits both of which are risk-free and perfect substitutes, $B_{h,t}$ denotes long-term bonds, W_t is the real wage, $R_{b,t}$ and R_t represent returns on long-term and short-term bonds, respectively (with the latter being the risk-free rate), $\bar{B}_h$ is the steady-state value of long-term bonds held by households, and $\kappa \geq 0$ governs the sensitivity of the quadratic transaction cost associated with purchases or sales of long-term bonds, and Π_t denotes real profits from the ownership of firms.[4]

Maximization of (1) subject to (2) yields the following expressions for marginal utility with respect to consumption (equation 3), optimal labor supply (equation 4), Euler equation for optimal short-term asset holdings (equation 5), and optimal long-term bond holdings (equation

[4]The price of long-term government bonds is linked to the rate of return as in $R_{b,t+1} = (\Xi + \varrho q_{t+1})/q_t$, where q_t denotes the unit price of domestic government long-term bonds with coupon payments Ξ and rate of decay $0 < \varrho < 1$.

6):

$$\varrho_t = (C_t - hC_{t-1})^{-\sigma_c} - \beta h \mathbb{E}_t (C_{t+1} - hC_t)^{-\sigma_c} \tag{3}$$

$$\chi H_t^{\varphi} = \varrho_t W_t \tag{4}$$

$$1 = \mathbb{E}_t \Big[\Lambda_{t,t+1} R_{t+1} \Big] \tag{5}$$

$$B_{h,t} = \bar{B}_h + \kappa^{-1} \mathbb{E}_t \Big[\Lambda_{t,t+1} (R_{b,t+1} - R_{t+1}) \Big] \tag{6}$$

where $\Lambda_{t,t+1} \equiv \beta \frac{\varrho_{t+1}}{\varrho_t}$ represents the discount factor.

Households consume both domestically produced, $C_{h,t}$, and imported goods, $C_{f,t}$. Aggregate consumption of households can therefore be expressed as:

$$C_t = \left[\gamma_c^{\frac{1}{\varepsilon_c}} (C_{h,t})^{\frac{\varepsilon_c - 1}{\varepsilon_c}} + (1 - \gamma_c)^{\frac{1}{\varepsilon_c}} (C_{f,t})^{\frac{\varepsilon_c - 1}{\varepsilon_c}} \right]^{\frac{\varepsilon_c}{\varepsilon_c - 1}} \tag{7}$$

where $0 < \gamma_c < 1$ represents the share of domestically produced goods in total consumption where $\varepsilon_c > 1$ is the elasticity of substitution between locally produced and imported consumer goods.

2.2 Producers

2.2.1 Intermediate goods producers

The production of the intermediate good by a representative producer v is governed by the Leontief technology combining labor $H_t(v)$, capital $K_t(v)$, and intermediate inputs $XS_t(v)$, as follows:

$$X_t(v) = \min \left[\frac{K_t(v)^{\alpha} H_t(v)^{1-\alpha}}{1 - \varphi_s}, \frac{XS_t(v)}{\varphi_s} \right] \tag{8}$$

where $0 < \varphi_s < 1$ is the share of intermediate inputs in technology and $0 < \alpha < 1$ is the share of capital in value added.

Capital $K_t(v)$, at both the individual producer and aggregate levels, is composed of local capital $K_{h,t}(v)$ and imported capital $K_{f,t}(v)$ where Z_t denotes the price of the former and Z_t^* the price of the latter denominated in foreign currency, common to all intermediate goods producers. Capital used in the production of intermediate goods is, therefore, given by:

$$K_t(v) = \left[\gamma_k^{\frac{1}{\varepsilon_k}} (K_{h,t}(v))^{\frac{\varepsilon_k - 1}{\varepsilon_k}} + (1 - \gamma_k)^{\frac{1}{\varepsilon_k}} (K_{f,t}(v))^{\frac{\varepsilon_k - 1}{\varepsilon_k}} \right]^{\frac{\varepsilon_k}{\varepsilon_k - 1}} \tag{9}$$

where $0 < \gamma_k < 1$ is the share of local capital in aggregate capital used for production of intermediate goods and $\varepsilon_k > 0$ is the elasticity of substitution between local and imported capital.

Similarly, producers utilize a composite index of intermediate inputs, $XS_t(v)$, made up of supplies by local retailers $XS_{h,t}(v)$ and imported supplies $XS_{f,t}(v)$, combined in the following form:

$$XS_t(v) = \left[{\gamma_s}^{\frac{1}{\varepsilon_s}} \left(XS_{h,t}(v) \right)^{\frac{\varepsilon_s - 1}{\varepsilon_s}} + (1 - \gamma_s)^{\frac{1}{\varepsilon_s}} \left(XS_{f,t}(v) \right)^{\frac{\varepsilon_s - 1}{\varepsilon_s}} \right]^{\frac{\varepsilon_s}{\varepsilon_s - 1}} \tag{10}$$

where $0 < \gamma_s < 1$ represents the share of domestically produced supplies in the total use of supplies and $\varepsilon_s > 0$ is the Armington elasticity of substitution between local and imported inputs.

Given the properties of the Leontief specification, cost minimization requires that output be produced using constant shares of each input. This implies that both the value-added and intermediate inputs constitute a fixed share of the output, given respectively by $(1 - \varphi_s)$ and φ_s:

$$K_t(v)^{\alpha} H_t(v)^{1-\alpha} = (1 - \varphi_s) X_t(v) \tag{11}$$

$$XS_t(v) = \varphi_s X_t(v) \tag{12}$$

The first-order conditions yield the following optimal use of labor and capital in technology by the representative producer:

$$H_t(v) = (1 - \varphi_s) \left[\frac{1-\alpha}{\alpha} \frac{Z_t}{W_t} \right]^{\alpha} X_t(v) \tag{13}$$

$$K_t(v) = (1 - \varphi_s) \left[\frac{\alpha}{1-\alpha} \frac{W_t}{Z_t} \right]^{1-\alpha} X_t(v) \tag{14}$$

where W_t and Z_t are unit prices of labor and capital inputs, respectively, common to all intermediate goods producers.

Expressing the cost function of intermediate goods producers in optimal values of labor, capital, and intermediate inputs, as given by equations (12) - (14), and weighting them according to their respective shares in technology yields the following real marginal cost:

$$mc_t(v) = (1 - \varphi_s) \frac{Z_t^{\alpha} W_t^{1-\alpha}}{\alpha^{\alpha} (1-\alpha)^{1-\alpha}} + \varphi_s P_t^s \tag{15}$$

where P_t^s denotes the unit price of a basket of domestic and imported intermediate goods, which can be thought of as the Producer Price Index (PPI) in this setting.

All intermediate goods producers operate in a monopolistically competitive market structure and only update their prices with a constant probability $0 < (1 - \theta_p) \leq 1$ along the lines of Calvo (1983). This suggests that, on average, prices cannot be updated for $1/(1 - \theta_p)$ periods. Firms that cannot reoptimize in a given period keep their price from the previous period $t - 1$.

2.2.2 Capital goods producers

Similar to Christiano et al. (2005), Fernández-Villaverde (2010) and Jarociński and Karadi (2020), capital goods producers incur a quadratic investment adjustment cost per unit of investment I_t, as given by:

$$f\left(\frac{I_t}{I_{t-1}}\right) \equiv \frac{\eta_i}{2}\left[\frac{I_t}{I_{t-1}} - 1\right]^2 \tag{16}$$

where $\eta_i > 0$ is the adjustment cost parameter.

Capital producers choose their optimal investment by maximizing the present discounted profits as follows:

$$\max_{I_t} \mathbb{E}_t \sum_{t=0}^{\infty} \Lambda_{t,t+1}\left[Q_t I_t - \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t\right] \tag{17}$$

where Q_t is the price of an asset that finances the purchase of a unit of physical capital.

The optimality condition results in the following Q-investment relation for capital goods:

$$Q_t = 1 + \frac{\eta_i}{2}\left[\left(\frac{I_t}{I_{t-1}}\right) - 1\right]^2 + \eta_i\left[\frac{I_t}{I_{t-1}} - 1\right]\frac{I_t}{I_{t-1}} - \mathbb{E}_t\left[\Lambda_{t,t+1}\eta_i\left[\frac{I_{t+1}}{I_t} - 1\right]\left(\frac{I_{t+1}}{I_t}\right)^2\right] \tag{18}$$

Given that capital goods producers produce and refurbish capital goods used in the production of intermediate goods, the aggregate capital stock is determined by the following law of motion equation:

$$K_{t+1} = I_t\left[1 - f\left(\frac{I_t}{I_{t-1}}\right)\right] + (1 - \delta)K_t \tag{19}$$

where $0 < \delta < 1$ denotes the rate at which capital depreciates.

The return on physical capital that results from the intermediate goods producers' optimal demand for physical capital backed by financial assets is:

$$R_{k,t+1} = \frac{[Z_{t+1} + (1 - \delta)Q_{t+1}]}{Q_t} \tag{20}$$

In financing their investment, intermediate goods producers secure loans from banks to acquire physical capital from capital goods producers. At the end of each period, new capital is acquired at a price Q_t, resulting in the issuance of a claim for each unit acquired. Consequently, assets within the banking sector are backed by physical capital utilized in the production process. Importantly, a certain proportion of intermediate goods producers opt to borrow from foreign banks instead of engaging in local borrowing, with clear implications for the response of the domestic economy to global disturbances.

2.3 Banks

Banks extend loans to both local intermediate goods producers and those abroad, hence, their portfolio contains corporate bonds backed partially by local capital and partially by capital abroad. Specifically, one type of corporate bond is backed by physical capital used in the production of intermediate goods locally $S_{h,t-1} = K_{h,t}$, while another type is backed by physical capital used in production abroad $S_{f,t-1} = K^*_{h,t}$. Banks also hold long-term bonds issued by the local government, $B_{b,t}$.

The liabilities part of the banks' balance sheet is composed of households' deposits, D_t, and net worth, N_t. Apart from holding long-term bonds, financial intermediaries diversify their asset portfolio by securing financial assets backed by physical capital utilized by both domestic and foreign intermediate goods producers:

$$Q_t S_{h,t} + e_t Q^*_t S_{f,t} + q_t B_{b,t} = N_t + D_t \tag{21}$$

where e_t denotes the exchange rate expressed as the amount of domestic currency per unit of foreign currency; Q^*_t the price of foreign capital denominated in the foreign currency; $B_{b,t}$ banks' holding of long-term government bonds where q_t is the unit price of those bonds.

Net worth evolves according to the following:

$$\begin{aligned} N_t = &\left(R_{k,t} - R_t\right) Q_{t-1} S_{h,t-1} + \left(e_t R^*_{k,t} - e_{t-1} R_t\right) Q^*_{t-1} S_{f,t-1} \\ &+ \left(R_{b,t} - R_t\right) q_{t-1} B_{b,t-1} + R_t N_{t-1} + J_{t-1} \end{aligned} \tag{22}$$

where $R^*_{k,t}$ is the return on capital in the foreign economy and J_t represents the issuance of equity.

The end-of-period value function, considering the issuance of new equity J_t conditional on the survival of the bank, is:

$$\mathcal{V}_t(N_t) = \max_{S_{h,t},S_{f,t},J_t,D_t} \mathbb{E}_t\Big[\Lambda_{t,t+1}\Big[\ (1-\theta_b)N_{t+1} + \theta_b\Big(\mathcal{W}_{t+1}(N_{t+1}) - J_t - C(J_t,N_t)\Big)\ \Big]\Big] \tag{23}$$

where $0 < \theta_b < 1$ is the survival rate of banks; $\mathcal{W}_t$ is the beginning-of-period bank value; and the cost of equity issuance $C(J_t, N_t) \equiv \zeta/2\xi_t^2 N_t$ is linear in the banks' net worth N_t, quadratic in the share of new equity issuance relative to outstanding equity $\xi_t \equiv J_t/N_t$ and its level is governed by the parameter $\zeta > 0$, disincentivizing the bank from large equity issuance.

The bank's capacity to attract deposits is constrained by the risks perceived by depositors of the potential for the bank to divert a fraction, denoted as $0 < \theta < 1$, of its funds from its assets to the household that owns the bank. The risk with such fund diversion arises from the depositors' ability to force the bank into bankruptcy, enabling them to recover the residual portion of assets. We also assume that the bank finds it more feasible to divert funds from its private than government bond portfolio, given by a fraction, respectively, of θ and $\Gamma\theta$, where $0 < \Gamma < 1$.

Consequently, the bankers' optimization problem is to choose $S_{h,t}$, $S_{f,t}$, and $B_{b,t}$ to maximize $\mathcal{V}_t(N_t)$ subject to the following incentive constraint:

$$\mathcal{V}_t(N_t) \geq \theta Q_t S_{h,t} + e_t Q_t^* S_{f,t} + \Gamma\theta q_t B_{b,t} \tag{24}$$

and to choose its equity issuance J_t to maximize $\mathcal{W}_{t+1}(N_{t+1})$ subject to the evolution of net worth given by equation (22); maintaining the existence of a linear solution of the form $\mathcal{V}_t = \mu_{s,t}\left(Q_t S_{h,t} + e_t Q_t^* S_{f,t}\right) + \mu_{b,t} q_t B_{b,t} + \nu_t N_t$ and $\mathcal{W}_t = \eta_t N_t$. The left-hand side of (24) represents what the banker would lose by diverting assets, while the right side is the gain from doing so.

The solution to the banker's optimization problem can be characterized as follows: at the end of each period, an individual bank maximizes the present value of its future dividends given the quadratic cost of equity issuance.

$$\begin{aligned}
\mathcal{V}_t(N_t) = \max_{S_{h,t},S_{f,t},J_t,D_t} \mathbb{E}_t\Big[\Lambda_{t,t+1}\Big[\ (1-\theta_b)N_{t+1} + \theta_b\mathcal{W}_{t+1}(N_{t+1}) - J_t - \tfrac{\zeta}{2}\tfrac{J_t^2}{N_t}\ \Big]\Big] \\
\text{s.t.}\quad \mathcal{V}_t(S_{h,t}, S_{f,t}, B_{b,t}, N_t) \geq \theta\left(Q_t S_{h,t} + e_t Q_t^* S_{f,t}\right) + \Gamma\theta q_t B_{b,t} \\
\text{for}\quad N_{t+1} = \left(R_{k,t+1} - R_t\right) Q_t S_{h,t} + \left(e_{t+1} R_{k,t+1}^* - e_t R_t\right) Q_t^* S_{f,t} \\
+ \left(R_{b,t+1} - R_t\right) q_t B_{b,t} + R_{t+1} N_t + J_t
\end{aligned} \tag{25}$$

It follows from the banks' optimization in (25) that cross-border lending has important implications for the model dynamics. The expected excess returns on banks' domestic corporate bonds satisfies $\mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}\left(R_{k,t+1}-R_t\right)\right]=\theta\lambda_t$ while $\mathbb{E}_t\left[\Lambda_{t,t+1}\Omega_{t+1}\left(e_{t+1}/e_t R^*_{k,t+1}-R_t\right)\right]=\theta\lambda_t$ describes the condition corresponding to the expected excess returns on foreign corporate bonds. Therefore, a crucial assumption underpinning these dynamics is the alignment between the anticipated changes in the real exchange rate and the anticipated return to domestic relative to foreign capital, ensuring the Uncovered Interest Parity (UIP) condition:

$$\frac{\mathbb{E}_t(e_{t+1})}{e_t}=\frac{\mathbb{E}_t(R_{k,t+1})}{\mathbb{E}_t(R^*_{k,t+1})} \tag{26}$$

It is maintained that the cost of equity is paid regardless of whether a bank survives or not. The first-order condition with respect to the cost of equity issuance J_t is $\xi_t=\mathbb{E}_t\Lambda_{t,t+1}(\Omega_{t+1}-1)/\zeta$, which suggests that equity issuance increases with the expected profitability of the bank, particularly during periods of tight credit conditions and elevated excess premia.

Let ν_t be the marginal value of banks' net worth. Given the first-order conditions of the optimization problem of banks, we arrive at the following value for the multiplier λ_t, which determines how tightly the incentive constraint binds:

$$\lambda_t=\max\left[0;1-\frac{\nu_t}{\theta\phi_t}\right] \tag{27}$$

where ϕ_t is the banks' leverage, the ratio of the banks' portfolio relative to net worth, as given by:

$$\phi_t=\frac{Q_tS_{h,t}+e_tQ^*_tS_{f,t}+\Gamma q_tB_{b,t}}{N_t}\leq\bar{\phi}_t \tag{28}$$

The incentive constraint places an occasionally binding constraint on the banks' leverage ratio by limiting the portfolio size so that ϕ_t does not exceed its maximum level $\bar{\phi}_t$:

$$\bar{\phi}_t=\frac{\mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}R_{t+1}}{\theta\mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\big(R_{k,t+1}-R_{t+1}\big)}=\frac{\mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}R_{t+1}}{\theta\mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\big(e_{t+1}/e_tR^*_{k,t+1}-R_t\big)} \tag{29}$$

When banks' balance sheet constraints are loose ($\phi_t<\bar{\phi}_t$), central bank asset purchases are ineffective. In such instances, the lending volume to intermediate goods producers is determined by a no-arbitrage condition, where the expected excess returns on corporate assets equal zero.[5]

[5] No arbitrage conditions for the domestic and foreign corporate bonds are given, respectively, by $\mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\big(R_{k,t+1}-R_{t+1}\big)=0$; and $\mathbb{E}_t\Lambda_{t,t+1}\Omega_{t+1}\big(e_{t+1}/e_tR^*_{k,t+1}-R_t\big)=0$.

The effectiveness of the policy can be restored if banks are affected by a shock or if the central bank sells a significant portion of the long-term bonds it holds, inducing the banks' collateral constraints to bind.

2.4 Monetary and fiscal authorities

In the benchmark case, monetary policy is formulated according to a standard Taylor rule, which implies that the deviations of the nominal risk-free interest rate r_t from its deterministic steady state r respond to the deviations of inflation π_t and output X_t from their deterministic steady-state values, π and X, respectively, allowing for interest rate smoothing:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi}\right)^{\varphi_\pi} \left(\frac{X_t}{X}\right)^{\varphi_x}\right]^{1-\rho_r} exp(\sigma_{r,t}) \tag{30}$$

where $0 \leq \rho_r \leq 1$ is the smoothing parameter; $\varphi_\pi > 0$ describes the central bank's weight on the deviations of inflation; $\varphi_x > 0$ describes the central bank's weight on the deviations of output; and $\sigma_{r,t}$ is the conventional monetary policy shock in the form of a one-off innovation to the risk-free rate with a zero mean.

In both countries, the relation between the nominal interest rate r_t and the real rate R_t is determined by the following Fisher equation:

$$r_t = R_t \pi_{t+1} \tag{31}$$

Given that our focus in this paper is on monetary policy and its global spillovers, we adopt a simple form of fiscal policy where the government spends a fixed share of τ on local goods, i.e. $G = \tau X$.

2.5 Market clearing conditions

The government issues short-term and long-term bonds. Aggregate long-term bonds are at the fixed quantity, B, at all times. Long-term government bonds held by the central bank $B_{g,t}$ are fixed exogenously. The higher the share of bonds held by the central bank the lower the share of debt held by banks and households. The clearing condition of long-term bonds held by the central bank, households, and banks is:

$$B = B_{g,t} + B_{h,t} + B_{b,t} \tag{32}$$

In our quantitative analysis, following Karadi and Nakov (2021), we simulate unconventional monetary policy action by using shocks to the balance sheet of the domestic monetary authority. The size of the balance sheet as a proportion of annual GDP is given by:

$$BS_t \equiv \frac{q_t B_{g,t}}{4 \times X} \tag{33}$$

where BS_t follows an AR(1) process with persistence, $0 \leq \rho_b < 1$, and a zero-mean uncorrelated innovation, $\sigma_{b,t}$, with standard deviation, σ_b. An expansionary monetary policy action through a rise in the total value of long-term bonds held by the monetary authority corresponds to large asset purchase programs in practice, widely known as quantitative easing (QE). Conversely, a negative shock to BS_t represents quantitative tightening (QT).

Finally, goods market clearing conditions can be stated as:

$$X_t = C_{h,t} + C^*_{h,t} + XS_{h,t} + XS^*_{h,t} + G + I_t \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] + \frac{\zeta}{2}\xi_t^2 N_t \tag{34}$$

indicating that total domestic output equals the sum of the demands from local and foreign consumers, intermediate goods producers in both countries, demand from the local government, investment demand from domestic firms adjusted for investment adjustment cost, and the cost of new equity issuance.

3 Calibration

In this section, we outline the parameterization of the model. Given our interest in studying the transmission of globally important policy shocks, we calibrate the foreign economy using data from the US. In turn, EM is calibrated to a sample of emerging economies the choice of which is dictated by data availability, particularly regarding input-output variation. Our resulting sample of EM countries is composed of Brazil, Bulgaria, China, Croatia, Hungary, Indonesia, Mexico, Poland, Romania, Russia, and Turkey. We adhere to the established convention of aligning the model's parameters with several key steady-state ratios observed in the data.

A subset of these parameters are set to standard values, while others are informed by estimates specific to the US and EMs in the existing literature. To capture supply chain networks accurately, we derive relevant parameters from the 2016 World Input-Output Database (WIOD). Additionally, our calibration of the credit network draws upon data from the Quarterly Public Sector Debt Database (QPSD) provided by the World Bank and the Coordinated Portfolio Investment Survey (CPIS) of the International Monetary Fund (IMF).

We present the specific structural parameter values for each model configuration in Table 1. In what follows, we set out how individual parameter values are chosen in our calibration for each set of agents as well as provide details of the shock processes we utilize in our simulations.

3.1 Households

In both the US and the EM, we set the discount parameters β to 0.995, corresponding to a steady-state risk-free annualized quarterly interest rate of 2%. The inverse of the Frisch elasticity of labor supply, denoted as φ_h, is set at 2.45 for the US, following Smets and Wouters (2005), and at 1.6 for EM, in line with Chang and Fernández (2013). We set parameters describing habit persistence in consumption h at 0.68 for the US, following Smets and Wouters (2007), and at 0.85 for EM, based on estimates in Jin et al. (2022). Labor disutility parameters ϑ are fixed to match labor demand with labor supply in the steady state.

We set the steady-state inflation π at unity and maintain that coupons of long-term bonds held by households decay exponentially at a rate of ϱ. In the US, ϱ is set to 0.974, resulting in an average bond duration of 7.5 years, as in Chen et al. (2012). Following Dvorkin et al. (2021), the average maturity of long-term bonds in emerging markets is set at 3.43 years, implying a value of 0.936 for ϱ for long-term EM bonds. Lastly, coupon payments of long-term bonds Ξ are set at 0.0359, as in Karadi and Nakov (2021).

In the non-stochastic steady state, short-term bonds in both countries are in zero quantities, while the quantities of long-term bonds are calibrated to match the shares of long-term bonds to GDP, based on the Quarterly Public Sector Debt (QPSD) data from the World Bank. We find that the steady-state ratio of long-term debt maturing in one year or longer represents 105.85% of US GDP and 34.25% of EM GDP. In our model, households hold three-quarters of long-term bonds in the steady state, with financial intermediaries holding the remaining share, consistent with Karadi and Nakov (2021).

To calibrate the key parameters of households' consumption baskets, we leverage data from the World Input-Output Database (WIOD), as in Timmer et al. (2015). This calibration enables us to dissect aggregate consumption in each country by its countries of origin. In the EM, domestic consumer goods account for 97.25% of total households' consumption. In contrast, in the US, this parameter representing home bias stands at 92.5%, signaling a relatively greater reliance of US households on EM-produced consumer goods. Consequently, we maintain that 2.75% of EM consumer goods originate from the US, while 7.5% of goods consumed by US households are of EM origin. The elasticity of substitution between domestic and foreign consumer goods ε_c is set at 1.5, consistent with Monacelli (2004).

3.2 Producers

The calibration of labor shares in output, α, in both the US and EM are based on the steady-state ratios of investment to GDP and are set at 0.3 and 0.33, respectively. Correspondingly, the shares of intermediate inputs in output, represented by φ_s, are set at 0.44 for the US and 0.61 for EM, relying on data sourced from the WIOD.

Leveraging data from WIOD, we calibrate the supply chain parameters, specifying the breakdown of aggregate intermediate input utilization in each country by the countries of origin. In the EM, domestic inputs constitute a substantial 96.04% of total intermediate inputs. In contrast, in the US, this parameter, symbolizing home bias in the real sector, registers at 89.96%, indicating a relatively greater reliance on EM-produced supplies in the US economy. This prompts us to conclude that 3.96% of EM intermediate inputs originate from the US, while 10.04% of the supplies used by the US intermediate goods producers are of EM origin. The elasticity of substitution between domestic and foreign supplies ε_s is set equal to the corresponding elasticity of substitution between domestic and imported consumer goods ε_c.

In addition to mapping the supply chain linkages, we incorporate a credit network in our model that mirrors the financial interdependence between the two countries. The steady-state shares of domestic versus foreign credit have been derived from the World Bank's QPSD and the IMF's Coordinated Portfolio Investment Survey (CPIS). Based on QPSD, we find that 71.37% of the US total long-term credit is domestic and the rest, 28.63%, is foreign. CPIS suggests that 11.45% of US foreign creditors come from EMs. Consequently, we maintain that in our model 96.72% of US aggregate capital is domestic and the rest is of EM origin. Similarly, we set EM long-term domestic debt at 81.83% and foreign debt at 18.17%. US creditors represent 35.56% of all EM foreign creditors. This suggests that 93.54% of EM capital is domestic and

6.46% is capital originated in the US. Following Leblebicioğlu and Weinberger (2021), we set the elasticity of substitution between domestic and foreign physical capital, ε_k, at 1.85.

The elasticity of substitution between intermediate goods, η, reflects the extent of retailers' monopoly power. The markups in each country are calculated using data from Compustat on the ratio of net profits - measured as the difference between net sales and cost of goods sold. Accordingly, η values are computed as the inverse of these markups, weighted by net sales of each listed firm, yielding values of 5.73 and 7.66 for the US and EM, respectively, aligning with markups of 17.45% and 13.05%.

In the US, the Calvo parameter is set at 0.81, in line with Smets and Wouters (2005), corresponding to an average price resetting period of approximately 21 months. Following Chen et al. (2023), this value is set at 0.84 for the EM, implying that EM firms adjust prices at an average interval of 25 months. Notably, both countries exhibit relatively high Calvo parameters.

The depreciation rate, δ, is set at the standard value of 0.025, in accordance with Faia and Monacelli (2007), indicating an annual capital depreciation rate of 10%. The investment adjustment cost parameter, denoted as η_i, is set at 5 in the US, similar to Smets and Wouters (2005), and 3.6 in EM, as per Elekdag and Alp (2011).

3.3 Banks

The calibration of banks in our model is based on broadly similar parameters for the two countries, with differences in the duration of long-term bonds, leverage ratios, and variations in steady-state financial asset values. These parameters are drawn from the framework outlined in Karadi and Nakov (2021). Importantly, banks' balance sheet constraints are loose in the non-stochastic steady state, leading to banks' equity exceeding the demand for credit. This implies that central banks have no incentive to hold long-term bonds in the steady state, and lending spreads are zero in both countries.

The survival rate of banks, represented by σ, is set at 0.972 in both the US and EM, corresponding to an average expected longevity of banks of 10 years. The fraction of divertable funds, denoted as θ, is 0.167 in the US, implying a bank leverage of 6. In EM, a higher leverage of 8.5 is adopted, resulting in a value of θ of 0.118. Transfers to entering bankers, symbolized as ω, are structured in such a way that interest rate premia are set at zero in both countries. The relative absconding rate of government debt relative to private assets, expressed as Γ, is set at 0.83. Household portfolio adjustment costs, denoted as κ, take a value of 0.009. In both the US

Table 1: Calibrated parameters.

Parameter		US	EM	Source
Households				
Discount factor	β	0.995	0.995	Assumption
Inverse Frisch elasticity	φ_h	2.450	1.600	SW05; CF13
Habit persistence	h	0.680	0.850	SW07; JK22
Labor disutility	ϑ	60.56	38.44	Target value
Geometric decay	ϱ	0.974	0.936	CC12; DS21
Coupon	Ξ	0.036	0.036	KN21
Share of local goods	γ_c	0.925	0.973	WIOD
e.o.s. domestic and foreign goods	ε_c	1.500	1.500	MO04
Producers				
Labor share	α	0.300	0.330	Target value
Share of supplies	φ_s	0.440	0.610	WIOD
Share of local supplies	γ_s	0.900	0.960	WIOD
Share of local capital	γ_k	0.967	0.935	BIS and IMF
e.o.s. intermediate inputs	ε_r	5.730	7.660	Compustat
e.o.s. domestic and foreign supplies	ε_s	1.500	1.500	MO04
Calvo parameter	θ_p	0.810	0.840	SW07; CK23
Depreciation rate	δ	0.025	0.025	FM07
Investment adjustment cost	η_i	5.000	3.600	SW05; EA11
Financial intermediaries				
Survival rate of banks	σ	0.972	0.972	KN21
Portfolio adjustment cost	κ	0.009	0.009	KN21
e.o.s. between long-term bonds	ε_s	1.850	1.850	LW21
Advantage in absconding rate	Γ	0.830	0.830	KN21
Cost of equity issuance parameter	ζ	28	28	AQ22
Fraction of divertable funds	θ	0.167	0.118	KN21; Assumption
Transfer to entering banks	ω	0.038	0.032	Target value
Government				
Government spending	τ	0.149	0.154	World Bank
Interest rate smoothing	ρ_r	0.870	0.910	SW07; CK23
Taylor rule parameter	φ_π	1.680	1.340	SW07; CK23
Taylor rule parameter	φ_x	0.060	0.030	SW07; CK23
Taylor rule parameter	ς	-	0.230	CK23
Shocks				
Persistence of asset purchases	ρ_b	0.990	-	KW20
Persistence of capital quality shock	ρ_k	0.660	0.660	GK11
Persistence of trade shock	ρ_m	0.900	0.900	KP16
Interest rate shock size	$\sigma_{r,t}$	$\pm$0.003	-	Assumption
QE/QT shock size	$\sigma_{b,t}$	$\pm$0.100	-	Assumption
Capital quality shock size	$\sigma_{k,t}$	-0.003	-0.003	Assumption
Trade shock size	$\sigma_{m,t}$	0.126	0.126	Assumption

AQ22: Akinci and Queralto (2022); CC12: Chen et al. (2012); CF13: Chang and Fernández (2013); CK23: Chen et al. (2023); DS21: Dvorkin et al. (2021); EA11: Elekdag and Alp (2011); FM07: Faia and Monacelli (2007); GK11: Gertler and Karadi (2011); JK22: Jin et al. (2022); KN21: Karadi and Nakov (2021); KP16: Kollmann et al. (2016); KW20: Kolasa and Wesołowski (2020); LW21: Leblebicioğlu and Weinberger (2021); MO04: Monacelli (2004); SW05: Smets and Wouters (2005); SW07: Smets and Wouters (2007).

and EM equity issuance costs represented by ζ are set at 28, as per Akinci and Queralto (2022).

3.4 Monetary and fiscal policy

The calibration of the Taylor rule parameters is based on Smets and Wouters (2007) for the US and Chen et al. (2023) for EM. We set the persistence of the nominal interest rate, ρ_r, at 0.87 for the US and 0.91 for EM. The sensitivity of interest rate adjustments to changes in inflation, φ_π, is set at 1.68 for the US and 1.34 for EM. Furthermore, the sensitivity of interest rate changes in response to the output gap, φ_x, is set at 0.06 for the US and 0.03 for EM. In our extensions, we also allow the EM monetary authority to take into account exchange rate fluctuations when setting monetary policy. As part of this exercise, we set the sensitivity of the EM monetary authority to deviations of the exchange rate ς at 0.23 based on Chen et al. (2023). Alternative values for these parameters are considered as part of our robustness checks in Section 5.

Government spending in our model constitutes a fixed proportion of total output, contributing to aggregate demand for the domestic final good. The share of government spending on retail production, τ, is computed as the proportion of general government final consumption expenditure in GDP, using data from the World Bank. Consequently, the share of government spending in total output is set at 14.87% in the US and at 15.37% in EM.

3.5 Shocks

In our analysis, we consider four types of US monetary policy shocks to capture key macroeconomic dynamics. The first two are shocks to conventional monetary policy: a positive and a negative 100 basis point US interest rate change.[6] Our third and fourth shocks are QE and QT shocks corresponding, respectively, to an expansion and contraction of the monetary authority's balance sheet. The sizes of these shocks are calibrated to match an expansion and contraction of the US monetary authority's balance sheet by 10% of the annual US GDP.

We maintain that long-term bonds held by central banks, B_g, are zero in the steady state in both countries. Over time, the evolution of $B_{g,t}$ depends on the balance sheet of a central bank which follows an AR(1) process, characterized by a high degree of persistence in asset purchase programs, with ρ_b set at 0.99, following the approach of Kolasa and Wesołowski (2020). To

[6] A positive (negative) 100 basis point US interest rate shock corresponds to a 0.003 (-0.003) standard deviation shock.

analyze the effects of QE and equal-sized QT, we make the occasionally binding constraint binding by introducing financial and trade shocks. Specifically, following a negative capital quality shock that reduces output and inflation, QE is triggered. Conversely, in response to a trade disruption that reduces the share of imported products in both countries by 12.6%,[7] inflation rises and output falls, making QT more appropriate. In the absence of adverse shocks and under loose conditions for financial intermediaries, QE remains ineffective. Our choice of financial and trade shocks triggering QE and QT, respectively, is motivated by the observed policy in the global economy: (i) the adoption of QE in the aftermath of the GFC that was triggered by financial shocks; and (ii) the implementation of QT following trade disruptions in the aftermath of the COVID-19 pandemic.

4 Spillovers of monetary policy shocks: trade and financial networks

Our quantitative analysis is organized in four separate scenarios corresponding to the examination of the four shocks originating in the US economy and spilling over to EM: (i) an interest rate hike of 100 basis points; (ii) an interest rate cut of 100 basis points; (iii) expansionary unconventional monetary policy in the form of QE in the US corresponding to asset purchases equivalent to 10% of US annual GDP; and (iv) contractionary unconventional monetary policy in the form of QT corresponding to asset sales equivalent to 10% of US annual GDP.

To analyze the effects of these four shocks, we solve the two-country model outlined in Section 2 by using the Levenberg-Marquardt Mixed Complementarity Problem (LMMCP) solver (see Kanzow and Petra, 2004) over 1000 quarters given the presence of the occasionally binding balance-sheet constraints facing banks in our set up. In what follows, we present our solution in the form of a simulation analysis examining each policy shock in turn. In each case, we consider three distinct configurations of our model to capture the complexity of interactions, ranging from the simplest to the most extended version featuring: (i) trade in final consumer goods only; (ii) trade in final consumer goods and intermediate inputs (supply chains); and (iii) trade in final goods, supply chains and credit networks between the two countries.

In what follows we present the responses of a set of key variables characterizing both the

[7] The sizes of both trade and financial shocks are calibrated in a way that they increase yields on US government bonds by 20 basis points.

US and the EM, carefully tracing the dynamics and the spillover effects associated with varying degrees of financial and trade integration; and policy interdependence.

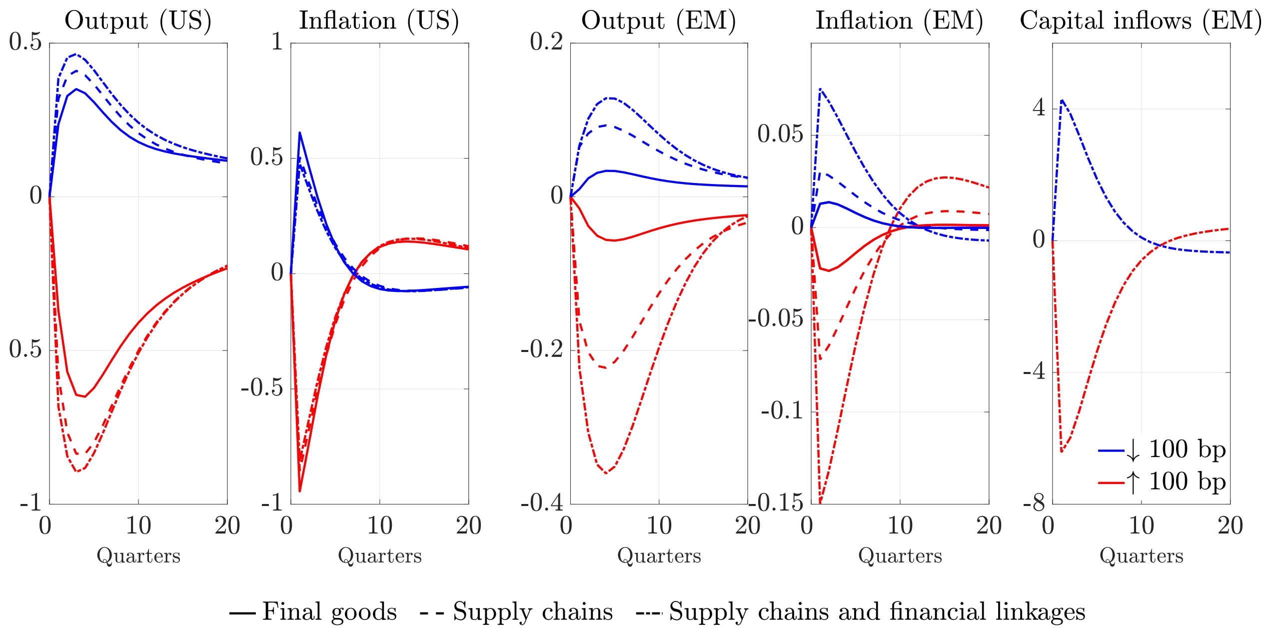
4.1 Conventional monetary policy

We start by examining the effects of the US conventional monetary policy on both the US economy and its spillovers onto the EM. In the US, a 100 basis point increase in the policy rate (represented by red lines in Figure 2), results in a 0.65% decline in output in the benchmark version (with final goods trade only displayed by the straight lines), through lower consumption, investment, and net exports following the appreciation of the US dollar. As we move from the benchmark to the extended version by iteratively adding layers of interconnectedness between the two economies the loss in US output becomes larger, as is seen in the first panel in Figure 2. When we allow for supply chain linkages between the two countries, represented by the dashed lines in the plots, there is a further loss in US output through the impact of lower US demand for EM supplies as intermediate inputs, which reduces EM output and hence demand for US supplies as inputs in the production of intermediate goods in the EM. Finally, incorporating the cross-country financing of capital yields a reduction in US output resulting in a 0.9% drop, as the initial US interest rate hike reduces financing and hence capital to be used in production in both countries.

As is clear from Figure 2, the impact of US monetary policy shock manifests significant variability on EM outcomes depending upon the nature of interlinkages between the two countries (the third and the fourth panels in Figure 2). In the benchmark with trade in final consumer goods only, a 100 basis point increase in the US policy rate results in a marginal 0.06% reduction in EM output. This effect amplifies nearly four-fold to a 0.22% reduction with supply chains, further escalating to a 0.36% drop with cross-country financial linkages accounted for, represented by the dash-dot lines. Both trade and financial linkages matter significantly for the EM dynamics in response to a US monetary contraction. This arises from the fact that (i) both the share of intermediate inputs in output and the external (US) reliance on domestic (EM) goods are greater in the EM; and (ii) the share of local capital is lower in the EM, making the domestic economy more exposed to international financing of capital.

Importantly, an equal-sized opposite policy action, a 100 basis point decrease in the US interest rates, denoted by the blue lines, yields a much smaller hence an asymmetric response of output both in the US and EM, with increases in the range of only 0.35% - 0.46% in the

Figure 2: Responses of output and inflation to the US conventional monetary policy shocks.



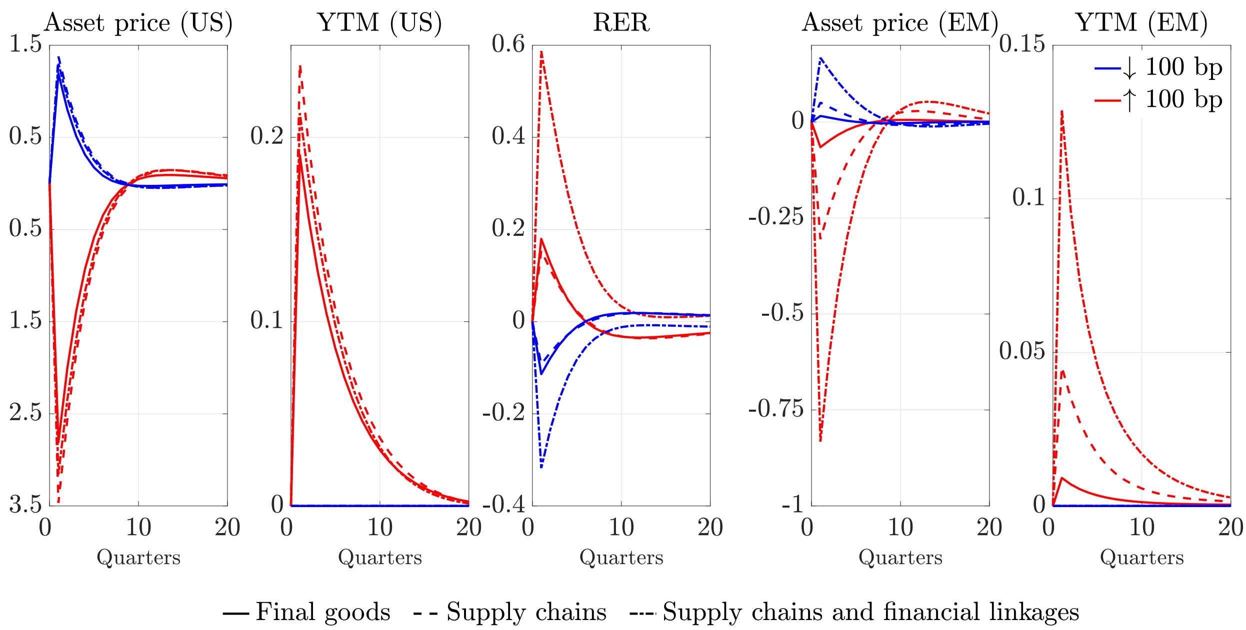
Note: The responses are expressed in % deviations from steady-state; the responses of inflation are annualized; responses in blue represent the effects of US monetary policy expansion by 100 basis points, while responses in red represent the effects of US monetary policy tightening by 100 basis points.

US and 0.03% - 0.13% in the EM, as is displayed in Figure 2. This asymmetry in the effects of US monetary policy during expansions versus contractions arises from the presence of the occasionally binding balance sheet constraints facing banks in both countries, amplifying the negative outcomes domestically and their global spillovers. When such constraints bind, as is the case when contractionary policy is adopted, any tightening in lending conditions associated with the rise in US rates will be magnified, which, in turn, will heighten the loss in real activity at home and abroad. This chain of events explains why US output shrinks more in the wake of a monetary contraction than it expands following a monetary easing. Given that the EM banks also face occasionally binding constraints, output in both countries is hit twice, intensifying the unfavorable spillover effects from US monetary tightening. With the greater reliance of the EM on both the supply chains and external financing of capital, the EM faces a double whammy bearing the brunt of both sets of balance sheet constraints. In contrast, the impact of a monetary action on lending conditions is much smaller when constraints are loose, significantly dampening policy effectiveness under an expansionary monetary policy, driving a wedge between the size of the policy impact between tightening and easing episodes. Notably, the scale of asymmetry is higher in the EM, as adverse US shocks move the balance sheet constraints of EM banks into the binding territory, amplifying the negative outcomes, and underscoring the heightened sensitivity of EM to external shocks.

The second and the fourth panels of Figure 2 repeat the same exercise for inflationary outcomes in the US and the EM, respectively, tracing the effects of the same two US monetary policy shocks. As is seen in the second panel of Figure 2, inflation in the US exhibits similar reactions to shifts in the policy rate across all three model versions. A 100 basis point increase in the US policy rate yields a corresponding 0.94% decrease in annualized US inflation in the most extended version. The asymmetry in the responses prevails with a 0.61% increase in inflation following a 100 basis points drop in the US policy rate under the same model specification. In the EM, the impact of changes in the US policy rate on inflation again displays significant variation across the three model versions, fluctuating in the range of a reduction of 0.02% in the benchmark, 0.07% with supply chains, and 0.15% with financial linkages also incorporated. In contrast, an equal-sized monetary policy easing induces a rise in EM inflation, ranging from 0.01% in the benchmark to 0.08% with both supply and credit networks, half the size of the fall accompanying an equal-sized monetary tightening.

One of the key implications of monetary policy changes is their impact on asset prices and yields. The US monetary policy inversely impacts the US discount rate, which directly translates to changes in asset prices. When, in turn, the occasionally binding balance sheet constraint is activated due to a tightening of financial conditions of banks, a spread between the interest rates on government bonds and the risk-free rate emerges, consequently leading to a rise in bond yields. Figure 3 displays the responses of asset prices and yield to maturity in both countries as well as the real exchange rates following the US monetary policy action, revealing a consistently negative impact on financial variables during periods of tightening and *vice versa* during a monetary easing. In the extended version, a 100 basis point increase in the US policy rate brings about a 3.16% decline in US asset prices, in contrast to a 1.3% increase following a 100 basis point reduction. The effect is similar across all three model versions. In contrast, the impact on EM asset prices displays considerably more variations depending on the model specification. The modest 0.07% reduction in EM asset prices in the benchmark escalates to 0.31% with supply chains, which further enlarges to 0.83% with financial linkages. In contrast, an equal-sized US monetary policy easing prompts much smaller increases in EM asset prices, ranging from 0.02% in the benchmark to 0.17% in the most extended version.

Figure 3: Responses of asset prices, yield-to-maturity, and real exchange rate to the US conventional monetary policy shocks.



Note: The responses are expressed in % deviations from steady-state; the responses of YTM are annualized; responses in blue represent the effects of US monetary policy expansion by 100 basis points, while responses in red represent the effects of US monetary policy tightening by 100 basis points; a rise in RER represents an appreciation of the US dollar.

As is clear, the fluctuation in asset prices under tight versus loose monetary policy contains even greater asymmetry compared to those related to real activity. The same applies to the movement in other financial variables across tightening versus easing policy episodes. For example, the response in the yield-to-maturity (YTM) in the US, as presented in the second panel of Figure 3, comprises a clear jump under a monetary contraction versus no response under monetary loosening, owing to the persistently non-binding banks' balance sheet constraints in the latter due to the benign conditions of banks in both countries.[8] Parallel to the above, the impact on EM YTM reveals substantial disparities. In the benchmark case, a 100 basis point increase in the US policy rate leads to a modest 0.91 basis point increase in EM YTM, increasing to 4.52 basis points when supply chains are incorporated; and further increasing to 12.89 basis points in the version that also allows for financial linkages. Overall, the spillover effects of global shocks on financial outcomes exhibit a more pronounced impact relative to that on real activity,

[8]YTM is defined as the difference between the annualized yield on a risky long-term bond and a risk-free equivalent.

as in Ca'Zorzi et al. (2023).

Another key effect of monetary policy changes is on the exchange rate, especially for emerging economies. The responses in the exchange rate as displayed in the middle panel of Figure 3 exhibit significant variation across the different model specifications. In the benchmark, a 100 basis-point increase in the US policy rate generates a 0.18% depreciation of the EM currency (appreciation of the US dollar), increasing to 0.59% when supply chains and financial linkages are incorporated. An equal-sized monetary easing, on the other hand, induces an appreciation of the EM currency by 0.11%, 0.09%, and 0.32% in the there respective model versions.

In the benchmark version with trade in final goods only, changes in the exchange rate are determined by the difference in inflation rates. In models that account for financial linkages, the difference in the returns on capital plays a key role in the determination of the exchange rate (equation 26). As the returns on capital respond more sharply to monetary policy changes compared to the responses of inflation, the exchange rate exhibits a more robust response to US monetary policy shocks when the model incorporates cross-border capital flows. Indeed, a 100 basis point increase in the US policy rate triggers a 6.42% decrease in capital flows to EM in the model incorporating both supply chains and financial linkages (see Figure 2), as compared to a 4.3% increase in capital flows following a 100 basis point decrease in the US policy rate.

4.2 Unconventional monetary policy: QE and QT

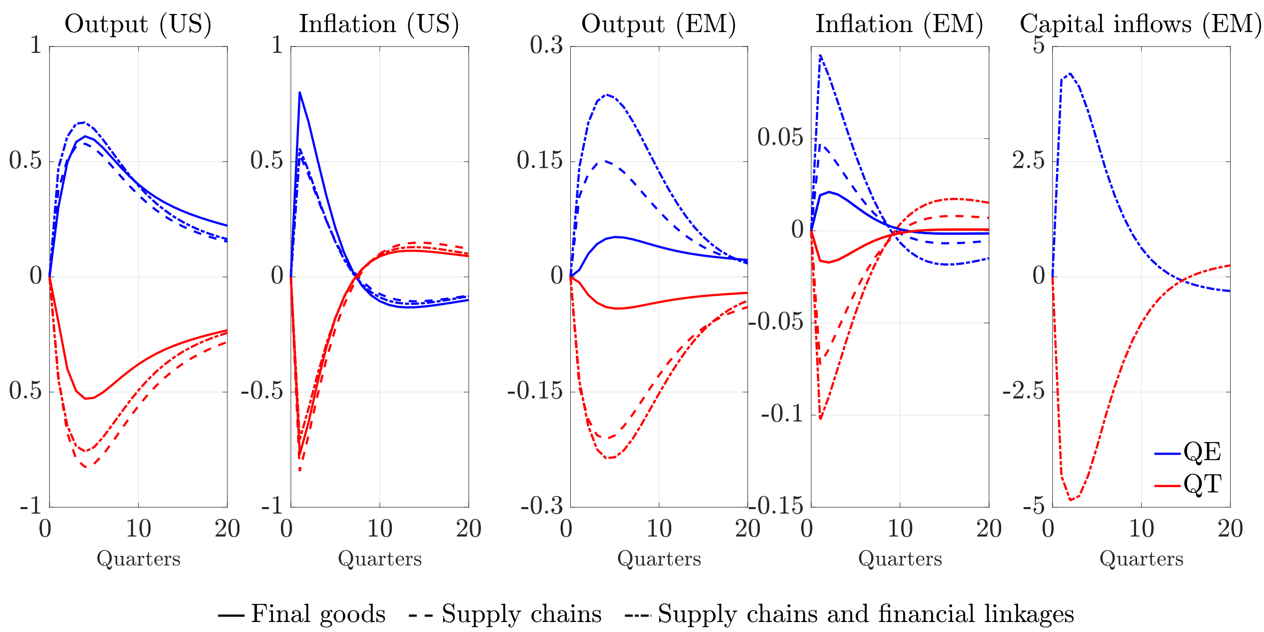
In the aftermath of the GFC, many central banks particularly in advanced economies routinely adopted unconventional monetary policy (UMP) in the form of large asset purchase programs (QE), due to conventional policy having hit its limit with near-zero nominal interest rates. In contrast, more recently, to fight the hikes in inflation rates to levels unseen in four decades, central banks, including the Fed, again resorted to UMP, this time in the opposite direction, by engaging in quantitative tightening (QT) via asset sales, in addition to the significant monetary tightening through conventional means - rises in interest rates.

An obvious question arising from our analysis above is whether the asymmetry in the spillovers of US monetary policy shocks extends to the effects of UMP changes. To evaluate the impacts of QE and QT, we introduce simulated adverse financial and trade shocks.[9] The financial shock, in the form of a global capital quality deterioration (see Gertler and Karadi,

[9]In the absence of the underlying shocks QE proves ineffective, confirming the state-dependent nature of UMP effects, as highlighted by Cantore and Meichtry (2024) among others.

2011), leads to a decline in output and inflation. Conversely, a supply shock resulting in a 12.6% reduction in imports for both countries decreases output but increases inflation. Within the context of these financial and supply chain disruptions, both of which make the occasionally-binding balance sheet constraints in both countries binding, we examine the consequences of (i) QE equivalent to 10% of the US GDP in the presence of the capital quality shock, and (ii) QT of an equal size following the trade shock. As explained above, the reasoning for introducing these shocks lies in the nature of the occasionally binding constraints: when these do not bind, QE becomes ineffective. Hence, for a proper comparative analysis of both types of UMP, it is necessary to examine circumstances under which both policy stances have real effects.[10]

Figure 4: Responses of output and inflation to the US unconventional monetary policy shocks.



Note: The responses are expressed in % deviations from steady-state; the responses of inflation are annualized; responses in blue color represent the effects of US asset purchases of 10% of GDP, while responses in red color represent the effects of US asset sales of 10% of GDP.

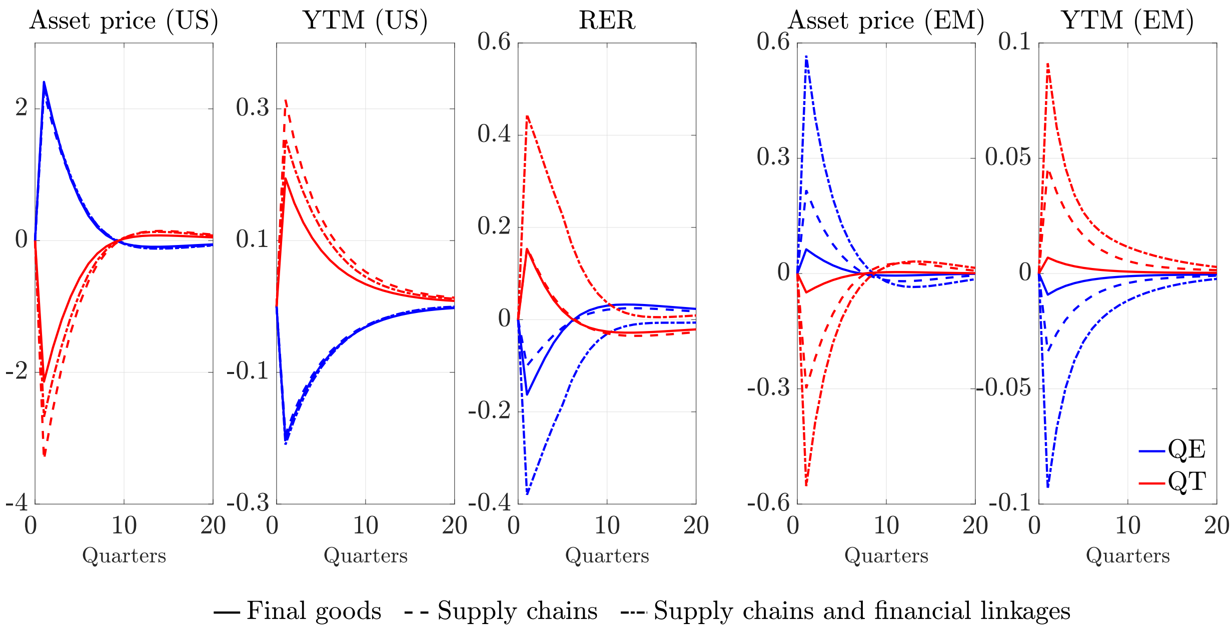
Responses of output and inflation to the QE and QT shocks are displayed in Figure 4. As is evident in Figure 4, the asymmetry in the effects of tightening versus loosening US monetary policy prevails under UMP. In particular, the adoption of QT reduces US output by 0.53% in the benchmark with trade in final goods only and by 0.76% in the extended version with supply

[10]We also set the US nominal interest rates at their steady-state level for the first four quarters to isolate the effects of UMP tools from an accommodative conventional monetary policy response.

chains and financial linkages. In contrast, QE has a similar symmetric effect on output in the benchmark case, which increases to 0.67% when supply and financial linkages are incorporated, thus revealing the asymmetry.

Regarding the size of spillovers, in the benchmark with trade in final goods only, the impact of US QE and QT on EM output and inflation remains small. However, when supply chains and financial linkages are accounted for, the spillovers are amplified, driving a wedge between the effects of the two opposite shocks, underscoring the major role both channels play in the size and the asymmetries of US monetary policy spillovers onto other countries.

Figure 5: Responses of asset prices, yield-to-maturity, and real exchange rate to the US unconventional monetary policy shocks.



Note: The responses are expressed in % deviations from steady-state; the responses of YTM are annualized; responses in black color represent the effects of US asset purchases of 10% of GDP, while responses in red color represent the effects of US asset sales of 10% of GDP; a rise in RER represents an appreciation of the US dollar.

Figure 5 presents the effects of US-originated QE and QT on both US and EM financial variables. The falls in US YTM following monetary policy easing are approximately 20 basis points under the three versions. In line with our previous results, QT exerts a greater influence on financial outcomes with US YTM climbing by 31.37 basis points in the extended version. The yields in the EM, however, no longer exhibit asymmetry and the impact of QE and QT on YTM in EM in the model with trade limited to final goods is marginal. Figure 5 also displays the impact of US UMP shocks on the real exchange rate between the US dollar and the basket of EM currencies, under three separate versions of the benchmark model. Unsurprisingly, financial linkages emerge as a key factor in the transmission of QE and QT effects on the exchange rate. A US monetary expansion by asset purchases equivalent to 10% of its GDP generates 0.38% depreciation in the EM currency while an equivalent tightening through asset sales appreciates it by 0.44%, in the extended model with both supply chains and financial linkages. It is also clear from Figure 5 that incorporating financial linkages has the greatest impact on the size of the variation in the exchange rate and hence the magnitude of the asymmetry between the two policy stances.

In the model configuration with financial linkages, the US monetary policy tightening is followed by a significant reduction in EM capital inflows, by 4.85% in our simulations (not reported). In contrast, a symmetrical monetary policy easing in the US generates a 4.42% increase in capital inflows to EM in the extended version. Taken together with our earlier results on EM output in Figure 4, it is clear that the source of fluctuation in EM outcomes varies; while it is the external financing of capital that magnifies the spillovers on EM financial outcomes, it is the supply chains that generates the greatest impact on the real activity in the EM.

4.3 Fear of floating

An important feature of monetary policy making in emerging economies is the significant role exchange rate considerations play in monetary policy decisions. This sensitivity to exchange rate volatility on the part of policymakers is widely acknowledged and has been known as the fear of floating (henceforth FoF), following Calvo and Reinhart (2002) (see, for example, Levy-Yeyati and Sturzenegger, 2005, Honig, 2005, and Garcia et al., 2011 among many others).

Two characteristics of emerging economies have been seen as the root cause of such fear of floating; high pass-through from exchange rates to domestic prices and significant liability dollarization (see, for example, Hausmann et al., 2001). In countries that feature foreign-currency exposures, policymakers attempt to reduce the variation in the exchange rate by mimicking the foreign monetary policy action, aggravating the unfavorable effects of global shocks on the domestic economy (Honig, 2005, Ottonello, 2021, Georgiadis and Zhu, 2021, and Bianchi and Coulibaly, 2023).

As documented by Ilzetzki et al. (2019), policymakers' aversion to exchange rate fluctuations, particularly in EMs, has prevailed even in the post-Bretton Woods era. This is not surprising given the increase in financial globalization in recent decades, resulting in significant EM reliance on external finance, heightening the cost of variation in the exchange rate in these economies.

To allow us to explore the implications of such FoF behavior on the transmission of external monetary policy shocks on domestic outcomes, we now reconsider the EM monetary policy-making structure by adopting an augmented Taylor rule incorporating exchange rate movements:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi}\right)^{\varphi_\pi} \left(\frac{X_t}{X}\right)^{\varphi_x} \left(\frac{s_t}{s}\right)^{\varsigma}\right]^{1-\rho_r} exp(\sigma_{r,t}) \tag{35}$$

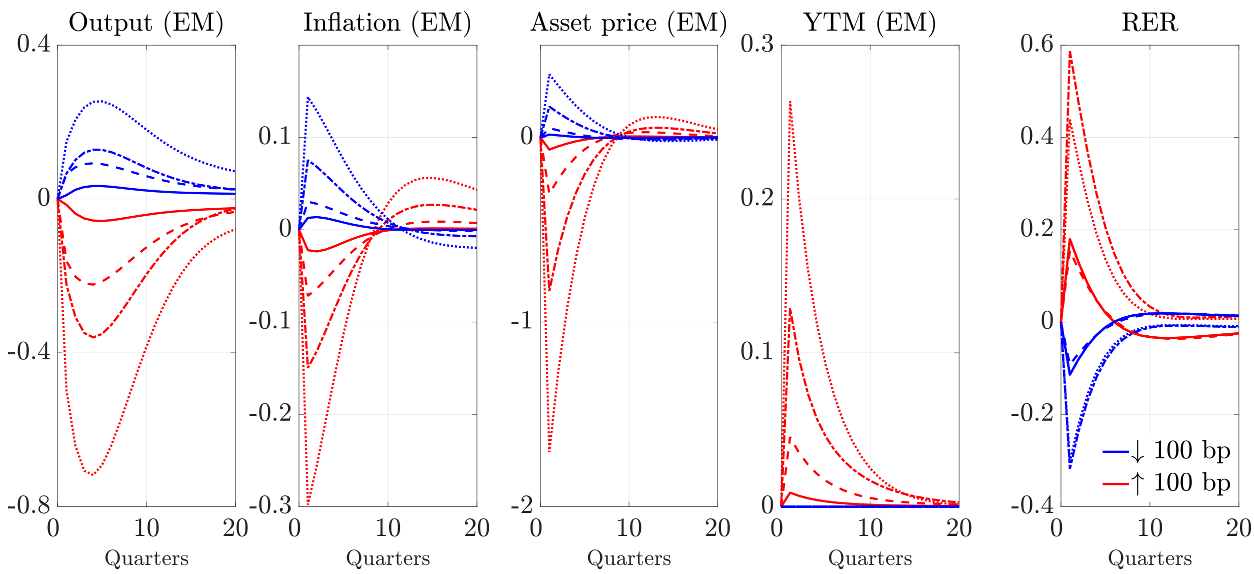
where ς denotes the degree of policymakers' dislike for the deviations of the nominal exchange rate s_t from its non-stochastic steady state. It, therefore, follows that when the US adopts a contractionary monetary policy leading to the dollar's appreciation, the domestic monetary authority raises its policy rate to reduce the scale of the loss in the value of the domestic currency.

Figure 6 and Figure 7 present the evolution of a set of EM variables in response to US conventional and unconventional monetary policy shocks, respectively, now also featuring outcomes under FoF. As is seen from both sets of figures, policymakers' aversion to exchange rate fluctuations significantly impacts both real and financial variables in EM. This is because the attempt to limit the variation in the exchange rate following the US monetary contraction forces domestic policymakers to hike domestic interest rates, further alleviating output loss, thereby magnifying the fall in inflation. The reduction in both output and inflation is significantly greater under FoF relative to the extended model.

As is set out above, the key focus of the FoF behavior is the variation in the exchange rate. The fifth panel in Figure 6 displays the responses of the real exchange rate following both types of conventional monetary policy shocks in the US. Indeed, in the presence of FoF, the depreciation of the EM currency is contained, falling from a rise of 0.59% to 0.44%, with important implications for other outcomes. An equal-sized monetary easing, on the other hand, induces an appreciation of the EM currency (depreciation of the US dollar) by 0.3%, down from 0.32%. The fifth panel in Figure 7 presenting the movements in the real exchange rate in response to QT and QE reveals that the same holds under UMP.

The rise in the EM interest rates, in an attempt to limit the depreciation of domestic currency following a global (US) monetary contraction, has important implications for both macroeconomic and financial stability at home.[11] On the one hand, higher domestic interest rates further deteriorate the domestic macroeconomic conditions, already weakened due to lower demand from the US. For instance, the contraction in EM output stands at 0.72% when considering FoF, double the 0.36% fall in the extended model. Moreover, the expenditure-switching channel through which the improved competitiveness of the domestic economy yields an improvement in net exports is also curtailed on account of a smaller depreciation, resulting in an unambiguous negative impact on domestic macroeconomic stability.

Figure 6: Responses of the EM economy to the US conventional monetary policy shocks.



Note: The responses are expressed in % deviations from steady-state; the responses of inflation and YTM are annualized; responses in blue represent the effects of US monetary policy expansion by 100 basis points, while responses in red represent the effects of US monetary policy tightening by 100 basis points; a rise in RER represents an appreciation of the US dollar.

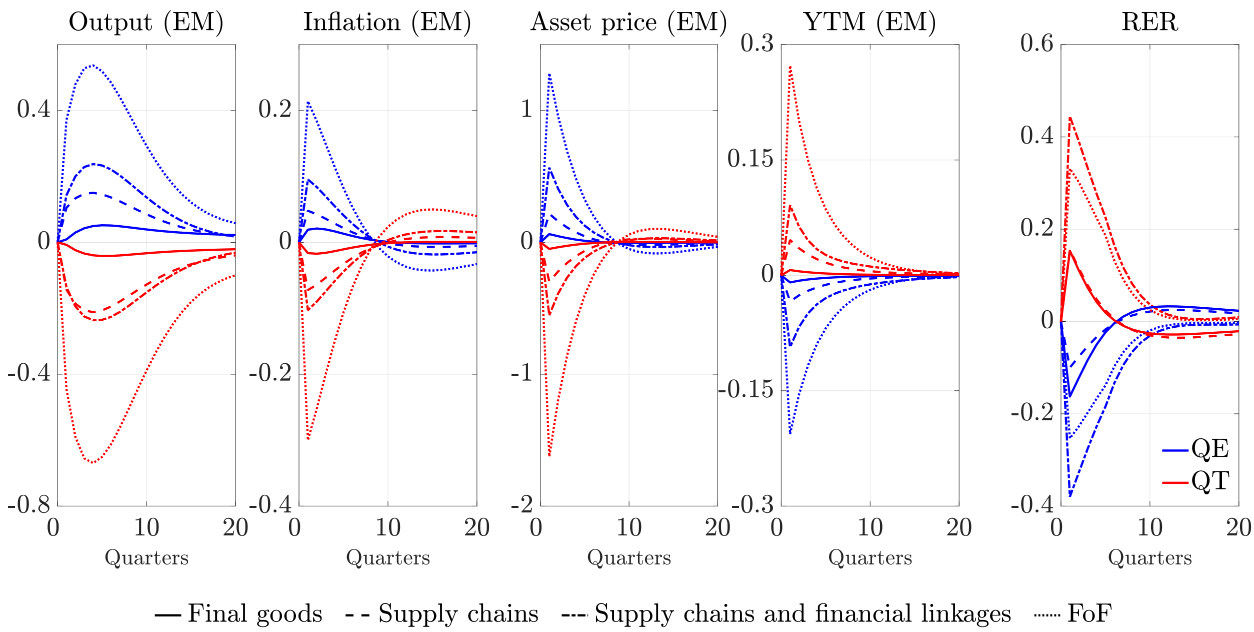
On the other hand, while higher interest rates are also bad for financial stability, the containment in the depreciation of the domestic currency is beneficial, particularly for countries with significant foreign-currency exposures, a key source of FoF behavior. Hence, the impact on financial stability is not as clear-cut. The third and the fourth panels in Figure 6 reveal the amplified impacts on financial variables. The fall in asset prices peaks at 1.7% with FoF, relative

[11] See, for example, Georgiadis and Zhu (2021) and Kolasa and Wesołowski (2023) both of whom point to the tension between macroeconomic and financial stability in small open economies following global monetary policy shocks.

to a 0.83% drop in the extended case without FoF. Similarly, the impact on YTM jumps from a rise of 12.89 to 26.37 basis points. This significant jump in YTM is attributed to the heightened risk of investing in EM bonds. Due to a strong co-movement across the two financial sectors, changes in EM yields closely track movements in US yields, with the former (latter) rising by 27.27 (30.12) basis points following QT and falling by 20.64 (21.74) basis points following QE in the US.

FoF also impacts the size of capital flows in and out of EM in response to US-originated monetary policy shocks. In the aftermath of a 100 basis point monetary policy tightening (easing) in the US, capital flows into EM decrease (increase) by 5.16% (3.72%), pointing to the lessened response in capital flows to the US-originated monetary policy shocks. In our calibration, the benefit from the reduced fluctuations in capital flows and the exchange rate is relatively small compared to the cost for the EM's financial sector. Overall, financial outcomes and hence financial stability are also impacted unfavorably by the hike in domestic interest rates arising from the FoF behavior.

Figure 7: Responses of the EM economy to the US unconventional monetary policy shocks.



Note: The responses are expressed in % deviations from steady-state; the responses of inflation and YTM are annualized; responses in blue represent the effects of US asset purchases of 10% of GDP, while responses in red represent the effects of US asset sales of 10% of GDP; a rise in RER represents an appreciation of the US dollar.

Figure 7 repeats the same exercise for unconventional US monetary policy shocks and reveals that both the nature of the FoF effect on outcomes and the asymmetry between the spillover effects of tightening versus loosening US monetary policy shocks also hold under UMP.

5 Extensions and robustness checks

To check the robustness of our findings, in this section, we subject our baseline model to a battery of additional tests. We first present three separate exercises probing our results under each scenario varying across: (i) specification of technology in production; (ii) the share of intermediate inputs in technology; and (iii) the share of home versus foreign currency debt. We then turn to an extensive set of sensitivity checks, primarily focusing on, but not limited to, the key parameters directly influencing trade and financial linkages.

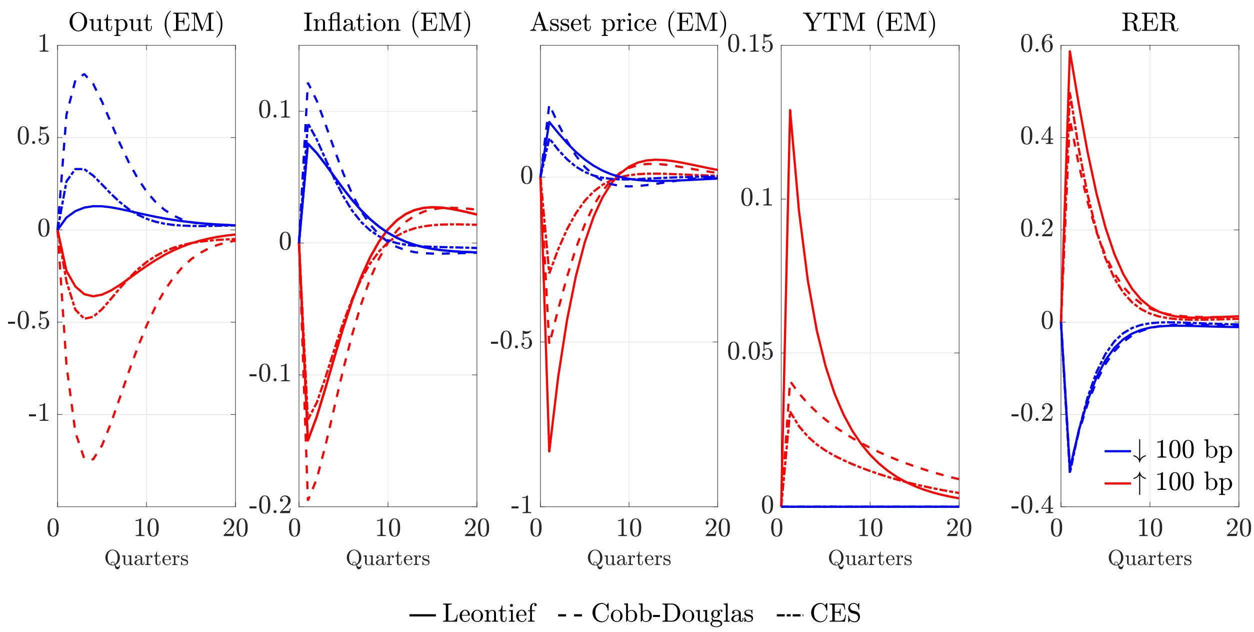
5.1 Production function

In our model in Section 2, we employed a Leontief function to characterize the technology for producing intermediate goods in both countries. We now present results under three alternative specifications, including a Cobb-Douglas production function with a unit elasticity of substitution between value-added and intermediate inputs; and a Constant Elasticity of Substitution (CES) function; in addition to our benchmark Leontief specification.

Figure 8 displays EM outcomes in response US conventional monetary policy shocks with three production function specifications using the model version with trade and financial linkages. Clearly, the greater the substitutability between the domestic and foreign goods increases, the larger the size of negative spillovers on domestic outcomes. When US producers import a fixed share of supplies from the EM, as is the case under the Leontief technology, a change in relative prices of goods in the two countries has a smaller impact on imported quantities, hence the smaller response of EM output. The magnitude of the impact on EM is more substantial when the US can substitute supplies imported from EM for locally produced goods when the local price level drops. Indeed, the fall in EM output is nearly three times larger under the Cobb-Douglas technology relative to the benchmark Leontief specification. Regarding financial outcomes, the Leontief function generates the most adverse effects on asset prices and yields. The inability to readily substitute between two capital types leads to more substantial declines in asset portfolio value and net worth compared to scenarios where the capital portfolio adjusts more flexibly.

Overall, our findings on the asymmetry of spillovers prevail regardless of the specification of

Figure 8: Responses of the EM economy to the US conventional monetary policy shocks under alternative production functions.



Note: The responses are expressed in % deviations from steady-state; the responses of inflation and YTM are annualized; responses in blue represent the effects of US monetary policy expansion by 100 basis points, while responses in red represent the effects of US monetary policy tightening by 100 basis points.

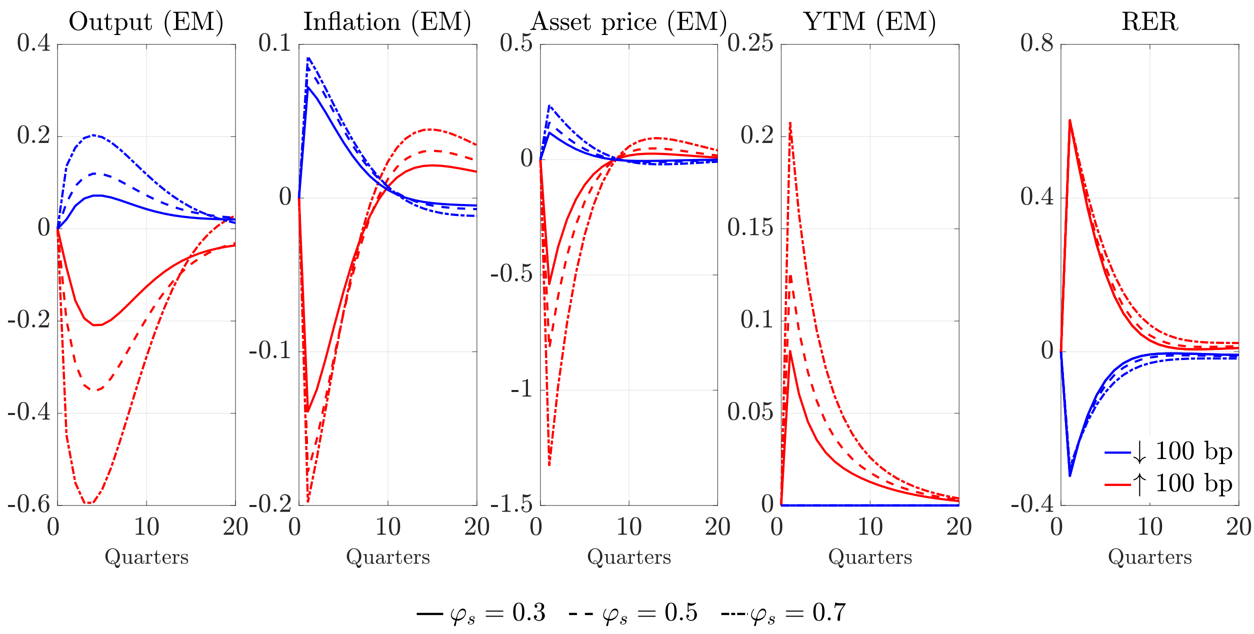
the production function. The same also holds under unconventional monetary policy shocks, as is displayed in Figures B.1 to B.4 in Appendix B.

5.2 Share of intermediate inputs

To examine the role supply chains play in monetary policy spillovers, we run the same set of simulations under three configurations for the share of intermediate inputs in production, φ_s; 30%, 50%, and 70%, as displayed in Figure 9. As can be seen, spillovers from US monetary policy to EM significantly vary with the share of intermediate inputs. EM output exhibits more than a threefold decline when φ_s rises from 30% to 70%. Similarly, both asset prices and YTM demonstrate a pronounced sensitivity, exhibiting almost a threefold increase in their response to US monetary policy tightening when intermediate input shares are elevated to 70%.

A higher share of intermediate inputs indicates a greater reliance on imported goods and services and deeper integration into global supply chains, signifying stronger interdependencies between the US and EM economies. When US monetary policy tightens, appreciation of the dollar raises the cost of imported intermediate inputs for EM firms, thus elevating production costs. This, in turn, exerts additional pressure on EM output, magnifying the impact of the monetary shock. This heightened interdependence also exacerbates the transmission of US monetary policy shocks to EM financial outcomes, leading to significant fluctuations in asset prices, exchange rates, and borrowing costs, thereby intensifying the overall impact on the EM economy.

Figure 9: Responses of the EM economy to the US conventional monetary policy shocks under different shares of intermediate inputs in technology.



Note: The responses are expressed in % deviations from steady-state; the responses of inflation and YTM are annualized; responses in blue represent the effects of US monetary policy expansion by 100 basis points, while responses in red represent the effects of US monetary policy tightening by 100 basis points; a rise in RER represents an appreciation of the US dollar.

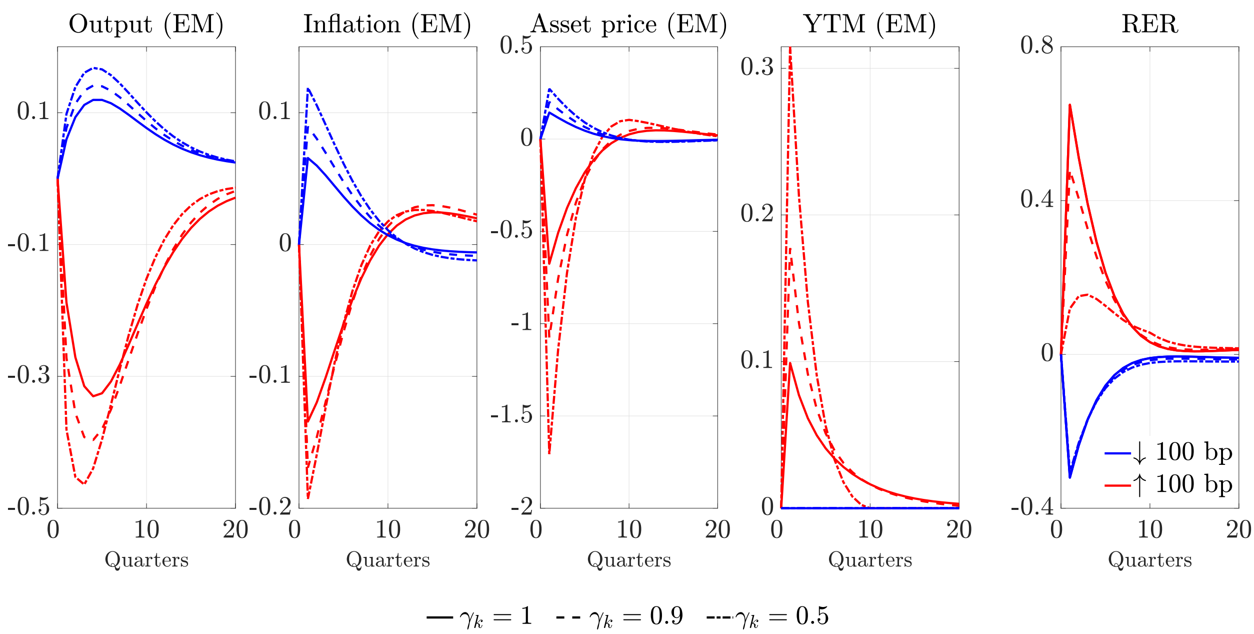
In sum, the asymmetry in US monetary spillovers to EM remains intact for all three configurations of input shares. Our results also extend to spillovers under UMP across the three cases, as presented in Figures B.5 to B.8 in Appendix B.

5.3 Share of foreign currency debt

It is widely documented that US monetary policy shocks wield substantial influence over capital flows directed toward emerging markets (see, for example, Faia and Iliopulos, 2011, Dahlhaus and Vasishtha, 2014, Kiendrebeogo, 2016 and Alper et al., 2020). Clearly, the greater a country's share of foreign currency liabilities, the greater its exposure to the fluctuations in capital flows in response to US monetary policy changes. To quantify this effect in our setting, Figure 10 presents the response of the EM economy to US conventional monetary policy shocks across varying shares of dollar-denominated liabilities in EM. We consider three distinct scenarios: 100% domestic capital (0% foreign capital), 90% domestic capital (10% foreign capital), and 50% domestic capital (50% foreign capital).

As can be seen, following the US monetary policy tightening, the deterioration in EM outcomes worsens as the share of dollar-denominated liabilities raises. This is especially the case for financial variables: the fall in asset prices reaches 0.68%, 1.08%, and 1.71%, under the three respective cases. Similarly, YTM surges with increasing reliance on foreign currency debt, rising by 9.9 basis points, 17.74 basis points, and 31.47 basis points as the share of foreign currency liabilities rises from 0% to 50%. Naturally, greater exposure to foreign currency fluctuations amplifies the correlation between the movement of the US and EM variables, underscoring the heightened interdependence.

Figure 10: Responses of the EM economy to the US conventional monetary policy shocks under different levels of financial openness.



Note: The responses are expressed in % deviations from steady-state; the responses of inflation and YTM are annualized; responses in blue represent the effects of US monetary policy expansion by 100 basis points, while responses in red represent the effects of US monetary policy tightening by 100 basis points; a rise in RER represents an appreciation of the US dollar.

Of note, the asymmetry in spillovers on EM across the contractionary versus expansionary US monetary policy shocks prevails and gets enlarged as the share of EM liabilities denominated in dollars intensifies. The same also holds for other variables and under UMP, as can be seen from the plots displayed in Figures B.9 to B.12 in Appendix B.

5.4 Further sensitivity checks

As part of our robustness checks, we also explore the sensitivity of our findings to variations in the Armington elasticity of substitution between domestic and imported goods, the elasticity of substitution between domestic and foreign capital, the Calvo parameter, the sensitivity to inflation, sensitivity to the output gap, persistence in the policy rate, the cost of equity issuance, the fraction of divertable funds, the investment adjustment cost, habit formation, and endogenous ZLB. As is clear from the plots presented in Figures B.13 to B.58 in Appendix B, our results exhibit significant robustness across a diverse range of specifications and parameter values.

6 Conclusions

The US monetary policy changes have been a major source of fluctuations in much of the rest of the world, particularly since the global financial crisis in 2008-09. This has been due to (i) the significant variation in the US monetary policy over this period through both conventional and unconventional tools; (ii) the Fed's central position in the global financial system generating substantial spillovers from US monetary policy to economic activity in other countries. Emerging economies with strong trade and financial linkages to the global economy have been particularly impacted.

Existing work has documented several asymmetries in the transmission of US monetary policy across policy tools; policy episodes; transmission channels; and the recipient country characteristics. In contrast, in this paper, we investigate the asymmetry in global spillovers from US monetary policy across tightening versus easing episodes several examples of which have been implemented since the global financial crisis. In doing so, we build a dynamic general equilibrium model featuring (i) financial frictions in the form of occasionally binding collateral constraints in the financial sector; (ii) cross-border loans extended to intermediate goods producers for purchases of physical capital; and (iii) global supply chains allowing for imported intermediate inputs to be a core part of the production process. By utilizing this framework, we then examine spillovers from US monetary policy shocks on a small open economy - calibrated on a sample of emerging economies - across three distinct scenarios mapping to three versions of our model: (i) international trade in final consumer goods only; (ii) trade in final consumer goods and intermediate inputs representing supply chains; and (iii) trade in final goods, supply chains, and credit networks between the two countries.

Our findings reveal significant asymmetries in the effects of monetary policy shocks across tightening versus loosening episodes. At the heart of this asymmetry is occasionally binding constraints facing the banking sector. When these balance sheet constraints bind, associated with tightening policy episodes, reduced liquidity magnifies the detrimental impact of monetary contraction, resulting in a more sizable negative impact on outcomes. In contrast, periods of monetary expansion coincide with loose balance sheet constraints resulting in a moderate impact from expansionary monetary policy changes. Interestingly, the asymmetry in the impact of the expansionary versus contractionary US monetary policy does not only spill across borders, it also magnifies. This is because the balance sheet constraints in the rest of the world aggravate the unfavorable spillover effects from US monetary tightening, further worsening domestic outcomes in these countries. The policy asymmetry across monetary contractions versus expansions prevails under both conventional and unconventional monetary policy changes in the US. We also show that both supply chains and credit networks contribute significantly to the asymmetry in spillovers.

Importantly, our results also reveal that EM policymaker's aversion to exchange rate fluctuations plays a major role in aggravating the detrimental effects of US monetary tightening, thus magnifying the asymmetric effects of global monetary policy shocks. We also find that the spillovers are greater (i) the greater the size of financial frictions; (ii) the greater the elasticity of substitution between the domestic and foreign capital; (iii) the greater the substitutability of domestic and foreign inputs; and (iv) the greater the inflation aversion of policymakers in both countries. Finally, we establish that our results are robust to several configurations and across a wide range of parameter values.

Overall, our findings point to the substantial spillovers from US monetary policy shocks to the rest of the world, that are significantly larger in contractionary episodes. Given that extensive global value chains and deepening cross-country financial linkages are key features of the current global economic landscape, the strength of such spillovers is unlikely to abate. We argue that our model with its detailed specification of both trade and financial linkages as well as a realistic depiction of financial frictions provides a suitable framework for policy analysis for small open economies at the mercy of global disturbances.

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Appendix A Derivations

The derivations outlined in this Appendix complement the model presented in the paper "Asymmetric monetary policy spillovers: the role of supply chains, credit networks and fear of floating". Our model economy represents a world consisting of two economies: domestic and foreign. The model can be easily calibrated to feature any two countries or regions, it can also be straightforwardly extended to more than two countries. Drawing on the framework proposed by Garcia-Lazaro et al. (2021), our benchmark model integrates cross-border lending as a form of financial linkages and incorporates financial frictions, aligning with the approach of Karadi and Nakov (2021) with occasionally binding balance sheet constraints facing banks.

In Section A.1 of this Appendix, we provide derivations for the benchmark version of our model. We then introduce modifications to the benchmark framework in Section A.2: (i) CES technology for intermediate goods producers and Cobb-Douglas production function, as well as two simplified versions of the benchmark model to isolate the impact of each element in the dynamics: (i) trade in final goods only and (ii) incorporating supply chains while excluding financial linkages.

Within each country, our model includes households, competitive retailers, monopolistically competitive intermediate goods producers, capital goods producers, financial intermediaries and a government engaged in both monetary and fiscal policies. This Appendix offers an exposition of the optimization problems faced by agents in the domestic economy, utilizing an asterisk to denote variables associated with the foreign economy when necessary. It is essential to note that, unless explicitly stated otherwise, the optimization problems of both countries mirror each other.

A.1 Supply chains and financial linkages model

A.1.1 The households' problem

Representative household maximizes lifetime utility over consumption C_t, labor inputs supplied to intermediate goods producers H_t, optimal holdings of short-term assets B_t (which include government-issued short-term bonds and bank deposits, both of which are risk-free and perfect substitutes), and long-term bonds $B_{h,t}$ to maximize their discounted lifetime utility:

$$\max_{C_t,H_t,B_t,B_{h,t}} \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t U(C_t, H_t) \tag{A.1}$$

where the utility function $U(C_t, H_t)$ takes the form:

$$\max_{C_t,H_t,B_t,B_{h,t}} \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - hC_{t-1})^{1-\sigma_c}}{1-\sigma_c} - \vartheta \frac{H_t{}^{1+\varphi_h}}{1+\varphi_h} \right] \tag{A.2}$$

subject to a sequence of intertemporal budget constraints of the form:

$$C_t + B_t + B_{h,t} = W_t H_t + R_{b,t} B_{h,t-1} - \frac{1}{2}\kappa \left(B_{h,t} - \bar{B}_h\right)^2 + R_t B_{t-1} + \Pi_t \tag{A.3}$$

where W_t is the real wage, $R_{b,t}$ and R_t represent returns on long-term and short-term bonds, respectively (with the latter being the risk-free rate), $\bar{B}_h$ is the steady-state value of long-term bonds held by households, $\kappa \geq 0$ governs the sensitivity of the quadratic transaction cost associated with purchases or sales of long-term bonds, and Π_t denotes real profits from the ownership of firms.

The Lagrangian associated with the households' optimization problem is given by:

$$\begin{aligned} \mathcal{L}(C_t, H_t, B_t, B_{h,t}) = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - hC_{t-1})^{1-\sigma_c}}{1-\sigma_c} - \vartheta \frac{H_t{}^{1+\varphi_h}}{1+\varphi_h} \right] \\ -\mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \varrho_t \left[\begin{array}{l} C_t + B_t + B_{h,t} - W_t H_t - R_{b,t} B_{h,t-1} \\ +\frac{1}{2}\kappa \left(B_{h,t} - \bar{B}_h\right)^2 - R_t B_{t-1} - \Pi_t \end{array} \right] \end{aligned} \tag{A.4}$$

FOCs:

$$\frac{\partial \mathcal{L}(C_t, H_t, B_t, B_{h,t})}{\partial C_t} = \beta^t \left(C_t - hC_{t-1}\right)^{-\sigma_c} - \beta^{t+1} h \left(C_{t+1} - hC_t\right)^{-\sigma_c} - \beta^t \varrho_t = 0 \tag{A.5}$$

$$\frac{\partial \mathcal{L}(C_t, H_t, B_t, B_{h,t})}{\partial H_t} = -\beta^t \chi H_t^{\varphi} + \varrho_t \beta^t W_t = 0 \tag{A.6}$$

$$\frac{\partial \mathcal{L}(C_t, H_t, B_t, B_{h,t})}{\partial B_t} = -\varrho_t \beta^t + \varrho_{t+1} \beta^{t+1} R_{t+1} = 0 \tag{A.7}$$

$$\frac{\partial \mathcal{L}(C_t, H_t, B_t, B_{h,t})}{\partial B_{h,t}} = -\varrho_t \beta^t + \varrho_{t+1} \beta^{t+1} R_{b,t+1} - \varrho_t \beta^t \kappa \left(B_{h,t} - \bar{B}_h\right) = 0 \tag{A.8}$$

From equation (A.5) we can derive the following marginal utility of consumption:

$$\varrho_t = (C_t - hC_{t-1})^{-\sigma_c} - \beta h \mathbb{E}_t (C_{t+1} - hC_t)^{-\sigma_c} \tag{A.9}$$

From equation (A.6) we derive the following optimal supply of labor:

$$\chi H_t^{\varphi} = \varrho_t W_t \tag{A.10}$$

We simplify equation (A.7) to get the optimal holdings of short-term bonds given by equation (A.13):

$$\varrho_t \beta^t = \varrho_{t+1} \beta^{t+1} R_{t+1} = 0 \tag{A.11}$$

$$\frac{\varrho_t}{\varrho_{t+1}} = \beta R_{t+1} \tag{A.12}$$

$$1 = \beta \frac{\varrho_{t+1}}{\varrho_t} R_{t+1} \tag{A.13}$$

Next, from equation (A.8) we obtain:

$$1 = \beta \frac{\varrho_{t+1}}{\varrho_t} R_{b,t+1} - \kappa \left(B_{h,t} - \bar{B}_h \right) \tag{A.14}$$

We then combine equations (A.14) and (A.13) and derive the optimal holdings of long-term bonds by households (equation A.16):

$$\beta \frac{\varrho_{t+1}}{\varrho_t} R_{t+1} = \beta \frac{\varrho_{t+1}}{\varrho_t} R_{b,t+1} - \kappa \left(B_{h,t} - \bar{B}_h \right) \tag{A.15}$$

$$B_{h,t} = \bar{B}_h + \frac{\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} (R_{b,t+1} - R_{t+1})}{\kappa} \tag{A.16}$$

The aggregate consumption of households C_t consists of consumption of goods produced domestically $C_{h,t}$ and goods imported from the foreign economy $C_{f,t}$ aggregated as in follows:

$$C_t = \left[\gamma_c^{\frac{1}{\varepsilon_c}} (C_{h,t})^{\frac{\varepsilon_c - 1}{\varepsilon_c}} + (1 - \gamma_c)^{\frac{1}{\varepsilon_c}} (C_{f,t})^{\frac{\varepsilon_c - 1}{\varepsilon_c}} \right]^{\frac{\varepsilon_c}{\varepsilon_c - 1}} \tag{A.17}$$

where $0 < \gamma_c < 1$ represents the share of goods produced in the domestic economy in total consumption and $\varepsilon_c > 1$ is the elasticity of substitution between locally produced and imported consumer goods.

Domestic households optimize their consumption basket of domestic and imported goods subject to the following aggregate expenditure on consumer goods:

$$P_t^c C_t = P_t C_{h,t} + e_t P_t^* C_{f,t} \tag{A.18}$$

where e_t is the real exchange rate expressed as units of domestic currency per unit of foreign currency; P_t and P_t^* are prices of final goods expressed in the number of, respectively, domestic and foreign currency units; and P_t^c is the consumer price index (CPI) composed of the prices of goods consumed by the local households and weighted by their corresponding shares in the aggregate consumption basket:

$$P_t^c = \left[\gamma_c \left(P_t\right)^{1-\varepsilon_c} + \left(1-\gamma_c\right)\left(e_t P_t^*\right)^{1-\varepsilon_c}\right]^{\frac{1}{1-\varepsilon_c}} \tag{A.19}$$

The Lagrangian associated with household's optimization of expenditures on domestically-produced versus imported goods is given by:

$$\begin{aligned} \mathcal{L}\left(C_{h,t}, C_{f,t}\right) = &\left[\gamma_c^{\frac{1}{\varepsilon_c}}\left(C_{h,t}\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}} + \left(1-\gamma_c\right)^{\frac{1}{\varepsilon_c}}\left(C_{f,t}\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}}\right]^{\frac{\varepsilon_c}{\varepsilon_c-1}} \\ &-\varrho_t^c\left(P_t C_{h,t} + e_t P_t^* C_{f,t} - P_t^c C_t\right) \end{aligned} \tag{A.20}$$

where ϱ_t^c is the Lagrange multiplier associated with the households' optimization of consumption basket.

The first-order conditions of the optimization problem w.r.t. $C_{h,t}$ and $C_{f,t}$ are as follows:

$$\begin{aligned} \frac{\partial \mathcal{L}\left(C_{h,t}, C_{f,t}\right)}{\partial C_{h,t}} &= \gamma_c^{\frac{1}{\varepsilon_c}}\left(C_{h,t}\right)^{-\frac{1}{\varepsilon_c}} \\ \times\left[\gamma_c^{\frac{1}{\varepsilon_c}}\left(C_{h,t}\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}} + \left(1-\gamma_c\right)^{\frac{1}{\varepsilon_c}}\left(C_{f,t}\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}}\right]^{\frac{1}{\varepsilon_c-1}} &- \varrho_t^c P_t = 0 \end{aligned} \tag{A.21}$$

$$\begin{aligned} \frac{\partial \mathcal{L}\left(C_{h,t}, C_{f,t}\right)}{\partial C_{f,t}} &= \left(1-\gamma_c\right)^{\frac{1}{\varepsilon_c}}\left(C_{f,t}\right)^{-\frac{1}{\varepsilon_c}} \\ \times\left[\gamma_c^{\frac{1}{\varepsilon_c}}\left(C_{h,t}\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}} + \left(1-\gamma_c\right)^{\frac{1}{\varepsilon_c}}\left(C_{f,t}\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}}\right]^{\frac{1}{\varepsilon_c-1}} &- \varrho_t^c e_t P_t^* = 0 \end{aligned} \tag{A.22}$$

Combining and simplifying the first-order conditions - equations (A.21) and (A.22) - yields:

$$C_{f,t} = \varepsilon_{\tau,t}\frac{\left(1-\gamma_c\right)}{\gamma_c}\left[\frac{e_t P_t^*}{P_t^c}\right]^{-\varepsilon_c} C_{h,t} \tag{A.23}$$

We then substitute (A.23) into the budget constraint (A.18), which results in:

$$P_t^c C_t = P_t C_{h,t} + e_t P_t^* \frac{(1-\gamma_c)}{\gamma_c} \left[\frac{e_t P_t^*}{P_t^c}\right]^{-\varepsilon_c} C_{h,t} \tag{A.24}$$

Utilizing the definition of the price index from (A.19) in (A.24) and simplifying results in the following optimal allocation of the households' budget to domestically-produced consumer goods:

$$C_{h,t} = \gamma_c \left[\frac{P_t}{P_t^c}\right]^{-\varepsilon_c} C_t \tag{A.25}$$

It is then straightforward to substitute (A.25) back into (A.23), which results in the following:

$$C_{f,t} = \varepsilon_{\tau,t} \frac{(1-\gamma_c)}{\gamma_c} \left[\frac{e_t P_t^*}{P_t^c}\right]^{-\varepsilon_c} \gamma_c \left[\frac{P_t}{P_t^c}\right]^{-\varepsilon_c} C_t \tag{A.26}$$

Simplifying further yields the following optimal demand condition for imported goods:

$$C_{f,t} = \varepsilon_{\tau,t}(1-\gamma_c) \left[\frac{e_t P_t^*}{P_t^c}\right]^{-\varepsilon_c} C_t \tag{A.27}$$

A.1.2 The firms' problem

Retailers

Competitive retailers purchase differentiated goods from intermediate goods producers and combine them into a homogeneous final good. Aggregate output of retailers X_t is given by the following CES aggregate of a continuum of differentiated intermediate goods:

$$X_t = \left[\int_0^1 X_t(v)^{\frac{\varepsilon_r - 1}{\varepsilon_r}} dv\right]^{\frac{\varepsilon_r}{\varepsilon_r - 1}} \tag{A.28}$$

where $\varepsilon_c > 1$ signifies the elasticity of substitution between varieties.

The profit maximization problem of the representative retailer v is given by the difference between the revenues from the sales of the final good and the expenditures on intermediate goods. Retailers are perfectly competitive and, therefore, price-takers. They optimize the quantity of intermediate goods they purchase from intermediate goods producers $X_t(v)$ to maximize profits:

$$\max_{X_t(v)} \left[P_t X_t - \int_0^1 P_t(v) X_t(v) dv\right] \tag{A.29}$$

which given the definition of the final good from (A.28) yields:

$$\max_{X_t(v)} \left[P_t \left[\int_0^1 X_t(v)^{\frac{\varepsilon_r - 1}{\varepsilon_r}} dv \right]^{\frac{\varepsilon_r}{\varepsilon_r - 1}} - \int_0^1 P_t(v) X_t(v) dv \right] \tag{A.30}$$

The first-order condition of the retailers' profit maximization problem w.r.t. $X_t(v)$ is:

$$P_t \left[\int_0^1 X_t(v)^{\frac{\varepsilon_r - 1}{\varepsilon_r}} dv \right]^{\frac{1}{\varepsilon_r - 1}} X_t(v)^{-\frac{1}{\varepsilon_r}} - P_t(v) = 0 \tag{A.31}$$

which, using the definition of aggregate retailers' output from equation (A.28), can be simplified into the following retailers' demand for a typical variety of the intermediate good produced by the representative firm v:

$$X_t(v) = \left[\frac{P_t(v)}{P_t} \right]^{-\varepsilon_r} X_t \tag{A.32}$$

Using the definition of $X_t(v)$ following from the optimization problem of intermediate goods producers (equations A.37 and A.38) equation (A.32) becomes:

$$\int_0^1 \frac{K_t(v)^\alpha H_t(v)^{1-\alpha}}{(1 - \varphi_s)} dv = \int_0^1 \frac{XS_t(v)}{\varphi_s} dv = \left[\frac{P_t(v)}{P_t} \right]^{-\varepsilon_r} X_t \tag{A.33}$$

Finally, by utilizing the zero-profit condition, the price of the final good can be defined by:

$$P_t = \left[\int_0^1 P_t(v)^{1-\varepsilon_r} dv \right]^{\frac{1}{1-\varepsilon_r}} \tag{A.34}$$

Intermediate goods producers

We maintain that capital $K_t(v)$, labor $H_t(v)$, and intermediate inputs $XS_t(v)$ are combined according to the following Leontief technology:

$$X_t(v) = \min \left[\frac{K_t(v)^\alpha H_t(v)^{1-\alpha}}{1 - \varphi_s}, \frac{XS_t(v)}{\varphi_s} \right] \tag{A.35}$$

where $0 < \varphi_s < 1$ represents the share of intermediate inputs in output $X_t(v)$ and $0 < \alpha < 1$ is the share of capital in value added.

Given the properties of the Leontief specification, cost minimization requires that output is produced using equal shares of each input. That is:

$$X_t(v) = \frac{K_t(v)^\alpha H_t(v)^{1-\alpha}}{1 - \varphi_s} = \frac{XS_t(v)}{\varphi_s} \tag{A.36}$$

It, therefore, implies that the value added is a fixed share $(1-\varphi_s)$ of output:

$$K_t(v)^{\alpha} H_t(v)^{1-\alpha} = (1-\varphi_s) X_t(v) \tag{A.37}$$

and the share of intermediate inputs in output equals φ_s at all times:

$$XS_t(v) = \varphi_s X_t(v) \tag{A.38}$$

Capital K_t is composed of local capital $K_{h,t}$ and capital imported from the foreign economy $K_{f,t}$:

$$K_t(v) = \left[\gamma_k^{\frac{1}{\varepsilon_k}} \left(K_{h,t}(v)\right)^{\frac{\varepsilon_k-1}{\varepsilon_k}} + (1-\gamma_k)^{\frac{1}{\varepsilon_k}} \left(K_{f,t}(v)\right)^{\frac{\varepsilon_k-1}{\varepsilon_k}}\right]^{\frac{\varepsilon_k}{\varepsilon_k-1}} \tag{A.39}$$

where $0 < \gamma_k < 1$ is the share of local capital in aggregate capital used for production of intermediate goods and $\varepsilon_k > 0$ is the elasticity of substitution between local and imported capital.

The price of domestic capital is Z_t, while the price of foreign capital expressed in the domestic currency is $e_t Z_t^*$. Domestic intermediate goods producers optimize their use of domestic and imported capital subject to the following aggregate expenditure on physical capital:

$$P_t^k K_t = Z_t K_{h,t} + e_t Z_t^* K_{f,t} \tag{A.40}$$

where P_t^k is the price index composed of the prices of capital utilized by the local intermediate goods producers and weighted by their corresponding shares in the aggregate use of capital:

$$P_t^k = \left[\gamma_k \left(Z_t\right)^{1-\varepsilon_k} + (1-\gamma_k)\left(e_t Z_t^*\right)^{1-\varepsilon_k}\right]^{\frac{1}{1-\varepsilon_k}} \tag{A.41}$$

The Lagrangian associated with intermediate goods producers' optimization of expenditures on domestic versus foreign capital is given by:

$$\begin{aligned}\mathcal{L}\left(K_{h,t}, K_{f,t}\right) = &\left[\gamma_k^{\frac{1}{\varepsilon_k}} \left(K_{h,t}\right)^{\frac{\varepsilon_k-1}{\varepsilon_k}} + (1-\gamma_k)^{\frac{1}{\varepsilon_k}} \left(K_{f,t}\right)^{\frac{\varepsilon_k-1}{\varepsilon_k}}\right]^{\frac{\varepsilon_k}{\varepsilon_k-1}} \\ &- \varrho_t^k \left(Z_t K_{h,t} + e_t Z_t^* K_{f,t} - P_t^k K_t\right)\end{aligned} \tag{A.42}$$

where ϱ_t^k is the Lagrange multiplier associate with intermediate goods producers' optimization of the basket of physical capital.

The first-order conditions of the optimization problem w.r.t. $K_{h,t}$ and $K_{f,t}$ are as follows:

$$\begin{aligned}\frac{\partial \mathcal{L}\left(K_{h,t}, K_{f,t}\right)}{\partial K_{h,t}} &= {\gamma_k}^{\frac{1}{\varepsilon_k}} \left(K_{h,t}\right)^{-\frac{1}{\varepsilon_k}} \\ \times \left[{\gamma_k}^{\frac{1}{\varepsilon_k}} \left(K_{h,t}\right)^{\frac{\varepsilon_k-1}{\varepsilon_k}} + \left(1-\gamma_k\right)^{\frac{1}{\varepsilon_k}} \left(K_{f,t}\right)^{\frac{\varepsilon_k-1}{\varepsilon_k}}\right]^{\frac{1}{\varepsilon_k-1}} &- \varrho_t^k Z_t = 0\end{aligned} \tag{A.43}$$

$$\begin{aligned}\frac{\partial \mathcal{L}\left(K_{h,t}, K_{f,t}\right)}{\partial K_{f,t}} &= \left(1-\gamma_k\right)^{\frac{1}{\varepsilon_k}} \left(K_{f,t}\right)^{-\frac{1}{\varepsilon_k}} \\ \times \left[{\gamma_k}^{\frac{1}{\varepsilon_k}} \left(K_{h,t}\right)^{\frac{\varepsilon_k-1}{\varepsilon_k}} + \left(1-\gamma_k\right)^{\frac{1}{\varepsilon_k}} \left(K_{f,t}\right)^{\frac{\varepsilon_k-1}{\varepsilon_k}}\right]^{\frac{1}{\varepsilon_k-1}} &- \varrho_t^k e_t Z_t^* = 0\end{aligned} \tag{A.44}$$

Following the simplification of the households' FOCs with respect to domestic and foreign consumer goods (equations A.23 to A.27), the FOCs of intermediate goods producers with respect to domestic and foreign capital take the following final form:

$$K_{h,t} = \gamma_k \left[\frac{Z_t}{P_t^k}\right]^{-\varepsilon_k} K_t \tag{A.45}$$

$$K_{f,t} = \left(1-\gamma_k\right) \left[\frac{e_t Z_t^*}{P_t^k}\right]^{-\varepsilon_k} K_t \tag{A.46}$$

Similarly, intermediate inputs are in the form of both domestic and foreign supplies. Therefore, XS_t is a composite index of supplies used in domestic production and disaggregated into goods delivered by the local retailers $XS_{h,t}$ and imported goods $XS_{f,t}$:

$$XS_t(v) = \left[{\gamma_s}^{\frac{1}{\varepsilon_s}} \left(XS_{h,t}(v)\right)^{\frac{\varepsilon_s-1}{\varepsilon_s}} + \left(1-\gamma_s\right)^{\frac{1}{\varepsilon_s}} \left(XS_{f,t}(v)\right)^{\frac{\varepsilon_s-1}{\varepsilon_s}}\right]^{\frac{\varepsilon_s}{\varepsilon_s-1}} \tag{A.47}$$

where $0 < \gamma_s < 1$ denotes the share of supplies produced in the domestic economy in the total use of supplies and $\varepsilon_s > 0$ is the Armington elasticity of substitution between local and imported supplies.

Domestic intermediate goods producers optimize their use of domestic and imported intermediate goods subject to the following aggregate expenditure on intermediate goods:

$$P_t^s XS_t = P_t XS_{h,t} + e_t P_t^* XS_{f,t} \tag{A.48}$$

where P_t denotes the price of domestic intermediate goods and $e_t P_t^*$ the price of foreign intermediate goods expressed in the domestic currency. The price index composed of the prices of intermediate goods utilized by the local intermediate goods producers (PPI) is denoted by P_t^s and is given by the following:

$$P_t^s = \left[\gamma_s \left(P_t\right)^{1-\varepsilon_s} + \left(1-\gamma_s\right) \left(e_t P_t^*\right)^{1-\varepsilon_s}\right]^{\frac{1}{1-\varepsilon_s}} \tag{A.49}$$

The Lagrangian associated with intermediate goods producers' optimization of expenditures on domestic versus foreign intermediate goods is given by:

$$\begin{aligned}\mathcal{L}\left(XS_{h,t},XS_{f,t}\right)=&\left[\gamma_s{}^{\frac{1}{\varepsilon_s}}\left(XS_{h,t}\right)^{\frac{\varepsilon_s-1}{\varepsilon_s}}+\left(1-\gamma_s\right)^{\frac{1}{\varepsilon_s}}\left(XS_{f,t}\right)^{\frac{\varepsilon_s-1}{\varepsilon_s}}\right]^{\frac{\varepsilon_s}{\varepsilon_s-1}}\\&-\varrho_t^s\left(P_tXS_{h,t}+e_tP_t^*XS_{f,t}-P_t^sXS_t\right)\end{aligned}\tag{A.50}$$

in which ϱ_t^s is the Lagrange multiplier associated with the optimization of the intermediate goods' use of domestic versus imported supplies.

The first-order conditions of the optimization problem w.r.t. $XS_{h,t}$ and $XS_{f,t}$ are as follows:

$$\begin{aligned}\frac{\partial\mathcal{L}\left(XS_{h,t},XS_{f,t}\right)}{\partial XS_{h,t}}&=\gamma_s{}^{\frac{1}{\varepsilon_s}}\left(XS_{h,t}\right)^{-\frac{1}{\varepsilon_s}}\\\times\left[\gamma_s{}^{\frac{1}{\varepsilon_s}}\left(XS_{h,t}\right)^{\frac{\varepsilon_s-1}{\varepsilon_k}}+\left(1-\gamma_s\right)^{\frac{1}{\varepsilon_s}}\left(XS_{f,t}\right)^{\frac{\varepsilon_s-1}{\varepsilon_s}}\right]^{\frac{1}{\varepsilon_s-1}}&-\varrho_t^sP_t=0\end{aligned}\tag{A.51}$$

$$\begin{aligned}\frac{\partial\mathcal{L}\left(XS_{h,t},XS_{f,t}\right)}{\partial XS_{f,t}}&=\left(1-\gamma_s\right)^{\frac{1}{\varepsilon_s}}\left(XS_{f,t}\right)^{-\frac{1}{\varepsilon_s}}\\\times\left[\gamma_s{}^{\frac{1}{\varepsilon_s}}\left(XS_{h,t}\right)^{\frac{\varepsilon_s-1}{\varepsilon_s}}+\left(1-\gamma_s\right)^{\frac{1}{\varepsilon_s}}\left(XS_{f,t}\right)^{\frac{\varepsilon_s-1}{\varepsilon_s}}\right]^{\frac{1}{\varepsilon_s-1}}&-\varrho_t^se_tP_t^*=0\end{aligned}\tag{A.52}$$

Following the simplification of the households' FOCs with respect to domestic and foreign consumer goods (equations A.23 to A.27), the FOCs of intermediate goods producers with respect to domestic and foreign intermediate goods take the following final form:

$$XS_{h,t}=\gamma_s\left[\frac{P_t}{P_t^s}\right]^{-\varepsilon_s}XS_t\tag{A.53}$$

$$XS_{f,t}=\left(1-\gamma_s\right)\left[\frac{e_tP_t^*}{P_t^s}\right]^{-\varepsilon_s}XS_t\tag{A.54}$$

Now define the cost function of intermediate goods producers $\mathcal{C}_t(v)$ is the sum of inputs multiplied by their corresponding unit prices:

$$\mathcal{C}_t(v)=Z_tK_t(v)+W_tH_t(v)+P_t^sXS_t(v)\tag{A.55}$$

Solving the first-order condition (A.37) for capital $K_t(v)$ yields:

$$K_t(v)=\left[(1-\varphi_s)\frac{X_t(v)}{H_t(v)^{1-\alpha}}\right]^{\frac{1}{\alpha}}\tag{A.56}$$

Consequently, the cost function becomes:

$$\mathcal{C}_t(v)=Z_t\left[(1-\varphi_s)\frac{X_t(v)}{H_t(v)^{1-\alpha}}\right]^{\frac{1}{\alpha}}+W_tH_t(v)+P_t^sXS_t(v)\tag{A.57}$$

Intermediate goods producers face the following cost minimization problem:

$$\min_{H_t(v)} \left[Z_t \left[(1-\varphi_s) \frac{X_t(v)}{H_t(v)^{1-\alpha}} \right]^{\frac{1}{\alpha}} + W_t H_t(v) + P_t^s XS_t(v) \right] \tag{A.58}$$

The first-order condition of the cost-minimization problem with respect to labor $H_t(v)$ is:

$$W_t = Z_t \frac{1-\alpha}{\alpha} \left[(1-\varphi_s) \frac{X_t(v)}{H_t(v)} \right]^{\frac{1}{\alpha}} \tag{A.59}$$

So, the optimal use of labor in technology $H_t(v)$ by the representative producer is given by:

$$H_t(v) = (1-\varphi_s) \left[\frac{1-\alpha}{\alpha} \frac{Z_t}{W_t} \right]^{\alpha} X_t(v) \tag{A.60}$$

Substituting for $H_t(v)$ in equation (A.57) the optimal demand for labor defined by equation (A.60) gives the optimal use of capital $K_t(v)$ in technology:

$$K_t(v) = (1-\varphi_s) \left[\frac{\alpha}{1-\alpha} \frac{W_t}{Z_t} \right]^{1-\alpha} X_t(v) \tag{A.61}$$

Substituting for $H_t(v)$ and $K_t(v)$ in the cost function their optimal quantities - equations (A.60) and (A.61) - and using condition (A.38) yields:

$$\begin{aligned} \mathcal{C}_t(v) &= Z_t(1-\varphi_s) \left[\frac{W_t}{Z_t} \frac{\alpha}{1-\alpha} \right]^{1-\alpha} X_t(v) \\ +W_t(1-\varphi_s) &\left[\frac{Z_t}{W_t} \frac{1-\alpha}{\alpha} \right]^{\alpha} X_t(v) + P_t^s \varphi_s X_t(v) \end{aligned} \tag{A.62}$$

The marginal cost is the derivative of the cost function with respect to output $X_t(v)$:

$$\begin{aligned} \frac{\partial \mathcal{C}_t(v)}{\partial X_t(v)} = mc_t(v) &= Z_t(1-\varphi_s) \left[\frac{W_t}{Z_t} \frac{\alpha}{1-\alpha} \right]^{1-\alpha} \\ &+W_t(1-\varphi_s) \left[\frac{Z_t}{W_t} \frac{1-\alpha}{\alpha} \right]^{\alpha} + \varphi_s P_t^s \end{aligned} \tag{A.63}$$

which can be simplified into the following formula with the weighted unit cost of value added and intermediate inputs:

$$mc_t(v) = (1-\varphi_s) \frac{Z_t^{\alpha} W_t^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}} + \varphi_s P_t^s \tag{A.64}$$

Define the flow profit of the representative producer by the difference between the revenues and costs:

$$\Pi_t(v) = \frac{P_t(v)}{P_t} X_t(v) - Z_t K_t(v) - W_t H_t(v) - P_t^s XS_t(v) = \frac{P_t(v)}{P_t} X_t(v) - \mathcal{C}_t(v) \tag{A.65}$$

which after substituting for $\mathcal{C}_t(v)$ from equation (A.62) takes the form:

$$\begin{aligned}\Pi_t(v) = \frac{P_t(v)}{P_t}X_t(v) - Z_t(1-\varphi_s)\left[\frac{W_t}{Z_t}\frac{\alpha}{1-\alpha}\right]^{1-\alpha} X_t(v) \\ +W_t(1-\varphi_s)\left[\frac{Z_t}{W_t}\frac{1-\alpha}{\alpha}\right]^{\alpha} X_t(v) + P_t^s\varphi_s X_t(v)\end{aligned} \tag{A.66}$$

Using the formula from equation (A.64) in equation (A.66) yields:

$$\Pi_t(v) = \frac{P_t(v)}{P_t}X_t(v) - mc_t X_t(v) \tag{A.67}$$

By substituting for $X_t(v)$ the optimal demand for intermediate inputs from equation (A.32), the definition of profits becomes:

$$\Pi_t(v) = \frac{P_t(v)}{P_t}X_t(v) - mc_t\left[\frac{P_t(v)}{P_t}\right]^{-\varepsilon_r} X_t \tag{A.68}$$

In a manner similar to Calvo (1983), we introduce a staggered price setting where firms are unable to update their prices with probability $0 < \theta_p < 1$. Firms that receive the price signal to reset their price do so with the expectation that for the next $1/(1-\theta_p)$ periods they will not be able to do so until they receive the price signal again.

The profit maximization problem of a firm that is able to reset its price can, therefore, be written as:

$$\max_{P_t(v)} \mathbb{E}_t \sum_{k=0}^{\infty} (\beta\theta_p)^k \varrho_{t+k}\left[\ \frac{P_t(v)}{P_{t+k}}X_{t+k}(v) - mc_{t+k}\left[\frac{P_t(v)}{P_{t+k}}\right]^{-\varepsilon_r} X_{t+k}\ \right] \tag{A.69}$$

which given the definition of $X_t(v)$ from equation (A.32) can be rewritten as:

$$\max_{P_t(v)} \mathbb{E}_t \sum_{k=0}^{\infty} (\beta\theta_p)^k \varrho_{t+k}\left[\begin{array}{c}\frac{P_t(v)}{P_{t+k}}\left[\frac{P_{t+k}(v)}{P_{t+k}}\right]^{-\varepsilon_r} X_{t+k} \\ -mc_{t+k}(v)\left[\frac{P_t(v)}{P_{t+k}}\right]^{-\varepsilon_r} X_{t+k}\end{array}\right] \tag{A.70}$$

The first-order condition of the profit-maximization problem w.r.t. $P_t(v)$ is:

$$\begin{aligned}(1-\varepsilon_r)(P_t(v))^{-\varepsilon_r}\mathbb{E}_t\sum_{k=0}^{\infty}(\beta\theta_p)^k\varrho_{t+k}(P_{t+k})^{\varepsilon_r-1}X_{t+k} \\ +\varepsilon_r(P_t(v))^{-\varepsilon_r-1}\mathbb{E}_t\sum_{k=0}^{\infty}(\beta\theta_p)^k\varrho_{t+k}mc_{i,t+k}(P_{t+k})^{\varepsilon_r}X_{t+k} = 0\end{aligned} \tag{A.71}$$

Therefore, the optimal price of firms that receive the price signal and are able to reset their price is:

$$\widetilde{P}_t(v) = \frac{\varepsilon_r}{\varepsilon_r - 1}\frac{\mathbb{E}_t\sum_{k=0}^{\infty}(\beta\theta_p)^k\varrho_{t+k}mc_{i,t+k}(P_{t+k})^{\varepsilon_r-1}X_{t+k}}{\mathbb{E}_t\sum_{k=0}^{\infty}(\beta\theta_p)^k\varrho_{t+k}(P_{t+k})^{\varepsilon_r}X_{t+k}} \tag{A.72}$$

which can be written as:

$$\widetilde{P}_t(v) = \frac{\varepsilon_r}{\varepsilon_r - 1} \frac{e_t}{f_t} \tag{A.73}$$

where $e_t = \varrho_t mc_t (P_{n,t})^{\varepsilon_r} X_t + \theta_p \beta \mathbb{E}_t e_{t+1}$ and $f_t = \varrho_t (P_{n,t})^{\varepsilon_r - 1} X_t + \theta_p \beta \mathbb{E}_t f_{t+1}$.

Capital goods producers

Capital goods producers incur a quadratic investment adjustment cost per unit of investment I_t, similar to Christiano et al. (2005), Fernández-Villaverde (2010) and Jarociński and Karadi (2020), defined as:

$$f\left(\frac{I_t}{I_{t-1}}\right) \equiv \frac{\eta_i}{2}\left[\frac{I_t}{I_{t-1}} - 1\right]^2 \tag{A.74}$$

where $\eta_i > 0$ is the adjustment cost parameter.

Capital goods producers maximize their present discounted profits by choosing the optimal quantity of investment by solving the following problem:

$$\max_{I_t} \mathbb{E}_t \sum_{t=0}^{\infty} \Lambda_{t,t+1} \left[Q_t I_t - \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t\right] \tag{A.75}$$

where Q_t is the price of a security that finances the purchase of a unit of physical capital.

The FOC condition yields the following Q-investment relation for capital goods:

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \frac{I_t}{I_{t-1}} f'\left(\frac{I_t}{I_{t-1}}\right) - \mathbb{E}_t\left[\Lambda_{t,t+1}\left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right)\right] \tag{A.76}$$

which given the definition of the quadratic investment adjustment cost from equation (A.74) corresponds to:

$$Q_t = 1 + \frac{\eta_i}{2}\left[\left(\frac{I_t}{I_{t-1}}\right) - 1\right]^2 + \eta_i\left[\frac{I_t}{I_{t-1}} - 1\right]\frac{I_t}{I_{t-1}} - \mathbb{E}_t\left[\Lambda_{t,t+1}\eta_i\left[\frac{I_{t+1}}{I_t} - 1\right]\left(\frac{I_{t+1}}{I_t}\right)^2\right] \tag{A.77}$$

The aggregate capital stock in period t is given by the following law of motion of capital:

$$K_{t+1} = I_t\left[1 - f\left(\frac{I_t}{I_{t-1}}\right)\right] + (1-\delta)K_t \tag{A.78}$$

where $0 < \delta < 1$ is the depreciation rate of capital.

The return on physical capital that results from the intermediate goods producers' optimal demand for physical capital backed by financial assets is:

$$R_{k,t+1} = \frac{[Z_{t+1} + (1-\delta)Q_{t+1}]}{Q_t} \tag{A.79}$$

A.1.3 The banks' problem

The financial intermediaries' balance sheet is given by:

$$Q_t S_{h,t} + e_t Q_t^* S_{f,t} + q_t B_{b,t} = N_t + D_t \tag{A.80}$$

where $S_{h,t-1} = K_{h,t}$ and $S_{f,t-1} = K_{h,t}^*$ and net worth evolves according to the following rule:

$$N_t = R_{k,t} Q_{t-1} S_{h,t-1} + e_t R_{k,t}^* Q_{t-1}^* S_{f,t-1} + R_{b,t} q_{t-1} B_{b,t-1} - R_t D_{t-1} + J_{t-1} \tag{A.81}$$

The pricing of long-term bonds is linked to the rate of return using the formula:

$$R_{b,t+1} = \frac{\Xi + \varrho q_{t+1}}{q_t} \tag{A.82}$$

From (A.80) deposits are given by:

$$D_t = Q_t S_{h,t} + e_t Q_t^* S_{f,t} + q_t B_{b,t} - N_t \tag{A.83}$$

So, by substituting the definition of deposits from (A.83) in $t-1$ to (A.81), the net worth becomes:

$$\begin{aligned} N_t &= R_{k,t} Q_{t-1} S_{h,t-1} + e_t R_{k,t}^* Q_{t-1}^* S_{f,t-1} + R_{b,t} q_{t-1} B_{b,t-1} \\ -R_t &\left(Q_{t-1} S_{h,t-1} + e_{t-1} Q_{t-1}^* S_{f,t-1} + q_{t-1} B_{b,t-1} - N_{t-1} \right) + J_{t-1} \end{aligned} \tag{A.84}$$

which is equivalent to:

$$\begin{aligned} N_t = \big(R_{k,t} - R_t\big) Q_{t-1} S_{h,t-1} &+ \big(e_t R_{k,t}^* - e_{t-1} R_t\big) Q_{t-1}^* S_{f,t-1} \\ &+ \big(R_{b,t} - R_t\big) q_{t-1} B_{b,t-1} + R_t N_{t-1} + J_{t-1} \end{aligned} \tag{A.85}$$

The end-of-period value function with equity issuance conditional on the survival of the bank is:

$$\mathcal{V}_t(N_t) = \max_{S_{h,t}, S_{f,t}, J_t, D_t} \mathbb{E}_t \left[\beta \frac{\varrho_{t+1}}{\varrho_t} \left[\begin{array}{l} (1-\sigma) N_{t+1} \\ +\sigma \Big(W_{t+1}(N_{t+1}) - J_t - C(J_t, N_t) \Big) \end{array} \right] \right] \tag{A.86}$$

The bankers' maximization problem is to choose their portfolio of $S_{h,t}$, $S_{f,t}$ and $B_{b,t}$ to maximize

$\mathcal{V}_t(N_t)$ subject to the following incentive constraint:

$$\mathcal{V}_t(N_t) \geq \theta Q_t S_{h,t} + e_t Q_t^* S_{f,t} + \Gamma \theta q_t B_{b,t} \tag{A.87}$$

and to choose their equity issuance J_t to maximize $\mathcal{W}_{t+1}(N_{t+1})$ subject to the definition of net worth given by (A.85); assuming at the same time the existence a linear solution of the form:

$$\mathcal{V}_t = \mu_{s,t} \left(Q_t S_{h,t} + e_t Q_t^* S_{f,t} \right) + \mu_{b,t} q_t B_{b,t} + \nu_t N_t \tag{A.88}$$

and

$$\mathcal{W}_t = \eta_t N_t \tag{A.89}$$

Let υ_t be the Lagrange multiplier associated with the incentive constraint (A.87), $\lambda_t = \upsilon_t/(1+\upsilon_t)$ and Ω_{t+1} a term that augments the banks' discount factor relative to the household's discount factor. The bank's optimization problem is solved by guessing a linear value function on assets and deposits:

$$\mathcal{V}_t = \mu_{s,t} \left(Q_t S_{h,t} + e_t Q_t^* S_{f,t} \right) + \mu_{b,t} q_t B_{b,t} + \nu_t N_t \tag{A.90}$$

The Lagrangian is formalized as:

$$\begin{aligned} \mathcal{L}(S_{h,t}, S_{f,t}, B_{b,t}) &= \mu_{s,t} \left(Q_t S_{h,t} + e_t Q_t^* S_{f,t} \right) + \mu_{b,t} q_t B_{b,t} + \nu_t N_t \\ -\upsilon_t &\left[\begin{array}{l} \theta \left(Q_t S_{h,t} + e_t Q_t^* S_{f,t} \right) + \Gamma \theta q_t B_{b,t} - \nu_t N_t \\ -\Big(\mu_{s,t} \left(Q_t S_{h,t} + e_t Q_t^* S_{f,t} \right) + \mu_{b,t} q_t B_{b,t} + \nu_t N_t \Big) \end{array} \right] \end{aligned} \tag{A.91}$$

The first-order conditions with respect to $S_{h,t}$, $S_{f,t}$, $B_{b,t}$, and υ_t are expressed as follows:

$$\mu_{s,t} Q_t - \upsilon_t \theta Q_t + \upsilon_t \mu_{s,t} Q_t = 0 \Rightarrow \mu_{s,t} = \theta \frac{\upsilon_t}{1+\upsilon_t} \tag{A.92}$$

$$\mu_{s,t} e_t Q_t^* - \upsilon_t \theta e_t Q_t^* + \upsilon_t \mu_{s,t} e_t Q_t^* = 0 \Rightarrow \mu_{s,t} = \theta \frac{\upsilon_t}{1+\upsilon_t} \tag{A.93}$$

$$\mu_{b,t} q_t - \upsilon_t \Gamma \theta q_t + \upsilon_t \mu_{b,t} q_t = 0 \Rightarrow \mu_{b,t} = \Gamma \frac{\upsilon_t}{1+\upsilon_t} \tag{A.94}$$

$$\theta Q_t s_t + \Gamma \theta q_t B_{b,t} - \mu_{s,t} Q_t s_t - \mu_{b,t} q_t B_{b,t} - \nu_t n_t = 0 \tag{A.95}$$

where ν_t is the value of banks' net worth defined as (see equation A.104):

$$\nu_t = \mathbb{E}_t \left[\beta \frac{\varrho_{t+1}}{\varrho_t} Q_{t+1} R_{t+1} + \left(\beta \frac{\varrho_{t+1}}{\varrho_t} Q_{t+1} - 1 \right)^2 / (2\zeta) \right] \tag{A.96}$$

Then the solution can be characterized as follows: at the end of each period, an individual bank maximizes the present value of its future dividends given the quadratic cost of equity issuance:

$$\begin{aligned}
\mathcal{V}_t(N_t) = \max_{S_{h,t},S_{f,t},J_t,D_t} & \mathbb{E}_t \left[\beta \frac{\varrho_{t+1}}{\varrho_t} \left[(1-\theta_b)N_{t+1} + \theta_b \left(\mathcal{W}_{t+1}(N_{t+1}) - J_t - \frac{\zeta}{2}\frac{J_t^2}{N_t}\right)\right]\right] \\
\text{s.t.} \quad & \mathcal{V}_t(S_{h,t}, S_{f,t}, B_{b,t}, N_t) \geq \mu_{s,t}\left(Q_t S_{h,t} + e_t Q_t^* S_{f,t}\right) + \mu_{b,t} q_t B_{b,t} + \nu_t N_t \\
\text{for} \quad & N_{t+1} = (R_{k,t+1} - R_{t+1}) Q_t S_{h,t} + (e_{t+1} R^*_{k,t+1} - e_t R_{t+1}) Q_t^* S_{f,t} \\
& + (R_{b,t+1} - R_{t+1}) q_t B_{b,t} + R_{t+1} N_t + J_t
\end{aligned} \tag{A.97}$$

The Lagrangian is formalized as:

$$\begin{aligned}
\mathcal{L}(S_{h,t}, S_{f,t}, J_t, D_t) = \mathbb{E}_t & \left[\beta \frac{\varrho_{t+1}}{\varrho_t} \left[(1-\theta_b)N_{t+1} + \theta_b \left(\eta_{t+1} N_{t+1} - J_t - \frac{\zeta}{2}\frac{J_t^2}{N_t}\right)\right]\right] \\
& - \upsilon_t \Big[\theta\left(Q_t S_{h,t} + e_t Q_t^* S_{f,t}\right) + \Gamma \theta q_t B_{b,t} - \mathcal{V}_t(S_{h,t}, S_{f,t}, B_{b,t}, N_t)\Big]
\end{aligned} \tag{A.98}$$

Definitions:

$$\eta_t \equiv \frac{\partial \mathcal{V}_t}{\partial N_t}, \quad \xi_t \equiv \frac{J_t}{N_t}, \quad \lambda_t \equiv \eta_t (1-\lambda_t), \quad \Omega_t \equiv (1-\theta_b) + \theta_b \eta_t \tag{A.99}$$

Given the definition of the terms that augments the bankers' discount factor relative to that of households Ω_t in $t+1$, the Lagrangian given by equation (A.98) can be rewritten as:

$$\begin{aligned}
\mathcal{L}(S_{h,t}, S_{f,t}, J_t, D_t) = \mathbb{E}_t & \left[\beta \frac{\varrho_{t+1}}{\varrho_t} \left[\Omega_{t+1} N_{t+1} - \theta_b J_t - \theta_b \frac{\zeta}{2}\frac{J_t^2}{N_t}\right]\right] \\
- \upsilon_t & \Big[\theta\left(Q_t S_{h,t} + e_t Q_t^* S_{f,t}\right) + \Gamma \theta q_t B_{b,t} - \mathcal{V}_t(S_{h,t}, S_{f,t}, B_{b,t}, N_t)\Big]
\end{aligned} \tag{A.100}$$

which given the expression for N_{t+1} above yields:

$$\begin{aligned}
\mathcal{L}(S_{h,t}, S_{f,t}, B_{b,t}, N_t) = \mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} & \left[\begin{array}{l} \Omega_{t+1} \left[\begin{array}{l} (R_{k,t+1} - R_{t+1}) Q_t S_{h,t} \\ + (e_{t+1} R^*_{k,t+1} - e_t R_{t+1}) Q_t^* S_{f,t} \\ + (R_{b,t+1} - R_{t+1}) q_t B_{b,t} \\ + R_{t+1} N_t + J_t \end{array}\right] \\ - \theta_b J_t - \theta_b \frac{\zeta}{2}\frac{J_t^2}{N_t} \end{array}\right] \\
- \upsilon_t & \left[\begin{array}{l} \theta\left(Q_t S_{h,t} + e_t Q_t^* S_{f,t}\right) + \Gamma \theta q_t B_{b,t} \\ - \mu_{s,t}\left(Q_t S_{h,t} + e_t Q_t^* S_{f,t}\right) - \mu_{b,t} q_t B_{b,t} - \nu_t N_t \end{array}\right]
\end{aligned} \tag{A.101}$$

The FOC w.r.t. $S_{h,t}$ is:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{k,t+1} - R_{t+1}) Q_t - \upsilon_t \theta Q_t + \upsilon_t \mu_{s,t} Q_t = 0 \tag{A.102}$$

Substituting for $\mu_{s,t}$ using equation (A.92) into the above yields:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{k,t+1} - R_{t+1}) - \upsilon_t \theta + \upsilon_t \theta \frac{\upsilon_t}{1+\upsilon_t} = 0 \tag{A.103}$$

which can be further simplified into:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{k,t+1} - R_{t+1}) - \frac{\upsilon_t \theta (1+\upsilon_t)}{1+\upsilon_t} + \frac{\upsilon_t^2 \theta}{1+\upsilon_t} = 0 \tag{A.104}$$

Given that $\lambda_t = \upsilon_t/(1+\upsilon_t)$, the final form of the FOC w.r.t. $S_{h,t}$ is:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{k,t+1} - R_{t+1}) = \theta \lambda_t \tag{A.105}$$

The first-order condition with respect to $S_{f,t}$ is:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(e_{t+1} R^*_{k,t+1} - e_t R_{t+1}) Q^*_t - \upsilon_t \theta e_t Q^*_t + \upsilon_t \mu_{s,t} e_t Q^*_t = 0 \tag{A.106}$$

Substituting for $\mu_{s,t}$ using equation (A.92) yields:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(e_{t+1} R^*_{k,t+1} - e_t R_{t+1}) - \upsilon_t \theta e_t + \upsilon_t \theta \frac{\upsilon_t}{1+\upsilon_t} e_t = 0 \tag{A.107}$$

Given that $\lambda_t = \upsilon_t/(1+\upsilon_t)$, the final form of the FOC w.r.t. $S_{f,t}$ is:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} \left(\frac{e_{t+1}}{e_t} R^*_{k,t+1} - R_{t+1} \right) = \theta \lambda_t \tag{A.108}$$

The first-order condition of the optimization problem of banks with respect to $B_{b,t}$ is:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{b,t+1} - R_{t+1}) - \upsilon_t \Gamma \theta + \upsilon_t \mu_{b,t} = 0 \tag{A.109}$$

Substituting for $\mu_{b,t}$ yields:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{b,t+1} - R_{t+1}) - \upsilon_t \Gamma \theta + \upsilon_t \Gamma \frac{\upsilon_t}{1+\upsilon_t} = 0 \tag{A.110}$$

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{b,t+1} - R_{t+1}) + \frac{-\upsilon_t \Gamma \theta (1+\upsilon_t)}{1+\upsilon_t} + \frac{\upsilon_t \Gamma \upsilon_t}{1+\upsilon_t} = 0 \tag{A.111}$$

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{b,t+1} - R_{t+1}) + \frac{-\upsilon_t \Gamma \theta - \upsilon_t^2 \Gamma \theta + \upsilon_t^2 \Gamma \theta}{1+\upsilon_t} = 0 \tag{A.112}$$

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{b,t+1} - R_{t+1}) + \frac{-\upsilon_t \Gamma \theta}{1+\upsilon_t} = 0 \tag{A.113}$$

Given that $\lambda_t = \upsilon_t/(1+\upsilon_t)$:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{b,t+1} - R_{t+1}) = \theta \Gamma \lambda_t \tag{A.114}$$

From the perspective of the foreign economy, the first-order conditions of the optimization problem of foreign banks with respect to capital-backed lending by foreign banks - $S^*_{h,t}$ and $S^*_{f,t}$ - are the following:

$$\mathbb{E}_t \left[\Lambda^*_{t,t+1} \Omega^*_{t+1} \left(\frac{e_t}{e_{t+1}} R_{k,t+1} - R^*_t \right) \right] = \theta^* \Gamma^* \lambda^*_t \tag{A.115}$$

$$\mathbb{E}_t \left[\Lambda^*_{t,t+1} \Omega^*_{t+1} \left(R^*_{k,t+1} - R^*_t \right) \right] = \theta^* \Gamma^* \lambda^*_t \tag{A.116}$$

Cross-border lending has important implications for the model dynamics. It implies that the exchange rate is determined by the relative expected rates of return on capital in both domestic and foreign economies. Therefore, the following uncovered interest parity (UIP) condition holds:

$$\frac{e_{t+1}}{e_t} = \frac{R_{k,t+1}}{R^*_{k,t+1}} \tag{A.117}$$

By symmetry, the first-order approximation of the first-order conditions of banks in the foreign economy with respect to loans granted to local and foreign intermediate goods producers, which emerges from equations (A.115) and (A.116), leads to the same UIP condition as in the domestic economy expressed by equation (A.117).

The objective of the banker is to issue equity in order to maximize $\mathcal{W}_{t+1}(N_{t+1})$ subject to equation (A.85):

$$\max_{J_t} \mathbb{E}_t \left[\beta \frac{\varrho_{t+1}}{\varrho_t} \left[\Omega_{t+1} \left[\begin{array}{l} (R_{k,t+1} - R_{t+1}) Q_t S_{h,t} \\ +(R^*_{k,t+1} - R_{t+1}) e_t Q^*_t S_{f,t} \\ +(R_{b,t+1} - R_{t+1}) q_t B_{b,t} \\ +R_{t+1} N_t + J_t \end{array} \right] - J_t - \frac{\zeta}{2} \frac{J_t^2}{N_t} \right] \right] \tag{A.118}$$

It is, therefore, assumed that the equity is issued and the cost of equity is paid only by the surviving banks. So, conditional on the the bank surviving to $t+1$ the amount of equity it issues in t is such that the bank maximizes $\mathcal{W}_{t+1}(N_{t+1}) = \eta_{t+1} N_{t+1}$ subject to the cost of equity issuance.

The Lagrangian is formalized as:

$$\mathcal{L}(J_t, N_t) = \mathbb{E}_t \left[\begin{array}{l} \beta \frac{\varrho_{t+1}}{\varrho_t} \left[\Omega_{t+1} \left[\begin{array}{l} (R_{k,t+1} - R_{t+1})Q_t S_{h,t} \\ +(R^*_{k,t+1} - R_{t+1})e_t Q^*_t S_{f,t} \\ +(R_{b,t+1} - R_{t+1})q_t B_{b,t} \\ +R_{t+1}N_t + J_t \end{array} \right] - J_t - \frac{\zeta}{2}\frac{J_t^2}{N_t} \right] \\ -\lambda_t(\eta_t N_t - \mathcal{W}_t) \end{array} \right] \tag{A.119}$$

The first-order condition with respect to the cost of equity issuance J_t is:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t}(\Omega_{t+1} - 1) - \zeta \xi_t = 0 \tag{A.120}$$

which implies:

$$\xi_t = \frac{\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t}(\Omega_{t+1} - 1)}{\zeta} \tag{A.121}$$

$$\eta_t \equiv \frac{\partial \mathcal{V}_t}{\partial N_t} \Rightarrow \eta_t = \mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} R_{t+1} + \frac{\zeta}{2}\xi_t^2 + \lambda_t \eta_t \tag{A.122}$$

$$\nu_t = \mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} R_{t+1} + \frac{\mathbb{E}_t \left[\beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} - 1\right]^2}{2\zeta} \tag{A.123}$$

Finally, we characterize the behavior of the multiplier λ_t. In this case, since $V_t = \eta_t n_t$ and equation (A.87) holds with equality, it follows that:

$$\eta_t n_t = \theta(Q_t S_{h,t} + e_t Q^*_t S_{f,t} + q_t B_{b,t}) \tag{A.124}$$

From equation (A.122) it follows that:

$$\eta_t(1 - \lambda_t) = \nu_t \tag{A.125}$$

and substituting in equation (A.122) we get the following expression for λ_t:

$$\lambda_t = 1 - \frac{\nu_t}{\theta \phi_t} \tag{A.126}$$

A.1.4 Monetary and fiscal authorities

Monetary policy is conducted according to a standard Taylor rule, which implies that the deviations of the nominal risk-free interest rate r_t from its deterministic steady state r respond to the deviations of inflation π_t from its deterministic steady-state value π and to the deviations of output X_t from its deterministic steady-state value X, allowing additionally for interest rate smoothing:

$$\frac{r_t}{r} = \left(\frac{r_{t-1}}{r}\right)^{\rho_r} \left[\left(\frac{\pi_t}{\pi}\right)^{\varphi_\pi} \left(\frac{X_t}{X}\right)^{\varphi_x} \right]^{1-\rho_r} exp(\sigma_{r,t}) \tag{A.127}$$

where $0 \leq \rho_r \leq 1$ is the smoothing parameter; $\varphi_\pi > 0$ describes the central bank's weight on the deviations of inflation; $\varphi_x > 0$ describes the central bank's weight on the deviations of output; and $\sigma_{r,t}$ is the conventional monetary policy shock in the form of a one-off innovation to the risk-free rate with a zero mean.

In line with the existing literature on monetary policy in emerging markets, as part of our extensions we also incorporate deviations of the nominal exchange rate into the Taylor rule specific to the domestic economy. The domestic Taylor rule is augmented by the monetary authority taking into account the nominal exchange rate s_t when determining its monetary policy stance.

$$\frac{r_t^*}{r^*} = \left(\frac{r_{t-1}^*}{r^*}\right)^{\rho_r^*} \left[\left(\frac{\pi_t^*}{\pi^*}\right)^{\varphi_\pi^*} \left(\frac{X_t^*}{X^*}\right)^{\varphi_x^*} \left(\frac{s_t}{s}\right)^{\varsigma^*} \right]^{1-\rho_r^*} \tag{A.128}$$

where ς^* is the weight of the domestic monetary authority on the derivations of the nominal exchange rate s_t from its non-stochastic steady state. The relationship between the real and nominal exchange rates is $e_t \equiv \frac{s_t \pi_t}{\pi_t^*}$, where π_t^* is the inflation rate in the domestic economy.

In both countries, the relation between the nominal interest rate r_t and the real rate R_t is determined by the following Fisher equation:

$$r_t = R_t \pi_{t+1} \tag{A.129}$$

The domestic government fixes its spending on the domestic final good G by spending a fixed share τ on local goods:

$$G = \tau X \tag{A.130}$$

A.1.5 Market clearing conditions

The government issues short-term and long-term bonds. Aggregate long-term bonds are at the fixed quantity, B, at all times. Central bank-held bonds $B_{g,t}$ are fixed exogenously. The clearing condition of long-term bonds held by central bank, households and banks is:

$$B = B_{g,t} + B_{h,t}t + B_{b,t} \tag{A.131}$$

The size of the balance sheet in relation to annual GDP is defined as:

$$BS_t \equiv \frac{q_t B_{g,t}}{4 \times X} \tag{A.132}$$

where BS_t follows an AR(1) process with a $0 \leq \rho_b < 1$ persistence and a zero-mean uncorrelated innovation $\sigma_{b,t}$ with standard deviation σ_b:

$$BS_t = \rho_b BS_{t-1} + \sigma_{b,t} \tag{A.133}$$

Therefore, a positive shock to the size of the balance sheet will increase the value of long-term bonds held by the monetary authority, representing a QE shock. Conversely, a negative shock to BS_t would characterize a QT shock.

Finally, we introduce the following clearing conditions of the domestic goods market:

$$X_t = C_{h,t} + C^*_{h,t} + XS_{h,t} + XS^*_{h,t} + G + I_t \left[1 + f\left(\frac{I_t}{I_{t-1}}\right)\right] + \frac{\zeta}{2}\xi_t^2 N_t \tag{A.134}$$

suggesting that total output is matched by the sum of the demands for domestically-produced goods of local and foreign households, intermediate goods producers from both countries, local government, investment expenditures adjusted for investment adjustment cost, and the cost of new equity issuance.

A.2 Alternative model specifications

A.2.1 CES and Cobb-Douglas production functions

In the benchmark specification of our model, we adopt the Leontief technology for the production of intermediate goods. Our objective is to investigate the effects of two alternative functional forms; (i) the Constant Elasticity of Substitution (CES) technology; and (ii) the Cobb-Douglas technology. Within this part of Appendix A, we provide a detailed exposition of the optimization problem of intermediate goods producers under the CES and Cobb-Douglas specifications for the production function.

CES technology

Take the following CES technology with labor, capital, and intermediate inputs:

$$X_t(v) = \left[(1-\varphi_s)\left[K_t(v)^\alpha H_t(v)^{1-\alpha}\right]^{\frac{\eta-1}{\eta}} + \varphi_s XS_t(v)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{A.135}$$

where $\eta > 1$ is the elasticity of substitution between value added and intermediate inputs.

A Lagrangian corresponding the cost minimization problem is given by:

$$\begin{aligned} \mathcal{L}\left(H_t(v), K_t(v), XS_t(v)\right) = W_t H_t(v) + Z_t K_t(v) + P_t^s XS_t(v) \\ -mc_t(v)\left[\left[(1-\varphi_s)\left[K_t(v)^\alpha H_t(v)^{1-\alpha}\right]^{\frac{\eta-1}{\eta}} + \varphi_s XS_t(v)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} - \left[\frac{P_t(v)}{P_t}\right]^{-\varepsilon_r} X_t\right] \end{aligned} \tag{A.136}$$

The first-order conditions with respect to $H_t(v)$, $K_t(v)$, and $XS_t(v)$ are:

$$\begin{aligned}\frac{\partial \mathcal{L}\left(H_t(v), K_t(v), XS_t(v)\right)}{\partial H_t(v)} &= W_t - mc_t(v) \\ \times \left[(1-\varphi_s)\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{\frac{\eta-1}{\eta}} + \varphi_s XS_t(v)^{\frac{\eta-1}{\eta}}\right]^{\frac{1}{\eta-1}} \\ \times(1-\varphi_s)\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{-\frac{1}{\eta}}(1-\alpha) K_t(v)^{\alpha} H_t(v)^{-\alpha} \\ = W_t - mc_t(v)(1-\varphi_s)(1-\alpha) X_t(v)^{\frac{1}{\eta}} \frac{\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{\frac{\eta-1}{\eta}}}{H_t(v)} &= 0\end{aligned} \tag{A.137}$$

$$\begin{aligned}\frac{\partial \mathcal{L}\left(H_t(v), K_t(v), XS_t(v)\right)}{\partial K_t(v)} &= Z_t - mc_t(v) \\ \times \left[(1-\varphi_s)\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{\frac{\eta-1}{\eta}} + \varphi_s XS_t(v)^{\frac{\eta-1}{\eta}}\right]^{\frac{1}{\eta-1}} \\ \times(1-\varphi_s)\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{-\frac{1}{\eta}} \alpha K_t(v)^{\alpha-1} H_t(v)^{1-\alpha} \\ = Z_t - mc_t(v)(1-\varphi_s)\alpha X_t(v)^{\frac{1}{\eta}} \frac{\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{\frac{\eta-1}{\eta}}}{K_t(v)} &= 0\end{aligned} \tag{A.138}$$

$$\begin{aligned}\frac{\partial \mathcal{L}\left(H_t(v), K_t(v), XS_t(v)\right)}{\partial XS_t(v)} &= P_t^s - mc_t(v) \\ \times \left[(1-\varphi_s)\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{\frac{\eta-1}{\eta}} + \varphi_s XS_t(v)^{\frac{\eta-1}{\eta}}\right]^{\frac{1}{\eta-1}} \varphi_s XS_t(v)^{-\frac{1}{\eta}} \\ = P_t^s - mc_t(v)\varphi_s\left[\frac{X_t(v)}{XS_t(v)}\right]^{\frac{1}{\eta}} &= 0\end{aligned} \tag{A.139}$$

All intermediate goods producers are identical. Therefore, the first-order conditions of the cost-minimization problem of all intermediate goods producers with respect to labor, capital, and intermediate inputs under the CES specification of technology are, respectively:

$$W_t = mc_t(1-\varphi_s)(1-\alpha) X_t^{\frac{1}{\eta}} \frac{\left[K_t^{\alpha} H_t^{1-\alpha}\right]^{\frac{\eta-1}{\eta}}}{H_t} \tag{A.140}$$

$$Z_t = mc_t(1-\varphi_s)\alpha X_t^{\frac{1}{\eta}} \frac{\left[K_t^{\alpha} H_t^{1-\alpha}\right]^{\frac{\eta-1}{\eta}}}{K_t} \tag{A.141}$$

$$P_t^s = mc_t \varphi_s \left[\frac{X_t}{XS_t}\right]^{\frac{1}{\eta}} \tag{A.142}$$

Cobb-Douglas technology

Take the following Cobb-Douglas technology with labor, capital, and intermediate inputs:

$$X_t(v) = \left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{(1-\varphi_s)} XS_t(v)^{\varphi_s} \tag{A.143}$$

A Lagrangian corresponding the cost minimization problem is given by:

$$\begin{aligned}\mathcal{L}\left(H_t(v), K_t(v), XS_t(v)\right) &= W_t H_t(v) + Z_t K_t(v) + P_t^s XS_t(v) \\ -mc_t(v)\Big(&\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{(1-\varphi_s)} XS_t(v)^{\varphi_s} - \left[\tfrac{P_t(v)}{P_t}\right]^{-\varepsilon_r} X_t \Big)\end{aligned} \tag{A.144}$$

The first-order conditions with respect to $H_t(v)$, $K_t(v)$, and $XS_t(v)$ are:

$$\begin{aligned}\frac{\partial\mathcal{L}\left(H_t(v), K_t(v), XS_t(v)\right)}{\partial H_t(v)} &= W_t - mc_t(v)(1-\varphi_s)(1-\alpha)\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{-\varphi_s} \\ \times XS_t(v)^{\varphi_s} K_t(v)^{\alpha} H_t(v)^{-\alpha} &= W_t - mc_t(v)(1-\varphi_s)(1-\alpha)\frac{X_t(v)}{K_t(v)^{\alpha} H_t(v)^{1-\alpha}} \\ \times K_t(v)^{\alpha} H_t(v)^{-\alpha} &= W_t - mc_t(v)(1-\varphi_s)(1-\alpha)\frac{X_t(v)}{H_t(v)} = 0\end{aligned} \tag{A.145}$$

$$\begin{aligned}\frac{\partial\mathcal{L}\left(H_t(v), K_t(v), XS_t(v)\right)}{\partial K_t(v)} &= Z_t - mc_t(v)(1-\varphi_s)\alpha\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{-\varphi_s} \\ \times XS_t(v)^{\varphi_s} K_t(v)^{\alpha-1} H_t(v)^{1-\alpha} &= Z_t - mc_t(v)(1-\varphi_s)\alpha\frac{X_t(v)}{K_t(v)^{\alpha} H_t(v)^{1-\alpha}} \\ \times K_t(v)^{\alpha-1} H_t(v)^{1-\alpha} &= Z_t - mc_t(v)(1-\varphi_s)\alpha\frac{X_t(v)}{K_t(v)} = 0\end{aligned} \tag{A.146}$$

$$\begin{aligned}\frac{\partial\mathcal{L}\left(H_t(v), K_t(v), XS_t(v)\right)}{\partial XS_t(v)} &= P_t^s - mc_t(v)\varphi_s\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha}\right]^{(1-\varphi_s)} \\ \times XS_t(v)^{\varphi_s-1} &= P_t^s - mc_t(v)\varphi_s\frac{X_t(v)}{XS_t(v)} = 0\end{aligned} \tag{A.147}$$

All intermediate goods producers are identical. Therefore, the first-order conditions of the cost-minimization problem of all intermediate goods producers with respect to labor, capital, and intermediate inputs given the Cobb-Douglas specification of technology are, respectively:

$$W_t = mc_t(1-\varphi_s)(1-\alpha)\frac{X_t}{H_t} \tag{A.148}$$

$$Z_t = mc_t(1-\varphi_s)\alpha\frac{X_t}{K_t} \tag{A.149}$$

$$P_t^s = mc_t\varphi_s\frac{X_t}{XS_t} \tag{A.150}$$

A.2.2 Model with final goods

This version of the model assumes that trade between the two countries is in final consumer goods only. This implies that intermediate goods producers use labor and capital inputs only in their technology. Consequently, there are no supply chains linkages between producers in one country and retailers in another. A Cobb-Douglas production function in both countries is assumed.

Intermediate goods producers combine labor inputs and transform labor into a distinctive good:

$$X_t(v) = K_t(v)^{\alpha} H_t(v)^{1-\alpha} \tag{A.151}$$

Intermediate goods producers face the common wage rate W_t and plan their future production with a goal to minimize cost. Their optimization problem can be formalized as:

$$\min_{K_t(v),H_t(v)} Z_{k,t}K_t(v) + W_t H_t(v) \tag{A.152}$$

s.t.

$$K_t(v)^{\alpha} H_t(v)^{1-\alpha} \geq \left[\frac{P_{n,t}(v)}{P_{n,t}}\right]^{-\varepsilon_r} X_t \tag{A.153}$$

The corresponding Lagrangian is given by:

$$\begin{aligned} \mathcal{L}\left(K_t(v), H_t(v)\right) &= Z_{k,t}K_t(v) + W_t H_t(v) \\ -mc_t(v) &\left[K_t(v)^{\alpha} H_t(v)^{1-\alpha} - \left[\frac{P_{n,t}(v)}{P_{n,t}}\right]^{\frac{\varepsilon_r}{1-\varepsilon_r}} X_t\right] \end{aligned} \tag{A.154}$$

The first-order conditions of the cost minimization problem w.r.t. $K_t(v)$ and $H_t(v)$ are:

$$\frac{\partial \mathcal{L}\left(K_t(v), H_t(v)\right)}{\partial K_t(v)} = Z_{k,t} - mc_t(v)\alpha K_t(v)^{\alpha-1} H_t(v)^{1-\alpha} = 0 \tag{A.155}$$

$$\frac{\partial \mathcal{L}\left(K_t(v), H_t(v)\right)}{\partial H_t(v)} = W_t - mc_t(v)(1-\alpha) K_t(v)^{\alpha} H_t(v)^{-\alpha} = 0 \tag{A.156}$$

A.2.3 Model with supply chains

This model version we exclude financial linkages between countries. Intermediate goods producers, therefore, on top of intermediate goods use labor inputs and local capital inputs only to produce goods. This simplified model version abstracts from the use of foreign capital in production of intermediate goods and from cross-border loans. Banks extend their loans only to local intermediate goods producers for their purchases of capital.

The financial intermediaries' balance sheet is given by:

$$Q_t S_t + q_t B_{b,t} = N_t + D_t \tag{A.157}$$

where $S_{t-1} = K_t$ and net worth evolves according to the following rule:

$$N_t = R_{k,t}Q_{t-1}S_{t-1} + R_{b,t}q_{t-1}B_{b,t-1} - R_tD_{t-1} + J_{t-1} \tag{A.158}$$

From (A.157) deposits are given by:

$$D_t = Q_tS_t + q_tB_{b,t} - N_t \tag{A.159}$$

So, by substituting the definition of deposits from (A.159) in $t-1$ to (A.158), the net worth becomes:

$$N_t = R_{k,t}Q_{t-1}S_t + R_{b,t}q_{t-1}B_{b,t-1} - R_t\left(Q_tS_t + q_tB_{b,t} - N_t\right) + J_{t-1} \tag{A.160}$$

which is equivalent to:

$$N_t = \left(R_{k,t} - R_t\right)Q_{t-1}S_{t-1} + \left(R_{b,t} - R_t\right)q_{t-1}B_{b,t-1} + R_tN_{t-1} + J_{t-1} \tag{A.161}$$

The end-of-period value function with equity issuance conditional on the survival of the bank is:

$$\mathcal{V}_t(N_t) = \max_{S_t,J_t,D_t} \mathbb{E}_t\left[\beta\frac{\varrho_{t+1}}{\varrho_t}\left[\begin{array}{l}(1-\sigma)N_{t+1}\\ +\sigma\Big(\mathcal{W}_{t+1}(N_{t+1}) - J_t - C(J_t,N_t)\Big)\end{array}\right]\right] \tag{A.162}$$

The bankers' maximization problem is to choose their portfolio of S_t and $B_{b,t}$ to maximize $\mathcal{V}_t(N_t)$ subject to the following incentive constraint:

$$\mathcal{V}_t(N_t) \geq \theta Q_tS_t + \Gamma\theta q_tB_{b,t} \tag{A.163}$$

and to choose their equity issuance J_t to maximize $\mathcal{W}_{t+1}(N_{t+1})$ subject to the definition of net worth given by (A.161); assuming at the same time the existence a linear solution of the form $\mathcal{V}_t = \mu_{s,t}Q_tS_t + \mu_{b,t}q_tB_{b,t} + \nu_tN_t$ and $\mathcal{W}_t = \eta_tN_t$.

Let υ_t be the Lagrange multiplier associated with the incentive constraint (A.163), $\lambda_t = \upsilon_t/(1+\upsilon_t)$ and Ω_{t+1} a term that augments the banks' discount factor relative to the household's discount factor.

The bank's optimization problem is solved by guessing a linear value function on assets and deposits:

$$\mathcal{V}_t = \mu_{s,t}Q_tS_t + \mu_{b,t}q_tB_{b,t} + \nu_tN_t \tag{A.164}$$

The Lagrangian is formalized as:

$$\begin{aligned}\mathcal{L}(S_t, B_{b,t}) &= \mu_{s,t}Q_tS_t + \mu_{b,t}q_tB_{b,t} + \nu_tN_t \\ &-\upsilon_t\left[\begin{array}{l}\theta Q_tS_t + \Gamma\theta q_tB_{b,t} - \nu_tN_t \\ -\Big(\mu_{s,t}Q_tS_t + \mu_{b,t}q_tB_{b,t} + \nu_tN_t\Big)\end{array}\right]\end{aligned} \tag{A.165}$$

The first-order conditions with respect to S_t, $B_{b,t}$, and υ_t are expressed as follows:

$$\mu_{s,t}Q_t - \upsilon_t\theta Q_t + \upsilon_t\mu_{s,t}Q_t = 0 \Rightarrow \mu_{s,t} = \theta\frac{\upsilon_t}{1+\upsilon_t} \tag{A.166}$$

$$\mu_{b,t}q_t - \upsilon_t\Gamma\theta q_t + \upsilon_t\mu_{b,t}q_t = 0 \Rightarrow \mu_{b,t} = \Gamma\frac{\upsilon_t}{1+\upsilon_t} \tag{A.167}$$

$$\theta Q_tS_t + \Gamma\theta q_tB_{b,t} - \mu_{s,t}Q_ts_t - \mu_{b,t}q_tB_{b,t} - \nu_tn_t = 0 \tag{A.168}$$

where ν_t is the value of banks' net worth.

Then the solution can be characterized as follows: at the end of each period, an individual bank maximizes the present value of its future dividends given the quadratic cost of equity issuance:

$$\begin{aligned}\mathcal{V}_t(N_t) = \max_{S_t,J_t,D_t} \mathbb{E}_t &\left[\beta\frac{\varrho_{t+1}}{\varrho_t}\left[(1-\theta_b)N_{t+1} + \theta_b\left(\mathcal{W}_{t+1}(N_{t+1}) - J_t - \frac{\zeta}{2}\frac{J_t^2}{N_t}\right)\right]\right] \\ \text{s.t.} \quad &\mathcal{V}_t(S_t, B_{b,t}, N_t) \geq \mu_{s,t}Q_tS_t + \mu_{b,t}q_tB_{b,t} + \nu_tN_t \\ \text{for} \quad N_{t+1} &= (R_{k,t+1} - R_{t+1})Q_tS_t + (R_{b,t+1} - R_{t+1})q_tB_{b,t} + R_{t+1}N_t + J_t\end{aligned} \tag{A.169}$$

The Lagrangian is formalized as:

$$\begin{aligned}\mathcal{L}(S_t, J_t, D_t) = \mathbb{E}_t &\left[\beta\frac{\varrho_{t+1}}{\varrho_t}\left[(1-\theta_b)N_{t+1} + \theta_b\left(\eta_{t+1}N_{t+1} - J_t - \frac{\zeta}{2}\frac{J_t^2}{N_t}\right)\right]\right] \\ &-\upsilon_t\Big[\theta Q_tS_t + \Gamma\theta q_tB_{b,t} - \mathcal{V}_t(S_t, B_{b,t}, N_t)\Big]\end{aligned} \tag{A.170}$$

Given the definition of Ω_t in $t+1$, the Lagrangian can be rewritten as:

$$\begin{aligned}\mathcal{L}(S_t, J_t, D_t) = \mathbb{E}_t &\left[\beta\frac{\varrho_{t+1}}{\varrho_t}\left[\Omega_{t+1}N_{t+1} - \theta_bJ_t - \theta_b\frac{\zeta}{2}\frac{J_t^2}{N_t}\right]\right] \\ &-\upsilon_t\Big[\theta Q_tS_t + \Gamma\theta q_tB_{b,t} - \mathcal{V}_t(S_t, B_{b,t}, N_t)\Big]\end{aligned} \tag{A.171}$$

which given the formula for N_{t+1} yields:

$$\mathcal{L}(S_t, B_{b,t}, N_t) = \mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \begin{bmatrix} \Omega_{t+1} \begin{bmatrix} (R_{k,t+1} - R_{t+1}) Q_t S_t \\ +(R_{b,t+1} - R_{t+1}) q_t B_{b,t} \\ +R_{t+1} N_t + J_t \end{bmatrix} \\ -\theta_b J_t - \theta_b \frac{\zeta}{2} \frac{J_t^2}{N_t} \end{bmatrix} - \upsilon_t \begin{bmatrix} \theta Q_t S_t + \Gamma \theta q_t B_{b,t} \\ -\mu_{s,t} Q_t S_t - \mu_{b,t} q_t B_{b,t} - \nu_t N_t \end{bmatrix} \tag{A.172}$$

The first-order condition with respect to S_t is:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{k,t+1} - R_{t+1}) Q_t - \upsilon_t \theta Q_t + \upsilon_t \mu_{s,t} Q_t = 0 \tag{A.173}$$

Substituting for $\mu_{s,t}$ using equation (A.166) yields:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{k,t+1} - R_{t+1}) - \upsilon_t \theta + \upsilon_t \theta \frac{\upsilon_t}{1 + \upsilon_t} = 0 \tag{A.174}$$

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{k,t+1} - R_{t+1}) - \frac{\upsilon_t \theta (1 + \upsilon_t)}{1 + \upsilon_t} + \frac{\upsilon_t^2 \theta}{1 + \upsilon_t} = 0 \tag{A.175}$$

Given that $\lambda_t = \upsilon_t / (1 + \upsilon_t)$:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{k,t+1} - R_{t+1}) = \theta \lambda_t \tag{A.176}$$

The first-order condition of the optimization problem of banks with respect to $B_{b,t}$ is:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{b,t+1} - R_{t+1}) - \upsilon_t \Gamma \theta + \upsilon_t \mu_{b,t} = 0 \tag{A.177}$$

Substituting for $\mu_{b,t}$ yields:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{b,t+1} - R_{t+1}) - \upsilon_t \Gamma \theta + \upsilon_t \Gamma \frac{\upsilon_t}{1 + \upsilon_t} = 0 \tag{A.178}$$

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{b,t+1} - R_{t+1}) + \frac{-\upsilon_t \Gamma \theta (1 + \upsilon_t)}{1 + \upsilon_t} + \frac{\upsilon_t \Gamma \upsilon_t}{1 + \upsilon_t} = 0 \tag{A.179}$$

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{b,t+1} - R_{t+1}) + \frac{-\upsilon_t \Gamma \theta - \upsilon_t^2 \Gamma \theta + \upsilon_t^2 \Gamma \theta}{1 + \upsilon_t} = 0 \tag{A.180}$$

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} (R_{b,t+1} - R_{t+1}) + \frac{-\upsilon_t \Gamma \theta}{1 + \upsilon_t} = 0 \tag{A.181}$$

Given that $\lambda_t = \upsilon_t/(1+\upsilon_t)$:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1}(R_{b,t+1} - R_{t+1}) = \theta \Gamma \lambda_t \tag{A.182}$$

The objective of the banker is to issue equity in order to maximize $\mathcal{W}_{t+1}(N_{t+1})$ subject to equation (A.161):

$$\max_{J_t} \mathbb{E}_t \left[\beta \frac{\varrho_{t+1}}{\varrho_t} \left[\Omega_{t+1} \begin{bmatrix} (R_{k,t+1} - R_{t+1}) Q_t S_t \\ +(R_{b,t+1} - R_{t+1}) q_t B_{b,t} \\ +R_{t+1} N_t + J_t \end{bmatrix} - J_t - \frac{\zeta}{2} \frac{J_t^2}{N_t} \right] \right] \tag{A.183}$$

It is, therefore assumed that the equity is issued and the cost of equity is paid only by the surviving banks. So, conditional the bank has survived to $t+1$ the amount of equity it issues in t is such that the bank maximizes $\mathcal{W}_{t+1}(N_{t+1}) = \eta_{t+1} N_{t+1}$ subject to the cost of equity issuance.

The Lagrangian is formalized as:

$$\mathcal{L}(J_t, N_t) = \mathbb{E}_t \begin{bmatrix} \beta \frac{\varrho_{t+1}}{\varrho_t} \left[\Omega_{t+1} \begin{bmatrix} (R_{k,t+1} - R_{t+1}) Q_t S_t \\ +(R_{b,t+1} - R_{t+1}) q_t B_{b,t} \\ +R_{t+1} N_t + J_t \end{bmatrix} - J_t - \frac{\zeta}{2} \frac{J_t^2}{N_t} \right] \\ -\lambda_t (\eta_t N_t - \mathcal{W}_t) \end{bmatrix} \tag{A.184}$$

The first-order condition with respect to the cost of equity issuance J_t is:

$$\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} (\Omega_{t+1} - 1) - \zeta \xi_t = 0 \tag{A.185}$$

which implies:

$$\xi_t = \frac{\mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} (\Omega_{t+1} - 1)}{\zeta} \tag{A.186}$$

$$\eta_t \equiv \frac{\partial \mathcal{V}_t}{\partial N_t} \Rightarrow \eta_t = \mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} R_{t+1} + \frac{\zeta}{2} \xi_t^2 + \lambda_t \eta_t \tag{A.187}$$

$$\nu_t = \mathbb{E}_t \beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} R_{t+1} + \frac{\mathbb{E}_t \left[\beta \frac{\varrho_{t+1}}{\varrho_t} \Omega_{t+1} - 1 \right]^2}{2\zeta} \tag{A.188}$$

We also need to characterize the behavior of the multiplier λ_t. In this case, since $V_t = \eta_t n_t$ and equation (A.163) holds with equality, it follows that:

$$\eta_t n_t = \theta (Q_t S_t + q_t B_{b,t}) \tag{A.189}$$

From equation (A.187) it follows that:

$$\eta_t(1-\lambda_t) = \nu_t \tag{A.190}$$

and substituting in equation (A.189) we get the following expression for λ_t:

$$\lambda_t = 1 - \frac{\nu_t}{\theta\phi_t} \tag{A.191}$$

which under complementary slackness holds under the following form:

$$\lambda_t = \max\left[0, 1 - \frac{\nu_t}{\theta\phi_t}\right] \tag{A.192}$$

Appendix B Robustness checks and sensitivity analysis

B.1 Production function

Figure B.1: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

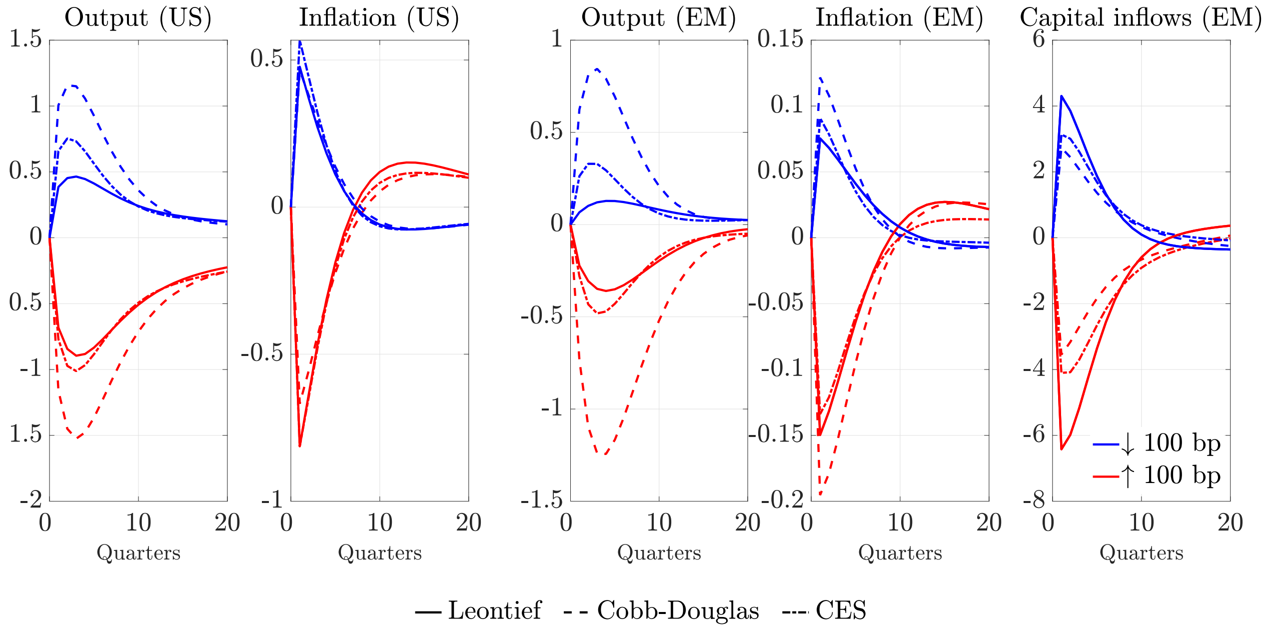


Figure B.2: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

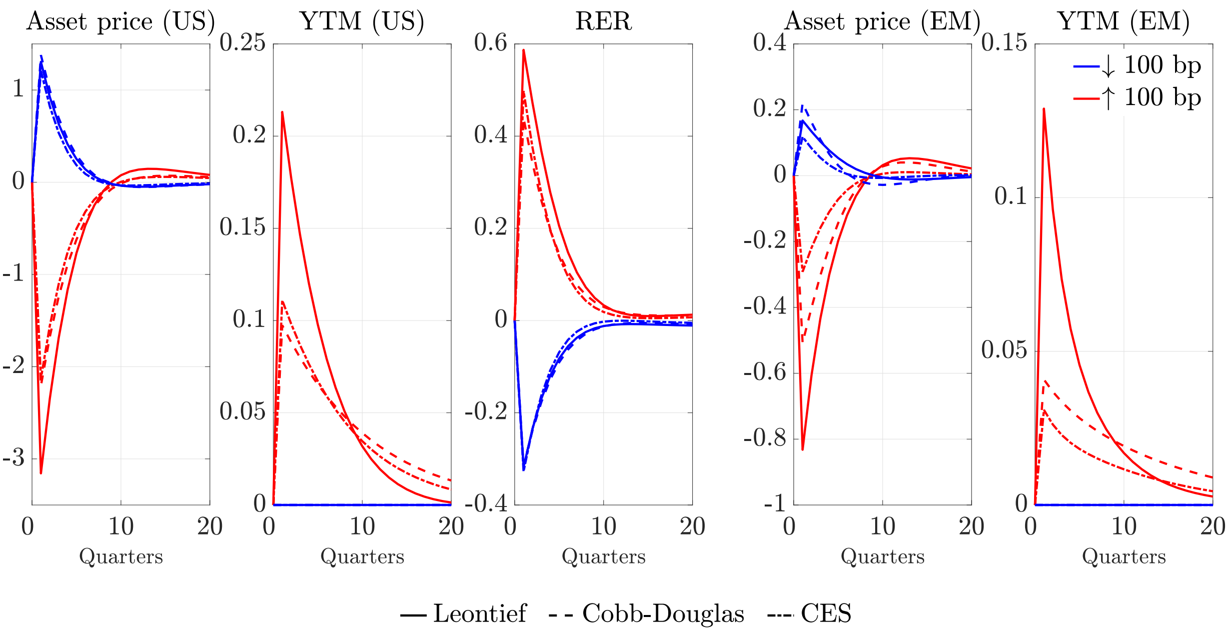


Figure B.3: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

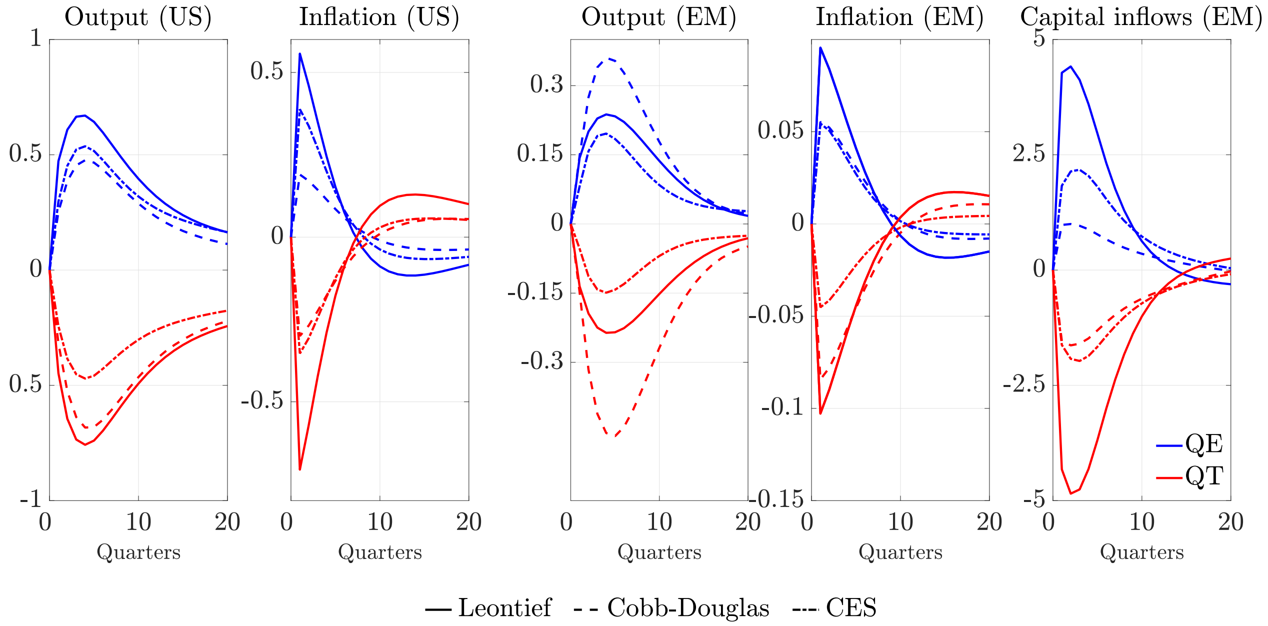
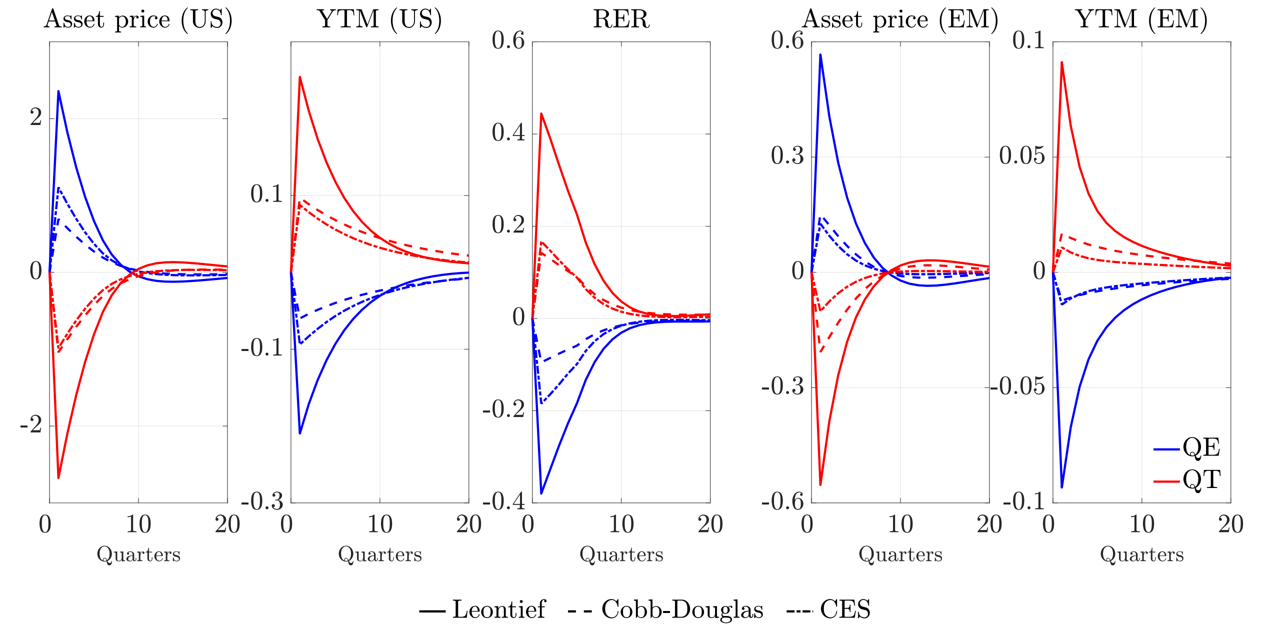


Figure B.4: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.2 Share of intermediate inputs

Figure B.5: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

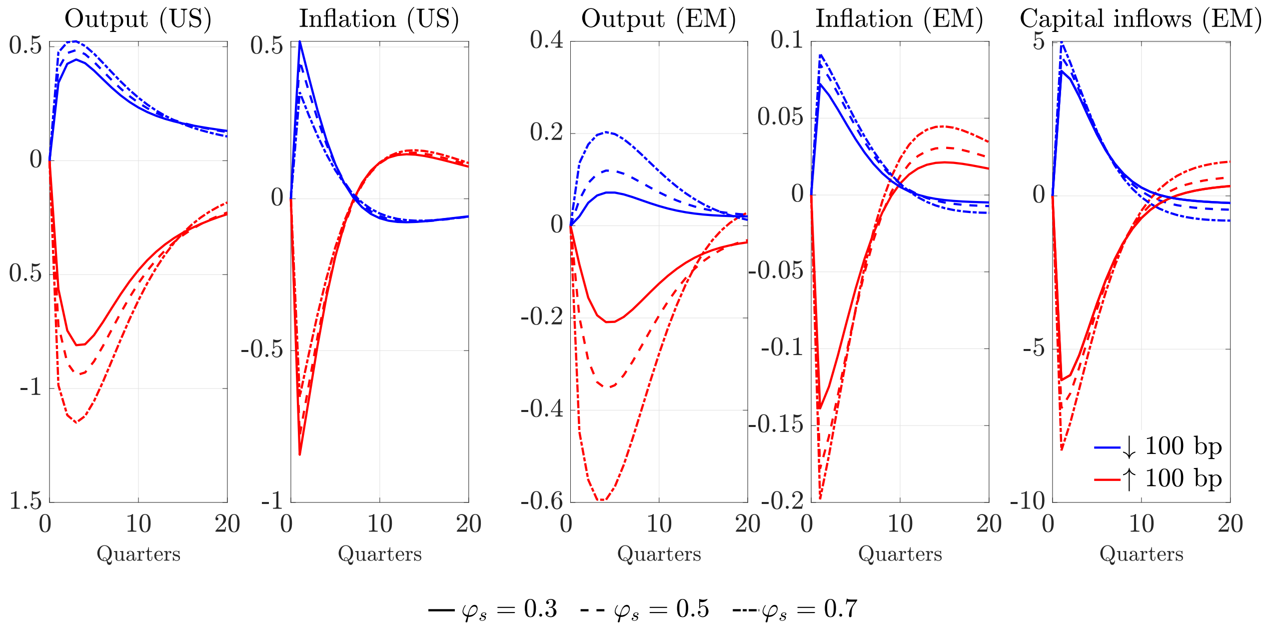


Figure B.6: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

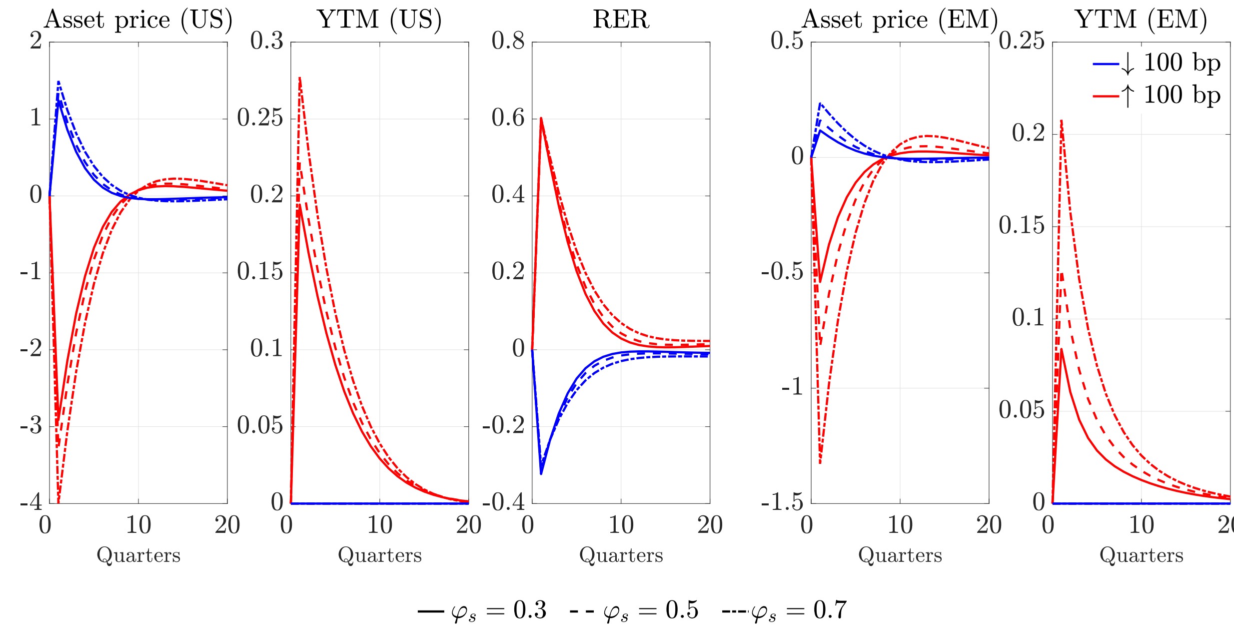


Figure B.7: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

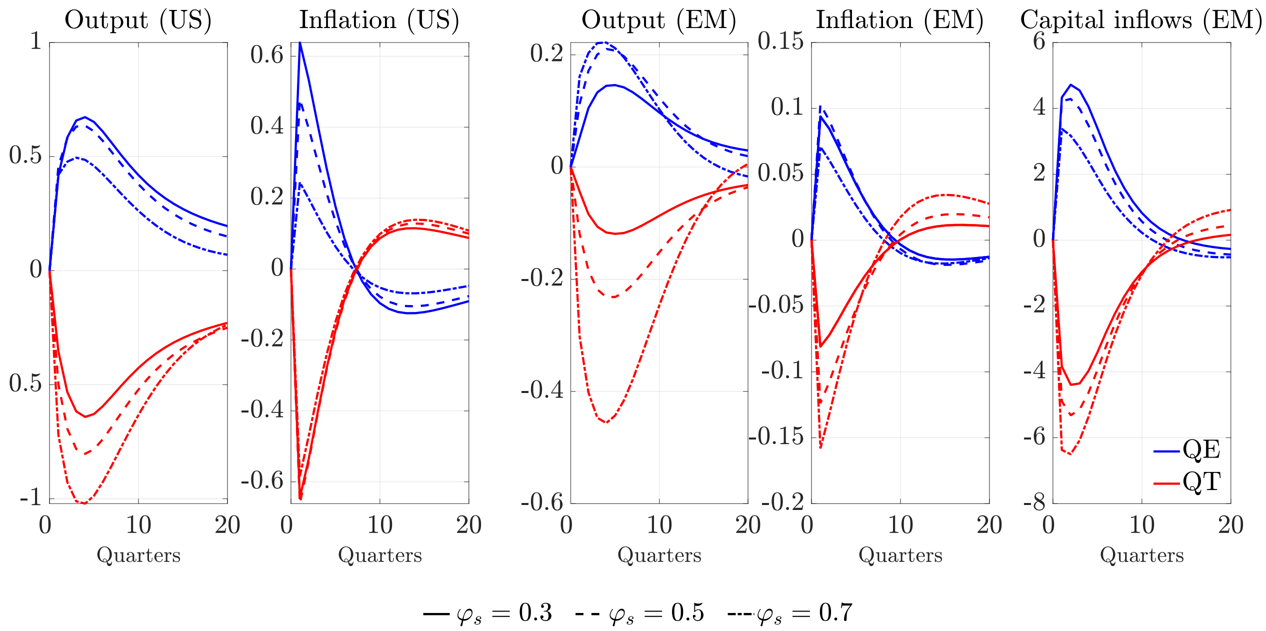
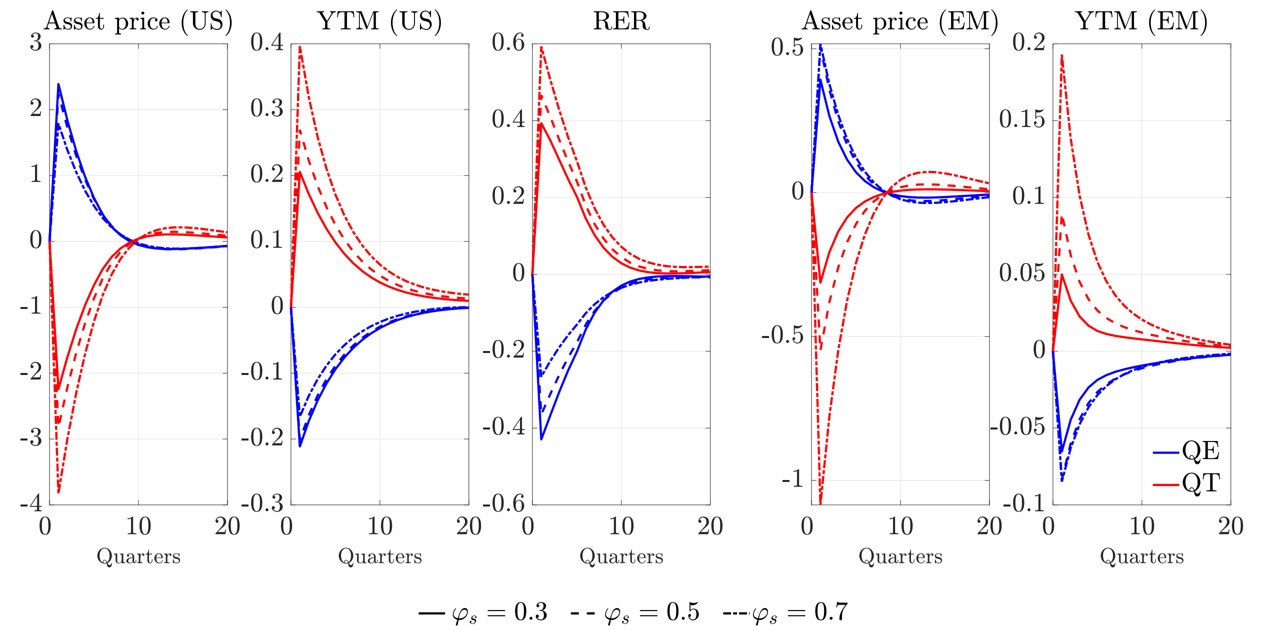


Figure B.8: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.3 Share of foreign currency debt

Figure B.9: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

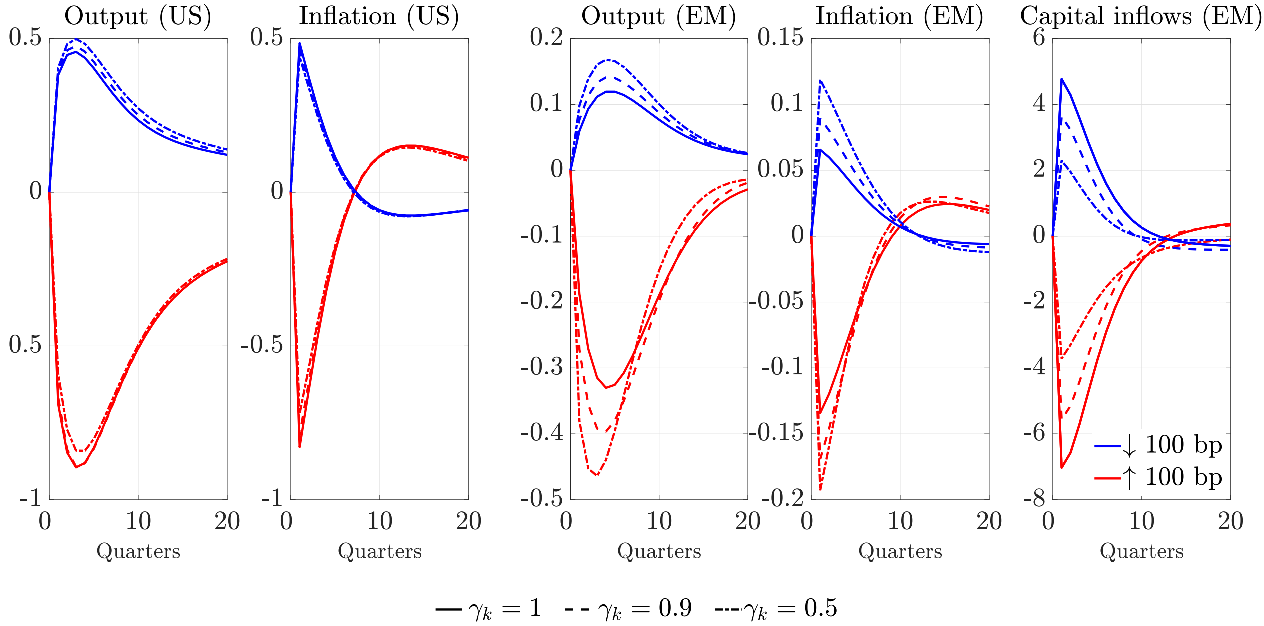


Figure B.10: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

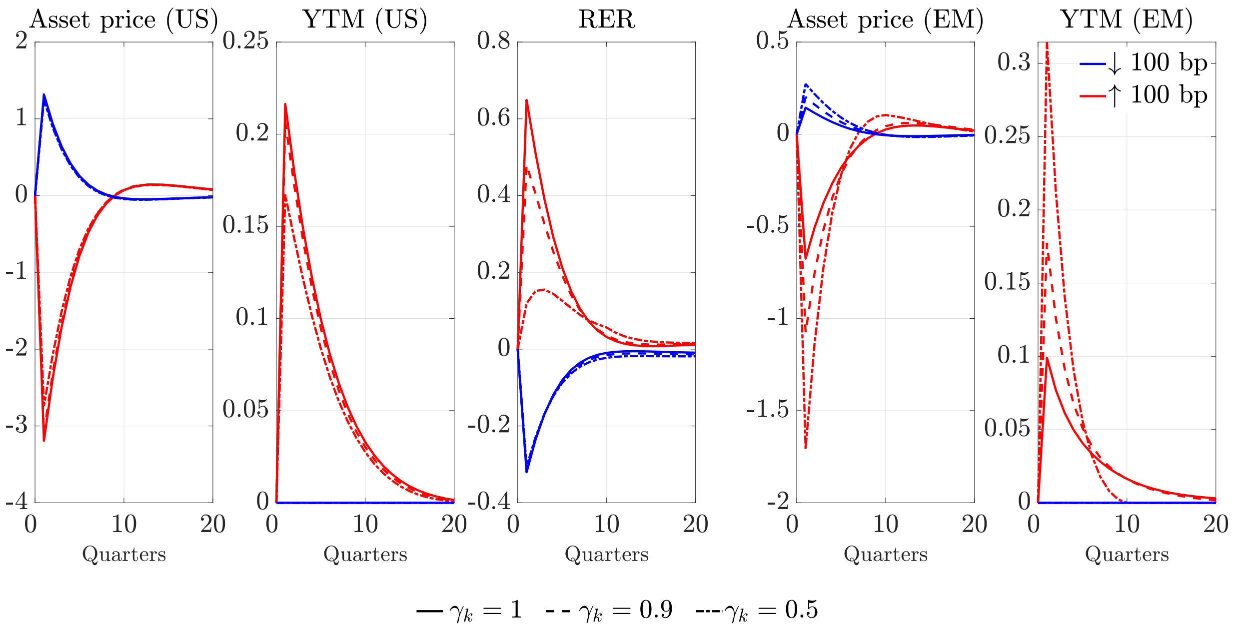


Figure B.11: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

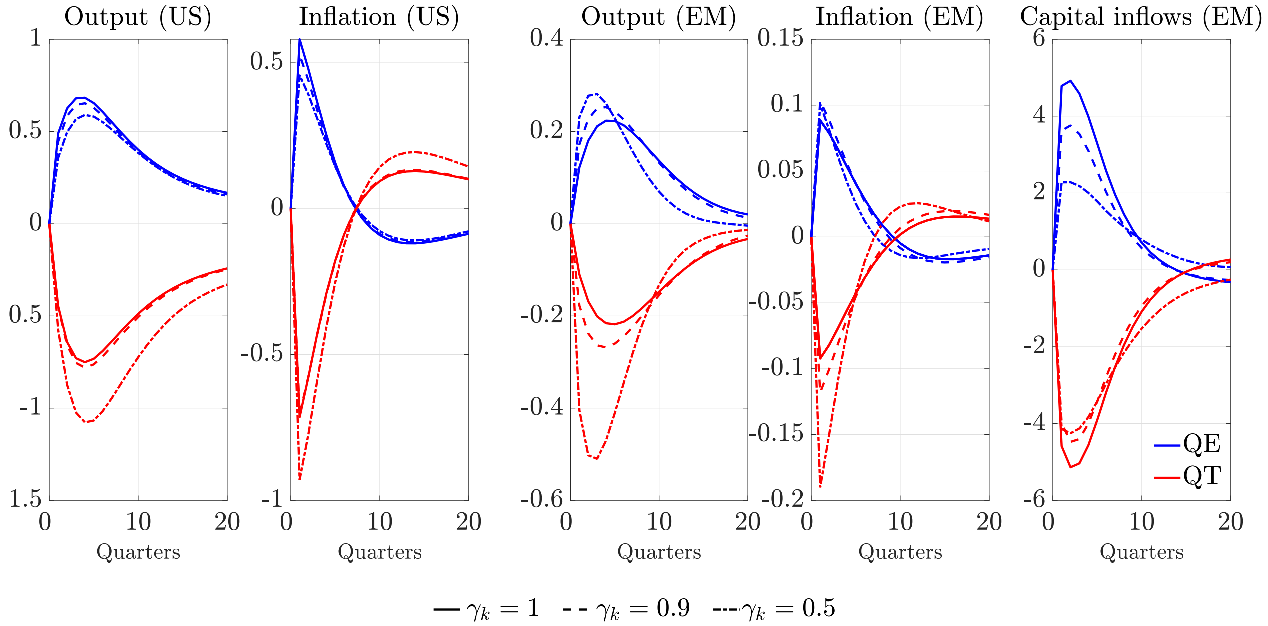
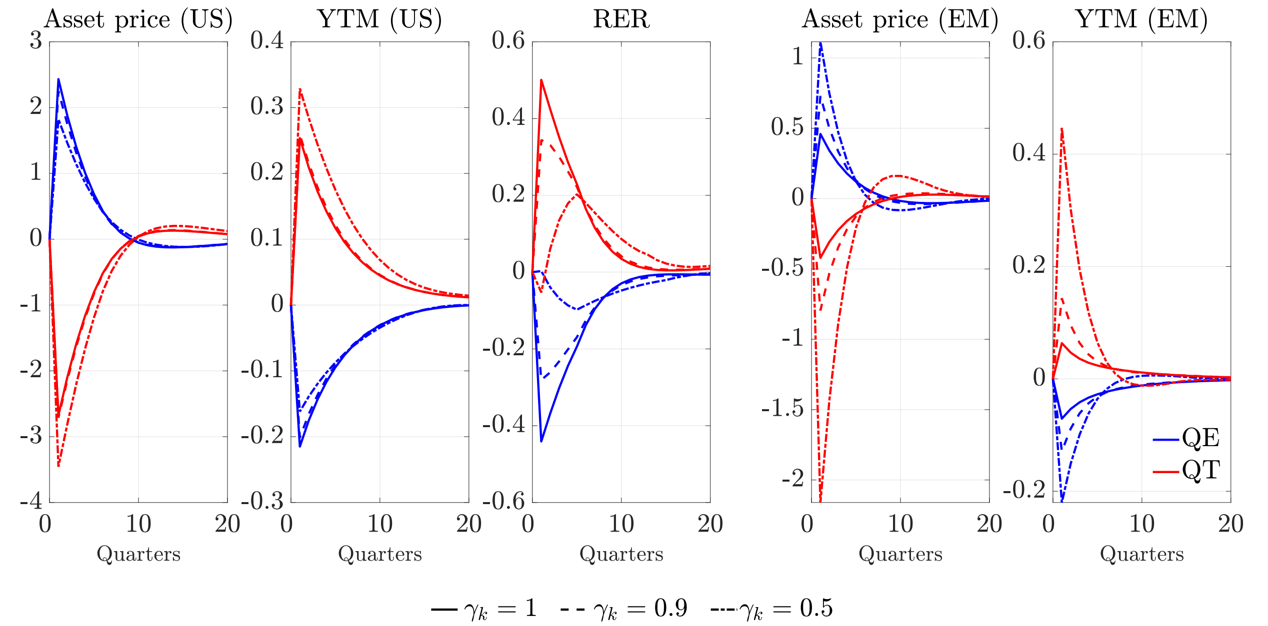


Figure B.12: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.4 Sensitivity to nominal exchange rate

Figure B.13: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

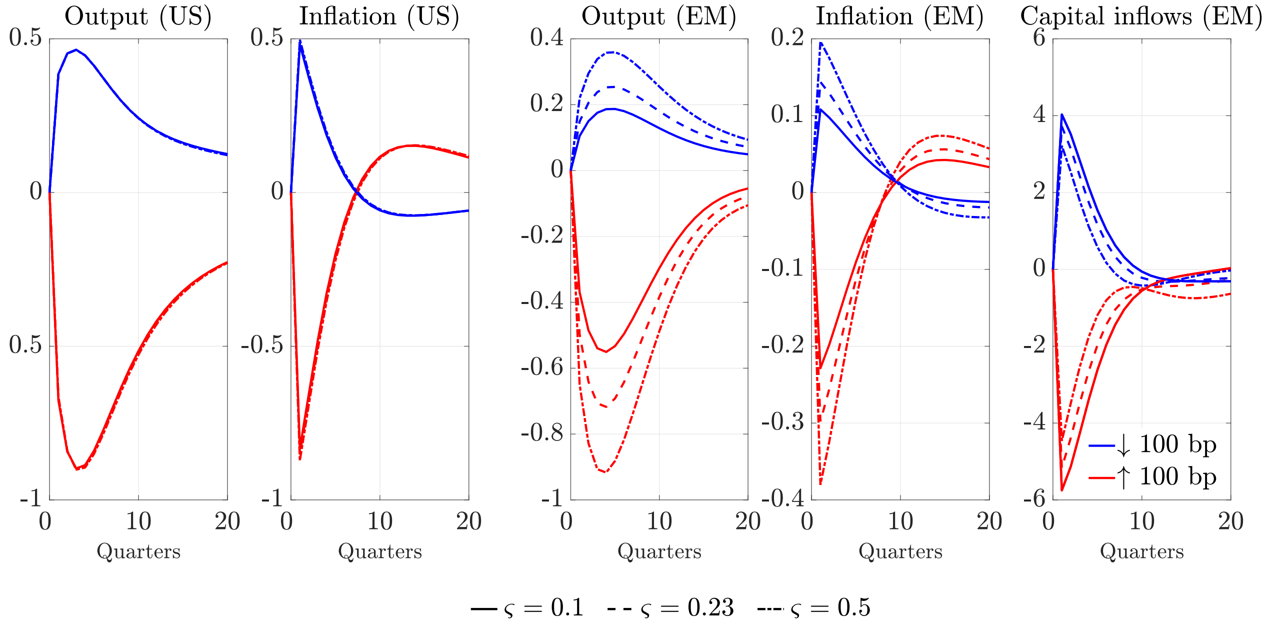


Figure B.14: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

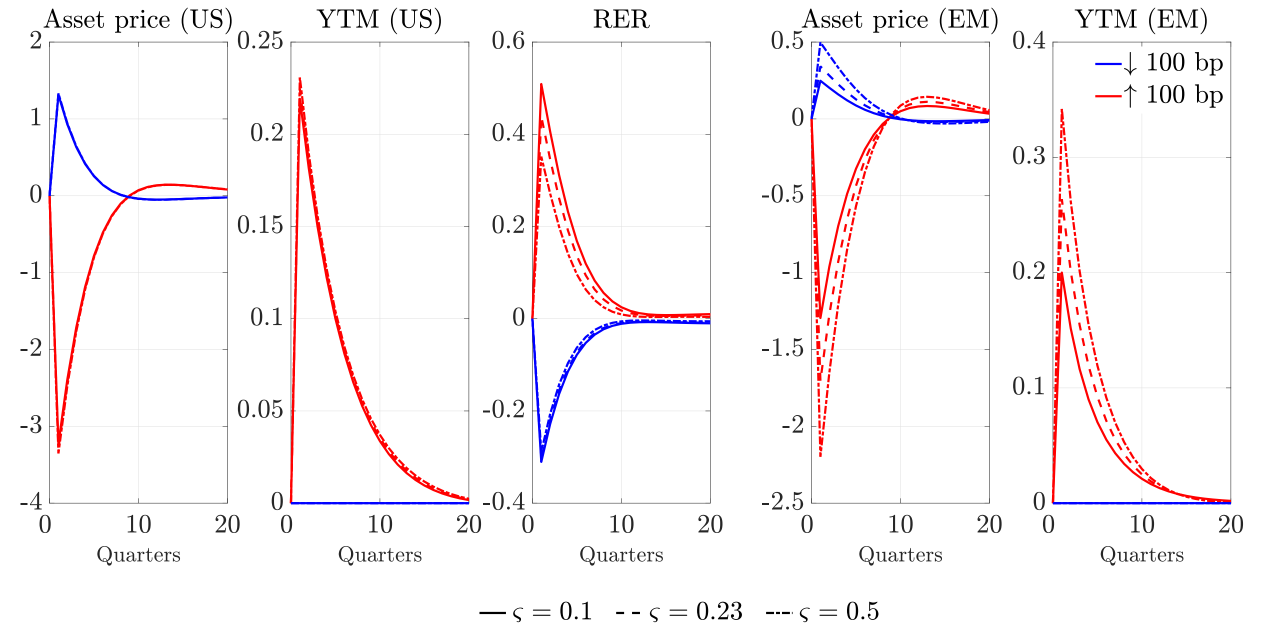


Figure B.15: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

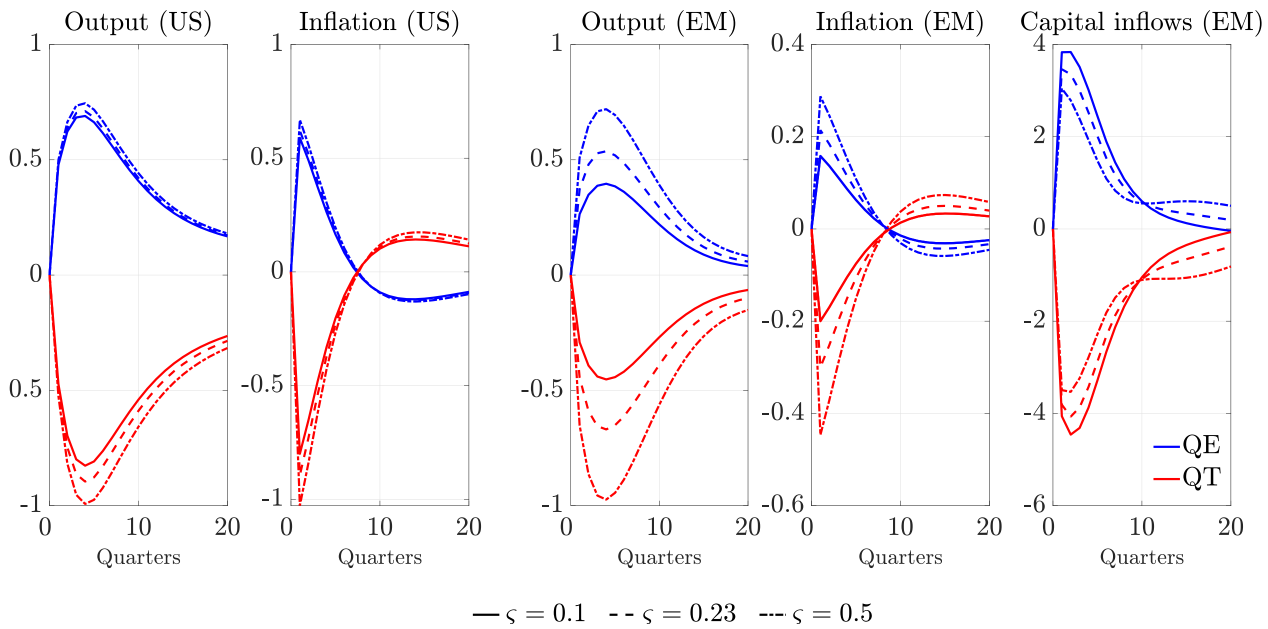
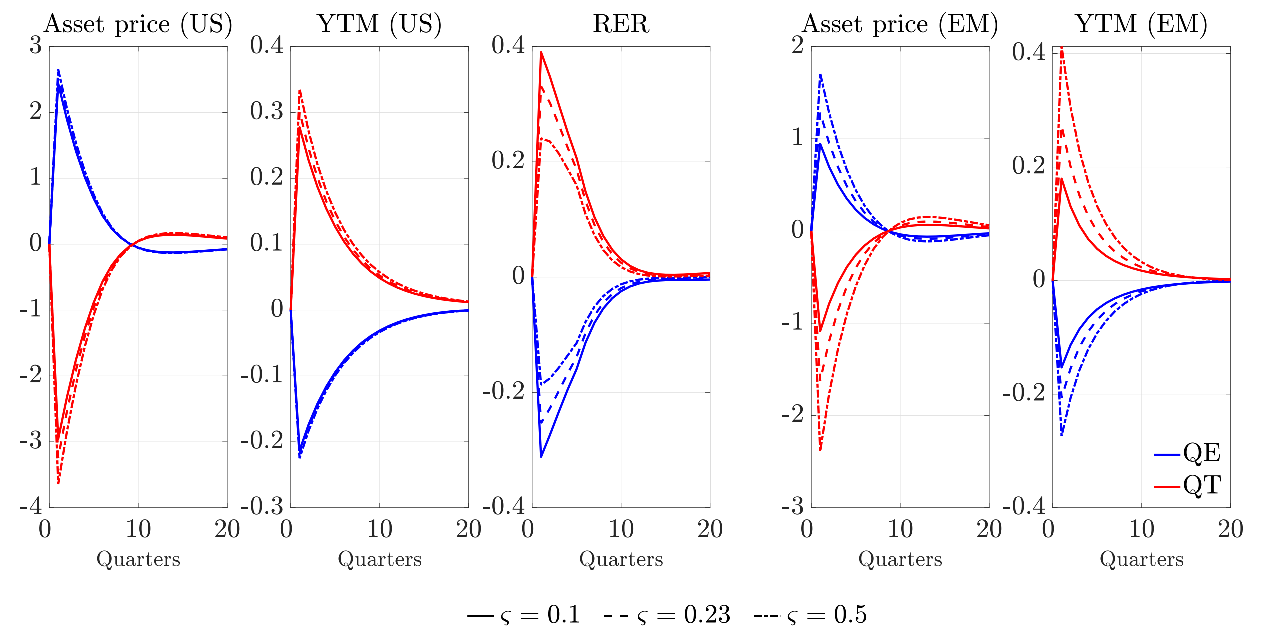


Figure B.16: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.5 Armington elasticity

Figure B.17: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

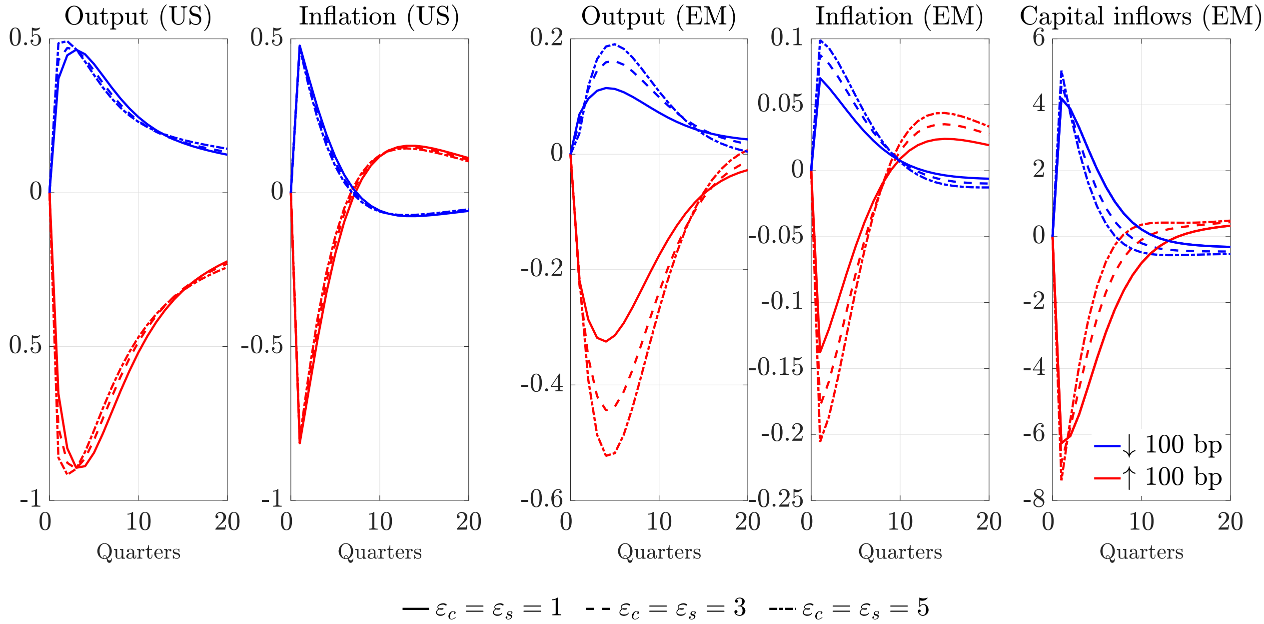


Figure B.18: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

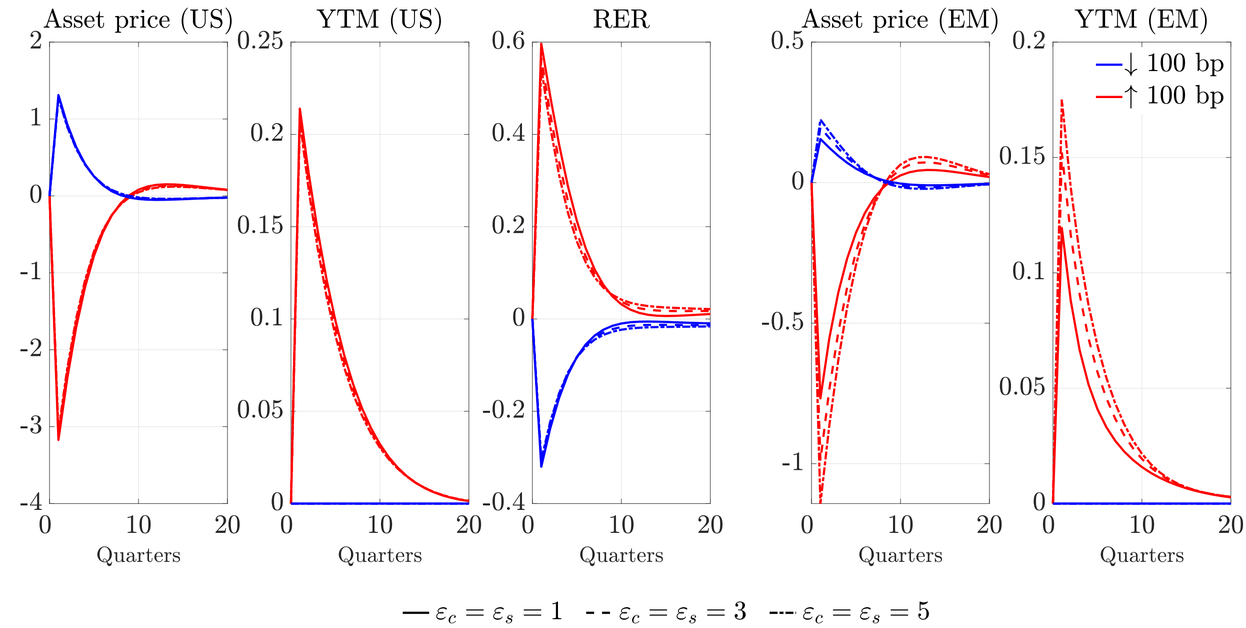


Figure B.19: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

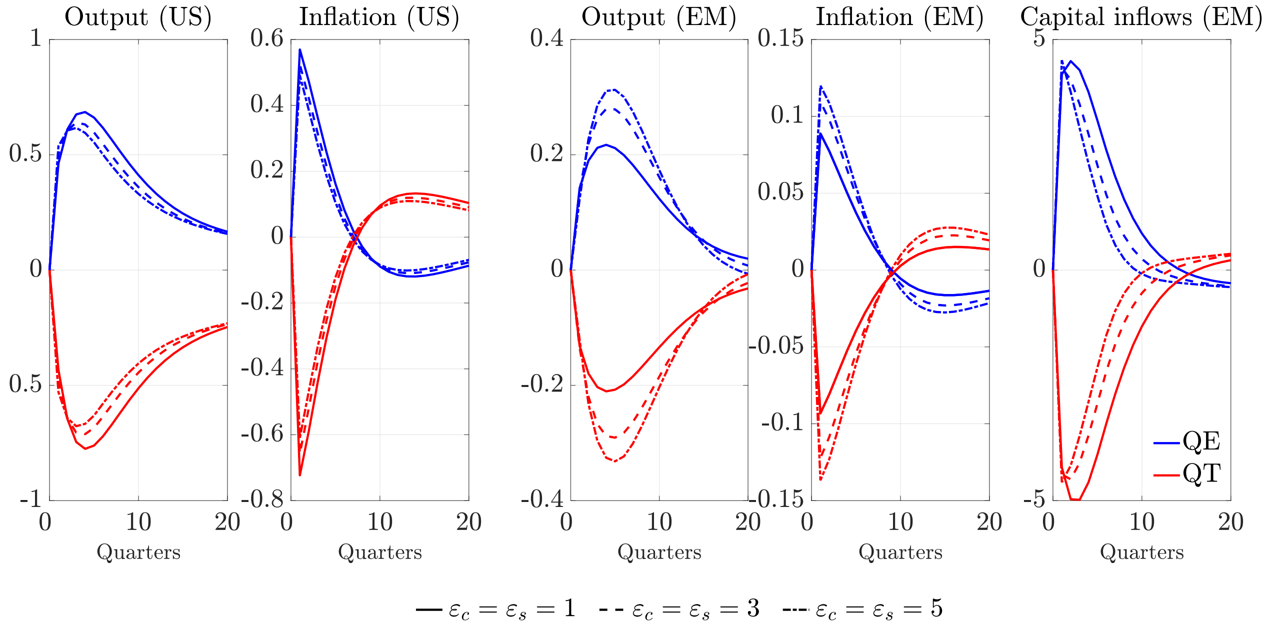
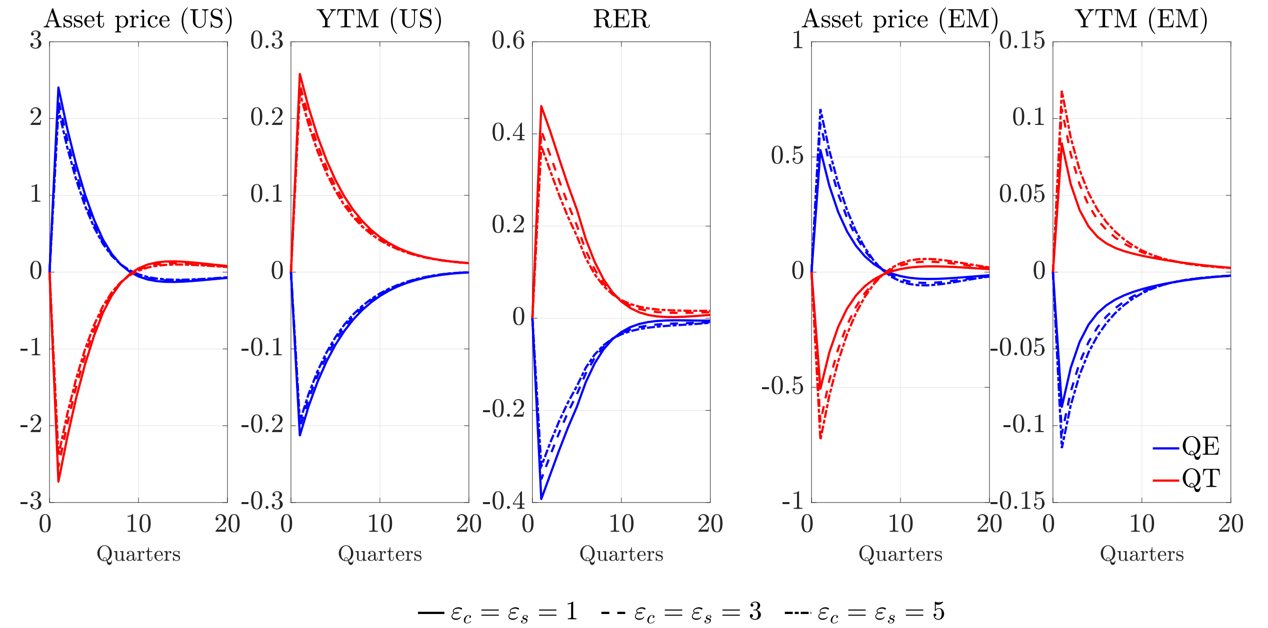


Figure B.20: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.6 Elasticity of substitution between capital inputs

Figure B.21: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

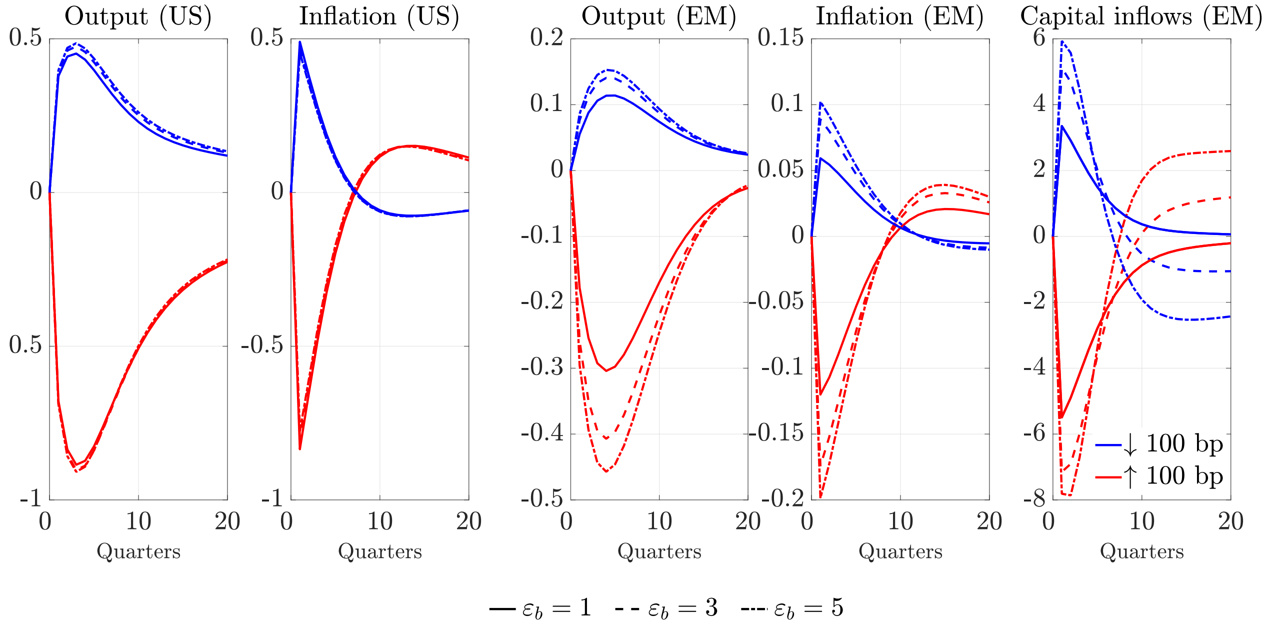


Figure B.22: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

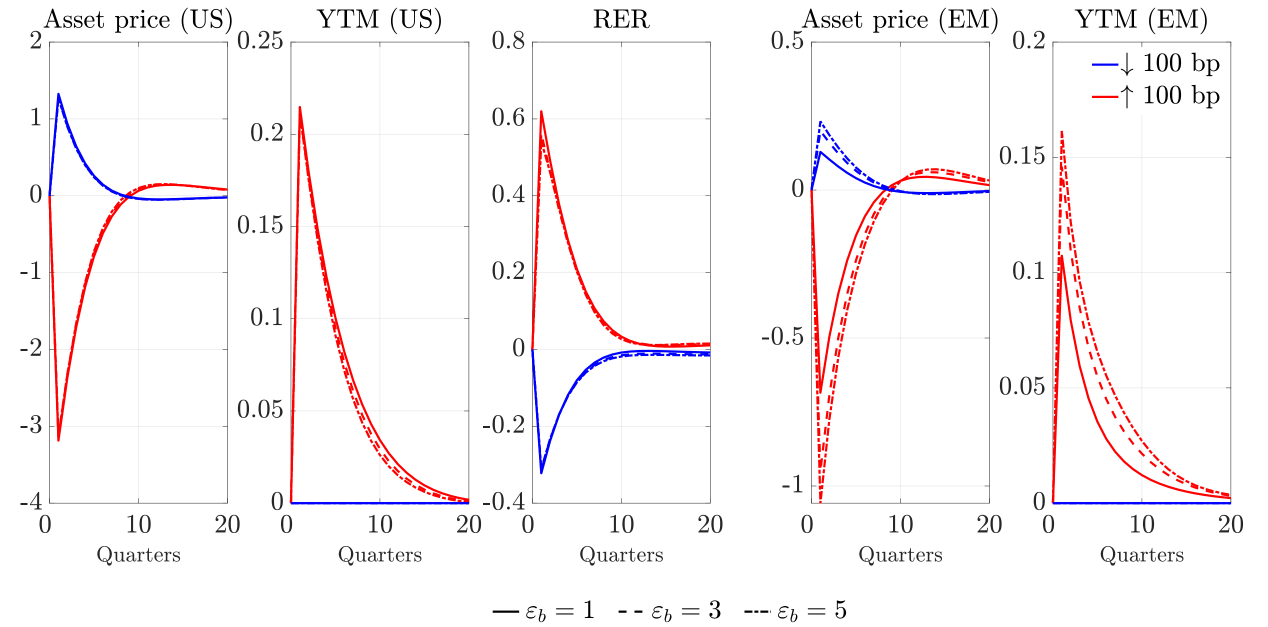


Figure B.23: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

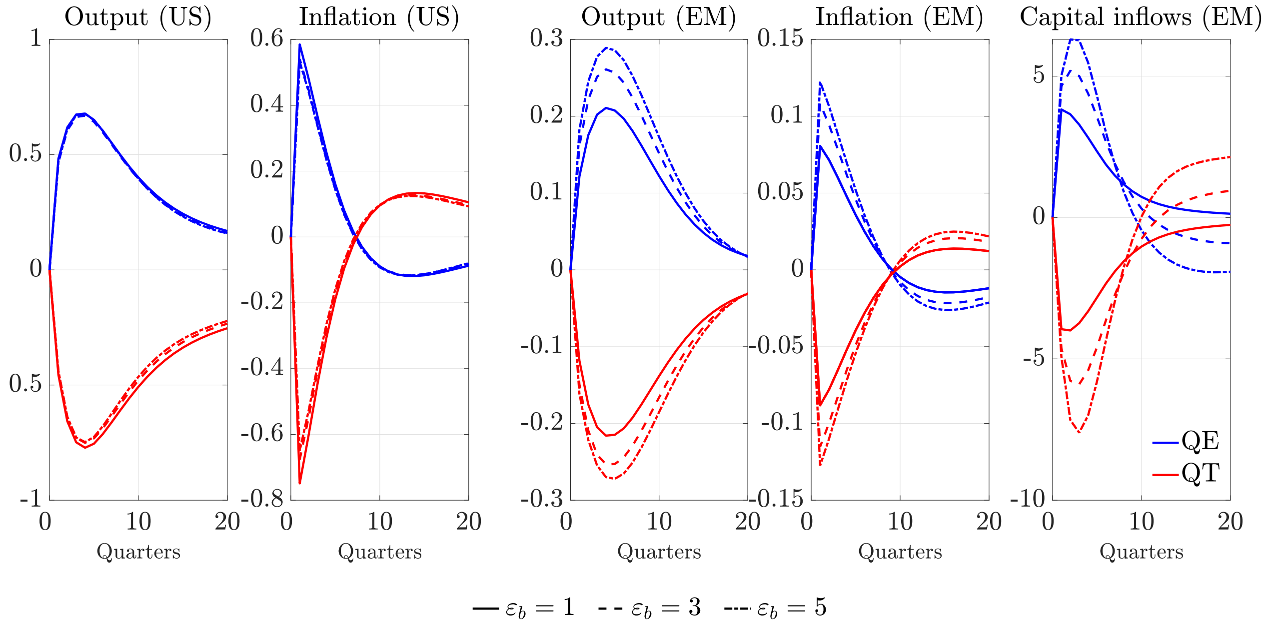
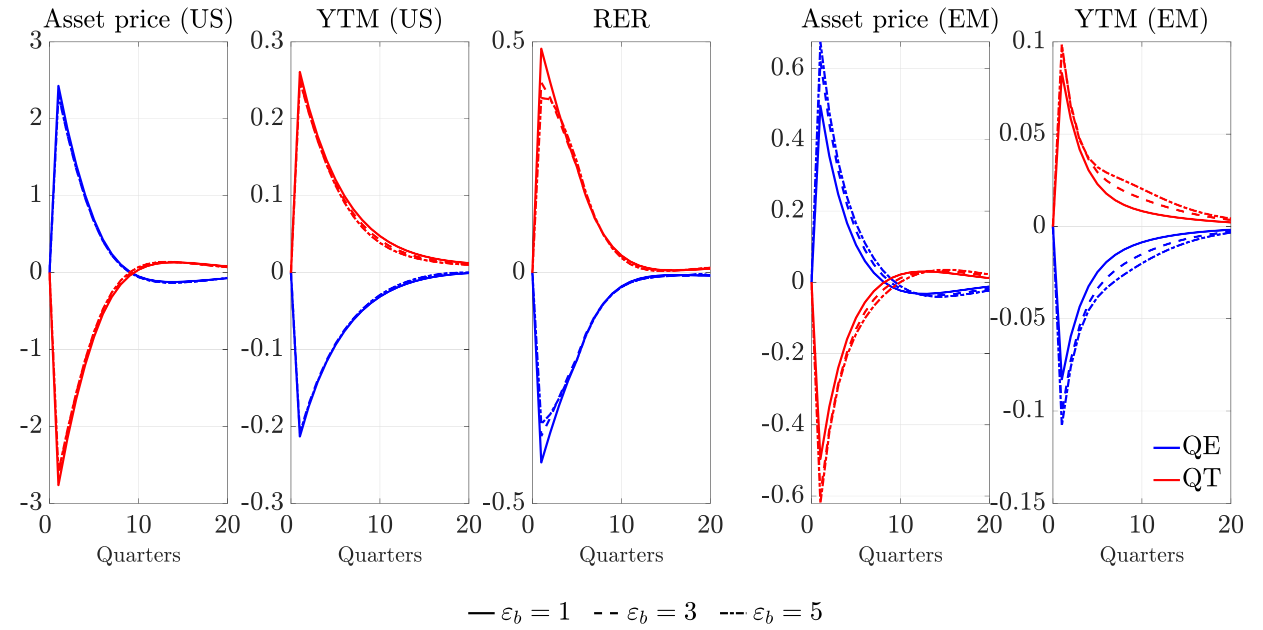


Figure B.24: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.7 Calvo parameter

Figure B.25: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

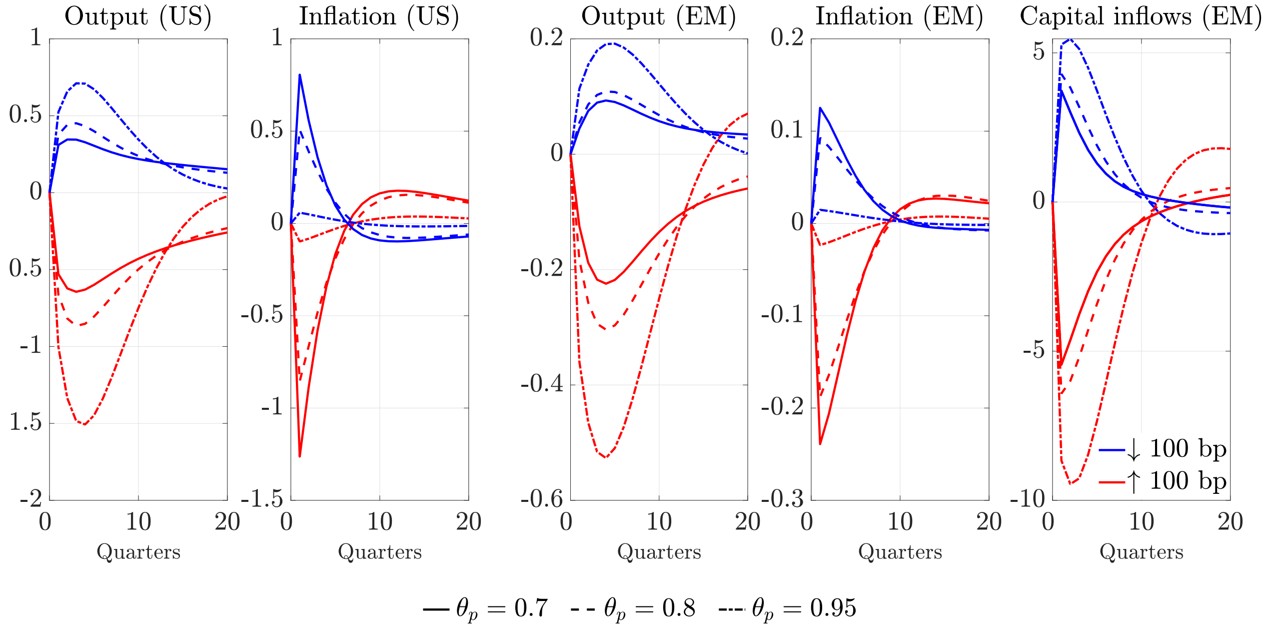


Figure B.26: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

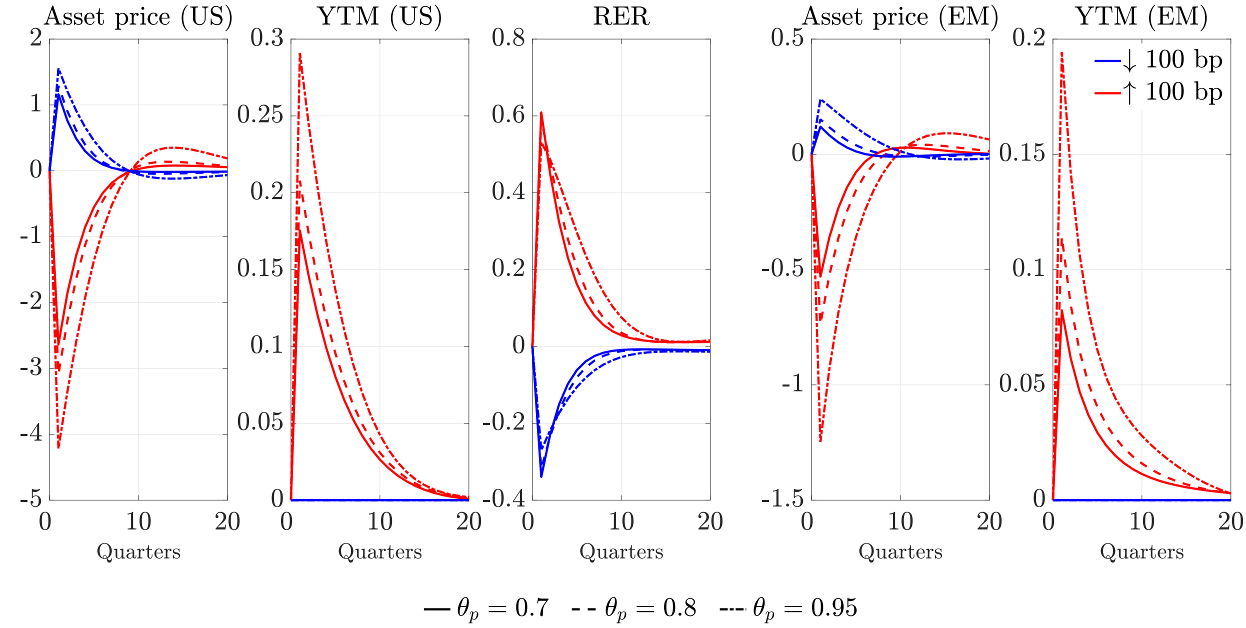


Figure B.27: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

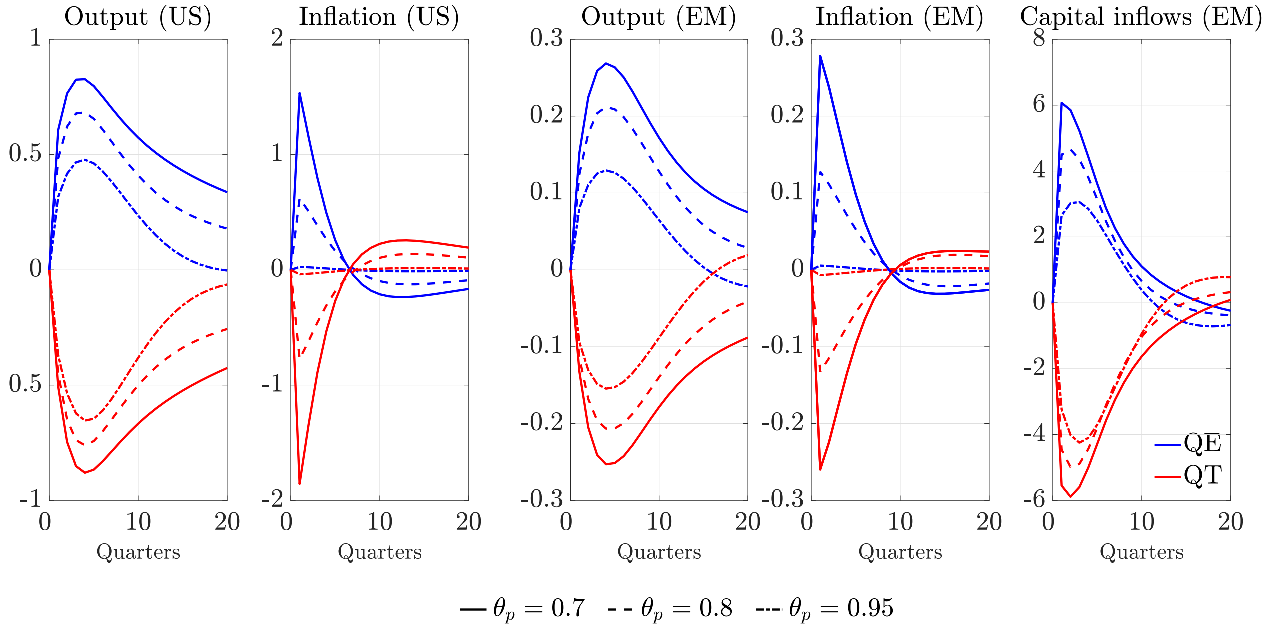
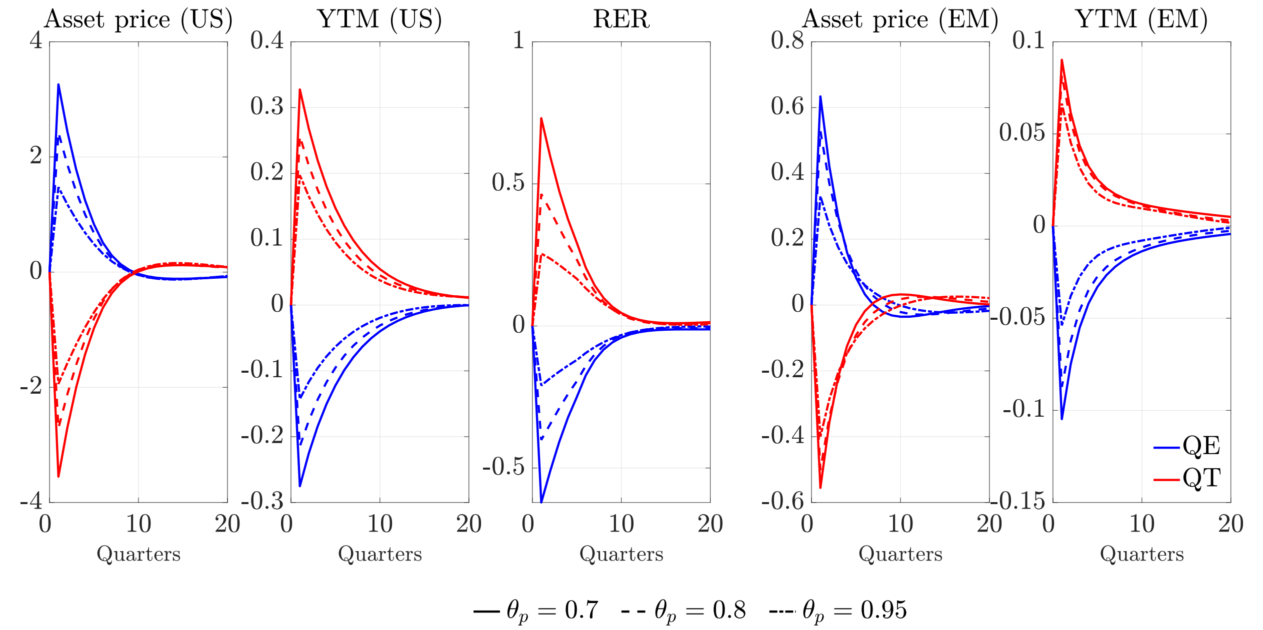


Figure B.28: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.8 Sensitivity to inflation

Figure B.29: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

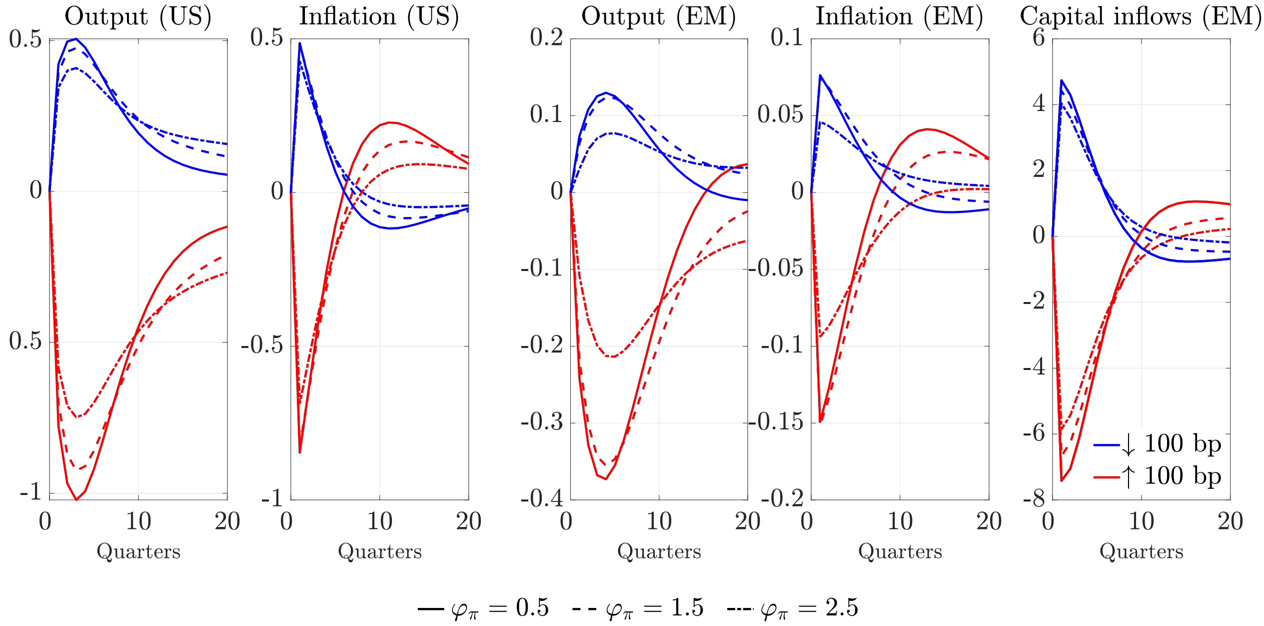


Figure B.30: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

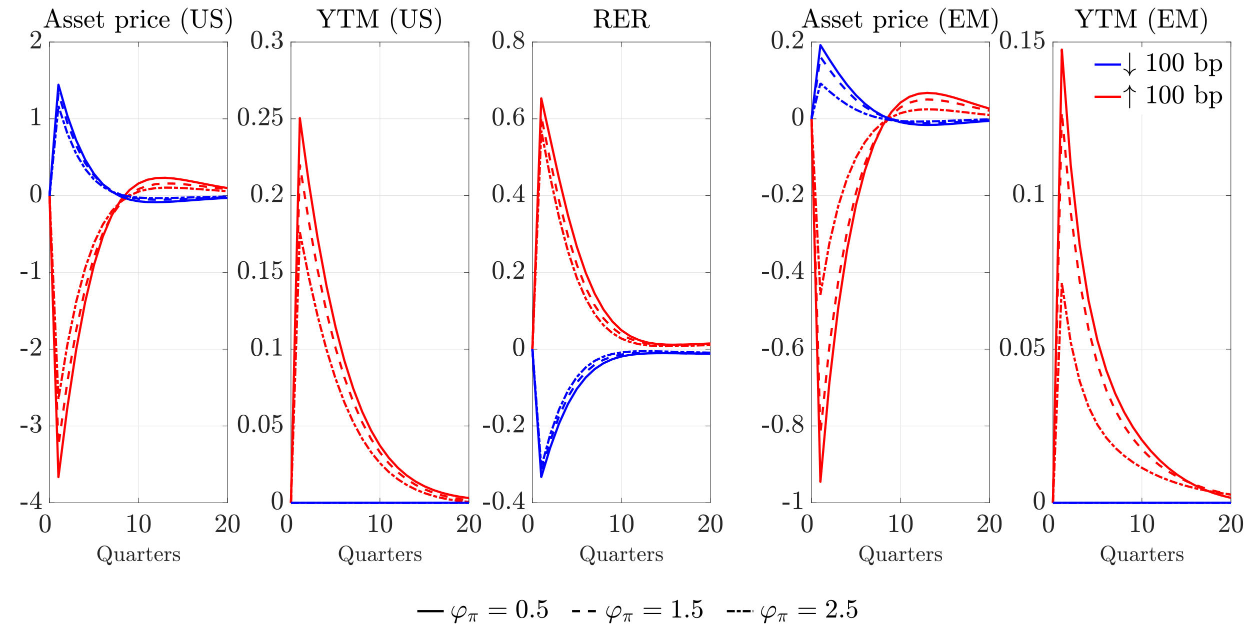


Figure B.31: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

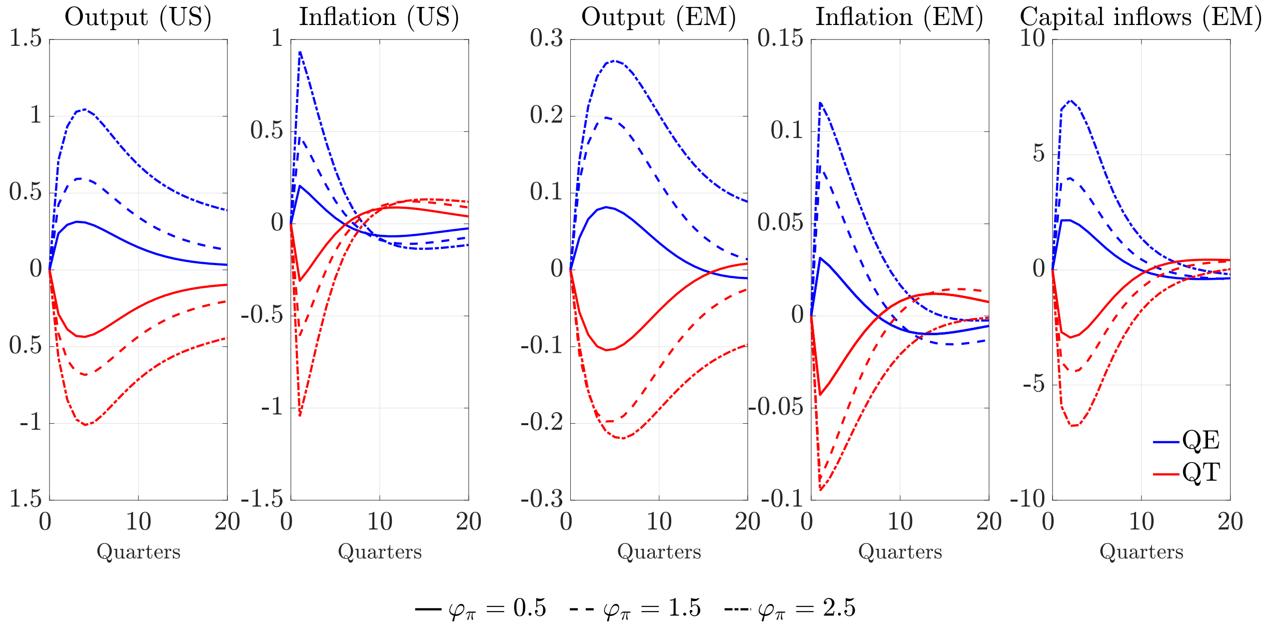
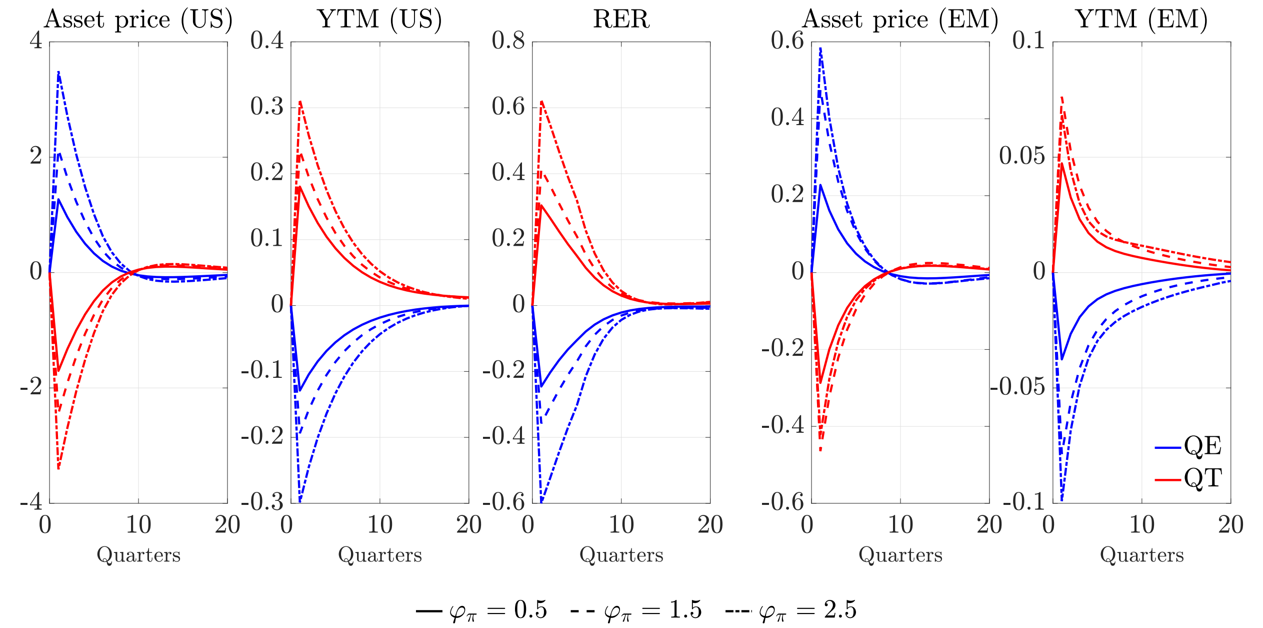


Figure B.32: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.9 Sensitivity to output gap

Figure B.33: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

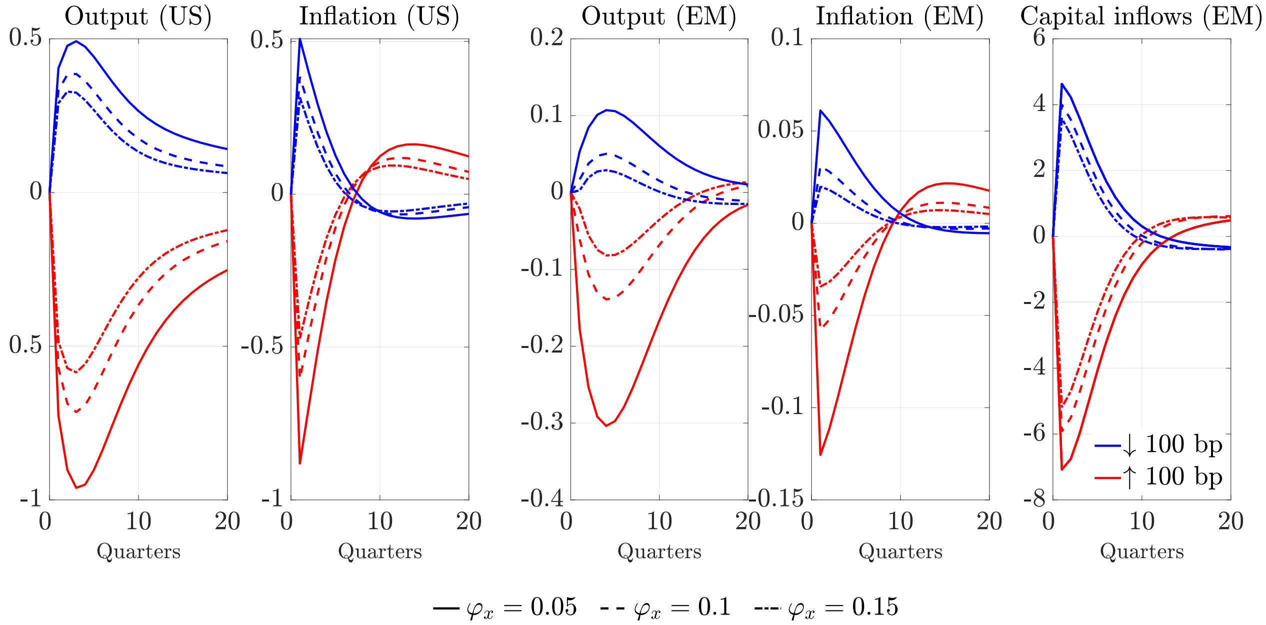


Figure B.34: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

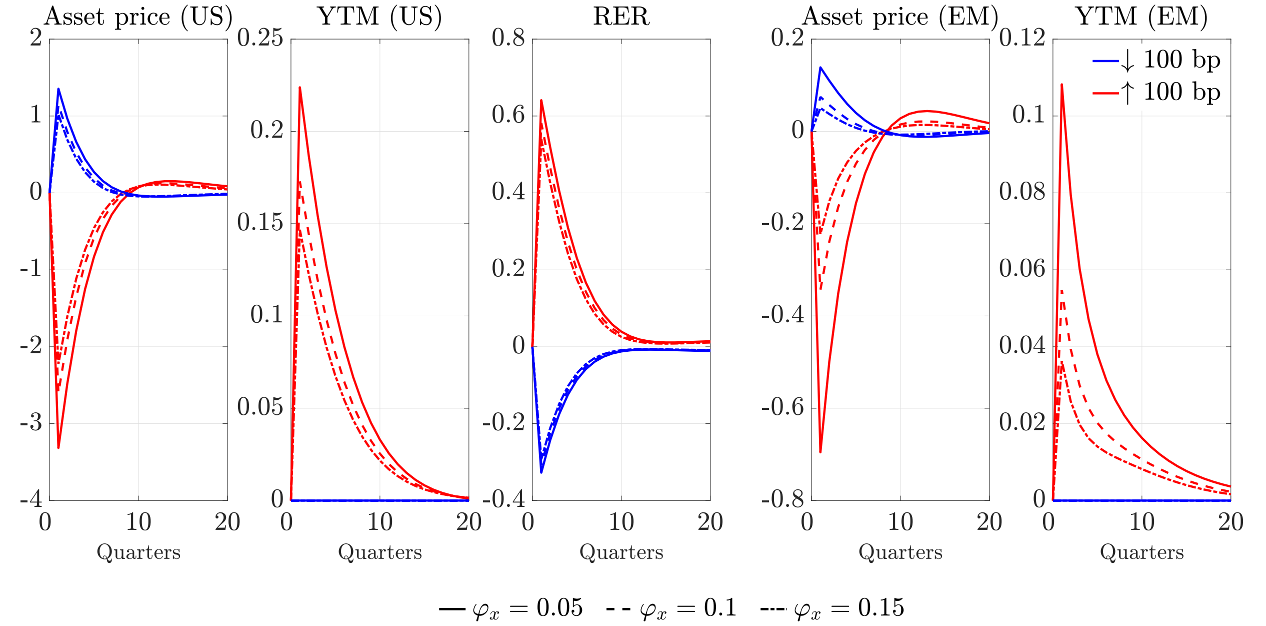


Figure B.35: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

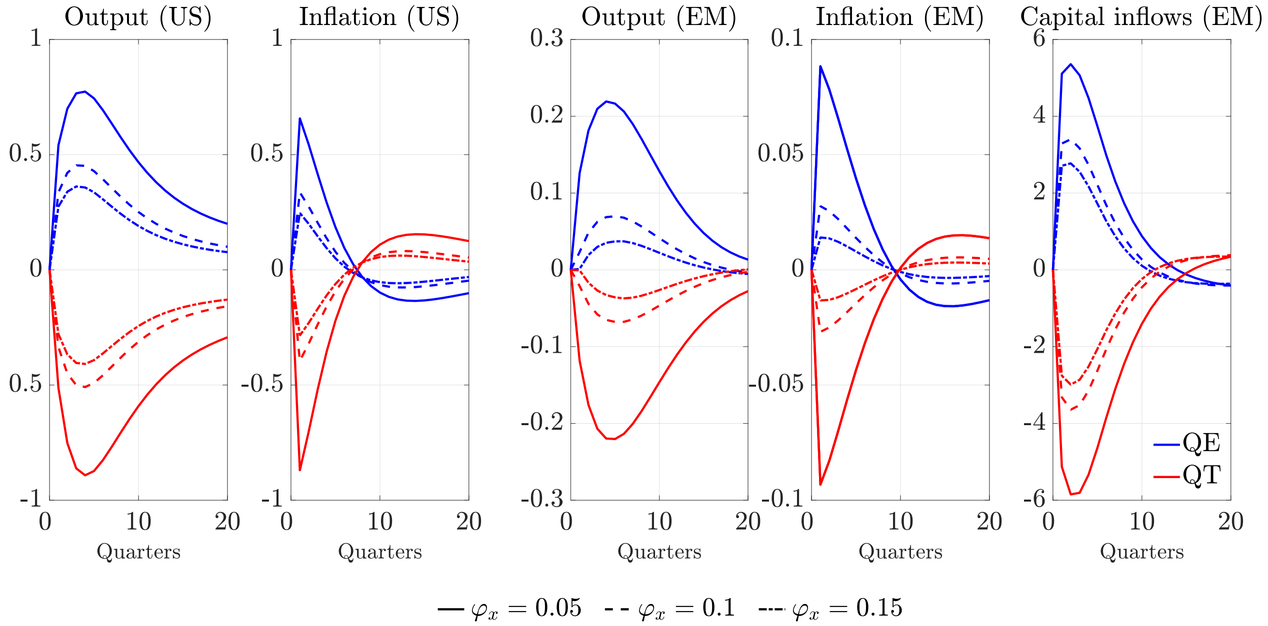
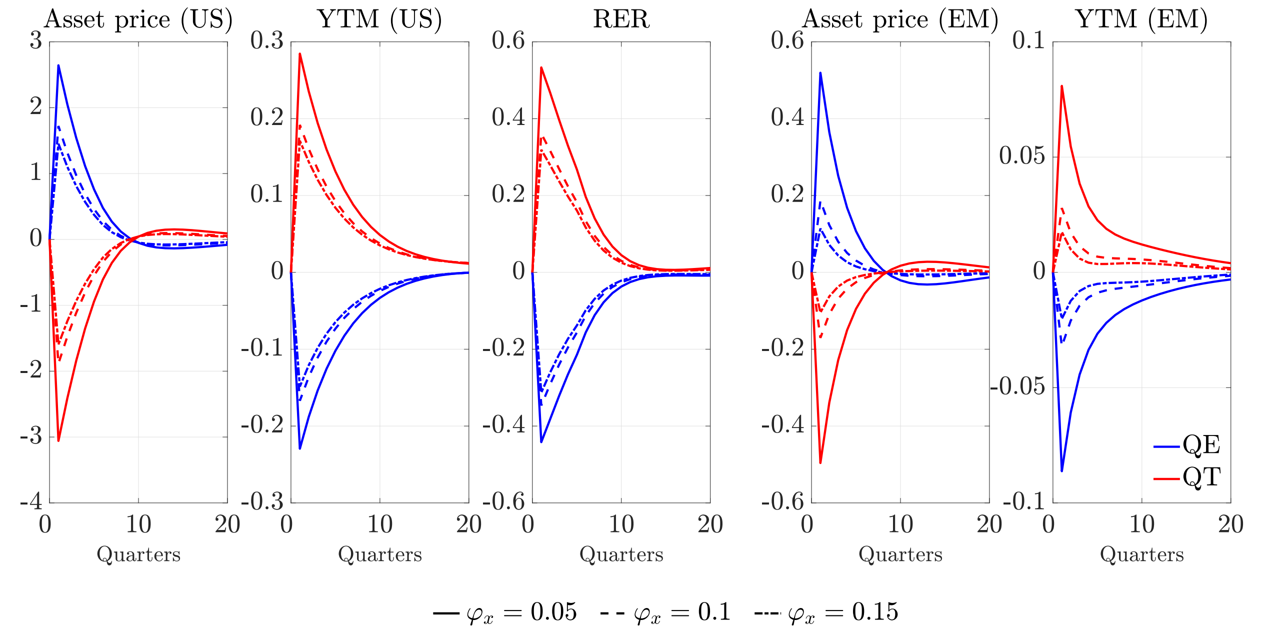


Figure B.36: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.10 Interest rate smoothing

Figure B.37: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

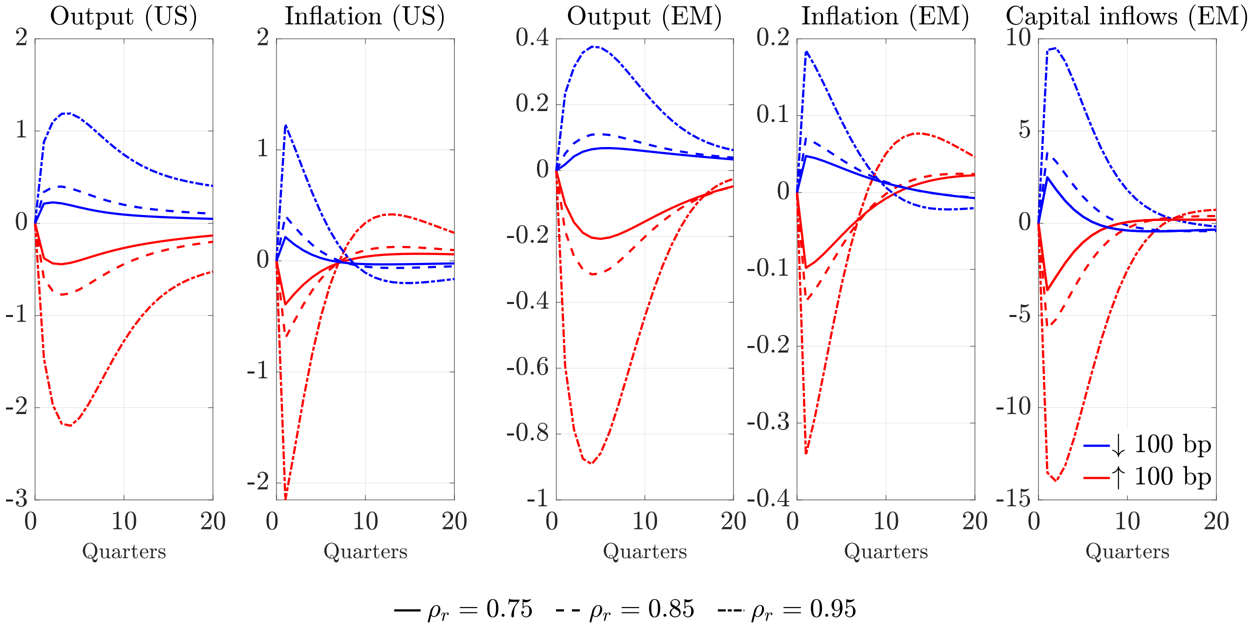


Figure B.38: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

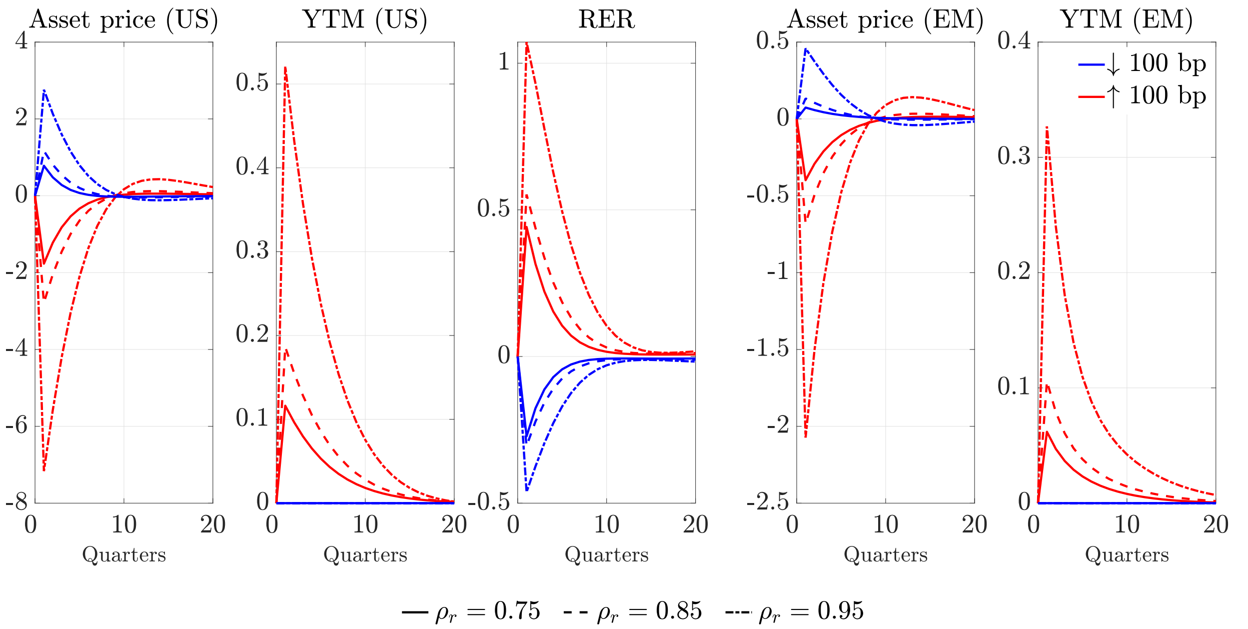


Figure B.39: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

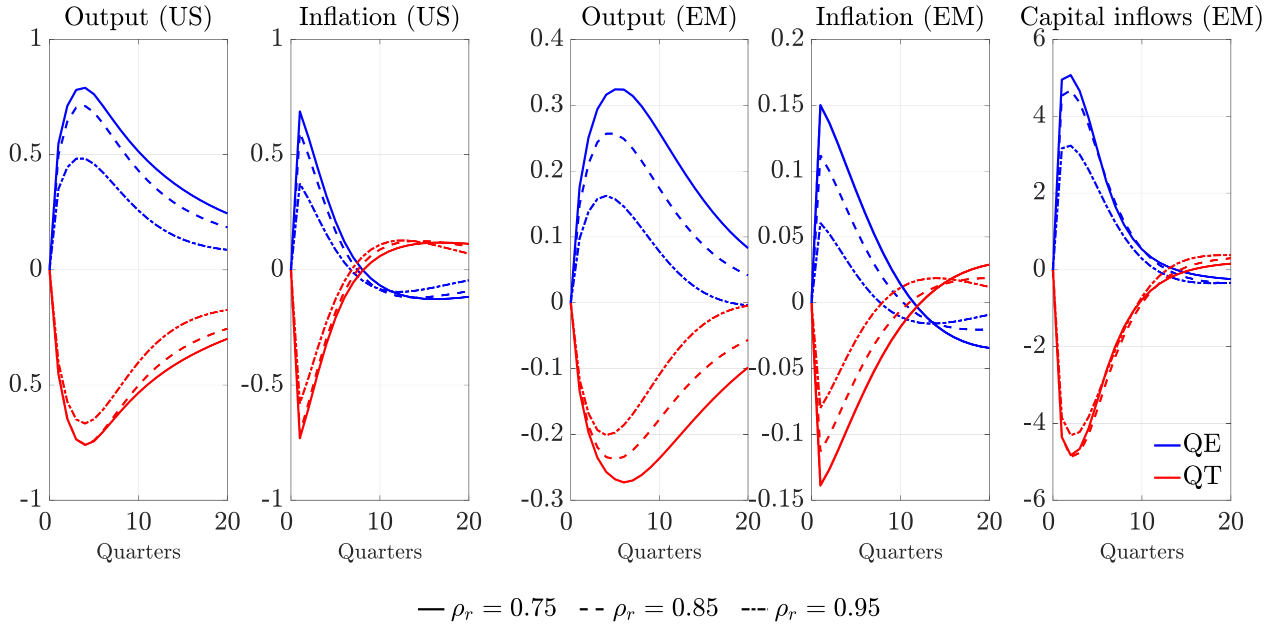
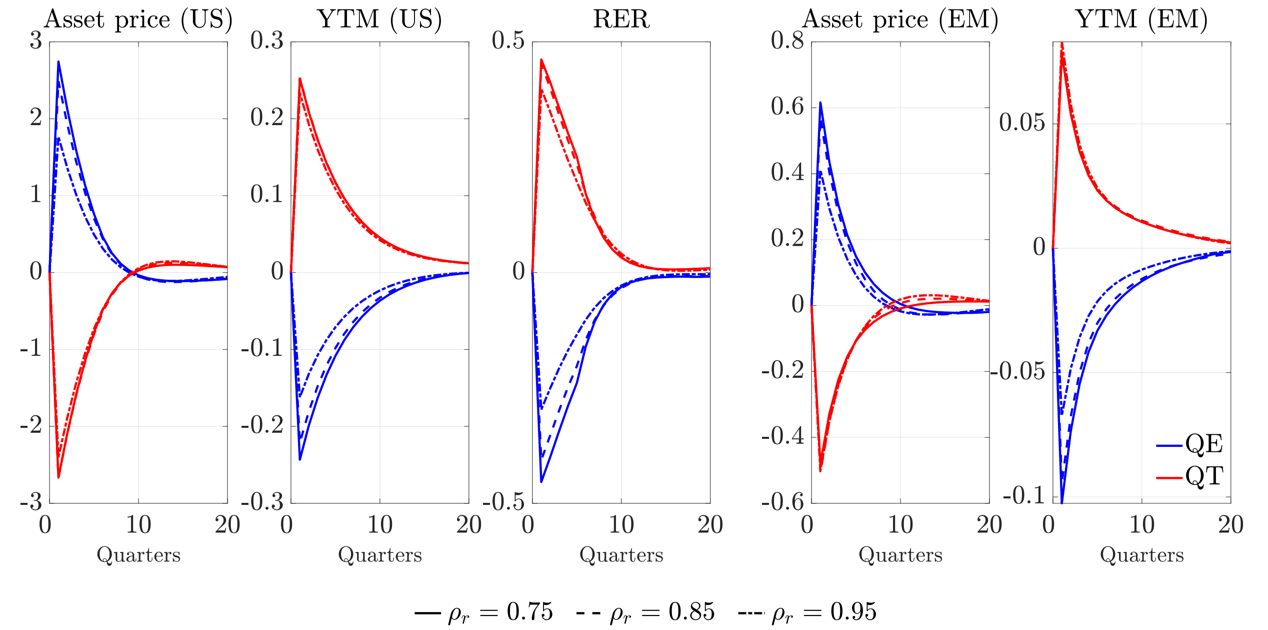


Figure B.40: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.11 Cost of equity issuance

Figure B.41: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

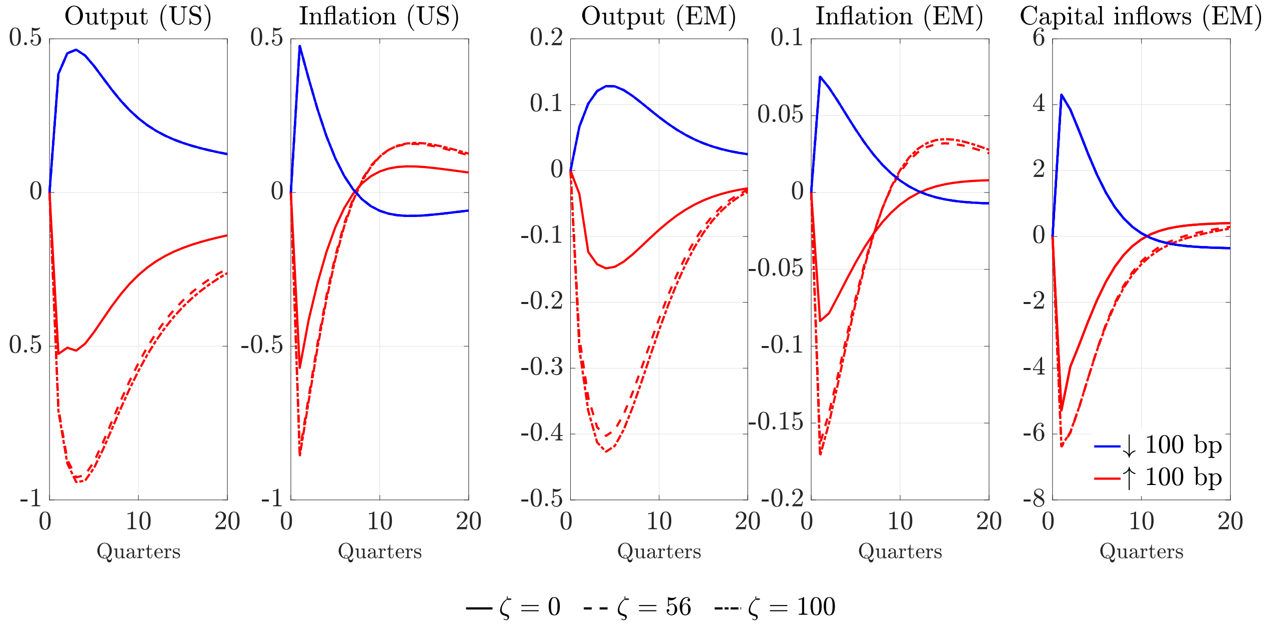


Figure B.42: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

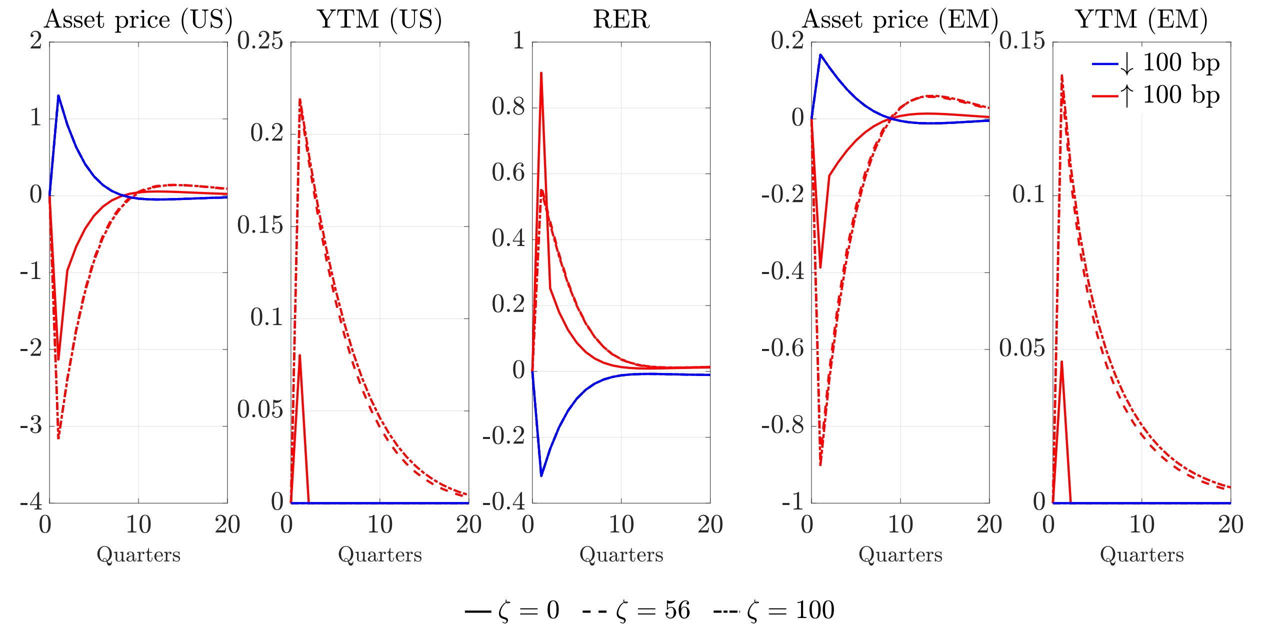


Figure B.43: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

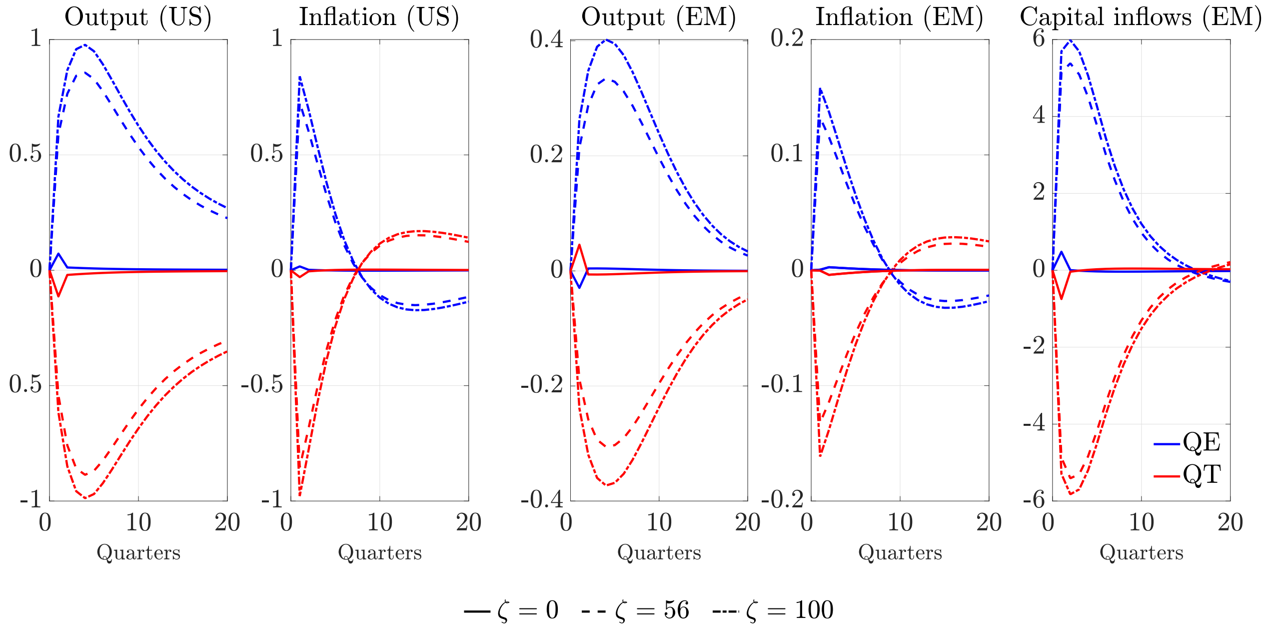
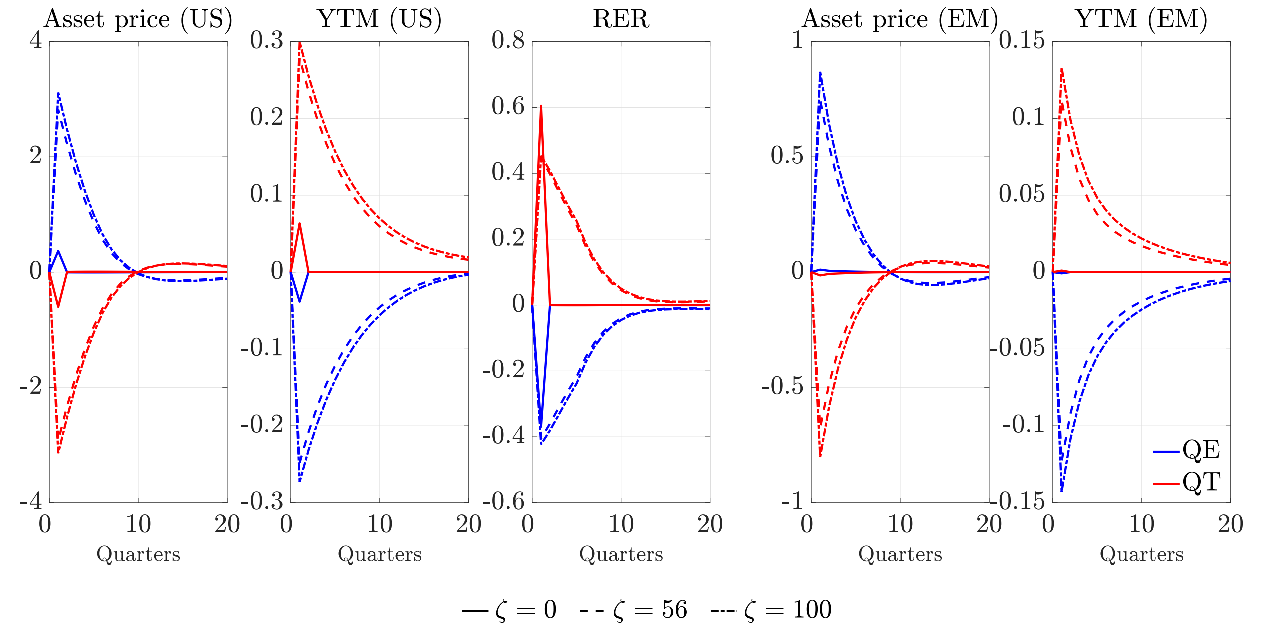


Figure B.44: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.12 Fraction of divertable funds

Figure B.45: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

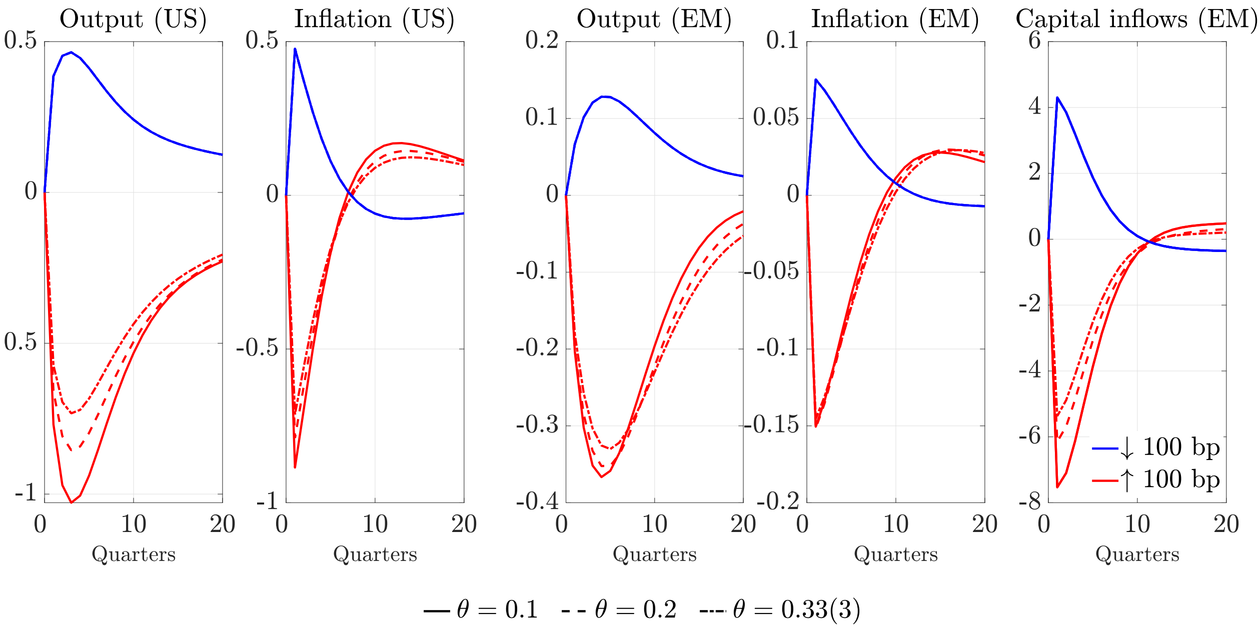


Figure B.46: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

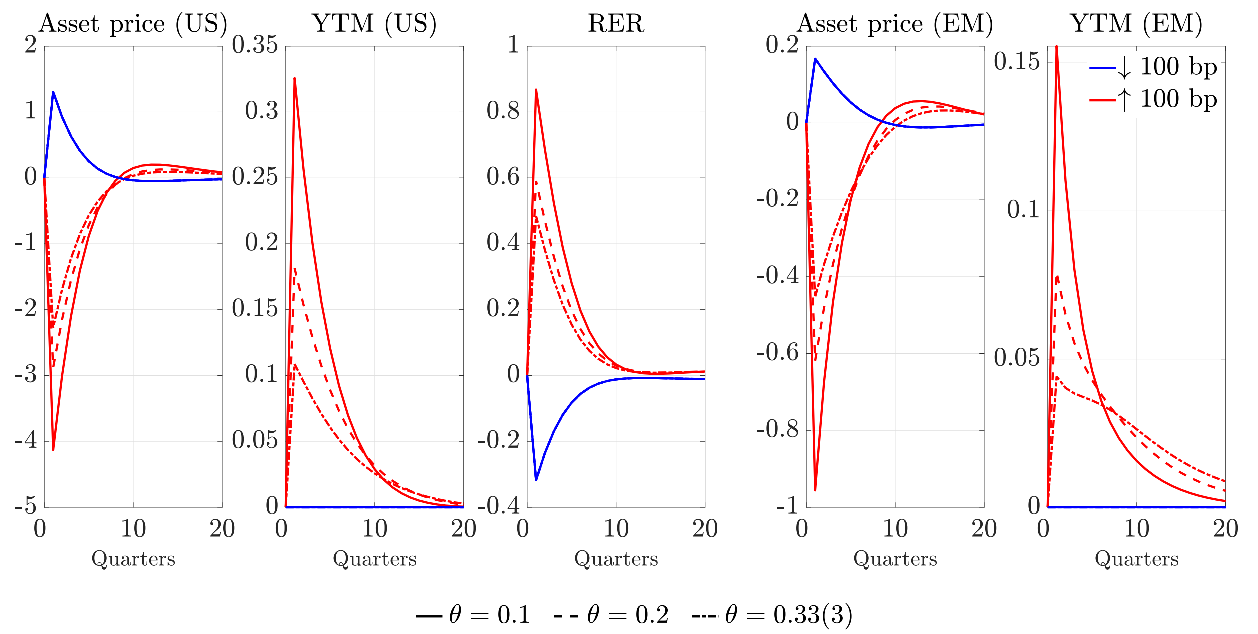


Figure B.47: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

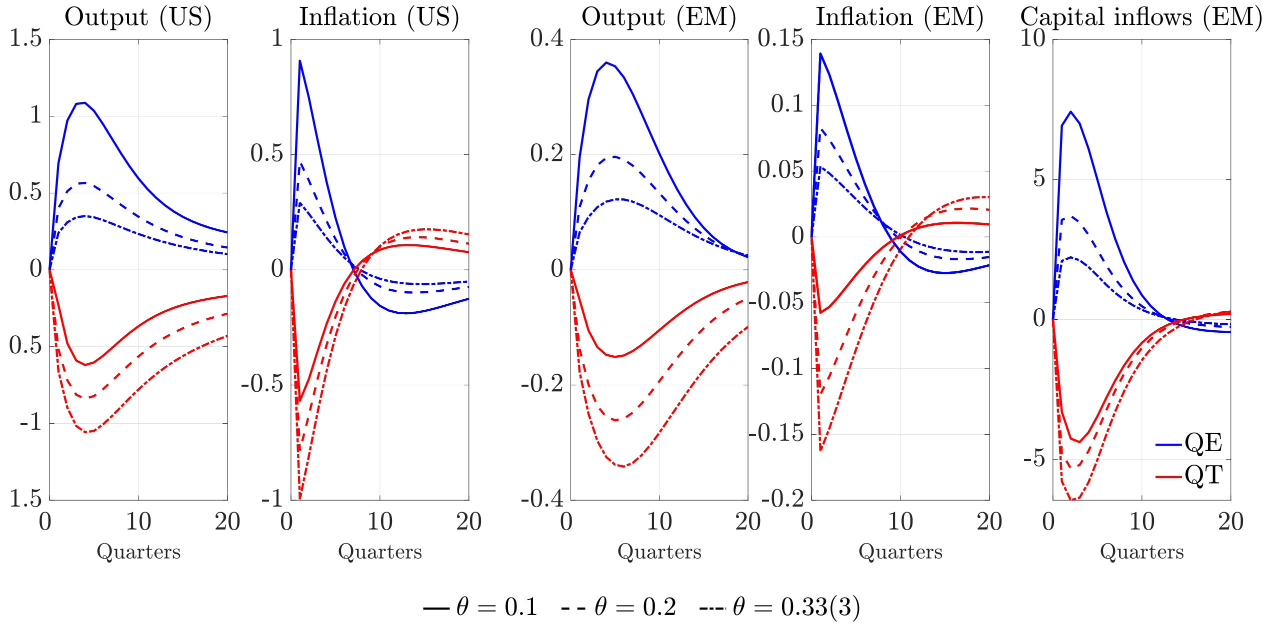
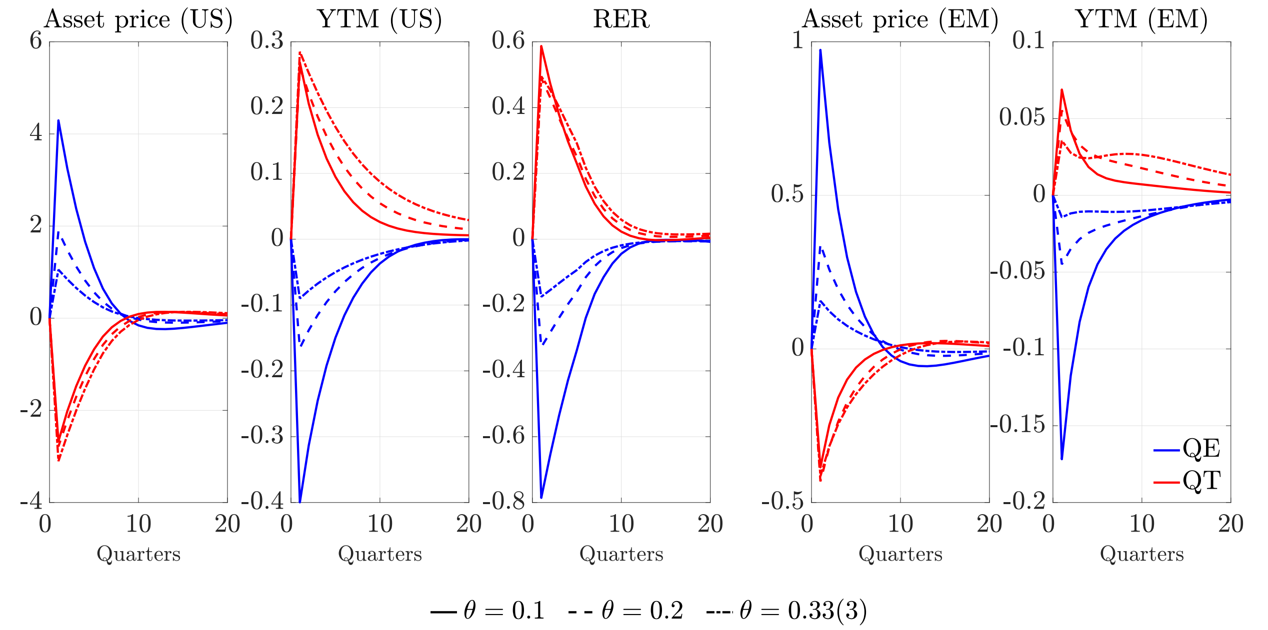


Figure B.48: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.13 Investment adjustment cost

Figure B.49: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

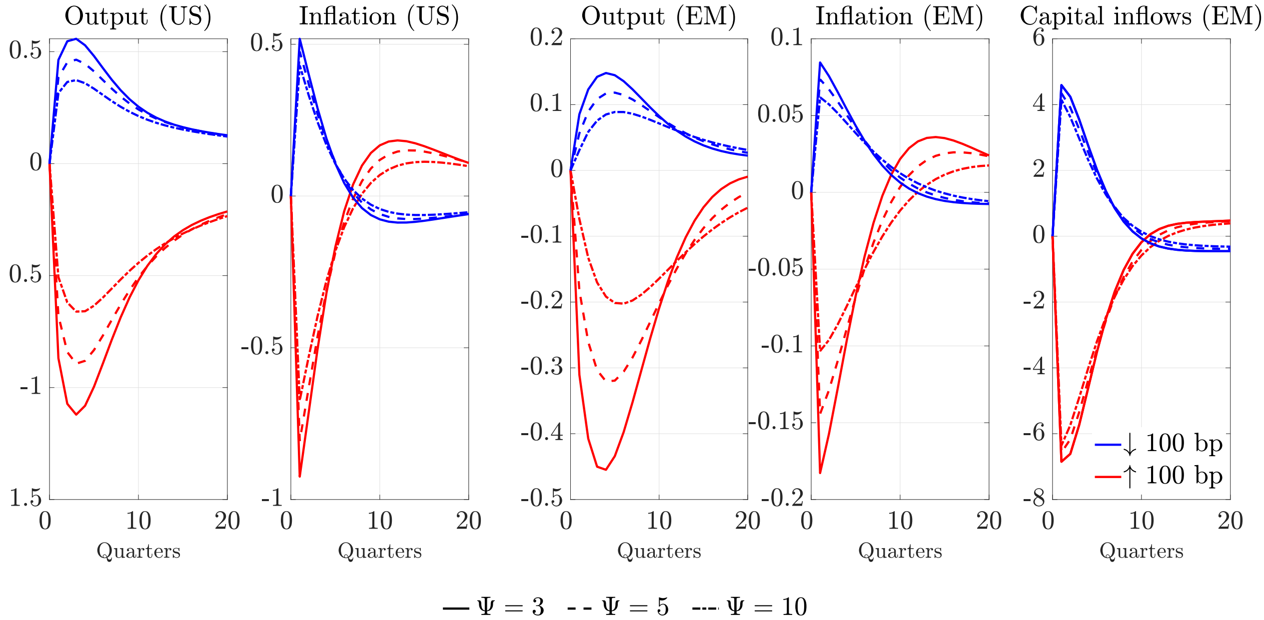


Figure B.50: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

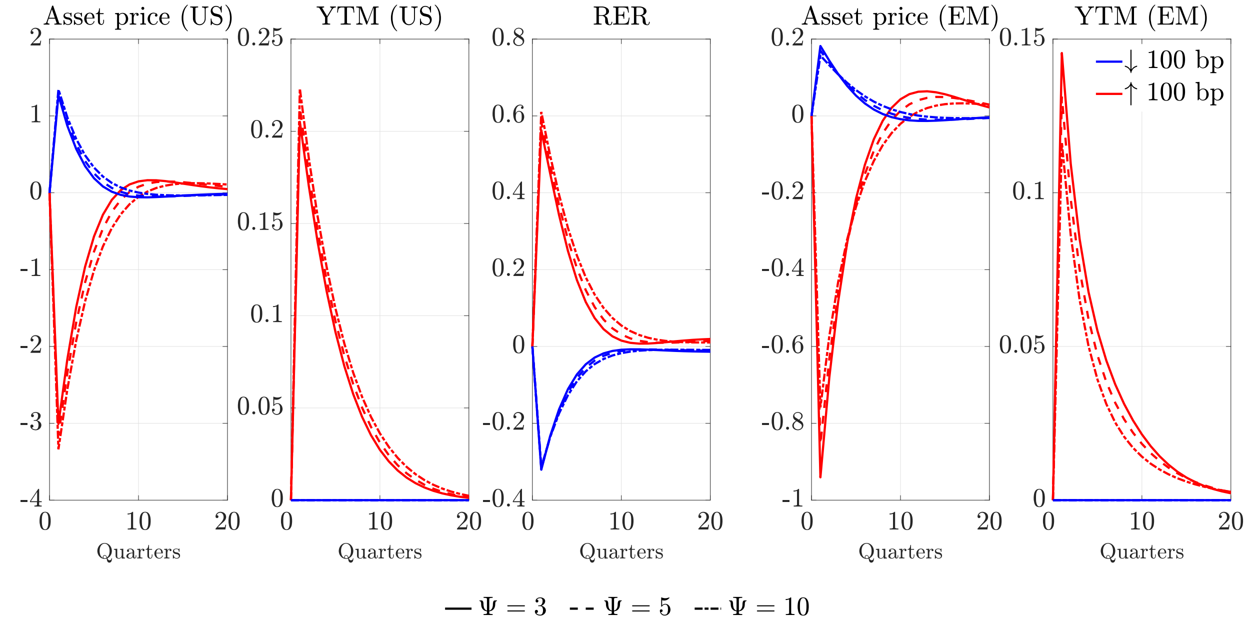


Figure B.51: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

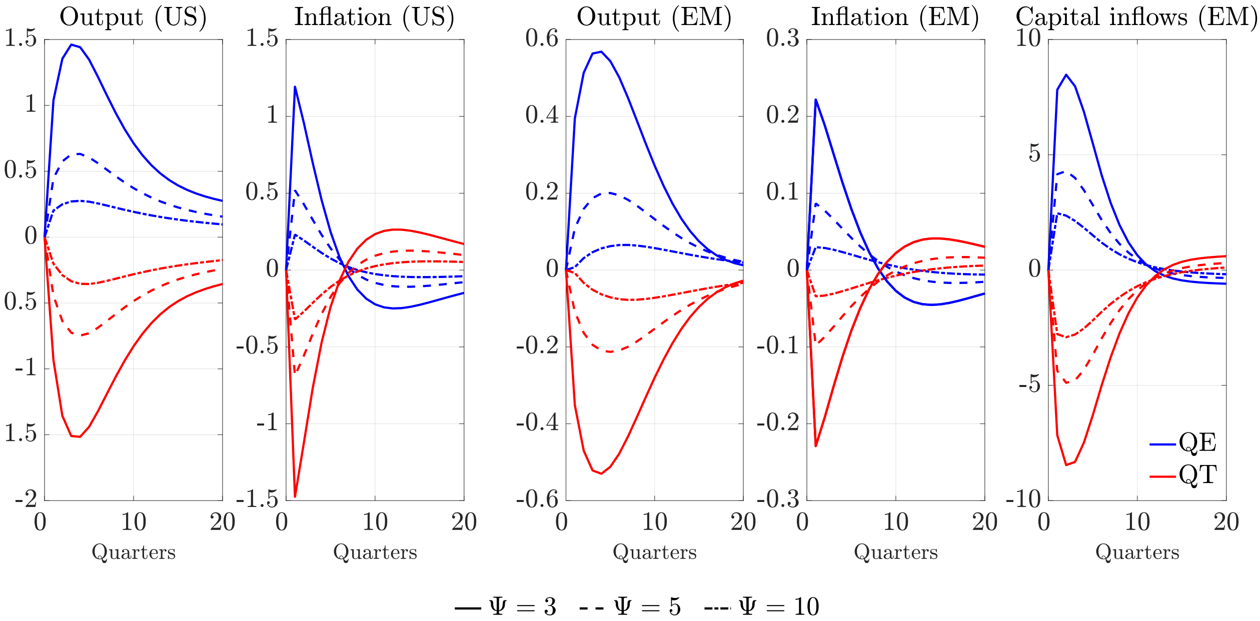
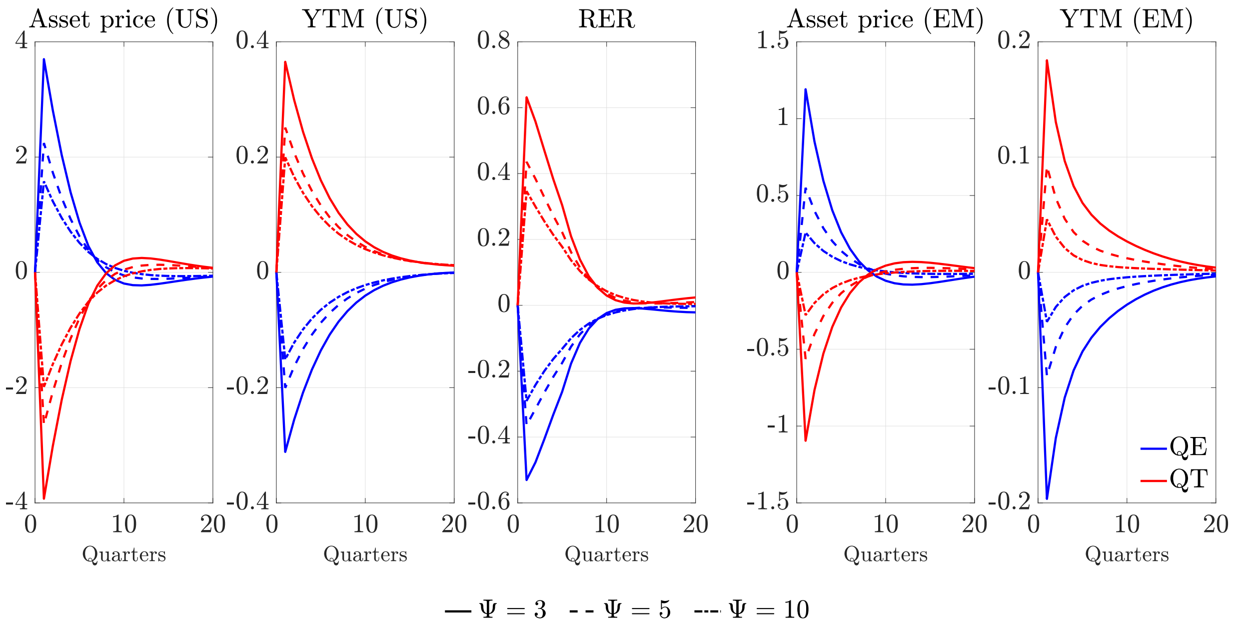


Figure B.52: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



B.14 Habit formation

Figure B.53: Responses of output, inflation, and capital inflows to EM to the US conventional monetary policy shocks (in % deviations from the steady-state).

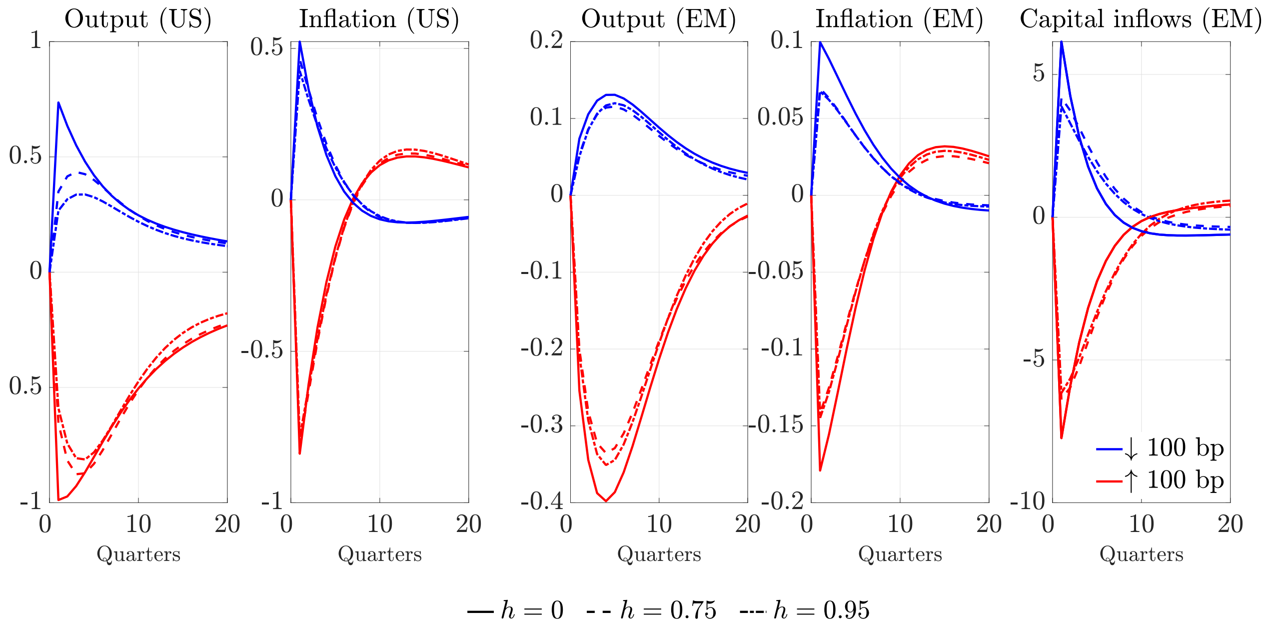


Figure B.54: Responses of asset prices, YTM, and exchange rate to the US conventional monetary policy shocks (in % deviations from the steady-state).

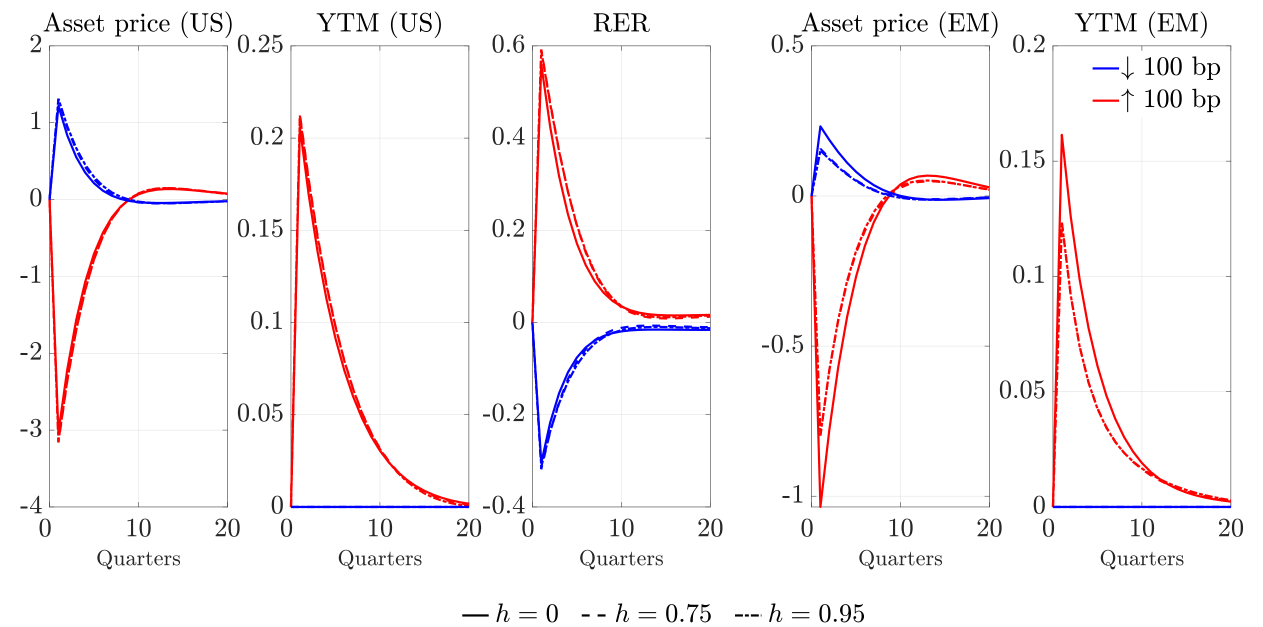


Figure B.55: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks (in % deviations from the steady-state).

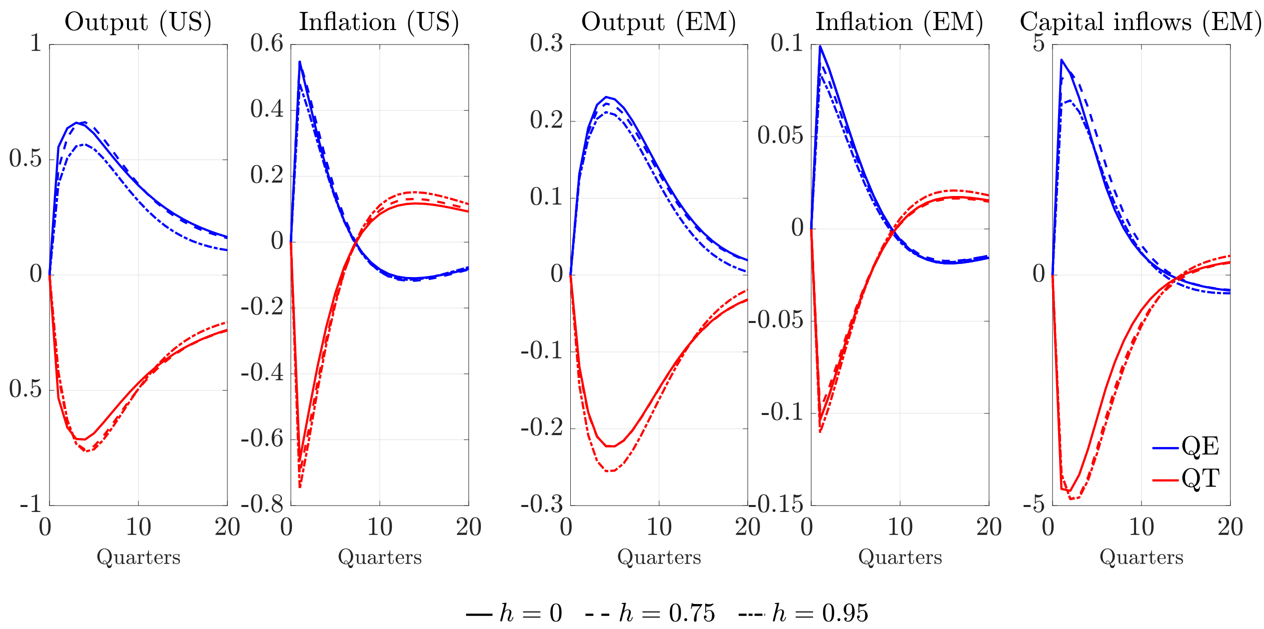
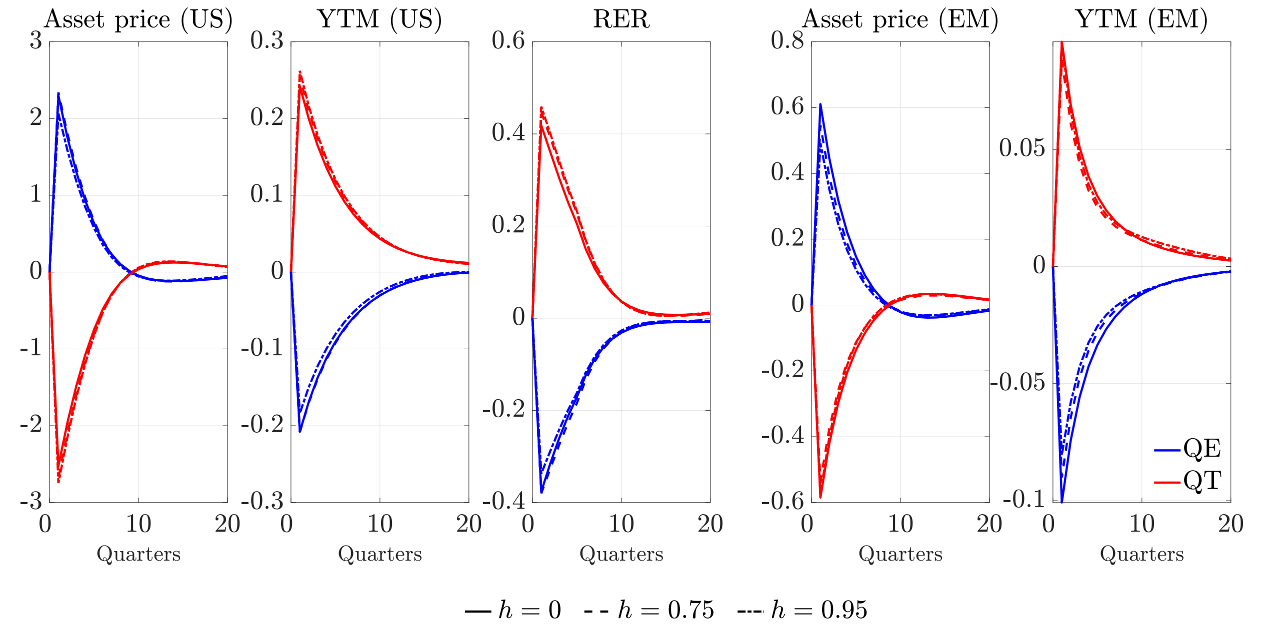
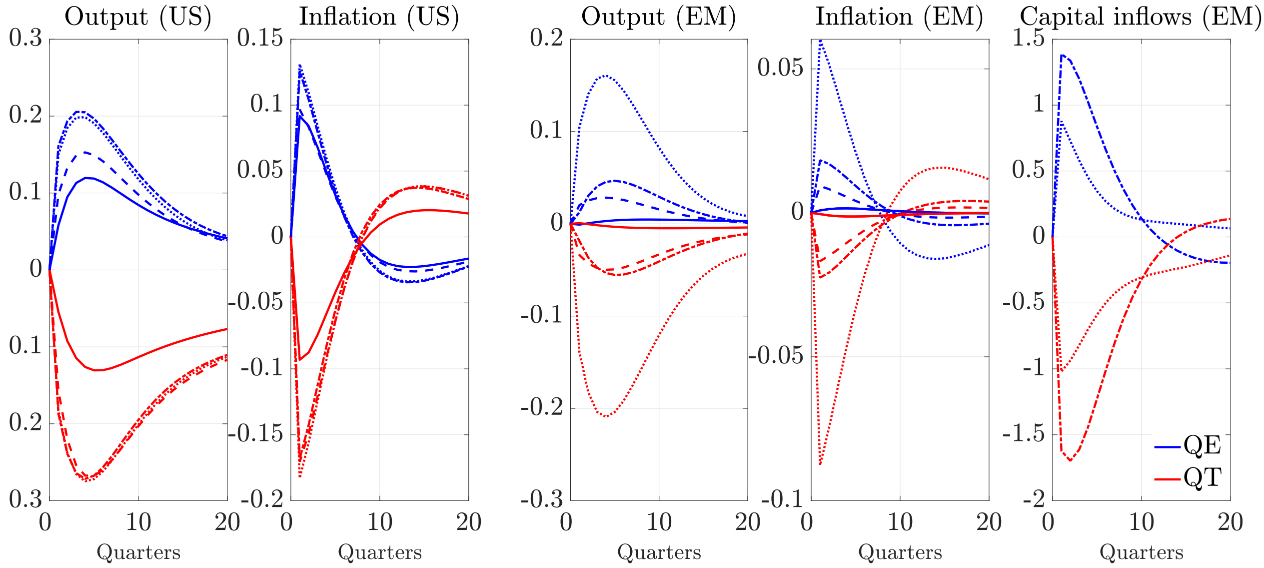


Figure B.56: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks (in % deviations from the steady-state).



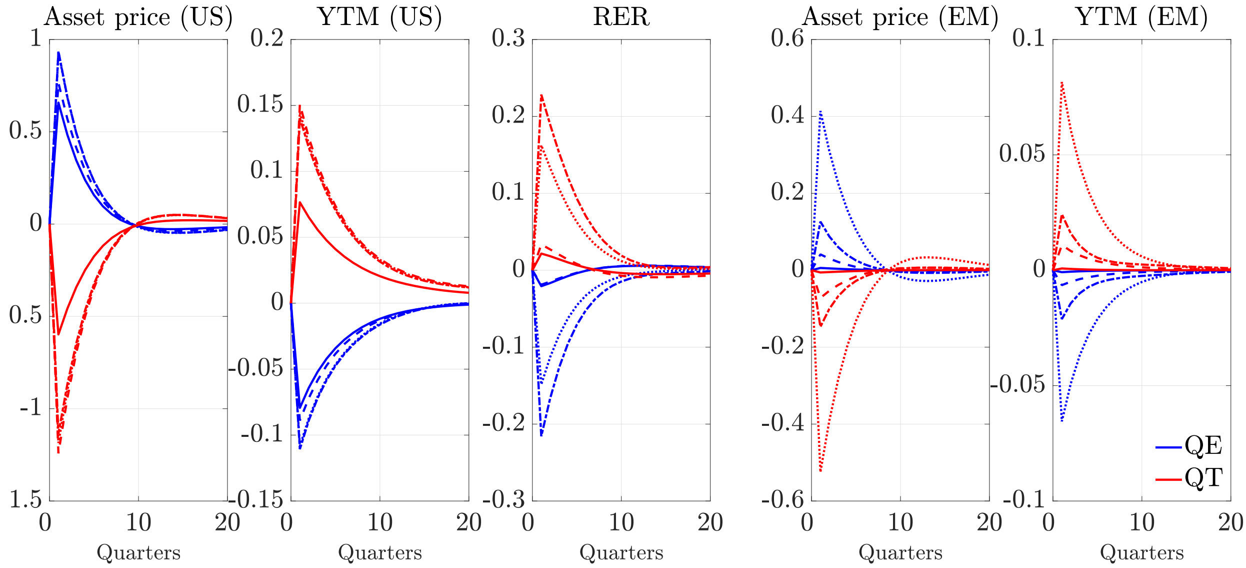
B.15 Endogenous ZLB

Figure B.57: Responses of output, inflation, and capital inflows to EM to the US unconventional monetary policy shocks with endogenous ZLB (in % deviations from the steady-state).



— Final goods - - Supply chains --- Supply chains and financial linkages ······ FoF

Figure B.58: Responses of asset prices, YTM, and exchange rate to the US unconventional monetary policy shocks with endogenous ZLB (in % deviations from the steady-state).



— Final goods - - Supply chains --- Supply chains and financial linkages ······ FoF

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The views expressed here do not necessarily reflect those of the European Central Bank or the Eurosystem.

Jakub Mistak
European Central Bank, Frankfurt am Main, Germany; email: jakub.mistak@ecb.europa.eu

F. Gulcin Ozkan
King's College London, London, United Kingdom; email: gulcin.ozkan@kcl.ac.uk

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

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