Monetary and Financial Policies in Emerging Markets

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Abstract

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1 Introduction

In the past few decades, we have observed a significant process of international financial integration characterized by the rising importance of international financial flows and larger gross external assets and liabilities.[1] To what extent does the international financial integration pose challenges for the conduct of monetary and financial policies in open economies, particularly for emerging market economies? How should government conduct policy during global financial booms and recessions?

Following the extraordinarily expansionary monetary policies of major advanced countries in the aftermath of the Global Financial Crisis from 2007, many emerging market economies experienced a large surge of capital inflow. Emerging market economies adopted a variety of policy tools aimed at curbing credit growth.[2] Later on, in May 2013, the opposite situation materialized: following Bernanke's congressional testimony about the possibility that the Federal Reserve would begin normalizing its highly accommodative monetary policy, many emerging economies experienced sharp capital outflows. Brazil, Indonesia, India, South Africa and Turkey – dubbed the Fragile Five - were at the center of an emerging markets turmoil. After the Federal Reserve started gradually raising the policy rate from December 2015, the capital flow reversals intensified and caused significant local currency depreciation in many emerging market economies, including

[1]See for example Lane and Milesi Ferretti (2007), Gourinchas and Jeanne (2013), Alfaro, Kalemli-Ozcan and Volosovych (2014) and Avdjiev, Hardy, Kalemli-Ozcan and Serven (2018).

[2]In October 2009, Brazil adopted a tax of 2% on portfolio flows, covering both equities and fixed income securities. The tax on fixed income securities flows was then raised to 4% and shortly afterwards to 6% in October 2010. Turkey in late 2010 increased reserve requirements to temper loan growth. Moreover, starting in June 2011, the banking regulation agency increased risk weights for new general purpose loans and raised provisioning requirements for banks with high levels of consumer loans or non-performing consumer loans.

the Fragile five and Argentine. These sharp retrenchments of capital flows, known as sudden stops, posed a different policy trade-offs for these economies. They could generate currency depreciation that can result in inflationary pressure. Fighting inflation may require tighter monetary policy, which could lower the growth prospect.[3] In addition, currency depreciations reduce the net worth of sectors which have outstanding debts denominated in foreign currencies.[4]

These developments have opened a debate about the role of monetary and macroprudential policies. On one end, Rey (2013) suggests not only that international financial integration exposes emerging market economies to new sources of shocks to the economy (the "global financial cycle") but that "*monetary policies are possible if and only if the capital account is managed, directly or indirectly, regardless of the exchange rate regime.*" Obstfeld (2014) in contrast asserts still the ability of emerging market economies to conduct their own monetary policy under the flexible exchange rates, but emphasizes how financial globalization has changed the trade-offs that monetary policies in emerging markets face, arguing "*the monetary trilemma remains, but the difficulty of the trade-offs that alternative choices entails can be worsened by financial globalization.*" Indeed,

[3] Brazil and Indonesia started raising interest rates since the spring of 2013 just before Bernanke's testimony. Facing a depreciating currency, Brazil removed the international financial transaction tax on portfolio flows in June 2013. From May 2013 to January 2014, Brazilian policy rate increased from 8% to above 10%. Turkey in contrast hiked the policy rate only in January 2014 by 5.5% in single policy move to contain the pressure on the Turkish Lira.

[4] During the covid-19 pandemic crisis, the emerging market economies experienced sudden stops: the spread of their government bond yield over the US treasury securities rose sharply in the spring of 2020. To fight with their own recession, the central banks of developed countries reduced their policy rates and supplied liquidity aggressively. In particular, the US Federal Reserve expanded the dollar swap lines with the central banks of the other countries, including those of Brazil and Mexico, and allowed the other central banks to borrow dollars against US treasury securities. Thanks to the highly accomodative monetary policy support of advanced economies, the sudden stop of the emerging market economies has been mitigated.

financial stability considerations can alter the policy trade-offs limiting the ability of monetary policy to pursue the standard macroeconomic stability objectives. Exchange rate movements could further exacerbates the tension between monetary and financial stability, complicating the policy problem in emerging market economies. The issue, in Obstfeld's view, is about the effectiveness of monetary policy rather than its independence per se.

Concerning the transmission of the US monetary policy to the rest of the world, Degasperi, Hong and Ricco (2021) among others conduct VAR on monthly data of 15 advanced and 15 emerging market economies to document that a US monetary policy tightening affects the other economy through four channels: (i) US demand for the other countries's output shrinks as the US economy contracts (contractionary); (ii) As US real exchange rate tends to appreciate with US monetary tightening, the products of the other countries become more competitive (expansionary); (iii) With US real exchange rate appreciation, the balance sheet of local and global banks with dollar-denominated debt worsened and their financing capacity shrinks (contractionary); (iv) With higher US interest rate, primary commodity prices fall, which transmits to output and inflation of the other economies (contractionary for commodity exporters, and expansionary for commodity importers). Using a high-frequency identification strategy for the US monetary policy shock, they find (iii) financial transmission channel and (iv) commodity price channel are particularly important for emerging market economies.

The aim of this research is to develop a framework to examine the transmission of external shocks to emerging market economies and to provide some guidance for policy. To do so, we propose a model of a small open economy integrated into international financial markets. Building upon a conventional New Keynesian open economy framework, we allow for financial intermediaries which fund capital investment by issuing deposit to home households and borrowing from foreigners. The defining feature of our financial intermediaries (we simply call banks) is the fact that home deposits are denominated in home currency while foreign borrowings are denominated in foreign currency. This feature captures "the original sin" phenomenon that affects emerging market economies.

The banking sector creates an important new mechanism through which shocks propagate into our small open economy: movements in asset prices, nominal price level and exchange rate can amplify the initial impact of a shock by affecting the balance sheet of banks creating a source of financial instability that can affect the macroeconomic performance. The policy problem now becomes more delicate since macroeconomic stability might come at a cost in terms of financial instability.

We first examine how various shocks affect our economy. As a proxy for the global financial cycle, we consider changes in the foreign interest rate - due to changes in foreign monetary policy and/or the risk premium foreign lenders require (see Miranda-Agrippino and Rey, 2014). We also consider "non financial shocks" as to shocks to primary commodity price (denominated in foreign currency) and foreign demand. Although we do not model the advanced economies, we analyze how correlated shocks to the foreign interest rate, primary commodity price, foreign demand affect a small emerging market economy.

In our model, foreign interest rate shocks generate more volatility in the economy consistent with the idea that emerging market economies are vulnerable to the global financial cycle. The crucial transmission comes from the exchange rate. An increase in the foreign interest rate leads to a depreciation of the currency that has an expansionary impact via expenditure switching channel initially, but eventually leads to a recession as the depreciation reduces the net worth and intermediation capacity of banks exposed to foreign currency liabilities. Moreover the ensuing higher inflation associated with exchange rate depreciation requires the monetary authority to raise the nominal interest rates that further worsens the balance sheet of banks and depresses the economy. Despite of banks having worsening balance sheet, they still have to roll over the foreign debts the country accumulated in the past, which leads to further depreciation of local currency. The combination of depreciated currency, declining asset prices, higher inflation and pressure for tighter monetary policy are consistent with the dynamics observed during the "taper tantrum" in 2013 and the turmoil associated with the US monetary policy tightening before covid-19 pandemic. When banks lend to businesses in foreign currency, the balance sheets of businesses are worsened with currency depreciation, which leads to a similar contraction. See Bruno and Shin (2013) and Shin (2013) for example. Since we abstract the financial friction between home banks and businesses in our model below, the same analysis applies irrespective of whether home banks or businesses absorb the exchange rate risk.

In addition, the real exchange rate depreciation makes primary commodity and imported intermediated goods more expensive to domestic producers. This reduces the value-added productivity of final goods sector. When primary commodity price falls with higher foreign interest rate, the effect on productivity of final goods sector is mitigated at the expense of commodity production sector.

We then study the effect of macroprudential policy (bank capital requirement and a tax on foreign currency borrowing) and their interaction with monetary policy. Welfare gains from these permanent prudential policies turns out to be relatively modest in our parametrization, because the gain from more stability is offset by the loss from the smaller gains from trade and intermediations. On the other hand, there is a significant welfare gain from cyclical macroprudential policy, especially when foreign interest rate shocks are more important and nominal prices are more flexible. Not only the cyclical macroprudential policy helps stabilizing the bank balance sheet, but it allows monetary policy to focus on the more traditional macro stability objective and leads to larger welfare gains. If monetary policy pursues a strict inflation targeting without macroprudential policy, it can reduce the welfare when the prices are relatively flexible and external financial shocks are important.

Our paper is related to different strands of literature. The paper follows Gertler and Karadi (2011) and Gertler and Kiyotaki (2011) for the modelling financial intermediation (banking) sector. It is related to the literature on open economy financial accelerator model such as Krugman (1999), Aghion, Bachetta and Banerjee (2001) and Gertler, Gilchrist and Natalucci (2007) for the small open economy, and two-country model by Faia (2007). It is also related to literature on macroprudential policy based on the sudden stop model of Mendoza (2010). Most of the analysis (which include Benigno et al. (2012), Bianchi (2011), Bianchi and Mendoza (2010), Jeanne and Korinek (2010), Korinek (2010)) focus on real models in which there is no scope for monetary policy intervention.[5]

[5] An exception within this approach is Benigno, Chen, Otrok, Rebucci and Young (2010) and Fornaro (2015).

There is an emerging and growing literature that studies the interaction between monetary and macroprudential policy in both closed and open economies. Some early contributions include the works by Angeloni and Faia (2013), Kannan, Rabanal, and Scott (2012), Collard, Dellas, Diba and Oisel (2012), Lambertini, Mendicino and Punzi (2011) who analyze closed economy environments and Unsal (2013), Medina and Roldos (2014), Chang, Cespedes and Velasco (2014, 2017) Chang and Velasco (2017) and Davis and Presno (2016) for open economy.[6] Perhaps the closest contemporary paper to ours is Mimir and Sunel (2019), which examines the Ramsey optimal policy when the various shocks affect the emerging market economies through the bank balance sheet channels.

Perhaps a distinctive feature is of our analysis is that we consider a small open economy with commodity sector and financial intermediaries when their domestic debt is denominated by home currency and their foreign debt is denominated by foreign currency. In this way, we can analyze the powerful transmission mechanism of external financial and nonfinancial shocks on the macro economy through the fluctuation of exchange rate, prices of commodity and final goods, asset price and bank balance sheet, and we can explore the role of monetary and macroprudential policies in emerging market economy. Of course, a deeper question is why agents in emerging markets borrow in foreign currency and do not hedge against the exchange rate risk. We take the allocation of exchange rate risk as given in order to explore the transmission of shocks, leaving these questions for future study.

[6]See also Angelini, Neri and Panetta (2014) and Beau, Clerc and Mojon (2012).

2 Basic Model

2.1 Producers

There are two types of producers, one producing primary commodity (called "commodity") and the other producing final goods. Each commodity producer has a fixed amount of capital (such as agricultural land or mine) k^x, uses labor l, imported material m and commodity x to produce commodity y^x according to constant returns to scale production function

$$y^x = A^x \left(\frac{k^x}{\alpha_X}\right)^{\alpha_K} \left(\frac{l}{\alpha_L}\right)^{\alpha_L} \left(\frac{m}{\alpha_M}\right)^{\alpha_M} \left(\frac{x}{\alpha_X}\right)^{\alpha_X}$$

where $\alpha_K + \alpha_L + \alpha_M + \alpha_X = 1$. The commodity market is perfectly competitive. The price of imported material in terms of home final goods equals the real exchange rates;

$$\epsilon_t = e_t P_t^* / P_t$$

where e_t is nominal exchange rate, P_t^* is the price of foreign final goods in terms of foreign currency, and P_t is the price level of home final goods. We assume there is no inflation of final goods in foreign country, normalizing $P_t^* = 1$. The price of commodity in terms of home final goods p_t^x depends commodity price in terms of foreign currency P_t^{x*} and the real exchange rate as

$$p_t^x = \frac{e_t P_t^{x*}}{P_t} = \epsilon_t P_t^{x*}. \tag{1}$$

For a given level of k^x, each producer chooses output and input to maximize the profit $\Pi^x = p_t^x y^x - w_t l - \epsilon_t m - p_t^x x$, taking the real wage rate w_t, imported material price ϵ_t and real commodity price p_t^x as given. Because the marginal product of labor, imported material and commodity are all equalized across producers in equilibrium, the marginal product of capital Z_t^x is equalized due to constant returns to scale and satisfies

$$p_t^x = \frac{1}{A_t^x} (Z_t^x)^{\alpha_K} w_t^{\alpha_L} \epsilon_t^{\alpha_M} (p_t^x)^{\alpha_X} \tag{2}$$

This equation says the commodity price equals the marginal cost of production, including imputed rental cost of capital in commodity sector. Aggregate production of commodity Y_t^x only depends upon aggregate capital K^x (which equals the sum of individual k^x and is fixed), labor L_t^x, imported material M_t^x and commodity X_t^x used in the commodity sector:[7]

$$Y_t^x = A^x \left(\frac{K^x}{\alpha_X}\right)^{\alpha_K} \left(\frac{L_t^x}{\alpha_L}\right)^{\alpha_L} \left(\frac{M_t^x}{\alpha_M}\right)^{\alpha_M} \left(\frac{X_t^x}{\alpha_X}\right)^{\alpha_X}. \tag{4}$$

The final good, Y_t, is produced using a variety of differentiated intermediate goods y_{it}, $i \in [0,1]$ under perfect competition according to a constant returns to scale technology as

$$Y_t = \left(\int_0^1 y_{it}^{\frac{\eta-1}{\eta}} di\right)^{\frac{\eta}{\eta-1}}, \tag{5}$$

where $\eta > 1$ is the elasticity of substitution among differentiated intermediate goods. Each differentiated intermediate goods is produced from capital k'_{it}, labor l_{it}, imported

[7] The profit maximization condition also implies

$$Z_t^x K^x : w_t L_t^x : \epsilon_t M_t^x : p_t^x X_t^x = \alpha_K : \alpha_L : \alpha_M : \alpha_X \tag{3}$$

material m_{it} and commodity x_{it} according to

$$y_{it} = A^y \left(\frac{k'_{it}}{\alpha_K}\right)^{\alpha_K} \left(\frac{l_{it}}{\alpha_L}\right)^{\alpha_L} \left(\frac{m_{it}}{\alpha_M}\right)^{\alpha_M} \left(\frac{x_{it}}{\alpha_X}\right)^{\alpha_X}.$$

We assume $\alpha_K, \alpha_L, \alpha_M$ and α_X are the same with commodity sector, but capital is distinct from commodity sectors.

The producer of each differentiated intermediate goods operates in a monopolistically competitive environment and faces a demand curve for its product (which is consistent with final good production function (5)) as

$$y_{it} = \left(\frac{p_{it}}{P_t}\right)^{-\eta} Y_t,$$

where p_{it} is nominal price of goods i and P_t is aggregate price index defined as $P_t = \left(\int_0^1 {p_{it}}^{1-\eta} di\right)^{\frac{1}{1-\eta}}$. Denoting Z_t^y to be rental price of capital in final gods sector, the minimized unit cost of production is

$$m_{Ct}^y = \frac{1}{A_t^y} (Z_t^y)^{\alpha_K} w_t^{\alpha_L} \epsilon_t^{\alpha_M} (p_t^x)^{\alpha_X}. \tag{6}$$

The monopolistic producer i chooses a rule of (p_{it}, y_{it}) to maximize the expected discounted value of profit

$$E_0 \left\{ \sum_{t=0}^{\infty} \Lambda_{0,t} \left[\left(\frac{p_{it}}{P_t} - m_{Ct}^y \right) y_{it} - \frac{\kappa}{2} \left(\frac{p_{it}}{p_{it-1}} - 1 \right)^2 Y_t \right] \right\},$$

where the quadratic term is the adjustment cost of the price (with $\kappa > 0$), and $\Lambda_{0,t}$ is the stochastic discount factor of the representative households (to be defined below), as monopolistic intermediate goods producers are owned by household. From the first order condition with respect to p_{it} evaluated under symmetric equilibrium $p_{it} = P_t$, we obtain

$$(\pi_t - 1)\pi_t = \frac{\eta}{\kappa}\left(m^y_{Ct} - \frac{\eta - 1}{\eta}\right) + E_t\left[\Lambda_{t,t+1}\frac{Y_{t+1}}{Y_t}\pi_{t+1}(\pi_{t+1} - 1)\right], \tag{7}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is the final goods' gross inflation rate.

Under symmetric equilibrium, we also learn aggregate output, Y_t is

$$Y_t = A^y_t \left(\frac{K_{t-1}}{\alpha_K}\right)^{\alpha_K}\left(\frac{L^y_t}{\alpha_L}\right)^{\alpha_L}\left(\frac{M^y_t}{\alpha_M}\right)^{\alpha_M}\left(\frac{X^y_t}{\alpha_X}\right)^{\alpha_L}, \tag{8}$$

where K_{t-1}, L^y_t, M^y_t and X^y_t are aggregate capital stock, labor, imported materials and commodity used for final goods production, defined as

$$K_{t-1} = \int_0^1 k'_{it}di, \quad L^y_t = \int_0^1 l_{it}di, \; M^y_t = \int_0^1 m_{it}di, \; X^y_t = \int_0^1 x_{it}di.$$

Here we consider K_{t-1} as aggregate capital stock of final goods sector accumulated by the end of the $t-1$ period (and the beginning of t period) which is used for production at time t.[8]

Capital producers make new capital using the final good as input and subject to an adjustment cost. Following Christiano, Eichenbaum and Evans (2005), the adjustment

[8]The cost minimization also implies

$$Z^y_t K_{t-1} : w_t L^y_t : \epsilon_t M^y_t : p^x_t X^y_t = \alpha_K : \alpha_L : \alpha_M : \alpha_X \tag{9}$$

cost is a function of the ratio of total investment cost of present and the last periods as $\Phi\left(\frac{I_t}{I_{t-1}}\right)$ in which $\Phi(1) = \Phi'(1) = 0$ and $\Phi"\left(\frac{I_t}{I}\right) > 0$. Capital producers are owned by households and distribute their profits to households. When the representative household spends total investment cost I_t in the aggregate, aggregate capital stock of final goods sector at the end of period t (which is available to use in period t+1) is

$$K_t = \lambda K_{t-1} + \left[1 - \Phi\left(\frac{I_t}{I_{t-1}}\right)\right] I_t, \tag{10}$$

where $\lambda \in (0, 1)$ is one minus constant depreciation rate. The specific function we use is $\Phi\left(\frac{I_t}{I_{t-1}}\right) = \frac{\kappa_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$, where $\kappa_I > 0$.

Finally we assume that export demand for final goods by foreigners is a decreasing function of relative price of the export and foreign income as

$$E_{Xt} = \left(\frac{P_t}{e_t P_t^*}\right)^{-\varphi} Y_t^* = {\epsilon_t}^{\varphi} Y_t^*, \tag{11}$$

where φ is a constant price elasticity of foreign demand, and Y_t^* is foreign demand which exogenously given from the perspective of the small open economy.[9]

2.2 Households

We follow Gertler and Karadi (2011) and Gertler and Kiyotaki (2011) in developing an infinite horizon macroeconomic model with banking. The representative household

[9]As Gopinath et al. (2020) emphasizes, if the export of emerging market economies are largely denominated in dollars and their prices are sticky in dollars, the trade-off between macro and financial stabilities becomes worse. We abstract from the dollar-price stickiness of the exports in order to focus on the bank balance sheet channel.

consists of a continuum of bankers and workers with the total population size being normalized to unity. Each banker member manages a bank until he/she retires with probability $1-\sigma$. The retired bankers transfer their remaining net worth as dividend, to the household and are replaced by an equal number of workers who become new bankers. The new bankers receive ξ fraction of total asset from the household as a total start-up funds.

As in Gertler and Karadi (2011) we focus on an environment in which financing constraint are present at the banking level abstracting from financing constraint faced by nonfinancial businesses. In other words, banks provide funds to nonfinancial businesses by buying ownership of capital (equity) to receive the rental income and the resale value of capital as the payoff in the next period.

Workers can also directly buy equity but face an extra cost $\chi^h(K_t^h, K_t) = \frac{\varkappa^h}{2}\left(\frac{K_t^h}{K_t}\right)^2 K_t$ that we interpret as management cost, in order to receive the same payoff as the banker. A positive parameter $\varkappa^h$ represents the disadvantage of workers relative to bankers in financing businesses. In addition to direct capital holding, workers can save in bank deposit. We assume the deposit contract is nominal, short term and non-contingent. Those who deposit D_t^n amount of money at date t will receive $(1+i_t)D_t^n$ amount of money at date $t+1$ irrespective of the state, where i_t is the nominal interest rate on deposit.

Workers cannot directly hold foreign debt nor borrow from foreigners due to lack of expertise and/or capital control.[10] In addition, foreigners do not directly own domestic

[10]This assumption is not critical. In our model, typical home residents do not want to hold foreign bonds unless the incentive to insure against exchange rate risk is large, because the real interest rate tends to be lower in foreign country than our emerging market economy.

capital, nor lend to nonfinancial businesses. Therefore, all the financial transaction between home and the foreign economy are conducted through domestic intermediaries.

The representative household chooses consumption C_t, labor supply L_t, direct capital ownership K_t^h and nominal bank deposit D_t^n, to maximize the expected utility[11]

$$E_0\left[\sum_{t=0}^{\infty}\beta^t \ln\left(C_t - \frac{\zeta_0}{1+\zeta}{L_t}^{1+\zeta}\right)\right]$$

subject to the budget constraint

$$C_t + D_t + Q_t K_t^h + \chi^h(K_t^h, K_t) = w_t L_t + \Pi_t + R_t D_{t-1} + (Z_t + \lambda Q_t)K_{t-1}^h. \tag{12}$$

The variable Q_t is the real equity price, $D_t = D_t^n/P_t$ is the real value of deposit, w_t is the real wage rate and

$$R_t = \frac{1+i_{t-1}}{\pi_t} \tag{13}$$

is the gross real interest rate on home deposit from date $t-1$ to date t. The subjective discount factor β is in $(0,1)$ while the utility weigh on labor, ζ, and the inverse of the Frisch elasticity of labor supply, ζ_0, are both positive. The left hand side (LHS) of (12) represents the use of funds - consumption and saving in deposit and equity including the management cost of equity, while the right hand side (RHS) is the source of funds - wages, profit distribution and the returns on saving. Π_t represents the distribution of real profits from production of differentiated goods and investment goods as well as

[11]We use Greenwood-Hercowitz-Hoffman style utility function in order to capture the procyclicality of employment in the formal sector of the emerging economy.

banking:

$$\Pi_t = Z_t^x K^x + \int_0^1 \left[\left(\frac{p_{it}}{P_t} - m_t^C \right) y_{it} - \frac{\kappa}{2} \left(\frac{p_{it}}{p_{it-1}} - 1 \right)^2 Y_t \right] di + Q_t \left(K_t - \lambda K_{t-1} \right) - I_t$$

$$+(1-\sigma) \left[(Z_t + \lambda Q_t) K_{t-1}^b - R_t D_{t-1} - \epsilon_t R_{t-1}^* D_{t-1}^* - \chi^b \left(\epsilon_t D_t^*, Q_t K_t^b \right) \right] - \xi (Z_t + \lambda Q_t) K_{t-1}.$$

The first two component are profits from the production of commodity and differentiated goods, the third component are profits from the investment goods production, the fourth component are the dividends from the retiring bankers minus the start-up fund for the entering bankers. There are no profits from final goods production under perfect competition.

The first order conditions for labor, savings in direct capital ownership and deposit and investment goods production imply:

$$w_t = \zeta_0 {L_t}^{\zeta}, \tag{14}$$

$$1 = E_t \left(\Lambda_{t,t+1} \frac{Z_{t+1} + \lambda Q_{t+1}}{Q_t + \varkappa^h \frac{K_t^h}{K_t}} \right), \tag{15}$$

$$1 = E_t \left(\Lambda_{t,t+1} R_{t+1} \right), \tag{16}$$

$$1 = Q_t \left[1 - \Phi \left(\frac{I_t}{I_{t-1}} \right) - \left(\frac{I_t}{I_{t-1}} \right) \Phi' \left(\frac{I_t}{I_{t-1}} \right) \right] + E_t \left[\Lambda_{t,t+1} Q_{t+1} \left(\frac{I_{t+1}}{I_t} \right)^2 \Phi' \left(\frac{I_{t+1}}{I_t} \right) \right] \tag{17}$$

where $\Lambda_{t,\tau} = \beta^{\tau - t} \frac{C_t - \frac{\zeta_0}{1+\zeta} {L_t}^{1+\zeta}}{C_\tau - \frac{\zeta_0}{1+\zeta} {L_\tau}^{1+\zeta}}$ is the households' stochastic discount factor from period t to period τ.

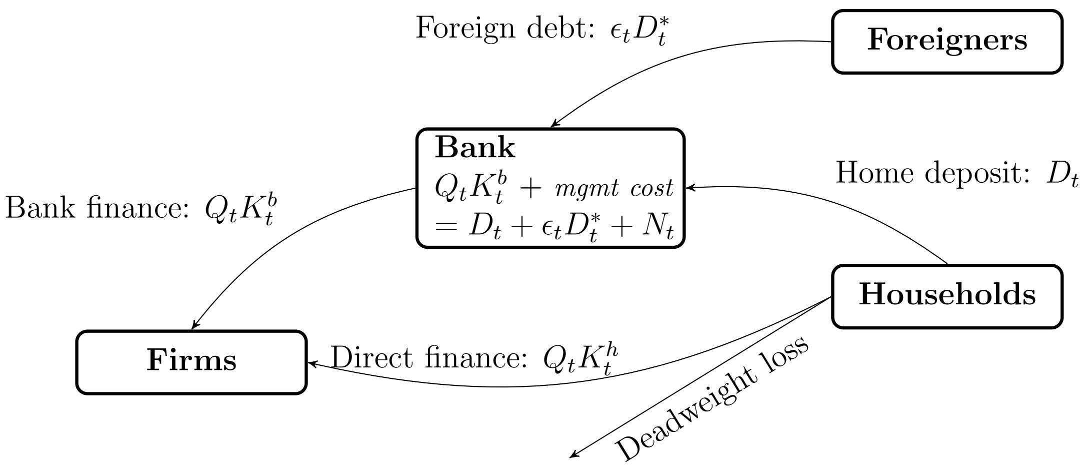


Figure 1: Flow of Funds

2.3 Banks

Figure 1 describes the flow-of-funds of the aggregate economy. Banks fund capital investment (ownership of capital) by issuing deposits to households, borrowing from foreigners and using their own net worth. Moreover, we assume all the foreign financial contracts are short term, non-contingent and denominated in foreign currency. Thus the home banks face the exchange rate risk. Each banker member manages a bank until retirement. After then, the bank brings back the net worth as dividend. This retirement limits the possibility that banks may save their way out of the financing constraints (described below) by accumulating retained earnings. The objective of the bank is to maximize the expected present value of future dividend, V_t, as

$$V_t = E_t \left[\sum_{j=1}^{\infty} \Lambda_{t,t+j} \sigma^{j-1} (1-\sigma) n_{t+j} \right],$$

where n_{t+j} is net worth (or dividend) of the bank when it retires at date $t+j$ with probability $\sigma^{j-1}(1-\sigma)$ and $\Lambda_{t,t+j}$ is stochastic discount factor of the representative household.

The individual bank chooses capital holding, home real deposit and foreign debt, k_t^b, d_t and d_t^*. We assume that borrowing from foreigners is costly in terms of resources as

$$\chi^b\left(\epsilon_t d_t^*, Q_t k_t^b\right) = \frac{\varkappa^b}{2}\gamma_t^2 Q_t k_t^b, \tag{18}$$

where $\varkappa^b$ is a positive parameter and where $\gamma_t = \frac{\epsilon_t d_t^*}{Q_t k_t^b}$ is the fraction of assets financed by foreign borrowing. Thus, even though borrowing from foreigners may be cheaper with relatively low real interest rate, it is increasingly costly as the fraction of assets financed by foreign borrowing increases.

We denote with R_t^* the foreign real gross interest rate from date t to t+1 (which equals to the foreign nominal interest rate because we assumed there is no inflation in foreign country) and express the flow of funds constraints of a typical bank by

$$\left(1+\frac{\varkappa^b}{2}\gamma_t^2\right) Q_t k_t = n_t + d_t + \epsilon_t d_t^*, \tag{19}$$

$$n_t = (Z_t + \lambda Q_t)k_{t-1} - R_t d_{t-1} - \epsilon_t R_{t-1}^* d_{t-1}^*, \tag{20}$$

Equation (19) represents the balance sheet constraint of the individual bank and (20) is the law of motion of the individual bank's net worth. The net worth of a new banker is the initial start-up fund given by the household.

To motivate a limit on the bank's ability to raise funds, we introduce the following moral hazard problem: After raising funds and buying assets at the beginning of the period t, but still during the period, the banker decides whether to operate honestly or divert assets for personal use. Operating honestly means holding capital until the payoffs are realized in the next period and then meet the obligations to creditors. To divert means to secretly channel funds as much as θ fraction of total asset away from investment in order to consume personally. The parameter $\theta > 0$ represents the severity of the bank moral hazard problem. We assume the process of diverting assets takes time. The banker cannot quickly liquidate a large amount of assets without the transaction being noticed. Thus the banker must decide whether to divert at t prior to the realization of uncertainty at $t + 1$. When the banker diverts the asset between dates t and $t + 1$, the creditors will force the intermediary into bankruptcy at the beginning of the next period, and banker will loose the franchise completely. The banker's decision boils down to comparing the franchise value of the bank V_t at the end of period t, which measures the present discounted value of future payouts from operating honestly, with the gain from the diverting the funds. In this regard, rational creditors will not supply funds to the banker if he has an incentive to cheat. Any financial arrangement between the bank and its creditors must satisfy the following incentive constraint:

$$V_t \geq \theta Q_t k_t. \tag{21}$$

Figure 2 describes the timing of the bank's choice.

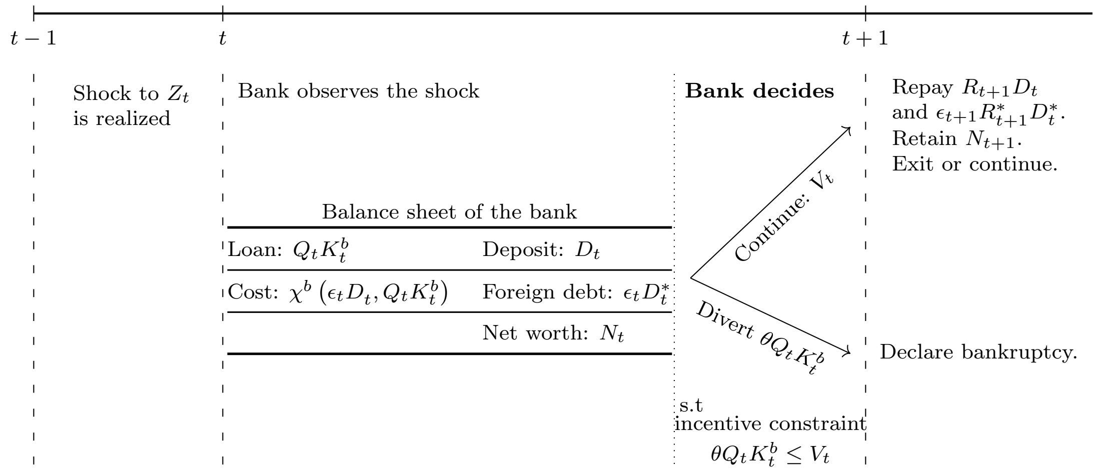


Figure 2: Timing of Bank's Choice

Each bank chooses the balance sheet (k_t, d_t, d^*_t) to maximize its franchise value

$$V_t = E_t\left\{\Lambda_{t,t+1}\left[(1-\sigma)n_{t+1} + \sigma V_{t+1}\right]\right\},$$

subject to the balance sheet constraint (19), the law of motion of net worth (20) and the incentive constraint (21).

Because the objective, the balance sheet and the incentive constraint are all constant returns to scale, we can write the value function as

$$\psi_t \equiv \frac{V_t}{n_t} = E_t\left[\Lambda_{t,t+1}(1-\sigma+\sigma\psi_{t+1})\frac{n_{t+1}}{n_t}\right],$$

where we interpret ψ_t as Tobin's Q ratio of the bank. Using the law of motion of net worth (20), the balance sheet condition (19), we can rewrite the law of motion of net worth in terms of the leverage multiple $\phi_t = \frac{Q_tk_t}{n_t}$ and the fraction of assets financed by foreign borrowing $\gamma_t = \frac{\epsilon_t d_t^*}{Q_t k_t^b}$ as

$$\frac{n_{t+1}}{n_t} = \frac{Z_{t+1} + \lambda Q_{t+1}}{Q_t} \frac{Q_t k_t}{n_t} - R_{t+1} \frac{d_t}{n_t} - R_t^* \frac{\epsilon_{t+1}}{\epsilon_t} \frac{\epsilon_t d_t^*}{n_t} = \tag{22}$$
$$= \left(\frac{Z_{t+1} + \lambda Q_{t+1}}{Q_t} - R_{t+1} \right) \phi_t + \left(R_{t+1} - \frac{\epsilon_{t+1} R_t^*}{\epsilon_t} \right) \gamma_t \phi_t + \left(1 - \frac{\varkappa^b}{2} \gamma_t^2 \phi_t \right) R_{t+1}.$$

Thus the bank chooses (ϕ_t, γ_t) to maximize Tobin's Q ratio:

$$\psi_t = \underset{\phi_t, \gamma_t}{Max} \left[\mu_t \phi_t + \mu_t^* \phi_t \gamma_t + \left(1 - \frac{\varkappa^b}{2} \gamma_t^2 \phi_t \right) \nu_t \right],$$

subject to the incentive constraint

$$\psi_t \geq \theta \phi_t,$$

where

$$\mu_t = E_t \left[\Omega_{t+1} \left(\frac{Z_{t+1} + \lambda Q_{t+1}}{Q_t} - R_{t+1} \right) \right], \tag{23}$$

$$\mu_t^* = E_t \left[\Omega_{t+1} \left(R_{t+1} - \frac{\epsilon_{t+1}}{\epsilon_t} R_t^* \right) \right], \tag{24}$$

$$\nu_t = E_t(\Omega_{t+1} R_{t+1}), \tag{25}$$

$$\Omega_{t+1} = \Lambda_{t,t+1}(1 - \sigma + \sigma \psi_{t+1}). \tag{26}$$

We can regard Ω_{t+1} as the stochastic discount factor of the banker in which the bank values the return by $\Lambda_{t,t+1}$ (household's stochastic discount factor) when exits with probability $1 - \sigma$, and values the return by Tobin's Q ratio times $\Lambda_{t,t+1}$ when continues with probability σ. We can think of μ_t as the excess return on capital over home deposit, μ_t^* as the cost advantage of foreign currency debt over home deposit, and ν_t as the marginal cost of deposit. In the following, we restrict our attention to the case in which both μ_t and μ_t^* are strictly positive so that the incentive compatibility constraint is always binding. (We will verify them later).

In such case, the incentive constraint is binding and we get

$$\phi_t = \frac{\nu_t}{\theta - \mu_t - \frac{\mu_t^{*2}}{2\varkappa^b \nu_t}} \tag{27}$$

$$\psi_t = \theta \phi_t. \tag{28}$$

$$\gamma_t = \frac{\mu_t^*}{\varkappa^b \nu_t} = \gamma\left(\frac{\mu_t^*}{\nu_t}\right). \tag{29}$$

We learn the leverage multiple ϕ_t is a decreasing function of a moral hazard parameter θ and an increasing function of μ_t and μ_t^*. We also know γ_t is an increasing function of $\frac{\mu_t^*}{\nu_t}$. (See Appendix A for the detail). Intuitively, if the cost advantage of foreign debt over home deposit is large, the bank raises more fund from foreigners.

2.4 Market Equilibrium

Final goods output is either consumed, invested, exported, or used to pay the cost of changing prices, managing households's capital and raising funds from foreigners as

$$Y_t = C_t + I_t + E_{Xt} + \frac{\kappa}{2}\left(\pi_t - 1\right)^2 Y_t + \chi^h(K_t^h, K_t) + \chi^b(\epsilon_t D_t^*, Q_t K_t^b). \tag{30}$$

GDP equals final goods output minus the value of import plus the net export of commodity as

$$Y_t^{GDP} = Y_t - \epsilon_t \left(M_t^x + M_t^y\right) + p_t^x \left(Y_t^x - X_t^x - X_t^y\right).$$

Net output which corresponds to final expenditure is

$$Y_t^{net} = Y_t^{GDP} - \frac{\kappa}{2}\left(\pi_t - 1\right)^2 Y_t - \chi^h(K_t^h, K_t) - \chi^b(\epsilon_t D_t^*, Q_t K_t^b).$$

The aggregate balance sheet of the bank is given by

$$Q_t K_t^b \left(1 + \frac{\varkappa^b}{2}\gamma_t^2\right) = \left(1 + \frac{\varkappa^b}{2}\gamma_t^2\right)\phi_t N_t \tag{31}$$

$$= N_t + D_t + \epsilon_t D_t^* \tag{32}$$

$$\epsilon_t D_t^* = \gamma_t Q_t K_t^b = \gamma\left(\frac{\mu_t^*}{\nu_t}\right)\phi_t N_t. \tag{33}$$

The aggregate net worth of banks evolves as

$$N_t = \sigma[(Z_t + \lambda Q_t)K_{t-1}^b - R_t D_{t-1} - \epsilon_t R_{t-1}^* D_{t-1}^*] + \xi(Z_t + \lambda Q_t)K_{t-1}. \tag{34}$$

The market equilibrium for capital ownership (equity) implies

$$K_t = K_t^b + K_t^h. \tag{35}$$

Labor market clearing is given by

$$L_t = L_t^x + L_t^y \tag{36}$$

Net foreign debt, which equals to the foreign debt of home banks, evolves through net import and the repayment of foreign debt from the previous period as

$$D_t^* = R_{t-1}^* D_{t-1}^* + M_t - \frac{1}{\epsilon_t} E_{Xt}. \tag{37}$$

We consider the home nominal interest rate follows a simple Taylor rule as

$$i_t - i = (1 - \rho_i)\omega_\pi (\pi_t - 1) + \rho_i (i_{t-1} - i) + \xi_t^i. \tag{38}$$

We consider foreign interest rate and income, and commodity price in terms of foreign currency (R_t^*, Y_t^*, P_t^{x*}) follow an exogenous process, possibly correlated each other. The endogenous state variables are $\left(K_{t-1}, K_{t-1}^b, D_{t-1}, R_{t-1}^* D_{t-1}^*, i_{t-1}\right)$. The recursive competitive equilibrium is given by ten price variables $(p_t^x, m_{Ct}^y, \pi_t, \epsilon_t, R_t, w_t, Q_t, Z_t^x, Z_t^y, i_t)$, eighteen quantity variables $(C_t, L_t, I_t, K_t,\ Y_t^x, Y_t, L_t^x, L_t^y, M_t^x, M_t^y, X_t^x, X_t^y, E_{Xt},\ N_t,\ K_t^b,\ K_t^h,$ $D_t,\ D_t^*)$ and seven bank variables $(\gamma_t, \psi_t, \phi_t, \nu_t, \mu_t, \mu_t^*, \Omega_t)$ which satisfy thirty five equations $(1-4, 6-11, 13-17, 23-38)$ as functions of the state variables $(K_{t-1}, K_{t-1}^b, D_{t-1},$ $R_{t-1}^* D_{t-1}^*, i_{t-1}, R_t^*, Y_t^*, P_t^{x*})$.[12] The household budget constraint is satisfied automatically in equilibrium by Walras' law.

In Appendix, we derive the properties of the competitive equilibrium as well as the

[12]Each of $(3, 9)$ has 3 equalities.

non-stochastic steady state (in which there are no stochastic shocks and all variables are constant).

3 Transmission mechanism: Role of exchange rate

In this section we analyze the effect of foreign interest rate shock to our small open economy. In Table 1, we report the values of our parameters for the baseline calibration of our economy. In Table 2 we report the implied non-stochastic steady state of the equilibrium allocation.[13],[14]

Most parameters of the production and households sectors are relatively standard in macroeconomics models. These includes the discount factor β, the utility weight on labor ζ_0, the inverse of the Frisch elasticity of labor supply ζ, the capital share parameter

[13] Log linearly approximating around the non-inflationary steady state in which $\pi = \frac{\eta}{\eta-1} m^C = 1$, we get a usual New Keynesian Phillips curve as

$$\widehat{\pi}_t = \frac{\eta - 1}{\kappa} \hat{m}_t^C + \beta E_t \left(\widehat{\pi}_{t+1} \right),$$

where $\widehat{x}_t = \left(x_t - x \right) / x$ denotes the proportional deviation from the steady state value. In a Calvo style model in which each monopolistic producer can change its price according to a Bernoulli process with arrival rate $1 - \omega$, we get the same expression, up to a first order approximation, if we choose

$$\kappa = \frac{(\eta - 1)\omega}{(1 - \omega)(1 - \beta\omega)}.$$

We calibrate κ from a standard choice of ω from this relationship. The monopolistic competition of the intermediate goods sector helps explaining why the nominal prices are sticky and why the producers accommodate the demand.

[14] A particular function of adjustment cost of investment is

$$\Phi \left(\frac{I_t}{I} \right) = \frac{\kappa_I}{2} \left(\frac{I_t}{I} - 1 \right)^2.$$

We choose $\Phi"(1) = \kappa_I$ so that the price elasticity of investment is consistent with instrumental variable estimates in Eberly (1997).

Table 1: Calibration: Baseline Model

Bankers		
θ	Divertible proportion of assets	0.359
σ	Survival probability	0.94
ξ	Fraction of total assets brought by new banks	0.001 74
χ^b	Management cost for foreign borrowing	0.0197
Households		
β	Discount rate	0.985
ζ	Inverse of Frisch elasticity of labor supply	0.333
χ^h	Cost parameter of direct finance	0.0197
Producers		
α_K	Cost share of capital	0.395
α_M	Cost share of imported intermediate goods	0.182
α_L	Cost share of labor	0.245
λ	One minus depreciation rate	0.98
η	Elasticity of demand for each intermediate good variety	10
ω	Fraction of non-adjusters	0.66
κ_I	Cost of adjusting investment goods production	0.67
φ	Price elasticity of export demand	1
Monetary Policy		
ρ_i	Smoothing coefficient in the Taylor rule	0.8
ω_π	Inflation coefficient in the Taylor rule	1.5

Main targeted moments and steady state values

Rates of return (annual)			
R^*	Return on risk-free foreign asset	4	%
R	Return on risk-free domestic asset	6	%
R_k	Return on capital	8	%
Banking sector			
γ	Share of bank assets financed by foreign debt	25	%
$\frac{K^b}{K}$	Share of intermediated capital in total capital	75	%
ϕ	Leverage multiple	6	
Production			
π	Inflation rate	1	%
μ^p	Monopolistic price markup	11	%
$\frac{K^x}{K}$	Share of commodity sector capital in total capital	16.06	%
$\frac{\tau^i}{GDP}$	Share of indirect tax revenues to GDP	10	%
τ^s	Sales tax	7.69	%

α_K, the depreciation rate $1-\lambda$ and the cost of adjusting investment goods production, κ_I. For these parameters we use reasonably conventional values as reported in Table 1.

Parameters of banks are unique to our model. We choose the bank survival rate σ so that the annual dividend payout is $4(1-\sigma) = 24\%$ of net worth.[15] We choose the parameters $\left(\theta, \varkappa^b, \xi\right)$ to hit the targets in which bank leverage multiple equals 6, the spread between the rate of returns on bank asset and deposit equals 2% annual and the fraction of foreign borrowing is 25% of bank asset in the baseline calibration. We also choose $\varkappa^h$ so that the fraction of capital financed by banks instead of households is 0.75.[16] In the baseline, we choose the mean of foreign real interest rate $R^* = 1.04$ in annual which is lower than home real interest rate of 6% annual.

In the baseline we also choose the coefficient of monetary policy rule as $\omega_\pi = 1.5$ and $\rho_i = 0.8$ (based on a quarterly calibration). The foreign interest rate and log level of foreign demand and commodity price (in terms of foreign currency) $(R_t^* - 1, \ln Y_t^*, P_t^{x*})$ follow independent AR(1) process with serial correlation coefficient of 0.9 (quarterly). In the benchmark example, we choose the standard deviation of innovations of $R_t^* - 1$ to be 1% in annualized rate, that of $(\ln Y_t^*, P_t^{x*})$ to be 3% and xx quarterly, and all four shocks are uncorrelated. These numbers are broadly consistent with the literature such as [Mendoza(2010)] and [Avdjiev, Hardy, Kalemli-Ozcan and Serven(2018)]. Given the simplicity of our model, these numerical examples provide a qualitative assessment of the model.

To understand how a foreign interest rate shock propagates into our small open

[15] This number looks high, but is not high if we include bonus payments to the executives.

[16] Given that our capital output ratio of 1.98, the foreign debt to GDP ratio equals 37 percent $(0.25 \times .75 \times 1.98 = 0.37)$.

economy, we focus on the key expressions that characterize our framework. First, we examine the expression that determines the cost advantage from financial intermediaries' perspective in borrowing from foreigners over domestic funding:

$$\mu_t^* = E_t \left[\Omega_{t+1} \left(R_{t+1} - \frac{\epsilon_{t+1}}{\epsilon_t} R_t^* \right) \right].$$

In particular, when there is a shock that increases the foreign interest rate, the cost advantage for banks to borrow in foreign currency debt over home deposit shrinks for a given expectation of exchange rates. As the cost advantage of foreign currency debt shrinks, banks tend to reduce the fraction of assets financed by foreign borrowing, $\gamma_t \equiv \frac{\epsilon_t D_t^*}{Q_t K_t^b}$. This channel is common to portfolio balance models. What is unique to our small open economy framework is that the banking sector have to intermediate the outstanding net foreign debt, D_t^*:

$$\epsilon_t D_t^* = \gamma_t Q_t K_t^b = \gamma_t \left(\frac{\mu_t^*}{\nu_t} \right) \phi_t N_t. \tag{39}$$

The net foreign debt in the left-hand side of (39) equals the accumulation of net foreign debt from (37) , which adjusts slowly over time. Then in order to clear the foreign debt market and to induce banks to roll-over net foreign debt, the present exchange rate has to depreciate in order to have the expectations of home currency appreciation in future, i.e., $\frac{\epsilon_{t+1}}{\epsilon_t}$ needs to decrease to offset a rise in R_t^* and restore the cost advantage in borrowing in foreign currency. But the home currency depreciation increases the foreign debt burden $\epsilon_t D_t^*$ and reduces the bank's net worth:

$$N_t = \sigma[(Z_t + \lambda Q_t) K_{t-1}^b - R_t D_{t-1} - \epsilon_t R_{t-1}^* D_{t-1}^*] + \xi (Z_t + \lambda Q_t) K_{t-1}. \tag{40}$$

Therefore, home currency has to depreciate significantly in order to decrease $\frac{\epsilon_{t+1}}{\epsilon_t}$ much more than a rise in foreign interest rate to sustain the fraction of asset financed by foreign borrowing. The interaction between a declining net worth and a depreciated exchange rate creates the financial amplification mechanism that is specific to our framework.

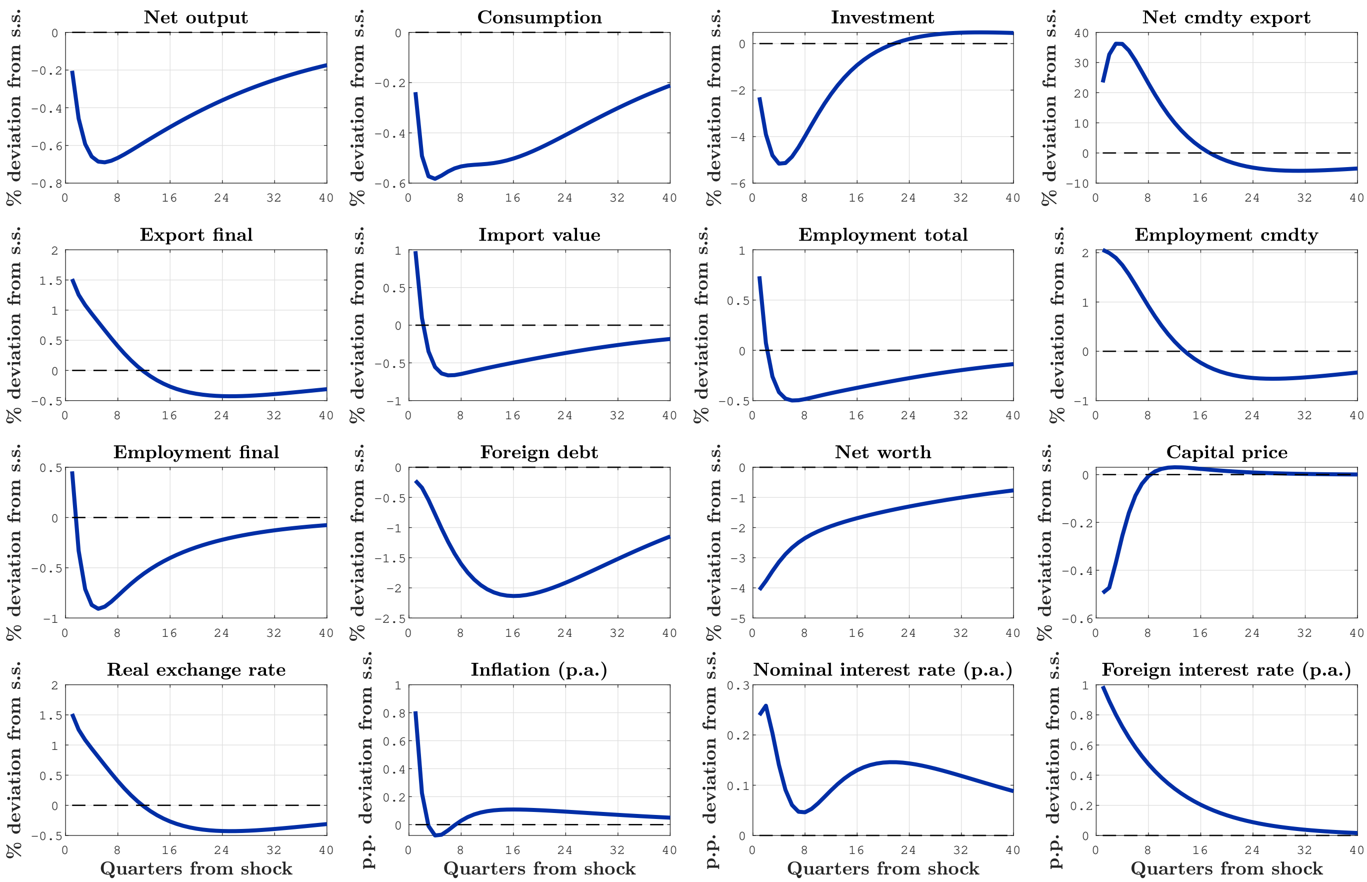
Because our economy use imported foreign goods and commodity as input for production, the real exchange rate depreciation also reduces the value added productivity $(A_t/\epsilon_t^{\alpha_M})$, acting as a supply shock, similarly with an oil shock to oil importing countries. This further reduces return on capital and bank net worth.

In Figure 3, we plot the impulse responses to a foreign interest shock of 1% (annualized) for our baseline economy.[17] As the foreign interest rate raises by 1% persistently, the real exchange rates depreciates on impact by nearly 2%.

The depreciation of the real exchange rate boosts export through the usual expenditure switching effect by the same magnitude as the price elasticity of export demand is set to unity. This tends to stimulate output as the output is determined by the aggregate demand. Moreover, the depreciation leads to a higher inflation rate by 1.2%, against which the central bank needs to raise the nominal rate more than one-for-one in a few quarters under Taylor rule. Thus the real interest rises and asset prices falls by 0.9%. Although a higher inflation reduces a real burden of home currency debt in the second term of bank net worth in the RHS of (40), $R_t D_{t-1} = \frac{1+i_{t-1}}{\pi_t} D_{t-1}$, the fall in capital price and real exchange rate depreciation reduce the bank net worth significantly by 4%.

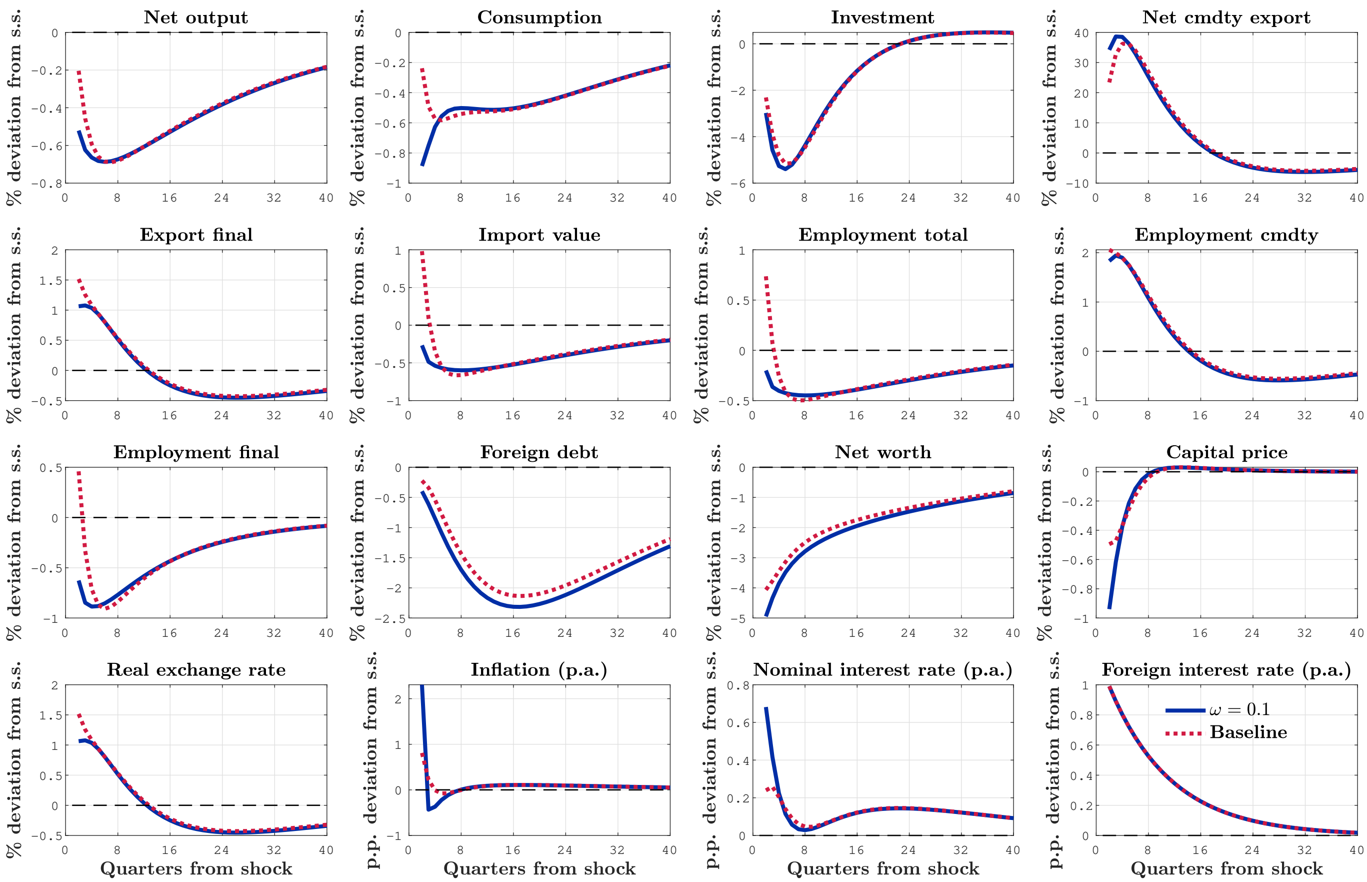
[17] The impulse response functions are simulated up to a the first order approximation of the decision rules around the non-stochastic steady state. All the variables are in the log-scale so that the changes are in quarter percentage, except for home and foreign interest rates and inflation rates that are expressed in annual level.

Figure 3: Foreign Interest Rate Shock: Baseline Model



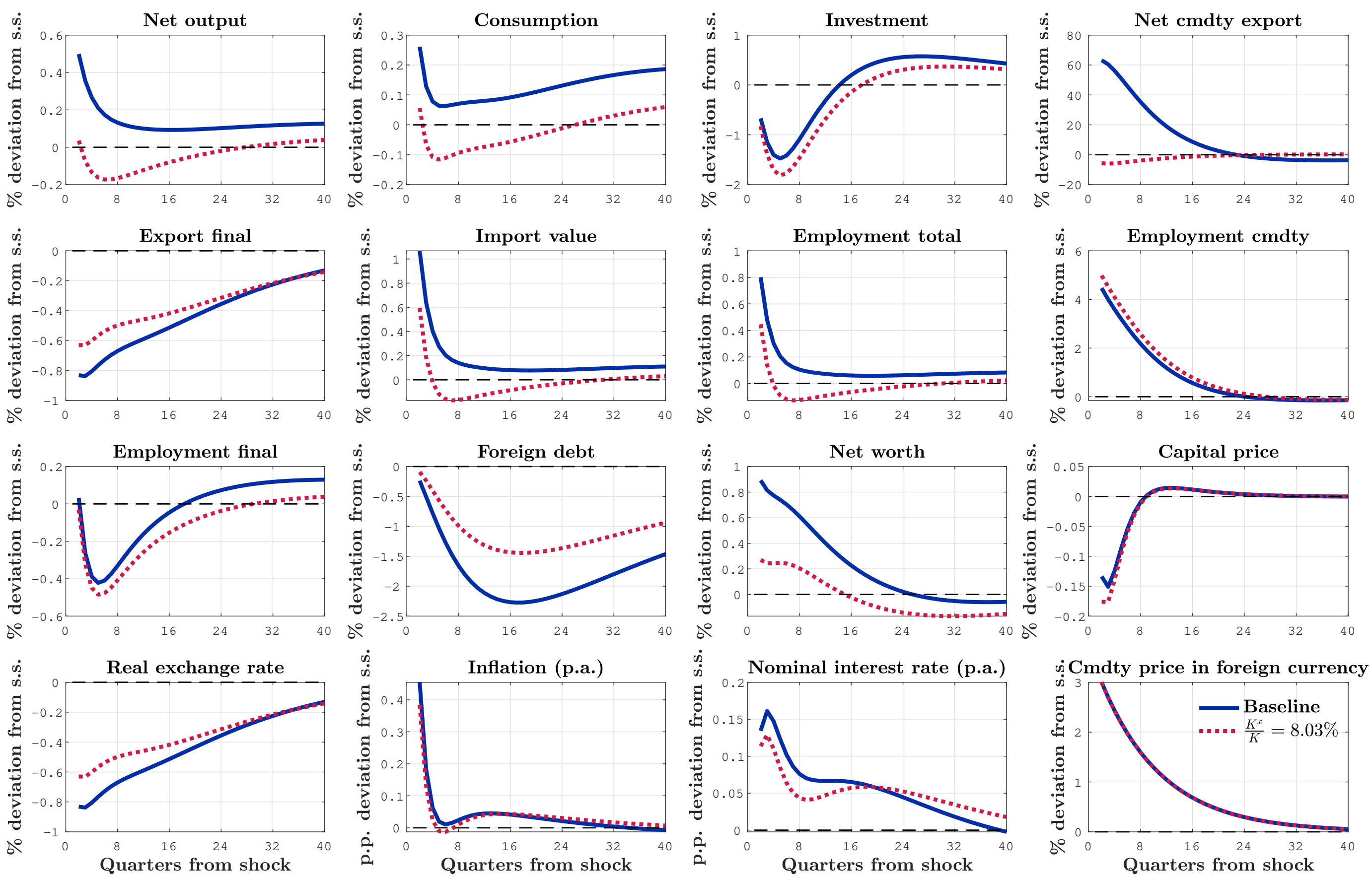
Notes:

Figure 4: Foreign Interest Rate Shock: More Flexible Prices



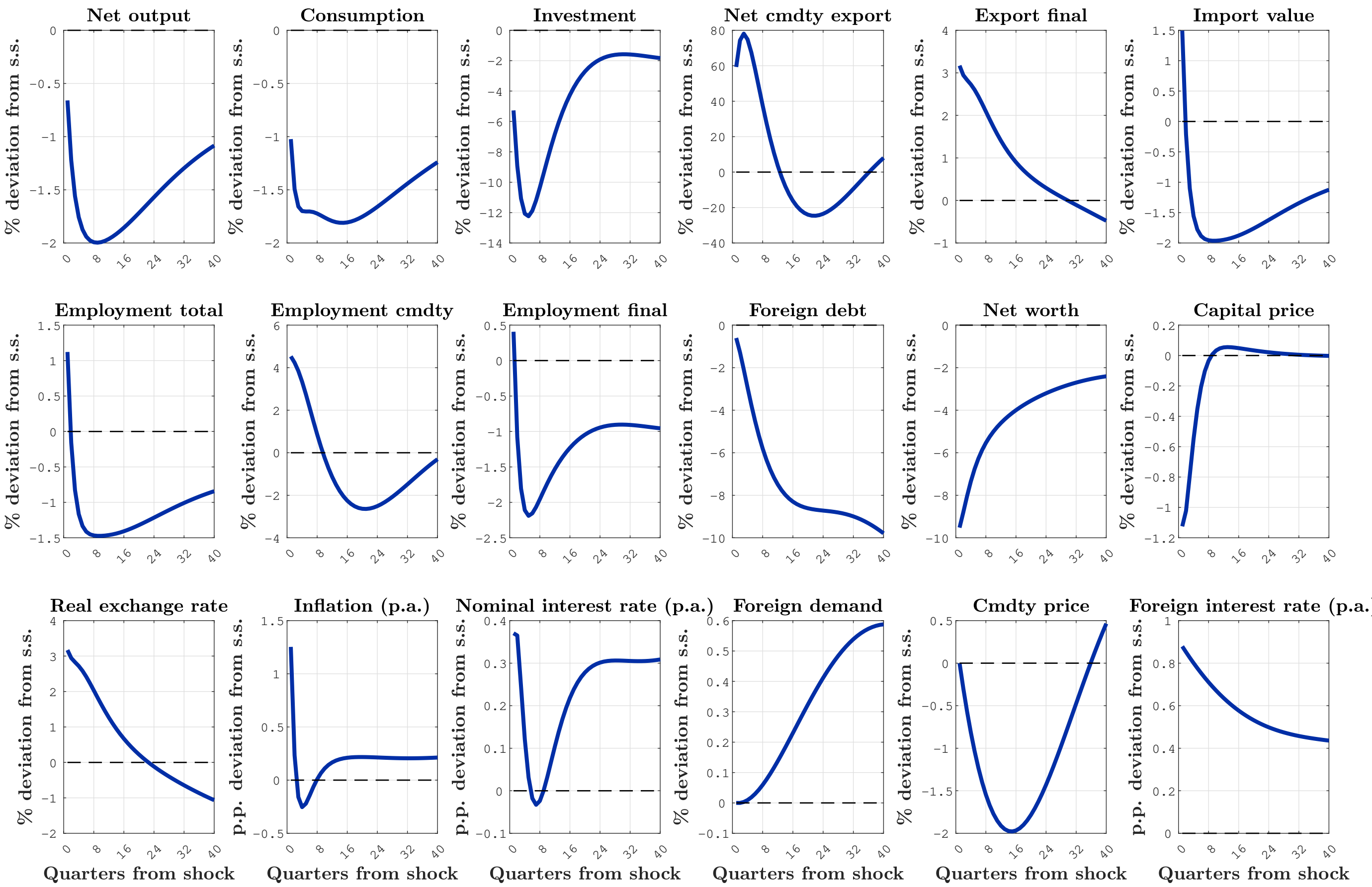
Notes:

Figure 5: Commodity Price Shock: Net Commodity Importer



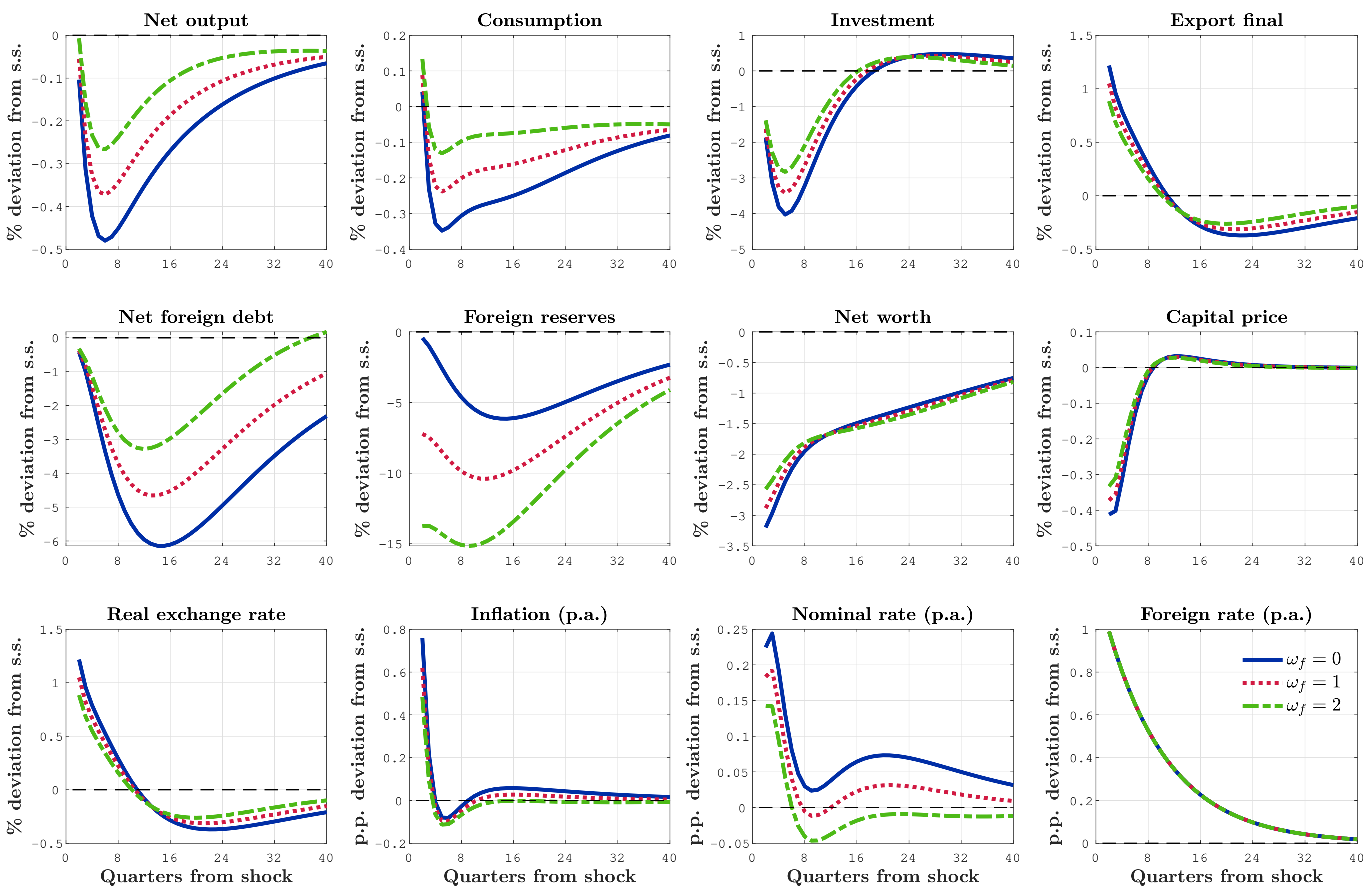
Notes:

Figure 6: Commodity Price Shock: Correlated Shocks



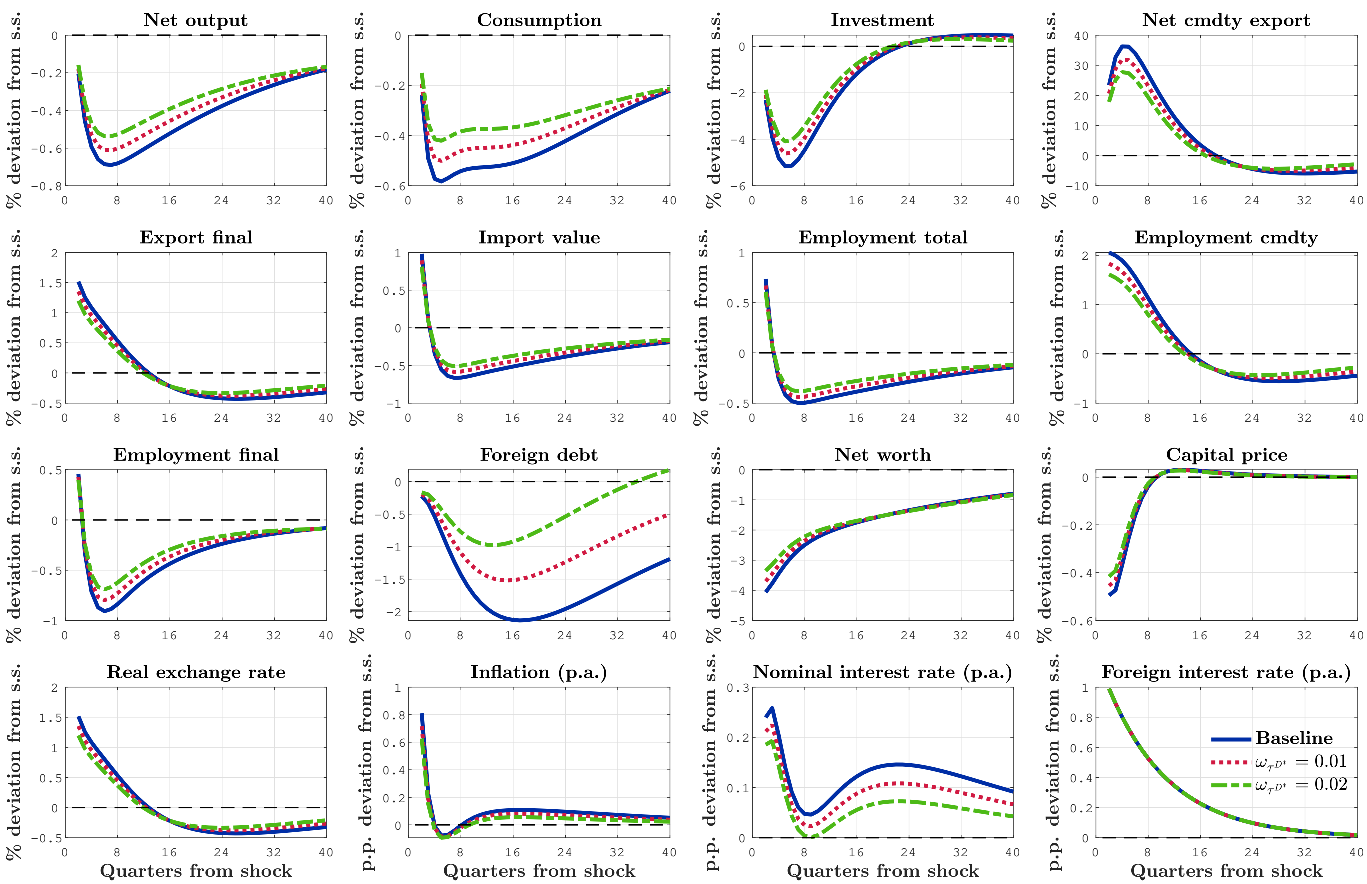
Notes: Recursive identification scheme: Y*, Px*, R*, where R* reacts to all shocks, while Y* reacts only to its own shocks.

Figure 7: Foreign Interest Rate Shock: Foreign Exchange Rate Intervention



Notes:

Figure 8: Foreign Interest Rate Shock: Tax on Foreign Debt



Notes:

As the net worth decreases, banks' capacity to finance capital decreases and households have to finance a larger capital to clear the market. When a larger fraction of capital is financed by households who are not as good as banks in managing capital, capital price falls further and investment declines significantly by 1.3%. The vicious cycle between worsening bank balance sheet and falls in investment and capital price is similar to Kiyotaki and Moore (1997) and Gertler and Kiyotaki (2015). With a large foreign currency debt, the interaction between home currency depreciation and bank balance sheet deterioration further magnifies this vicious cycle. As these contractionary effects through bank balance sheet dominates an expansionary effect of export stimulus in our small open economy, net output falls by 0.4% in two quarters. As output decreases, consumption decreases by 0.7% and import decreases by 0.3%. Concerning the current account adjustment, initially the net foreign debt foreign debt declines thanks to export expansion as the current account improves, but then it starts increasing due to higher interest burden before slowly going back to the steady state.

The emerging market economy is so vulnerable to the foreign borrowing interest rate hike because it leads to a "debt deflation" of increasing the real value of foreign currency denominated debt and a "credit cycles" of falling the productive asset values: both depresses the aggregate investment and production through the worsening the balance sheet of intermediaries.[18]

To understand the transmission through the bank balance sheet further, we next compare our baseline monetary model with a non-monetary version of our economy. In non-monetary model, bank deposit from home households and differentiated goods price are denominated in terms of home final goods.[19] Foreign debt of banks is denominated by foreign goods, so that its value in terms of home final goods increases with real exchange rates depreciation. In Appendix C we provide a characterization of the non-monetary version of our economy.

In Figure 4 we compare the impulse responses to a foreign interest rate hike in non-monetary (solid lines) and in monetary (dashed lines) models. Interestingly, we find the overall contractionary effects of the foreign interest rate hike are *larger* in the non-monetary than monetary models, (even though the depreciation of real exchange rate is a slightly smaller). The main difference between the two cases is that the real value of the liabilities in domestic units (the deposit) is rigid in the non-monetary model, while it decreases because of inflation in the monetary model. In the non-monetary model, therefore, the bank net worth falls more by 6% (compared to 4% in the monetary version) through a larger leverage effect, which leads to larger falls in asset prices, investment

[18]This combination of debt deflation and credit cycles is not explicit in Mimir and Sunel (2019) in which individual banks are indifferent between raising fund from domestic savers and foreign lenders, (because the ratio of the excess return on capital over home deposit (μ_t) and the cost advantage of foreign currency debt over home deposit (μ_t^*) equals the ratio of the cost in terms of the incentive constraint). On the other hand, Mimir and Sunel (2019) conduct a more sophisticated quantitative analysis and focus on the characterization of optimized interest rate rule. They also determime Ramsey type welfare analysis around the steady state, while we take into account the transition of introducing the policy.

[19]We can interpret this case as the situation in which the deposit returns are fully indexed by the final goods price index.

and net output than the monetary model. Moreover, on impact in the non-monetary economy, net output declines as the contractionary effect coming from the balance sheet effect dominates the expansionary effect from the real depreciation.

Finally, we analyze how the transmission mechanism is affected by the degree of price flexibility. Higher price flexibility is also more common in emerging markets compared to more developed economies: For example, Gouvea (2007) reports that in Brazil the average duration of prices is between 2.7 and 3.8 months, much shorter than the US estimates.[20] It turns out that the degree of price flexibility is important in understanding how foreign interest rate shocks propagates into emerging market economies.

Figure 5 presents the impulse response to the foreign interest rate shock of the economy in which the nominal prices more flexible. With more flexible nominal prices, the foreign interest rate hikes leads to a higher inflation and a sharper rise of the nominal interest rate. Although the real exchange rate depreciation is smaller, asset prices fall more, and the bank net worth decreases more significantly. The mitigating effect on home currency liabilities coming from higher inflation is now offset by higher nominal and real interest rates. As the result, the economy enters into a deeper recession straight away. Here we note that the economy with higher price flexibility suffers more from the foreign interest rate hike: the paradox of price flexibility that we are emphasizing arises through the balance sheet financial intermediaries and is not related to the economy being at the zero-lower bound on the nominal interest rate as in the Keynesian tradition (see for example Eggertsson and Krugman, 2012). From a policy point of view, this

[20]For example, Nakamura and Steinsson (2007) report the average duration of regular prices is between 8 and 11 months. Also, see Kiley (2000) for cross-country comparison of price flexibility.

implies that the orthodox monetary policy which aims at stabilizing inflation in an environment of higher price flexibility tends to worsen the recession triggered by the foreign interest rate hike. The only bright side of the more flexible prices is that the current account tends to improve, mostly due to a sharp decline of import quantity.[21]

In appendix E, we analyze the transmission mechanism following shocks to commodity price and foreign demand. Here we note that the foreign interest rate hike is particularly contractionary because it depreciates both the real exchange rate and asset price to deteriorate the net worth of the banking sector.

4 Financial Policies

When the emerging economy is vulnerable to shocks, especially to shocks to the foreign interest rate, one of the most common policy prescription suggests to limit the extent to which financial intermediaries borrow in foreign currency. The borrowing in foreign currency is considered as the "original sin." In order to analyze the effects of this policy recommendation, we consider both permanent and cyclical policies for taxes on foreign currency borrowing.

We refer to this taxes on foreign borrowing of bankers as financial policies. We assume that the revenues from taxation are rebated to bankers through a subsidy on their net worth, τ_t^N so that our policy doesn't have any redistributive effects. Let τ_t^{D*} as the tax rate on foreign debt, and let τ_t^N be the subsidy rate on net worth.[22] The taxes

[21]Import quantity declines by 2%, more than import value (0.5%) due to the exchange rate depreciation.

[22]Gertler, Kiyotaki mand Queralto (2012) consider a similar policy scheme.

and subsidy are balanced in the budget in the aggregate,

$$\tau_t^N N_t = \tau_t^{D*} \epsilon_t D_t^*, \tag{41}$$

where N_t and D_t^* are aggregate net worth and net foreign debt of the entire banking sector. The balanced budget makes our policy similar to a flexible quantity constraint on foreign currency borrowing.

4.1 Permanent Policy

We first examine the effects of permanent taxation on foreign currency borrowing. Here, comparing the welfare of two steady states is misleading because home people may suffer in order to reduce the foreign debt in transition.[23] Therefore, we compute the welfare of the representative household, taking into account the transition. At date t-1, the economy was in a stochastic steady state without the policy. At date-t, there is an unexpected once and for all changes in $\tau_t^{D^*}$. We examine how the economy converges towards the new stochastic steady state.[24] To examine the effect of policy, we use the second order approximation of the decision rules and the value function around the non-stochastic steady state.[25]

[23] Consider a standard Cass and Koopmans style optimal growth model: Even if the competitive equilibrium achieves the first best allocation, its steady state welfare and consumption are lower than those in the golden rule steady state (which maximizes the steady state consumption).

[24] In a stochastic steady state, individual agents anticipate recurrent arrivals of various shocks and choose the quantities as the function of the state variables; and when aggregate shocks never materialize, the economy settles in the stochastic steady state. There is a bit of contradiction in the stochastic steady state: Even though every agent anticipates aggregate shocks to arrive in future, the shocks never arrive.

[25] The first order approximation is not suitable for policy evaluation because it ignores an important second order issue of risks and because our economy has distortions in the non-stochastic steady state.

Figure 6.1 shows how the economy converges after government introduces the permanent tax on foreign currency borrowing by $\tau_t^{D*} = 0.01\%$ at date t in which tax revenue is transferred back in proportion to the bank net worth as in (41).[26] The welfare is measured as the expected discounted utility of representative household who have both workers and bankers as its members. In the baseline economy, the welfare decreases with the introduction of the tax on bank foreign borrowing. Even though the allocation improves over time, the initial damage due to mainly the fall in capital price, the real exchange rate depreciation, and associated decrease in bank net worth dominates the future gains in the expected discounted utility calculation. Although the home country becomes less vulnerable to the shocks, it loses the benefit of borrowing cheap from foreigners. Define the consumption equivalence as a percentage change of the initial stochastic steady state consumption (net of disutility of labor) which makes the household indifferent between the economy with introduction of policy at date t and the economy without such policy. Then the consumption equivalent is -0.11% in the second order approximation.[27] Despite of the welfare being higher in the new steady state, the welfare declines modestly when the permanent tax is introduced.

4.2 Cyclical Policy

From the final goods market equilibrium condition (30), we observe three distortions: One is the cost of adjusting nominal prices under inflation, $\frac{\kappa}{2}(\pi_t - 1)^2 Y_t$ (which may be

[26] We choose the size of tax being small in order to increase the accuracy of the simulation.

[27] Although the size of consumption equivalent is small because the size of the tax is small, the elasticity is not so small: If approximation holds for a larger tax change, then 1% permanent increase of the tax on bank foreign borrowing will reduce the welfare by 2.3% in terms of consumption equivalent.

distortion due to the relative price dispersion in Calvo style model), second is the cost of intermediation of households relative to banks, $\chi^h(K_t^h, K_t)$, and the last is the cost for banks to borrow from abroad $\chi^b(\epsilon_t D_t^*, Q_t K_t^b)$. An orthodox policy assignment according to Mundell argues that the monetary policy is responsible to stabilize the inflation rate while the macroprudential policy is responsible to achieve the stable and efficient financial intermediation. In this section, we examine the relative merits of monetary and macroprudential policies in emerging market economy using our framework. For a macroprudential policy we consider government commits to the following cyclical tax (or subsidy) on the foreign debt of the bank:

$$\tau_t^{D*} = \omega_{\tau^{D*}}(\ln K_t^b - \ln K^b). \tag{42}$$

Here, the tax rate on bank foreign debt is an increasing function of the percentage deviation of bank risky asset holding from the non-stochastic steady state. Thus when banks intermediate more to nonfinancial businesses during credit boom, government raises the tax rate on bank foreign debt.

Figure 7 presents the impulse response to a foreign interest rate shock of the economy in which the tax rate on bank foreign debt is adjusted with coefficient of $\omega_{\tau^{D*}} = 0.05$ (the solid line). The dashed line is the baseline economy without such policy. In both economies, monetary policy follows a standard Taylor rule of coefficient of $\omega_\pi = 1.5$. With an increase in the foreign interest rate, the economy with the macroprudential policy experiences smaller movement in the real exchange rate (0.7% depreciation instead of 1.8%), inflation rate, nominal interest rate and capital price than the economy without macroprudential policy. As the result, bank net worth and aggregate output and consumption move less, making the recession less severe with macroprudential policy.

Table 2: Welfare Results: Tax Policy

ω_π \ $\omega_{\tau^{D*}}$	0	0.01	0.02
1.25	-0.047	-0.028	-0.033
1.5	0.000	0.015	0.006
2	0.021	0.035	0.025

Notes: $\lambda \times 100$ is reported.
The value of $\lambda \times 100$ represents the percentage of (distorted) steady-state consumption of in the baseline economy (comparable $\bar{\tau}^{D^*}$, $\omega_{\tau^{D*}} = 0$, $\omega_\pi = 1.5$) that an agent in such an economy would be willing to forego to join the alternative economy. A positive value indicates that the agent would prefer to switch to the alternative economy.

Table 4 shows the welfare gains from different combinations of monetary policy and macroprudential policy rule. Each column corresponds alternative macroprudential policy $\omega_{\tau^{D*}} = 0$, 0.01 and 0.02, and each row corresponds alternative Taylor coefficient $\omega_\pi = 1.05, 1.5$ and 2, and the number in the Table is percentage change in welfare in terms of consumption equivalence in the second order approximation relative to the baseline economy of $\omega_{\tau^{D*}} = 0$ and $\omega_\pi = 1.5$.

We observe a relatively modest macroprudential policy of $\omega_{\tau^{D*}} = 0.02$ leads to welfare gains which is equivalent to permanent increase of consumption level by 0.11% when we have a standard monetary policy rule of $\omega_\pi = 1.5$. There are welfare gains from increasing the Taylor coefficient from $\omega_\pi = 1.5$ to 2.0. When the macroprudential policy $\omega_{\tau^{D*}} = 0.02$ is combined with Taylor coefficient of $\omega_\pi = 2$, the welfare gain becomes significant as the consumption equivalent gain equals 0.29%.

Table 5 shows the welfare effect of alternative policy in the economy in which the standard deviation of foreign interest rate shock is twice as large as the baseline economy (while all the other shocks have the same standard deviations).

We observe the welfare gains from macroprudential policy is larger than the baseline economy, even though the pattern of welfare effect is similar to the economy. (The gain from having macroprudential policy of $\omega_{\tau^{D*}} = 0.02$ is 0.42% of the steady state net consumption instead of 0.11% in the baseline economy.) The welfare gains from the combination of macroprudential policy and strict inflation targeting ($\omega_{\tau^{D*}} = 0.02$ and $\omega_\pi = 2$) is equivalent to permanent consumption increases by 0.72%.

Table 6 shows the welfare effect of alternative policy in the economy in which the nominal price is more flexible price and the standard deviation of foreign interest rate shock is twice as large as the baseline economy. The fraction of monopolistic producers who do not adjust their prices within a quarter is 0.1 instead of 0.66 in the baseline.

Under relatively flexible prices, the monetary policy is less effective than the economy under more stick prices. Moreover, the strict inflation targeting tends to reduce the welfare, especially without macroprudential policy. If the monetary authority tries hard to offset the inflationary pressure from the exchange rate depreciation without reducing tax on foreign borrowing of banks, the economy enters into a deeper recession with a foreign interest rate hike. The macroprudential policy mitigates this side effect of monetary policy and improves the welfare. Notice that the welfare gains from introducing macroprudential policy is larger when the Taylor coefficient is larger: The welfare gains from shifting $\omega_{\tau^{D*}}$ from 0 to 0.02 equals $0.26 - (-0.12) = 0.38\%$ for $\omega_\pi = 2$, while it is 0.21% ($= 0.32 - 0.11$) for $\omega_\pi = 1.25$. The above examples show that the macroprudential policy is particularly useful when the external financial shock is large and the nominal price level is relatively flexible.

5 Foreign Exchange Intervention

Another commonly used policy in emerging markets is that government intervenes the foreign exchange market using its foreign reserve to stabilize the foreign exchange rate. With government holding foreign reserve, the foreign debt intermediated through home banks D_t^* is the sum of the net foreign debt of the country B_t^* and foreign reserve held by the government F_t as

$$D_t^* = B_t^* + F_t, \tag{43}$$

all in terms of the foreign currency. The net foreign debt evolves with net import as before (37) as

$$B_t^* = R_{t-1}^* B_{t-1}^* + M_t - \frac{1}{\epsilon_t} E_{Xt}. \tag{44}$$

We consider a foreign exchange intervention rule which is partly permanent and partly cyclical as

$$\frac{F_t}{B_t^*} = f_0 - \omega_f \left(\ln K_t^b - \ln K^b \right). \tag{45}$$

Positive ω_f implies government sells foreign reserve when real exchange rate depreciates in order to smooth exchange rate.

The integrated budget constrained of government and central bank becomes

$$G_t + R_t D^g_{t-1} + \epsilon_t F_t = T_t + D^g_t + \epsilon_t R^*_{t-1} F_{t-1}, \tag{46}$$

where G_t and T_t are fiscal purchase of goods and taxes and D^g_t is real value of short-term government bond. Because we assume government bond and deposit are perfect substitute and that tax is lump-sum, the Ricardian equivalence theorem holds. So we consider the government budget is balanced without government bond issue and fiscal expenditure is constant.

$$D^g_t = D^g_{t-1} = 0 \text{ and } G_t = G.$$

The aggregate output of home final goods becomes

$$\begin{aligned} Y_t &= C_t + I_t + G + E_{Xt} \\ &\quad + \frac{\kappa}{2} (\pi_t - 1)^2 Y_t + \chi^h(K^h_t, K_t) + \chi^b(\epsilon_t D^*_t, Q_t K^b_t). \end{aligned} \tag{47}$$

The endogenous state variables are $\left(K_{t-1}, K^b_{t-1}, D_{t-1}, R^*_{t-1}D^*_{t-1}, R^*_{t-1}B^*_{t-1}, i_{t-1}\right)$. The recursive competitive equilibrium is given by ten price variables $(p^x_t, m^y_{Ct}, \pi_t, \epsilon_t, R_t, w_t, Q_t, Z^x_t, Z^y_t, i_t)$, twenty one quantity variables $(C_t, L_t, I_t, K_t, Y^x_t, Y_t, L^x_t, L^y_t, M^x_t, M^y_t, X^x_t, X^y_t, E_{Xt}, N_t, K^b_t, K^h_t, D_t, D^*_t, B^*_t, F_t, T_t)$ and seven bank variables $(\gamma_t, \psi_t, \phi_t, \nu_t, \mu_t, \mu^*_t, \Omega_t)$ which satisfy thirty eight equations $(1-4, 6-11, 13-17, 23-29, 31-\textbf{??}, 38, 43-47)$ as functions of the state variables $(K_{t-1}, K^b_{t-1}, D_{t-1}, R^*_{t-1}D^*_{t-1}, i_{t-1}, R^*_t, Y^*_t, P^{x*}_t)$.

Table 3: Welfare Results: Foreign Exchange Policy

ω_π \ ω_f	0	1	2
1.25	-0.009	0.109	0.469
1.5	0.000	0.117	0.470
2	0.003	0.123	0.485

Notes: $\lambda \times 100$ is reported.
The value of $\lambda \times 100$ represents the percentage of (distorted) steady-state consumption of in the baseline economy (comparable f_0, $\omega_f = 0$, $\omega_\pi = 1.5$) that an agent in such an economy would be willing to forego to join the alternative economy. A positive value indicates that the agent would prefer to switch to the alternative economy.

6 Conclusion

In this paper we propose a framework for studying the interaction between monetary and macroprudential policies for an emerging market economy. Our analysis emphasizes the importance of distinguishing between external financial and nonfinancial shocks. In general external financial shocks generates a volatile response of key macroeconomic variables. From a normative point of view, the combination of external financial shocks with relatively flexible domestic nominal prices creates a scope for a coordination between monetary and cyclical macroprudential policies: a cyclical tax on foreign currency borrowing by banks combined with a relatively strict inflation targeting enhances welfare. Indeed, the same inflation targeting *alone* without macroprudential policy could reduce welfare.

The distinctive feature of our framework is the presence of financial intermediaries (banks) that borrow in foreign currency. We can interpret our "banks" as agents who have access to foreign financial market and can engage in financial intermediation. They could also be interpreted as large nonfinancial corporations that have foreign branches and borrow using offshore accounts (Bruno and Shin (2013)). Under these circumstances the practical implementation of cyclical macroprudential policies might be problematic.

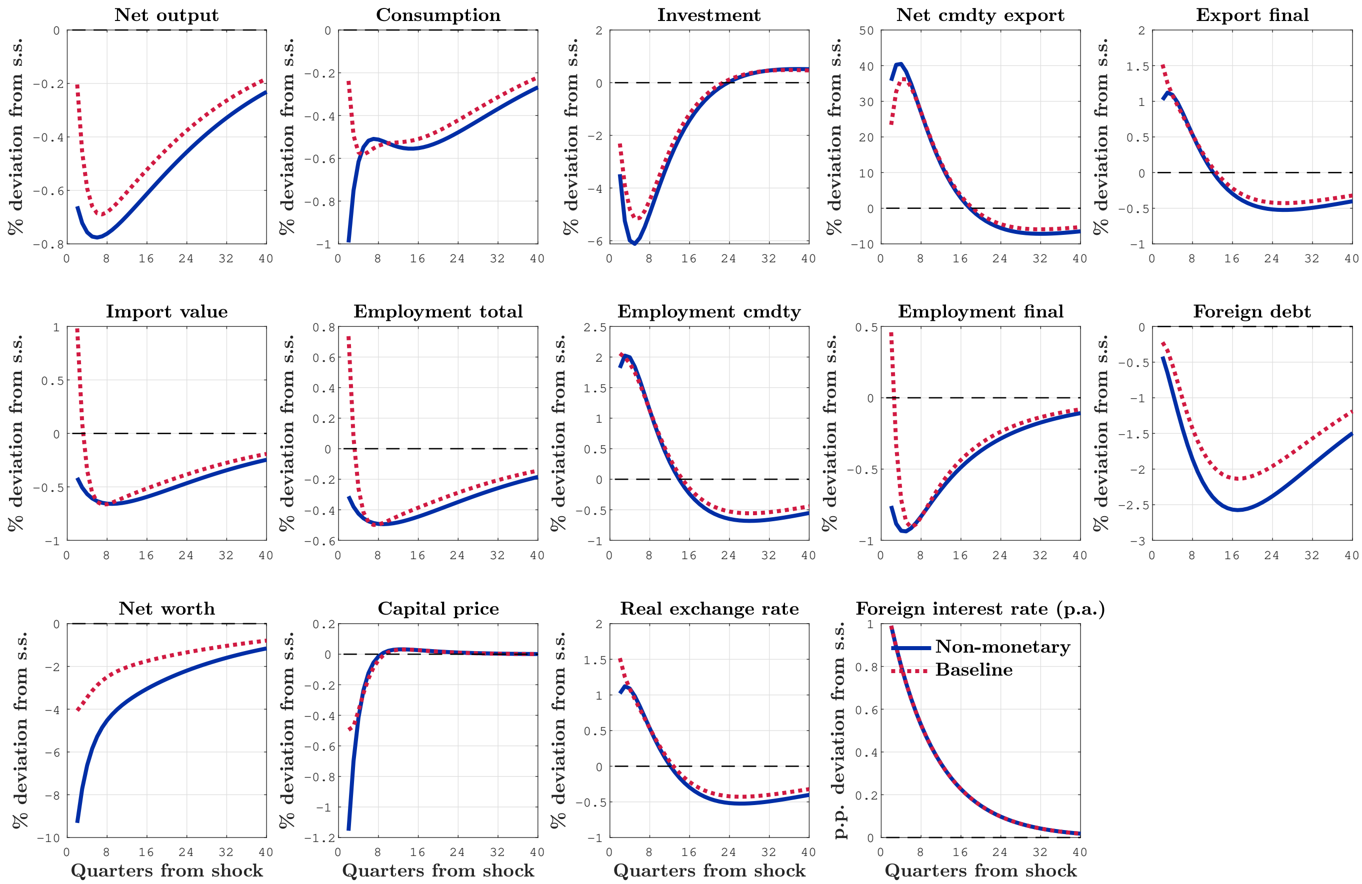
Our framework while capturing some critical features of emerging market economies, abstracts from other relevant aspects. We abstract from a richer specification of international capital flows (home currency denominated debt, currency hedging, equity flows and foreign direct investment) and the role of cross border gross flows that could have a destabilizing role for financial stability. These are topics for future research.

7 Appendix

7.1 Appendix A: Competitive Equilibrium

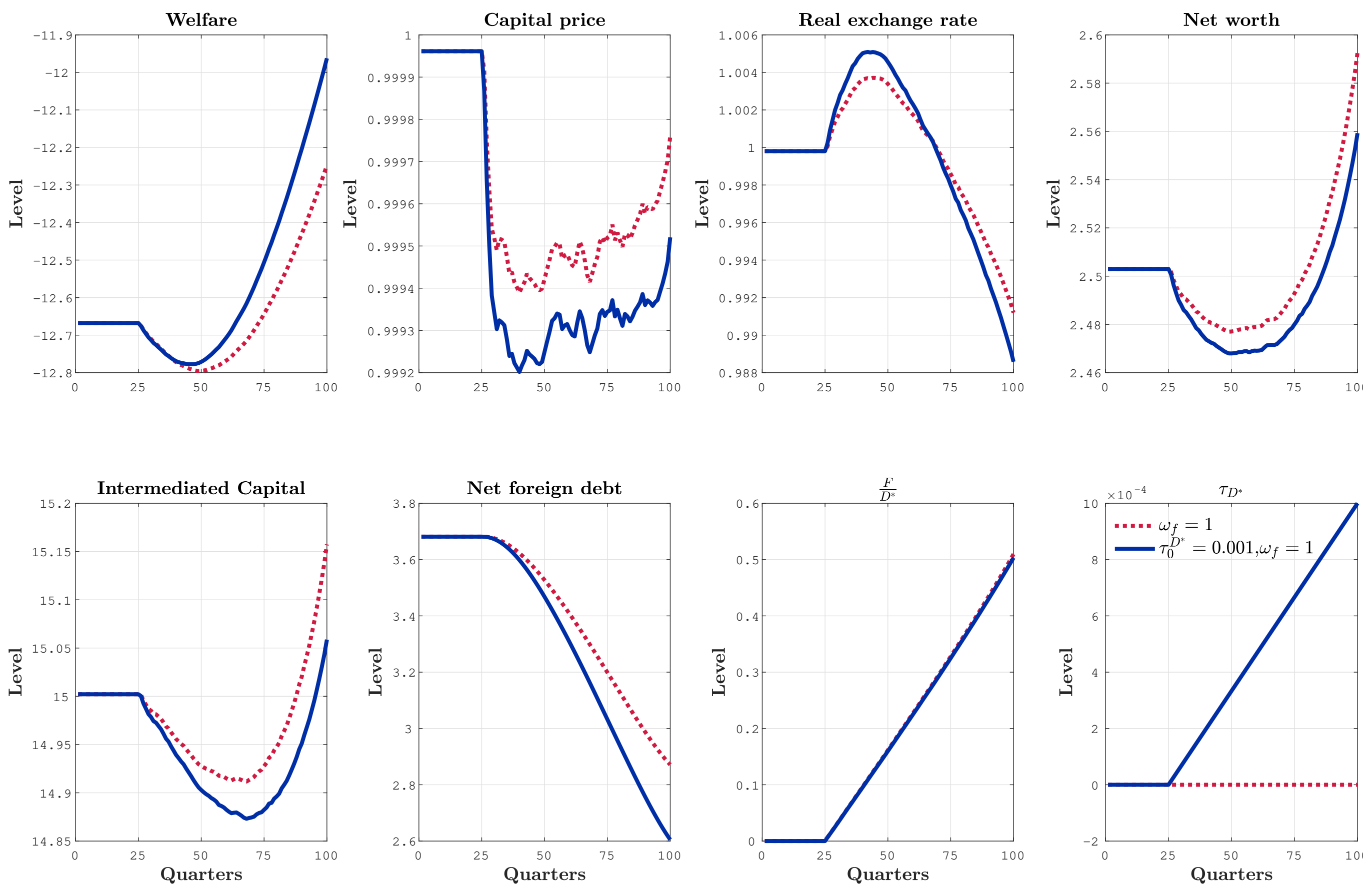
In Appendix, we derives the details of the model with taxes and subsidies to examine the effect of policy. We also introduce sales tax on commodity and final goods sector at constant rate τ^S to make model comparable with data. For a given k^x, each producer chooses (y^x, l, m, x) to maximize the profit $\Pi^x = \underset{y^x,l,m,x}{Max}[(1-\tau^s)p_t^x y^x - w_t l - \epsilon_t m - p_t^x x]$ taking prices as given. Because the marginal product of labor, imported material and commodity are equalized across producers, the marginal product of capital Z_t^x is

Figure 9: Foreign Interest Rate Shock: Non-Monetary Economy



Notes:

Figure 10: Permanent Policy Transition



Notes: At time t_0 the economy is at the risky steady state, where agents expect the distribution of future foreign interest rate shocks to be normally distributed with mean 0 and standard deviation of 40 bps annualized. At time $t_0 + 1$ agents are surprised by the implementation of policy, but past $t_0 + 1$ through $t_0 + T$ they perfectly anticipate the path of the permanent components of the policy rules. Results are obtained by averaging across 10,000 histories of interest rate shocks.

Table 4: Variance Decomposition (%)

Shock	P^{x*}	Y^*	R^*
Baseline			
$\ln Y_t$	15.82	12.58	71.60
$\ln \pi_t$	20.18	11.61	68.22
$\ln \epsilon_t$	39.67	7.02	53.31
$\ln Q_t$	8.74	0.90	90.36
$\ln N_t$	3.21	10.43	86.37
More flexible prices ($\omega = 0.1$)			
$\ln Y_t$	13.79	11.21	75.00
$\ln \pi_t$	17.64	4.73	77.63
$\ln \epsilon_t$	43.91	8.23	47.87
$\ln Q_t$	11.60	0.03	88.37
$\ln N_t$	1.40	6.87	91.74

Notes: The share of variation explained by each individual shock is reported.

equalized due to constant returns to scale and satisfies

$$(1-\tau^s)p_t^x = \frac{1}{A_t^x}\left(Z_t^x\right)^{\alpha_K} w_t^{\alpha_L} \epsilon_t^{\alpha_M} \left(p_t^x\right)^{\alpha_X} \tag{48}$$

There is not change in aggregate production and factor demand of commodity sector $(4,3)$. There is no change in final goods production sector, except that the price setting rule of each monopolist becomes

$$\pi_t\left(\pi_t-1\right) = \frac{\eta}{\kappa}\left[m_{Ct}^y - \frac{\eta-1}{\eta}(1-\tau^s)\right] + E_t\left[\Lambda_{t,t+1}\frac{Y_{t+1}}{Y_t}\pi_{t+1}\left(\pi_{t+1}-1\right)\right]. \tag{49}$$

Here, current inflation rate depends upon the gap between marginal cost and after-tax marginal revenue in addition to future inflation rate.

Bank does not pay sales tax. With tax on foreign borrowing and subsidy on net worth, the balance sheet of the bank constraint becomes

$$Q_t k_t^b\left(1+\frac{\varkappa^b}{2}\gamma_t^2\right) = (1+\tau_t^N)n_t + d_t + \left(1-\tau_t^{D*}\right)\epsilon_t d_t^*,$$

that can be rewritten as in terms of leverage multiple ϕ_t as:

$$\phi_t\left(1+\frac{\varkappa^b}{2}\gamma_t^2\right) = 1+\tau_t^N + \frac{d_t}{n_t} + \left(1-\tau_t^{D*}\right)\gamma_t\phi_t.$$

Thus the growth of net worth becomes

$$\begin{aligned}\frac{n_{t+1}}{n_t} &= \frac{\left(Z_{t+1}+\lambda Q_{t+1}\right)k_t^b - R_{t+1}d_t - \epsilon_{t+1}R_t^* d_t^*}{n_t} \\ &= (R_{t+1}^b - R_{t+1})\phi_t + \left(1+\tau_t^N\right)R_{t+1} \\ &+ \left\{\left[R_{t+1}\left(1-\tau_t^{D*}\right) - \frac{\epsilon_{t+1}}{\epsilon_t}R_t^*\right]\gamma_t - R_{t+1}\frac{\varkappa^b}{2}\gamma_t^2\right\}\phi_t.\end{aligned}$$

As we discussed in the main text, the bank chooses ϕ_t and γ_t, to maximize Tobin's Q ratio, ψ_t

$$\begin{aligned}\psi_t &= E_t\left(\Omega_{t+1}\frac{n_{t+1}}{n_t}\right) \\ &= \mu_t\phi_t + \left(\mu_t^*\gamma_t - \nu_t\frac{\varkappa^b}{2}\gamma_t^2\right)\phi_t + \left(1+\tau_t^N\right)\nu_t\end{aligned}$$

subject to the incentive constraint $\psi_t \geq \theta\phi_t$, where

$$\mu_t = E_t[\Omega_{t+1}(R_{t+1}^b - R_{t+1})], \tag{50}$$

$$\mu_t^* = E_t\left\{\Omega_{t+1}\left[R_{t+1}\left(1-\tau_t^{D*}\right) - \frac{\epsilon_{t+1}}{\epsilon_t}R_t^*\right]\right\}, \tag{51}$$

$$\nu_t = E_t\left(\Omega_{t+1}R_{t+1}\right). \tag{52}$$

We can express the bank's optimization problem using the Lagrangian

$$\mathcal{L}_t = (1+\lambda_t)\left[\mu_t\phi_t + \mu_t^*\gamma_t\phi_t + \left(1+\tau_t^N - \frac{\varkappa^b}{2}\gamma_t^2\phi_t\right)\nu_t\right] - \lambda_t\theta\phi_t.$$

The first order conditions with respect to γ_t and ϕ_t imply

$$(\varkappa^b \nu_t \gamma_t - \mu_t^*) = 0 \Leftrightarrow \gamma_t = \frac{\mu_t^*}{\varkappa^b \nu_t} \tag{53}$$

$$(1+\lambda_t)\left(\mu_t + \mu_t^* \gamma_t - \frac{\varkappa^b}{2}\gamma_t^2 \nu_t\right) = \lambda_t \theta. \tag{54}$$

When the incentive constraint is binding

$$\psi_t = \theta \phi_t$$

that could be used to obtain the leverage as

$$\theta \phi_t = \mu_t \phi_t + \mu_t^* \gamma_t \phi_t + \left(1 + \tau_t^N - \frac{\varkappa^b}{2}\gamma_t^2 \phi_t\right)\nu_t$$
$$\phi_t = \frac{\left(1+\tau_t^N\right)\nu_t}{\theta - \mu_t - \mu_t^* \gamma_t + \frac{\varkappa^b}{2}\gamma_t^2 \nu_t}$$

Using the government budget constraint (41), we find in equilibrium

$$\psi_t = E_t\left\{\Omega_{t+1}\left[\left(R_{t+1}^b - R_{t+1}\right)\phi_t + \left(R_{t+1} - \frac{\epsilon_{t+1}}{\epsilon_t}R_t^*\right)\gamma_t \phi_t + \left(1 - \frac{\varkappa^b}{2}\gamma_t^2 \phi_t\right)R_{t+1}\right]\right\}$$
$$= \theta \phi_t, \tag{55}$$

or

$$\phi_t = \frac{E_t\left(\Omega_{t+1} R_{t+1}\right)}{\Gamma_t\left(\gamma_t\right)}, \text{ where} \tag{56}$$

$$\Gamma_t\left(\gamma_t\right) \equiv \theta - E_t\left\{\Omega_{t+1}\left[R_{t+1}^b - R_{t+1} + \left(R_{t+1} - \frac{\epsilon_{t+1}}{\epsilon_t}R_t^*\right)\gamma_t - \frac{\varkappa^b}{2}\gamma_t^2 R_{t+1}\right]\right\}.$$

Thus we have

$$\Gamma_t'(\gamma_t) = \varkappa^b \gamma_t E_t(\Omega_{t+1} R_{t+1}) - E_t\left[\Omega_{t+1}\left(R_{t+1} - \frac{\epsilon_{t+1}}{\epsilon_t} R_t^*\right)\right]. \qquad (57)$$

From (53) , RHS equals zero in the neighborhood of $\tau_t^{D*} = 0$. Thus we learn the leverage multiple is not sensitive to τ_t^{D*} in the neighborhood of $\tau_t^{D*} = 0$. When we start with $\tau_t^{D*} > 0$, then we learn from (53) that a further increase in τ_t^{D*} reduces γ_t and the leverage multiple.

The general equilibrium with taxes and subsidies are given by ten endogenous price variables $(p_t^x, m_{Ct}^y, \pi_t, \epsilon_t, w_t, R_t, Q_t, Z_t^x, Z_t^y, i_t)$, eighteen quantity variables $(C_t, L_t, I_t, K_t, Y_t^x, Y, L_t^x, L_t^y,$ $M_t^x, M_t^y, X_t^x, X_t^y, E_{Xt}^y, D_t^*, N_t, D_t, K_t^b, K_t^h)$ and 9 bank variables $\left(\gamma_t, \psi_t, \phi_t, \nu_t, \mu_t, \mu_t^*, \Omega_t, \tau_t^{D*}, \tau_t^N\right)$ which satisfy 37 equations $(1, 3, 4, 6, 8-11, 13-17, 26, 30-38,\ 41, 42, 48-53, 55, 56)$ as functions of the state variables $(K_{t-1}, K_{t-1}^b, D_{t-1},\ R_{t-1}^* D_{t-1}^*, i_{t-1}, R_t^*, Y_t^*, P_t^{x*})$.

7.2 Appendix B: Steady State

From the household's optimization, we get

$$\begin{aligned} Q &= 1, \\ R &= \frac{1}{\beta}. \end{aligned}$$

The banker's stochastic discount factor is

$$\Omega = \beta(1 - \sigma + \sigma\psi).$$

As we are considering the equilibrium in which the incentive compatibility constraint is binding, we define the discounted spreads as

$$s^* \equiv 1 - \beta R^*,$$

with s^* denoting the spread between the foreign interest rate and the domestic deposit rate. We also define

$$s \equiv \beta(Z + \lambda) - 1,$$

where s denotes the spread between the rate of return to physical capital and the domestic deposit rate. We note here that where s is endogenously determined in the steady state system of equations while s^* is exogenously given. Moreover from the household's optimization, we have

$$\frac{K^h}{K} = \frac{s}{\varkappa^h},$$

that determines the share of capital held by the household (K^h/K) for a given s.

From the first order condition of the banking problem we obtain

$$\begin{aligned} \frac{\mu^*}{\nu} &= s^* - \tau^{D*} \\ \frac{\mu}{\nu} &= s, \end{aligned}$$

and

$$\gamma = \frac{s^* - \tau^{D*}}{\varkappa^b} = \gamma\left(s^* - \tau^{D*}\right).$$

Because of the balanced budget condition on taxes and subsidy of government, we learn

$$
\begin{aligned}
G &\equiv \frac{n_{t+1}}{n_t} = [Z + \lambda - R]\phi + [R - R^*]\,\phi\gamma + \left(1 - \frac{\varkappa^b}{2}\gamma^2\phi\right) R \\
&= \frac{1}{\beta}[p(s; s^*, \tau^{D*})\phi + 1], \text{ where} \\
p(s; s^*, \tau^{D*}, \tau^K) &\equiv s + s^*\gamma - \frac{\varkappa^b}{2}\gamma^2 : \text{ return premium.}
\end{aligned}
$$

Then we get

$$
\beta = \sigma\beta G + \xi(1+s)\phi\frac{1}{1 - \frac{K^h}{K}} = \sigma + \left[\sigma p(s; s^*, \tau^{D*}) + \xi\frac{1+s}{1 - \frac{s}{\varkappa^h}}\right]\phi,
$$

or

$$
\phi = \frac{\beta - \sigma}{\sigma p(s; s^*, \tau^{D*}) + \xi\frac{1+s}{1-\frac{s}{\varkappa^h}}}.
$$

We also learn

$$
\begin{aligned}
\psi &= \beta(1 - \sigma + \sigma\psi)G \\
&= \frac{(1-\sigma)[p(s; s^*, \tau^{D*})\phi + 1]}{1 - \sigma - \sigma p(s; s^*, \tau^{D*})\phi} \\
&= \theta\phi.
\end{aligned}
$$

Putting together, we get

$$
\begin{aligned}
0 &= H(s; s^*, \tau^{D*}) \\
&= (1-\sigma)\left[\beta p(s; s^*, \tau^{D*}) + \xi \frac{1+s}{1-\frac{s}{\varkappa^h}}\right]\left[\sigma p(s; s^*, \tau^{D*}) + \xi \frac{1+s}{1-\frac{s}{\varkappa^h}}\right] \\
&\quad -\theta(\beta-\sigma)\left[\sigma(1-\beta)p(s; s^*, \tau^{D*}) + (1-\sigma)\xi \frac{1+s}{1-\frac{s}{\varkappa^h}}\right]. \qquad (58)
\end{aligned}
$$

When $\tau^{D*} \to 0$, we have

$$
p(s; s^*, \tau^{D*}) \to s + \frac{s^{*2}}{2\varkappa^b},
$$

and

$$
\begin{aligned}
H(s; s^*, 0) &= (1-\sigma)\left[\beta\left(s + \frac{s^{*2}}{2\varkappa^b}\right) + \xi \frac{1+s}{1-\frac{s}{\varkappa^h}}\right]\left[\sigma\left(s + \frac{s^{*2}}{2\varkappa^b}\right) + \xi \frac{1+s}{1-\frac{s}{\varkappa^h}}\right] \\
&\quad -\theta(\beta-\sigma)\left[\sigma(1-\beta)\left(s + \frac{s^{*2}}{2\varkappa^b}\right) + (1-\sigma)\xi \frac{1+s}{1-\frac{s}{\varkappa^h}}\right].
\end{aligned}
$$

Then as $\xi \to 0$, we have

$$
s + \frac{s^{*2}}{2\varkappa^b} \to \theta \frac{(\beta-\sigma)(1-\beta)}{\beta(1-\sigma)}.
$$

Thus we learn that there exists a unique steady state equilibrium with positive spread $s > 0$ for a small enough (s^*, ξ) and the tax rates. Due to the constant returns to scale property of the bank operation, we learn that bank variables (s, x, ϕ, ψ) depend upon only the parameters of banker $\left(s^*, \tau^{D*}, \theta, \xi, \beta, \sigma\right)$, not the parameters of productions in the steady state.

Once we find the equilibrium value of s, we get

$$Z^y = \frac{1}{\beta}(1+s) - \lambda. \tag{59}$$

In the steady state, the marginal cost equals marginal revenue as

$$\begin{aligned} \frac{1}{A^y}\left(Z^y\right)^{\alpha_K} w^{\alpha_L} \epsilon^{\alpha_M} \left(p^x\right)^{\alpha_X} &= \left(1-\frac{1}{\eta}\right)\left(1-\tau^s\right) \\ \frac{1}{A^x}\left(Z^x\right)^{\alpha_K} w^{\alpha_L} \epsilon^{\alpha_M} \left(p^x\right)^{\alpha_X} &= p^x\left(1-\tau^s\right) \end{aligned} \tag{60}$$

Dividing side by side, we get

$$\frac{Z^x}{Z^y} = \left[\frac{\epsilon P^{x*} A^x}{\left(1-\frac{1}{\eta}\right) A^y}\right]^{\frac{1}{\alpha_K}} \tag{61}$$

The ratio of imputed rental prices of capital between commodity and final goods sectors depends upon the ratio of revenue productivity. Also from (60) , we get

$$w = \left[\frac{\left(1-\frac{1}{\eta}\right)\left(1-\tau^s\right) A^y}{\left(Z^y\right)^{\alpha_K} \epsilon^{\alpha_M} \left(p^x\right)^{\alpha_X}}\right]^{\frac{1}{\alpha_L}} \tag{62}$$

From the cost minimization of producers, we have in the steady state as

$$
\begin{aligned}
Z^y K &= \alpha_K \left(1-\frac{1}{\eta}\right)(1-\tau^s)\,Y,\ Z^x K^x = \alpha_K\,(1-\tau^s)\,p^x Y^x, && (63)\\
wL^y &= \alpha_L \left(1-\frac{1}{\eta}\right)(1-\tau^s)\,Y,\ wL^x = \alpha_L\,(1-\tau^s)\,p^x Y^x && (64)\\
\epsilon M^y &= \alpha_M \left(1-\frac{1}{\eta}\right)(1-\tau^s)\,Y,\ \epsilon M^x = \alpha_M\,(1-\tau^s)\,p^x Y^x\\
p^x X^y &= \alpha_K \left(1-\frac{1}{\eta}\right)(1-\tau^s)\,Y,\ p^x X^x = \alpha_X\,(1-\tau^s)\,p^x Y^x
\end{aligned}
$$

Now we define aggregate value of output evaluated at marginal revenue as

$$
\overline{Y} \equiv \left(1-\frac{1}{\eta}\right) Y + p^x Y^x. \tag{65}
$$

Then, we have

$$
\begin{aligned}
wL &= \alpha_L\,(1-\tau^s)\,\overline{Y}\\
\epsilon(M^x+M^y) &= \alpha_M\,(1-\tau^s)\,\overline{Y}\\
p^x(X^x+X^y) &= \alpha_X\,(1-\tau^s)\,\overline{Y}
\end{aligned}
$$

From the labor supply and demand (64), we also know

$$
wL = w\left(\frac{w}{\zeta_0}\right)^{\frac{1}{\zeta}} = \alpha_L\,(1-\tau^s)\,\overline{Y}.
$$

Thus together with (62) and $p^x = \epsilon P^{x*}$, we get

$$w = \{\zeta_0[\alpha_L (1-\tau^s) \overline{Y}]^\zeta\}^{\frac{1}{1+\zeta}} = \left[\frac{\left(1-\frac{1}{\eta}\right)(1-\tau^s) A^y}{(Z^y)^{\alpha_K} (P^{x*})^{\alpha_X} \epsilon^{\alpha_M+\alpha_X}}\right]^{\frac{1}{\alpha_L}} \tag{66}$$

Because we know Z^y is only a function of the spread s and P^{x*} is exogenous, equation (66) gives us aggregate value of output and real exchange rate $\left(\overline{Y}, \epsilon\right)$ which clears the labor market.

From (63), we learn

$$\begin{aligned} \frac{(1-\tau^s) p^x Y^x}{\overline{Y}} &= \frac{Z^x K^x}{\alpha_K \overline{Y}} \\ \frac{K}{\overline{Y}} &= \frac{\alpha_K}{Z^y} \frac{\left(1-\frac{1}{\eta}\right)(1-\tau^s) Y}{\overline{Y}} = \frac{\alpha_K}{Z^y}\left(1-\tau^s - \frac{Z^x K^x}{\alpha_K \overline{Y}}\right) \end{aligned}$$

Dividing current account balance by aggregate value of output in the steady state, we have

$$\frac{\epsilon^\varphi Y^*}{\overline{Y}} + \frac{p^x Y^x}{\overline{Y}} = \frac{\epsilon(M^x + M^y)}{\overline{Y}} + \frac{p^x(X^x + X^y)}{\overline{Y}} + (R^* - 1)\gamma \frac{K^b}{K}\frac{K}{\overline{Y}},$$

or

$$\begin{aligned} & \frac{\epsilon^\varphi Y^*}{\overline{Y}} + \frac{Z^x K^x}{\alpha_K (1-\tau^s) \overline{Y}} \\ = \; & (1-\tau^s)(\alpha_M + \alpha_X) + (R^*-1)\gamma(s)\left(1 - \frac{s}{\varkappa^h}\right)\left[\frac{\alpha_K}{Z^y}(1-\tau^s) - \frac{Z^x}{Z^y}\frac{K^x}{\overline{Y}}\right] \end{aligned} \tag{67}$$

Equation (67) gives us $\left(\overline{Y}, \epsilon\right)$ which balance the current account in the steady state. Given the spread s being satisfying (58), the steady state equilibrium of $\left(\overline{Y}, \epsilon\right)$ will satisfy $(66,67)$

Then we have

$$\frac{Y}{\overline{Y}}=\frac{1}{1-\frac{1}{\eta}}\left(1-\frac{1}{1-\tau^s}\frac{Z^xK^x}{\alpha_K\overline{Y}}\right)$$

$$\frac{C}{Y}=1-(1-\lambda)\frac{K}{Y}-\frac{\epsilon^{\varphi}Y^*}{Y}-\frac{s^2}{2\varkappa^h}\frac{K}{Y}-\frac{\varkappa^b}{2}\gamma(s)^2\left(1-\frac{s}{\varkappa^h}\right)\frac{K}{Y}.$$

7.3 Appendix C

In the non-monetary economy without government, the marginal cost equals the marginal revenue as

$$\frac{1}{A_t}(Z_t^y)^{\alpha_K}{w_t}^{\alpha_L}{\epsilon_t}^{\alpha_M}(p_t^x)^{\alpha_X}=1-\frac{1}{\eta}. \tag{68}$$

The other equilibrium conditions are similar to the one in Baseline model which are given by $(8-11),(14-17)$ and $(23-37)$. The recursive equilibrium is defined as 7 prices $(p_t^x, w_t, R_t, \epsilon_t, Q_t, Z_t^x, Z_t^y)$ and 18 quantity variables $(C_t, L_t, I_t, K_t, Y_t^x, Y, L_t^x, L_t^y, M_t^x, M_t^y, X_t^x, X_t^y,$ $E_{Xt}^y, D_t^*, N_t, D_t, K_t^b, K_t^h\ )$ and 7 bank variables $(\mu_t, \mu_t^*, \nu_t, \phi_t, \psi_t, \gamma_t, \Omega_t)$ as functions of the state variables $(K_{t-1}, K_{t-1}^b, D_{t-1}, R_{t-1}^*D_{t-1}^*, i_{t-1}, R_t^*, Y_t^*, P_t^{x*})$ which satisfies 32 equations $(1-4, 8-11, 13-17, 23-37, 68)$.

7.4 Appendix D: Matching the IO table to the model

Using the input-output table of OECD for various countries, we define the sectors as follows

(a) The "commodity sector" is: D01T03 Agriculture, D05T06 Mining&extraction, D07T08 Mining&quarrying, D09 Mining Support Service, D19 Coke&Refined Petro, D24 Basic Metal, D25 Fabricated Metal.

(b) The other sectors are defined as the "final goods sector"

Then input-output table looks like

	X	Y	C	I	G	E_X	$-I_M$	total output
X	U_{xx}	U_{xy}	C_x	I_x	G_x	E_{Xx}	$-I_{Mx}$	S_x
Y	U_{yx}	U_{yy}	C_y	I_y	G_y	E_{Xy}	$-I_{My}$	S_y
value added	GDP_x	GDP_y						
total output	S_x	S_y						

where: X is commodity sector; Y is final goods sector; U_{ij}: intermediate input of good i by sector j; C: consumption; I: investment; E_X: export; I_M: import; GDP: value added; S: total output.

GDP is therefore defined as

$$
\begin{aligned}
GDP &= GDP_x + GDP_y \\
&= C_x + C_y + I_x + I_y + G_x + G_y + E_{Xx} + E_{Xy} - (I_{Mx} + I_{My})
\end{aligned}
$$

In our model:

(a) Commodity is only used as intermediate input.

(b) Imported material (foreign final goods) is distinct from the final goods produced at home, and is used only as intermediate input.

Therefore, we modify the IO table as

	X	Y	C	I	G	E_X	$-I_M$	model-b output
X	U_{xx}	U_{xy}				E_{Xx}	$-I_{Mx}$	$p^x Y^x$
Y	U_{yx}	U_{yy}	$C_x + C_y$	$I_x + I_y$	$G_x + G_y$	E_{Xy}	0	Y
Import	ϵM^x	ϵM^y						
value added	VA_x	VA_y						
model-b output	$p^x Y^x$	Y						

where

$$I_{My} = \epsilon M_x + \epsilon M_y.$$

The value added of this country is

$$\begin{aligned} VA_x + VA_y &= p^x Y^x + Y - (U_{xx} + U_{xy} + U_{yx} + U_{yy}) - \epsilon (M_x + M_y) \\ &= C_x + C_y + I_x + I_y + G_x + G_y + E_{Xx} + E_{Xy} - I_{Mx} - I_{My}. \end{aligned}$$

In this modified IO table, C_x, I_x, G_x are treated as final goods. For example, imagine wheat. Wheat is commodity, when wheat is sold as intermediate input or exported, it is sold at the world competitive and flexible price. When wheat is sold to retailers (say, at a supermarket), it is combined with retail services and its price is sticky.

The ratio of final goods import to GDP and commodity use to GDP are measured as

$$\begin{aligned} \widetilde{\alpha}_M &= \frac{I_{My}}{GDP} \\ \widetilde{\alpha}_X &= \frac{U_{xx} + U_{xy}}{GDP} \end{aligned}$$

However, note that $\widetilde{\alpha}_M$ and $\widetilde{\alpha}_X$ are not equal to α_M and α_X in the production function.

At income account of GDP data is divided into

$$\begin{aligned} GDP &= \text{compensation of employees} \\ &\quad + \text{operating profit and mixed income} \\ &\quad + \text{indirect tax.} \end{aligned}$$

We can define the indirect tax-GDP ratio as

$$\tau^i = \frac{\text{indirect tax}}{GDP}$$

The ratio of GDP to total value of output at marginal revenue (Y) is defined by

$$\begin{aligned} GDP &= Y + p^x Y^x - \epsilon(M^x + M^y) - p^x(X^x + X^y) \\ &= v\overline{Y} \end{aligned}$$

We can define the tax rate on total value of output Y as

$$\tau^s = \tau^i \cdot v.$$

The first order conditions for the choice of labor, imported input and commodity input imply

$$\begin{aligned} wL &= \alpha_L(1-\tau^s)\overline{Y} \\ \epsilon(M^x+M^y) &= \alpha_M(1-\tau^s)\overline{Y} \\ p^x(X^x+X^y) &= \alpha_X(1-\tau^s)\overline{Y} \end{aligned}$$

Divide both sides by GDP, we have

$$\begin{aligned} \widetilde{\alpha}_M &= \frac{\alpha_M(1-\tau^s)}{v} \\ \widetilde{\alpha}_X &= \frac{\alpha_X(1-\tau^s)}{v}, \end{aligned}$$

we learn

$$\begin{aligned} v &= \frac{Y+p^xY^x-\epsilon(M^x+M^y)-p^x(X^x+X^y)}{\overline{Y}} \\ &= 1+\frac{\frac{1}{\eta}Y}{\overline{Y}}-(\widetilde{\alpha}_M+\widetilde{\alpha}_X)\,v \\ &= \frac{1+\frac{\frac{1}{\eta}Y}{\overline{Y}}}{1+\widetilde{\alpha}_M+\widetilde{\alpha}_X} \end{aligned}$$

Thus we have

$$\begin{aligned} \alpha_M &= \widetilde{\alpha}_M\cdot\frac{v}{1-\tau^i\cdot v} \\ \alpha_X &= \widetilde{\alpha}_X\cdot\frac{v}{1-\tau^i\cdot v}. \end{aligned}$$

In many emerging market economies, compensation of employees is unusually small share of GDP. We suspect that a significant fraction of gross operating surplus and gross mixed income is labor income. Here, however, we assume this is the correct number so that labor share is

$$\widetilde{\alpha}_L = \frac{wages}{GDP}.$$

The share of capital income is

$$\widetilde{\alpha}_K = \frac{\text{capital income}}{GDP}.$$

Thus we have

$$\alpha_L = \widetilde{\alpha}_M \cdot \frac{v}{1 - \tau^i \cdot v}.$$

Capital income equals sum of capital rental income and monopoly profit

$$\text{capital income} \;=\; Z^y K + Z^x K^x + \frac{1}{\eta} Y.$$

Thus we have

$$\alpha_K = \frac{\widetilde{\alpha}_K \cdot v - \frac{\frac{1}{\eta}Y}{Y}}{1 - \tau^i \cdot v}.$$

We can check $\alpha_L + \alpha_K + \alpha_M + \alpha_X = 1$.

Finally, we can compute the steady state value of K and K^x as

$$\begin{aligned} K &= \frac{\alpha_K}{Z^y} \left(1 - \tau^i \cdot v\right) \left(1 - \frac{1}{\eta}\right) Y \\ K^x &= \frac{\alpha_K}{Z^y} p^x Y^x. \end{aligned}$$

In the latter equation, we assume the rental rate of capital is equal between commodity and final goods sector in the steady state $Z^x = Z^y$.

7.5 Appendix E

Figure A1 shows the impulse response to the innovation of nominal interest rate by 1%. Because our economy has relatively flexible nominal price, the inflation rate falls by 1.4%. Because the nominal interest rate reacts to the inflation instantaneously, it rises by 0.6%. Net output fall by 1.1%, consumption falls by 1.5%, investment falls by 1.2% and import value falls by 2.4%. Capital price falls by 0.8%, real exchange rate appreciates by 0.6%, and the bank net worth falls significantly by 3.5%. The interaction between the capital price and bank net worth makes the contractionary effect of monetary policy significant in out economy.

Figure A2 shows the impulse response to the innovation of foreign demand by 1%. With the increase of foreign demand, export increases by 0.8% despite of real exchange rate appreciation of 0.3%. With currency appreciation and increasing demand offset each other, inflation rate increases by 0.15% and nominal interest rate falls by 0.06%. The price of capital increases by 0.03% and investment increase by 0.5%, and bank net worth increases by 0.5%. Net output, consumption and import all increase by about 0.2-0.3%. Because the increase of export exceeds that of import, net foreign debt decreases over time. The economy enters into a boom driven by the export expansion.

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