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(Working Papers)

Capital controls, macroprudential measures  
and monetary policy interactions in an emerging economy

by Valerio Nispi Landi

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# CAPITAL CONTROLS, MACROPRUDENTIAL MEASURES AND MONETARY POLICY INTERACTIONS IN AN EMERGING ECONOMY

by Valerio Nispi Landi\*

## Abstract

Are capital controls and macroprudential measures desirable in an emerging economy? How do these instruments interact with monetary policy? I address these questions in a DSGE model for an emerging economy whose banks are indebted in foreign currency. The model is augmented with financial frictions. The main findings are as follows: (i) capital controls and macroprudential policies are able to mitigate the adverse effects of an increase in the foreign interest rate; (ii) the desirability of these measures is shock dependent; and (iii) capital controls and monetary policy are complementary in addressing the trade-off between inflation and financial fluctuations.

**JEL Classification:** E44, E52, E58, F41.

**Keywords:** Financial Markets, Monetary Policy, Small Open Economy.

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\* Bank of Italy, Directorate General for Economics, Statistics and Research.



# 1 Introduction<sup>1</sup>

The three decades preceding the Great Recession have witnessed a massive wave of financial liberalization in emerging economies, which have removed many restrictions on cross-border financial flows. These countries were able to borrow from advanced economies mainly in foreign currency, becoming highly dependent on external debt and exposing themselves to financial stability risks. In fact, capital inflows tend to be extremely volatile, and episodes of sudden stops have often coincided with financial and monetary crises in Asia, Latin America and Africa during the 1980s and the 1990s. Both push and pull factors are responsible for such high volatility: the former are due to global conditions and have been increasing their importance in the last few years (see Ahmed and Zlate (2014)).

As argued by Rey (2015), financial flows in emerging markets are largely driven by swings in foreign investors' risk aversion, which in turn is strongly affected by US monetary policy. As a consequence, in a financially integrated world, monetary conditions in the centre country tend to be exported globally via cross-border capital flows. This implies that emerging economies may lose their monetary independence even under floating exchange rates, invalidating the celebrated open-economy trilemma: according to Rey (2015), monetary policy is independent if and only if prudential policies restrict financial openness, regardless of the exchange rate regime.

Against this background, policy makers have been using several tools to manage capital flows. As reported in Ghosh et al. (2017), the more orthodox instruments such as monetary and exchange rate policies have been combined with both macroprudential policies and capital controls<sup>2</sup>. While macroprudential policy aims to safeguard financial stability, capital controls are tools designed to limit capital flows, discriminating debt instruments on the basis of residency.

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<sup>2</sup>Some examples include Korea, that adjusted the loan to value ratio for mortgage loans several times in the last decade, and Brazil, that has applied a tax on the exchange rate transaction when capital first entered the country.

The International Monetary Fund has also revised its historical position about the benefits associated with financial integration. In 2012, the IMF Institutional View<sup>3</sup> recognized the risks of a more open financial account and suggested the use of restrictions on capital inflows under specific situations. One year earlier, the G20 Coherent Conclusions had supported capital flow management measures, stating that they can complement appropriate monetary and prudential policies.

The goal of this paper is to study the interaction between monetary policy, macroprudential measures and capital controls in an emerging economy. Notably, I focus on the following questions:

1. What is the role of capital controls and macroprudential policies in dampening the effect of a foreign interest rate hike in a small open economy?
2. How do these instruments interact with monetary policy and different exchange rate regimes?
3. Are these instruments welfare improving?
4. Does the central bank need to modify its optimal policy stance when these policies are in place?

These questions are addressed by using a DSGE model along the lines of Rannenberg (2016), augmented with an open economy dimension, as in Garcia-Cicco and Kirchner (2016). Indeed, the model features a moral hazard problem between depositors and banks (as in Gertler and Karadi (2011), GK from now on) and between banks and the non-financial sector (as in Bernanke et al. (1999), BGG henceforth). I choose to adopt the Rannenberg's specification for two reasons: first, it captures reasonably well business cycle fluctuations in a closed economy model; second, it provides a more realistic design of the financial sector, with frictions on both sides of banks' balance sheets. The model is calibrated to match some features of Brazil, which currently uses several of these policy instruments. An impulse response analysis is performed to address the first two questions, from a positive perspective; a welfare analysis is conducted to answer questions 3-4, from a normative perspective.

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<sup>3</sup>See IMF (2012).



The theoretical literature on the role of macroprudential policies and capital controls in emerging economies has been growing quickly. A first strand of studies justifies the use of prudential capital controls (modelled as a tax on foreign borrowing) because they are able to reduce the probability of a financial crisis. The model in Mendoza (2010) is the baseline framework in these papers: the novelty of this model is the presence of an emerging economy which is subject to an occasionally binding collateral constraint when it borrows from abroad. Korinek (2011) and Bianchi (2011) argue that capital controls reduce the probability of a sudden stop since they allow to internalize the risk of hitting the collateral constraint. Moreover, Korinek and Sandri (2016) and Farhi and Werning (2016) show that both macroprudential regulation (modeled as a tax on total borrowing) and capital controls are desirable. Benigno et al. (2013) find that welfare gains of credible commitment to support the real exchange rate through distortionary taxes are much larger than those of prudential policies. However, if financing exchange rate policies during crisis times is excessively costly, Benigno et al. (2016) state that capital controls together with an exchange rate policy (a tax on domestic goods in the model) can be welfare improving.

A second strand of the literature focuses on the role of capital controls in manipulating terms of trade. The analysis of Costinot et al. (2014) and Heathcote and Perri (2016) suggest that a country should tax capital inflows in order to induce favourable changes in international prices. Farhi and Werning (2014) find that a tax on external flows is desirable since it smooths the response of the terms of trade to a capital inflows shock, and can help monetary policy to stabilize the business cycle.

While the first strand of the literature fully abstracts from monetary policy considerations, the second one does not feature any financial frictions. Not surprisingly, a third stream of papers has integrated both these features in DSGE models of a small open economy<sup>4</sup>. In a model characterized by frictions between lenders and entrepreneurs, Unsal (2013) finds that a cyclical tax applying to both domestic and foreign credit yields positive yet small welfare gains, when the econ-

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<sup>4</sup>Clearly, DSGE models have been deeply using to study interactions between macroprudential and monetary policy in a closed economy. Angeloni and Faia (2013), Angelini et al. (2014), Farhi and Werning (2016) and De Paoli and Paustian (2017) are relevant contributions in this research area.

omy is hit by entrepreneurs' risk shocks; however, prudential policies applying only to foreign borrowing are not desirable. In a model characterized by frictions between depositors and banks, Ghilardi and Peiris (2016) compare the performance of a macroprudential tax on bank capital with a Taylor rule augmented with credit growth: the latter is dominant under a broad set of shocks. In a similar model, Aoki et al. (2016) show that a tax on bank external borrowing, that targets aggregate credit growth, is welfare improving under foreign interest rate shocks; moreover, this instrument calls for a more aggressive response by the monetary authority. The latter result is confirmed by Davis and Presno (2016), who argue that, in a model with collateral constraints, a tax on foreign bond holding restores monetary policy independence by allowing the central bank to focus mainly on price stability.

This paper belongs to this last stream of the literature, since it addresses the interactions between monetary policy, macroprudential measures and capital controls in a model with financial frictions. Macroprudential policies are modelled as a tax/subsidy on bank capital while the capital control instrument is a tax/subsidy on bank foreign debt: they respond to total credit and foreign debt respectively. The main results are as follows:

1. Capital controls and macroprudential policy are able to greatly dampen the effect of a foreign interest rate shock, in line with the results in Aoki et al. (2016) but unlike Unsal (2013).
2. Capital controls are particularly useful to counteract the effect of foreign interest rate shocks if the central bank pegs the nominal exchange rate.
3. Capital controls are welfare improving and are preferred to macroprudential policy<sup>5</sup> under foreign interest rate and financial shocks<sup>6</sup>. By contrast, macroprudential policy is more desirable under technology shocks.
4. Monetary policy and capital controls are strongly complementary under both

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<sup>5</sup>This result differs from Unsal (2013) who finds that financial policies applying only to foreign credit are not desirable, because they bring a shift from foreign to domestic debt.

<sup>6</sup>The financial shock is modelled as an exogenous reduction in the net worth of entrepreneurs, as in Nolan and Thoenissen (2009), Christiano et al. (2010) and Rannenberg (2016).

foreign interest rate and financial shocks, however the degree of this complementarity is different, as explained below.

Some of these results are in line with the existent literature. In particular, as Aoki et al. (2016) (the paper closest to mine), I find that capital controls allow monetary policy to focus more on price stability under foreign interest rate shocks. The intuition is the following. A monetary tightening in the rest of the world *raises* domestic inflation (via a nominal depreciation) and generates inefficient financial fluctuations (e.g. an increase in the lending spread). If the social planner increases the interest rate to dampen inflation, she amplifies financial fluctuations even more. However, if capital controls are available, they can be loosened to mitigate inefficient financial fluctuations, leaving more room for a monetary tightening. On top of that, I add three novel contributions. First I show that this mechanism does not hold under shocks that increase the lending spread but *reduce* the inflation rate (financial shocks in my model): accordingly, in this case the social planner does not face any trade-off between inflation and financial fluctuations, thus optimal monetary policy is independent from the capital controls stance. Second, I find that under financial shocks, the optimal stance of capital controls crucially hinges on the degree of monetary policy's aggressiveness against inflation fluctuations: indeed, a capital control loosening mitigates the inefficient increase in the lending spread but amplifies deflationary pressures, by appreciating the currency. Third, I stress that if external debt increases during crises (this is the response under a negative technology shock), then capital controls are not optimal anymore and macroprudential policy becomes desirable. To the best of my knowledge, these findings are new in the literature.

The remainder of the paper is organized as follows. Section 2 characterizes the efficient allocation in a closed economy with financial frictions and nominal rigidities. Section 3 presents the model and the calibration strategy. Section 4 analyzes the simulation results. Section 5 concludes.

## 2 Efficiency in Models with Financial Frictions

Before introducing the model and analyzing different policy scenarios, it is necessary to clarify an important issue. In the framework presented in the next section, characterizing the optimal policy analytically is not feasible, since the model features too many variables and distortions. Therefore, it is not possible to rely either on a linear quadratic approach à la Benigno and Woodford (2003) or on the optimization by a Ramsey social planner, as done in Farhi and Werning (2014). Accordingly, in Section 4 I will use the approach developed by Schmitt-Grohé and Uribe (2004): I take a second order approximation of the model and numerically compute the parameters of the policy instruments by maximizing households' expected welfare, conditional on being in the steady state. The drawback of this method is that it is not always straightforward to correctly understand the economic intuition underlying the numerical results, especially if the model is relatively large and features several distortions, both in the short-run and in the steady state. Hence, the goal of this section is to provide some theoretical results about the inefficiencies in a basic model with financial frictions, in order to better understand the simulation exercise performed in Section 4

### 2.1 A simple model with financial frictions

Consider a standard closed-economy real business cycle model. Households maximize utility by choosing consumption  $c_t$ , labor  $h_t$ , capital  $k_{t-1}$  and the amount invested in a risk-less real bond yielding a gross return of  $r_t$ . Firms use capital and labor to produce the consumption good using a standard Cobb-Douglas production function  $F(k_{t-1}, h_t)$ ; they operate in perfect competition and prices are fully flexible. It is well known that the competitive equilibrium of this model is

efficient and is characterized by the following equilibrium conditions:

$$F(k_{t-1}, h_t) = c_t + k_t - (1 - \delta) k_{t-1} \quad (1)$$

$$\beta \mathbb{E}_t \left[ \frac{U_c(c_{t+1}, h_{t+1})}{U_c(c_t, h_t)} r_t \right] = 1 \quad (2)$$

$$mpl_t(k_{t-1}, h_t) = mrs_t(c_t, h_t) \quad (3)$$

$$r_t^K = mpk_t(k_{t-1}, h_t) \quad (4)$$

$$\mathbb{E}_t \{U_c(c_{t+1}, h_{t+1}) [(r_{Kt+1} + 1 - \delta) - r_t]\} = 0 \quad (5)$$

Expression (1) is the resource constraint. The second condition pins down the risk-less real interest rate (where  $U_c(\cdot)$  is the marginal utility of consumption). Equation (3) equalizes the marginal product of labor  $mpl_t$  with the marginal rate of substitution between consumption and labor  $mrs_t$ . Equation (4) equalizes the marginal product of capital  $mpk_t$  with capital rental rate  $r_t^K$ . Condition (5) states that the expected spread between the gross rental rate of capital and the return in investing in risk-less bonds must be zero; if this is not the case (say, the spread is positive), then households would start to borrow (i.e. sell bonds) and massively invest in capital: this would reduce  $\mathbb{E}_t mpk_{t+1}$  and  $\mathbb{E}_t r_{t+1}^K$  via (4), increase  $r_t$  and close the spread. However, financial frictions may limit this arbitrage mechanism. For instance, this occurs if it is not possible to borrow indefinitely, as in GK and BGG, where borrowing depends on the net worth of those agents that invest in capital (banks in GK, entrepreneurs in BGG). In a real business cycle model augmented with financial frictions à la GK, the equilibrium is described by equations (1)-(4) together with:

$$\mathbb{E}_t \{U_c(c_{t+1}, h_{t+1}) [(r_{Kt+1} + 1 - \delta) - r_t]\} = spread_t,$$

where  $spread_t$  is determined by the set of equations describing the financial sector. Accordingly, any policy that ensures:

$$spread_t = 0 \quad \forall t \quad (6)$$

is able to guarantee efficiency<sup>7</sup>.

In order to introduce some degree of price stickiness, suppose now that firms pay adjustment costs to change prices. This friction generates a time varying mark-up  $\mu_t$  between the price level and the firms' nominal marginal costs. Equilibrium conditions are modified as follows:

$$\begin{aligned}
 F(k_{t-1}, h_t) &= c_t + k_t - (1 - \delta)k_{t-1} + C(\pi_t) \\
 \beta \mathbb{E}_t \left[ \frac{U_c(c_{t+1}, h_{t+1})}{U_c(c_t, h_t)} r_t \right] &= 1 \\
 \frac{mpl_t(k_{t-1}, h_t)}{\mu_t} &= mrs_t(c_t, h_t) \\
 r_t^K &= \frac{mpk_t(k_{t-1}, h_t)}{\mu_t}
 \end{aligned}$$

$$\mathbb{E}_t \{U_c(c_{t+1}, h_{t+1}) [(r_{Kt+1} + 1 - \delta) - r_t]\} = spread_t$$

where gross inflation  $\pi_t$  and mark-up  $\mu_t$  are determined by monetary policy and the supply side of the economy.  $C(\cdot)$  is an increasing and convex function such that  $C(\pi) = 0$ , capturing price adjustment costs, where  $\pi$  is the central bank inflation target. In this model, it is easy to see that efficiency is guaranteed if  $\forall t$ :

$$\pi_t = \pi$$

$$\mu_t = 1$$

$$spread_t = 0.$$

Under some assumptions (i.e. a firm subsidy that ensures a steady state of  $\mu = 1$ ),  $\pi_t = \pi \iff \mu_t = 1$ . Then, the optimal policy prescribes stabilizing inflation around the target and closing the expected spread between the marginal product of capital and the real interest rate. This does not necessarily hold in models featuring a foreign sector, monitoring costs and different types of agents like the DSGE developed in the next section. For instance, the social planner may find

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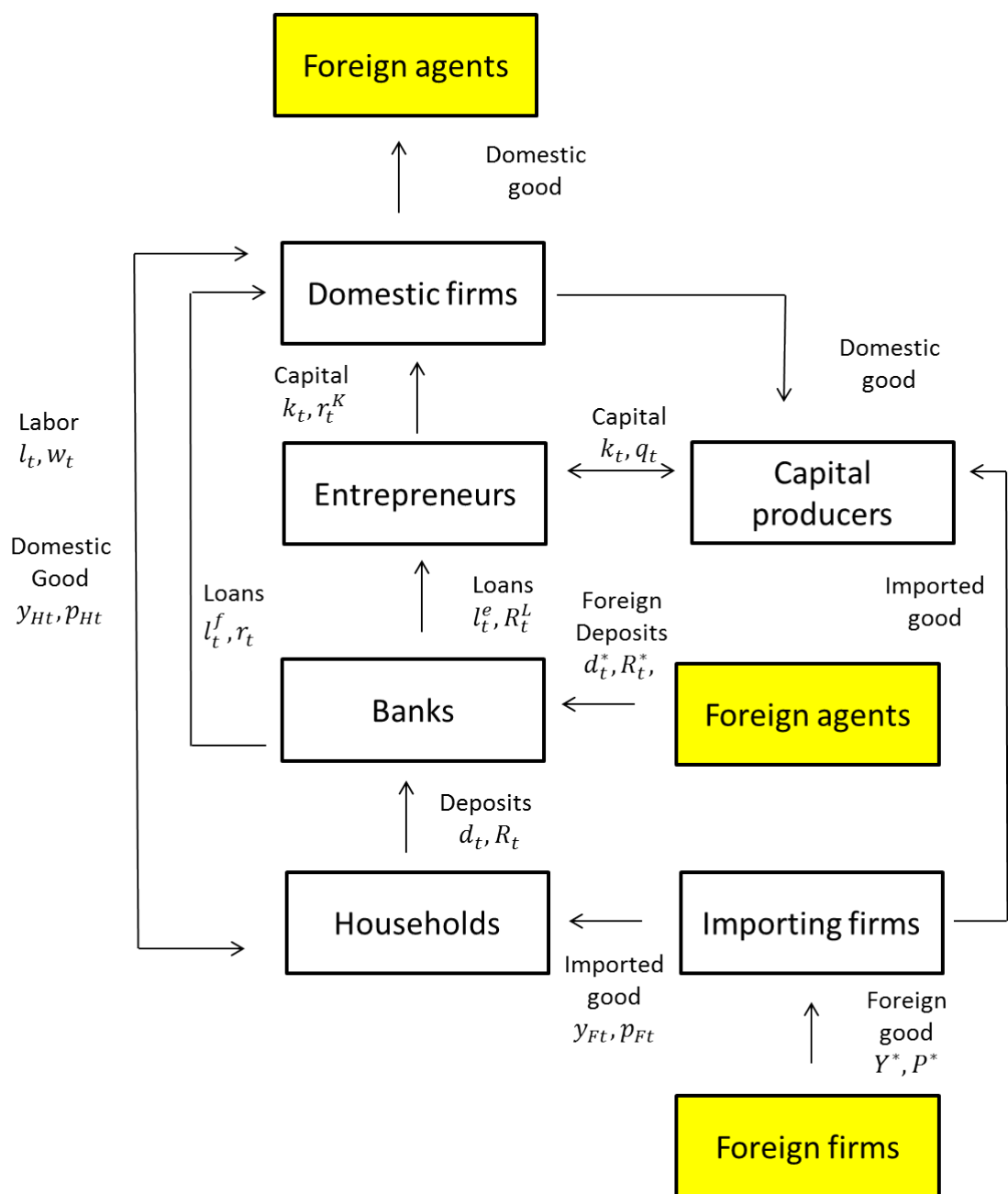
<sup>7</sup>The same holds in the BGG framework, if we assume that monitoring cost paid by lenders are transferred back to households.

it optimal to use policy instruments also to manipulate terms of trades, as in Heathcote and Perri (2016). However, simulations in Section 4 will suggest that the social planner actually tries to stabilize spread and inflation fluctuations.

### 3 The Model

The model is a DSGE for a small open economy augmented with nominal rigidities and financial frictions. Financial frictions are modeled as in Rannenberg (2016), who merges the GK banking sector with the BGG entrepreneurs' framework, in a closed economy. The economy works as follows (see figure 1). Households consume, hold deposits in domestic banks and work for domestic firms; the consumption good consists of a bundle of differentiated domestic goods (produced by domestic firms) and a bundle of differentiated imported goods (produced by importing firms); banks collect funds through domestic and foreign deposits and by accumulating net worth; entrepreneurs borrow from banks to hold and invest in the capital stock of the economy, which they rent to domestic firms. The model is closed with an exogenous foreign sector which includes a demand function for the domestic good and a stochastic process for the foreign interest rate.

In what follows, I describe the model in detail, leaving the derivation of most of the equilibrium conditions to the Appendix.



**Figure 1:** The model. Quantities are expressed in real terms ; lower-case price variables are relative prices, with the domestic CPI as the numéraire. Interest rates are expressed in nominal terms, consistent with the text (except for loans to firms, that are intraperiod and pay the real interest rate). For the sake of simplicity, in the scheme the realized rates of return of banks and entrepreneurs ( $R_t^B$  and  $R_t^{KG}$ ) are not reported.



### 3.1 Households

The representative household solves the following maximization problem:

$$\max_{\{c_t, h_t, d_t\}_{t=0}^{\infty}} \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[ \frac{1}{1-\sigma} \left( c_t - \kappa_L \frac{h_t^{1+\varphi}}{1+\varphi} \right)^{1-\sigma} \right] \right\}$$

$$s.t. \ c_t + d_t + t_t = w_t h_t + \frac{R_{t-1}}{\pi_t} d_{t-1} + \Pi_t,$$

where  $h_t$  denotes hours of work in domestic firms;  $d_t$  denotes bank deposits (expressed in terms of the domestic CPI), yielding a risk-free nominal interest rate  $R_t$ ;  $t_t$  is a lump-sum tax;  $w_t$  is the real hourly wage;  $\pi_t$  is the CPI gross inflation rate;  $\Pi_t$  denotes profits from the ownership of domestic firms, importing firms and capital producers; finally,  $c_t$  is a CES consumption bundle:

$$c_t = \left[ (1-\gamma)^{\frac{1}{\eta}} c_{Ht}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} c_{Ft}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (7)$$

where  $c_{Ht}$  and  $c_{Ft}$  are bundles of differentiated domestic and imported goods respectively. The associated CPI index  $P_t$  reads:

$$P_t = \left[ (1-\gamma) P_{Ht}^{1-\eta} + \gamma P_{Ft}^{1-\eta} \right]^{\frac{1}{1-\eta}}, \quad (8)$$

where  $P_{Ht}$  and  $P_{Ft}$  are the prices of domestic and imported goods respectively (both expressed in domestic currency). Solution of the household's maximization problem yields a standard Euler equation and a labor supply condition which does not feature a wealth effect, following Greenwood et al. (1988)<sup>8</sup>.

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<sup>8</sup>This preference specification better captures business cycle dynamics in a small open economy (see, for instance, Neumeyer and Perri (2005)).

## 3.2 Firms

### 3.2.1 Domestic firms

There is a continuum of domestic firms, indexed with  $i$ , producing a differentiated domestic good with the following production function:

$$y_{Ht}(i) = A_t (k_{t-1}(i))^\alpha (h_t(i))^{1-\alpha}, \quad (9)$$

where  $k_t$  is physical capital,  $A_t$  is total factor productivity and  $y_{Ht}(i)$  is production of domestic good  $i$ ; these goods are combined into domestic output through the following Dixit-Stiglitz aggregator:

$$y_{Ht} = \left[ \int_0^1 y_{Ht}(i)^{\frac{\varepsilon_H-1}{\varepsilon_H}} di \right]^{\frac{\varepsilon_H}{\varepsilon_H-1}}.$$

Firms set prices in monopolistic competition and they pay adjustment costs à la Rotemberg (1982): this nominal rigidity is necessary to give a role to monetary policy. Following Rannenberg (2016), I assume that domestic firms must borrow from banks to pay a fraction of their input costs in advance; these loans are intraperiod and the interest rate is the risk-free real rate  $r_t \equiv \frac{R_t}{\mathbb{E}\pi_{t+1}}$ . Total loans  $l_t^f(i)$  to firm  $i$  are given by:

$$l_t^f(i) = \psi_h w_t h_t(i) + \psi_k r_t^K k_{t-1}(i), \quad (10)$$

where  $r_t^K$  is the rental rate of capital. Every firm  $i$  maximizes the discounted expect difference between revenues and costs:

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[ (p_{Ht}(i) - mc_{Ht}(i)) y_{Ht}(i) - \frac{\kappa_{PH}}{2} \left( \frac{P_{Ht}(i)}{P_{Ht-1}(i)} - \pi \right)^2 p_{Ht} y_{Ht} \right] \right\}$$

subject to (9) and the following demand function:

$$y_{Ht}(i) = \left( \frac{p_{Ht}(i)}{p_{Ht}} \right)^{-\varepsilon} y_{Ht},$$

where  $\lambda_t$  is the marginal utility of consumption<sup>9</sup>;  $p_{Ht} \equiv \frac{P_{Ht}}{P_t}$ ,  $mc_{Ht}$  is the real marginal cost (the exact expression is derived in the Appendix) and  $\pi$  is the steady-state inflation rate. The solution of this problem yields a New Keynesian Phillips Curve.

### 3.2.2 Importing firms

There is a continuum of importers indexed with  $f$  whose role consists in transforming an imported foreign good into a differentiated good  $y_{Ft}(f)$ . These goods are aggregated into the total imported good via to the following Dixit-Stiglitz aggregator:

$$y_{Ft} = \left[ \int_0^1 y_{Ft}(f)^{\frac{\varepsilon_F - 1}{\varepsilon_F}} df \right]^{\frac{\varepsilon_F}{\varepsilon_F - 1}}.$$

The nominal marginal cost of these firms is given by:

$$P_{Ft} = ner_t P_t^*, \quad (11)$$

where  $ner_t$  is the nominal exchange rate (that is the price of one unit of foreign currency in terms of domestic currency) and  $P_t^*$  is the foreign CPI expressed in foreign currency. These firms operate in monopolistic competition and are subject to Rotemberg adjustment costs. The generic firm  $f$  maximizes the expected discounted difference between revenues and costs:

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[ (p_{Ft}(f) - (1 - \tau_F^M) rer_t) y_{Ft}(f) - \frac{\kappa_{PF}}{2} \left( \frac{P_{Ft}(f)}{P_{Ft-1}(f)} - \pi \right)^2 p_{Ft} y_{Ft} \right] \right\}$$

where  $p_{Ft} \equiv \frac{P_{Ft}}{P_t}$ ,  $rer_t \equiv ner_t \frac{P_t^*}{P_t}$  is the real exchange rate and  $\tau_F^M$  is a subsidy whose nature will be clear in next paragraphs. Importers face the following demand function:

$$y_{Ft}(f) = \left( \frac{p_{Ft}(f)}{p_{Ft}} \right)^{-\varepsilon} y_{Ft}.$$

---

<sup>9</sup>Given that firms are owned by households, they value the future stream of profits using the households' stochastic discount factor.

The first order condition of the importer's problem yields a Phillips curve which features a time-varying wedge between the real exchange rate and the imported goods price.

### 3.3 Banks

The economy features a continuum of financial intermediaries, managed by bankers. Bankers are risk neutral and die<sup>10</sup> with probability  $1 - \chi_b$ ; when a banker  $b$  dies, she is replaced by new ones, which receive a small start-up fund  $\frac{ub}{1-\chi_b}$  by households; exiting bankers consume their remaining net worth  $n_t^b(b)$ . Every banker faces the following budget constraint:

$$l_t^e(b) = n_t^b(b)(1 - \tau_t^n) + rer_t d_t^*(b)(1 - \tau_t^d) + d_t(b). \quad (12)$$

Hence, bankers raise funds from three different sources:

1. accumulated net worth  $n_t^b$  (expressed in terms of the domestic CPI);
2. one-period foreign deposits  $P_t^* d_t^*$  denominated in foreign currency;
3. one-period domestic deposits  $P_t d_t$  denominated in domestic currency.

Loans to entrepreneurs  $l_t^e$  (expressed in terms of the domestic CPI) are the counterpart of these liabilities: loans are made at  $t$  and are due at the beginning of  $t+1$ , yielding an average nominal return of  $R_{t+1}^b$ . Loans to firms do not show up in banks' balance sheets, since they are intraperiod (they are made at the beginning of period  $t$  and are due at the end of the same period).

Furthermore, it is important to highlight the role of  $\tau_t^n$  and  $\tau_t^d$ , which are the macroprudential and the capital control instrument respectively. The former is a tax (subsidy) to discourage (incentivize) the use of net worth; the latter is a tax (subsidy) on foreign debt which resembles capital controls implemented in some emerging economies over the last few years.

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<sup>10</sup>If bankers were infinitely lived, they would accumulate an infinite amount of net worth, making financial frictions irrelevant.

Banks' net worth is accumulated only through profits<sup>11</sup>:

$$n_t^b(b) = \frac{R_{t-1}^b}{\pi_t} l_{t-1}^e(b) - \frac{R_{t-1}^*}{\pi_t^*} r e r_t d_{t-1}^*(b) - \frac{R_{t-1}}{\pi_t} d_{t-1}(b), \quad (13)$$

where  $R_t^*$  is the foreign nominal interest rate, and  $\pi_t^* \equiv \frac{P_t^*}{P_{t-1}^*}$  is foreign inflation. For the small open economy of this model, foreign deposits represent the unique way to financially trade with the rest of the world: since  $d_t^*$  is not state contingent, international financial markets are incomplete.

Following GK, I assume that bankers can divert a fraction of bank assets for personal use, after raising funds but before buying new assets. Clearly, depositors anticipate this behaviour and impose an incentive constraint to limit the moral hazard problem. Notably, depositors require that the present value of the bank  $V_t(b)$  is never lower than the total amount of loans that bankers can divert:

$$V_t(b) \geq \theta_t(b) l_t^e(b), \quad (14)$$

with  $\theta_t$  given by:

$$\theta_t(b) = \theta_0 \left[ 1 + \frac{\theta_1}{2} \left( \frac{r e r_t d_t^*(b)}{l_t^e(b)} \right)^2 \right]. \quad (15)$$

As in Aoki et al. (2016), I am assuming that the ability to divert fund is an increasing function of the fraction of loans financed by foreign debt. This implies that banks financing themselves relatively more from abroad are able to divert assets more easily, and accordingly they should be monitored more carefully. This assumption has the same role of a debt-elastic foreign interest rate premium, which is necessary to ensure a steady state independent from initial conditions and a stationary equilibrium dynamics in an open economy model with incomplete financial markets<sup>12</sup>.

Let  $lev_t^b(b) = \frac{l_t^e(b)}{n_t^b(b)}$  be the bank leverage ratio. In the Appendix, it is shown that the value function of bankers is given by:

$$V_t = \nu_{lt} l_t^e + \nu_{dt}^* d_t^* + \nu_{nt} n_t^b \quad (16)$$

<sup>11</sup>So it is assumed that banks cannot issue new shares.

<sup>12</sup>See Schmitt-Grohé and Uribe (2003) for a discussion on this issue.

and so bank leverage can be written as<sup>13</sup>:

$$lev_t^b = \frac{\nu_{nt}}{\theta_t - (\nu_{lt} + \nu_{dt} dl_t)}, \quad (17)$$

where  $dl_t \equiv \frac{rer_t d_t^*}{l_t^e}$  and  $\nu_{nt}$ ,  $\nu_{lt}$  and  $\nu_{dt}^*$  denote the marginal gain of increasing net worth, loans and foreign deposits by one unit respectively, holding other variables constant. Notice that these three variables all increase the leverage ratio: indeed, they all raise the marginal cost for bankers of diverting assets, which is equivalent to the loss of the bank franchise value. On the other hand, when  $\theta_t$  is high, the marginal gain from diverting assets gets larger, hence depositors will tolerate a lower leverage ratio. In equilibrium, it turns out that the marginal gain of expanding loans is an increasing function of lending spread<sup>14</sup>:

$$\nu_{lt} = f(\underset{+}{spread_t^B}), \quad (18)$$

with  $spread_t^B \equiv \mathbb{E}_t \left( \frac{R_{t+1}^B}{R_t} \right)$ . Intuitively, an increase in the lending spread improves banks' profitability, discouraging bankers from diverting assets. A shock that reduces banks' net worth raises the marginal gain from diverting funds (bankers have "less skin in the game"): in equilibrium, the marginal cost has to increase too, so the lending spread rises and banks are expected to be more profitable in the future. In frictionless financial markets, as soon as the lending spread is positive, bankers would expand assets indefinitely and this would compress the spread to one. However, the moral hazard friction puts a limit on banks' borrowing, leaving room for a positive lending spread. Finally, the ratio  $\nu_t^{dl} \equiv \frac{\nu_{dt}^*}{\nu_{lt}}$  plays an important role: this is the marginal gain of increasing foreign debt compared to the marginal gain of expanding loans. Up to a linear approximation, the following holds:

$$\tilde{\nu}_t^{dl} = \tilde{u} \tilde{p}_t - \tilde{spread}_t^{Bn}, \quad (19)$$

---

<sup>13</sup>Since all banks choose the same leverage in equilibrium, the  $b$  index can be suppressed.

<sup>14</sup>While the nominal deposit rate is known when the deposit contract is signed, the average nominal loan return is not.

where  $wip_t \equiv 1 - \left[ \frac{R_t^*}{R_t} \mathbb{E}_t \left( \frac{ner_{t+1}}{ner_t} \right) + \tau_t^D \right]$  denotes deviations from the uncovered interest parity and  $spread_t^{Bn} \equiv \mathbb{E}_t \left( \frac{R_{t+1}^B}{R_t} - 1 \right)$  (variables with a tilde are expressed in percentage deviations from the steady state). Intuitively, higher values of  $wip_t$  reflect larger benefits from borrowing abroad compared to investing in loans; the opposite is true when the lending spread is big, since bank would prefer to lend more. Given that in equilibrium the share of total loans financed through foreign deposits is increasing in  $\nu_t^{dl}$ , the linearized modified uncovered interest parity reads:

$$\tilde{R}_t = \tilde{R}_t^* + \mathbb{E}_t (\tilde{ner}_{t+1} - \tilde{ner}_t) + \tau_t^D + D_0 \mathbb{E}_t \left( \tilde{R}_{t+1}^B - \tilde{R}_t \right) + D_1 \left( r\tilde{er}_t + \tilde{d}_t^* - \tilde{l}_t^e \right) \quad (20)$$

where  $D_0$  and  $D_1$  are positive parameters defined in the Appendix.

### 3.4 Entrepreneurs

As in BGG, there is a continuum of risk neutral entrepreneurs who hold and manage the capital stock of the economy. The timing of entrepreneurs' business consists in the following steps:

1. At the end of period  $t$  entrepreneur  $j$  buys capital  $k_t(j)$  from capital good producers at nominal price  $Q_t$ .
2. At the beginning of period  $t + 1$  she receives an idiosyncratic shock  $\omega(j)$ : this shock is i.i.d. among entrepreneurs, with log-normal density function  $f(\omega)$  (having mean 1 and variance  $\sigma_e^2$ ). The effective amount of capital  $\omega_{t+1}(j) k_t(j)$  is rented to domestic firms at rental rate  $r_{t+1}^K$ .
3. Domestic firms use capital to produce the domestic good; at the end of period  $t + 1$  they give back capital net of depreciation  $(1 - \delta)\omega_{t+1}(j) k_t(j)$  to entrepreneurs which in turn sell it to capital good firms at nominal price  $Q_{t+1}$ .

Accordingly, the nominal average return of capital is given by:

$$R_{t+1}^{KG} = \frac{r_{t+1}^K + q_{t+1}(1 - \delta)}{q_t} \pi_{t+1}, \quad (21)$$

with  $q_t = \frac{Q_t}{P_t}$ . Entrepreneurs finance the acquisition of capital through bank loans and their own net worth  $n_t^e(j)$ :

$$q_t k_t(j) = n_t^e(j) + l_t^e(j). \quad (22)$$

The loan contract made in period  $t$  specifies an optimal leverage  $lev_t^e \equiv \frac{q_t k_t(j)}{n_t^e(j)}$  and a cutoff value  $\bar{\omega}_{t+1}(j)$  such that:

- if  $\omega_{t+1}(j) \geq \bar{\omega}_{t+1}(j)$  entrepreneur  $j$  pays back  $\bar{\omega}_{t+1}(j) R_{t+1}^{KG} q_t k_t(j)$ ;
- if  $\omega_{t+1}(j) < \bar{\omega}_{t+1}(j)$ , entrepreneur  $j$  defaults and the bank can seize his assets.

Following BGG, only entrepreneur  $j$  has information on  $\omega(j)$ : as a result, entrepreneurs may misreport the correct realization of the shock. Banks can verify the true value by paying a monitoring cost, equal to a fraction  $\mu$  of the entrepreneur's assets: in equilibrium, entrepreneurs always report truthfully and so banks pay the monitoring cost only in case of a low realization of  $\omega$ . The presence of this friction creates a wedge between the loan rate  $R_t^L$  and the effective return for banks  $R_t^B$ , because not all loans are paid back. The loan rate is known when the contract is signed and it is defined as:

$$R_{t-1}^L = \frac{\bar{\omega}_t(j) R_t^{KG} k_{t-1}(j)}{l_t^e(j)} \pi_t. \quad (23)$$

On the other hand, the effective return obtained by banks  $R_t^B$  depends on aggregate conditions at time  $t$ . Accordingly, banks are willing to lend if and only if the following incentive constraint holds state by state:

$$R_{t+1}^B l_t^e(j) = \left\{ [1 - F(\bar{\omega}_{t+1}(j))] \bar{\omega}_{t+1}(j) + (1 - \mu) \int_0^{\bar{\omega}_{t+1}(j)} \omega f(\omega) d\omega \right\} R_{t+1}^{KG} q_t k_t(j). \quad (24)$$

The left-hand-side of (24) is the bank's total return from the contract with entrepreneur  $j$ ; the right-hand-side consists of two parts: the former is the total return in case of non-default ( $F(\cdot)$  is the cdf function of  $\omega$ ) and the latter is the total return in the event of the entrepreneur's bankruptcy.



The expected profits function of entrepreneurs is<sup>15</sup>:

$$\mathbb{E}_t \left\{ \frac{R_{t+1}^{KG}}{\pi_{t+1}} q_t k_t(j) \left[ \int_{\bar{\omega}_{t+1}(j)}^{\infty} \omega f(\omega) d\omega - \bar{\omega}_{t+1}(j) [1 - F(\bar{\omega}_{t+1})] \right] \right\}, \quad (25)$$

where the first term is the expected revenue, the second one is the expected repayment. The optimal loan contract is chosen by maximizing (25) subject to (24). As shown by BGG and Rannenberg (2016), the first order condition yields a positive relation between the external finance premium and the leverage ratio:

$$\mathbb{E}_t \left[ \frac{R_{t+1}^{KG}}{R_{t+1}^B} \right] = f(lev_t^e). \quad (26)$$

Indeed, when the leverage rises, expected marginal default cost increases and this requires a higher entrepreneurial profitability, captured by the expected external finance premium  $\mathbb{E}_t \left[ \frac{R_{t+1}^{KG}}{R_{t+1}^B} \right]$ .

Finally, entrepreneurs exit the market with probability  $1 - \chi_e$  in each period<sup>16</sup> and, if they do, they consume their accumulated net worth. They are replaced by new entrepreneurs that start the activity with funds  $\frac{l_e}{1 - \chi_e}$  provided by households.

### 3.5 Capital producers

Capital firms produce the capital good. They use an investment good which has the same composition of the consumption bundle:

$$i_t = \left[ (1 - \gamma)^{\frac{1}{\eta}} i_{Ht}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} i_{Ft}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}. \quad (27)$$

This good is an input to produce the capital good sold to entrepreneurs at nominal price  $Q_t$ . Moreover, capital producers buy back capital net of depreciation from entrepreneurs. These agents, maximize the following profit function:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \frac{\lambda_t}{\lambda_0} [q_t (k_t - (1 - \delta) k_{t-1}) - i_t]$$

<sup>15</sup>Index  $j$  is suppressed since in equilibrium entrepreneurs will choose the same leverage

<sup>16</sup>See footnote 10.

subject to the capital law of motion:

$$k_t = (1 - \delta) k_{t-1} + \left[ 1 - \frac{\kappa_I}{2} \left( \frac{i_t}{i_{t-1}} - 1 \right)^2 \right] i_t. \quad (28)$$

The first order condition of this problem positively links investment growth with the current and future price of capital.

### 3.6 Foreign economy

This paper focuses on an economy which is small compared to the rest of the world and therefore it takes all foreign variables as given: these are output  $y_t^*$ , price  $P_t^*$ , and nominal interest rate  $R_t^*$ . The first two are assumed to be constant over time, while the foreign rate follows an autoregressive stochastic process:

$$y_t^* = 1 \quad (29)$$

$$P_t^* = 1 \quad (30)$$

$$R_t^* = (1 - \rho_p) R^* + \rho_p R_{t-1}^* + v_t^p, \quad (31)$$

with  $R^*$  denoting the steady-state level of the foreign interest rate and  $v_t^p$  is an exogenous shock driving business cycle fluctuations in the small open economy:

$$v_t^p \sim N(0, \sigma_p^2).$$

Finally, foreign households demand domestic good according to the following function:

$$x_t = \gamma^* \left( \frac{p_{Ht}}{rer_t} \right)^{-\eta^*} y_t^*. \quad (32)$$

Thus, foreign demand for the domestic good increases when the real exchange rate depreciates.

### 3.7 Policy

The policy maker sets the nominal interest rate, the macroprudential policy stance and the size of capital controls. The nominal interest rate follows a Taylor rule, which responds to inflation and output gap:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[ \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{gdp_t}{gdp_t^N}\right)^{\phi_y} \right]^{1-\rho_R}, \quad (33)$$

where  $R$  is the steady-state nominal interest rate,  $gdp_t$  is gross domestic product and  $gdp_t^N$  is the frictionless level of output, defined as the level of GDP that would result in an economy without financial frictions, nominal rigidities and monopolistic competition. As a result, the ratio  $\frac{gdp_t}{gdp_t^N}$  can be interpreted as a measure of output gap. Moreover, in some simulations two alternative monetary policies will be considered:

$$\begin{aligned} \pi_t &= \pi \\ \frac{ner_t}{ner_{t-1}} &= \pi. \end{aligned}$$

The first one is a strict inflation targeting; the second one is a policy that sets the rate of change of the nominal exchange rate (a crawling peg)<sup>17</sup>.

The macroprudential instrument is a counter-cyclical tax on bank net worth, which targets the percentage gap between total loans (both to firms and to entrepreneurs) and their deterministic steady state. The choice to target loans reflects the common practice of several advanced and emerging economies, whose macroprudential instruments target credit to the non-financial sector. Given that in periods of financial boom the tax subtracts resources which banks could use to extend loans, this macroprudential instrument resembles a countercyclical capital regulation:

$$\tau_t^n = \tau^n + \phi_n \log\left(\frac{l_t}{l}\right). \quad (34)$$

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<sup>17</sup>Since in this model the real exchange rate is a stationary variable and there is no inflation in the foreign economy, in the steady-state it must hold  $\frac{ner_t}{ner_{t-1}} = \Delta rer \frac{\pi}{\pi^*} = \pi$ .

On the other hand, capital controls are policy measures that apply only to some financial instruments, by discriminating on the basis of residency<sup>18</sup>: in this model they are a tax on foreign debt<sup>19</sup>, and they tend to discourage foreign debt accumulation when this variable is higher than its long-run level.

$$\tau_t^d = \tau^d + \phi_d \log \left( \frac{d_t^*}{d^*} \right). \quad (35)$$

Both these taxes are rebated as lump-sum transfers to households. Total taxes paid by households read:

$$t_t = gov_t + \vartheta - (\tau_t^n n_t^b + \tau_t^d rer_t d_t^*) \quad (36)$$

where  $gov_t$  denotes exogenous public spending and  $\vartheta$  is a subsidy to domestic firms whose nature will be clear below. For simplicity, government spending is constant over time:

$$gov_t = gov \quad \forall t.$$

### 3.8 Market clearing

In equilibrium, all differentiated domestic firms produce the same quantities and use the same amount of inputs. Equilibrium in the domestic good market requires:

$$y_{Ht} = c_{Ht}^{tot} + i_{Ht} + gov_{Ht} + x_t + \frac{\kappa_{PH}}{2} (\pi_{Ht} - \pi)^2 y_t^H + mo\hat{n}c_{Ht},$$

where  $mo\hat{n}c_{Ht}$  denotes monitoring costs in deviation from the steady state,  $gov_{Ht}$  is public spending on domestic good and  $c_{Ht}^{tot}$  includes consumption of domestic goods by households, exiting bankers and exiting entrepreneurs. Similarly, different importers will produce same quantities and use same amount of inputs. So

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<sup>18</sup>See IMF (2017).

<sup>19</sup>Foreign deposits are one-period securities, so taxing foreign debt stocks is equivalent to taxing foreign debt flows.

equilibrium in imported good market requires:

$$y_{Ft} = c_{Ft}^{tot} + i_{Ft} + gov_{Ft} + \frac{\kappa_{PF}}{2} (\pi_{Ft} - \pi)^2 y_t^F + mo\hat{n}c_{Ft}. \quad (37)$$

The net financial position of the small open economy evolves according to:

$$rer_t d_t^* = R_{t-1}^* rer_t d_{t-1}^* - tb_t \quad (38)$$

where  $tb_t$  is the trade balance:

$$tb_t = p_{Ht} x_t - rer_t y_t^F. \quad (39)$$

In equilibrium, all banks will choose the same leverage ratio:

$$lev_t^b = \frac{l_t^e}{n_t^b} \quad (40)$$

and have same balance sheets:

$$l_t^e = n_t^b (1 - \tau_t^n) + rer_t d_t^* (1 - \tau_t^d) + d_t. \quad (41)$$

The evolution of banks' net worth reads:

$$n_t^b = \chi_b \left\{ \frac{(R_t^b - R_{t-1}) l_{t-1}^e}{\pi_t} - \left[ \frac{R_{t-1}^* rer_t}{rer_{t-1}} - \frac{(1 - \tau_{t-1}^d) R_{t-1}}{\pi_t} \right] rer_{t-1} d_{t-1}^* + \frac{R_{t-1} n_{t-1}^b (1 - \tau_{t-1}^n)}{\pi_t} \right\} + \iota_b \quad (42)$$

Similarly, entrepreneurs' leverage ratio, balance sheets and net worth evolution are given by:

$$lev_t^e = \frac{q_t k_t}{n_t^e} \quad (43)$$

$$q_t k_t = n_t^e + l_t^e \quad (44)$$

$$n_t^e = \chi_e \left\{ \frac{R_t^{KG}}{\pi_t} k_{t-1} q_{t-1} \left[ \int_{\bar{\omega}_t}^{\infty} \bar{\omega} f(\omega) d\omega - \bar{\omega}_t [1 - F(\bar{\omega}_t)] \right] \right\} + \iota^e. \quad (45)$$

Equilibrium in the loan market requires:

$$l_t = l_t^e + l_t^f. \quad (46)$$

Definition of gross domestic product:

$$gdp_t \equiv p_{Ht}y_{Ht} + (p_{Ft} - rer_t)y_{Ft} \quad (47)$$

and  $gdp_t^{net}$  is GDP net of monitoring and price adjustment costs:

$$gdp_t^{net} \equiv c_t^{tot} + i_t + gov_t + tb_t. \quad (48)$$

Finally, the credit spread is defined as:

$$spread_t = \mathbb{E}_t \left( \frac{R_{t+1}^B}{R_t} \frac{R_{t+1}^{Kg}}{R_{t+1}^B} \right) = \mathbb{E}_t \left( \frac{R_{t+1}^{KG}}{R_t} \right). \quad (49)$$

### 3.9 Correcting frictions in the steady state

The steady state of the model is affected both by financial frictions and monopolistic competition. Hence, a-priori, the social planner has no intrinsic motivation to use countercyclical financial policies that, by mitigating the impact of economic shocks, move the economy close to an inefficient steady state in each period. Therefore, some assumptions are made in order to eliminate frictions from the steady state. In particular, it is assumed that in the steady state domestic firms receive a subsidy that fully compensates them for the presence of financial frictions and monopolistic competition<sup>20</sup>; in particular, total cost for domestic firms are given by:

$$TC_t = r_t^K k_{t-1} [1 + \psi_k (r_t - 1)] (1 - \tau^K) (1 - \tau_H^M) + w_t h_t [1 + \psi_h (r_t - 1)] (1 - \tau^W) (1 - \tau_H^M). \quad (50)$$

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<sup>20</sup>A subsidy to compensate for monopolistic competition in the steady state is often assumed in papers studying optimal monetary policy (see Woodford (2003)). A subsidy to compensate for financial frictions in the steady state is assumed in De Paoli and Paustian (2017).

with:

$$\tau^W = 1 - \frac{1}{[1 + \psi_h (r - 1)]} \quad (51)$$

$$\tau^K = 1 - \frac{r + \delta - 1}{r^K [1 + \psi_k (r - 1)]} \quad (52)$$

$$\tau_H^M = \frac{1}{\varepsilon_H}. \quad (53)$$

Under these assumptions, in the steady state the efficient conditions (3) and (5) hold. Indeed, in the steady state:

$$r^K = r - (1 - \delta).$$

For the same reason, a subsidy to importing firms is assumed:

$$\tau_F^M = \frac{1}{\varepsilon_F}.$$

Moreover, I further assume that in steady state, monitoring costs are transferred from the government to households. So, the tax that shows up in the government budget constraint (36) is given by:

$$\vartheta = [\tau^W (1 - \tau_H^M) + \tau_H^M] h \cdot w + [\tau^K (1 - \tau_H^M) + \tau_H^M] r^K k + \tau_F^M rer \cdot y_F - mon, \quad (54)$$

where, as usual, variables without time subscript are taken in the steady state.

### 3.9.1 Short-run inefficiencies

At this point it is useful summarizing the short-run inefficiencies of this model economy. There are two sets of frictions. The first set concerns nominal rigidities: both domestic and importing firms pay adjustment costs when they change prices. The second set regards financial frictions. First, the presence of frictions between domestic depositors and banks and between banks and entrepreneurs creates a wedge between the expected return on capital and the risk-free interest rate (variable  $spread_t$  in the model). Second, monitoring costs paid by banks are resources subtracted to consumption or investment. Third, the presence of working capital

loans creates a wedge between firms' input costs and the marginal productivity of these inputs. These three frictions characterize the model of Rannenberg (2016) too. In addition, in my model the interest parity condition is broken (see section 3.3) and a foreign interest spread opens up:

$$spread_t^* = R_t - \left[ R_t^* + \mathbb{E}_t \left( \frac{ner_{t+1}}{ner_t} \right) \right].$$

Henceforth, I refer to this second set of inefficiencies as financial fluctuations.

### 3.10 Calibration

The model is calibrated at the quarterly frequency to match some empirical Brazilian facts. Brazil is chosen for three reasons: i) it is one of the main emerging economies; ii) most of Brazil's foreign debt is financed in foreign currency (mainly US Dollars); iii) more importantly, since late 2009 Brazil has implemented controls on capital inflows, which took the form of a tax on the exchange rate transaction when capital first entered Brazil<sup>21</sup> (similar to the capital control instrument considered in this paper). The first set of parameters are those governing preferences and production. The inverse of intertemporal elasticity of substitution and the inverse of Frisch elasticity are set to standard values:  $\sigma = 2$  and  $\varphi = 1$ ; the discount factor is set to  $\beta = 0.9811$ , which implies an annual steady-state real interest rate of 7.71% (average real rate<sup>22</sup> during the period 2009-2014); the labor supply shifter  $\kappa_L$  is fixed to 6.03 to match steady-state hours of work of 1/3; the capital elasticity in the production function is set to  $\alpha = 0.33$ ; it is assumed that domestic firms have to pre-finance entirely labor and capital costs, so both  $\psi_k$  and  $\psi_h$  are set to one; steady-state domestic production is normalized to 1, which implies  $A = 1.0758$ ; the capital depreciation rate is fixed to  $\delta = 0.025$ ; the elasticity of substitution between domestic and foreign goods  $\eta$  is set to 1.3 and the same number is used also to calibrate its foreign counterpart  $\eta^*$ , both being in the range of values used in the open economy literature;  $\gamma$ , the weight of foreign good in final good bundle, is set to 0.15, to match an imports/gdp ratio of 15%;

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<sup>21</sup>See Chamon and Garcia (2016).

<sup>22</sup>The Brazilian real interest rate is computed as the difference between SELIC rate (the Brazilian Central Bank target rate) and inflation rate.



the elasticity of substitution between differentiated goods is set to 11 both in the domestic and in the importing sector, following Carvalho and Castro (2015); the domestic relative price  $p_H$  is normalized to one: this implies  $\gamma^* = 0.1586$ .

Moving to financial sector parameters, the steady-state total bank leverage ratio<sup>23</sup> is set to 10, consistently with an average bank capital-asset ratio of 10% in Brazil during the period 2005-2014: this value corresponds to a pretty high divertable proportion of bank assets in steady state,  $\theta = 0.64$ . The annual lending spread  $R^L - R$  is calibrated to 4.3%, in line with the average difference between lending rate and the policy rate SELIC during 2005-2014; Brazilian foreign debt was 25% of GDP on average during 2000-2014, so  $\frac{rer \cdot d^*}{4 \cdot gdp}$  is set to 0.25: this implies  $\theta_0 = 0.5606$  and  $\theta_1 = 3.9897$ ; as standard, the foreign discount factor is calibrated at 0.99<sup>24</sup>; bank survival probability is set to 0.912, implying a bank start-up fund equal<sup>25</sup> to  $\iota_b = 0.0003$ . As reported in Karpowicz et al. (2016), in the Brazilian non-financial sector, the average equity/asset ratio is 42% during the period 2005-2015: this implies a steady-state entrepreneurs' leverage equal to 2.06, net of loans to domestic firms, resulting in a start-up fund parameter  $\iota_e = 0.0005$ ; the entrepreneurs' steady-state default rate is set to 3.3% of total assets (annually) to match bank non-performing loans average from 2005 to 2014; this implies an idiosyncratic shock standard deviation  $\sigma_e = 0.27$ ; finally, I calibrate  $\chi_e$  at 0.95<sup>26</sup> and the monitoring cost  $\mu = 0.2981$  (as in Rannenberg (2016)).

Moving to the parameters governing the model's dynamics (but not the steady state), the cost of adjusting investment goods production  $\kappa_I$  is set to 2.66, as in Carvalho and Castro (2015); the Rotemberg price adjustment costs in the two sectors  $\kappa_{PH}$  and  $\kappa_{PF}$  are both set to 55.1: this value corresponds to an average price duration of three quarters in the Calvo framework<sup>27</sup>. In order to calibrate the two parameters pertaining to the autoregressive exogenous process for the foreign

<sup>23</sup>In the definition of total bank leverage loans to domestic firms are also included.

<sup>24</sup>This implies a foreign interest rate higher than the average historical US policy rate. However, it is reasonable to assume that Brazilian banks pay a premium on this rate, when they borrow from abroad.

<sup>25</sup>Higher survival probability would result in a negative bank start-up fund.

<sup>26</sup>Higher values would result in a negative entrepreneurs' start-up fund.

<sup>27</sup>In the standard Calvo price-rigidity framework, a price duration of three quarters implies a fraction of firms that does not adjust prices in every period equal to 2/3: this number is in the lower bound of values in the open economy New Keynesian literature; however, Gouvea (2007) shows that prices in Brazil are relatively flexible, therefore my choice seems reasonable.

rate, an AR(1) model is estimated using quarterly data for the LIBOR rate, with time span 2000-2014: results yield  $\rho_p = 0.95$  and  $\sigma_p = 0.12\%$ <sup>28</sup>.

Finally, the parameters of the policy rules are the following: in the baseline specification, both the constant (steady-state) and the counter-cyclical coefficients of macroprudential and capital control instruments are set to zero; following Carvalho and Castro (2015), the monetary rule features a smoothing parameter  $\rho_m = 0.825$ , an inflation response  $\phi_\pi = 1.9$  and an output gap response  $\phi_y = 0$ ; moreover, steady-state inflation is calibrated at 4.5% annually, in line with the Brazilian Central Bank's target. Finally, the government's spending/gdp ratio is set to 20%. Table 1 summarizes the calibration; table 2 shows the steady-state targets chosen to set some parameters.

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<sup>28</sup>Using the Fed Funds Rate estimates are very similar.

Parameters	Description	Value
$\beta$	Discount factor	0.9811
$\sigma$	Inverrse of EIS	2
$\varphi$	Inverse of Frisch elsticity	1
$\kappa_L$	Labor supply shifter	6.03
$\gamma$	Weight of foreign good	0.15
$\gamma^*$	Foreign demand shifter	0.1586
$\eta, \eta^*$	ES between domestic and foreign good	1.3
$\varepsilon_H, \varepsilon_F$	ES between differentiated goods	11
$\alpha$	Share of capital in production	0.33
$A$	Steady-state TFP	1.0758
$\psi_h, \psi_k$	Share of input cost paid in advance	1
$\kappa_{PH}, \kappa_{PF}$	Price adjustment costs	55.743
$\delta$	Depreciation rate	2.5%
$\kappa_I$	Investment adjustment cost	2.66
$\mu$	Monitoring cost	0.2981
$\sigma_e$	Entr. dispersion	0.2667
$\chi_e$	Entr. survival probability	0.9490
$\theta_0$	Divertable proportion of assets	0.5606
$\theta_1$	Home bias in funding	3.9897
$\chi_b$	Bank survival probability	0.912
$\iota_b$	Wealth for new banks.	0.0003
$\iota_e$	Wealth for new entr.	0.0005
$\phi_\pi, \phi_y$	Taylor rule coefficients	1.9, 0
$\rho_m$	Interest rate smoothing coefficient	0.825
$\pi$	Steady-state inflation	1.0133
$gov$	Steady-state public spending	0.2
$\tau^d, \tau^n$	Stead-state instruments	0
$\rho_p$	Persistence of foreign interest shock	0.95
$\sigma_p$	SD of foreign interest shock shock	0.012
$y^*, P^*$	Foreign output and price	1
$R^*$	Foreign interest rate	1.0101

**Table 1:** Calibrated parameters

SS Target	Description	Value
$r$	Real interest rate	7.77% <i>p.a.</i>
$h$	Hours of work	1/3
$y_H$	Domestic output	1
$p_H$	Relative price of domestic good	1
$\frac{imp}{gdp}$	Import/gdp ratio	13%
$\frac{rer \cdot d^*}{A \cdot gdp}$	External debt/gdp ratio	25% <i>p.a.</i>
$R^L - R$	Bank lending spread	4.3% <i>p.a.</i>
$\frac{n^b}{l}$	Equity/loan ratio (banks)	10
$\frac{n^e}{l+n^e}$	Equity/asset ratio (non fin. sector)	42%
$def$	Default rate	3.3% <i>p.a.</i>

**Table 2:** Steady-state targets

## 4 Numerical Simulation

This section illustrates the quantitative results of the paper. In the first paragraph, I show the impact of a foreign interest rate hike and analyze whether macroprudential policies and capital controls can smooth the effect of the shock, when monetary policy follows a standard Taylor rule; in the second paragraph, I numerically compute the optimal policy from a social planner point of view, conditional on the instruments that are available: I initially focus only on monetary policy, then I assume that the policy maker<sup>29</sup> can manage three instruments (interest rate, macroprudential and capital control tax). In the third paragraph, I repeat these simulations with technological and financial shocks. Finally, I show impulse response functions to a foreign interest rate shock when the central bank uses a strict inflation targeting and when it pegs the nominal exchange rate.

### 4.1 Positive Analysis

In order to simulate impulse response functions, the model is solved using a first-order approximation around the deterministic steady state. In the baseline scenario (figure 2, blue solid line), an increase in the foreign interest rate by one

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<sup>29</sup>I assume that there is just one policy maker that sets the three policy instruments: studying coordination issues between monetary and financial authorities goes beyond the goal of the paper.

standard deviation (48 basis points in annual terms) depreciates the real exchange rate ( $rer_t$  is higher), generating three main effects: i) the trade account improves; ii) imports are more costly, and this increases inflation and induces a monetary tightening. iii) bank profits fall, since the cost of both domestic and foreign deposit is higher, so banks' net worth drops by about 4%; on top of that, banks reduce foreign debt: capital inflows (expressed in foreign currency) decline by about 0.8% at the trough. Effect i) is not able to compensate the recessionary impact of ii) and iii): the monetary tightening reduces consumption and investment, driving down asset prices. On the banks' side, the fall in net worth decreases the cost for bankers to divert assets: therefore, depositors require a higher bank profitability in order to not withdraw funds, hence the lending spread rises. Banks' net worth quickly rebounds thanks to the improved profitability. On the other side, the decline in asset price  $q_t$  caused by monetary tightening, decreases entrepreneurs' net worth and raises their leverage: more entrepreneurs default, expected bankruptcy costs get higher and this requires an increase in entrepreneurs' profitability, so the external finance premium  $spread_t^e$  must also rise. All in all, banks provide less loans to the non-financial sector by about 0.5% at the trough, GDP falls by 0.4% on impact, while the drops in consumption and investment are even more pronounced; finally, the credit spread rises almost by 300 basis point in annual terms. Notice that impulse responses are consistent with Rey (2015)'s view: a monetary restriction in the core country strongly affects financial conditions and monetary policy in an emerging market even if a flexible exchange rate regime is in place.

A capital control instrument with a counter-cyclical coefficient  $\phi_d = 1^{30}$  (figure 2, red crossed line) is able to counteract very well the increase in foreign debt cost. In particular, a capital control loosening reduces the spread between the domestic and the foreign interest rate. The real exchange rate depreciates by less, the inflation response is almost nil and so is the monetary policy reaction. These effects substantially alleviate the recessionary impact of the shock: GDP decreases by one half compared to the baseline scenario, while the total spread rises by less than 100 basis points. When instead the macroprudential instrument is in place with a coefficient  $\phi_n = 1^{31}$  (figure 2, black dashed line), the marginal gain to the

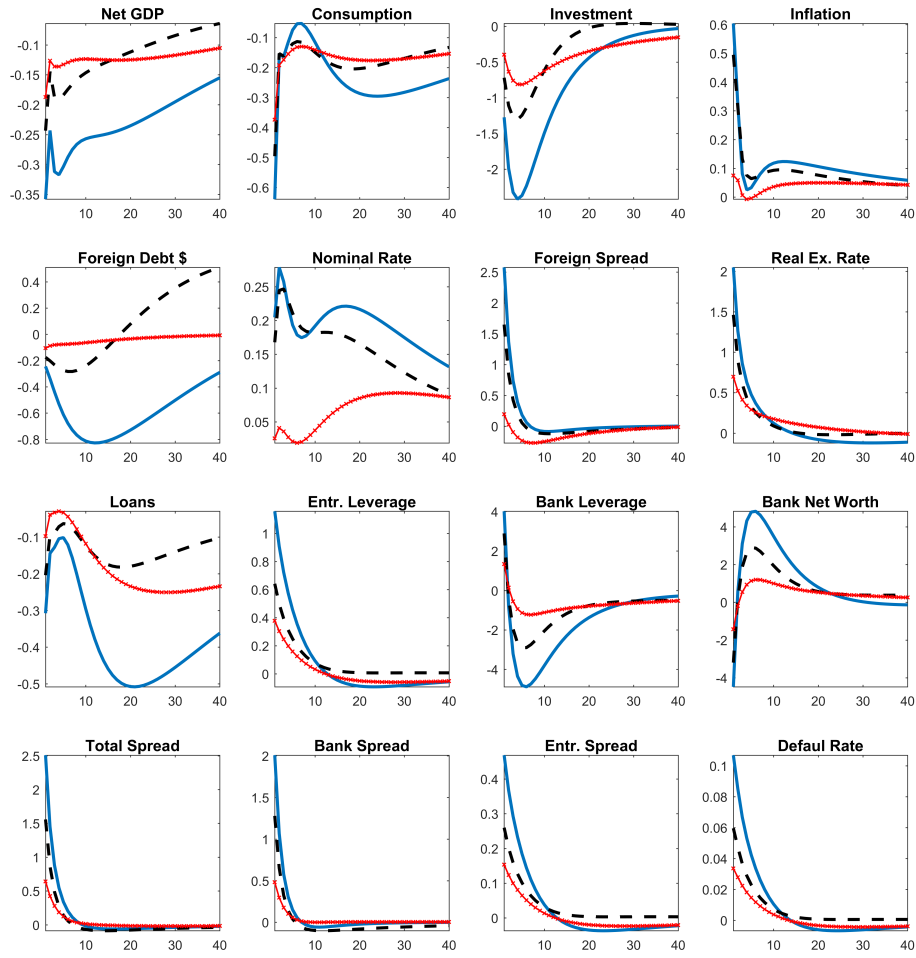
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<sup>30</sup>This means that a reduction in foreign debt by 1% implies a decrease in  $\tau_t^d$  by 0.01.

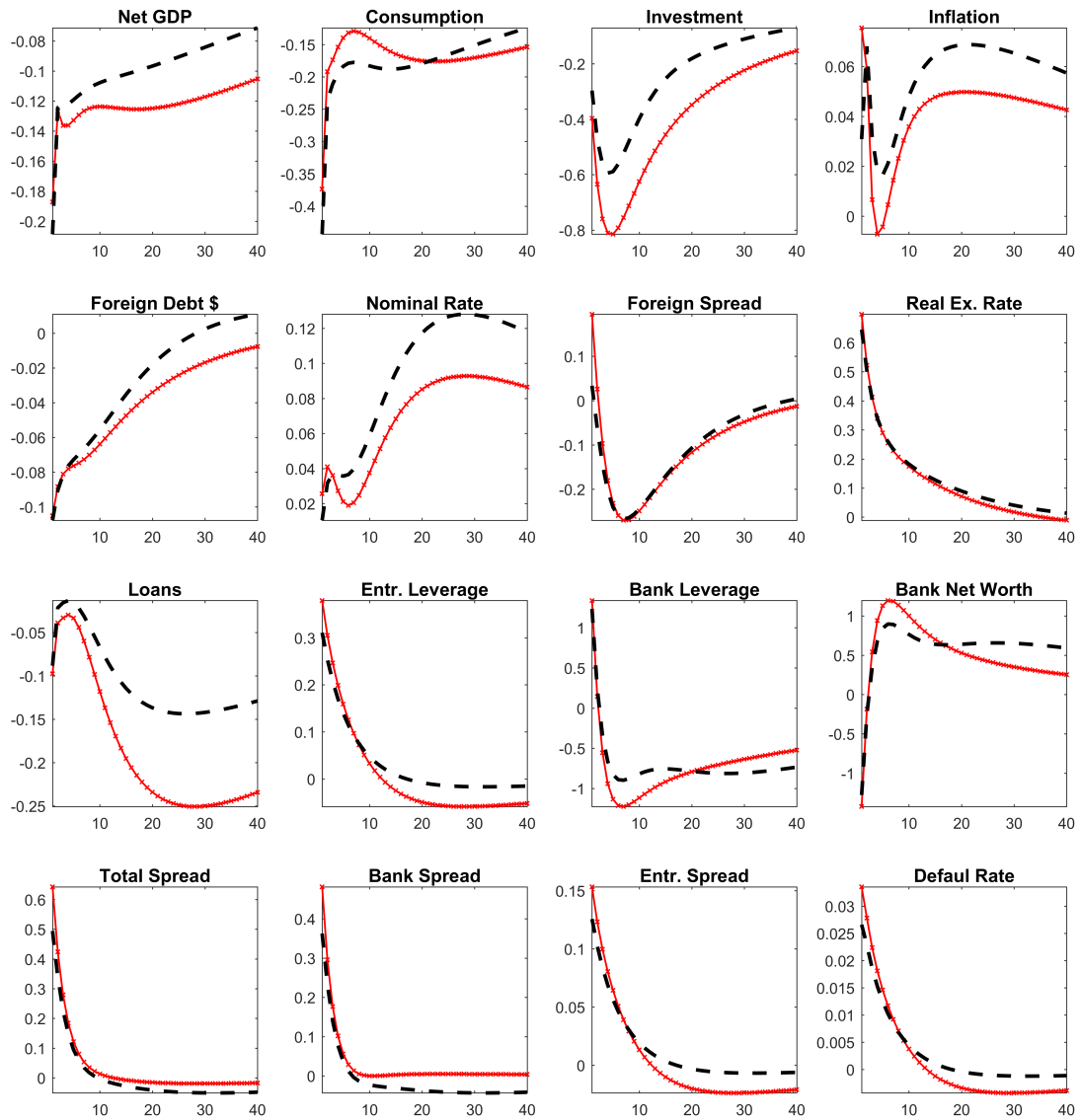
<sup>31</sup>This means that a reduction in total loans by 1% implies a decrease in  $\tau_t^n$  by 0.01.

banker of having an additional unit of net worth is higher, holding other variables constant. As a result, the cost for bankers from diverting assets decreases by less compared to the model without policies. The required rise in bank profitability is milder and this brings positive spillovers on the economy. However, such a policy is not able to sufficiently dampen the real exchange rate depreciation and the resulting boost in inflation: indeed, monetary tightening is almost as strong as in the baseline case, as well as the response of the real economy.

Finally, when both policies are active (black dashed line in figure 3), the economic downturn is even more mitigated, compared to the scenario in which only capital controls are implemented (red crossed line in figure 3).



**Figure 2:** IRFs to a one standard deviation increase in the foreign interest rate, when the central bank adopts a Taylor rule. Responses are in log-deviations from the steady state, except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The blue solid line is the baseline model, the red dashed line adds an active capital control with  $\phi_d = 1$  to the baseline model, the black dashed line adds an active macroprudential tax with  $\phi_n = 1$  to the baseline model. One period corresponds to one quarter.



**Figure 3:** IRFs to a standard deviation increase in the foreign interest rate, when the central banks adopts a Taylor rule. Responses are in log-deviations from the steady state except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The red crossed line adds an active capital control with  $\phi_d = 1$  to the baseline model, the black dashed line adds an active macroprudential tax with  $\phi_n = 1$  and an active capital control, with  $\phi_d = 1$  to the baseline model. One period corresponds to one quarter.



## 4.2 Normative Analysis

Up to now no statement has been made about the optimal monetary policy stance and the desirability of macroprudential and capital control policies: this is the goal of this paragraph. I conduct the welfare analysis by taking a second order approximation of the model, as done in Schmitt-Grohé and Uribe (2004). Even if my model features heterogeneous agents, bankers and entrepreneurs are risk neutral and their average consumption is independent from stochastic shocks<sup>32</sup>. Therefore, I can assume that the welfare metric is the conditional expected discounted utility of the representative household, taking the deterministic steady state as the initial condition:

$$\mathcal{W}_t = \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[ \frac{1}{1-\sigma} \left( c_t - \kappa_L \frac{h_t^{1+\varphi}}{1+\varphi} \right)^{1-\sigma} \right] \right\}.$$

In order to provide a quantitative economic meaning to the analysis, I compute a compensating fraction  $\Omega$  of households' consumption that would be necessary to equate expected welfare  $\mathcal{W}_t$  in the baseline scenario to the level of welfare under a generic policy<sup>33</sup>.

The first experiment is an optimal monetary policy analysis, assuming that macroprudential policy and capital controls are not in the policy maker's toolkit: so I set  $\phi_d = \phi_n = 0$  and I maximize over  $\phi_\pi$  and  $\phi_y$ . The resulting optimal parameters are  $\phi_\pi = 1.01$ , and  $\phi_y = 0.5$  which yield a welfare gain of 0.16% in terms of consumption equivalent (table 3) with respect to the baseline calibration; what prevents the central bank from responding more aggressively? The monetary authority has to trade-off inefficient inflation and financial fluctuations: indeed, the foreign interest rate innovation is similar to a supply shock, since it pushes output and inflation in opposite directions; on top of that, the credit spread increases. Hence, if the central bank responds aggressively to CPI growth, it would reduce output even more, amplifying the widening of credit and foreign spread and boosting default costs. Notice that the interpretation of foreign interest rate shocks as cost push factors is confirmed by empirical evidence: indeed, the em-

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<sup>32</sup>See Faia and Monacelli (2007).

<sup>33</sup>Remind that the baseline scenario consists of a Taylor rule with  $\phi_\pi = 1.9$ , with no macroprudential and capital control policies.

irical work by Maćkowiak (2007) finds that an increase in the Fed Funds rate boosts inflation in a sample of emerging countries, with impulse responses close in magnitude to my simulations in the previous paragraph. Therefore, a full inflation targeting ( $\pi_t = \pi \forall t$ ) is not welfare improving compared to the baseline scenario (first column in table 3), since it would entail an excessive interest rate tightening. The same reasoning holds for a policy pegging the nominal exchange rate: impulse responses in the next paragraph point out how the monetary tightening necessary to defend the exchange rate would greatly exacerbate the recessionary impact of the shock.

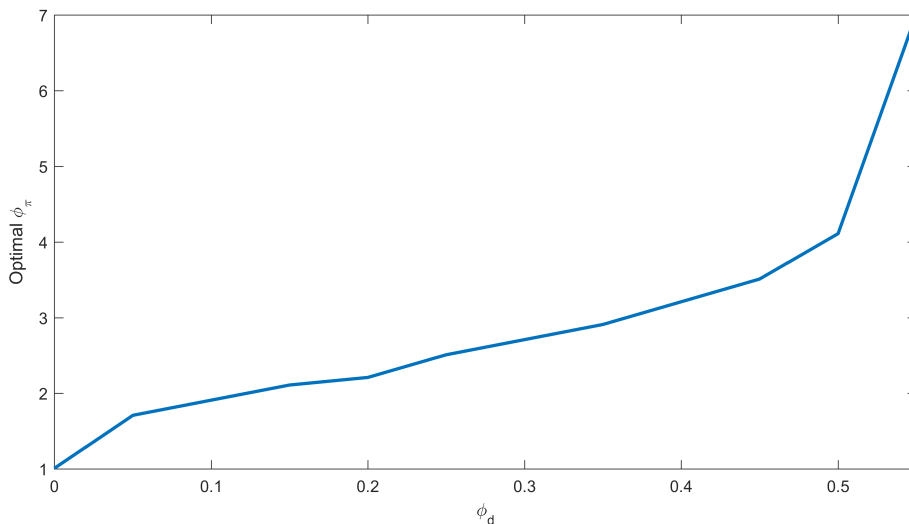
The second experiment is an optimal policy analysis conditional on three instruments (monetary, macroprudential and capital controls policies): it turns out that monetary policy should follow a strict inflation targeting<sup>34</sup>, capital controls are active with a coefficient equal to 6.8 and the macroprudential instrument is set to 0 in every period. This policy yields a relevant welfare gain of 0.46% in terms of consumption equivalents. Intuitively, capital controls counterbalance movements in the foreign interest rate: their easing reduces the cost of foreign debt when  $R_t^*$  is relatively high and their tightening does the opposite when  $R_t^*$  is relatively low. As a consequence, this instrument is able to stabilize financial fluctuations. Once these fluctuations are stabilized, monetary policy can then safely target inflation, without any need to trade-off financial stability concerns against the inflation objective. Indeed, the degree of inflation targeting is increasing in the capital control coefficient  $\phi_d$  (table 4), while optimal  $\phi_y$  is decreasing. Therefore, the simulation suggests that financial account restrictions tend to make the central bank less dependent on foreign monetary policy, as suggested by Rey (2015).

The results of the analysis so far leave macroprudential policy out of the picture: does this mean that macroprudential instruments are not useful in an emerging economy? The answer suggested by further experiments is no. First, if the country cannot impose restrictions on foreign capital flows for some reasons - e.g. constraints arising from international agreements - then the optimal  $\phi_n$  turns out to be positive, and an active macroprudential policy is optimal jointly with a strict inflation targeting. Second, if the macroprudential instrument directly targets the credit spread rather than loans, then both capital controls and macroprudential

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<sup>34</sup>In the numerical optimization  $\phi_\pi \rightarrow \infty$  and  $\phi_y = 0$

policy should be active (although the welfare gain compared to the case with only active capital controls is very small). Third, macroprudential policy is preferred to capital controls if the economy is hit by TFP shocks (see next paragraph).



**Figure 4:** Optimal Taylor rule coefficient as a function of capital controls, under  $v_t^p$  shocks.

	Target	Peg	Opt. Mon.	Optimal
$\phi_\pi$	—	—	1.01	$\infty$
$\phi_y$	—	—	0.5	0
$\phi_d$	—	—	—	6.8
$\phi_n$	—	—	—	0
$\Omega$	-0.10%	-1.62%	0.16%	0.46%

**Table 3:** Welfare analysis under foreign interest rate shocks.

### 4.3 Other shocks

Monetary policy and capital controls are strongly complementary because, in this model, foreign interest rate shocks move output and inflation in opposite directions. Now I consider an exogenous innovation which instead drives output and prices in the same direction, thus behaving as a demand shock. Suppose that

entrepreneurs are subject to shocks  $v_t^e$  hitting their net worth. Equation (45) can be rewritten as:

$$n_t^e = \chi_e \left\{ \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} \left[ \int_{\bar{\omega}_t}^{\infty} \bar{\omega} f(\omega) d\omega - \bar{\omega}_t [1 - F(\bar{\omega}_t)] \right] \right\} \exp(v_t^e) + \iota^e. \quad (55)$$

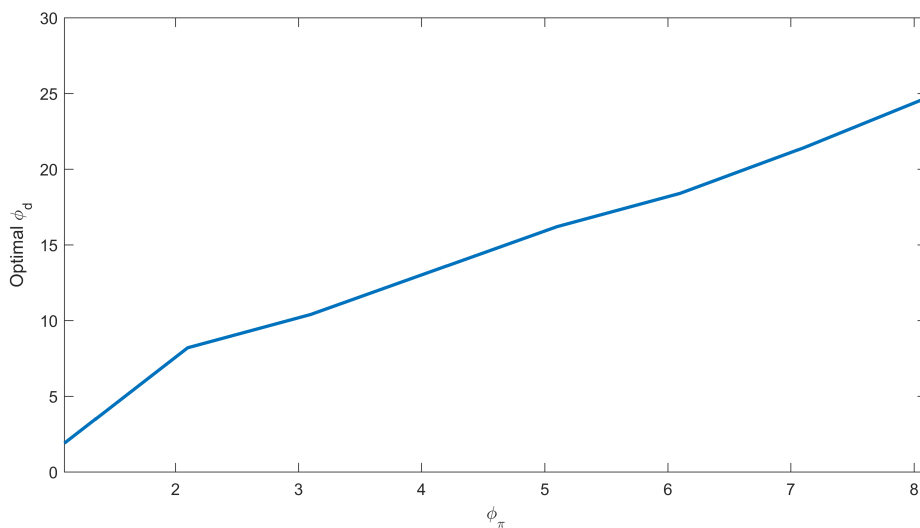
The size of the shock is set to  $v_t^e = -0.035$ , to get a decline in foreign debt as large as under foreign interest rate shocks. This shock can be interpreted as a financial shock that captures “irrational exuberance” or asset price bubbles, given that it modifies the net worth of entrepreneurs without movements in fundamentals (see Nolan and Thoenissen (2009) and Christiano et al. (2010)). The shock causes a reduction in investment and consumption, which depresses domestic and foreign good demand (figure 6): inflation goes down, the central bank cuts the nominal interest rate and the real exchange rate depreciates. A lower entrepreneurial net worth increases leverage and  $spread_t^e$ . Moreover, since the decline in  $n_t^e$  exceeds the drop in  $q_t k_t$ , entrepreneurs demand more loans. Therefore, financial intermediaries expand their balance sheets, depositors require a higher bank profitability and  $spread_t^b$  rises. On top of that, given that the marginal gain of expanding loans is higher compared to the marginal gain of borrowing abroad, foreign debt falls.

A capital control loosening (red crossed line) makes foreign debt more attractive: the cost of foreign borrowing declines, foreign spread narrows and this has positive spillovers on bank leverage and the credit spread. Furthermore, given that the foreign debt’s fall is mitigated, the real depreciation is fully offset and this creates deflationary pressures. All in all, the investment fall is partially dampened thanks to capital controls, while inflation response is amplified.

Under this scenario, macroprudential policy is not countercyclical, if it targets loans: as the latter expand after a net worth shock, the macroprudential tax is increased, exacerbating the recession (black dashed line).

Given the impulse response analysis, it is not surprising that optimal monetary policy alone (keeping  $\phi_d$  and  $\phi_n$  fixed to 0) prescribes a strict inflation targeting in response to a shock to entrepreneurs’ net worth: indeed, during demand-driven recessions inflation targeting implies an interest rate cut, which partially dampens the rise in  $spread_t$ . Therefore, the central bank does not face any trade-off between

inflation and financial fluctuations. When the capital control tax is active, it helps to stabilize spreads and default rate, by reducing bank borrowing costs: the optimal monetary and capital control policy consist in  $\phi_\pi \rightarrow \infty$  and  $\phi_d \rightarrow \infty$ . On the other hand, macroprudential policy is not welfare improving, because it tends to worsen the negative impact of the shock. Finally, it is interesting to study a situation in which the policy maker takes as given monetary policy and chooses the optimal capital control. The optimal coefficient  $\phi_d$  is increasing in  $\phi_\pi$  (figure 5): indeed, for low values of  $\phi_\pi$ , capital controls magnify inflation fall, forcing firms to pay high adjustment costs. Thus, shocks to entrepreneurs' net worth reverse the interaction between monetary policy and capital controls, compared to the foreign interest shock scenario: under  $v_t^e$  shocks, capital controls are *more* desirable when monetary policy is tighter, while the opposite holds under  $v_t^p$  innovations.



**Figure 5:** Optimal capital control as a function of Taylor rule coefficient, under  $v_t^e$  shocks.

	Target	Peg	Opt. Mon.	Optimal
$\phi_\pi$	—	—	$\infty$	$\infty$
$\phi_y$	—	—	0	0
$\phi_d$	—	—	—	$\infty$
$\phi_n$	—	—	—	0
$\Omega$	0.92%	-2.22%	0.92%	2.04%

**Table 4:** Welfare analysis under shocks to entrepreneurs net worth.

The benefits of macroprudential policy emerge best under technology shocks. TFP  $A_t$  is assumed to follow an  $AR(1)$  process, with persistence  $\rho_a = 0.95$  and one-standard-deviation shock  $v_t^a$ , standard values in the international macroeconomic literature.

A negative TFP shock of one standard deviation brings about a fall in domestic production, consumption and investment, amplified by the monetary tightening needed to mitigate inflationary pressures (figure 7). Banks find it more profitable to substitute foreign with domestic deposits; moreover, they find themselves with a higher net worth, due to a real appreciation which reduces the burden of foreign debt. Entrepreneurs reduce loan demand, since capital investment is now less profitable: their leverage slightly decreases, and this requires a mild rise in the external premium.

Macroprudential policy dampens the loan reduction, inducing entrepreneurs to invest more; interestingly, the spread's response switches sign and gets negative: this entails that a small macroprudential subsidy is sufficient to stabilize  $spread_t$ . On the other hand, the capital control tax magnifies the crisis given that it increases when foreign debt is higher.

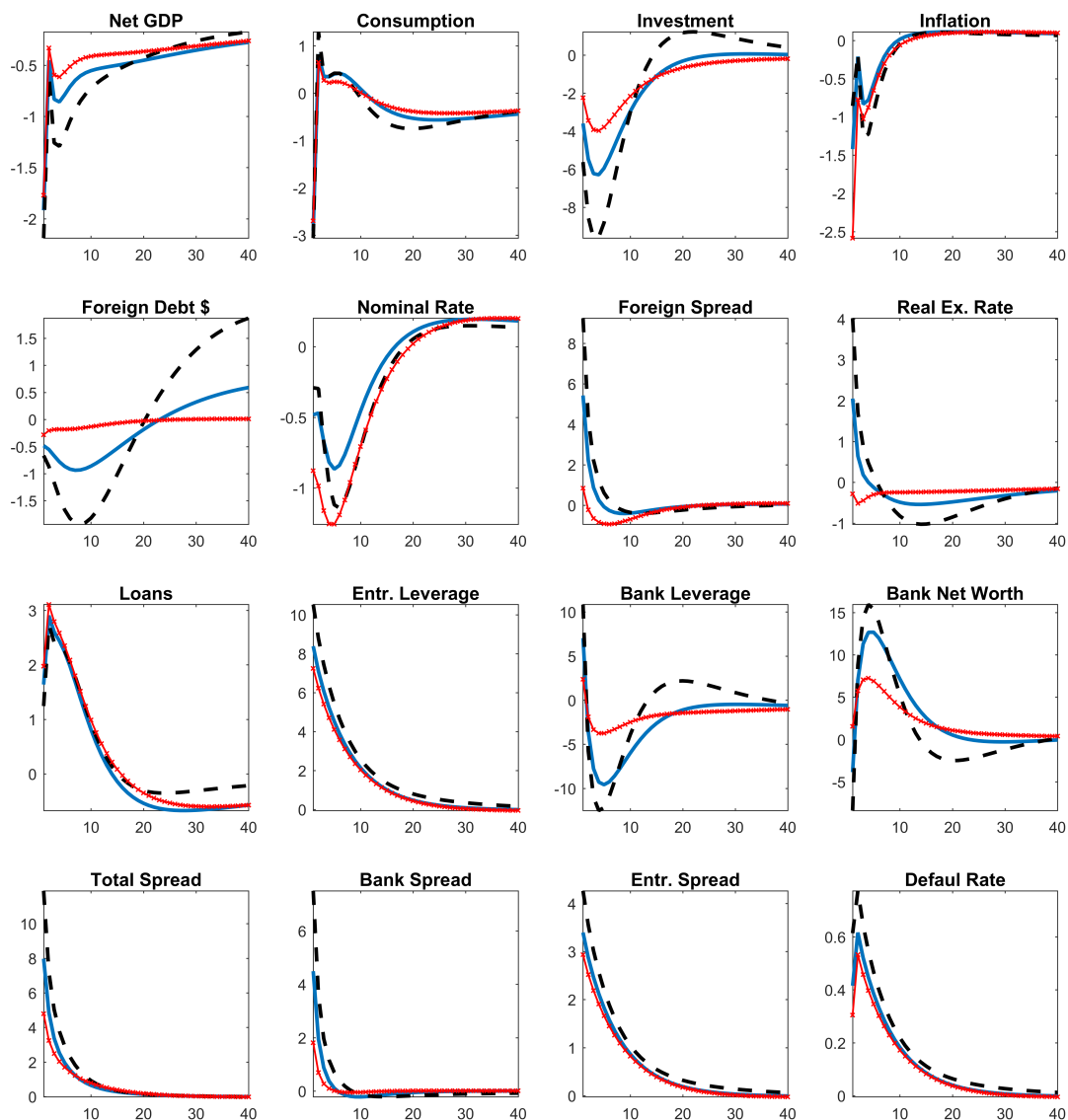
On the normative side, if monetary policy were alone it would have to follow a strict inflation targeting. When three instruments are available,  $\pi_t = \pi \forall t$  continues to be optimal, jointly with a mild macroprudential policy ( $\phi_n = 0.22$ ). As expected, capital controls are not welfare improving, since foreign debt is counter-cyclical under TFP shocks.

The bottom line of the normative analysis is that the desirability of capital controls and macroprudential policy is shock dependent. Furthermore, monetary policy is shown to be highly complementary with capital controls: while under

foreign interest rate shocks capital controls allow the monetary authority to be more aggressive against inflation, under entrepreneurs net worth shocks, an aggressive monetary policy helps capital controls to be tighter in mitigating financial fluctuations.

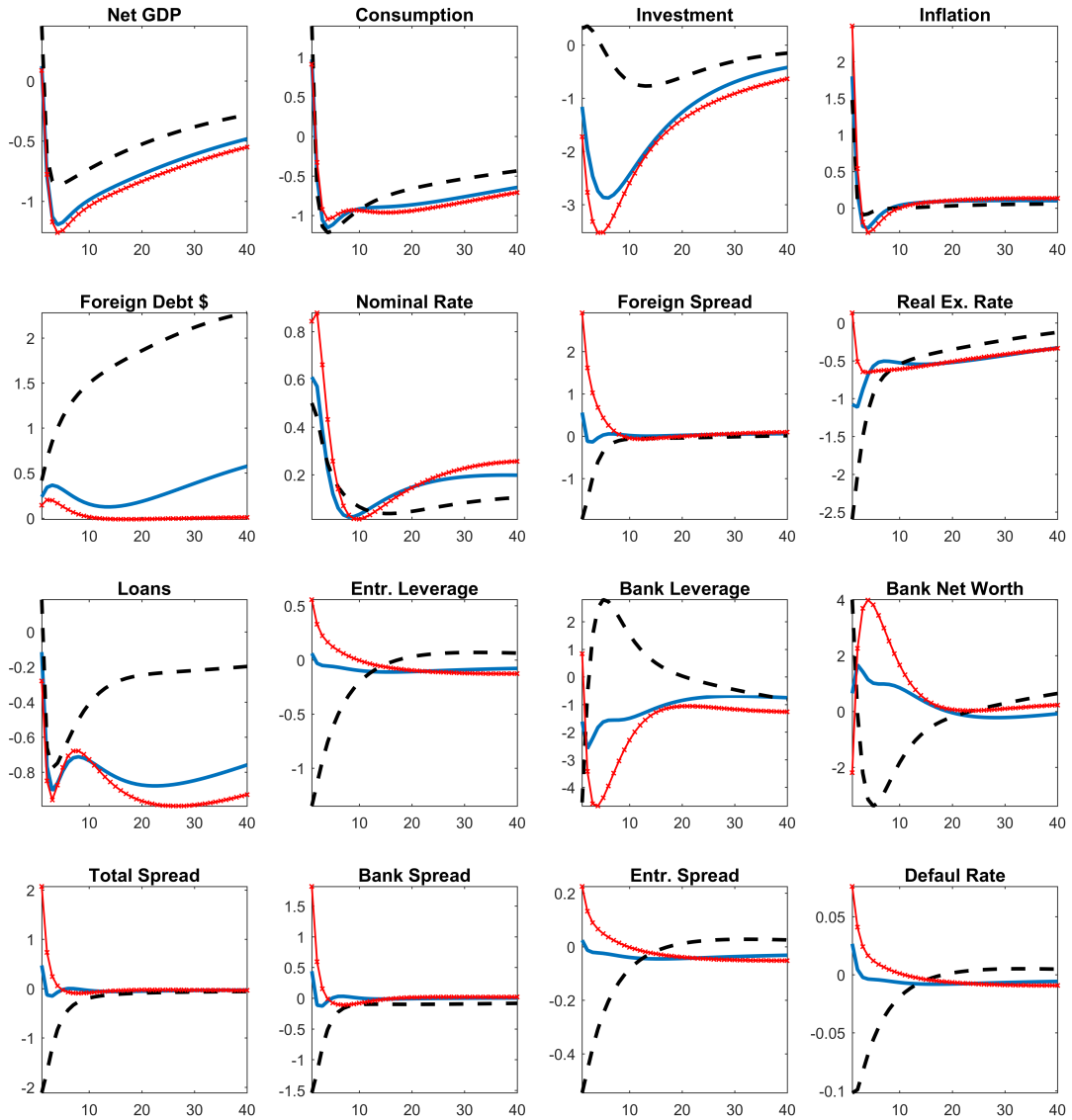
	<b>Target</b>	<b>Peg</b>	<b>Opt. Mon.</b>	<b>Optimal</b>
$\phi_\pi$	—	—	$\infty$	$\infty$
$\phi_y$	—	—	0	0
$\phi_d$	—	—	—	0
$\phi_n$	—	—	—	0.22
$\Omega$	0.33%	-0.37%	0.33%	0.37%

**Table 5:** Welfare analysis under technology shocks.



**Figure 6:** IRFs to a standard deviation reduction in entrepreneur net worth when the central bank adopts a Taylor rule. Responses are in log-deviations from the steady state except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The red dashed line adds an active capital control, with  $\phi_d = 1$  to the baseline model, the black dashed line adds an active macroprudential tax, with  $\phi_n = 1$  and an active capital control, with  $\phi_d = 1$  to the baseline model. One period corresponds to one quarter.





**Figure 7:** IRFs to a standard deviation reduction in TFP when the central bank adopts a Taylor rule (blue solid line). Responses are in log-deviations from the steady state except for inflation, nominal rate and spread, whose response is in annual deviations from the steady state. The crossed red line adds an active capital control, with  $\phi_d = 1$  to the baseline model, the dashed black line adds an active macroprudential tax, with  $\phi_n = 1$  and active capital control, with  $\phi_d = 1$  to the baseline model. One period corresponds to one quarter.

## 4.4 Alternative monetary policies

What is the role of the other two financial policies when the central bank can choose between fully stabilizing inflation or the nominal exchange rate? I answer these questions in what follows<sup>35</sup>.

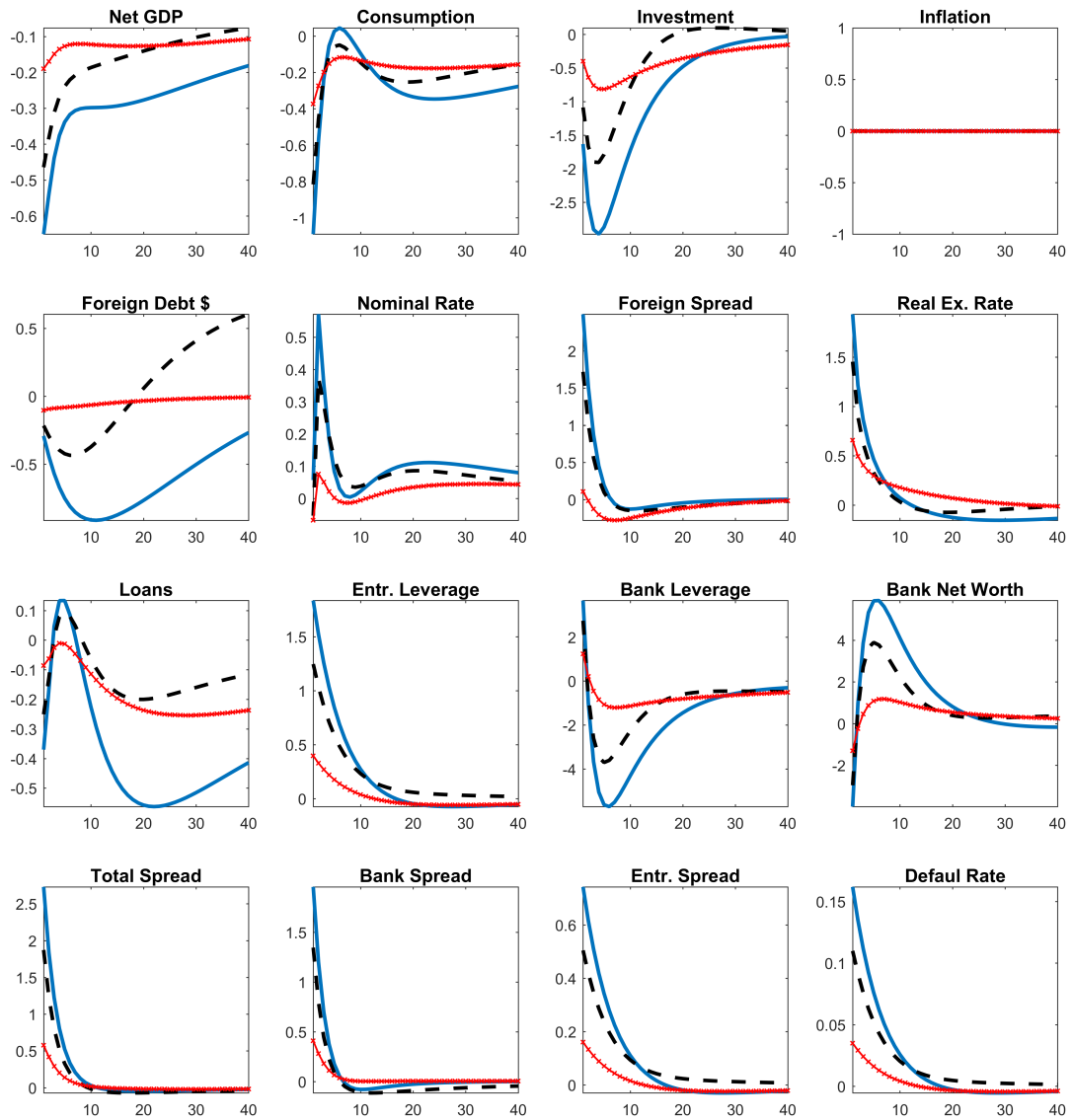
When the central bank follows a strict inflation targeting, the response without macroprudential and capital control policies (figure 8, blue solid line) resembles the Taylor rule scenario: indeed, a Taylor coefficient of 1.9 (as in the baseline calibration) is not so far from a strict inflation targeting; the consumption drop is amplified and reaches  $-1\%$  due to the stronger response of the nominal interest rate; under this policy scenario, capital controls (mostly) and macroprudential policy greatly help to smooth the shock's recessionary impact.

When the central bank pegs the nominal exchange rate, the recession is greatly exacerbated, absent other policies (figure 9, blue solid line): GDP, investment and consumption fall on impact by 4%, 5% and 6% respectively. Indeed, the modified UIP condition (equation 20) requires a stronger increase in the nominal interest rate which amplifies the negative impact of the shock. Notice that under a peg, banks' net worth goes up on impact<sup>36</sup>, and then continues to rise for some quarters, boosting loan supply: since the macroprudential instrument targets loans, it does not work as stabilization policy, (black dashed line). On the other hand, a capital control loosening (crossed red line) exhibits a great stabilization power, because it mitigates the interest rate tightening implied by the modified UIP condition (see equation 20).

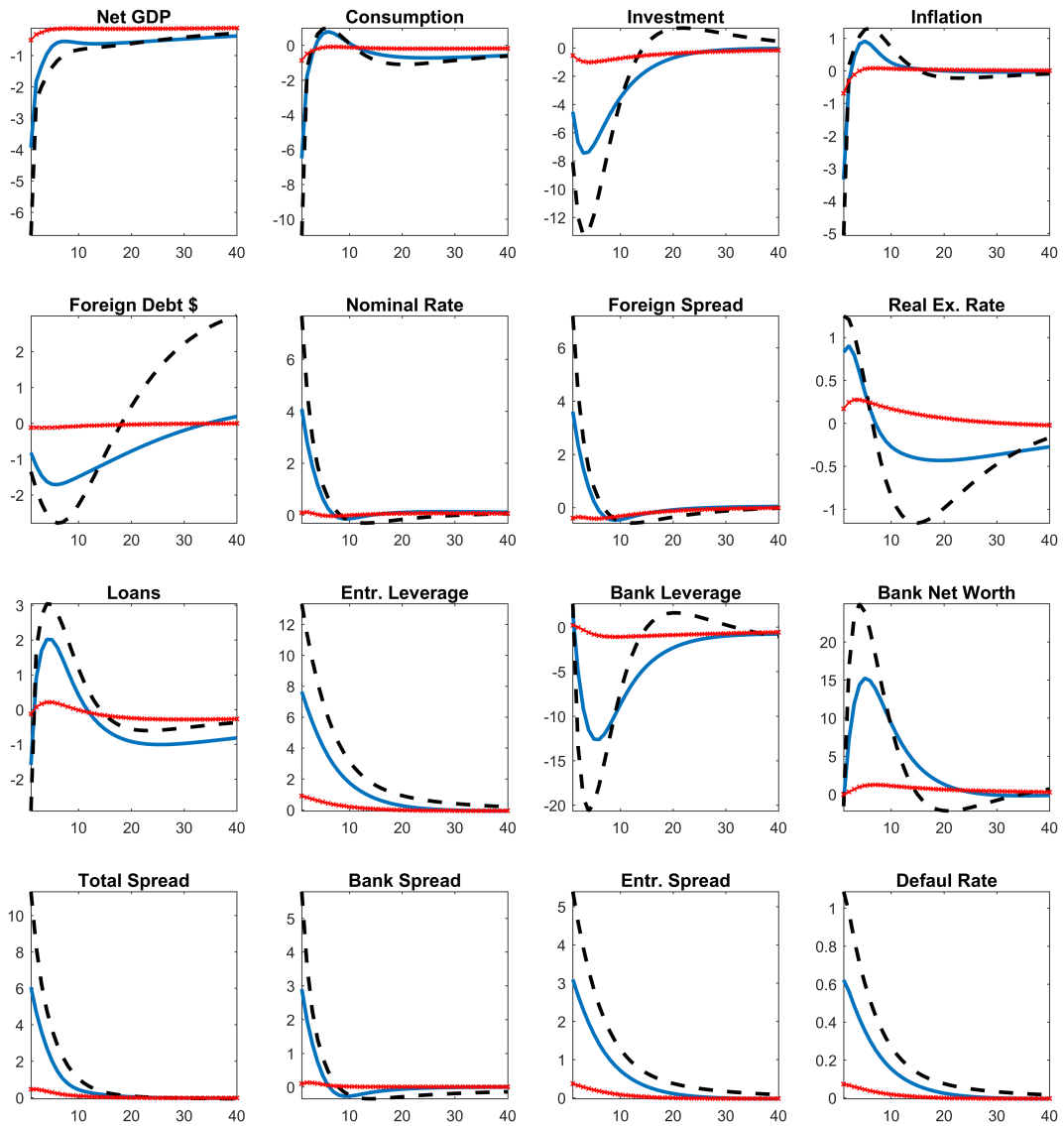
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<sup>35</sup>The number of emerging economies targeting inflation has been increasing in the last twenty years. For instance, in 1999 Brazil formally adopted the inflation targeting regime as monetary policy guideline: currently, the inflation target is 4.5% considering the 12 months from January to December; the target is achieved if the realized inflation rate lies in the interval 2.5 – 6.5. On the other hand, some emerging economies are currently adopting a fixed exchange rate regime: for example, this is the case of Ecuador and Bulgaria.

<sup>36</sup>In the Taylor rule case net worth drops on impact and then starts to rise.



**Figure 8:** IRFs to a one-standard-deviation increase in the foreign interest rate when the central bank fully stabilizes inflation. Responses are in log-deviations from the steady state except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The blue solid line is the baseline model with inflation targeting, the red crossed line adds an active capital control, with  $\phi_d = 1$ , the black dashed line adds an active macroprudential tax, with  $\phi_n = 1$ . One period corresponds to one quarter.



**Figure 9:** IRFs to a standard deviation increase in the foreign interest rate, when the central bank pegs the nominal exchange rate. Responses are in log-deviations from the steady state except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The blue solid line is the baseline model with the peg, the red crossed line adds an active capital control, with  $\phi_d = 1$ , the black dashed line adds an active macroprudential tax, with  $\phi_n = 1$ . One period corresponds to one quarter.

## 5 Conclusions

This paper studies the properties and the interactions of monetary policies, macroprudential measures and capital controls in an emerging economy characterized by financial frictions. The main result of the paper is that monetary policy and capital controls are strongly complementary, under foreign interest rate and financial shocks. In particular, the social planner tries to stabilize inflation and spread fluctuations, with capital controls helping to reach this goal. On the other hand, macroprudential policy is welfare improving if capital controls are not available or if the economy is hit by technology shocks.

Nevertheless, the DSGE model used to simulate different policy scenarios abstracts from some relevant features of an emerging market: for instance, in the model neither households nor firms can borrow in foreign currency; moreover, for the small open economy the only channel to financially trade with the rest of the world is through bank deposits: accordingly, there is no role for foreign direct investments, which are considered the most beneficial category of capital inflows. In addition, while the analysis shows that under some conditions capital controls and macroprudential policies are welfare improving for an emerging economy, these policies may generate negative spillovers in other countries and thus they may be not desirable for a global social planner. Finally, an important assumption of the model is that banks cannot circumvent the capital control tax: relaxing this hypothesis can undermine the effectiveness of capital controls, as argued by some empirical papers<sup>37</sup>. These issues are left for future research.

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<sup>37</sup>E.g. Baba and Kokenyne (2011).

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# Appendix

## A Model Equations

The equilibrium is characterized by equations (56)-(125) listed below, that describe the dynamics of 71 endogenous variables. The missing equation is an expression for the frictionless level of output  $gdp_t^N$  which is provided in Appendix B. There are three exogenous shocks driving business cycle fluctuations:  $\{v_t^p, v_t^e, v_t^a\}$ .

### A.1 Households

Marginal utility of consumption:

$$\lambda_t = \left( c_t - \kappa_L \frac{h_t^{1+\varphi}}{1+\varphi} \right)^{-\sigma}. \quad (56)$$

Euler equation:

$$1 = \beta \mathbb{E}_t \left( \frac{\lambda_{t+1} R_t}{\lambda_t \pi_{t+1}} \right). \quad (57)$$

Labor supply:

$$\kappa_L h_t^\varphi = w_t. \quad (58)$$

Demand for domestic and foreign good:

$$c_{Ht} = (1 - \gamma) (p_{Ht})^{-\eta} c_t \quad (59)$$

$$c_{Ft} = \gamma (p_{Ft})^{-\eta} c_t. \quad (60)$$

Consumption bundle:

$$c_t = \left[ (1 - \gamma)^{\frac{1}{\eta}} c_{Ht}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} c_{Ft}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}. \quad (61)$$

## A.2 Firms

### A.2.1 Domestic firms

Input demands

$$k_{t-1} = \alpha \frac{m c_{Ht} y_{Ht}}{r_t^K (1 - \tau^K) (1 - \tau_H^M) [1 + \psi_k (r_t - 1)]} \quad (62)$$

$$h_t = (1 - \alpha) \frac{m c_{Ht} y_{Ht}}{w_t (1 - \tau^W) (1 - \tau_H^M) [1 + \psi_H (r_t - 1)]}. \quad (63)$$

Total factor productivity:

$$A_t = (1 - \rho_a) A + \rho_a A_{t-1} + v_t^a \quad (64)$$

Domestic Phillips curve:

$$\pi_{Ht} (\pi_{Ht} - \pi) = \mathbb{E}_t \left[ \beta \frac{\lambda_{t+1}}{\lambda_t} \pi_{Ht+1} (\pi_{Ht+1} - \pi) \frac{p_{Ht+1} y_{Ht+1}}{p_{Ht} y_{Ht}} \right] + \frac{\varepsilon_H}{\kappa_{PH}} \left[ \frac{m c_t^H}{p_{Ht}} - \left( \frac{\varepsilon_H - 1}{\varepsilon_H} \right) \right]. \quad (65)$$

Definition of good  $H$  price inflation (remind that  $p_{Ht} \equiv \frac{P_{Ht}}{P_t}$ ):

$$\pi_{Ht} = \frac{p_{Ht}}{p_{Ht-1}} \pi_t. \quad (66)$$

Production:

$$y_{Ht} = A_t k_{t-1}^\alpha h_t^{1-\alpha}. \quad (67)$$

Loans to domestic firms:

$$l_t^f = \psi_h w_t h_t + \psi_k r_t^K k_{t-1}. \quad (68)$$

### A.2.2 Importing firms

Phillips curve:

$$\pi_{Ft} (\pi_{Ft} - \pi) = \mathbb{E}_t \left[ \beta \frac{\lambda_{t+1}}{\lambda_t} \pi_{Ft+1} (\pi_{Ft+1} - \pi) \frac{p_{Ft+1} y_{Ft+1}}{p_{Ft} y_{Ft}} \right] + \frac{\varepsilon_F}{\kappa_{PF}} \left[ \frac{(1 - \tau_F^M) r e r_t}{p_{Ft}} - \left( \frac{\varepsilon_F - 1}{\varepsilon_F} \right) \right]. \quad (69)$$

Definition of good  $F$  price inflation (remind that  $p_{Ft} \equiv \frac{P_{Ft}}{P_t}$ ):

$$\pi_t^F = \frac{p_{Ft}}{p_{Ft-1}} \pi_t. \quad (70)$$

### A.3 Banks

Marginal benefit of having one unit of loans, foreign deposits and net worth respectively:

$$\nu_{lt} = \mathbb{E}_t \left[ \beta \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \frac{(R_{t+1}^B - R_t)}{\pi_{t+1}} \right] \quad (71)$$

$$\nu_{dt}^* = \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \left[ \frac{R_t}{\pi_{t+1}} (1 - \tau_t^d) - R_t^* \frac{rer_{t+1}}{rer_t} \right] \right\} \quad (72)$$

$$\nu_{nt} = \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \frac{R_t}{\pi_{t+1}} (1 - \tau_t^n) \right\}. \quad (73)$$

Bank discount factor:

$$\nu_t = 1 - \chi_b + \chi_b \beta \mathbb{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \left\{ \left[ \frac{(R_{t+1}^B - R_t)}{\pi_{t+1}} + \left[ \frac{R_t}{\pi_{t+1}} (1 - \tau_t^d) - R_t^* \frac{rer_{t+1}}{rer_t} \right] dl_t \right] lev_t^b + \frac{R_t}{\pi_{t+1}} (1 - \tau_t^n) \right\} \right\}. \quad (74)$$

Evolution of net worth:

$$n_t^b = \chi_b \left[ \frac{(R_t^B - R_{t-1})}{\pi_t} l_{t-1}^e - \left[ R_{t-1}^* \frac{rer_t}{rer_{t-1}} - \frac{R_{t-1}}{\pi_t} (1 - \tau_{t-1}^d) \right] rer_{t-1} d_{t-1}^* + \frac{R_{t-1}}{\pi_t} n_{t-1}^b (1 - \tau_{t-1}^n) \right] + l^b \quad (75)$$

Equilibrium leverage:

$$lev_t^b = \frac{\nu_{nt}}{\theta_t - (\nu_{lt} + \nu_{dt}^* dl_t)}. \quad (76)$$

Leverage definition:

$$lev_t^b = \frac{l_t^e}{n_t^b}. \quad (77)$$

Definition of  $dl_t$ :

$$dl_t = \frac{rer_t d_t^*}{l_t^e}. \quad (78)$$

Foreign deposit demand:

$$dl_t = \frac{-1 + \sqrt{1 + \frac{2}{\theta_1} \left( \frac{\nu_{dt}^*}{\nu_{lt}} \right)^2}}{\frac{\nu_{dt}^*}{\nu_{lt}}}. \quad (79)$$

Balance sheets:

$$l_t^e = n_t^b (1 - \tau_t^n) + rert_t d_t^* (1 - \tau_t^d) + d_t. \quad (80)$$

Fraction of divertable assets:

$$\theta_t = \theta_0 \left( 1 + \frac{\theta_1}{2} dl_t^2 \right). \quad (81)$$

## A.4 Entrepreneurs

Definition of loan return:

$$R_{t-1}^L = \frac{\bar{\omega}_t R_t^{KG}}{l_{t-1}^e} q_{t-1} k_{t-1}. \quad (82)$$

Bank participation constraint:

$$R_t^B l_{t-1}^e = g_t R_t^{KG} q_{t-1} k_{t-1}. \quad (83)$$

Leverage definition:

$$lev_t^e = \frac{q_t k_t}{n_t^e}. \quad (84)$$

Net worth evolution:

$$n_t^e = \chi_e \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} m_t \exp(v_t^e) + l^e. \quad (85)$$

External finance premium in equilibrium:

$$\mathbb{E}_t \left( \frac{R_{t+1}^{KG}}{R_{t+1}^B} \right) = \mathbb{E}_t \left( \frac{m'_{t+1}}{m'_{t+1} g_{t+1} - m_{t+1} g'_{t+1}} \right). \quad (86)$$

Balance sheets:

$$q_t k_t = n_t^e + l_t^e. \quad (87)$$

Definition of capital return:

$$R_t^{KG} = \pi_t \frac{r_t^K + (1 - \delta) q_t}{q_{t-1}}. \quad (88)$$

Auxiliary variables:

$$a_t = \frac{\ln(\bar{\omega}_t) + 0.5\sigma_e^2}{\sigma_e} \quad (89)$$

$$g_t = \bar{\omega}_t [1 - \Phi(a_t)] + (1 - \mu) \Phi(a_t - \sigma_e) \quad (90)$$

$$m_t = [1 - \Phi(a_t - \sigma_e)] - \bar{\omega}_t [1 - \Phi(a_t)] \quad (91)$$

$$g'_t = [1 - \Phi(a_t)] - \frac{\mu}{\sigma_e} \phi(a_t) \quad (92)$$

$$m'_t = -[1 - \Phi(a_t)] \quad (93)$$

$$\psi_t = 1 - g_t - m_t, \quad (94)$$

where  $\Phi(\cdot)$  and  $\phi(\cdot)$  are the c.d.f. and p.d.f. of the standard normal distribution respectively.

## A.5 Capital producers

Law of motion of capital:

$$k_t = (1 - \delta) k_{t-1} + \left[ 1 - \frac{\kappa_I}{2} \left( \frac{i_t}{i_{t-1}} - 1 \right)^2 \right] i_t. \quad (95)$$

Optimal investment:

$$1 = q_t \left[ 1 - \frac{\kappa_I}{2} \left( \frac{i_t}{i_{t-1}} - 1 \right)^2 - \kappa_I \left( \frac{i_t}{i_{t-1}} - 1 \right) \frac{i_t}{i_{t-1}} \right] + \beta \kappa_I \mathbb{E}_t \left[ \frac{\lambda_{t+1}}{\lambda_t} q_{t+1} \left( \frac{i_{t+1}}{i_t} - 1 \right) \left( \frac{i_{t+1}}{i_t} \right)^2 \right] \quad (96)$$

Investment good demands:

$$i_{Ht} = (1 - \gamma) (p_{Ht})^{-\eta} i_t \quad (97)$$

$$i_{Ft} = \gamma (p_{Ft})^{-\eta} i_t. \quad (98)$$

## A.6 Foreign economy

Exports:

$$x_t = \gamma^* \left( \frac{p_{Ht}}{rer_t} \right)^{-\eta^*} y^*. \quad (99)$$

Foreign interest rate:

$$R_t^* = (1 - \rho_p) R^* + \rho_p R_{t-1}^* + v_t^p. \quad (100)$$

## A.7 Policy

In the baseline scenario, the central bank adopts a Taylor rule:

$$\frac{R_t}{R} = \left( \frac{R_{t-1}}{R} \right)^{\rho_R} \left[ \left( \frac{\pi_t}{\pi} \right)^{\phi_\pi} \left( \frac{gdp_t^N}{gdp_t} \right)^{\phi_y} \right]^{1-\rho_R}. \quad (101)$$

In alternative scenarios the central bank follows either an inflation targeting or an nominal exchange rate peg:

$$\begin{aligned} \pi_t &= \pi \\ \Delta ner_t &= \pi, \end{aligned}$$

where  $\Delta ner_t \equiv \frac{ner_t}{ner_{t-1}}$  and it holds (remind that foreign inflation is zero):

$$\Delta ner_t = \frac{rer_t}{rer_{t-1}} \pi_t.$$

Macroprudential instrument:

$$\tau_t^n = \tau^n + \phi_n \log \left( \frac{l_t}{l} \right). \quad (102)$$

Capital control:

$$\tau_t^d = \tau^n + \phi_d \log \left( \frac{d_t^*}{d^*} \right). \quad (103)$$

Government spending demand:

$$gov_{Ht} = (1 - \gamma) (p_{Ht})^{-\eta} gov \quad (104)$$

$$gov_{Ft} = \gamma (p_{Ft})^{-\eta} gov. \quad (105)$$

## A.8 Market clearing and definitions

Good market equilibrium:

$$y_{Ht} = c_{Ht}^{tot} + i_{Ht} + gov_{Ht} + x_t + \frac{\kappa_{PH}}{2} (\pi_{Ht} - \pi)^2 y_t^H + monoc_{Ht} - monoc_H \quad (106)$$

$$y_{Ft} = c_{Ft}^{tot} + i_{Ft} + gov_{Ft} + \frac{\kappa_{PF}}{2} (\pi_{Ft} - \pi)^2 y_t^F + monoc_{Ft} - monoc_F \quad (107)$$

$$monc_t = \frac{R_t^{KG}}{\pi_t} \psi_t q_{t-1} k_{t-1} \quad (108)$$

$$monc_{Ht} = (1 - \gamma) (p_{Ht})^{-\eta} monc_t \quad (109)$$

$$monc_{Ft} = \gamma (p_{Ft})^{-\eta} monc_t \quad (110)$$

Evolution of net financial asset position:

$$tb_t = r_{t-1}^* rer_t d_{t-1}^* - rer_t d_t^*. \quad (111)$$

GDP:

$$gdp_t = p_{Ht} y_{Ht} + (p_{Ft} - rer_t) y_{Ft}. \quad (112)$$

GDP net of monitoring and price adjustment costs:

$$gdp_t^{net} = c_t + i_t + gov + tb_t. \quad (113)$$

Equilibrium in loan market:

$$l_t = l_t^e + l_t^f. \quad (114)$$

Trade balance:

$$tb_t = p_{Ht} x_t - rer_t y_{Ft} \quad (115)$$



Total consumption:

$$c_t^{tot} = c_t + c_t^b + c_t^e. \quad (116)$$

Bankers consumption:

$$c_t^b = (1 - \chi_b) \left\{ \frac{(R_t^B - R_{t-1})}{\pi_t} l_t^e - \left[ R_{t-1}^* \frac{rer_t}{rer_{t-1}} - \frac{R_{t-1}}{\pi_t} (1 - \tau_{t-1}^d) \right] rer_{t-1} d_{t-1}^* + \frac{R_{t-1}}{\pi_t} n_{t-1}^b (1 - \tau_{t-1}^n) \right\} \quad (117)$$

$$c_{Ht}^b = (1 - \gamma) (p_{Ht})^{-\eta} c_t^b \quad (118)$$

$$c_{Ft}^b = \gamma (p_{Ft})^{-\eta} c_t^b. \quad (119)$$

Entrepreneurs consumption:

$$c_t^e = (1 - \chi_e) \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} m_t \exp(v_t^e) \quad (120)$$

$$c_{Ht}^e = (1 - \gamma) (p_{Ht})^{-\eta} c_t^e \quad (121)$$

$$c_{Ft}^e = \gamma (p_{Ft})^{-\eta} c_t^e. \quad (122)$$

Credit spread definition:

$$spread_t = \mathbb{E}_t \left( \frac{R_{t+1}^{KG}}{R_t} \right). \quad (123)$$

Default rate definition:

$$defrate_t = F \left( \frac{\log(\bar{\omega}_t) + \frac{1}{2} \sigma_e^2}{\sigma_e} \right). \quad (124)$$

Real interest rate definition:

$$r_t = \frac{R_t}{\mathbb{E}_t(\pi_{t+1})}. \quad (125)$$

## B The Frictionless Level of Output

The frictionless level of output that shows up in the Taylor rule is defined as the gross domestic product that would result in an economy without monopolistic

competition, nominal rigidities and financial frictions. In this economy households directly invest in capital and borrow from the foreign economy. The role of bankers and entrepreneurs is limited to consume a constant fraction of output<sup>38</sup>. Variables in the frictionless economy are indexed with an  $N$ . The equilibrium is characterized by equations (126)-(144) that describe the dynamics of 19 endogenous variables.

## B.1 Households

Marginal utility of consumption:

$$\lambda_t^N = \left( c_t^N - \kappa_L \frac{h_t^{N(1+\varphi)}}{1+\varphi} \right)^{-\sigma}. \quad (126)$$

Euler equation for domestic bond:

$$1 = \beta \mathbb{E}_t \left( \frac{\lambda_{t+1}^N}{\lambda_t^N} r_t \right). \quad (127)$$

Euler equation for capital:

$$1 = \beta \mathbb{E}_t \left[ \frac{\lambda_{t+1}^N}{\lambda_t^N} \frac{r_{t+1}^{N,K} + (1-\delta) q_{t+1}^N}{q_t^N} \right]. \quad (128)$$

Euler equation for foreign bonds:

$$1 = \beta \mathbb{E}_t \left[ \frac{\lambda_{t+1}^E}{\lambda_t^E} \frac{rer_{t+1}^N}{rer_t^N} R_t^N \right], \quad (129)$$

where  $prem \equiv \frac{R}{R^*}$  and

$$R_t^N = R_t^* \cdot prem \cdot \left[ \exp \kappa_D \left( \frac{rer_t^P d_t^{N*}}{rer \cdot d^*} - 1 \right) \right]. \quad (130)$$

The assumption of a debt-elasticity foreign interest rate is necessary to ensure stationarity in the frictionless economy (see Schmitt-Grohé and Uribe (2003)). In the model with financial frictions, this role is played by a debt elastic fraction of

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<sup>38</sup>I prefer to not eliminate these two agents in order to have in steady state  $gdp^N = gdp$ .

divertable assets. As standard in the literature, I calibrate  $\kappa_D$  at a small value (0.01).

Labor supply:

$$\kappa_L h_t^{N(\varphi)} = w_t^N. \quad (131)$$

Price level:

$$1 = (1 - \gamma) p_{Ht}^{N(1-\eta)} + \gamma p_{Ft}^{N(1-\eta)}. \quad (132)$$

## B.2 Firms

### B.2.1 Domestic firms

Input demands

$$k_{t-1}^N = \alpha \frac{p_{Ht}^N y_{Ht}^N}{r_t^{N,K}} \quad (133)$$

$$h_t^N = (1 - \alpha) \frac{p_{Ht}^N y_{Ht}^N}{w_t^N}. \quad (134)$$

Production:

$$y_{Ht}^N = A_t k_{t-1}^{N(\alpha)} h_t^{N(1-\alpha)}. \quad (135)$$

### B.2.2 Importing firms

Equilibrium condition:

$$rer_t^N = p_{Ft}^N. \quad (136)$$

## B.3 Capital producers

Law of motion of capital:

$$k_t^N = (1 - \delta) k_{t-1}^N + \left[ 1 - \frac{\kappa_I}{2} \left( \frac{i_t^N}{i_{t-1}^N} - 1 \right)^2 \right] i_t^N. \quad (137)$$

Optimal investment:

$$1 = q_t^N \left[ 1 - \frac{\kappa_I}{2} \left( \frac{i_t^N}{i_{t-1}^N} - 1 \right)^2 - \kappa_I \left( \frac{i_t^N}{i_{t-1}^N} - 1 \right) \frac{i_t^N}{i_{t-1}^N} \right] + \beta \kappa_I \mathbb{E}_t \left[ \frac{\lambda_{t+1}^N}{\lambda_t^N} q_{t+1}^N \left( \frac{i_{t+1}^N}{i_t^N} - 1 \right) \left( \frac{i_{t+1}^N}{i_t^N} \right)^2 \right] \quad (138)$$

## B.4 Market clearing

Domestic and foreign good:

$$y_{Ht}^N = (1 - \gamma) p_{Ht}^{N(-\eta)} \left( c_t^{N,tot} + i_t^N + gov \right) + x_t^N \quad (139)$$

$$y_{Ft}^N = \gamma p_{Ft}^{N(-\eta)} \left( c_t^{N,tot} + i_t^N + gov \right). \quad (140)$$

Total consumption:

$$c_t^{N,tot} = c_t^N + c^b + c^e. \quad (141)$$

Exports:

$$x_t^N = \gamma^* \left( \frac{p_{Ht}^N}{rer_t^N} \right)^{-\eta^*} y^*. \quad (142)$$

Evolution of net financial position:

$$rer_t^N d_t^{N*} = rer_t^N R_{t-1}^* d_{t-1}^{N*} - (p_{Ht}^N x_t^N - p_{Ft}^N y_{Ft}^N). \quad (143)$$

Definition of frictionless level of output:

$$gd p_t^N = p_{Ht}^N y_{Ht}^N. \quad (144)$$

## C Derivation of Financial Sector Equations

Equations describing the dynamics of the financial sector are not standard in the open macroeconomic literature. Accordingly, I find it useful to formally derive the optimization problem of banks and entrepreneurs.

## C.1 Banks' optimization problem

Profits of bank  $b$  are given by<sup>39</sup>:

$$n_t^b(b) = \frac{R_t^B}{\pi_t} l_{t-1}^e(b) - R_{t-1}^* r e r_t d_{t-1}^*(b) - \frac{R_{t-1}}{\pi_t} d_{t-1}(b). \quad (145)$$

Using (80) it possible to write:

$$\frac{n_{t+1}^b(b)}{n_t^b(b)} = \left( \frac{R_{t+1}^B - R_t}{\pi_{t+1}} \right) lev_t^b(b) - \left[ R_t^* \frac{r e r_{t+1}}{r e r_t} - \frac{R_t}{\pi_{t+1}} (1 - \tau_t^d) \right] \frac{r e r_t d_t^*(b)}{n_t^b(b)} + \frac{R_t}{\pi_{t+1}} (1 - \tau_t^n). \quad (146)$$

The expected discounted value of bank  $b$  is defined as

$$V_t(b) = \mathbb{E}_t \left[ \sum_{i=0}^{\infty} (1 - \chi_b) \chi_b^i \beta^{i+1} \Lambda_{t,t+1+i} n_{t+1+i}^b(b) \right].$$

The Lagrangian function of bank  $b$  problem reads:

$$\begin{aligned} L_t(b) &= V_t(b) + \zeta_t(b) \left[ V_t - \theta_0 \left( 1 + \frac{\theta_1}{2} dl_t^2(b) \right) l_t^e(b) \right] \\ \frac{L_t(b)}{n_t^b(b)} &= \frac{V_t(b)}{n_t^b(b)} (1 + \zeta_t(b)) - \zeta_t(b) \theta_0 \left( 1 + \frac{\theta_1}{2} dl_t^2(b) \right) \frac{l_t^e(b)}{n_t^b(b)} \\ \mathcal{L}_t &= \mathcal{V}_t(b) (1 + \zeta_t(b)) - \zeta_t(b) \theta_0 \left( 1 + \frac{\theta_1}{2} dl_t^2(b) \right) lev_t^b(b), \end{aligned}$$

where  $\mathcal{L}_t(b) \equiv \frac{L_t(b)}{n_t^b(b)}$ ,  $\mathcal{V}_t(b) \equiv \frac{V_t(b)}{n_t^b(b)}$  and  $\zeta_t(b)$  is the lagrangian multiplier. Guess the following solution:

$$V_t(b) = \nu_{lt} l_t(b) + \nu_{nt} n_t^b(b) + \nu_{dt}^* d_t^*(b),$$

which can be rewritten as:

$$\mathcal{V}_t(b) = \nu_{lt} lev_t^b(b) + \nu_{nt} + \nu_{dt}^* dl_t(b) lev_t^b(b). \quad (147)$$

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<sup>39</sup>These derivations follow Aoki et al. (2016).

First order conditions with respect to  $lev_t^b(b)$  and  $dl_t(b)$ :

$$\begin{aligned} (1 + \zeta_t(b)) (\nu_{lt} + \nu_{dt}^* dl_t(b)) &= \zeta_t(b) \theta_0 \left( 1 + \frac{\theta_1}{2} dl_t^2(b) \right) \\ \nu_{dt}^* (1 + \zeta_t(b)) &= \zeta_t(b) \theta_0 \theta_1 dl_t(b). \end{aligned}$$

Combine the two conditions to get:

$$\frac{1}{2} \frac{\nu_{dt}^*}{\nu_{lt}} dl_t^2(b) + dl_t(b) - \frac{\nu_{dt}^*}{\nu_{lt} \theta_1} = 0,$$

whose positive solution is:

$$dl_t(b) = \frac{-1 + \sqrt{1 + \frac{2}{\theta_1} \left( \frac{\nu_{dt}^*}{\nu_{lt}} \right)^2}}{\frac{\nu_{dt}^*}{\nu_{lt}}}, \quad (148)$$

which corresponds to equation (79). Notice that  $dl_t$  is independent from bank  $b$  specific factors (so the index  $b$  can be suppressed). By using the incentive constraint and (147), it holds:

$$\begin{aligned} \theta_t lev_t^b(b) &= \nu_{lt} lev_t^b(b) + \nu_{dt}^* dl_t(b) lev_t^b(b) + \nu_{nt} \\ lev_t^b(b) &= \frac{\nu_{nt}}{\theta_t - (\nu_{lt} + \nu_{dt}^* dl_t)}, \end{aligned}$$

which corresponds to equation (76). Notice that  $lev_t^b$  is independent from bank  $b$  specific factors (so the index  $b$  can be suppressed); this also implies that  $\mathcal{V}_t$  is the same for every bank. The bank value can be rewritten as:

$$\begin{aligned} V_t &= \mathbb{E}_t \left[ \sum_{i=0}^{\infty} (1 - \chi_b) \chi_b^i \beta^{i+1} \Lambda_{t,t+1+i} n_{t+1+i}^b(b) \right] \\ V_t &= \mathbb{E}_t \left[ (1 - \chi_b) n_{t+1}^b(b) + \chi_b V_{t+1} \right] \\ \mathcal{V}_t &= \mathbb{E}_t \left[ (1 - \chi_b) \frac{n_{t+1}^b(b)}{n_t^b(b)} + \chi_b \mathcal{V}_{t+1} \frac{n_{t+1}^b(b)}{n_t^b(b)} \right] \\ \mathcal{V}_t &= \mathbb{E}_t \left[ (1 - \chi_b + \chi_b \mathcal{V}_{t+1}) \frac{n_{t+1}^b(b)}{n_t^b(b)} \right]. \end{aligned}$$

Use (147):

$$\nu_t = \mathbb{E}_t \left\{ \left[ 1 - \chi_b + \chi_b (\nu_{lt} lev_t^b + \nu_{dt}^* dl_t lev_t^b + \nu_{nt}) \right] \frac{n_{t+1}^b(b)}{n_t^b(b)} \right\}.$$

Finally, by using the last equation, (146) and (147), one can easily recover expressions for  $\nu_{lt}$ ,  $\nu_{dt}^*$  and  $\nu_{nt}$ :

$$\begin{aligned} \nu_{lt} &= \mathbb{E}_t \left[ \beta \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \frac{(R_{t+1}^L - R_t)}{\pi_{t+1}} \right] \\ \nu_{dt}^* &= \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \left[ \frac{R_t}{\pi_{t+1}} (1 - \tau_t^d) - R_t^* \frac{rer_{t+1}}{rer_t} \right] \right\} \\ \nu_{nt} &= \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \frac{R_t}{\pi_{t+1}} (1 - \tau_t^n) \right\} \end{aligned}$$

and for the bank discount factor:

$$\nu_t = 1 - \chi_b + \chi_b \beta \mathbb{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \left\{ \left[ \frac{(R_{t+1}^L - R_t)}{\pi_{t+1}} + \left[ \frac{R_t}{\pi_{t+1}} (1 - \tau_t^d) - R_t^* \frac{rer_{t+1}}{rer_t} \right] dl_t \right] lev_t^b + r_t (1 - \tau_t^n) \right\} \right\}.$$

Aggregate bank net worth consists of the net worth  $n_{ot}^b$  of bankers who do not exit the market between  $t - 1$  and  $t$  (they are a fraction  $\chi_b$ ) and the start-up fund  $n_{nt}^b$  of new bankers (they are a fraction  $1 - \chi_b$ ):

$$n_t^b = n_{ot}^b + n_{nt}^b.$$

Net worth of "old" bankers evolves according to (146). Define  $\Delta_t^b = \frac{n_t^b(b)}{n_{t-1}^b(b)}$ ; then it holds:

$$n_{ot}^b = \chi_b \Delta_t^b n_{t-1}^b.$$

Because it is assumed that each new banker receives  $\frac{l^b}{1 - \chi_b}$ , then:

$$n_{nt}^b = l^b.$$

Accordingly, I can get equation (75).

## C.2 Entrepreneurs' optimization problem

The<sup>40</sup> expected revenue for an entrepreneur  $j$ , conditional on not defaulting (that is if  $\omega_{t+1}(j) > \bar{\omega}_{t+1}(j)$ ), is given by:

$$\mathbb{E}_t \left[ \frac{R_{t+1}^{KG}}{\pi_{t+1}} q_t k_t(j) \int_{\bar{\omega}_{t+1}(j)}^{\infty} \omega f(\omega) d\omega \right].$$

Because entrepreneur  $j$  pays  $R_t^L P_t l_t^e$  upon not defaulting, expected costs (in real terms) are the following:

$$\mathbb{E}_t \left\{ \frac{R_t^L}{\pi_{t+1}} l_t^e [1 - F(\bar{\omega}_{t+1}(j))] \right\}.$$

Using the definition of loan rate (equation 82), entrepreneur  $j$  expected profits read:

$$\mathbb{E}_t \left\{ \frac{R_{t+1}^{KG}}{\pi_{t+1}} q_t k_t(j) \left[ \int_{\bar{\omega}_{t+1}(j)}^{\infty} \omega f(\omega) d\omega - \bar{\omega}_{t+1}(j) [1 - F(\bar{\omega}_{t+1}(j))] \right] \right\}. \quad (149)$$

Participation constraints of banks lending to entrepreneur  $j$  is given by:

$$\frac{R_t^B}{\pi_t} = \frac{\left\{ [1 - F(\bar{\omega}_t(j))] \bar{\omega}_t(j) + (1 - \mu) \int_0^{\bar{\omega}_t} \bar{\omega} f(\omega) d\omega \right\} \frac{R_t^{KG}}{\pi_t} q_t k_{t-1}(j)}{l_{t-1}^e(j)}, \quad (150)$$

which holds state by state. The left hand side of the last equation is the real interest rate that banks require to lend  $l_{t-1}^e(j)$ ; the first term in the right hand side is what bank get from non-defaulting entrepreneurs; the second term in the right hand is the value of assets of defaulting entrepreneurs, net of monitoring costs. Define  $m_t(j) \equiv \int_{\bar{\omega}_t(j)}^{\infty} \omega f(\omega) d\omega - \bar{\omega}_t(j) [1 - F(\bar{\omega}_t(j))]$  and  $g_t(j) \equiv [1 - F(\bar{\omega}_t)] \bar{\omega}_t(j) + (1 - \mu) \int_0^{\bar{\omega}_t(j)} \omega f(\omega) d\omega$ . The problem of entrepreneurs  $j$  is max-

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<sup>40</sup>In this section, the steps follow Garcia-Cicco and Kirchner (2016).



imizing (149) subject to (150):

$$\begin{aligned} & \max \mathbb{E}_t \left[ \frac{R_{t+1}^{KG}}{\pi_{t+1}} q_t k_t(j) m_{t+1}(j) \right] \\ \text{s.t. } & \frac{R_{t+1}^B}{\pi_{t+1}} l_t^e(j) = g_{t+1}(j) \frac{R_{t+1}^{KG}}{\pi_{t+1}} q_{t+1} k_t(j). \end{aligned}$$

Using the definition of  $lev_t^e$  and getting rid of  $n_t^e$  and  $\pi_{t+1}$ , the Lagrangian of the problem can be written as follows:

$$\mathcal{L}_t = \mathbb{E}_t \left\{ R_{t+1}^{KG} lev_t^e(j) m_{t+1}(j) - \xi_{t+1}(j) \left[ R_{t+1}^B (lev_t^e(j) - 1) - g_{t+1}(j) R_{t+1}^{KG} lev_t^e(j) \right] \right\},$$

where  $\xi_t(j)$  is the lagrangian multiplier. First order conditions with respect to  $lev_t^e(j)$  and  $\omega_t(j)$ :

$$\begin{aligned} \mathbb{E}_t \left[ R_{t+1}^{KG} m_{t+1}(j) - \xi_{t+1}(j) (R_{t+1}^B - g_{t+1}(j) R_{t+1}^{KG}) \right] &= 0 \\ \mathbb{E}_t \left[ m'_{t+1}(j) + \xi_{t+1}(j) g'_{t+1}(j) \right] &= 0 \end{aligned}$$

where  $m'_t(j)$  and  $g'_t(j)$  are the first derivative with respect to  $\bar{\omega}_t(j)$  of  $m_t(j)$  and  $g_t(j)$  respectively. Combine the two conditions:

$$\mathbb{E}_t \left( \frac{R_{t+1}^{KG}}{R_{t+1}^B} \right) = \mathbb{E}_t \left( \frac{m'_{t+1}(j)}{m'_{t+1}(j) g_{t+1}(j) + m_{t+1}(j) g'_{t+1}(j)} \right).$$

Since the left hand side does not depend on entrepreneur  $j$  specific factors,  $\bar{\omega}_t(j)$  is the same for all entrepreneurs. By equation (82), this also implies that entrepreneurs will choose the same leverage ratio. Following BGG and Garcia-Cicco and Kirchner (2016), I assume that:

$$\ln(\bar{\omega}_t) \sim N \left( -\frac{1}{2} \sigma_e^2, \sigma_e^2 \right).$$

This assumption ensures  $\mathbb{E}(\bar{\omega}) = 1$ . Moreover, this implies that  $a_t \equiv \frac{\ln(\bar{\omega}_t) + \frac{1}{2} \sigma_e^2}{\sigma_e}$  follows a standard normal distribution: by simple algebra it is easy derive equations (90)-(93).

Net worth of "old" entrepreneurs is given by:

$$\begin{aligned}
n_{ot}^e &= \exp(v_t^e) \chi_e \int_{\bar{\omega}_t}^{\infty} f(\omega) \left( \omega \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} - \frac{R_{t-1}^L}{\pi_t} l_{t-1}^e \right) d\omega \\
n_{ot}^e &= \exp(v_t^e) \chi_e \int_{\bar{\omega}_t}^{\infty} f(\omega) \left( \omega \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} - \bar{\omega}_t \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} \right) d\omega \\
n_{ot}^e &= \exp(v_t^e) \chi_e \int_{\bar{\omega}_t}^{\infty} f(\omega) \left[ \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} (\omega - \bar{\omega}_t) \right] d\omega \\
n_{ot}^e &= \exp(v_t^e) \chi_e \left\{ \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} \int_{\bar{\omega}_t}^{\infty} f(\omega) d\omega - \bar{\omega}_t [1 - F(\bar{\omega}_t)] \right\} \\
n_{ot}^e &= \exp(v_t^e) \chi_e \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} m_t.
\end{aligned}$$

Because it is assumed that each new entrepreneur receives  $\frac{l^e}{1-\chi_e}$ , then

$$n_{nt}^e = l^e$$

and I can get equation (85).

### C.3 Modified UIP Condition

The goal of this paragraph is to derive equation (20). By using (57), rewrite (71) and (72):

$$\begin{aligned}
\nu_{lt} &= \mathbb{E}_t [\nu_{t+1} spread_t^{Bn}] \\
\nu_{dt}^* &= \mathbb{E}_t \{ \nu_{t+1} uip_t \},
\end{aligned}$$

where  $spread_t^{bn} \equiv \mathbb{E}_t \left( \frac{R_{t+1}^B}{R_t} - 1 \right)$  is net lending spread and  $uip_t \equiv 1 - \left[ \frac{R_t^*}{R_t} \mathbb{E}_t \left( \frac{ner_{t+1}}{ner_t} \right) + \tau_t^d \right]$  denotes deviations from the uncovered interest parity. Linearizing the previous two expressions I can get:

$$\tilde{\nu}_{dt}^* - \tilde{\nu}_{lt} = \tilde{uip}_t - \tilde{spread}_t^{Bn},$$

with:

$$\tilde{uip}_t = \frac{r^*}{r-r^*}\tilde{R}_t - \frac{r^*}{r-r^*}\tilde{R}_t^* - \frac{r^*}{r-r^*}\mathbb{E}_t\left(\Delta n\tilde{e}r_{t+1}\right) - \frac{r^*}{r-r^*}\tau_t^d \quad (151)$$

$$spread_t^{Bn} = \frac{R^B}{R^B - R}\mathbb{E}_t\left(\tilde{R}_{t+1}^B - \tilde{R}_t\right), \quad (152)$$

where  $\tilde{x}_t$  is the percentage deviation from the steady state of variable  $x_t$  and  $\Delta n\tilde{e}r_{t+1} = \frac{n\tilde{e}r_{t+1}}{n\tilde{e}r_t}$ . Linearization of (79) yields:

$$\tilde{d}l_t = D(\tilde{\nu}_{dt}^* - \tilde{\nu}_{lt}), \quad (153)$$

where  $D \equiv \frac{\left(\frac{\nu_d^*}{\nu_l}\right)^2 \frac{4}{\theta_1} \left[1 + \frac{2}{\theta_1} \left(\frac{\nu_d^*}{\nu_l}\right)^2\right]^{-\frac{1}{2}} + 1 - \sqrt{1 + \frac{2}{\theta_1} \left(\frac{\nu_d^*}{\nu_l}\right)^2}}{\left(\frac{\nu_d^*}{\nu_l}\right)^3} > 0$ . Therefore it holds:

$$\tilde{d}l_t = D\left(\tilde{uip}_t - spread_t^{Bn}\right). \quad (154)$$

Combine (151), (152), (153) and (154) to get the modified linear UIP condition:

$$\tilde{R}_t = \tilde{R}_t^* + \mathbb{E}_t\left(\Delta n\tilde{e}r_{t+1}\right) + \tau_t^d + D_0\mathbb{E}_t\left(\tilde{R}_{t+1}^B - \tilde{R}_t\right) + D_1\left(r\tilde{e}r_t + \tilde{d}_t^* - \tilde{l}_t^e\right),$$

where  $D_0 \equiv \frac{(r-r^*)}{(r^b-r)}\frac{r^b}{r^*}$  and  $D_1 \equiv \frac{(r-r^*)}{r^*}\frac{1}{D}$  are positive parameters.

## C.4 The Steady State

The steady-state of ten variables (table 2) is calibrated ex-ante. As a consequence, the following ten parameters are treated as unknowns in the steady-state system:  $\{\beta, \kappa_L, A, \gamma^*, \gamma, \theta_0, \theta_1, \nu_b, \nu_e, \sigma_e\}$ . The Taylor rule and Euler equation imply that inflation is equal to its target,  $R = \pi \cdot r$  and  $\beta = \frac{1}{r}$ . Equation (96) yields:  $q = 1$ . Moreover, given  $R$  and the steady-state lending spread,  $R^L$  is known. By the domestic Phillips curve:

$$mc_H = p_H \frac{\varepsilon_H - 1}{\varepsilon_H}.$$

Equation (59), (60) and (61) yield:

$$1 = (1 - \gamma)p_H^{1-\eta} + \gamma p_F^{1-\eta},$$

which can be used to solve for  $p_F$ . By the Phillips curve for the importing sector and using the definition of  $\tau_F^M$ :

$$rer = p_F.$$

Then, I arbitrarily fix a value for  $\sigma_e$  to compute the steady state of entrepreneurs variables. Using the target value for the default rate, I solve the following equation for  $\bar{\omega}$ :

$$defrate = F\left(\frac{\log(\bar{\omega}) + \frac{1}{2}\sigma_e^2}{\sigma_e}\right)$$

and compute  $g$ ,  $g'$ ,  $m$  and  $m'$  using their definitions. By (82) and (83), it holds  $lev^e = \left(1 - g\frac{R^{KG}}{R^B}\right)^{-1}$ . Using (86) I find:

$$lev^e = \left(1 - \frac{gm'}{m'g - mg'}\right)^{-1}.$$

Use again (82):

$$\begin{aligned} R^{KG} &= \frac{R^L lev^e - 1}{\omega lev^e} \\ R^B &= \frac{R^{KG}(m'g - mg')}{m'}, \end{aligned}$$

which implies:

$$r^K = [qR^{KG} - (1 - \delta)q].$$

By the definition of firm subsidies, it holds:

$$\tau^K = 1 - \frac{r - (1 - \delta)}{r^K [1 + \psi_k(r - 1)]}, \quad \tau^W = 1 - \frac{1}{1 + \psi_h(r - 1)}.$$

Using input demands, I can solve for  $k$  and  $w$ :

$$k = \alpha \frac{m c_H y_H}{[1 + \psi_k (r - 1)] r^K (1 - \tau^K) (1 - \tau_H^M)}$$

$$w = (1 - \alpha) \frac{m c_H y_H}{[1 + \psi_h (r - 1)] h (1 - \tau^W) (1 - \tau_H^M)}$$

and I can find total firms loans:

$$l^f = \psi_k r^K k + \psi_h w h.$$

Using (84), (87) and (115):

$$n^e = \frac{k}{lev^e}$$

$$l^e = k - n^e$$

$$l = l^e + l^f.$$

At this stage, I verify if the resulting value for the equity/asset ratio in the non-financial sector  $\frac{n^e}{n^e + l}$  is equal to its target value; if it is not, I adjust  $\sigma_e$  to hit the target. Equation (85) yields:

$$l^e = n^e - \chi^e \frac{R^{KG}}{\pi} q \cdot k \cdot m.$$

Given the target value for total bank leverage  $lev^{btot} \equiv \frac{l}{n^b}$ , I can find:

$$lev^b = lev^{btot} \left( 1 - \frac{l^f}{l} \right)$$

$$n^b = \frac{l^e}{lev^b}.$$

The bank discount factor reads:

$$\nu = \frac{1 - \chi_b}{1 - \chi_b \beta \left[ \left( \frac{R^B - R}{\pi} \right) + \left( \frac{R}{\pi} - R^* \right) dl + lev^b \frac{R}{\pi} \right]}$$

and implies a fraction of divertable assets equal to:

$$\theta = \beta\nu \left[ \frac{r}{lev^b} + \left( \frac{R^B - R}{\pi} \right) + \left( \frac{R}{\pi} - R^* \right) dl \right].$$

Given the target value for the foreign debt ratio  $dratio \equiv \frac{rer \cdot d^*}{4 \cdot gdp}$  and  $gdp = p_H \cdot y_H$ , I can find  $d^*$  and  $dl$ :

$$\begin{aligned} d^* &= 4 \cdot dratio \frac{y_H}{rer} \\ dl &= \frac{rer \cdot d^*}{l^e}. \end{aligned}$$

Using (75), it holds:

$$l^b = n^b \left\{ 1 - \chi_b \left[ \left( \frac{R^B - R}{\pi} \right) lev^b + \left( \frac{R}{\pi} - R^* \right) dl + lev^b \frac{R}{\pi} \right] \right\}$$

By (71) and (72), I find:

$$\frac{\nu_{dl}^*}{\nu_l} = \frac{R^B - R}{R - \pi R^*},$$

and then by equation (79) I can solve for  $\theta_1$ . By (81) I recover  $\theta_0$ :

$$\theta_0 = \frac{\theta}{1 + \frac{\theta_1}{2} dl^2}.$$

The law of motion of capital implies  $i = \delta k$ . By solving the following system in three equations (106, 107 and 111):

$$\begin{aligned} y_H &= (1 - \gamma) p_H^{-\eta} (c^{tot} + i + gov) + x \\ y_F &= \gamma p_F^{-\eta} (c^{tot} + i + gov) \\ p_H x - rer \cdot y_F &= (R^* - 1) \cdot rer \cdot d^*, \end{aligned}$$

I obtain expressions for  $c^{tot}$ ,  $x$  and  $y^F$ . Using (116), (117), (120), I get:

$$\begin{aligned} c^b &= (1 - \chi_b) \left[ \left( \frac{R^B - R}{\pi} \right) l^b + \left( \frac{R}{\pi} - R^* \right) rer \cdot d^* + \frac{R}{\pi} n^b \right] \\ c^e &= (1 - \chi_e) \left[ \frac{R^{KG}}{\pi} q \cdot k \cdot m \right] \\ c &= c^{tot} - c^b - c^e. \end{aligned}$$

Finally, labor supply and export demand yield values for parameters  $\kappa_L$  and  $\gamma^*$ :

$$\begin{aligned} \kappa_L &= \frac{w}{h^\varphi} \\ \gamma^* &= \frac{x}{y^*} \left( \frac{rer}{p_H} \right)^{-\eta^*}. \end{aligned}$$

The steady state of the other variables can be easily computed from remaining equations.

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