PhD THESIS DECLARATION

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Date *31 January 2018*

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Abstract

This PhD thesis is composed of three chapters on the linkages between financial markets and the real economy and on the role played by economic policies.

In the first Chapter I raise the following questions: 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 foreign interest rate; (ii) 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.

In the second Chapter I set up an international business cycle model with three countries (one AE and two symmetric EMEs) to analyze global spillovers effects arising from capital controls policies. I find that if one EME restricts its financial account to curb capital inflows, the latter are deflected to the other EME, whose economic activity expands. In addition, if the EMEs are big enough, AE business cycle is positively affected.

In the third Chapter, motivated by the events of the Great Recession, I estimate a time-varying structural VAR model with labor market variables to analyze the effects of a financial shock, focusing on the US. The findings point out that a tightening of financial conditions is highly detrimental for the labor market. Moreover, I show that financial shocks have hit the unemployment rate asymmetrically in the last three decades, an implication that a standard VAR cannot capture: while negative financial shocks have been responsible for increases in unemployment, the model does not find significant contribution of financial shocks throughout expansion periods. The source of this asymmetry is the time-varying standard deviation of the identified shock, which is higher in period of financial distress; on the other hand, I find the transmission mechanism is almost constant over time.

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Disclaimer

Part of the research contained in this dissertation was carried out while the author worked at the Bank of Italy. The views expressed herein are the author's only and do not necessarily reflect those of the Bank of Italy.

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Introduction

The global financial crisis spurred a vivid debate on the role of financial markets in affecting the business cycle and on how policy makers should deal with financial crises. Some consensus seems to have been reached on the following grounds:

1. Financial markets are not just a veil through which credit is intermediated. As financial markets are not frictionless, they both amplify macroeconomic shocks and are an autonomous source of economic fluctuations.

2. Financial crises can occur both in advanced and emerging economies.

3. Sound economic policies have a crucial role in reducing financial crises probability and dampening their adverse impact, when they arise.

This PhD dissertation is composed of three research papers that start from these remarks to improve our understanding on the linkages between financial markets and real economy and on the role played by economic policies. Two papers (Chapter 1 and 2) analyze capital controls, a policy tool that several emerging countries use in order to deal with capital flows. Both these papers share the instrument of analysis, a dynamic stochastic general equilibrium (DSGE) model. In particular, in Chapter 1, a DSGE model with frictional financial markets is set up to study the interactions between capital controls and other instruments in the policy toolkit (such as macroprudential measures and monetary policy). The model aims to simulate the response of a small open economy hit by different kinds of financial shocks. In Chapter 2, a DSGE model for the world economy (composed of one advanced economy and two emerging countries) is developed to study potential spillover effects arising from capital controls. In Chapter 3, the analysis moves to the labor market, a sector of the economy that was massively hurt in many countries during the global financial crisis. A vector autoregressive model (VAR) with time-varying parameters is estimated to evaluate the impact of financial shocks on US labor market variables.

More specifically, Chapter 1 (”Capital Controls, Macroprudential Measures and Monetary Policy Interactions in an Emerging Economy”) contains an analysis of the interactions between capital controls, macroprudential measures and monetary policy, both from a positive and a normative perspective. This work is motivated from the observation that, since the global financial crisis policy makers have used several tools to manage capital flows. As reported in Ghosh et al. (2017) more orthodox instruments such as monetary and exchange rate policies have been combined with both macroprudential measures and capital controls: while the goal of macroprudential policy is to safeguard financial stability, capital controls aim to limit capital flows, discriminating debt instruments on the basis of residency. These policy tools are supported also by the IMF, which has recently revised its institutional view on the benefits associated with financial integration (IMF, 2012). Indeed, the IMF now recognizes the risks of a more open financial account and suggests the use of restrictions on capital inflows under specific circumstances. The analysis is conducted through the lenses of a standard DSGE model augmented with financial frictions and calibrated with Brazilian data. The main finding of the paper is that strong complementarity exists between capital controls and monetary policy. Such a complementarity is due to the trade-off between inflation and lending spread fluctuations (i.e. the two frictions of the model). Indeed, policy makers should take into account that: i) a monetary tightening is able to counteract inflationary pressures, with the cost of increasing the lending spread; and ii) capital control loosening can close the lending spread, with the cost of creating deflationary pressures by appreciating the domestic currency.

In Chapter 2 (”Capital Controls Spillovers”) I point out that, if capital controls are not set in a coordinated fashion, a capital control tightening in some countries is likely to deflect capital flows to other countries with no controls in place, especially if cross-border flows are driven by global drivers. On the one hand, an additional wave of capital flows can be welcome, whenever they finance productive investments. On the other hand, capital flows may increase macroeconomic volatility and appreciate the exchange rate: these facts may lead these countries to restrict financial account in turn, thus triggering a capital controls war. In addition, if capital controls are used by some big emerging markets, there could be consequences also for advanced economies. These simple intuitions are confirmed by a growing empirical literature that reports spillover effects from capital controls.[1] The aim of this Chapter is specifically to assess these spillover effects in a theoretical framework. To this end, I set up an international real business cycle model consisting of one advanced economy (AE, henceforth) and two

[1]See Giordani et al. (2016) and Forbes et al. (2016).

emerging economies (EME1 and EME2, henceforth). By simulating a capital controls tightening in EME1, simultaneously with a shock to the international interest rate, I can assess how much the effects of such a policy spill over to EME2 and AE. I show that if EME2 does not use capital controls, it receives an additional wave of capital inflow, which amplifies the initial shock and further boosts the macroeconomy. On top of that, if EME1 is not too small compared to AE, its policy affects AE business cycle too: EME1 capital controls slightly reduce the AE interest rate, due to the higher desire of AE households to invest in domestic bonds, and this induces a positive response of AE economic activity.

In Chapters 1 and 2, all the policy experiments conducted are conditional on some exogenous financial shock. However, the analysis partially ignores[2] the adverse consequences that a tightening of financial conditions can entail on the labor market: in Chapter 3 (”Labor Market and Financial Shocks: a Time-Varying Analysis”, co-authored with Francesco Corsello) we focus on the effects of a financial shock on labor market variables. This analysis is motivated by the huge impact that the Great Recession had on the US labor market. We develop a time-varying VAR with stochastic volatility a là Primiceri (2005), including five labor market variables, the GDP growth rate, the inflation rate, and a financial indicator (the National Financial Condition Index constructed by the Chicago Fed, the NFCI henceforth). We argue that allowing for time variation in the estimation is important to capture the stylized fact that financial time series are typically asymmetric and exhibit changes in volatility over time. Moreover, a time-varying VAR takes into account the transmission mechanism of financial shocks can change with the economic cycle - for instance due to the presence of occasionally binding financial constraints. Our results point out that a tightening of financial conditions is highly detrimental for the labor market. Moreover, we show that financial shocks have hit the unemployment rate asymmetrically over the last three decades, an implication that a standard VAR cannot capture: while negative financial shocks have been responsible for increases in unemployment, our model does not find significant contribution of financial shocks throughout expansion periods. The source of this asymmetry is the time-varying standard deviation of the identified shock, which is higher in period of financial distress; on the other hand, we find that the transmission mechanism is almost constant over time.

[2]In Chapters 1 and 2, I assume a frictionless labor market, in which a representative household chooses how many hours to work. As such, there is no room to study fluctuations in key variables such as unemployment, labor force or vacancy posting.

All in all, the several findings described above can be summarized by the following two concluding remarks:

- Capital controls and macroprudential measures are useful tools for emerging markets to deal with capital flows and financial stability. Both instruments are able, under some situations, to mitigate the effects of financial and economic shocks. Capital controls seem to be the ideal policy tool to face international interest rate movements. However, policy makers should be aware that capital controls entail some spillover effects: i) on the domestic economy, by affecting the inflation rate. This implies that monetary policy considerations cannot be ignored when the capital controls policy stance is established; and ii) on the world economy, by deflecting capital flows to other countries. Accordingly, some other countries could in turn respond by tightening capital controls, thus triggering a capital controls war.

- Adverse financial shocks have a strong impact on the labor market and tend to be larger and less frequent than positive shocks. This finding should guide policy makers in drawing appropriate macroprudential and labor market policies. For instance, policies reducing funding costs of the corporate sector appear notably appropriate to mitigate the big impact of financial crises. Macroprudential measures limiting the probability of a financial crisis may yield significant benefits to the economic activity via the labor market channel. Moreover, given the importance of the labor market in transmitting the effect of financial crises, macroprudential measures can be calibrated according to some labor market indicators. Finally, these results highlight the importance of using a time-varying framework to estimate the effects of financial shocks: had we ignored time variation in the shock volatility, we would have overestimated the effects that financial shocks have had in the US over the last four decades.

These findings open up several promising avenues for future research. First, it would be interesting to test the theoretical predictions of Chapter 1: do capital controls affect inflation? Do they imply a monetary policy response? Second, it would be intriguing to extend the positive analysis of Chapter 2 to a normative analysis, in order to study the Nash equilibrium between two emerging countries that set capital controls. Third, it seems promising to include some indicators of the macroprudential stance in the VAR estimated in Chapter 3, in order to understand the role of policy in dampening the impact of financial shocks.

Chapter 1

Capital Controls, Macroprudential Measures and Monetary Policy Interactions in an Emerging Economy

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 foreign interest rate; (ii) 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.

1.1 Introduction

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) more orthodox instruments such as monetary and exchange rate policies have been combined with both macroprudential policies and capital controls.[1] 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.

The International Monetary Fund has also revised its historical position about the benefits associated with financial integration. In 2012, the IMF Institutional View[2] 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

[1] 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.

[2] See IMF (2012).

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 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.

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.[3] 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 economy is hit by 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 modeled 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).

[3]Clearly, DSGE models have been deeply using to study interactions between macropudential 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.

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[4] under foreign interest rate and financial shocks.[5] By contrast, macroprudential policy is more desirable under technology shocks.

4. Monetary policy and capital controls are strongly complementary under both 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.

[4]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.

[5]The financial shock is modeled as an exogenous reduction in the net worth of entrepreneurs, as in Nolan and Thoenissen (2009), Christiano et al. (2010) and Rannenberg (2016).

1.2 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.

1.2.1 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 $F\left(k_{t-1}, h_t\right)$; 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:

$$c_t + k_t - (1-\delta)\, k_{t-1} = F\left(k_{t-1}, h_t\right) \tag{1.1}$$

$$\beta \mathbb{E}_t \left[\frac{U_c\left(c_{t+1}, h_{t+1}\right)}{U_c\left(c_t, h_t\right)} r_t \right] = 1 \tag{1.2}$$

$$mpl_t\left(k_{t-1}, h_t\right) = mrs_t\left(c_t, h_t\right) \tag{1.3}$$

$$r_t^K = mpk_t(k_{t-1}, h_t) \tag{1.4}$$

$$\mathbb{E}_t \left\{ U_c\left(c_{t+1}, h_{t+1}\right) \left[\left(r_{t+1}^K + 1 - \delta \right) - r_t \right] \right\} = 0 \tag{1.5}$$

Expression (1.1) 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 (1.3) equalizes the marginal product of labor mpl_t with the marginal rate of substitution between consumption and labor mrs_t. Equation (1.4) equalizes the marginal product of capital mpk_t with capital rental rate r_t^K. Condition (1.5) 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 (1.4), 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 (1.1)-(1.4) together with:

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

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

$$spread_t = 0 \ \forall t \tag{1.6}$$

is able to guarantee efficiency.[6]

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 μ_t between the price level and the firms' nominal marginal costs. Equilibrium conditions

[6]The same holds in the BGG framework, if we assume that monitoring cost paid by lenders are transferred back to households.

are modified as follows:

$$F\left(k_{t-1},h_t\right)=c_t+k_t-\left(1-\delta\right)k_{t-1}+C\left(\pi_t\right)$$

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

$$\frac{mpl_t\left(k_{t-1},h_t\right)}{\mu_t}=mrs_t\left(c_t,h_t\right)$$

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

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

where gross inflation π_t and mark-up μ_t are determined by monetary policy and the supply side of the economy. $C\left(\cdot\right)$ is an increasing and convex function such that $C\left(\pi\right)=0$, capturing price adjustment costs, where π 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 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.

1.3 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 1.1). 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.

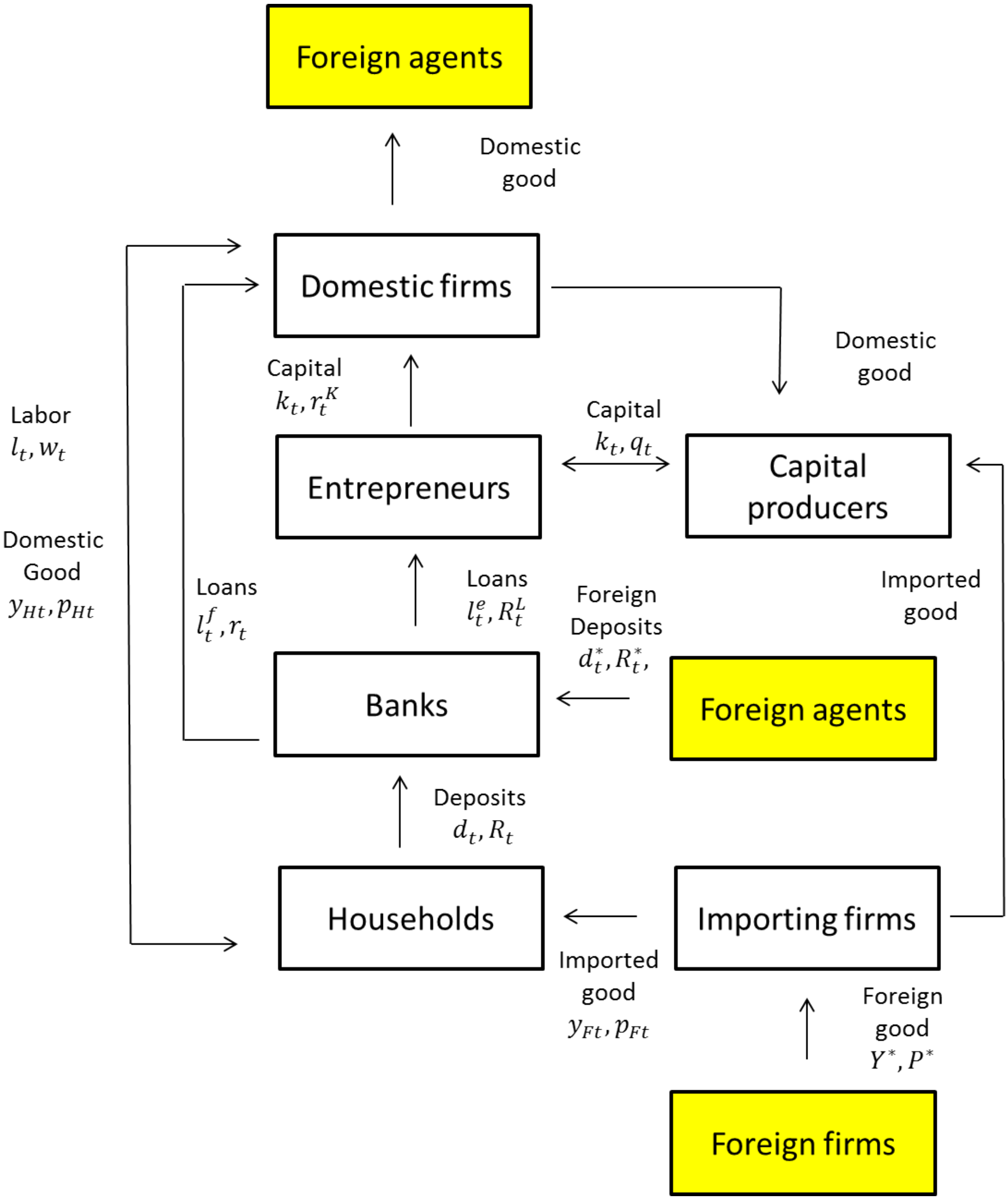

Figure 1.1: The model. Quantities are expressed in real terms; lower-case price variables are relative prices, with the domestic CPI as the numéraire. Interest rates are expressed in nominal terms, consistent with the text (except for loans to firms, that are intraperiod and pay the real interest rate). 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.

1.3.1 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; π_t is the CPI gross inflation rate; Π_t denotes profits from the ownership of domestic firms, importing firms and capital producers; finally, c_t is a CES consumption bundle:

$$c_t = \left[(1-\gamma)^{\frac{1}{\eta}} c_{Ht}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} c_{Ft}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{1.7}$$

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

$$P_t = \left[(1-\gamma) P_{Ht}^{1-\eta} + \gamma P_{Ft}^{1-\eta} \right]^{\frac{1}{1-\eta}}, \tag{1.8}$$

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).[7]

1.3.2 Firms

Domestic firms

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

$$y_{Ht}(i) = A_t \left(k_{t-1}(i) \right)^{\alpha} \left(h_t(i) \right)^{1-\alpha}, \tag{1.9}$$

[7] This preference specification better captures business cycle dynamics in a small open economy (see, for instance, Neumeyer and Perri, 2005).

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:

$$l_t^f(i) = \psi_h w_t h_t(i) + \psi_k r_t^K k_{t-1}(i), \tag{1.10}$$

where r_t^K is the rental rate of capital. Every firm i maximizes the discounted expected 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 (1.9) and the following demand function:

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

where λ_t is the marginal utility of consumption;[8] $p_{Ht} \equiv \frac{P_{Ht}}{P_t}$, mc_{Ht} is the real marginal cost (the exact expression is derived in the Appendix) and π is the steady-state inflation rate. The solution of this problem yields a New Keynesian Phillips Curve.

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

[8]Given that firms are owned by households, they value the future stream of profits using the households' stochastic discount factor.

into the total imported good via 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:

$$P_{Ft} = ner_t P_t^*, \tag{1.11}$$

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:

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

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 τ_F^M is a subsidy whose nature will be clear in next paragraphs. Importers face the following demand function:

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

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.

1.3.3 Banks

The economy features a continuum of financial intermediaries, managed by bankers. Bankers are risk neutral and die[9] with probability $1 - \chi_b$; when a banker b dies, she is replaced by new ones, which receive a small start-up fund $\frac{\iota_b}{1-\chi_b}$ by households; exiting bankers consume their remaining net worth $n_t^b(b)$. Every banker faces the following budget constraint:

$$l_t^e(b) = n_t^b(b)\left(1 - \tau_t^n\right) + rer_t d_t^*(b)\left(1 - \tau_t^d\right) + d_t(b). \tag{1.12}$$

Hence, bankers raise funds from three different sources:

[9]If bankers were infinitely lived, they would accumulate an infinite amount of net worth, making financial frictions irrelevant.

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 τ_t^n and τ_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.

Banks' net worth is accumulated only through profits:[10]

$$n_t^b(b) = \frac{R_{t-1}^b}{\pi_t} l_{t-1}^e(b) - \frac{R_{t-1}^*}{\pi_t^*} rer_t d_{t-1}^*(b) - \frac{R_{t-1}}{\pi_t} d_{t-1}(b), \tag{1.13}$$

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. 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:

$$V_t(b) \geq \theta_t(b)\, l_t^e(b), \tag{1.14}$$

with θ_t given by:

$$\theta_t(b) = \theta_0 \left[1 + \frac{\theta_1}{2}\left(\frac{rer_t d_t^*(b)}{l_t^e(b)}\right)^2\right]. \tag{1.15}$$

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

[10] So it is assumed that banks cannot issue new shares.

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.[11]

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:

$$V_t = \nu_{lt} l_t^e + \nu_{dt}^* d_t^* + \nu_{nt} n_t^b \tag{1.16}$$

and so bank leverage can be written as:[12]

$$lev_t^b = \frac{\nu_{nt}}{\theta_t - (\nu_{lt} + \nu_{dt} dl_t)}, \tag{1.17}$$

where $dl_t \equiv \frac{rer_t d_t^*}{l_t^e}$ and ν_{nt}, ν_{lt} and ν_{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 θ_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:[13]

$$\nu_{lt} = \underset{+}{f}\left(spread_t^B\right), \tag{1.18}$$

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

[11]See Schmitt-Grohé and Uribe (2003) for a discussion on this issue.

[12]Since all banks choose the same leverage in equilibrium, the b index can be suppressed.

[13]While the nominal deposit rate is known when the deposit contract is signed, the average nominal loan return is not.

following holds:

$$\tilde{\nu}_t^{dl} = \tilde{uip}_t - \tilde{spread}_t^{Bn}, \tag{1.19}$$

where $uip_t \equiv 1 - \left[\frac{R_t^*}{R_t}\mathbb{E}_t\left(\frac{ner_{t+1}}{ner_t}\right) + \tau_t^D\right]$ denotes deviations from the uncovered interest parity 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 uip_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 ν_t^{dl}, the linearized modified uncovered interest parity reads:

$$\tilde{R}_t = \tilde{R}_t^* + \mathbb{E}_t\left(\tilde{ner}_{t+1} - \tilde{ner}_t\right) + \tau_t^D + D_0\mathbb{E}_t\left(\tilde{R}_{t+1}^B - \tilde{R}_t\right) + D_1\left(\tilde{rer}_t + \tilde{d}_t^* - \tilde{l}_t^e\right) \tag{1.20}$$

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

1.3.4 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 σ_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:

$$R_{t+1}^{KG} = \frac{r_{t+1}^K + q_{t+1}(1-\delta)}{q_t}\pi_{t+1}, \tag{1.21}$$

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

$$q_t k_t(j) = n_t^e(j) + l_t^e(j). \tag{1.22}$$

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 $\overline{\omega}_{t+1}(j)$ such that:

- if $\omega_{t+1}(j) \geq \bar{\omega}_{t+1}(j)$ entrepreneur j pays back $\overline{\omega}_{t+1}(j) R_{t+1}^{KG} q_t k_t(j)$;
- 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 μ 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 ω. 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:

$$R_{t-1}^L = \frac{\bar{\omega}_t(j) R_t^{KG} k_{t-1}(j)}{l_t^e(j)} \pi_t. \tag{1.23}$$

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:

$$R_{t+1}^B l_t^e(j) = \left\{ \left[1 - F\left(\bar{\omega}_{t+1}(j)\right)\right] \bar{\omega}_{t+1}(j) + (1-\mu) \int_0^{\bar{\omega}_{t+1}(j)} \omega f(\omega)\, d\omega \right\} R_{t+1}^{KG} q_t k_t(j). \tag{1.24}$$

The left-hand-side of (1.24) 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 ω) and the latter is the total return in the event of the entrepreneur's bankruptcy.

The expected profits function of entrepreneurs is:[14]

$$\mathbb{E}_t \left\{ \frac{R_{t+1}^{KG}}{\pi_{t+1}} q_t k_t(j) \left[\int_{\bar{\omega}_{t+1}(j)}^{\infty} \omega f(\omega)\, d\omega - \bar{\omega}_{t+1}(j) \left[1 - F\left(\overline{\omega}_{t+1}\right)\right] \right] \right\}, \tag{1.25}$$

where the first term is the expected revenue, the second one is the expected repayment. The optimal loan contract is chosen by maximizing (1.25) subject to (1.24). As shown by BGG and Rannenberg (2016), the first order condition yields a positive relation between the external finance premium and the leverage ratio:

$$\mathbb{E}_t \left[\frac{R_{t+1}^{KG}}{R_{t+1}^B} \right] = \underset{+}{f}(lev_t^e). \tag{1.26}$$

[14] Index j is suppressed since in equilibrium entrepreneurs will choose the same leverage

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

Finally, entrepreneurs exit the market with probability $1-\chi_e$ in each period[15] and, if they do, they consume their accumulated net worth. They are replaced by new entrepreneurs that start the activity with funds $\frac{\iota_e}{1-\chi_e}$ provided by households.

1.3.5 Capital producers

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

$$i_t = \left[(1-\gamma)^{\frac{1}{\eta}}\, i_{Ht}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} i_{Ft}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}. \tag{1.27}$$

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:

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

subject to the capital law of motion:

$$k_t = (1-\delta)\,k_{t-1} + \left[1-\frac{\kappa_I}{2}\left(\frac{i_t}{i_{t-1}}-1\right)^2\right] i_t. \tag{1.28}$$

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

1.3.6 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

[15] If entrepreneurs were infinitely lived, they would accumulate an infinite amount of net worth, making financial frictions irrelevant.

foreign rate follows an autoregressive stochastic process:

$$y_t^* = 1 \tag{1.29}$$

$$P_t^* = 1 \tag{1.30}$$

$$R_t^* = (1-\rho_p) R^* + \rho_p R_{t-1}^* + v_t^p, \tag{1.31}$$

whit 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:

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

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

$$x_t = \gamma^* \left(\frac{p_{Ht}}{rer_t}\right)^{-\eta^*} y_t^*. \tag{1.32}$$

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

1.3.7 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:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{gdp_t}{gdp_t^N}\right)^{\phi_y}\right]^{1-\rho_R}, \tag{1.33}$$

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:

$$\pi_t = \pi$$

$$\frac{ner_t}{ner_{t-1}} = \pi.$$

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).[16]

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:

$$\tau_t^n = \tau^n + \phi_n \log\left(\frac{l_t}{l}\right). \tag{1.34}$$

On the other hand, capital controls are policy measures that apply only to some financial instruments, by discriminating on the basis of residency:[17] in this model they are a tax on foreign debt,[18] and they tend to discourage foreign debt accumulation when this variable is higher than its long-run level.

$$\tau_t^d = \tau^d + \phi_d \log\left(\frac{d_t^*}{d^*}\right). \tag{1.35}$$

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

$$t_t = gov_t + \vartheta - \left(\tau_t^n n_t^b + \tau_t^d rer_t d_t^*\right) \tag{1.36}$$

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

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

[16] 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 $\frac{ner_t}{ner_{t-1}} = \Delta rer \frac{\pi}{\pi^*} = \pi$.

[17] See IMF (2017).

[18] Foreign deposits are one-period securities, so taxing foreign debt stocks is equivalent to taxing foreign debt flows.

1.3.8 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:

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

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 equilibrium in imported good market requires:

$$y_{Ft} = c_{Ft}^{tot} + i_{Ft} + gov_{Ft} + \frac{\kappa_{PF}}{2}\left(\pi_{Ft} - \pi\right)^2 y_t^F + mo\hat{n}c_{Ft}. \tag{1.37}$$

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

$$rer_t d_t^* = R_{t-1}^* rer_t d_{t-1}^* - tb_t \tag{1.38}$$

where tb_t is the trade balance:

$$tb_t = p_{Ht} x_t - rer_t y_t^F. \tag{1.39}$$

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

$$lev_t^b = \frac{l_t^e}{n_t^b} \tag{1.40}$$

and have same balance sheets:

$$l_t^e = n_t^b \left(1 - \tau_t^n\right) + rer_t d_t^* \left(1 - \tau_t^d\right) + d_t. \tag{1.41}$$

The evolution of banks' net worth reads:

$$\begin{aligned} n_t^b &= \chi_b \left\{ \frac{\left(R_t^b - R_{t-1}\right) l_{t-1}^e}{\pi_t} - \left[\frac{R_{t-1}^* rer_t}{rer_{t-1}} - \frac{\left(1 - \tau_{t-1}^d\right) R_{t-1}}{\pi_t} \right] rer_{t-1} d_{t-1}^* \right\} + \\ &+ \chi_b \left\{ \frac{R_{t-1} n_{t-1}^b \left(1 - \tau_{t-1}^n\right)}{\pi_t} \right\} + \iota_b \end{aligned} \tag{1.42}$$

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

$$lev_t^e = \frac{q_t k_t}{n_t^e} \tag{1.43}$$

$$q_t k_t = n_t^e + l_t^e \tag{1.44}$$

$$n_t^e = \chi_e \left\{ \frac{R_t^{KG}}{\pi_t} k_{t-1} q_{t-1} \left[\int_{\bar{\omega}_t}^{\infty} \bar{\omega} f(\omega)\, d\omega - \bar{\omega}_t \left[1 - F(\bar{\omega}_t)\right] \right] \right\} + \iota^e. \tag{1.45}$$

Equilibrium in the loan market requires:

$$l_t = l_t^e + l_t^f. \tag{1.46}$$

Definition of gross domestic product:

$$gdp_t \equiv p_{Ht} y_{Ht} + (p_{Ft} - rer_t)\, y_{Ft} \tag{1.47}$$

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

$$gdp_t^{net} \equiv c_t^{tot} + i_t + gov_t + tb_t. \tag{1.48}$$

Finally, the credit spread is defined as:

$$spread_t = \mathbb{E}_t \left(\frac{R_{t+1}^B}{R_t} \frac{R_{t+1}^{Kg}}{R_{t+1}^B} \right) = \mathbb{E}_t \left(\frac{R_{t+1}^{KG}}{R_t} \right). \tag{1.49}$$

1.3.9 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;[19] in particular, total cost for domestic firms are given by:

[19] 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).

$$TC_t = r_t^K k_{t-1} \left[1 + \psi_k \left(r_t - 1\right)\right] \left(1 - \tau^K\right) \left(1 - \tau_H^M\right) + w_t h_t \left[1 + \psi_h \left(r_t - 1\right)\right] \left(1 - \tau^W\right) \left(1 - \tau_H^M\right). \quad (1.50)$$

with:

$$\tau^W = 1 - \frac{1}{\left[1 + \psi_h \left(r - 1\right)\right]} \quad (1.51)$$

$$\tau^K = 1 - \frac{r + \delta - 1}{r^K \left[1 + \psi_k \left(r - 1\right)\right]} \quad (1.52)$$

$$\tau_H^M = \frac{1}{\varepsilon_H}. \quad (1.53)$$

Under these assumptions, in the steady state the efficient conditions (1.3) and (1.5) 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 (1.36) is given by:

$$\vartheta = \left[\tau^W \left(1 - \tau_H^M\right) + \tau_H^M\right] h \cdot w + \left[\tau^K \left(1 - \tau_H^M\right) + \tau_H^M\right] r^K k + \tau_F^M rer \cdot y_F - mon, \quad (1.54)$$

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

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:

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

1.3.10 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[20] (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[21] during the period 2009-2014); the labor supply shifter κ_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 ψ_k and ψ_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 η is set to 1.3 and the same number is used also to calibrate its foreign counterpart η^*, both being in the range of values used in the open economy literature; γ, the weight of foreign good in final good bundle, is set to 0.15, to match an imports/gdp ratio of 15%; 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[22] 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

[20]See Chamon and Garcia (2016).

[21]The Brazilian real interest rate is computed as the difference between SELIC rate (the Brazilian Central Bank target rate) and inflation rate.

[22]In the definition of total bank leverage loans to domestic firms are also included.

discount factor is calibrated at 0.99;[23] bank survival probability is set to 0.912, implying a bank start-up fund equal to $\iota_b = 0.0003$.[24] 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 χ_e at 0.95[25] 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 κ_I is set to 2.66, as in Carvalho and Castro (2015); the Rotemberg price adjustment costs in the two sectors κ_{PH} and κ_{PF} are both set to 55.1: this value corresponds to an average price duration of three quarters in the Calvo framework.[26] In order to calibrate the two parameters pertaining to the autoregressive exogenous process for the foreign 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 $\sigma_p = 0.12\%$.[27]

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 to 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 1.1 summarizes the calibration; table 1.2 shows the steady-state targets chosen to set some parameters.

[23]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.

[24]Higher survival probability would result in a negative bank start-up fund.

[25]Higher values would result in a negative entrepreneurs' start-up fund.

[26]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.

[27]Using the Fed Funds Rate estimates are very similar.

Parameters	**Description**	**Value**
β	Discount factor	0.9811
σ	Inverse of EIS	2
φ	Inverse of Frisch elasticity	1
κ_L	Labor supply shifter	6.03
γ	Weight of foreign good	0.15
γ^*	Foreign demand shifter	0.1586
η, η^*	ES between domestic and foreign good	1.3
$\varepsilon_H, \varepsilon_F$	ES between differentiated goods	11
α	Share of capital in production	0.33
A	Steady-state TFP	1.0758
ψ_h, ψ_k	Share of input cost paid in advance	1
κ_{PH}, κ_{PF}	Price adjustment costs	55.743
δ	Depreciation rate	2.5%
κ_I	Investment adjustment cost	2.66
μ	Monitoring cost	0.2981
σ_e	Entr. dispersion	0.2667
χ_e	Entr. survival probability	0.9490
θ_0	Divertable proportion of assets	0.5606
θ_1	Home bias in funding	3.9897
χ_b	Bank survival probability	0.912
ι_b	Wealth for new banks	0.0003
ι_e	Wealth for new entr.	0.0005
ϕ_π, ϕ_y	Taylor rule coefficients	$1.9, 0$
ρ_m	Interest rate smoothing coefficient	0.825
π	Steady-state inflation	1.0133
gov	Steady-state public spending	0.2
τ^d, τ^n	Stead-state instruments	0
ρ_p	Persistence of foreign interest shock	0.95
σ_p	SD of foreign interest shock shock	0.012
y^*, P^*	Foreign output and price	1
R^*	Foreign interest rate	1.0101

Table 1.1: Calibrated parameters.

SS Target	Description	Value
r	Real interest rate	7.77% $p.a.$
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%
$\frac{rer \cdot d^*}{4 \cdot gdp}$	External debt/gdp ratio	25% $p.a.$
$R^L - R$	Bank lending spread	4.3% $p.a.$
$\frac{n^b}{l}$	Equity/loan ratio (banks)	10
$\frac{n^e}{l+n^e}$	Equity/asset ratio (non fin. sector)	42%
def	Default rate	3.3% $p.a.$

Table 1.2: Steady-state targets.

1.4 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[28] 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.

1.4.1 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 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

[28] 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.

increases inflation and induces a monetary tightening; and 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 $\phi_d = 1$[29] (figure 1.2, 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 $\phi_n = 1$[30] (figure 1.2, black dashed line), the marginal gain to the 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 1.3), the economic

[29] This means that a reduction in foreign debt by 1% implies a decrease in τ_t^d by 0.01.

[30] This means that a reduction in total loans by 1% implies a decrease in τ_t^n by 0.01.

downturn is even more mitigated, compared to the scenario in which only capital controls are implemented (red crossed line in figure 1.3).

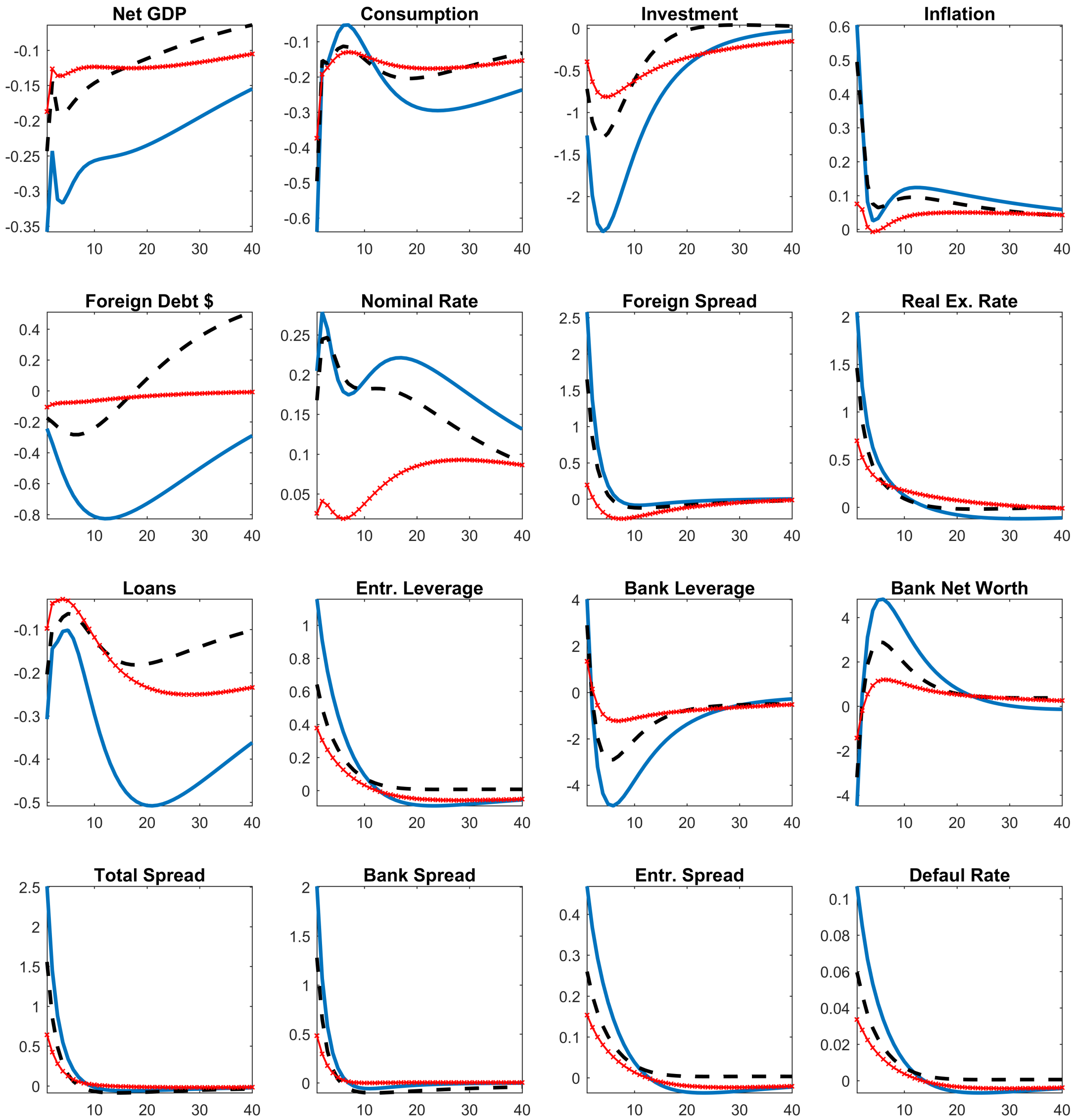

Figure 1.2: IRFs to a one standard deviation increase in the foreign interest rate, when the central bank adopts a Taylor rule. Responses are in log-deviations from the steady state, except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The blue solid line is the baseline model, the red 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 $\phi_n = 1$ to the baseline model. One period corresponds to one quarter.

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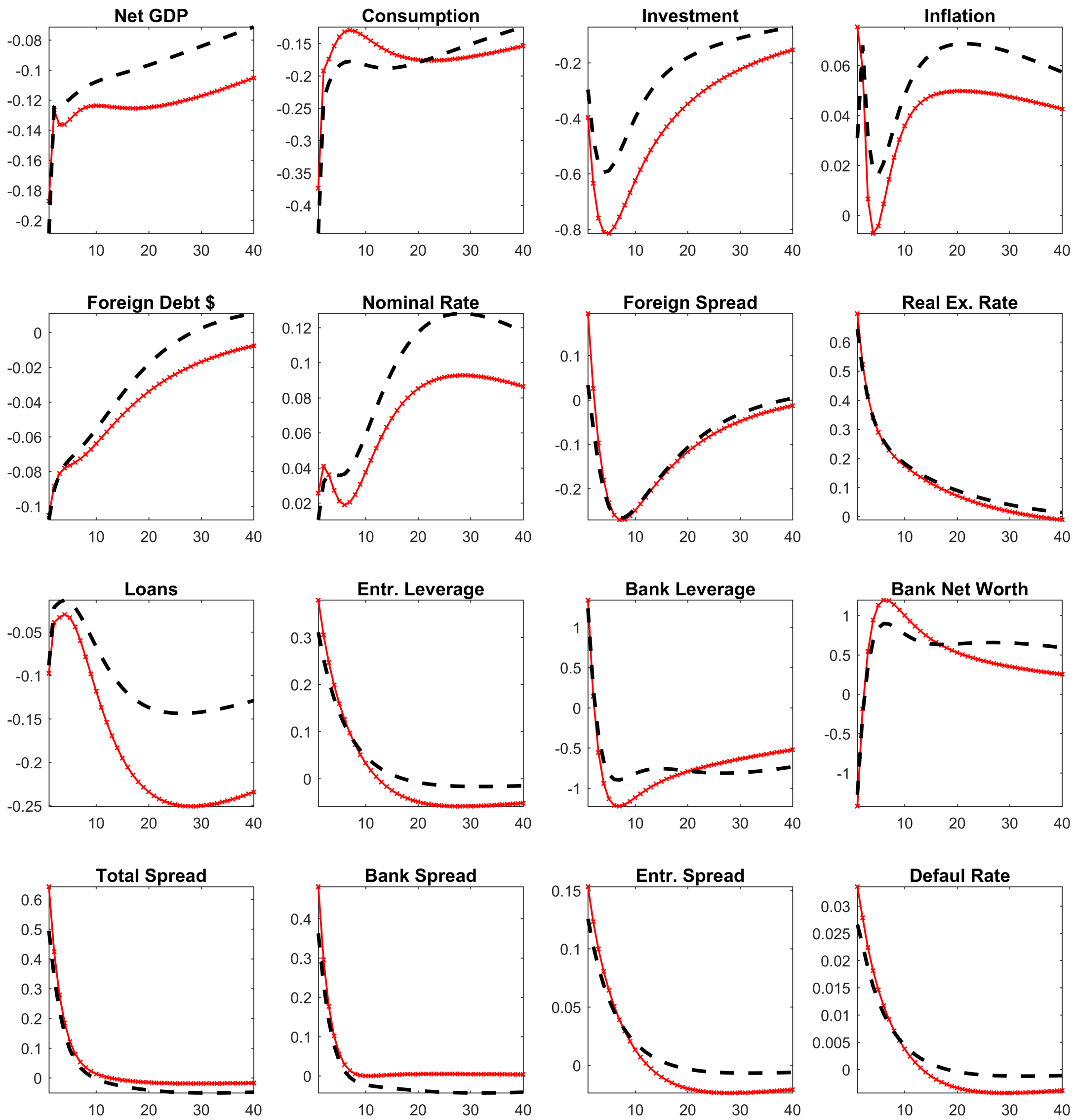

Figure 1.3: IRFs to a standard deviation increase in the foreign interest rate, when the central banks adopts a Taylor rule. Responses are in log-deviations from the steady state except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The red crossed 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.

1.4.2 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.[31] 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 Ω 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.[32]

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 ϕ_π and ϕ_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 1.3) 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 empirical 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 1.3), since it would entail an excessive interest rate tightening. The same reasoning holds for a policy pegging the nominal exchange rate: impulse responses

[31] See Faia and Monacelli (2007).

[32] Remind that the baseline scenario consists of a Taylor rule with $\phi_\pi = 1.9$, with no macroprudential and capital control policies.

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,[33] 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 ϕ_d (table 1.4), while optimal ϕ_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 ϕ_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 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).

[33]In the numerical optimization $\phi_\pi \to \infty$ and $\phi_y = 0$.

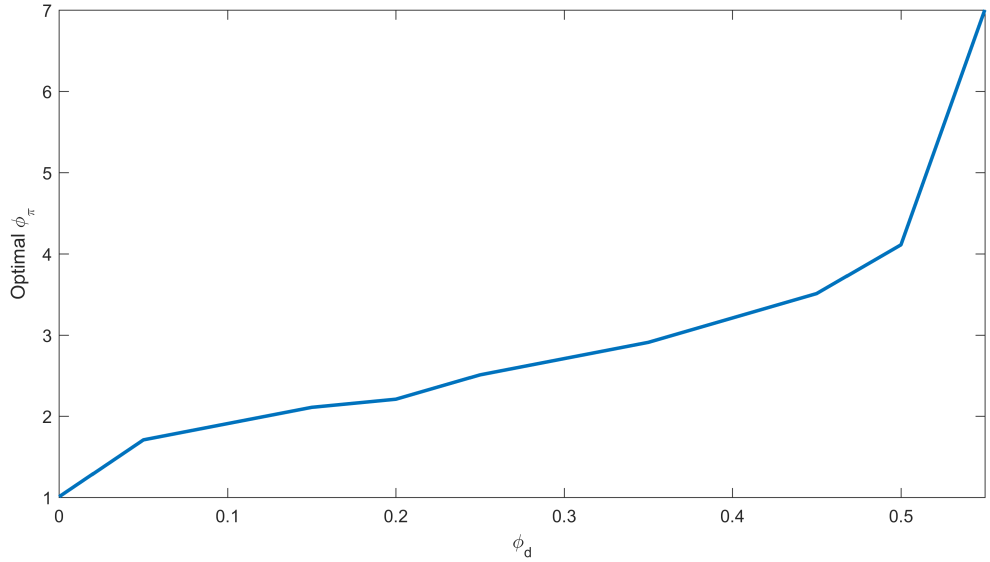

Figure 1.4: Optimal Taylor rule coefficient as a function of capital controls, under v_t^p shocks.

	Target	Peg	Opt. Mon.	Optimal
ϕ_π	–	–	1.01	∞
ϕ_y	–	–	0.5	0
ϕ_d	–	–	–	6.8
ϕ_n	–	–	–	0
Ω	-0.10%	-1.62%	0.16%	0.46%

Table 1.3: Welfare analysis under foreign interest rate shocks.

1.4.3 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 (1.45) can be rewritten as:

$$n_t^e = \chi_e \left\{ \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} \left[\int_{\bar{\omega}_t}^{\infty} \bar{\omega} f(\omega)\, d\omega - \bar{\omega}_t \left[1 - F(\bar{\omega}_t)\right] \right] \right\} \exp\left(v_t^e\right) + \iota^e. \tag{1.55}$$

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 1.6): 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 $spread^e_t$. Moreover, since the decline in n^e_t 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 $spread^b_t$ 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 ϕ_d and ϕ_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 $\phi_\pi \to \infty$ and $\phi_d \to \infty$. 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 ϕ_d is increasing in ϕ_π (figure 1.5): indeed, for low values of ϕ_π, 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^e_t shocks, capital controls are *more* desirable when monetary policy is tighter, while the opposite holds under v^p_t innovations.

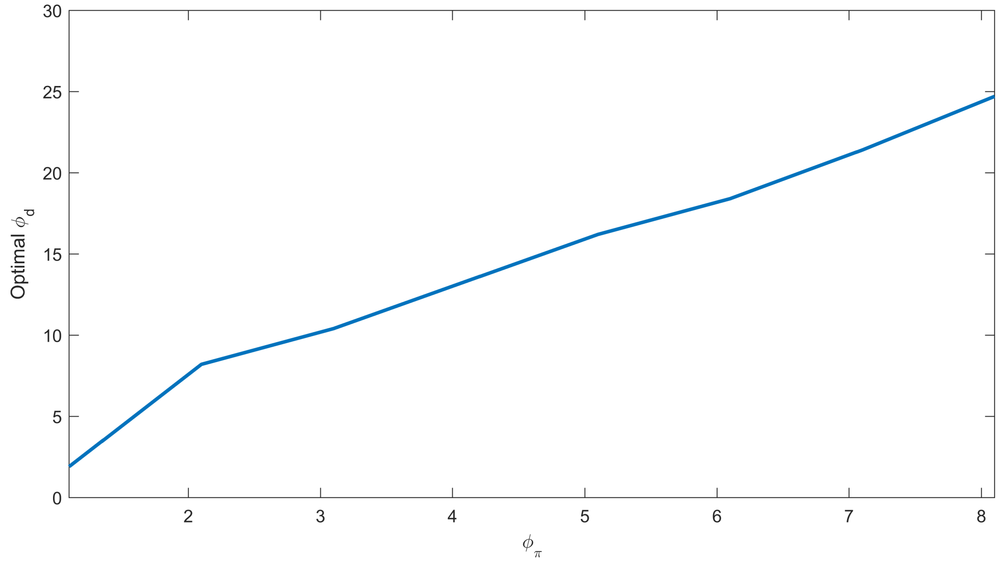

Figure 1.5: Optimal capital control as a function of Taylor rule coefficient, under v_t^e shocks.

	Target	**Peg**	**Opt. Mon.**	**Optimal**
ϕ_π	–	–	∞	∞
ϕ_y	–	–	0	0
ϕ_d	–	–	–	∞
ϕ_n	–	–	–	0
Ω	0.92%	−2.22%	0.92%	2.04%

Table 1.4: 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 1.7). 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 countercyclical 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.

	Target	**Peg**	**Opt. Mon.**	**Optimal**
ϕ_π	–	–	∞	∞
ϕ_y	–	–	0	0
ϕ_d	–	–	–	0
ϕ_n	–	–	–	0.22
Ω	0.33%	−0.37%	0.33%	0.37%

Table 1.5: Welfare analysis under technology shocks.

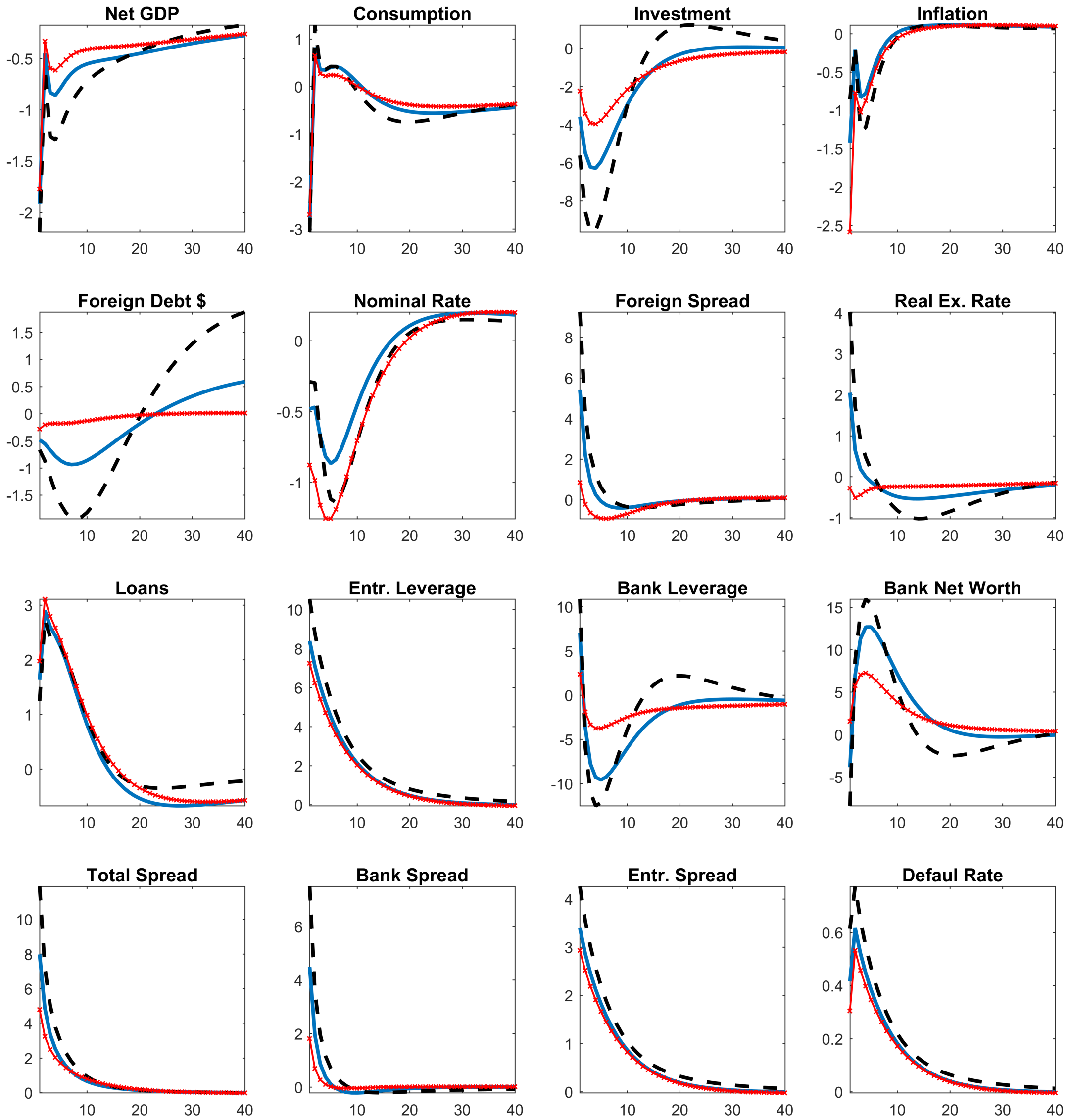

Figure 1.6: IRFs to a standard deviation reduction in entrepreneur net worth when the central bank adopts a Taylor rule. Responses are in log-deviations from the steady state except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The red crossed 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.

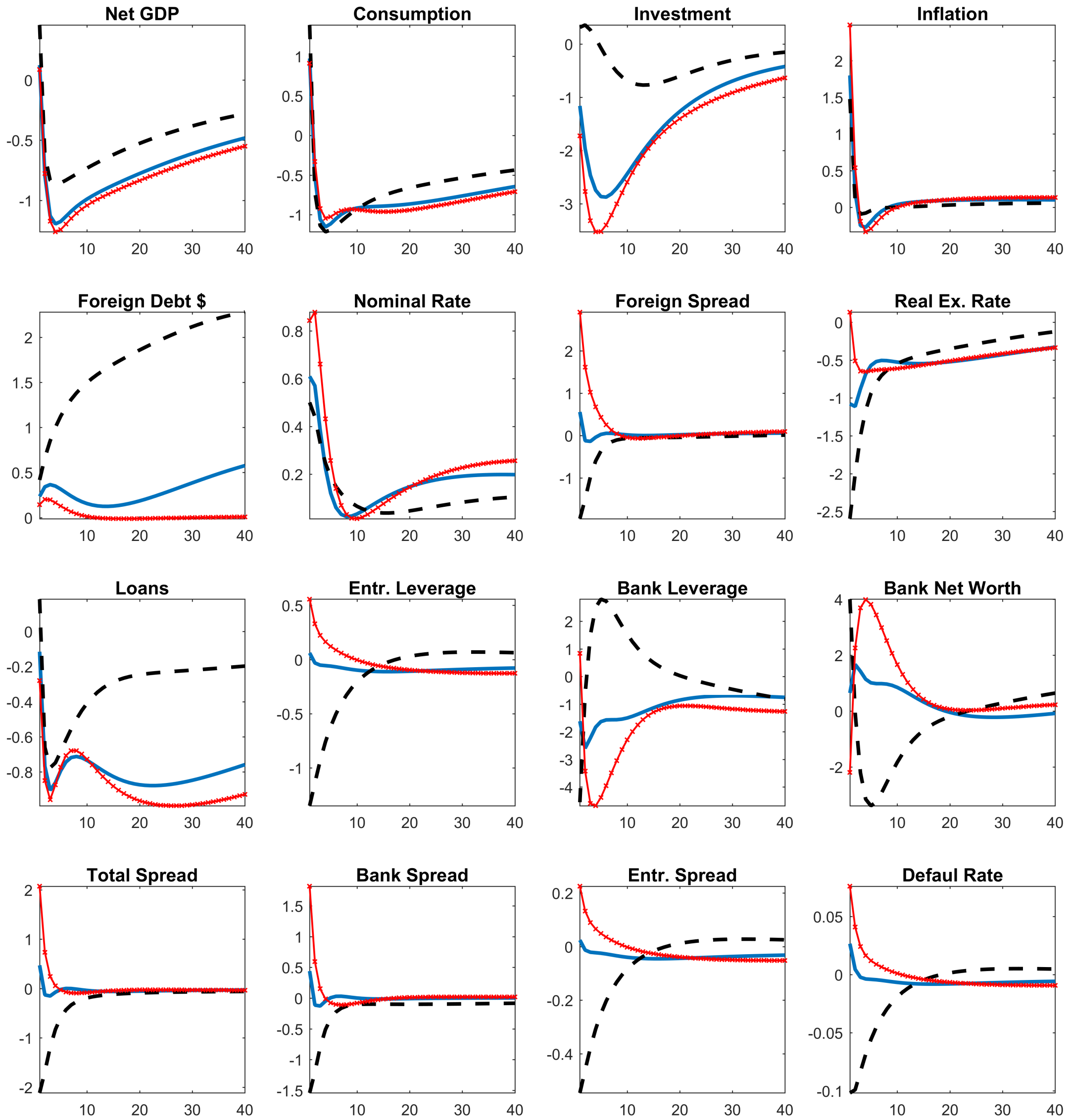

Figure 1.7: IRFs to a standard deviation reduction in TFP when the central bank adopts a Taylor rule (blue solid line). Responses are in log-deviations from the steady state except for inflation, nominal rate and spread, whose response is in annual deviations from the steady state. The crossed red line 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.

1.4.4 Alternative monetary policies

What is the role of the other policy tools when the central bank can choose between fully stabilizing inflation or the nominal exchange rate? I answer these questions in what follows.[34]

When the central bank follows a strict inflation targeting, the response without macroprudential and capital control policies (figure 1.8, 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 1.9, blue solid line): GDP, investment and consumption fall on impact by 4%, 5% and 6% respectively. Indeed, the modified UIP condition (equation 1.20) 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,[35] 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 1.20).

[34]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.

[35]In the Taylor rule case net worth drops on impact and then starts to rise.

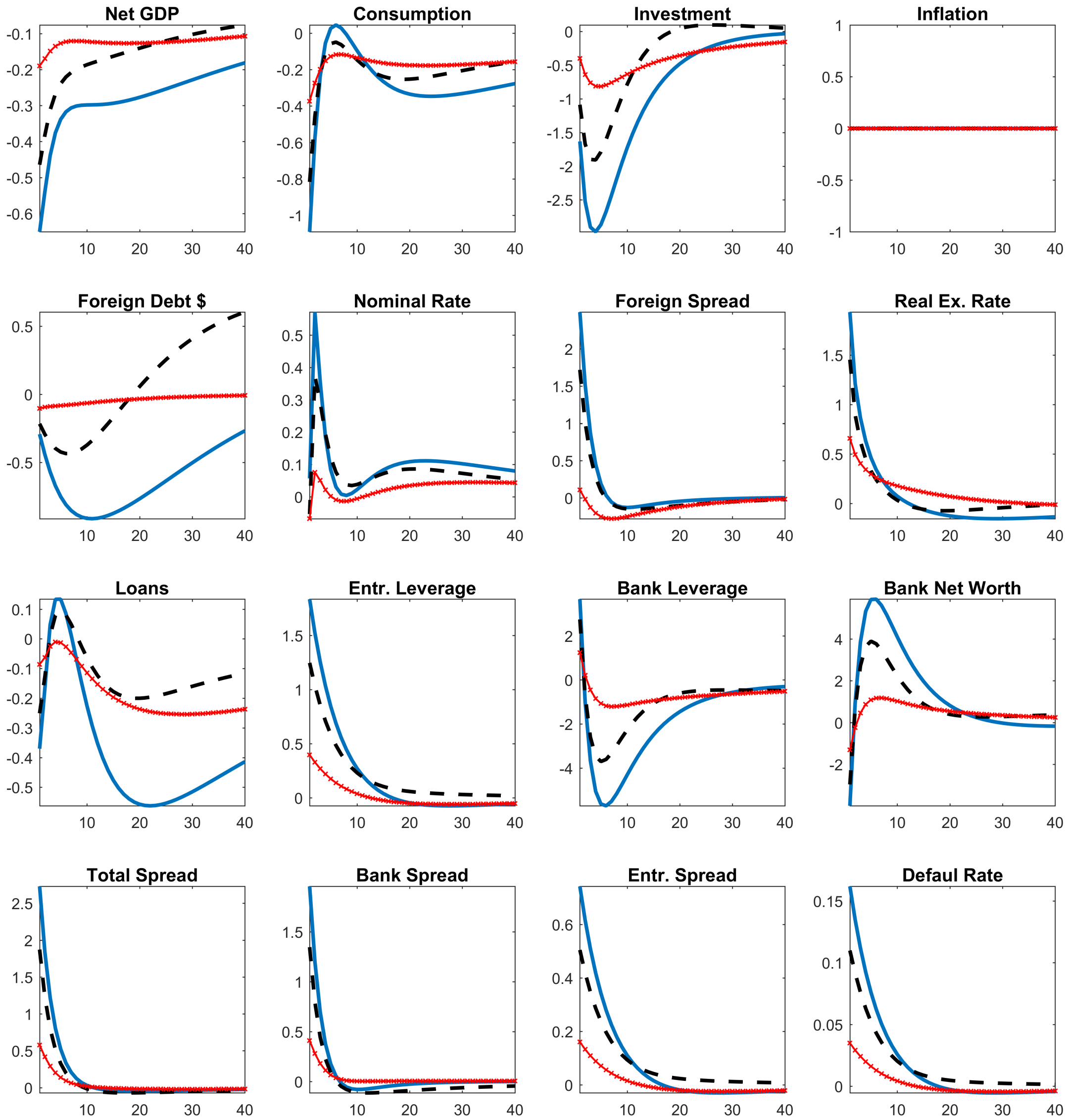

Figure 1.8: IRFs to a one-standard-deviation increase in the foreign interest rate when the central bank fully stabilizes inflation. Responses are in log-deviations from the steady state except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The 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.

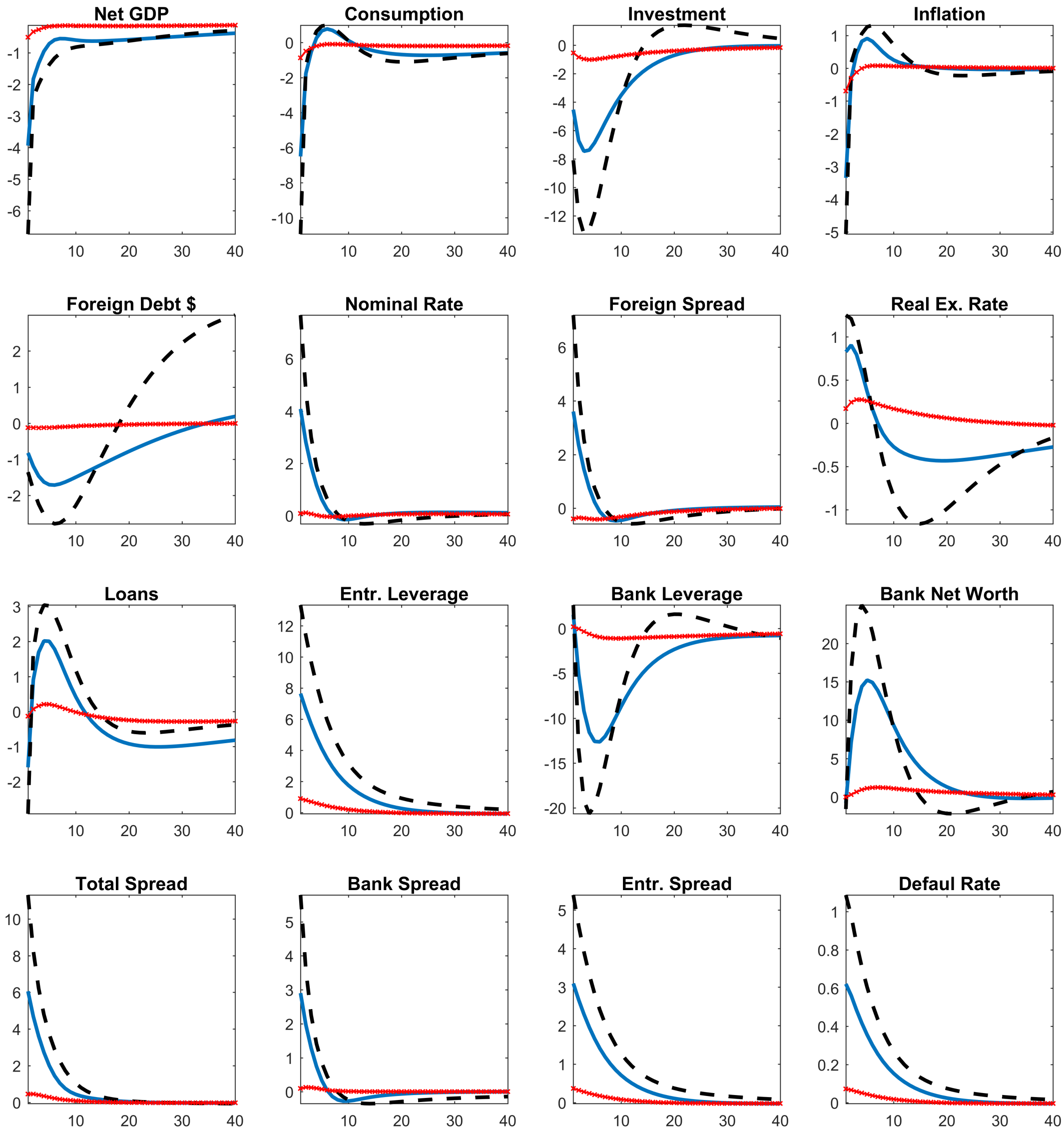

Figure 1.9: IRFs to a standard deviation increase in the foreign interest rate, when the central bank pegs the nominal exchange rate. Responses are in log-deviations from the steady state except for inflation, nominal rate and spreads, whose response is in annual deviations from the steady state. The 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.

1.5 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 credit 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.[36] These issues are left for future research.

[36]E.g. Baba and Kokenyne (2011).

Appendix

1.A Model Equations

The equilibrium is characterized by equations (1.56)-(1.125) 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: $\{v_t^p, v_t^e, v_t^a\}$.

1.A.1 Households

Marginal utility of consumption:

$$\lambda_t = \left(c_t - \kappa_L \frac{h_t^{1+\varphi}}{1+\varphi}\right)^{-\sigma}. \tag{1.56}$$

Euler equation:

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{R_t}{\pi_{t+1}}\right). \tag{1.57}$$

Labor supply:

$$\kappa_L h_t^{\varphi} = w_t. \tag{1.58}$$

Demand for domestic and foreign good:

$$c_{Ht} = (1-\gamma)(p_{Ht})^{-\eta} c_t \tag{1.59}$$

$$c_{Ft} = \gamma (p_{Ft})^{-\eta} c_t. \tag{1.60}$$

Consumption bundle:

$$c_t = \left[(1-\gamma)^{\frac{1}{\eta}} c_{Ht}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} c_{Ft}^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}. \tag{1.61}$$

1.A.2 Firms

Domestic firms

Input demands

$$k_{t-1} = \alpha \frac{mc_{Ht} y_{Ht}}{r_t^K (1-\tau^K)(1-\tau_H^M)[1+\psi_k (r_t - 1)]} \tag{1.62}$$

$$h_t = (1-\alpha) \frac{mc_{Ht} y_{Ht}}{w_t (1-\tau^W)(1-\tau_H^M)[1+\psi_H (r_t - 1)]}. \tag{1.63}$$

Total factor productivity:

$$A_t = (1-\rho_a) A + \rho_a A_{t-1} + \upsilon_t^a. \tag{1.64}$$

Domestic Phillips curve:

$$\begin{aligned} \pi_{Ht}(\pi_{Ht}-\pi) &= \mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\pi_{Ht+1}(\pi_{Ht+1}-\pi)\frac{p_{Ht+1}y_{Ht+1}}{p_{Ht}y_{Ht}}\right]+ \\ &\quad +\frac{\varepsilon_H}{\kappa_{PH}}\left[\frac{mc_t^H}{p_{Ht}}-\left(\frac{\varepsilon_H-1}{\varepsilon_H}\right)\right]. \end{aligned} \tag{1.65}$$

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

$$\pi_{Ht} = \frac{p_{Ht}}{p_{Ht-1}}\pi_t. \tag{1.66}$$

Production:

$$y_{Ht} = A_t k_{t-1}^{\alpha} h_t^{1-\alpha}. \tag{1.67}$$

Loans to domestic firms:

$$l_t^f = \psi_h w_t h_t + \psi_k r_t^K k_{t-1}. \tag{1.68}$$

Importing firms

Phillips curve:

$$\begin{aligned} \pi_{Ft}(\pi_{Ft}-\pi) &= \mathbb{E}_t\left[\beta\frac{\lambda_{t+1}}{\lambda_t}\pi_{Ft+1}(\pi_{Ft+1}-\pi)\frac{p_{Ft+1}y_{Ft+1}}{p_{Ft}y_{Ft}}\right]+ \\ &\quad +\frac{\varepsilon_F}{\kappa_{PF}}\left[\frac{\left(1-\tau_F^M\right)rer_t}{p_{Ft}}-\left(\frac{\varepsilon_F-1}{\varepsilon_F}\right)\right]. \end{aligned} \tag{1.69}$$

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

$$\pi_t^F = \frac{p_{Ft}}{p_{Ft-1}}\pi_t. \tag{1.70}$$

1.A.3 Banks

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

$$\nu_{lt} = \mathbb{E}_t \left[\beta \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \frac{\left(R^B_{t+1} - R_t\right)}{\pi_{t+1}} \right] \tag{1.71}$$

$$\nu^*_{dt} = \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \left[\frac{R_t}{\pi_{t+1}} \left(1 - \tau^d_t\right) - R^*_t \frac{rer_{t+1}}{rer_t} \right] \right\} \tag{1.72}$$

$$\nu_{nt} = \mathbb{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \frac{R_t}{\pi_{t+1}} \left(1 - \tau^n_t\right) \right\}. \tag{1.73}$$

Bank discount factor:

$$\begin{aligned} \nu_t &= 1 - \chi_b + \chi_b \beta \mathbb{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \left\{ \left\{ \frac{\left(R^B_{t+1} - R_t\right)}{\pi_{t+1}} + \left[\frac{R_t}{\pi_{t+1}} \left(1 - \tau^d_t\right) - R^*_t \frac{rer_{t+1}}{rer_t} \right] dl_t \right\} lev^b_t \right\} \right\} \\ &\quad + \chi_b \beta \mathbb{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \nu_{t+1} \left[\frac{R_t}{\pi_{t+1}} \left(1 - \tau^n_t\right) \right] \right\}. \end{aligned} \tag{1.74}$$

Evolution of net worth:

$$\begin{aligned} n^b_t &= \chi_b \left\{ \frac{\left(R^b_t - R_{t-1}\right) l^e_{t-1}}{\pi_t} - \left[\frac{R^*_{t-1} rer_t}{rer_{t-1}} - \frac{\left(1 - \tau^d_{t-1}\right) R_{t-1}}{\pi_t} \right] rer_{t-1} d^*_{t-1} \right\} + \\ &\quad + \chi_b \left\{ \frac{R_{t-1} n^b_{t-1} \left(1 - \tau^n_{t-1}\right)}{\pi_t} \right\} + \iota_b \end{aligned} \tag{1.75}$$

Equilibrium leverage:

$$lev^b_t = \frac{\nu_{nt}}{\theta_t - \left(\nu_{lt} + \nu^*_{dt} dl_t\right)}. \tag{1.76}$$

Leverage definition:

$$lev^b_t = \frac{l^e_t}{n^b_t}. \tag{1.77}$$

Definition of dl_t:

$$dl_t = \frac{rer_t d^*_t}{l^e_t}. \tag{1.78}$$

Foreign deposit demand:

$$dl_t = \frac{-1 + \sqrt{1 + \frac{2}{\theta_1} \left(\frac{\nu^*_{dt}}{\nu_{lt}}\right)^2}}{\frac{\nu^*_{dt}}{\nu_{lt}}}. \tag{1.79}$$

Balance sheets:

$$l_t^e = n_t^b (1 - \tau_t^n) + rer_t d_t^* \left(1 - \tau_t^d\right) + d_t. \tag{1.80}$$

Fraction of divertable assets:

$$\theta_t = \theta_0 \left(1 + \frac{\theta_1}{2} dl_t^2\right). \tag{1.81}$$

1.A.4 Entrepreneurs

Definition of loan return:

$$R_{t-1}^L = \frac{\bar{\omega}_t R_t^{KG}}{l_{t-1}^e} q_{t-1} k_{t-1}. \tag{1.82}$$

Bank participation constraint:

$$R_t^B l_{t-1}^e = g_t R_t^{KG} q_{t-1} k_{t-1}. \tag{1.83}$$

Leverage definition:

$$lev_t^e = \frac{q_t k_t}{n_t^e}. \tag{1.84}$$

Net worth evolution:

$$n_t^e = \chi_e \frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} m_t \exp\left(v_t^e\right) + \iota^e. \tag{1.85}$$

External finance premium in equilibrium:

$$\mathbb{E}_t \left(\frac{R_{t+1}^{KG}}{R_{t+1}^B}\right) = \mathbb{E}_t \left(\frac{m'_{t+1}}{m'_{t+1} g_{t+1} - m_{t+1} g'_{t+1}}\right). \tag{1.86}$$

Balance sheets:

$$q_t k_t = n_t^e + l_t^e. \tag{1.87}$$

Definition of capital return:

$$R_t^{KG} = \pi_t \frac{r_t^K + (1 - \delta) q_t}{q_{t-1}}. \tag{1.88}$$

Auxiliary variables:

$$a_t = \frac{\ln\left(\overline{\omega}_t\right) + 0.5\sigma_e^2}{\sigma_e} \tag{1.89}$$

$$g_t = \bar{\omega}_t \left[1 - \Phi\left(a_t\right)\right] + \left(1 - \mu\right)\Phi\left(a_t - \sigma_e\right) \tag{1.90}$$

$$m_t = \left[1 - \Phi\left(a_t - \sigma_e\right)\right] - \bar{\omega}_t \left[1 - \Phi\left(a_t\right)\right] \tag{1.91}$$

$$g_t' = \left[1 - \Phi\left(a_t\right)\right] - \frac{\mu}{\sigma_e}\phi\left(a_t\right) \tag{1.92}$$

$$m_t' = -\left[1 - \Phi\left(a_t\right)\right] \tag{1.93}$$

$$\psi_t = 1 - g_t - m_t, \tag{1.94}$$

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

1.A.5 Capital producers

Law of motion of capital:

$$k_t = \left(1 - \delta\right) k_{t-1} + \left[1 - \frac{\kappa_I}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2\right] i_t. \tag{1.95}$$

Optimal investment:

$$\begin{aligned} 1 &= q_t \left[1 - \frac{\kappa_I}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 - \kappa_I \left(\frac{i_t}{i_{t-1}} - 1\right)\frac{i_t}{i_{t-1}}\right] + \\ &\quad + \beta\kappa_I \mathbb{E}_t \left[\frac{\lambda_{t+1}}{\lambda_t} q_{t+1} \left(\frac{i_{t+1}}{i_t} - 1\right)\left(\frac{i_{t+1}}{i_t}\right)^2\right]. \end{aligned} \tag{1.96}$$

Investment good demands:

$$i_{Ht} = \left(1 - \gamma\right)\left(p_{Ht}\right)^{-\eta} i_t \tag{1.97}$$

$$i_{Ft} = \gamma \left(p_{Ft}\right)^{-\eta} i_t. \tag{1.98}$$

1.A.6 Foreign economy

Exports:

$$x_t = \gamma^* \left(\frac{p_{Ht}}{rer_t}\right)^{-\eta^*} y^*. \tag{1.99}$$

Foreign interest rate:

$$R_t^* = (1-\rho_p)\, R^* + \rho_p R_{t-1}^* + v_t^p. \tag{1.100}$$

1.A.7 Policy

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

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{gdp_t^N}{gdp_t}\right)^{\phi_y}\right]^{1-\rho_R}. \tag{1.101}$$

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:

$$\tau_t^n = \tau^n + \phi_n \log\left(\frac{l_t}{l}\right). \tag{1.102}$$

Capital control:

$$\tau_t^d = \tau^n + \phi_d \log\left(\frac{d_t^*}{d^*}\right). \tag{1.103}$$

Government spending demand:

$$gov_{Ht} = (1-\gamma)\,(p_{Ht})^{-\eta}\, gov \tag{1.104}$$

$$gov_{Ft} = \gamma\,(p_{Ft})^{-\eta}\, gov. \tag{1.105}$$

1.A.8 Market clearing and definitions

Good market equilibrium:

$$y_{Ht} = c_{Ht}^{tot} + i_{Ht} + gov_{Ht} + x_t + \frac{\kappa_{PH}}{2}\left(\pi_{Ht} - \pi\right)^2 y_t^H + monc_{Ht} - monc_H \quad (1.106)$$

$$y_{Ft} = c_{Ft}^{tot} + i_{Ft} + gov_{Ft} + \frac{\kappa_{PF}}{2}\left(\pi_{Ft} - \pi\right)^2 y_t^F + monc_{Ft} - monc_F \quad (1.107)$$

where:

$$monc_t = \frac{R_t^{KG}}{\pi_t}\psi_t q_{t-1} k_{t-1} \quad (1.108)$$

$$monc_{Ht} = (1-\gamma)\left(p_{Ht}\right)^{-\eta} monc_t \quad (1.109)$$

$$monc_{Ft} = \gamma\left(p_{Ft}\right)^{-\eta} monc_t. \quad (1.110)$$

Evolution of net financial asset position:

$$tb_t = r_{t-1}^{*} rer_t d_{t-1}^{*} - rer_t d_t^{*}. \quad (1.111)$$

GDP:

$$gdp_t = p_{Ht} y_{Ht} + \left(p_{Ft} - rer_t\right) y_{Ft}. \quad (1.112)$$

GDP net of monitoring and price adjustment costs:

$$gdp_t^{net} = c_t + i_t + gov + tb_t. \quad (1.113)$$

Equilibrium in loan market:

$$l_t = l_t^e + l_t^f. \quad (1.114)$$

Trade balance:

$$tb_t = p_{Ht} x_t - rer_t y_{Ft}. \quad (1.115)$$

Total consumption:

$$c_t^{tot} = c_t + c_t^b + c_t^e. \quad (1.116)$$

Bankers consumption:

$$
\begin{aligned}
c_t^b &= (1-\chi_b)\left\{\frac{\left(R_t^B - R_{t-1}\right)}{\pi_t} l_t^e - \left[R_{t-1}^* \frac{rer_t}{rer_{t-1}} - \frac{R_{t-1}}{\pi_t}\left(1-\tau_{t-1}^d\right)\right] rer_{t-1} d_{t-1}^*\right\} + \\
&\quad + (1-\chi_b)\left[\frac{R_{t-1}}{\pi_t} n_{t-1}^b \left(1-\tau_{t-1}^n\right)\right] \qquad (1.117)
\end{aligned}
$$

$$
\begin{aligned}
c_{Ht}^b &= (1-\gamma)\left(p_{Ht}\right)^{-\eta} c_t^b \qquad (1.118) \\
c_{Ft}^b &= \gamma \left(p_{Ft}\right)^{-\eta} c_t^b. \qquad (1.119)
\end{aligned}
$$

Entrepreneurs consumption:

$$
\begin{aligned}
c_t^e &= (1-\chi_e)\frac{R_t^{KG}}{\pi_t} q_{t-1} k_{t-1} m_t \exp\left(v_t^e\right) \qquad (1.120) \\
c_{Ht}^e &= (1-\gamma)\left(p_{Ht}\right)^{-\eta} c_t^e \qquad (1.121) \\
c_{Ft}^e &= \gamma \left(p_{Ft}\right)^{-\eta} c_t^e. \qquad (1.122)
\end{aligned}
$$

Credit spread definition:

$$
spread_t = \mathbb{E}_t\left(\frac{R_{t+1}^{KG}}{R_t}\right). \qquad (1.123)
$$

Default rate definition:

$$
defrate_t = F\left(\frac{\log\left(\bar{\omega}_t\right) + \frac{1}{2}\sigma_e^2}{\sigma_e}\right). \qquad (1.124)
$$

Real interest rate definition:

$$
r_t = \frac{R_t}{\mathbb{E}_t\left(\pi_{t+1}\right)}. \qquad (1.125)
$$

1.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.[37] Variables in the frictionless economy are indexed with an N. The equilibrium is characterized by equations (1.126)-(1.144) that describe the dynamics of 19 endogenous variables.

1.B.1 Households

Marginal utility of consumption:

$$\lambda_t^N = \left(c_t^N - \kappa_L \frac{h_t^{N(1+\varphi)}}{1+\varphi} \right)^{-\sigma}. \tag{1.126}$$

Euler equation for domestic bond:

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda_{t+1}^N}{\lambda_t^N} r_t \right). \tag{1.127}$$

Euler equation for capital:

$$1 = \beta \mathbb{E}_t \left[\frac{\lambda_{t+1}^N}{\lambda_t^N} \frac{r_{t+1}^{N,K} + (1-\delta) q_{t+1}^N}{q_t^N} \right]. \tag{1.128}$$

Euler equation for foreign bonds:

$$1 = \beta \mathbb{E}_t \left[\frac{\lambda_{t+1}^E}{\lambda_t^E} \frac{rer_{t+1}^N}{rer_t^N} R_t^N \right], \tag{1.129}$$

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

$$R_t^N = R_t^* \cdot prem \cdot \left[\exp \kappa_D \left(\frac{rer_t^P d_t^{N*}}{rer \cdot d^*} - 1 \right) \right]. \tag{1.130}$$

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

$$\kappa_L h_t^{N(\varphi)} = w_t^N. \tag{1.131}$$

Price level:

$$1 = (1-\gamma) p_{Ht}^{N(1-\eta)} + \gamma p_{Ft}^{N(1-\eta)}. \tag{1.132}$$

[37] In the frictionless economy, I do not eliminate these two agents to have in steady state $gdp^N = gdp$.

1.B.2 Firms

Domestic firms

Input demands:

$$k_{t-1}^{N} = \alpha \frac{p_{Ht}^{N} y_{Ht}^{N}}{r_{t}^{N,K}} \tag{1.133}$$

$$h_{t}^{N} = (1-\alpha) \frac{p_{Ht}^{N} y_{Ht}^{N}}{w_{t}^{N}}. \tag{1.134}$$

Production:

$$y_{Ht}^{N} = A_t k_{t-1}^{N(\alpha)} h_{t}^{N(1-\alpha)}. \tag{1.135}$$

Importing firms

Equilibrium condition:

$$rer_{t}^{N} = p_{Ft}^{N}. \tag{1.136}$$

1.B.3 Capital producers

Law of motion of capital:

$$k_{t}^{N} = (1-\delta) k_{t-1}^{N} + \left[1 - \frac{\kappa_I}{2} \left(\frac{i_{t}^{N}}{i_{t-1}^{N}} - 1\right)^2\right] i_{t}^{N}. \tag{1.137}$$

Optimal investment:

$$\begin{aligned} 1 = {} & q_{t}^{N} \left[1 - \frac{\kappa_I}{2} \left(\frac{i_{t}^{N}}{i_{t-1}^{N}} - 1\right)^2 - \kappa_I \left(\frac{i_{t}^{N}}{i_{t-1}^{N}} - 1\right) \frac{i_{t}^{N}}{i_{t-1}^{N}}\right] + \\ & + \beta \kappa_I \mathbb{E}_t \left[\frac{\lambda_{t+1}^{N}}{\lambda_{t}^{N}} q_{t+1}^{N} \left(\frac{i_{t+1}^{N}}{i_{t}^{N}} - 1\right) \left(\frac{i_{t+1}^{N}}{i_{t}^{N}}\right)^2\right]. \end{aligned} \tag{1.138}$$

1.B.4 Market clearing

Domestic and foreign good:

$$y_{Ht}^{N} = (1-\gamma) p_{Ht}^{N(-\eta)} \left(c_{t}^{N,tot} + i_{t}^{N} + gov\right) + x_{t}^{N} \tag{1.139}$$

$$y_{Ft}^{N} = \gamma p_{Ft}^{N(-\eta)} \left(c_{t}^{N,tot} + i_{t}^{N} + gov\right). \tag{1.140}$$

Total consumption:

$$c_t^{N,tot} = c_t^N + c^b + c^e. \tag{1.141}$$

Exports:

$$x_t^N = \gamma^* \left(\frac{p_{Ht}^N}{rer_t^N} \right)^{-\eta^*} y^*. \tag{1.142}$$

Evolution of net financial position:

$$rer_t^N d_t^{N*} = rer_t^N R_{t-1}^* d_{t-1}^{N*} - \left(p_{Ht}^N x_t^N - p_{Ft}^N y_{Ft}^N \right). \tag{1.143}$$

Definition of frictionless level of output:

$$gdp_t^N = p_{Ht}^N y_{Ht}^N. \tag{1.144}$$

1.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.

1.C.1 Banks' optimization problem

Profits of bank b are given by:[38]

$$n_t^b(b) = \frac{R_t^B}{\pi_t} l_{t-1}^e(b) - R_{t-1}^* rer_t d_{t-1}^*(b) - \frac{R_{t-1}}{\pi_t} d_{t-1}(b). \tag{1.145}$$

Using (1.80) it possible to write:

$$\frac{n_{t+1}^b(b)}{n_t^b(b)} = \left(\frac{R_{t+1}^B - R_t}{\pi_{t+1}} \right) lev_t^b(b) - \left[R_t^* \frac{rer_{t+1}}{rer_t} - \frac{R_t}{\pi_{t+1}} \left(1 - \tau_t^d \right) \right] \frac{rer_t d_t^*(b)}{n_t^b(b)} + \frac{R_t}{\pi_{t+1}} \left(1 - \tau_t^n \right). \tag{1.146}$$

The expected discounted value of bank b is defined as:

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

[38] These derivations follow Aoki et al. (2016).

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:

$$\mathcal{V}_t(b) = \nu_{lt} lev_t^b(b) + \nu_{nt} + \nu_{dt}^* dl_t(b)\, lev_t^b(b). \tag{1.147}$$

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:

$$dl_t(b) = \frac{-1 + \sqrt{1 + \frac{2}{\theta_1}\left(\frac{\nu_{dt}^*}{\nu_{lt}}\right)^2}}{\frac{\nu_{dt}^*}{\nu_{lt}}}, \tag{1.148}$$

which corresponds to equation (1.79). Notice that dl_t is independent from bank b specific factors (so the index b can be suppressed). By using the incentive constraint and (1.147), 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 (1.76). 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 (1.147):

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

Finally, by using the last equation, (1.146) and (1.147) , one can easily recover expressions for ν_{lt}, ν_{dt}^* and ν_{nt}:

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

and for the bank discount factor:

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

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 χ_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 (1.146). Define $\Delta_t^b \equiv \frac{n_t^b(b)}{n_{t-1}(b)}$; then it holds:

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

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

$$n_{nt}^b = \iota^b.$$

Accordingly, I can get equation (1.75).

1.C.2 Entrepreneurs' optimization problem

The 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:[39]

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

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

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

Using the definition of loan rate (equation 1.82), entrepreneur j expected profits read:

$$\mathbb{E}_t \left\{ \frac{R_{t+1}^{KG}}{\pi_{t+1}} q_t k_t(j) \left[\int_{\bar{\omega}_{t+1}(j)}^{\infty} \omega f(\omega) \, d\omega - \bar{\omega}_{t+1}(j) \left[1 - F\left(\bar{\omega}_{t+1}(j)\right) \right] \right] \right\}. \tag{1.149}$$

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

$$\frac{R_t^B}{\pi_t} = \frac{\left\{ \left[1 - F\left(\bar{\omega}_t(j)\right) \right] \bar{\omega}_t(j) + (1-\mu) \int_0^{\bar{\omega}_t} \bar{\omega} f(\omega) \, d\omega \right\} \frac{R_t^{KG}}{\pi_t} q_t k_{t-1}(j)}{l_{t-1}^e(j)}, \tag{1.150}$$

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

[39]In this section, the steps follow Garcia-Cicco and Kirchner (2016).

of defaulting entrepreneurs, net of monitoring costs. Define $m_t(j) \equiv \int_{\bar{\omega}_t(j)}^{\infty} \omega f(\omega)\, d\omega - \bar{\omega}_t(j)\left[1 - F(\bar{\omega}_t(j))\right]$ and $g_t(j) \equiv \left[1 - F(\bar{\omega}_t)\right]\bar{\omega}_t(j) + (1-\mu)\int_0^{\bar{\omega}_t(j)} \omega f(\omega)\, d\omega$. The problem of entrepreneurs j is maximizing (1.149) subject to (1.150):

$$\max \mathbb{E}_t \left[\frac{R^{KG}_{t+1}}{\pi_{t+1}} q_t k_t(j)\, m_{t+1}(j)\right]$$

$$s.t.\ \frac{R^{B}_{t+1}}{\pi_{t+1}} l^e_t(j) = g_{t+1}(j)\frac{R^{KG}_{t+1}}{\pi_{t+1}} q_{t+1} k_t(j).$$

Using the definition of lev^e_t and getting rid of n^e_t and π_{t+1}, the Lagrangian of the problem can be written as follows:

$$\mathcal{L}_t = \mathbb{E}_t \left\{ R^{KG}_{t+1} lev^e_t(j)\, m_{t+1}(j) - \xi_{t+1}(j)\left[R^B_{t+1}\left(lev^e_t(j) - 1\right) - g_{t+1}(j) R^{KG}_{t+1} lev^e_t(j)\right]\right\},$$

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

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

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:

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

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 (1.82), 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 $\mathbb{E}(\overline{\omega}) = 1$. 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 (1.90)-(1.93).

Net worth of "old" entrepreneurs is given by:

$$\begin{aligned} n_{ot}^{e} &= \exp\left(v_{t}^{e}\right)\chi_{e}\int_{\bar{\omega}_{t}}^{\infty} f\left(\omega\right)\left(\omega\frac{R_{t}^{KG}}{\pi_{t}}q_{t-1}k_{t-1}-\frac{R_{t-1}^{L}}{\pi_{t}}l_{t-1}^{e}\right)d\omega \\ n_{ot}^{e} &= \exp\left(v_{t}^{e}\right)\chi_{e}\int_{\bar{\omega}_{t}}^{\infty} f\left(\omega\right)\left(\omega\frac{R_{t}^{KG}}{\pi_{t}}q_{t-1}k_{t-1}-\bar{\omega}_{t}\frac{R_{t}^{KG}}{\pi_{t}}q_{t-1}k_{t-1}\right)d\omega \\ n_{ot}^{e} &= \exp\left(v_{t}^{e}\right)\chi_{e}\int_{\bar{\omega}_{t}}^{\infty} f\left(\omega\right)\left[\frac{R_{t}^{KG}}{\pi_{t}}q_{t-1}k_{t-1}\left(\omega-\bar{\omega}_{t}\right)\right]d\omega \\ n_{ot}^{e} &= \exp\left(v_{t}^{e}\right)\chi_{e}\left\{\frac{R_{t}^{KG}}{\pi_{t}}q_{t-1}k_{t-1}\int_{\bar{\omega}_{t}}^{\infty} f\left(\omega\right)d\omega-\bar{\omega}_{t}\left[1-F\left(\bar{\omega}_{t}\right)\right]\right\} \\ n_{ot}^{e} &= \exp\left(v_{t}^{e}\right)\chi_{e}\frac{R_{t}^{KG}}{\pi_{t}}q_{t-1}k_{t-1}m_{t}. \end{aligned}$$

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

$$n_{nt}^{e}=\iota^{e}$$

and I can get equation (1.85).

1.C.3 Modified UIP Condition

The goal of this paragraph is to derive equation (1.20). By using (1.57), rewrite (1.71) and (1.72):

$$\begin{aligned} \nu_{lt} &= \mathbb{E}_{t}\left[\nu_{t+1}spread_{t}^{Bn}\right] \\ \nu_{dt}^{*} &= \mathbb{E}_{t}\left\{\nu_{t+1}uip_{t}\right\}, \end{aligned}$$

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:

$$\begin{aligned} \tilde{uip}_{t} &= \frac{r^{*}}{r-r^{*}}\tilde{R}_{t}-\frac{r^{*}}{r-r^{*}}\tilde{R}_{t}^{*}-\frac{r^{*}}{r-r^{*}}\mathbb{E}_{t}\left(\Delta\tilde{ner}_{t+1}\right)-\frac{r^{*}}{r-r^{*}}\tau_{t}^{d} && (1.151) \\ \tilde{spread}_{t}^{Bn} &= \frac{R^{B}}{R^{B}-R}\mathbb{E}_{t}\left(\tilde{R}_{t+1}^{B}-\tilde{R}_{t}\right), && (1.152) \end{aligned}$$

where $\tilde{x}_t$ is the percentage deviation from the steady state of variable x_t and $\Delta ner_{t+1} \equiv \frac{ner_{t+1}}{ner_t}$. Linearization of (1.79) yields:

$$\tilde{dl}_t = D\left(\tilde{\nu}^*_{dt} - \tilde{\nu}_{lt}\right), \tag{1.153}$$

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:

$$\tilde{dl}_t = D\left(\tilde{uip}_t - \tilde{spread}^{Bn}_t\right). \tag{1.154}$$

Combine (1.151), (1.152), (1.153) and (1.154) to get the modified linear UIP condition:

$$\tilde{R}_t = \tilde{R}^*_t + \mathbb{E}_t\left(\Delta \tilde{ner}_{t+1}\right) + \tau^d_t + D_0\mathbb{E}_t\left(\tilde{R}^B_{t+1} - \tilde{R}_t\right) + D_1\left(\tilde{rer}_t + \tilde{d}^*_t - \tilde{l}^e_t\right),$$

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

1.C.4 The Steady State

The steady-state of ten variables (table 1.2) is calibrated ex-ante. As a consequence, the following ten parameters are treated as unknowns in the steady-state system:

$$\{\beta, \kappa_L, A, \gamma^*, \gamma, \theta_0, \theta_1, \iota_b, \iota_e, \sigma_e\}.$$

The Taylor rule and Euler equation imply that inflation is equal to its target, $R = \pi \cdot r$ and $\beta = \frac{1}{r}$. Equation (1.96) 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 (1.59), (1.60) and (1.61) 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 τ^M_F:

$$rer = p_F.$$

Then, I arbitrarily fix a value for σ_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 (1.82) and (1.83), it holds $lev^e = \left(1 - g\frac{R^{KG}}{R^B}\right)^{-1}$. Using (1.86) I find:

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

Use again (1.82):

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

which implies:

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

By the definition of firm subsidies, it holds:

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

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

$$\begin{aligned} k &= \alpha\frac{mc_H y_H}{\left[1 + \psi_k(r-1)\right] r^K (1-\tau^K)(1-\tau_H^M)} \\ w &= (1-\alpha)\frac{mc_H y_H}{\left[1 + \psi_h(r-1)\right] h (1-\tau^W)(1-\tau_H^M)} \end{aligned}$$

and I can find total firms loans:

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

Using (1.84), (1.87) and (1.115):

$$
\begin{aligned}
n^e &= \frac{k}{lev^e} \\
l^e &= k - n^e \\
l &= l^e + l^f.
\end{aligned}
$$

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 σ_e to hit the target. Equation (1.85) yields:

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

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

$$
\begin{aligned}
lev^b &= lev^{btot}\left(1 - \frac{l^f}{l}\right) \\
n^b &= \frac{l^e}{lev^b}.
\end{aligned}
$$

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 (1.75), it holds:

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

By (1.71) and (1.72), I find:

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

and then by equation (1.79) I can solve for θ_1. By (1.81) I recover θ_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 (1.106, 1.107 and 1.111):

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

I obtain expressions for c^{tot}, x and y^F. Using (1.116), (1.117), (1.120), 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 κ_L and γ^*:

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

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

Chapter 2

Capital Controls Spillovers

Abstract

In the last decade, some emerging economies have imposed capital controls to reduce the volatility of capital flows and to manage the exchange rate. However, a capital control tightening in some countries is likely to deflect capital flows to other countries with no controls in place. In this paper I set up an international business cycle model with three countries (one AE and two symmetric EMEs) to analyze these spillovers effects. I find that if one EME restricts its financial account to curb capital inflows, the latter are deflected to the other EME, whose economic activity expands. In addition, if the EMEs are big enough, AE business cycle is positively affected.

2.1 Introduction

Since the global financial crisis, many emerging countries have been restricting their financial account. The indicator *ka*, developed by Fernández et al. (2016), is a measure of capital controls, defined as restrictions on cross-border financial flows that discriminate between residents and non-residents: since 2006, in emerging markets this indicator is on an increasing pattern, reflecting a retrenchment of financial liberalization (figure 2.1). The economic theory provides at least three rationales which justify capital controls: i) they reduce the probability of a financial crisis (Korinek, 2011; ii) they allow to manipulate the exchange rate (Costinot et al., 2014 and Heathcote and Perri, 2016); and iii) they restore monetary independence in countries with a fixed exchange rate (according to the Mundellian impossible trinity). Nowadays the use of capital controls in certain circumstances is supported by the IMF, which recognizes these policy tools as useful for supporting macroeconomic policy adjustment and safeguarding financial system stability (see IMF, 2012). Nevertheless, not all countries have tightened capital controls in the last years. For instance, while Brazil introduced several restrictions on capital flows in 2008 and 2009, Russia made its financial account more open in this period. On the other hand, G7 economies do not seem to use these policy instruments extensively (figure 2.1).

Capital controls may entail some spillover effects to other countries, exactly as trade or monetary policies. Indeed, if capital controls are not set in a coordinated fashion (as figure 2.1 seems suggesting), a capital control tightening in some countries is likely to deflect capital flows to other countries with no controls in place, especially if cross-border flows are driven by global drivers. For instance, if Brazil raises capital controls in response to a capital inflow surge coming from the US, another emerging country, say Mexico, may experience an additional wave of capital inflows (figure 2.2). On the one hand, the latter can be welcome, whenever they finance productive investments. On the other hand, capital flows may increase macroeconomic volatility and appreciate the exchange rate: these facts may lead the Mexican government to restrict financial account in turn, thus triggering a capital control war. In addition, if capital controls are used by some big emerging markets, there could be consequences also for advanced economies. The aim of this paper is specifically to assess these spillover effects.

To this end, I set up an international real business cycle model consisting of one advanced economy (AE, henceforth) and two emerging economies (EME1 and EME2, henceforth). Capital inflows in the emerging economies are driven by preference shocks in AE. These shocks aim to capture exogenous changes in the international interest rate, which is considered one of the main drivers of capital flows.[1] Indeed, in the model, a

[1]Since the seminal works of Calvo et al. (1993) and Fernandez-Arias (1996) push factors such as

negative preference shock reduces the marginal utility of consumption of AE households, who increase their financial exposure to emerging markets. By simulating a capital controls tightening in EME1, simultaneously with the preference shock, I can assess how much the effects of such a policy spill over to EME2 and AE. Notably, I calibrate the model in order to replicate the relative size of population and GDP of advanced and emerging economies in the world. Accordingly, EME1 and EME2 (calibrated to be symmetric) are not (too) small compared to AE.

The type capital control instrument is a crucial choice for the analysis. I assume that investor in emerging economies pay a tax on cross-border financial flows. This policy tool resembles the "Impuesto sobre Operaciones Financieras ("IOF") applied in Brazil on some categories of capital inflows. Following part of the literature (e.g. Heathcote and Perri, 2016 and Unsal, 2013), the tax is assumed to react to variations in the country's net foreign asset position (NFA) relative to GDP: when the NFA is low (high) the government raises (lowers) the tax to dampen the capital inflow increase (reduction). This assumption is consistent with the Brazilian capital control policy: Brazil's controls were tightened in periods of large portfolio inflows (in Brazil and other EMEs) and were loosened in periods of lower inflows.[2]

The results of the paper are the following: i) an exogenous reduction in AE marginal utility of consumption drives capital flows from AE to EMEs; such a capital inflow shock boosts EMEs' economic activity and appreciate their exchange rate; ii) a capital control rule that aggressively reacts to NFA variations allows EME1 to shield the economy from the shock, curbing the capital inflow and mitigating the macroeconomic boom; iii) if EME2 does not use capital controls, it receives an additional inflow of capital, which amplifies the initial shock and further boosts the economic activity; and iv) given that EME1 is not small compared to AE, its policy affects AE business cycle too: in particular, EME1 capital controls slightly reduce the AE interest rate, due to the higher desire of AE households to invest in domestic bonds, driving a positive response of AE GDP, consumption and investment.

There is a growing empirical literature finding spillover effects from capital controls. Forbes et al. (2016) show that when Brazil increases its capital controls, portfolio flows move to those countries that are more closely linked to China through their exports. Moreover, they show that investors reduce their exposure to countries that are considered likely to mimic Brazilian policy and to raise capital controls. Lambert et al. (2013) find that Brazilian IOF may have contributed to divert capital flows to other Latin American

US interest rates were found to be the main determinant of capital flows in emerging countries. More recently, Rey (2015) shows that US monetary policy strongly affects financial conditions in the rest of the world. For an exhaustive survey of the literature, refer to Koepke (2015).

[2] As shown for instance by Forbes et al. (2016).

economies. The estimates provided by Giordani et al. (2016) suggest that when some countries restrict their financial account, capital flows are deflected to other countries with a similar risk profile. Pasricha et al. (2015) report evidence that capital controls in one of the BRICS economies entail relevant consequences for other BRICS economies, via net capital inflows and exchange rates. Ghosh et al. (2014) show that a country's bank flows are significantly higher when its neighbors are relatively closed to capital flows.

Unlike these empirical studies, I adopt a theoretical framework for the following reasons. First, I can overcome the endogeneity bias typical of an OLS approach.[3] Second, my analysis is fully dynamic, unlike OLS static models, and I can thus evaluate capital controls spillovers for an extended period.[4] Third, I do not have the problem to measure the intensity of capital controls, which, differently from other policy tools, are difficult to quantify in a single variable. Fourth, I can evaluate spillover effects not only on capital flows but also on a large set of macroeconomic variables. Clearly, a theoretical model is not lacking of drawbacks: notably, my analysis is not data-driven; moreover, I assume that capital controls cannot be circumvented, even if the empirical literature finds mixed results about the effectiveness of these policy tools in curbing capital flows.

The theoretical literature has focused on the normative side of capital controls spillovers, analyzing whether international coordination would end up in a welfare improvement. In a stylized model, Jeanne (2014) and Korinek (2017) derive some conditions under which there is no room for international cooperation, as long as capital control externalities are mediated through a competitive price (i.e. the international interest rate). However, if these conditions are violated (notably, when policy instruments are imperfect or during liquidity traps), then a coordinated use of capital controls is Pareto improving. In a two-country model, De Paoli and Lipinska (2013) find that capital control coordination is welfare improving, because it yields a better risk sharing. Unlike the works listed above, my analysis is purely on the positive side, since it aims to quantify the spillover effects of capital controls on the international business cycle, rather than deriving normative implications: to the best of my knowledge, I am not aware of any theoretical works which focuses on this research question, despite the relevance of the topic.

The remainder of the paper is organized as follows. Section 2 presents the model and the calibration strategy. Section 3 analyzes the simulation results. In Section 4 some sensitivity analysis are shown. Section 5 concludes.

[3]Capital controls in country x are not endogenous to country y's capital flows. Suppose that a common unobservable shock drives capital inflow both in country x and y and the former reacts by adopting capital controls: then the econometrician may erroneously conclude that the higher country y's capital flows are due to country x's policy.

[4]The VAR models of Lambert et al. (2013) and Pasricha et al. (2015) also allow a dynamic analysis.

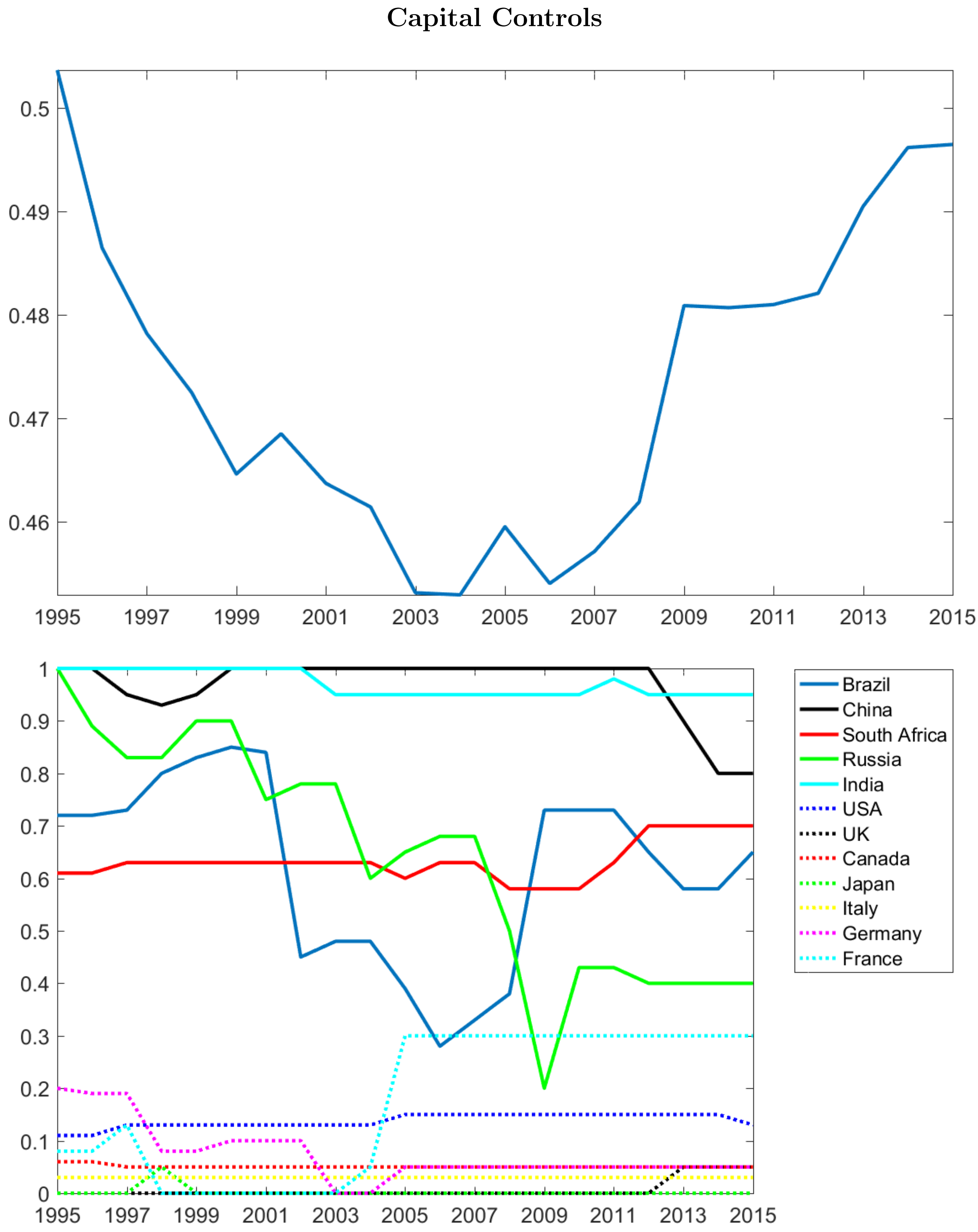

Figure 2.1: Top panel: Ka index in emerging economies, unweighted average across countries. The definition of emerging economies follows the IMF criterion. Bottom panel: Ka index in BRICS and G7 economies. The index lies between zero (the country has no restriction on any category of flows) and one (the country has restrictions on all categories of flows). Source: Fernández et al. (2016).

Capital Inflows Shock and Capital Controls

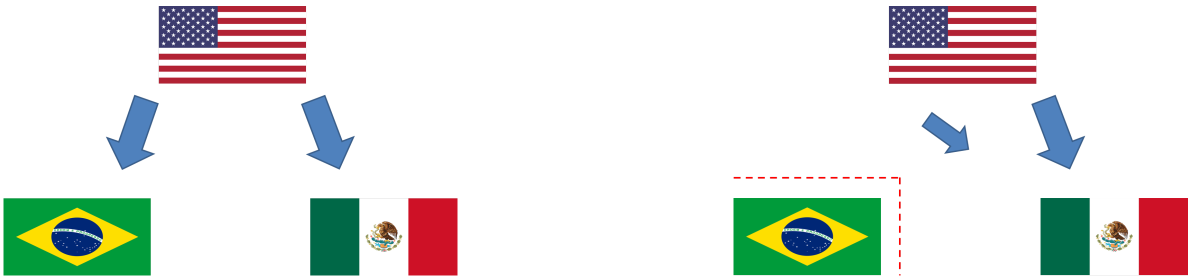

Figure 2.2: In the left panel capital moves from US to Brazil and Mexico. In the right panel, Brazil's imposition of capital controls deflects a share of the flows to Mexico, while the other share comes back to the US.

2.2 The Model

The world economy consists of three countries: one advanced economy (AE) with relative population size of n_3 and two emerging economies (EME1 and EME2) with relative size n_1 and n_2 respectively.[5] I depart from the standard two-country model because I want to analyze how capital controls implemented in one (emerging) country alter the macroeconomy response of another (emerging) country following a shock in a third (advanced) economy. Variables in EME2 are indexed with a star, variables in AE are indexed with "A". Each economy features a representative firm, producing a domestic good, and a representative household, consuming domestic and imported goods. Households rent physical capital and supply labor to firms: both production inputs are not mobile across countries. The three countries trade a one-period risk-free bond, denominated in the AE consumption bundle. AE and the two EMEs differ in the size of the economy, in the composition of consumption and investment bundles and in total factor productivity. On top of that, AE does not use capital controls. EME1 and EME2 are perfectly symmetric (so $n_1 = n_2$). In what follows, I describe the model, providing the complete list of the equations in the Appendix.

2.2.1 Bundles of Goods and Prices

The consumption good c_t in EME1 is a CES bundle of goods produced in the three countries:

$$c_t = \left[\nu_1^{\frac{1}{\mu}} c_{1t}^{\frac{\mu-1}{\mu}} + \nu_2^{\frac{1}{\mu}} c_{2t}^{\frac{\mu-1}{\mu}} + \nu_3^{\frac{1}{\mu}} c_{3t}^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \tag{2.1}$$

where c_{1t}, c_{2t} and c_{3t} are EME1 consumption of EME1, EME2 and AE goods respectively. The investment good i_t features an identical composition:

$$i_t = \left[\nu_1^{\frac{1}{\mu}} i_{1t}^{\frac{\mu-1}{\mu}} + \nu_2^{\frac{1}{\mu}} i_{2t}^{\frac{\mu-1}{\mu}} + \nu_3^{\frac{1}{\mu}} i_{3t}^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}. \tag{2.2}$$

The price of the consumption and investment bundle in EME1 p_t reads:

$$p_t = \left[\nu_1 p_{1t}^{1-\mu} + \nu_2 p_{2t}^{1-\mu} + \nu_3 p_{3t}^{1-\mu}\right]^{\frac{1}{1-\mu}} \tag{2.3}$$

where p_{1t}, p_{2t} and p_{3t} are the price of EME1, EME2 and AE goods respectively. These prices are all expressed in terms of AE consumption good which is the numéraire (so that $p_t^A = 1$). In the other two countries similar definitions apply. Accordingly, consumption

[5] By normalizing to 1 total population, it turns out $n_1 + n_2 + n_3 = 1$.

and investment bundle are defined as follow:

$$c_t^* = \left[\nu_1^{*\frac{1}{\mu}} c_{1t}^{*\frac{\mu-1}{\mu}} + \nu_2^{*\frac{1}{\mu}} c_{2t}^{*\frac{\mu-1}{\mu}} + \nu_3^{*\frac{1}{\mu}} c_{3t}^{*\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \tag{2.4}$$

$$c_t^A = \left[\nu_1^{A\frac{1}{\mu}} c_{1t}^{A\frac{\mu-1}{\mu}} + \left(\nu_2^A\right)^{\frac{1}{\mu}} c_{2t}^{A\frac{\mu-1}{\mu}} + \left(\nu_3^A\right)^{\frac{1}{\mu}} c_{3t}^{A\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \tag{2.5}$$

$$i_t^* = \left[\nu_1^{*\frac{1}{\mu}} i_{1t}^{*\frac{\mu-1}{\mu}} + \nu_2^{*\frac{1}{\mu}} i_{21t}^{*\frac{\mu-1}{\mu}} + \nu_3^{*\frac{1}{\mu}} i_{3t}^{*\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \tag{2.6}$$

$$i_t^A = \left[\nu_1^{A\frac{1}{\mu}} i_{1t}^{A\frac{\mu-1}{\mu}} + \left(\nu_2^A\right)^{\frac{1}{\mu}} i_{2t}^{A\frac{\mu-1}{\mu}} + \left(\nu_3^A\right)^{\frac{1}{\mu}} i_{3t}^{A\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \tag{2.7}$$

and it holds:

$$p_t^* = \left[\nu_1^* p_{1t}^{1-\mu} + \nu_2^* p_{2t}^{1-\mu} + \nu_3^* p_{3t}^{1-\mu}\right]^{\frac{1}{1-\mu}} \tag{2.8}$$

$$1 = \nu_1^A p_{1t}^{1-\mu} + \nu_2^A p_{2t}^{1-\mu} + \nu_3^A p_{3t}^{1-\mu}. \tag{2.9}$$

Notice that p_t (p_t^*) can be interpreted as the EME1 (EME2) real exchange rate vis-à-vis the AE good (so that if p_t is higher, EME1 faces a real appreciation). EME1 household's demand for the three consumption goods is given by:

$$c_{1t} = \nu_1 \left(\frac{p_{1t}}{p_t}\right)^{-\mu} c_t$$

$$c_{2t} = \nu_2 \left(\frac{p_{2t}}{p_t}\right)^{-\mu} c_t$$

$$c_{3t} = \nu_3 \left(\frac{p_{3t}}{p_t}\right)^{-\mu} c_t.$$

Analogous demand functions can be derived for investment goods. Similar expressions hold in the other two countries.

2.2.2 Households

In EME1 the representative household solves the following maximization problem:

$$\max_{\{c_t,h_t,b_{3t},b_{1t},k_t\}_{t=0}^{\infty}} \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1-\sigma} \left(c_t - \frac{h_t^{1+\varphi}}{1+\varphi} \right)^{1-\sigma} \right] \right\}$$

$$s.t.\ c_t + (1-\tau_t)\frac{b_{3t}}{p_t} + b_{1t} + k_t + \frac{\kappa}{2}\left(\frac{k_t}{k_{t-1}} - 1\right)^2 k_{t-1} =$$

$$w_t h_t + [u_t + (1-\delta)]\, k_{t-1} + r_{t-1}^A \frac{b_{t-1}}{p_t} + r_{t-1} b_{1t-1} \Pi_t + t_t.$$

where h_t denotes hours of work remunerated at wage w_t, k_t is physical capital rented at rate u_t, Π_t denotes profits from domestic firms and t_t denotes lump-sum transfers. As standard in the real business cycle literature, investment in new capital requires the payment of quadratic adjustment costs. b_{3t} denotes EME1 holding of a one-period international bond denominated in AE's consumption bundle, yielding a gross interest rate of r_t^A; notably, a capital control tax τ_t applies to holdings of this bond. Furthermore, households can also trade a one-period risk-free bond b_{1t} denominated in EME1 consumption bundle, yielding an interest rate of r_t: I assume that this bond is not traded abroad, given that emerging economies struggle to issue debt instruments in their own currency. Physical capital follows the standard law of motion:

$$k_t = (1-\delta)k_{t-1} + i_t. \tag{2.10}$$

First order conditions yield two bond euler equations, an investment euler equation and a labor supply expression:

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{r_t^A}{1-\tau_t} \frac{p_t}{p_{t+1}} \right) \tag{2.11}$$

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t} r_t \right) \tag{2.12}$$

$$1 + \kappa \left(\frac{k_t}{k_{t-1}} - 1 \right) = \beta \mathbb{E}_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \left[\kappa \frac{k_{t+1}}{k_t} \left(\frac{k_{t+1}}{k_t} - 1 \right) - \frac{\kappa}{2} \left(\frac{k_{t+1}}{k_t} - 1 \right)^2 + u_{t+1} + (1-\delta) \right] \right\} \tag{2.13}$$

$$h_t^{\varphi} = w_t \tag{2.14}$$

where λ_t is the marginal utility of consumption:

$$\lambda_t = \left(c_t - \frac{h_t^{1+\varphi}}{1+\varphi}\right)^{-\sigma}. \tag{2.15}$$

The household's maximization problem in EME2 is symmetric to EME1's problem. On the other hand, AE households are not subject to capital control and their maximization problem is the following:

$$\max_{\left\{c_t^A, h_t^A, k_t^A, b_{3t}^A\right\}_{t=0}^{\infty}} \mathbb{E}_0 \left\{\sum_{t=0}^{\infty} \beta^t \psi_t^A \left[\frac{1}{1-\sigma}\left(c_t^A - \frac{h_t^{A\,1+\varphi}}{1+\varphi}\right)^{1-\sigma}\right]\right\}$$

$$s.t.\ c_t^A + i_t^A + b_{3t}^A + \frac{\kappa}{2}\left(\frac{k_t^A}{k_{t-1}^A} - 1\right)^2 k_{t-1}^A =$$

$$w_t^A h_t^A + \left[u_t^A + (1-\delta)\right] k_{t-1}^A + r_{t-1}^A b_{t-1}^A + \Pi_t^A + t_t^A. \tag{2.16}$$

Notice the role of the preference shock ψ_t^A: when it is lower, AE households are willing to enjoy more consumption and leisure in the future rather than in the current period. It results that they invest more in international bonds: capitals move from advanced to the economies. First order conditions yield two euler equations, one for physical capital and one for the international bond, plus the labor supply expression:

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda_{t+1}^A}{\lambda_t^A} r_t^A\right) \tag{2.17}$$

$$1 + \kappa\left(\frac{k_t^A}{k_{t-1}^A} - 1\right) = \beta \mathbb{E}_t \left\{\frac{\lambda_{t+1}^A}{\lambda_t^A}\left[\kappa \frac{k_{t+1}^A}{k_t^A}\left(\frac{k_{t+1}^A}{k_t^A} - 1\right) - \frac{\kappa}{2}\left(\frac{k_{t+1}^A}{k_t^A} - 1\right)^2 + u_{t+1}^A + (1-\delta)\right]\right\} \tag{2.18}$$

$$h_t^{A\varphi} = w_t^A \tag{2.19}$$

where λ_t^A is AE's marginal utility of consumption:

$$\lambda_t^A = \psi_t^A \left(c_t^A - \frac{h_t^{A1+\varphi}}{1+\varphi}\right)^{-\sigma}. \tag{2.20}$$

Finally, it is assumed that the preference shifter follows an autoregressive process:

$$\log\left(\frac{\psi_t^A}{\psi}\right) = \rho_\psi \log\left(\frac{\psi_{t-1}^A}{\psi}\right) + v_t^A, \tag{2.21}$$

where ψ is the steady state of ψ_t and v_t^A is the exogenous shock driving business cycle fluctuations in the model.

2.2.3 Firms

In each country there is a representative firm producing the country-specific good. EME1 firm uses the following production function:

$$y_t = Z k_{t-1}^{\alpha} h_t^{1-\alpha}, \tag{2.22}$$

where y_t is EME1 output and Z is total factor productivity. The profit maximization problem reads:

$$\max_{k_{t-1},h_t} p_{1t} Z k_{t-1}^{\alpha} h_t^{1-\alpha} - p_t r_t^K k_{t-1} - p_t w_t h_t.$$

First order conditions yield the demand of input goods:

$$k_{t-1} = \alpha \frac{p_{1t} y_t}{p_t r_t^K} \tag{2.23}$$

$$h_t = (1-\alpha)\frac{p_{1t} y_t}{p_t w_t}. \tag{2.24}$$

Analogous expressions hold in the other two countries.

2.2.4 Policy Instruments

In the two EMEs, a tax can be applied on international bond holdings. This instrument has been deeply analyzed by other theoretical works on capital controls (see Korinek, 2011 and Bianchi, 2011). Furthermore, some emerging countries have been resorting to similar policy tools. Indeed, since early 90' Brazil has been charging a tax on the exchange rate transactions when capital first entered the country.[6] Instead, other emerging economies have resorted to unremunerated reserve requirements on capital inflows: this tool is a de facto tax on foreign investment.[7] Following Heathcote and Perri

[6] See Chamon and Garcia (2016) for an evaluation of the Brazilian recent experience with capital controls.

[7] Chile, Colombia and Thailand have used unremunerated reserve requirements in the past. These country-cases have been analyzed by Cowan and De Gregorio (2007), Cárdenas and Barrera (1997) and

(2016), I assume that this instrument responds endogenously to variation in the country's net foreign asset position (as a fraction of the GDP):

$$\tau_t = -\phi \left(\frac{b_{3t}/p_t}{p_{1t}y_t/p_t} - \bar{b} \right), \tag{2.25}$$

where $\bar{b}$ is the steady state of $\frac{b_{3t}}{p_{1t}y_t}$. When the net foreign asset position is lower (capital flows to EME1), the government raises the tax to discourage capital inflows (it does the opposite when the net foreign asset position is higher). Accordingly, this tool is consistent with the common practice of EMEs' policy makers, who tend to restrict capital controls when the economy experiences large capital inflows. In EME2, an analogous instrument is implemented. Revenues from capital controls are rebated lump sum to households.

2.2.5 Equilibrium

Market clearing in the international bond market requires:

$$n_1 b_{3t} + n_2 b_{3t}^* + n_3 b_{3t}^A = 0. \tag{2.26}$$

EME1 and EME2 domestic bonds are not traded abroad. It results in equilibrium:

$$n_1 b_{1t} = 0 \tag{2.27}$$

$$n_2 b_{2t}^* = 0. \tag{2.28}$$

Market clearing conditions for the three consumption goods read:

$$n_1 \left(c_{1t} + i_{1t} + Adj_{1t} \right) + n_2 \left(c_{1t}^* + i_{1t}^* + Adj_{1t}^* \right) + n_3 \left(c_{1t}^A + i_{1t}^A + Adj_{1t}^A \right) = n_1 y_t \tag{2.29}$$

$$n_1 \left(c_{2t} + i_{2t} + Adj_{2t} \right) + n_2 \left(c_{2t}^* + i_{2t}^* + Adj_{2t}^* \right) + n_3 \left(c_{2t}^A + i_{2t}^A + Adj_{2t}^A \right) = n_2 y_t^* \tag{2.30}$$

$$n_1 \left(c_{3t} + i_{3t} + Adj_{3t} \right) + n_2 \left(c_{3t}^* + i_{3t}^* + Adj_{3t}^* \right) + n_3 \left(c_{3t}^A + i_{3t}^A + Adj_{3t}^A \right) = n_3 y_t^A, \tag{2.31}$$

where Adj denotes capital adjustment costs. Notice that by Walras Law one of the previous conditions is redundant. Finally, it is useful to define the GDP in the three

Vithessonthi and Tongurai (2013) respectively.

countries:

$$gdp_t \equiv \frac{p_{1t}}{p_t} y_t = c_t + i_t + \frac{\kappa}{2}\left(\frac{k_t}{k_{t-1}} - 1\right)^2 k_{t-1} + tb_{3t} \quad (2.32)$$

$$gdp_t^* \equiv \frac{p_{2t}}{p_t^*} y_t^* = c_t^* + i_t^* + \frac{\kappa}{2}\left(\frac{k_t^*}{k_{t-1}^*} - 1\right)^2 k_{t-1}^* + tb_{3t}^* \quad (2.33)$$

$$gdp_t^A \equiv p_{3t} y_t^A = c_t^A + i_t^A + \frac{\kappa}{2}\left(\frac{k_t^A}{k_{t-1}^A} - 1\right)^2 k_{t-1}^A + tb_{3t}^A \quad (2.34)$$

where tb_t denotes the trade balance.

2.2.6 Calibration

There are three groups of parameters that must be calibrated. The first group includes those parameters that are specific to AE and EMEs. These are the parameters governing the population size, the steady-state GDP and net financial asset position, the coefficients in consumption and investment bundles and the steady-state preference shifter. I proceed as follows. I take a sample of advanced and emerging economies (those reporting the net financial asset position in 2016): there are 74 countries (34 advanced, 40 emerging) representing 91% of world GDP.[8] The population size of AE (parameter n_3) corresponds to the share of population of advanced economies in the sample: it results $n_3 = 0.19$; since I assume that the two EMEs are symmetric, $n_1 = n_2 = \frac{1-n_3}{2} = 0.405$. In the sample, GDP per capita in the advanced economies is 8.23 times the EMEs' one: therefore I set $\{Z, Z^*, Z^A\}$ such that in steady state $gdp^A = 8.23 gdp = 8.23 gdp^*$. By normalizing $Z = Z^* = 1$, I get $Z^A = 1.96$.[9] By aggregating the net financial asset positions of all countries in each of the two samples, advanced and emerging economies feature a similar small deficit (about 3% of GDP): hence, I set $\bar{b} = \bar{b}^* = 0$ (which implies that AE net financial position is zero too). The steady-state preference shifter is calibrated such that the three economies have the same marginal utility of consumption in steady state: this implies $\psi^A = 8.19$. In order to calibrate the weight coefficients in (2.1)-(2.7), I use the following strategy: the coefficient in the bundle of country i on a good produced by country j (with $i, j = EME1, EME2, AE$ and $i \neq j$) is the product of a parameter η capturing the openness of country i and the GDP share of country j; the weight on the good produced by the same country (when $i = j$), is the complement to one of the

[8]More detail on this dataset can be found in the Appendix.

[9]Notice that according to this calibration EME1 and EME2 are not too small relative to AE.

other two coefficients.[10] For instance, by calibrating the openness parameter η to 0.15, for EME1 this procedure yields:

$$\begin{aligned}
\nu_2 &= \eta \frac{n_2 gdp^*}{n_1 gdp + n_2 gdp^* + n_3 gdp^A} = 0.0255 \\
\nu_3 &= \eta \frac{n_3 gdp^A}{n_1 gdp + n_2 gdp^* + n_3 gdp^A} = 0.099 \\
\nu_1 &= 1 - \nu_2 - \nu_3 = 0.875.
\end{aligned}$$

The second group of parameters includes coefficients of utility and production functions, which are equal for the three countries in the model. I set these parameters following the quarterly calibration in Heathcote and Perri (2016), which study the desirability of capital controls in a standard two-country model. The inverse of the elasticity of intertemporal substitution σ and the inverse of the Frisch elasticity of labor supply ϕ are both calibrated to 1; the discount factor β assumes the standard value of 0.99; the capital share in production function α is 0.36; physical capital depreciates at a rate of $\delta = 1.5\%$ quarterly; the elasticity of substitution between domestic and foreign good μ is set to 1.5. Heathcote and Perri (2016) calibrate the openness parameter η in order to have a steady-state imports/GDP ratio of 30%, approximately the average trade share for advanced economies in 2015. However, the economies modeled in this paper aim to capture three groups of countries: thus, ideally, for AE η should be set in order to match the advanced economies' imports only from emerging economies (and the same for EME1 and EME2). Hence, I set η to an arbitrary low value ($\eta = 0.15$, small compared to values typically used in the literature).

The third group of coefficients includes those parameters that do not affect the steady state (I assume that these parameters are the same in the three countries). The capital adjustment cost κ is calibrated to 75, to match an EMEs' investment volatility equal to three times output volatility; I assume a rather persistent stochastic process, as standard in the international business cycle literature ($\rho_\psi = 0.9$); the standard deviation of the shock s_{ψ^A} is calibrated to 0.0418: this value ensures that following a one standard deviation negative preference shock, the AE interest rate decreases by 1% in annual terms on impact. The following table summarizes the calibration.

[10] This method is typically used in the calibration of bundle coefficients in two-country models, where the two countries are asymmetric in population.

Parameters	**Description**	**Value**
n_1, n_2, n_3	Population size	$0.405, 0.405, 0.19$
Z, Z^*, Z^A	Total factor productivity	$1, 1, 1.96$
$\bar{b}, \bar{b}^*$	Steady state NFA	$0, 0$
η	Openness degree	0.15
ν_1, ν_2, ν_3	Weight coefficients in EME1	$0.8755, 0.0255, 0.099$
$\nu_1^*, \nu_2^*, \nu_3^*$	Weight coefficients in EME2	$0.0255, 0.8755, 0.099$
$\nu_1^A, \nu_2^A, \nu_3^A$	Weight coefficients in AE	$0.0255, 0.0255, 0.949$
σ	Inverse of intertemporal ES	1
α	Share of capital in production	0.36
β	Discount rate	0.99
δ	Depreciation rate	0.015
φ	Inverse of Frisch elasticity of labor supply	1
μ	ES between domestic and foreign goods	1.5
κ	Capital adjustment cost coefficient	75
ψ^A	Steady-state preference shifter	8.19
ρ_ψ	Autoregressive parameter	0.9
s_{ψ^A}	Standard deviation of preference shock	0.042

Table 2.1: Calibration.

2.3 Simulations

In this section a capital inflows shock is simulated to analyze capital controls spillover effects. The model is solved through a first-order approximation around the non-stochastic steady state. [11]

2.3.1 A Capital Inflow Shock

A negative one-standard deviation preference shock in AE aims to capture the effects of a capital inflows surge in emerging economies driven by push factors. First, I consider a baseline scenario in which the policy rule coefficients are $\phi = \phi^* = 0.001$, implying a very mild endogenous response of capital controls to such a shock.[12] The latter induces AE households to shift resources from consumption to investment: they increase physical capital and buy more foreign bonds (figure 2.1, blue solid line). Accordingly, AE starts to run a trade balance surplus, which mirrors an improvement in the net financial asset position with the rest of the world. AE production decreases on impact by 0.1% driven by a smaller consumption demand and it recovers quickly due to a higher stock of capital (after few periods gross domestic product is higher than the steady-state level). The AE desire to save ends up with an international interest rate reduction which is transmitted to EMEs bonds (by construction, the international interest rate falls by 1% in annualized terms). In the baseline scenario, the impulse response of EME1 and EME2 are identical, given the symmetry of the two economies (blue solid line in figure 2.2 and 2.3). The interest rate decline allows emerging economies to borrow more from AE: this debt is used to increase consumption and investment in physical capital. As a result, gross domestic product rises considerably (by about 0.2% on impact), also driven by an increase in labor which is more productive for the higher stock of physical capital. Finally, the exchange rate appreciates for the emerging economies, reflecting the demand reduction in AE. All in all, the preference shock fosters a persistent capital inflow surge in EME1 and EME2 (around 3% of steady-state GDP at the peak), a financial account deficit (around 0.4% of steady-state GDP on impact) and a real appreciation of EMEs goods: this dynamics reasonably replicates the standard narrative of a capital inflow shock driven by push factors.

[11]A complete list of the model's equation as well as details on computation of the steady state can be found in the Appendix.

[12]If these coefficients were set to zero, the model would not be stationary. Indeed, by responding to foreign debt, in this model capital controls play the same role of debt adjustment costs or endogenous discount factor in eliminating the unit root characterizing open economy models with incomplete financial markets (see Schmitt-Grohé and Uribe, 2003 for a detailed discussion on this issue).

2.3.2 Capital Controls Spillovers

What happens if EME1 tightens capital controls? In this section I assume that EME1 capital controls rule responds more aggressively to changes in the net financial asset position. Notably, I set $\phi = 1$, while ϕ^* is kept unchanged to 0.001. Notice that this policy rule implies a strong commitment for EME1: whenever the net financial asset position deteriorates by 1% of GDP, the government commits to tight capital controls by 100 basis points and such a commitment is assumed to be fully credible.

This calibration of the policy rule shields EME1 from the shock. On impact, the capital inflow shrinks to just 0.07% of steady-state GDP (black dotted line, figure 2.2), given that borrowing abroad is now more costly for EME1 households. The capital control tightening breaks down the interest rate parity condition, since a smaller fall in EME1 interest rate is required to clear the bond market. Not surprisingly, EME1 macroeconomic boom is dampened: domestic demand grows by less and the exchange rate experiences a smaller appreciation. This capital control policy spills over into EME2 through an additional and persistent capital inflow surge (black dotted line, figure 2.3): on impact, foreign debt[13] is 0.05% higher (in terms of steady-state GDP) with respect to the baseline scenario; the maximum gap between the two scenarios is around 0.5%, reached after some years. This implies that, on impact, about 20% of capital that were pushed away from EME1 are deflected to EME2, while total AE capital outflows is reduced by one third. On top of that, in EME2, the by-product of EME1 capital control policy is not limited to capital inflows. Indeed, EME2 macroeconomy is further stimulated: consumption and investment impact response is 15% higher than the impact response under the baseline scenario.

It is worthy highlighting that EME1 is not calibrated as a small economy: we can think of EME1 as an homogeneous group of emerging countries with a similar (tight) capital controls policy. Hence EME1 policy may affect AE as well. A significant share of capital flows warded off by EME1 reduces AE external position, so AE financial account surplus is much lower compared to the baseline scenario. These smaller imbalances translate in a lower GDP decline on impact. The intuition is the following: in AE, the higher desire to consume more in the future (driven by the preference shock) can be fulfilled by investing more either in physical capital or in foreign bonds; however, EME1 capital control policy makes the latter option less profitable: hence, the AE capital stock rises, thus boosting AE production. In addition, AE interest rate decreases by slightly more to equalize the marginal return of capital, since EME1 households reduce their borrowing demand.

[13]Since the financial instrument is a one-period bond, debt corresponds to capital inflows.

Advanced Economy

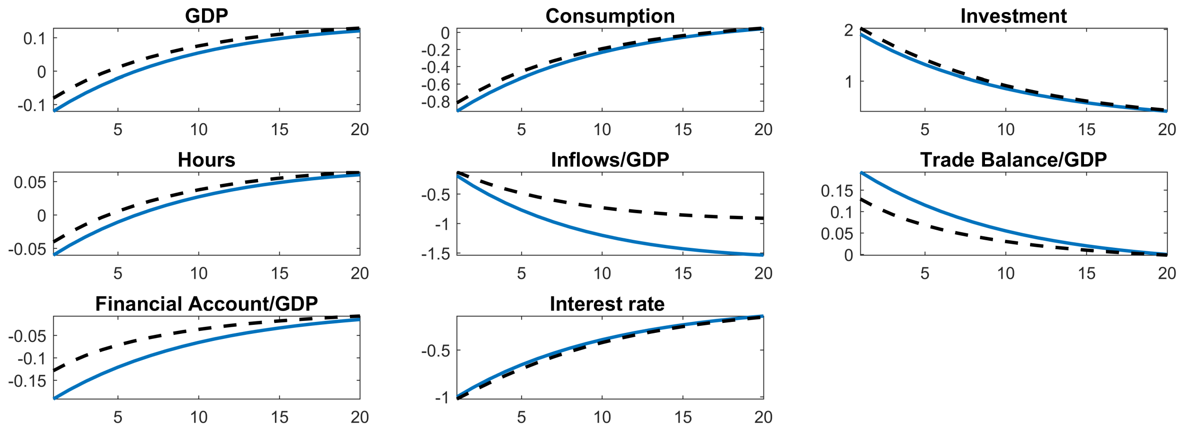

Figure 2.1: Impulse response functions to an AE preference shock ($v_t^A = -0.04$). In the blue solid line $\phi = 0.001 = \phi^*$, in the black dotted line $\phi = 1$ and $\phi^* = 0.001$. Responses are in log-deviations from the steady state. One period correspond to a quarter. Interest rate response is annualized. Interest rate, debt/GDP and financial account/GDP are expressed in level deviations from the steady state.

Emerging Economy 1

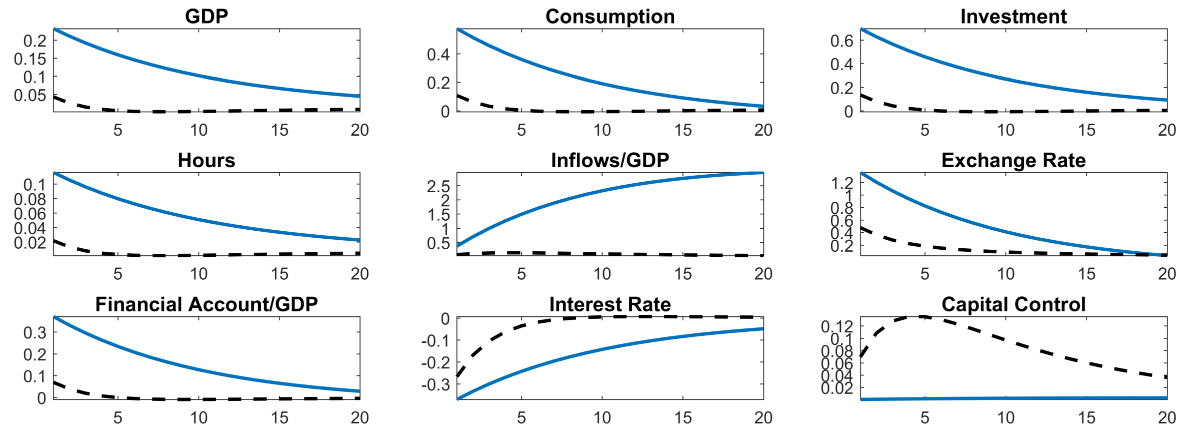

Figure 2.2: Impulse response functions to an AE preference shock ($v_t^A = -0.04$). In the blue solid line $\phi = 0.001 = \phi^*$, in the black dotted line $\phi = 1$ and $\phi^* = 0.001$. Responses are in log-deviations from the steady state. One period correspond to a quarter. Interest rate response is annualized. Interest rate, debt/GDP and financial account/GDP are expressed in level deviations from the steady state.

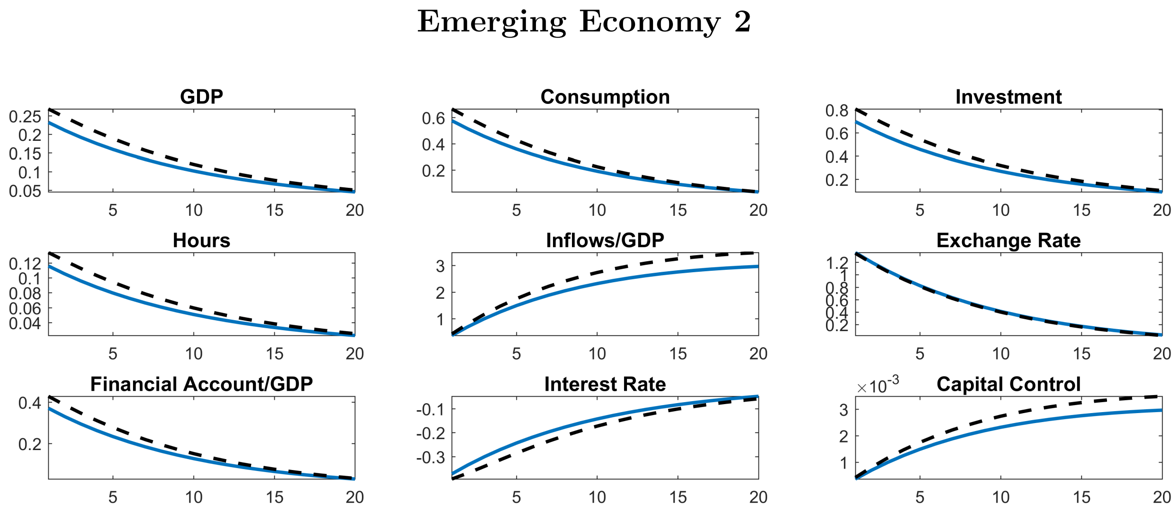

Figure 2.3: Impulse response functions to an AE preference shock ($v_t^A = -0.04$). In the blue solid line $\phi = 0.001 = \phi^*$, in the black dotted line $\phi = 1$ and $\phi^* = 0.001$. Responses are in log-deviations from the steady state. One period correspond to a quarter. Interest rate response is annualized. Interest rate, debt/GDP and financial account/GDP are expressed in level deviations from the steady state.

2.4 Other Experiments

2.4.1 EME1 Size

The relevance of capital control spillover crucially depends on the size of the countries tightening cross-border restrictions. If a single small country raises its capital controls, this policy hardly affect other economies. But if a large group of countries change the capital controls stance, then spillover effects may be sizable. In the previous section I have assumed that half of emerging economies in the world tight the capital control tax: now I calibrate this share to 80%[14]. Impulse responses are reported in the Appendix. Under this situation, EME2 experiences a higher capital inflow surge, after the AE preference shock: debt is 0.1% higher respect to a scenario with no changes in EME1 policy; the maximum gap between the two scenarios (reached after some years) is close to 1% in terms of steady-state GDP. The impact response of consumption and investment is now 28% larger than the impact response with no changes in EME1 policy. Clearly, if a large set of emerging economies restrict their financial account, the business cycle in advanced economies is not silent: the impact GDP reduction is half of the impact response under a loose EME1 policy. As in the previous section, the positive impact of

[14]It turns out $n_1 = 0.65$ and $n_2 = 0.16$.

EME1 policy on AE hinges on the amplified impulse response of investment in physical capital.

2.4.2 TFP Shocks

In what follow I simulate a persistent increase in AE total factor productivity Z_t^A. This technology shock is another potential push factor of capital inflows, if AE households invest more in foreign bonds when their firms are more productive. Technology is assumed to follow an $AR(1)$ process:

$$\log\left(\frac{Z_t^A}{Z}\right) = \rho_z \log\left(\frac{Z_{t-1}^A}{Z}\right) + \varepsilon_t^A. \tag{2.35}$$

This process is as persistent as the preference shifter ψ_t^A (so $\rho_z = \rho_\psi = 0.9$). The size of the shock is set to $\varepsilon_t^A = 0.02$, following Heathcote and Perri (2016). Impulse responses are reported in the Appendix. Following an increase in technology, AE households get richer, hence they consume more and increase investment in physical capital. Moreover, since the shock is transitory, AE households anticipate that in the future they will be less wealthy and save through international bonds. The higher demand for foreign products and international bonds appreciates EMEs'exchange rate and reduce the international interest rate. Accordingly, EMEs experience a capital inflow surge and an economic boom: these impulse responses are qualitatively close to the responses following a preference shock, analyzed in Section 4.

If EME1 adopts a tighter capital control policy, the macroeconomic boom is strongly mitigated: capital inflows are partially deflected to EME2, whose economy activity improves, though by a lesser extent compared to the preference shock case: consumption and investment impact response is 10% higher than the responses under the baseline scenario (figure 2.D.6, black solid line). As far as AE is concerned, it is barely affected by EME1 capital controls.

2.5 Conclusions

This paper analyzes the spillover effects produced by emerging economies when they impose capital controls in response to capital inflow shocks from the advanced economies. Simulations performed with a three-country (AE, EME1 and EME2) business cycle model show that capital controls implemented in EME1 deflect capital flows to EME2, if the latter does not resort to similar restrictions: the inflows deflection affects EME2 business cycle, bringing about an expansion of its economic activity. Moreover, since in the model EME1 is not small relatively to AE, the imposition of capital controls affects AE macroeconomy too.

These results point out that a disorderly imposition of capital controls in emerging economies can generate (possibly) undesired effects in other countries, both emerging and advanced. In particular, financial account restrictions in some countries, while reducing the impact of economic shocks in these economies, are likely to increase the volatility of other countries' business and financial cycle.

This paper is a first attempt to study capital controls spillover effects in an international business cycle model. Accordingly, I have used a rather standard model, where the only novelty is the presence of a third country, needed to study spillovers. Therefore it is self-evident that a number of extensions can be added to the model. First, in the model financial markets are frictionless, an assumption at odds with the history of international financial crises: thus, introducing financial frictions, would capture the standard amplification mechanism of the financial sector. Second, the model does not have any role for monetary policy: introducing nominal rigidities would allow to study spillovers resulting from the interactions of capital controls with different exchange rate regimes and interest-rate rules. Third, this work only considers portfolio bond flows, ignoring other important elements of the balance of payments, such as foreign direct investment, portfolio equity and bank flows. The latter, seem especially relevant given their abrupt decline, after the peak attained before the global financial crisis. These issues are all promising avenues for future research on capital controls.

Appendix

2.A Model Equations

The equilibrium can be characterized by equations (2.36)-(2.73) listed below, that describe the dynamics of 38 endogenous variables.

2.A.1 EME1

Marginal utility of consumption:

$$\lambda_t = \left(c_t - \frac{h_t^{1+\varphi}}{1+\varphi}\right)^{-\sigma}. \tag{2.36}$$

Euler equation for bonds and capital:

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t} \frac{r_t^A}{1-\tau_t} \frac{p_t}{p_{t+1}}\right) \tag{2.37}$$

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t} r_t\right) \tag{2.38}$$

$$1 = \beta \mathbb{E}_t \left\{\frac{\lambda_{t+1}}{\lambda_t}\left[\kappa \frac{k_{t+1}}{k_t}\left(\frac{k_{t+1}}{k_t}-1\right) - \frac{\kappa}{2}\left(\frac{k_{t+1}}{k_t}-1\right)^2 + u_{t+1} + (1-\delta)\right]\right\} - -\kappa\left(\frac{k_t}{k_{t-1}}-1\right) \tag{2.39}$$

Law of motion of capital:

$$k_t = (1-\delta)\, k_{t-1} + i_t. \tag{2.40}$$

Labor supply:

$$h_t^{\varphi} = w_t. \tag{2.41}$$

Input demands:

$$k_{t-1} = \alpha \frac{p_{1t} y_t}{u_t} \tag{2.42}$$

$$h_t = (1-\alpha) \frac{p_{1t} y_t}{w_t}. \tag{2.43}$$

Production function:

$$y_t = Z k_{t-1}^{\alpha} h_t^{1-\alpha}. \tag{2.44}$$

Resource constraint:

$$p_t c_t + p_t i_t + p_t \frac{\kappa}{2}\left(\frac{k_t}{k_{t-1}} - 1\right)^2 k_{t-1} + b_{3t} = p_{1t} y_t + r^A_{t-1} b_{t-1}. \tag{2.45}$$

Price level:

$$p_t^{1-\mu} = \nu_1 p_{1t}^{1-\mu} + \nu_2 p_{2t}^{1-\mu} + \nu_3 p_{3t}^{1-\mu}. \tag{2.46}$$

Capital control rule:

$$\tau_t = -\phi\left(\frac{b_{3t}}{p_{1t} y_t} - \bar{b}\right). \tag{2.47}$$

2.A.2 EME2

Marginal utility of consumption:

$$\lambda^*_t = \left(c^*_t - \frac{h_t^{*1+\varphi}}{1+\varphi}\right)^{-\sigma}. \tag{2.48}$$

Euler equation for bonds and capital:

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda^*_{t+1}}{\lambda^*_t} \frac{r^A_t}{1-\tau^*_t} \frac{p^*_t}{p^*_{t+1}}\right) \tag{2.49}$$

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda^*_{t+1}}{\lambda^*_t} r^*_t\right) \tag{2.50}$$

$$\begin{aligned} 1 = {} & \beta \mathbb{E}_t \left[\frac{\lambda^*_{t+1}}{\lambda^*_t}\left(\kappa \frac{k^*_{t+1}}{k^*_t}\left(\frac{k^*_{t+1}}{k^*_t} - 1\right) - \frac{\kappa}{2}\left(\frac{k^*_{t+1}}{k^*_t} - 1\right)^2 + u^*_{t+1} + (1-\delta)\right)\right] - \\ & -\kappa\left(\frac{k^*_t}{k^*_{t-1}} - 1\right). \end{aligned} \tag{2.51}$$

Law of motion of capital:

$$k^*_t = (1-\delta) k^*_{t-1} + i^*_t. \tag{2.52}$$

Labor supply:

$$h_t^{*\varphi} = w^*_t. \tag{2.53}$$

Input demands:

$$k^*_{t-1} = \alpha \frac{p_{2t} y^*_t}{u^*_t} \tag{2.54}$$

$$h^*_t = (1-\alpha) \frac{p_{2t} y^*_t}{w^*_t}. \tag{2.55}$$

Production function:

$$y_t^* = Z^* k_{t-1}^{*\alpha} h_t^{*1-\alpha}. \tag{2.56}$$

Resource constraint:

$$p_t^* c_t^* + p_t^* i_t^* + p_t^* \frac{\kappa}{2} \left(\frac{k_t^*}{k_{t-1}^*} - 1 \right)^2 k_{t-1}^* + b_{3t}^* = p_{2t} y_t^* + r_{t-1}^A b_{t-1}^*. \tag{2.57}$$

$$p_t^{*1-\mu} = \nu_1^* p_{1t}^{1-\mu} + \nu_2^* p_{2t}^{1-\mu} + \nu_3^* p_{3t}^{1-\mu}. \tag{2.58}$$

Capital control rule:

$$\tau_t^* = -\phi^* \left(\frac{b_{3t}^*}{p_{2t} y_t^*} - \overline{b}^* \right). \tag{2.59}$$

2.A.3 AE

Marginal utility of consumption:

$$\lambda_t^A = \psi_t^A \left(c_t^A - \frac{h_t^{A1+\varphi}}{1+\varphi} \right)^{-\sigma}. \tag{2.60}$$

Euler equation for bonds and capital:

$$1 = \beta \mathbb{E}_t \left(\frac{\lambda_{t+1}^A}{\lambda_t^A} r_t^A \right) \tag{2.61}$$

$$\begin{aligned} 1 = {} & \beta \mathbb{E}_t \left[\frac{\lambda_{t+1}^A}{\lambda_t^A} \left(\kappa \frac{k_{t+1}^A}{k_t^A} \left(\frac{k_{t+1}^A}{k_t^A} - 1 \right) - \frac{\kappa}{2} \left(\frac{k_{t+1}^A}{k_t^A} - 1 \right)^2 + u_{t+1}^A + (1-\delta) \right) \right] - \\ & -\kappa \left(\frac{k_t^A}{k_{t-1}^A} - 1 \right). \end{aligned} \tag{2.62}$$

Law of motion of capital:

$$k_t^A = (1-\delta) k_{t-1}^A + i_t^A. \tag{2.63}$$

Labor supply:

$$h_t^{A\varphi} = w_t^A. \tag{2.64}$$

Input demands:

$$h_t^{A\varphi} = w_t^A \tag{2.65}$$

$$k_t^A = (1-\delta) k_{t-1}^A. \tag{2.66}$$

Production function:

$$y_t^A = Z^A k_{t-1}^{A\alpha} h_t^{A1-\alpha}. \tag{2.67}$$

Resource constraint:

$$c_t^A + i_t^A + \frac{\kappa}{2}\left(\frac{k_t^A}{k_{t-1}^A} - 1\right)^2 k_{t-1}^A + b_{3t}^A = p_{3t} y_t^A + r_{t-1}^A b_{t-1}^A. \tag{2.68}$$

Price level:

$$1 = \nu_1^A p_{1t}^{1-\mu} + \nu_2^A p_{2t}^{1-\mu} + \nu_3^A p_{3t}^{1-\mu}. \tag{2.69}$$

Stochastic process of preference shifter:

$$\log\left(\frac{\psi_t^A}{\psi}\right) = \rho \log\left(\frac{\psi_{t-1}^A}{\psi}\right) + v_t^A. \tag{2.70}$$

2.A.4 Equilibrium

Clearing of good markets:

$$\begin{aligned} y_t &= \nu_1 \left(\frac{p_{1t}}{p_t}\right)^{-\mu} \left[c_t + i_t + \frac{\kappa}{2}\left(\frac{k_t}{k_{t-1}} - 1\right)^2 k_{t-1}\right] + \\ &+ \frac{n_2}{n_1}\nu_1^* \left(\frac{p_{1t}}{p_t^*}\right)^{-\mu} \left[c_t^* + i_t^* + \frac{\kappa}{2}\left(\frac{k_t^*}{k_{t-1}^*} - 1\right)^2 k_{t-1}^*\right] + \\ &+ \frac{n_3}{n_1}\nu_1^A \left(p_{1t}\right)^{-\mu} \left[c_t^A + i_t^A + \frac{\kappa}{2}\left(\frac{k_t^A}{k_{t-1}^A} - 1\right)^2 k_{t-1}^A\right]. \end{aligned} \tag{2.71}$$

$$\begin{aligned} y_t^* &= \nu_2^* \left(\frac{p_{2t}}{p_t^*}\right)^{-\mu} \left[c_t^* + i_t^* + \frac{\kappa}{2}\left(\frac{k_t^*}{k_{t-1}^*} - 1\right)^2 k_{t-1}^*\right] + \\ &+ \frac{n_1}{n_2}\nu_2 \left(\frac{p_{2t}}{p_t}\right)^{-\mu} \left[c_t + i_t + \frac{\kappa}{2}\left(\frac{k_t}{k_{t-1}} - 1\right)^2 k_{t-1}\right] + \\ &+ \frac{n_3}{n_2}\nu_2^A \left(p_{2t}\right)^{-\mu} \left[c_t^A + i_t^A + \frac{\kappa}{2}\left(\frac{k_t^A}{k_{t-1}^A} - 1\right)^2 k_{t-1}^A\right]. \end{aligned} \tag{2.72}$$

Clearing of bond markets:

$$n_1 b_{3t} + n_2 b_{3t}^* + n_3 b_{3t}^A = 0. \tag{2.73}$$

The market clearing condition of the AE good is redundant by Walras law. It reads as follows:

$$
\begin{aligned}
y_t^A &= \nu_3^A (p_{3t})^{-\mu} \left[c_t^A + i_t^A + \frac{\kappa}{2} \left(\frac{k_t^A}{k_{t-1}^A} - 1 \right)^2 k_{t-1}^A \right] + \\
&\quad + \frac{n_1}{n_3} \nu_3 \left(\frac{p_{3t}}{p_t} \right)^{-\mu} \left[c_t + i_t + \frac{\kappa}{2} \left(\frac{k_t}{k_{t-1}} - 1 \right)^2 k_{t-1} \right] + \\
&\quad + \frac{n_2}{n_3} \nu_3^* \left(\frac{p_{3t}}{p_t^*} \right)^{-\mu} \left[c_t^* + i_t^* + \frac{\kappa}{2} \left(\frac{k_t^*}{k_{t-1}^*} - 1 \right)^2 k_{t-1}^* \right].
\end{aligned}
$$

2.A.5 Useful Definitions

The impulse response functions shown in the paper plot some variables whose precise definition is provided below. Gross domestic product:

$$
\begin{aligned}
gdp_t &= \frac{p_{1t}}{p_t} y_t \\
gdp_t^* &= \frac{p_{2t}}{p_t^*} y_t^* \\
gdp_t^A &= p_{3t} y_t^A.
\end{aligned}
$$

Imports:

$$
\begin{aligned}
m_t &= \frac{1}{p_t} \left[p_{2t} \nu_2 \left(\frac{p_{2t}}{p_t} \right)^{-\mu} + p_{3t} \nu_3 \left(\frac{p_{3t}}{p_t} \right)^{-\mu} \right] \left[c_t + i_t + \frac{\kappa}{2} \left(\frac{k_t}{k_{t-1}} - 1 \right)^2 k_{t-1} \right] \\
m_t^* &= \frac{1}{p_t^*} \left[p_{1t} \nu_1^* \left(\frac{p_{1t}}{p_t^*} \right)^{-\mu} + p_{3t} \nu_3^* \left(\frac{p_{3t}}{p_t^*} \right)^{-\mu} \right] \left[c_t^* + i_t^* + \frac{\kappa}{2} \left(\frac{k_t^*}{k_{t-1}^*} - 1 \right)^2 k_{t-1}^* \right] \\
m_t^A &= \left(p_{1t}^{1-\mu} \nu_1^A + p_{2t}^{1-\mu} \nu_2^A \right) \left[c_t^A + i_t^A + \frac{\kappa}{2} \left(\frac{k_t^A}{k_{t-1}^A} - 1 \right)^2 k_{t-1}^A \right].
\end{aligned}
$$

Exports:

$$
\begin{aligned}
x_t &= \frac{1}{p_t}\left\{\frac{n_2}{n_1}p_{1t}\nu_1^*\left(\frac{p_{1t}}{p_t^*}\right)^{-\mu}\left[c_t^*+i_t^*+\frac{\kappa}{2}\left(\frac{k_t^*}{k_{t-1}^*}-1\right)^2 k_{t-1}^*\right]\right\} \\
&\quad +\frac{1}{p_t}\left\{\frac{n_3}{n_1}p_{1t}^{1-\mu}\nu_1^A\left[c_t^A+i_t^A+\frac{\kappa}{2}\left(\frac{k_t^A}{k_{t-1}^A}-1\right)^2 k_{t-1}^A\right]\right\} \\
x_t^* &= \frac{1}{p_t^*}\left\{\frac{n_1}{n_2}p_{2t}\nu_2\left(\frac{p_{2t}}{p_t}\right)^{-\mu}\left[c_t+i_t+\frac{\kappa}{2}\left(\frac{k_t}{k_{t-1}}-1\right)^2 k_{t-1}\right]\right\} \\
&\quad +\frac{1}{p_t^*}\left\{\frac{n_3}{n_2}p_{2t}^{1-\mu}\nu_2^A\left[c_t^A+i_t^A+\frac{\kappa}{2}\left(\frac{k_t^A}{k_{t-1}^A}-1\right)^2 k_{t-1}^A\right]\right\} \\
x_t^A &= \frac{n_1}{n_3}p_{3t}\nu_3\left(\frac{p_{3t}}{p_t}\right)^{-\mu}\left[c_t+i_t+\frac{\kappa}{2}\left(\frac{k_t}{k_{t-1}}-1\right)^2 k_{t-1}\right]+ \\
&\quad +\frac{n_2}{n_3}\left(\frac{p_{3t}}{p_t^*}\right)^{-\mu}\nu_3^*\left[c_t^*+i_t^*+\frac{\kappa}{2}\left(\frac{k_t^*}{k_{t-1}^*}-1\right)^2 k_{t-1}^*\right].
\end{aligned}
$$

Trade balance:

$$
\begin{aligned}
tb_t &= x_t - m_t \\
tb_t &= x_t^* - m_t^* \\
tb_t^A &= x_t^A - m_t^A.
\end{aligned}
$$

Debt:

$$
\begin{aligned}
d_t &= -\frac{b_{3t}}{p_t} \\
d_t^* &= -\frac{b_{3t}}{p_t^*} \\
d_t^A &= -b_{3t}^A.
\end{aligned}
$$

Financial account:

$$
\begin{aligned}
fa_t &= d_t - d_{t-1} \\
fa_t^* &= d_t^* - d_{t-1}^* \\
fa_t^A &= d_t^A - d_{t-1}^A.
\end{aligned}
$$

2.B Steady State

The computation of the non-stochastic steady state follows three steps. First, I can easily derive from equations (2.38), (2.39), (2.50), (2.51), (2.61) and (2.62):

$$
\begin{aligned}
r &= \frac{1}{\beta} = r^* = r^A \\
u &= \frac{1}{\beta} + 1 - \delta = u^* = u^A
\end{aligned}
$$

where variable without a time subscript denote their steady-state level. By (2.37) and (2.49) it results:

$$\tau = \tau^* = 0.$$

The three laws of motion of capital imply:

$$
\begin{aligned}
i &= \delta k \\
i^* &= \delta k^* \\
i^A &= \delta k^A.
\end{aligned}
$$

By using these findings I can solve numerically a system of 21 equations in 21 variables. The equations are the following:

- Three capital demand equations: (2.43), (2.55), and (2.66).
- Three labor market equations: eliminate the wage in each country and equalize (2.41) and (2.43), (2.53) and (2.55), (2.64) and (2.66).
- Three production functions: (2.44), (2.56) and (2.67).
- Three resource constraints: (2.45), (2.57) and (2.68).
- Three CPI equations: (2.46), (2.58) and (2.69).

- Three market clearing conditions (two for EMEs goods and one for bonds): (2.71), (2.72), (2.73).
- Two equations come from the two capital control rules which imply:

$$\frac{b}{p_1 y} = \bar{b}$$
$$\frac{b^*}{p_2 y^*} = \bar{b}^*.$$

- One equation comes from the following restriction:

$$\frac{p_3 y^A}{p_1 y} = gdp^{Ratio},$$

where gdp^{Ratio} is a parameter governing the ratio between AE and EME1 GDP in steady state. The 22 variables of this systems are the following:

$$\left\{c, c^*, c^A, h, h^*, h^A, p, p^*, k, k^*, k^A, y, y^*, y^A, p_1, p_2, p_3, b, b^*, b^A, Z^A\right\}.$$

Once the system is solved, one can easily derive the value of the other variables by using the remaining equations. In particular, after finding λ and λ^A, one can recover ψ^A by imposing $\lambda = \lambda^A$:

$$\psi^A = \lambda \left(c_t^A - \frac{h_t^{A1+\varphi}}{1+\varphi}\right)^{\sigma}.$$

2.C Data

The data used to calibrate some parameters come from the International Investment Position Database by the IMF. The sample includes all countries that have reported data on the net financial asset position in 2016. There are 34 advanced economies and 40 emerging economies, listed below.

Advanced Economies: Australia, Austria, Belgium, Canada, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, Korea, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States.

Emerging Economies: Albania, Armenia Bangladesh, Belarus, Bhutan, Brazil, Cape Verde, Chile, China, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Macedonia, Guatemala, Hungary, India, Indonesia, Jamaica, Latvia, Lesotho, Mexico, Moldova, Morocco, Nicaragua, Pakistan, Panama, Philippines, Poland, Romania, Russia, São Tomé and Principe, Saudi Arabia, South Africa, Suriname, Tajikistan, Thailand, Timor-Leste, Turkey.

The following table summarizes the statistics used in the calibration.

Variable	AE	EME
Population (bil.)	1.0	4.4
GDP (USD bil)	45373	23502
GDP per capita (USD)	44042	5353
NFA/GDP (%)	−2.9	−3.2

Table 2.C.1: Summary statistics (2016). NFA is the sum across countries of the net financial asset position (difference between external assets and external liabilities) of each country in the sample. Source: IIP Database, IMF.

2.D Additional Figures

2.D.1 Large EME1

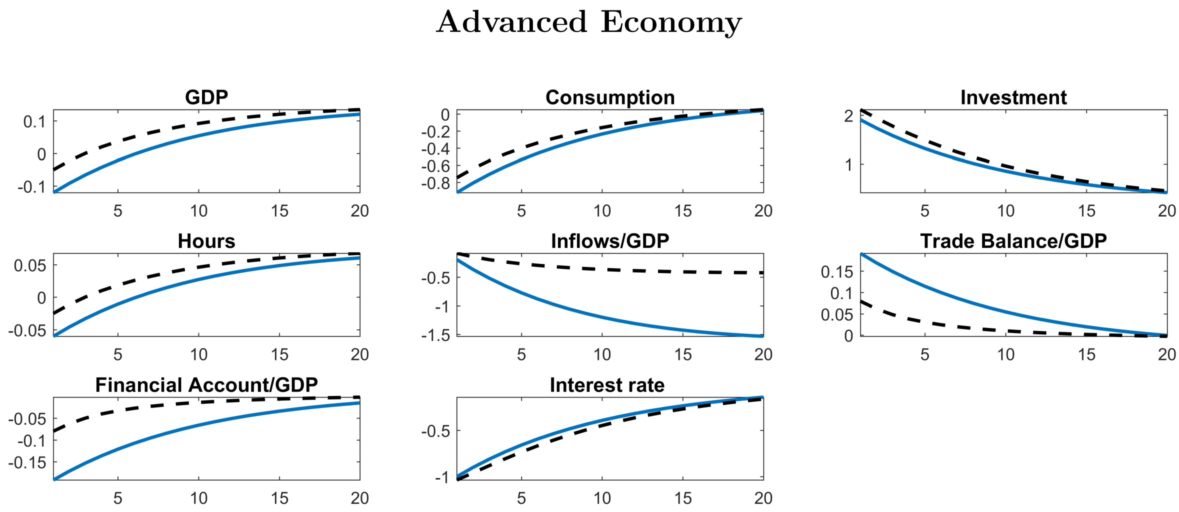

Figure 2.D.1: Impulse response functions to an AE preference shock ($v_t^A = -0.04$). In the blue solid line $\phi = 0.001 = \phi^*$, in the black dotted line $\phi = 1$ and $\phi^* = 0.001$. Responses are in log-deviations from the steady state. One period correspond to a quarter. Interest rate response is annualized. Interest rate, debt/GDP and financial account/GDP are expressed in level deviations from the steady state.

Emerging Economy 1

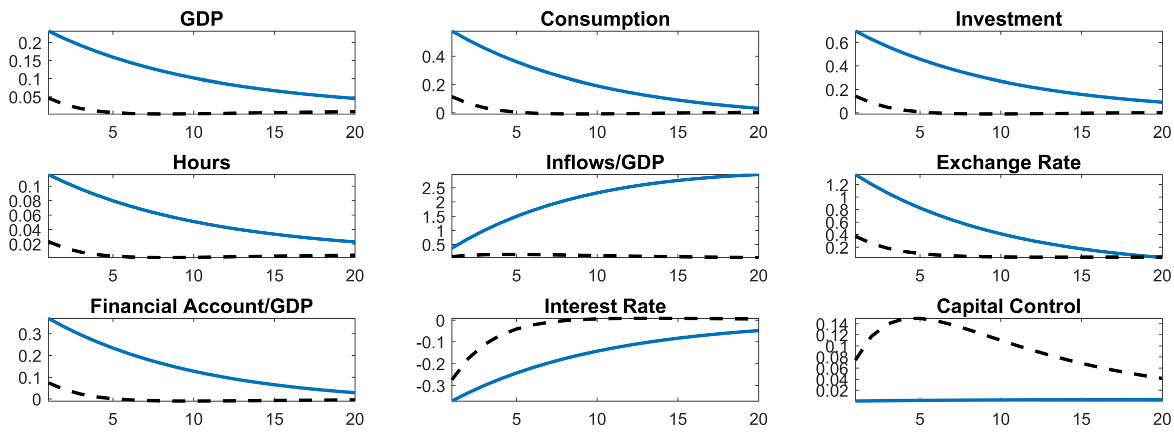

Figure 2.D.2: Impulse response functions to an AE preference shock ($v_t^A = -0.04$). In the blue solid line $\phi = 0.001 = \phi^*$, in the black dotted line $\phi = 1$ and $\phi^* = 0.001$. Responses are in log-deviations from the steady state. One period correspond to a quarter. Interest rate response is annualized. Interest rate, debt/GDP and financial account/GDP are expressed in level deviations from the steady state.

Emerging Economy 2

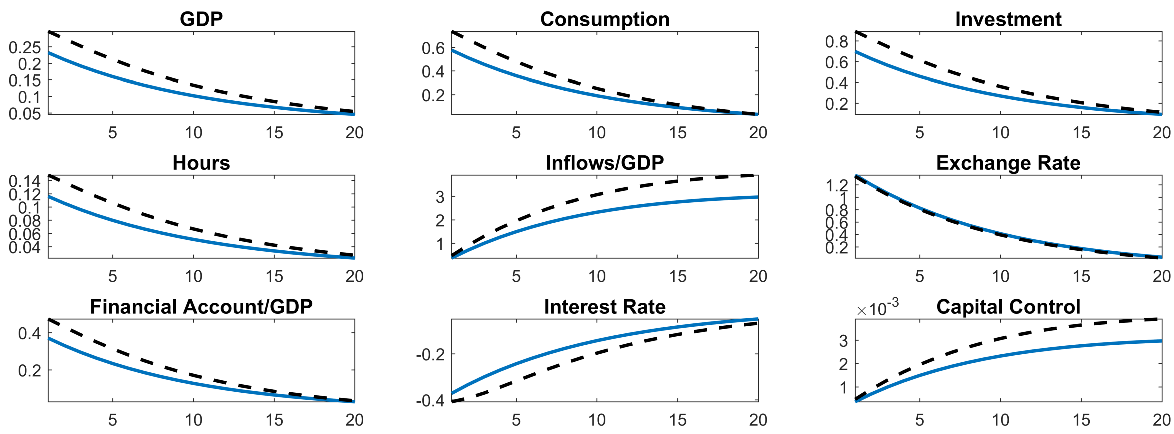

Figure 2.D.3: Impulse response functions to an AE preference shock ($v_t^A = -0.04$). In the blue solid line $\phi = 0.001 = \phi^*$, in the black dotted line $\phi = 1$ and $\phi^* = 0.001$. Responses are in log-deviations from the steady state. One period correspond to a quarter. Interest rate response is annualized. Interest rate, debt/GDP and financial account/GDP are expressed in level deviations from the steady state.

2.D.2 TFP Shocks

Advanced Economy

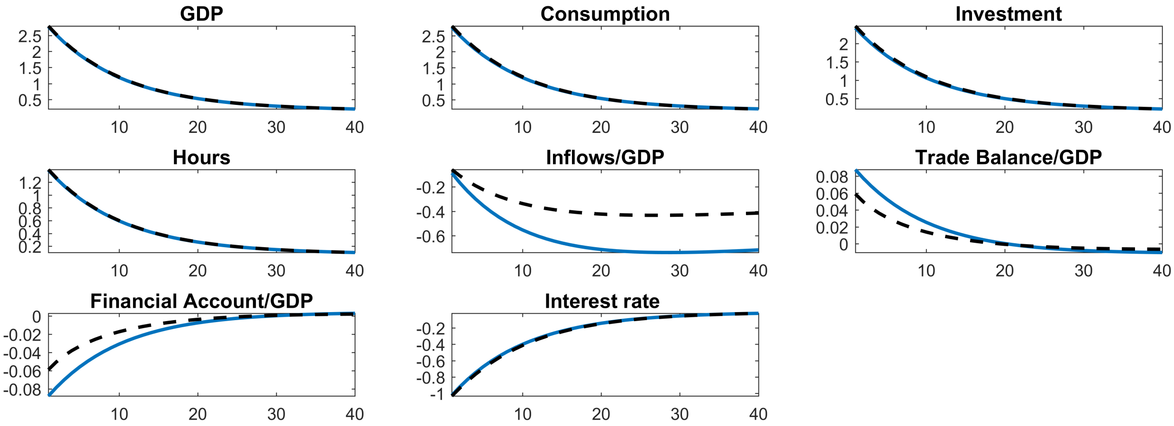

Figure 2.D.4: Impulse response functions to an AE technology shock ($\varepsilon_t^A = 0.02$).In the blue solid line $\phi = 0.001 = \phi^*$, in the black dotted line $\phi = 1$ and $\phi^* = 0.001$. Responses are in log-deviations from the steady state. One period correspond to a quarter. Interest rate response is annualized. Interest rate, debt/GDP and financial account/GDP are expressed in level deviations from the steady state.

Emerging Economy 1

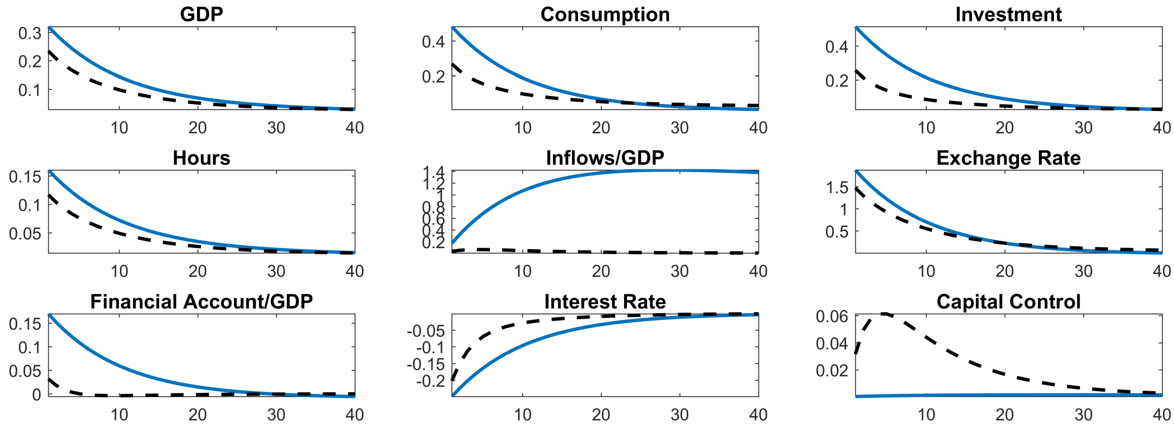

Figure 2.D.5: Impulse response functions to an AE preference shock ($\varepsilon_t^A = 0.02$). In the blue solid line $\phi = 0.001 = \phi^*$, in the black dotted line $\phi = 1$ and $\phi^* = 0.001$. Responses are in log-deviations from the steady state. One period correspond to a quarter. Interest rate response is annualized. Interest rate, debt/GDP and financial account/GDP are expressed in level deviations from the steady state.

Emerging Economy 2

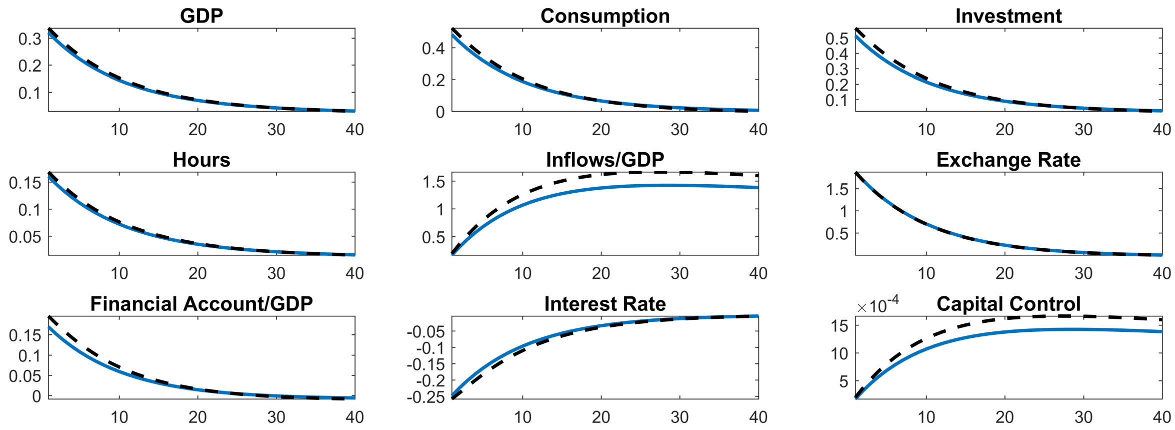

Figure 2.D.6: Impulse response functions to an AE technology shock ($\varepsilon_t^A = 0.02$). In the blue solid line $\phi = 0.001 = \phi^*$, in the black dotted line $\phi = 1$ and $\phi^* = 0.001$. Responses are in log-deviations from the steady state. One period correspond to a quarter. Interest rate response is annualized. Interest rate, debt/GDP and financial account/GDP are expressed in level deviations from the steady state.

Chapter 3

Labor Market and Financial Shocks: a Time-Varying Analysis (joint with F. Corsello)

Abstract

Motivated by the events of the Great Recession, we estimate a time-varying structural VAR model with labor market variables to analyze the effects of a financial shock, focusing on the US. Our results point out that a tightening of financial conditions is highly detrimental for the labor market. Moreover, we show that financial shocks have hit the unemployment rate asymmetrically in the last three decades, an implication that a standard VAR cannot capture: while negative financial shocks have been responsible for increases in unemployment, our model does not find significant contribution of financial shocks throughout expansion periods. The source of this asymmetry is the time-varying standard deviation of the identified shock, which is higher in period of financial distress; on the other hand, we find the transmission mechanism is almost constant over time.

3.1 Introduction

The Great Recession has been particularly detrimental for the US labor market, in terms of both magnitude and persistence of the effects (Figure 3.1). The unemployment rate reached a peak of about 10% at the end of 2009 and it fully recovered only in 2016; this employment collapse was mainly driven by an impressive layoffs growth in the private sector; in addition, hours worked per employee have heavily fallen down throughout the crisis and in 2017 they are still not back to their pre-crisis level. Labor force participation was also strongly affected ans has accelerated the downward trend started in the early 2000s. Finally, not surprisingly, the vacancy rate experienced a significant drop.

Given that the last recession was generated by a large turmoil in the financial sector (Figure 3.2), studying the linkages between financial and labor markets seems crucial to gain a better comprehension of business cycle fluctuations. Moreover, the last crisis has fostered a large debate about effectiveness of macroprudential policies aiming to maintain financial stability and to dampen financial shock impact: therefore, analyzing the effects of a financial tightening on the real economy, and especially on the labor market, can provide some useful guidance to policy makers.

In the empirical economic literature there are several works analyzing the macroeconomic effects of a financial shock, defined as a tightening of financial conditions (Gilchrist et al., 2009, and Gilchrist and Zakrajšek, 2012 are eminent examples). These works typically use a VAR model with constant standard deviations (CVAR henceforth) to identify the impact of a financial shock, using sign or short-run restrictions. However, the assumption of constant shock's standard deviation seems quite restrictive when the object of interest is a financial shock: financial time series are typically asymmetric and exhibit changes in volatility over time.[1] Figure 3.3 shows the time series of the Chicago Fed National Financial Condition Index (NFCI henceforth) and the Gilchrist and Zakrajsek Spread (GZ from now on). These indicators measure the tightness of financial conditions in the US, with higher values denoting periods of tighter conditions: both measures feature small fluctuations on average (associated with periods of financial calm) and few big and volatile peaks (associated with periods of financial distress); a VAR with stochastic volatility is able to distinguish between periods of high and low volatility: as a result the estimated standard deviation of financial shocks is likely to be high in periods of financial turbulence, as the data seem to suggest. Furthermore, the bias resulting from a CVAR estimation is magnified if the sample period includes the recent financial crisis: the estimated impact of a shock in a CVAR tries to summarize the effects of such a shock over time. Given that the Great Recession faced a huge drop in the real activity

[1] See Kim et al. (1998) for an overview of stochastic volatility models.

due to massive distress in financial markets, a CVAR may overestimate the effect of a financial innovation across the sample. In Section 4 we argue that this overestimation is particularly strong for the unemployment rate.

Nevertheless, time-varying volatility may not be enough to correctly capture the effect of a financial shock. Indeed, not only the size of a financial shock can be time-varying, but also its transmission mechanism. As shown by Gaiotti (2013), Silvestrini and Zaghini (2015) and Prieto et al. (2016), a change in financial conditions has a higher impact on the real economy during periods of financial distress: this can be explained theoretically by the presence of financial constraints that can be binding during recessions, as pointed out by Mendoza (2010), Bianchi (2011) and Guerrieri and Iacoviello (2017). Moreover, several recent papers show that labor market time series feature a significant degree of skewness.[2]

Motivated by all these considerations, we assess the interactions between labor market and financial shocks in a time-varying framework. In particular, the following research questions are tackled:

- What is the effect of a financial tightening on the labor market?
- How relevant are financial shocks in explaining historical labor market fluctuations?
- Is the response of labor market time-varying?
- Is the size of financial shocks changing over time?
- What are the main transmission mechanisms and how are they captured by VAR models?

To the best of our knowledge, there are no empirical studies in the literature focusing on the effects of financial shocks in the labor market and this is particularly surprising, given what happened during the Great Recession. Therefore, following the work of Primiceri (2005), we estimate a time-varying VAR with stochastic volatility (TV-VAR-SV henceforth), over the sample period 1973-2016. We include in the model eight US quarterly time series: five labor-market variables (unemployment rate, participation rate, hours worked per employee, nominal wage and vacancy rate), two macroeconomic variables (inflation rate and real GDP) and the National Financial Condition Index (the NFCI henceforth). The NFCI series and its three components (risk, credit and leverage) are published by the Federal Reserve of Chicago at weekly frequency. This index is a dynamic factor built from a balanced panel of 100 mixed-frequency indicators of

[2]See, for instance, McKay and Reis (2008), Ferraro (2017) and Pizzinelli and Zanetti (2017).

financial activity. The financial shock that we aim to identify is a tightening of financial conditions, modeled as an unanticipated exogenous increase in the NFCI: as such, this is a credit supply shock, deeply analyzed by theoretical studies.[3] The shock is identified through a short-run restriction: the labor market and the macroeconomy cannot simultaneously react to innovations in the NFCI, a standard assumption in the structural VAR literature. This restriction is even more reasonable in our framework, since the labor market is by its own nature sluggish to respond to economic shocks.

Our contribution to the literature is threefold. First we show that a tightening of financial conditions depresses the labor market and the GDP while the effect on inflation is positive and borderline significant.[4] Second, we find that financial shocks have hit the unemployment rate asymmetrically over the last three decades: while negative financial shocks have been responsible for the high unemployment rates in the early 1980s and during the Great Recession, our model does not find relevant contribution of financial shocks throughout expansion periods. We show that a CVAR is not able to capture this asymmetry. Third, we observe strong evidence of time variation in the financial shock volatility, with peaks during economic downturns, consistently with the works of Justiniano and Primiceri (2008), Stock and Watson (2012) and Prieto et al. (2016): accordingly, we find larger negative than positive shocks. Since the systematic transmission mechanism does not display time variation, we can conclude that the asymmetric response of the unemployment rate is entirely due to financial shock's drifting volatility.

The remainder of the paper is organized as follows: in Section 2 we provide a brief review of theoretical and empirical literatures on the transmission of financial shocks to real activity; Section 3 presents the time series used in the analysis; Section 4 introduces the estimation methodology; Section 5 describes the results; in Section 6 some robustness checks are reported; Section 7 concludes.

[3]See, for instance, the DSGE model by Jermann and Quadrini (2012).

[4]Notice that the DSGE literature is not unanimous about the effects of financial shocks on the inflation rate.

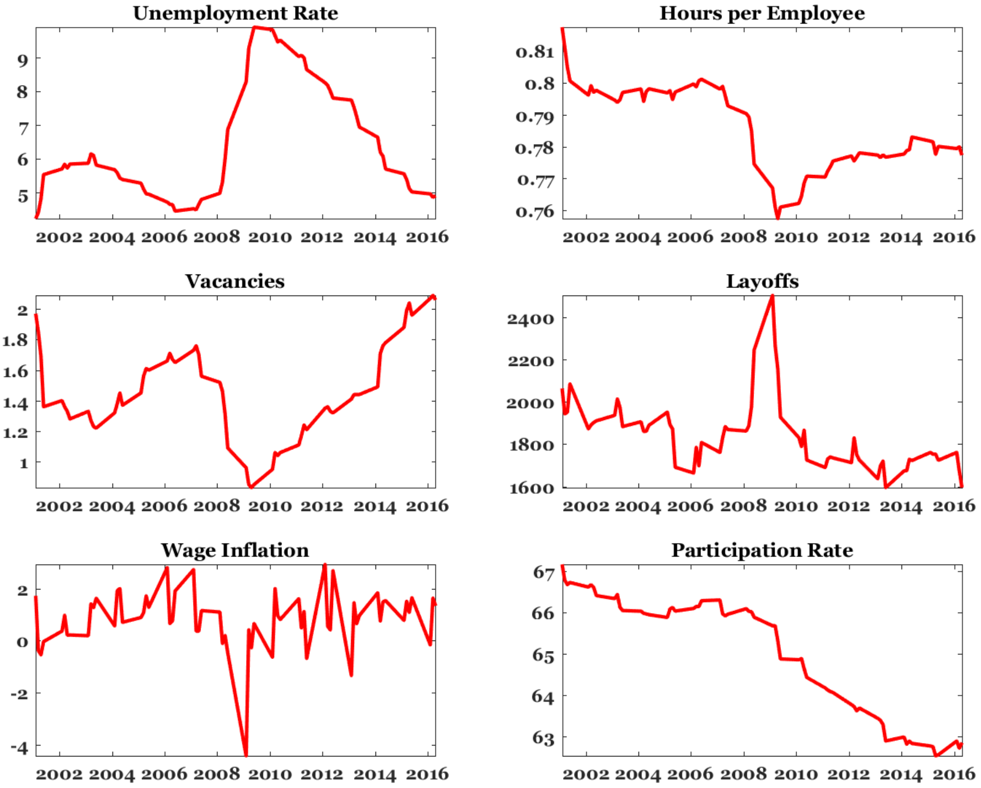

Figure 3.1: US labor market during the Great Recession. Unemployment rate, participation rate and wage inflation are expressed in percentage points. Hours per employee is the ratio between hours in nonfarm business sector (an index with base year 2010), and the number of employees in that sector. Layoffs in nonfarm business sector are expressed in thousands of workers. Vacancies are measured by the Help-Wanted Index developed by Barnichon (2010). All these variables but the vacancy index come from the BLS database.

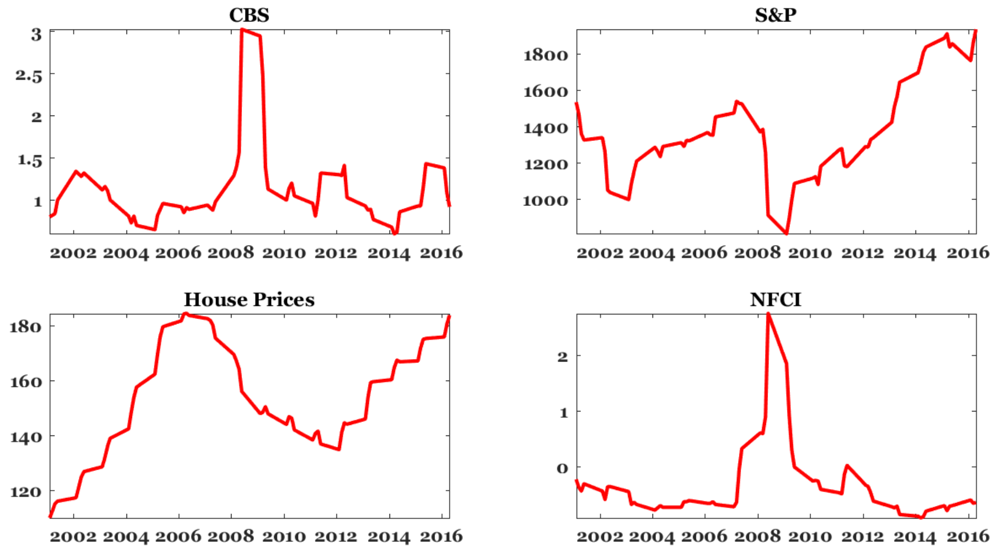

Figure 3.2: US financial markets during the Great Recession. CBS is the Moody's BAA-AAA corporate bond spread expressed in percentage points. S&P is the Standard & Poor stock market index. House prices are measured by the Standard & Poor's Case–Shiller Home Price Index (base year 2000). NFCI is the National Financial Condition Index developed by the Chicago Fed. Source: St. Louis Fed.

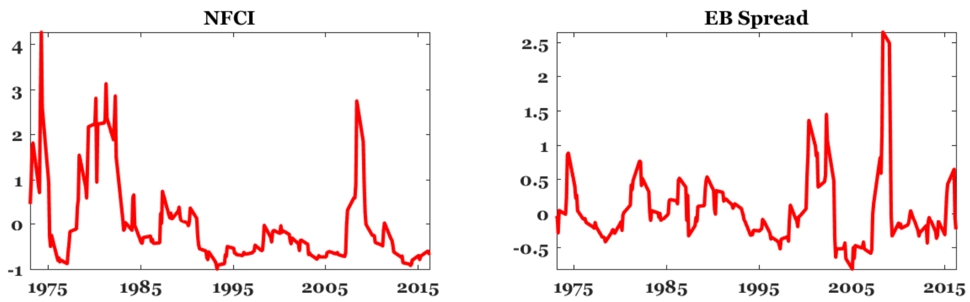

Figure 3.3: EB spread is the excess bond premium component of the GZ spread built by Gilchrist and Zakrajšek (2012).

3.2 Related Literature

3.2.1 Theoretical Literature

The macroeconomic theoretical literature has deeply analyzed the transmission mechanism linking real activity with the financial sector. The seminal paper by Bernanke and Gertler (1989) introduces the concept of financial accelerator: in presence of asymmetric information, lenders are more willing to provide funds if borrowers are endowed with high levels of net worth; since the latter is likely to be procyclical, following a recessionary shock firms find it harder to obtain outside funds; as a result, investment falls, reinforcing the initial drop in net worth, eventually magnifying the negative consequences on the real economy. Bernanke and Gertler (1995) argue that an unanticipated monetary policy tightening reduces firms cash flows and so their net worth, inducing smaller investments, reducing further the net worth and exacerbating the shock's negative effects. Kiyotaki and Moore (1997) build a model following the same intuition: if borrowers secure loans with capital and they face binding collateral constraints, any negative shock to the collateral's value force them to deleverage. As a result, they reduce investment in new capital, amplifying the deleveraging process and depressing future investment as well.

The aforementioned studies have formed the basis for business cycle models that incorporate the financial accelerator mechanism in a general equilibrium framework.[5] In particular, Jermann and Quadrini (2012) develop a model in which the financial sector is not only a source of amplification but also a driver of business cycle fluctuations, as witnessed by the Great Recession. In this model, a tightening of financial conditions reduces firms' borrowing ability and forces them to cut hours of work and production. Also in Gertler and Karadi (2011), the main driver of fluctuations originates in the financial sector: a deterioration in the quality of financial assets reduces the net worth of banks. In turn, banks raise the lending cost to remain profitable and avoid deposit withdrawals. The shock that we aim to identify in our model resembles those in Jermann and Quadrini (2012) and Gertler and Karadi (2011): it is a credit supply shock that makes it harder for firms to borrow funds; using the NFCI goes precisely in this direction, given that this indicator captures the tightness of financial conditions.

A recent strand of the macro-financial literature has departed from the assumption - made for computational reasons - that financial constraints are always binding: scholars have been starting to set up models characterized by occasionally binding collateral constraints, in order to study the (potentially) non-linear effects of economic shocks.[6]

[5] See also Bernanke et al. (1999) and Christiano et al. (2003).

[6] For example, occasionally binding collateral constraints characterize the model of Mendoza (2010)

During recessions, such constraints bind and firms deleverage; on the other hand, in expansions, a loosening of financial conditions does not have a direct impact on collateral constraints, which continue to be slack.

A common denominator of these papers is the abstraction from unemployment issues: the labor input is modeled as an intensive margin and so there is no room for unemployment. The Great Recession has provided motivation to fill this gap: frictional financial markets have been introduced in models featuring equilibrium unemployment à la Mortensen and Pissarides (1994): one contribution of our work is to qualitatively capture the dynamics highlighted in these models. A not comprehensive list includes Christiano et al. (2011), Petrosky-Nadeau and Wasmer (2013), Petrosky-Nadeau (2013), Iliopulos et al. (2014) and Zanetti (2017). In these works, financial and labor-matching frictions coexist: in particular, firms need external funding to finance the cost of posting vacancies and attracting unemployed workers. During crises, firms have limited access to external credit and thus reduce the number of posted vacancies, so that financial frictions magnify the role played by search and matching frictions in creating unemployment. Notably, Petrosky-Nadeau (2013) examines the impact of a credit shock on the labor market. In this model, a worsening of financial conditions induces firms to reduce the number of vacancies: the probability to find a job for an unemployed falls and the unemployment rate rises; as a consequence, labor market tightness (defined as the vacancy-unemployment ratio) collapses, making easier for firms to fill a vacancy. The obvious by-product of such a negative shock is a drop of aggregate production. On the other hand, Monacelli et al. (2011) propose a different mechanism. The authors argue that external debt allows firms to get a better position when bargaining wage with workers. In such a case, a negative financial shock forces firms to reduce borrowing and places them in a less favorable bargaining position with workers: as a result, firms will create less jobs.

3.2.2 Empirical Literature

There is a growing empirical literature analyzing the effects of financial shocks. One seminal paper of this literature is Gilchrist and Zakrajšek (2012): they construct the GZ credit spread index, an indicator with a significant predictive power for economic activity. The GZ spread is decomposed in two components: the expected default and the excess bond premium; the latter is used as financial variable in a macroeconomic VAR: an innovation in the excess bond premium leads to economically and statistically significant declines in the real activity. Fornari and Stracca (2012) estimate a panel VAR for a

and Guerrieri and Iacoviello (2017).

large set of advanced economies, in order to evaluate the effects of a credit supply shock, identified with sign restrictions. Their findings show that financial shocks exert a relevant influence on the real economy, both in terms of shock's size and variance explained. These results are confirmed by Caldara et al. (2016): they distinguish between financial and uncertainty shocks, finding that the former ones significantly affect economic conditions and are an important source of business cycle fluctuations; moreover, they amplify the negative effects of adverse uncertainty shocks. One of our goals is contributing to this literature, by augmenting the set of endogenous variables typically included in VAR with some labor-market variables.

The previous works all consider linear frameworks, in which estimated parameters are constant over time. Our work goes one step ahead by allowing time variation in parameters and shock standard deviations. Indeed, some papers point out that including time variation in a financial shock analysis yields some important insights. In particular, many studies find that standard deviation of financial shocks is changing over time and it is relatively higher in periods of financial distress. Using Italian firm-level, Gaiotti (2013) shows that quantitative credit constraints have a larger effect during economic slack. Silvestrini and Zaghini (2015) study the linkages between financial shocks and the macroeconomy in a time-varying framework. They estimate a time-varying VAR with euro-area variables, finding evidence of time variation in the transmission mechanism of a shock to the Composite Indicator of Systemic Stress, identified with short-run restrictions: notably, this financial shock has a more significant adverse impact during financial crises. Prieto et al. (2016) estimate a time-varying VAR for the US economy with three financial market variables (house prices, stock prices and credit spread). They find that during financial crisis, contribution of financial shocks in explaining fluctuations in GDP more than doubles, and this is mainly explained by a higher shock volatility. In a reduced-form model, Alessandri et al. (2017) find that changes in the GZ Excess Bond Premium have stronger predictive power for crisis than for expansions.

3.3 Data

The estimation is performed over the sample period 1973Q1-2016Q3, using eight US time series; the observations going from 1973Q1 to 1980Q4 are used as training sample to calibrate prior distributions. The sample starting point is dictated by availability of the NFCI.

In order to capture financial shocks' effects both on the extensive and intensive margin, the vector of endogenous variables comprises the unemployment rate, the log-first difference of the participation rate (defined as labor force over working age population) and the log-first difference of hours of work per capita in the non-farm business sector; in addition, we include the log-first difference of nominal wage, the vacancy index constructed by Barnichon (2010), GDP deflator and real GDP. Our financial measure is the NFCI.[7]

It deserves to spend some words about the NFCI, given the crucial role played in our analysis. The NFCI, published at weekly frequency by the Federal Reserve Bank of Chicago, is a weighted average of a set of financial indicators: the weight of each indicator is estimated by means of the principal component technique. The index captures measures of risk, liquidity and leverage. The risk component summarizes the premium yielded by risky assets and their volatility; the liquidity component provides an index of willingness to borrow and lend at prevailing prices; the leverage component assesses the economy-wide level of financial debt relative to equity. The index and its components are rescaled to have a zero mean and a unitary standard deviation; positive (negative) values denote financial conditions that are tighter (looser) than average. The main advantage of this indicator comes from an overall description of US financial conditions: this is particularly important due to the strong interconnectivity of US financial markets, in which shocks tend to have an impact on aggregate financial conditions rather than on one specific segment.[8]

In Figure 3.1 we plot the seven non-financial series we use in estimation, excluding training sample observations. The unemployment rate is above 5% in several periods of our sample:[9] it is particularly high during the 1980s and throughout the Great Recession. During the recent financial crisis we also observe unusual negative values for price and wage inflation along with a large drop in hours of work, vacancies and GDP. Figure 3.2 plots the NFCI and its subcomponents. The index displays positive values at the beginning of the sample (in correspondence with the less-developed-countries debt crisis occurred in the early 1980s), and in the late 1980s, in addition to the big spike in 2009; the years between the 1990's and the boom preceding the Great Recession were characterized by relatively looser financial conditions. The three NFCI components exhibit similar patterns: interestingly, the leverage component is much more volatile, while the credit index is more persistent.

[7]We are not the first ones to use the NFCI in a structural VAR: Fink and Schüler (2015) identify a financial shock as an innovation in the NFCI; Metiu et al. (2015) include the NFCI in a VAR in order to capture the transmission mechanism of a financial shock defined as an innovation to the GZ spread.

[8]See Brave and Butters (2011) and Brave and Butters (2012) for more details.

[9]According to FED estimates, the long-run normal rate of unemployment ranges from 4.5 to 5.0 percent.

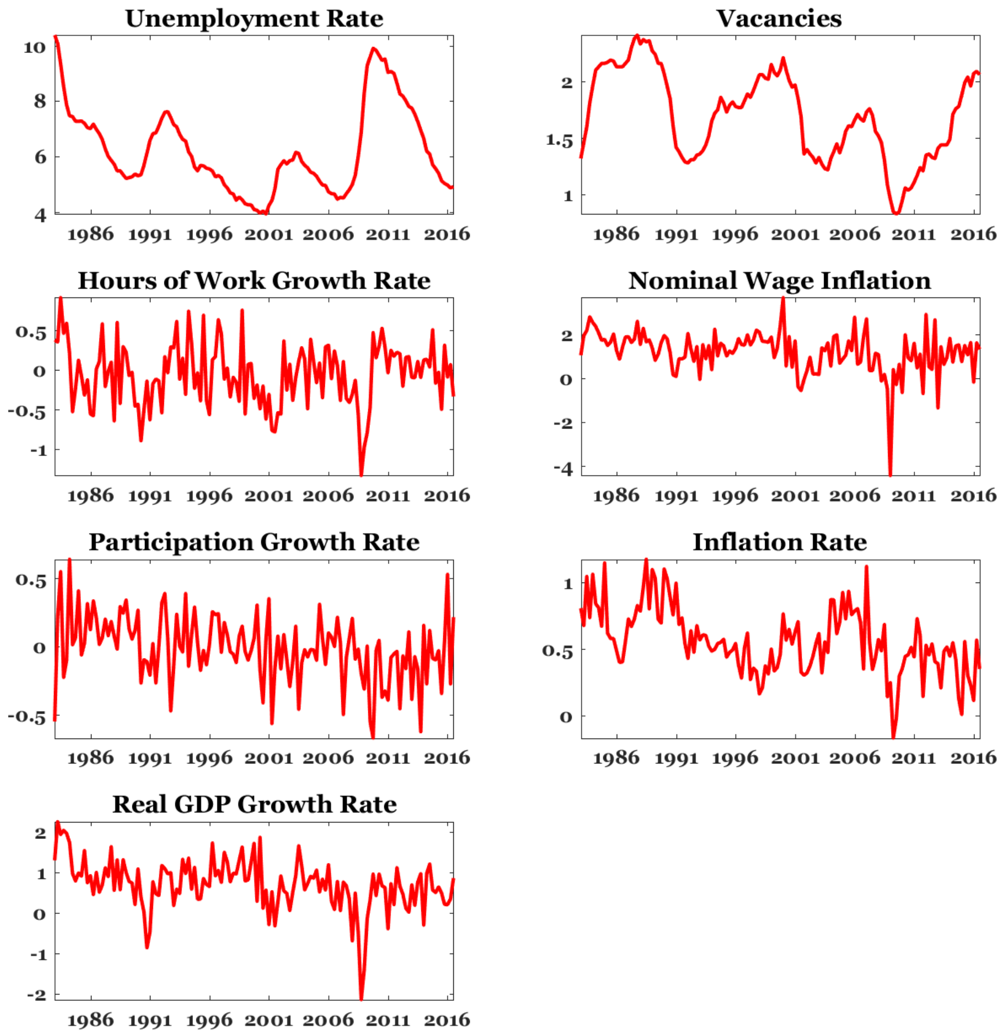

Figure 3.1: Labor and macroeconomic variables. Variables are expressed in percentage points except vacancies.

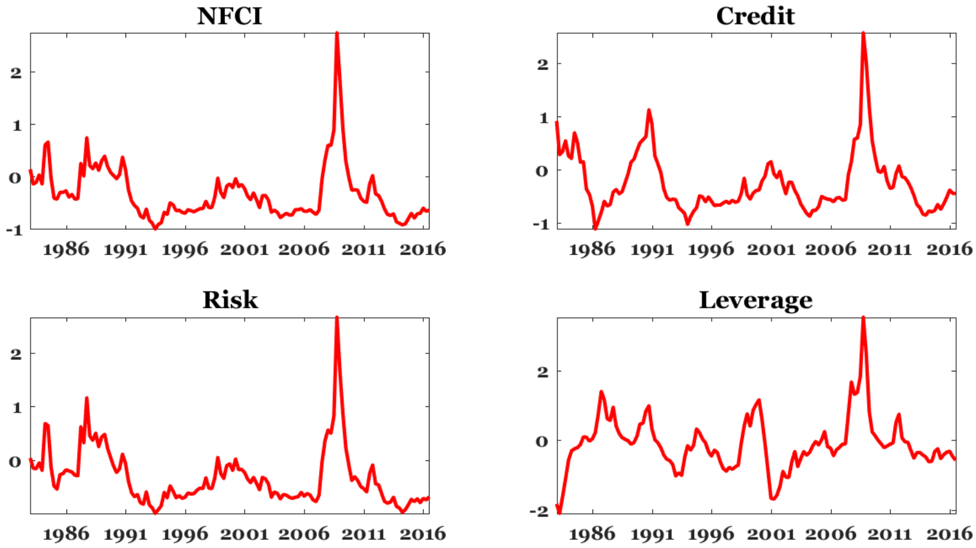

Figure 3.2: NFCI and its subcomponents.

3.4 Econometric Methodology

3.4.1 TV-VAR-SV and rank reduction

The n variables of interest are modeled through a time-varying coefficient VAR with stochastic volatility, whose reduced form follows the seminal work of Primiceri (2005):

$$\underbrace{y_t}_{n\times 1} = c_t + \sum_{\ell=1}^{p} \underbrace{B_{\ell,t}}_{n\times n} y_{t-\ell} + u_t, \qquad u_t \overset{i}{\sim} \mathcal{N}\left(\mathbf{0},\ \underbrace{\Omega_t}_{n\times n} \right).$$

Following the literature, for estimation purposes the model is transformed as:

$$y_t = X_t' \beta_t + A_t^{-1} \Sigma_t \varepsilon_t, \qquad \varepsilon_t \overset{iid}{\sim} \mathcal{N}\left(\mathbf{0},\ I_n \right),$$

$$\underbrace{X_t'}_{n\times k} \equiv I_n \otimes \begin{bmatrix} 1 & y_{t-1}' & y_{t-2}' & \dots & y_{t-p}' \end{bmatrix}$$

where the time-varying coefficients are stacked in a set of k-dimensional[10] vectors $(\beta_t)_{t=1}^T$ and the $n \times n$ reduced form covariances $(\Omega_t)_{t=1}^T$ face a triangular reduction, producing the lower triangular matrices $(A_t)_{t=1}^T$ and diagonal matrices $(\Sigma_t)_{t=1}^T$:

$$\underbrace{\beta_t}_{k\times 1} \equiv vec\left(\begin{bmatrix} c_t & B_{1,t} & \dots & B_{p,t} \end{bmatrix}' \right)$$

$$\Omega_t = A_t^{-1} \Sigma_t \Sigma_t \left(A_t^{-1} \right)'.$$

Each group of time-varying elements follows a multivariate random walk with Gaussian innovations, whose covariances are parametrized by matrices $\{Q_\alpha, Q_\beta, Q_\sigma\}$. Indeed, defining the r-dimensional vectors[11] $(\alpha_t)_{t=1}^T$ and the n-dimensional vectors $(\sigma_t)_{t=1}^T$ as the sets of vectors containing, respectively, the off-diagonal elements in $(A_t)_{t=1}^T$ and the diagonal elements in $(\Sigma_t)_{t=1}^T$, we can write the assumed law of motions:

$$\beta_t = \beta_{t-1} + \nu_{\beta,t}, \qquad \nu_{\beta,t} \overset{iid}{\sim} \mathcal{N}\left(\mathbf{0},\ Q_\beta \right)$$

$$\alpha_t = \alpha_{t-1} + \nu_{\alpha,t}, \qquad \nu_{\alpha,t} \overset{iid}{\sim} \mathcal{N}\left(\mathbf{0},\ Q_\alpha \right)$$

$$\log \sigma_t = \log \sigma_{t-1} + \nu_{\sigma,t}, \qquad \nu_{\sigma,t} \overset{iid}{\sim} \mathcal{N}\left(\mathbf{0},\ Q_\sigma \right).$$

[10] $k = n\,(np+1)$.
[11] $r = n\,(n-1)/2$.

As stressed in Primiceri (2005), the random walk assumption is not harmful for estimation purposes, especially since the process is operating for a finite number of periods. Moreover, the random walk specification is parsimonious and does not restrict much the elements' dynamics.

However, a rank reduction strategy proposed by De Wind and Gambetti (2014, WG henceforth) is implemented for the time-varying coefficients. The reason is twofold: first, the rank reduction methodology makes possible to reduce the computational burden of non-small TV-VAR-SV models (say, for larger models than the small one estimated in Primiceri, 2005); second, in line with the findings of Cogley and Sargent (2005) and WG, these models typically do not show large time variation of VAR coefficients when estimated with macro-financial variables. Therefore, a smaller number of components are able to capture coefficients time variation, especially considering that the number of VAR coefficients increases very fast with the number of variables and lags, and there is no reason to conceive such a large number of economic forces able to alter the transmission mechanism at every period.

In particular, Q_β is assumed to be a reduced-rank matrix with rank $q_\beta < k$ and it is eigendecomposed in the following way:

$$Q_\beta = \underbrace{\Lambda_\beta}_{k\times q_\beta} \Lambda'_\beta = \underbrace{V_\beta}_{k\times q_\beta} \underbrace{D_\beta}_{q_\beta\times q_\beta} V'_\beta, \qquad \Lambda_\beta \equiv V_\beta D_\beta^{1/2}$$

where D_β is a diagonal matrix containing the non-zero eigenvalues of Q_β and V_β is the matrix where the associated eigenvectors are stacked in columns. Following the procedure of WG, the time-varying coefficient law of motion can be transformed (projecting onto the column space of Λ_β) in order to reduce the number of time-varying components to q_β. WG highlight that this assumption is reasonable with macroeconomic variables, especially when k gets large; in these circumstances the time variation can be spanned using a smaller space without significant changes in the inference. To sum up, the time-varying coefficients are eventually linear combinations of time-varying components with the following associated laws of motion and time-invariant residual:[12]

$$\underbrace{\beta_t}_{k\times 1} = \Lambda_\beta \widetilde{\beta}_t + M_\beta \beta_0, \qquad \underbrace{\widetilde{\beta}_t}_{q_\beta\times 1} = \widetilde{\beta}_{t-1} + \widetilde{\nu}_{\beta,t}, \qquad \underbrace{\widetilde{\nu}_{\beta,t}}_{q_\beta\times 1} \overset{iid}{\sim} \mathcal{N}\left(\mathbf{0},\ I_{q_\beta}\right).$$

Inference on the covariance matrices of states' innovations and on the unobservable states (time-varying coefficients, off-diagonal elements and stochastic volatilities) is pro-

[12]The time invariant residual is obtained through the matrix $M_\beta \equiv I_m - \Lambda_\beta \left(\Lambda'_\beta \Lambda_\beta\right)^{-1} \Lambda'_\beta$. As shown in Corsello (2018), the residual only depends on the initial condition β_0.

duced by means of a Gibbs Sampler that draws from conditional posteriors. The Gibbs Sampler steps are listed below.

Gibbs Sampler Steps[13]

1. Initialize the Gibbs Sampler at some $(\beta_t^0,\ \alpha_t^0,\ \sigma_t^0)_{t=0}^T,\ Q_\beta^0, Q_\alpha^0, Q_\sigma^0$, set $i=1$.
2. Draw a history of time-varying coefficients $(\beta_t^i)_{t=1}^T$:
   (a) Draw a history of time-varying components $\left(\widetilde{\beta}_t^i\right)_{t=1}^T$;
   (b) Draw a vector of time invariant component $M_\beta \beta_0$ of $(\beta_t^i)_{t=1}^T$.
3. Draw a reduced-rank covariance matrix Q_β^i.
4. Draw a history of off-diagonal elements $(\alpha_t^i)_{t=1}^T$.
5. Draw a full rank covariance matrix Q_α^i.
6. Draw a history of volatilities $(\sigma_t^i)_{t=1}^T$.
7. Draw a full-rank covariance matrix Q_σ^i, set $i = i+1$ and restart at [2].

Draws from the posterior of unobservable states are obtained by means of the Carter and Kohn (1994) algorithm. Draws from the Singular Inverse Wishart are implemented differently from what proposed by WG, following the approach of Corsello (2018). The stochastic volatilities draws are implemented as in Primiceri (2005), but respecting the correct order described in Del Negro and Primiceri (2015). The $\log \chi_1^2$ distribution is approximated using the mixture of normal components proposed by Omori et al. (2007), which improves upon the previous standard set by Kim et al. (1998).

The prior distribution is set following Primiceri (2005) for $\{Q_\alpha, Q_\sigma\}$ and for the initial conditions α_0 and σ_0, while WG is used as benchmark for calibrating the prior distributions of Q_β and β_0. In particular, the training sample used to calibrate prior distributions runs from 1973Q1 to 1980Q4. Dealing with quarterly data, we set $p = 2$ lags (as in Primiceri, 2005), so having a total of $k = 78$ coefficients in the VAR. The reduced rank of the time-varying coefficients is chosen to be $q_\beta = 40$, which constitutes a good compromise between dimensionality and span time variation.[14]

[13]See Corsello (2018) for analytical details on each step.

[14]Increasing the rank does not produce any variation on time-varying coefficient inference, showing that the chosen dimension is sufficient to span the measured time-varying coefficient variations over time.

3.4.2 Identification Strategy

Our identification scheme relies on a short-run restriction: we assume that both the labor market (unemployment, vacancies, participation, hours and wage) and the macroeconomy (GDP and inflation) do not contemporaneously respond to innovations in the NFCI equation. Accordingly, we order NFCI last in the endogenous vector and impose a Cholesky structure to the matrix of contemporaneous relations.

This identification strategy is quite standard in the economic literature dealing with structural shocks identification. Christiano et al. (1999) and Bernanke et al. (2005) are pioneering examples for the identification of monetary shocks using a Cholesky approach. Gilchrist and Zakrajšek (2012), Prieto et al. (2016) and Silvestrini and Zaghini (2015) use short-run restrictions to identify a financial shock.

The rationale behind this assumption is that the private sector typically tends to react with a delay to economic shocks, due to real and nominal rigidities, such as, price and wage adjustment costs or habits persistence in consumption. A Cholesky identification scheme seems even more reasonable when the focus is on labor market, which is sluggish by its own nature. In Section 6 we estimate the model using monthly data, making the short-run assumption more realistic, and we show that results are barely affected.

3.5 Results

3.5.1 Structural Analysis

Impulse responses and stochastic volatilities

Following Lopez-Salido and Nelson (2010) and Prieto et al. (2016), we group quarterly observations available in the sample into financial crisis and non-financial crisis periods. In particular, we consider five periods of US financial distress: the Less-Developed-Countries Debt Crisis (1982-1984), the stock market crash of 1987, the Savings and Loan Crisis (1988-1991), the stock market crash of 2001 and the Global Financial Crisis (2008-2009). For these financially distressed periods (and for the non-crisis observations), we compute the averaged response of each variable to a standardized impulse (unitary increase) to the NFCI.[15] Standardization across periods allows to isolate the transmission mechanism from changes in shock volatilities.

All figures report the 16th and 84th percentiles as bounds for the credible region. We do not detect noticeable time variation in the transmission mechanism, between crisis and non-crisis period, since the response to a standardized impulse is almost constant

[15]Remind that NFCI is constructed to have zero mean and unitary standard deviation.

over time. We find that an impulse of one standard deviation to the NFCI significantly increases the unemployment rate by about 0.8% within 10 quarters and depresses hours of work per employee. Unemployed workers get discouraged and some of them exit the labor force, given the negative and persistent response of the participation rate. Moreover, wage inflation response shows a significant reduction by about 0.4% at the peak, because of lower labor demand, captured by a significant drop in the vacancy rate. The simultaneous reduction in employment and vacancy results in a fall in labor market tightness:[16] according to search and matching models, when labor market is less tight, the job finding rate decreases, while the vacancy filling rate rises. The labor market slack drives a reduction in GDP (by more than 1% in levels at the peak). Interestingly, price inflation is slightly positive and borderline significant: this result is consistent with the VAR estimates by Abbate et al. (2016), who, however, use a different identification strategy.[17]

As shown in Figure 3.2, we find evidence of time-varying volatility of the identified financial shock. In particular, the estimated standard deviation is very high in the beginning of the sample (in correspondence to the Less-Developed-Countries Debt Crisis) and during the Global Financial Crisis. On the other hand, consistently with a large strand of the literature, during the Great Moderation the identified financial shock displays a relatively small standard deviation. In particular, Justiniano and Primiceri (2008) report that the key factor to understand the Great Moderation is the reduction in volatility of the investment shock, defined as innovation to the technology that transforms investments in capital goods. They mention that this innovation may be tied with the cost of external financing for firms, which has shown an important reduction in those years, due to massive financial liberalization.

To better assess the role of drifting volatilities, Figure 3.3 reports the non-standardized responses to a one-standard-deviation impulse. Time variation is driven by the stochastic volatility that determines the size of the impulse.

[16]Labor market tightness is defined as the vacancy/unemployed ratio. The numerator decreases after the shock; the denominator is affected by two countervailing forces: unemployment rate goes up but labor participation is lower. However, given that the reduction in the participation rate is small in magnitude, we conclude that labor market is less tight following a financial shock.

[17]Theoretical models are not unanimous on the effects of a financial tightening on inflation; on the one hand, tighter financial conditions reduce households' expenditure via negative wealth effects, generating a reduction in aggregate demand and so a lower price level (this is the mechanism at work in Gertler and Karadi (2011)); on the other hand, if firms borrow in order to buy intermediate inputs, an increasing risk-premium boosts the marginal cost of firms, which respond by raising the price of their products (as in Atta-Mensah and Dib (2008)). On top of that, Gilchrist et al. (2016) build a model in which firms increase prices when an adverse shock weakens their balance sheets, in order to maintain profitability; this paper provides also empirical evidence showing that, during the Great Recession, firms with a limited internal liquidity decided to raise their prices.

As stated previously, there is a growing theoretical literature analyzing the linkages between financial frictions and the labor market. Some of these works focus on the effects of a financial shock on labor market variables: our estimated impulse responses are consistent with these models, at least qualitatively. For instance, in Monacelli et al. (2011) a negative credit shock (by one standard deviation) decreases the employment rate by about 0.35% of the steady state value (which is close to one) at the response peak: this value is close to our median estimate for the crisis periods; GDP and wage responses are close to our median values as well. In Petrosky-Nadeau (2013) a two standard deviations negative credit shock raises the unemployment rate by 2% points at the peak, a value higher than our median estimates during crisis periods; however, both shape and persistence of the reaction are very similar.

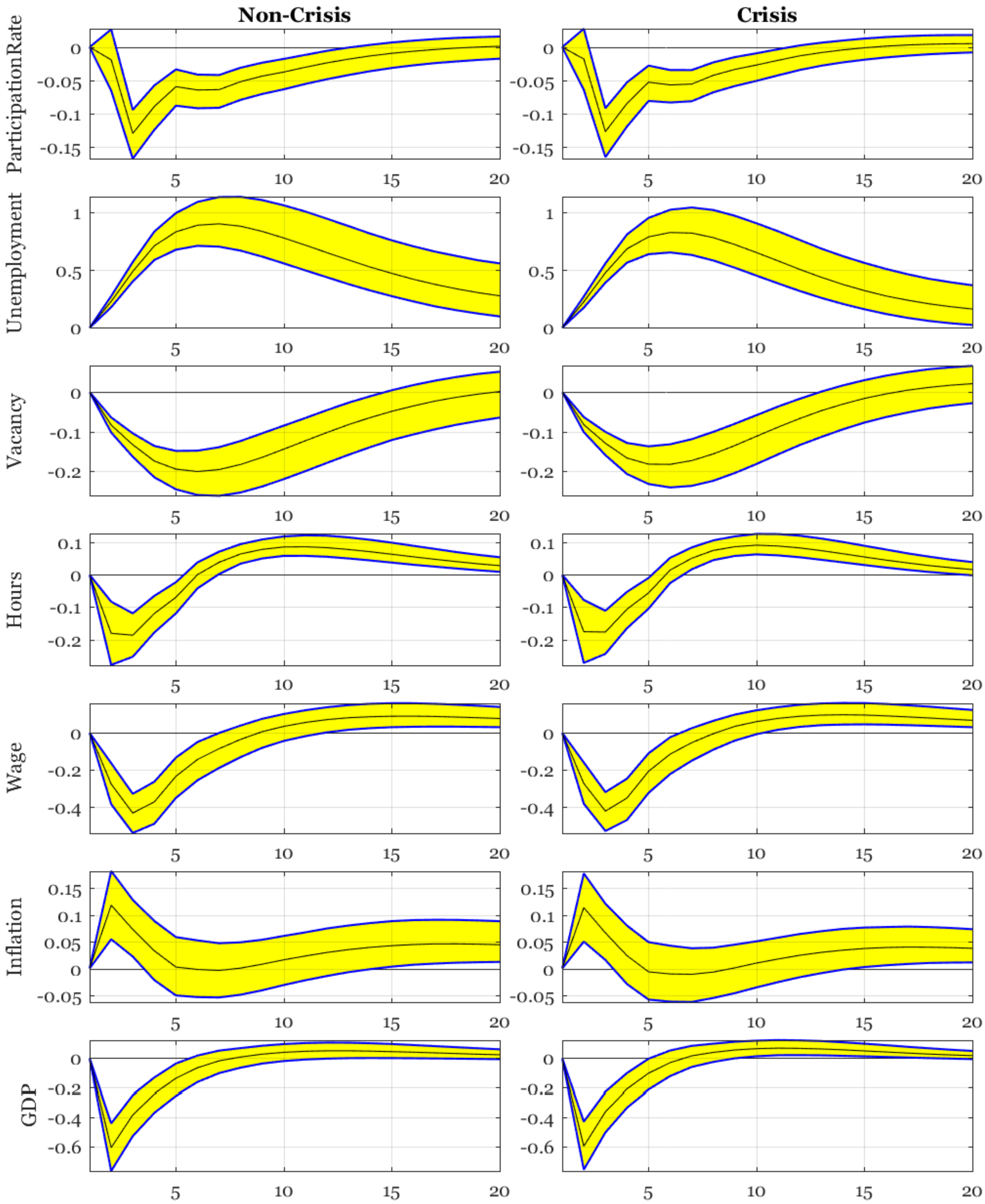

Figure 3.1: Time-varying impulse response functions to a standardized shock NFCI shock.

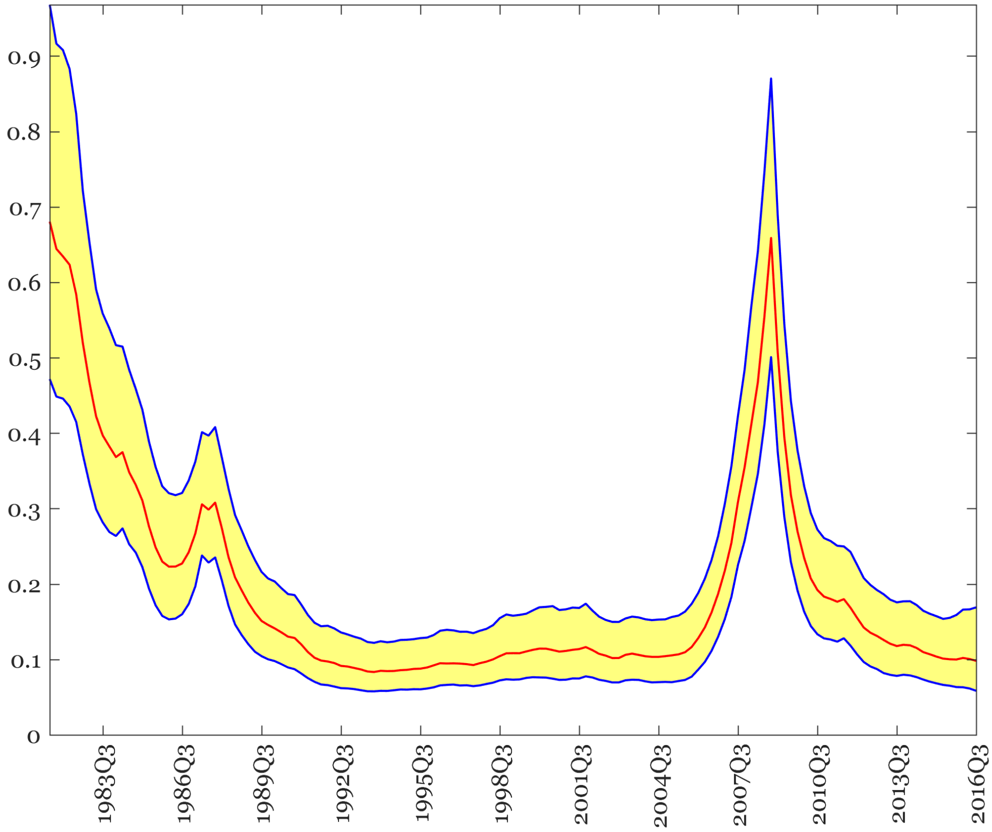

Figure 3.2: Stochastic volatility of the identified shock.

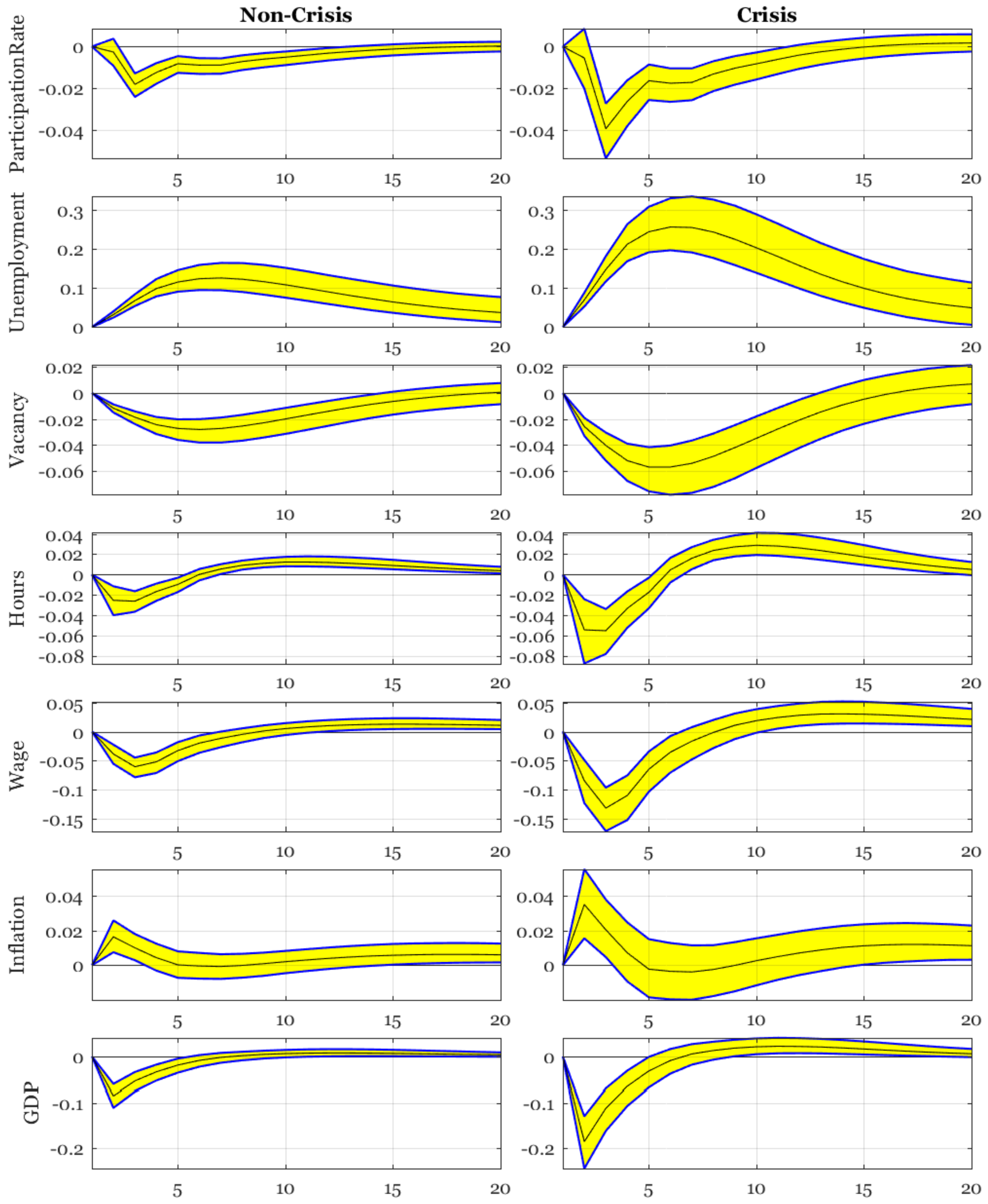

Figure 3.3: Time-varying impulse response functions to a (non-standardized shock) NFCI shock .

Historical Decomposition: comparing CVAR and TV-VAR-SV

Having observed significant time variation in the identified financial shock volatility, where larger levels of volatility tend to be associated with financial distress periods, we perform a historical decomposition analysis for the variables of interest.

A CVAR assumes constant volatility of the identified shock. When estimated using financial crisis observations, i.e. when large economic reactions follow financial distress, a CVAR framework may overstate the role of financial shocks in explaining unemployment over the sample. The TV-VAR-SV, instead, is able to discriminate between periods of large and small volatility, complying with the asymmetry of observed financial shocks: large and negative or small and positive.

If we estimate a CVAR using the entire sample (Figure 3.5), we find that the financial shock's role in explaining unemployment rate fluctuations is roughly as important as for other non-identified shocks. This finding is consistent with Caldara et al. (2016) that use a CVAR to estimate the effects of financial and uncertainty shocks on macroeconomic variables.[18] However, when the CVAR estimation sample ends in 2006Q4 (Figure 3.4), the picture changes: the financial shock contribution is much smaller across the entire sample period. In these experiments we observe that Great Recession observations are driving the importance of financial shocks across the sample.

Figure 3.6 displays the historical decomposition of unemployment in a TV-VAR-SV framework. The financial shock hits the unemployment rate asymmetrically: contributions are large and negative in periods of severe financial distress like the Great Recession and the 1982-1984 crisis, while there is almost no positive contributions in the 1990s and early 2000s. This result is in contrast with the previous CVAR analysis and provides solid ground for more general time-varying models when performing structural analysis. This asymmetric behavior is explained by the time-varying volatility of the financial shock, which is estimated to be higher in period of financial distress: indeed, we find that negative shocks tend to be larger and less frequent than positive shocks. Also for the vacancy rate, negative financial shocks are the main responsible for the fall in 1982-1984 crisis and during the Great Recession, while positive financial shocks cause only mild response in other periods. This difference between the CVAR and TV-VAR historical decomposition is less evident for hours and GDP, as shown in the Appendix. Hours of work enter the VAR in (log) first differences: while the level of hours worked per employee is not fully back to the pre-crisis level, the growth rate turned to be positive in 2009 (most recent observations are above the pre-crisis mean).

Accordingly, our identified financial shock was less severe on hours worked in terms of

[18] See figure B-1 in the working paper version of Caldara et al. (2016).

persistence: it is the prolonged negative effect on the unemployment rate that generates this sizable differences between the CVAR and TV-VAR historical decomposition. The same reasoning holds for real GDP, that, like hours worked, enters our model in (log) first differences.

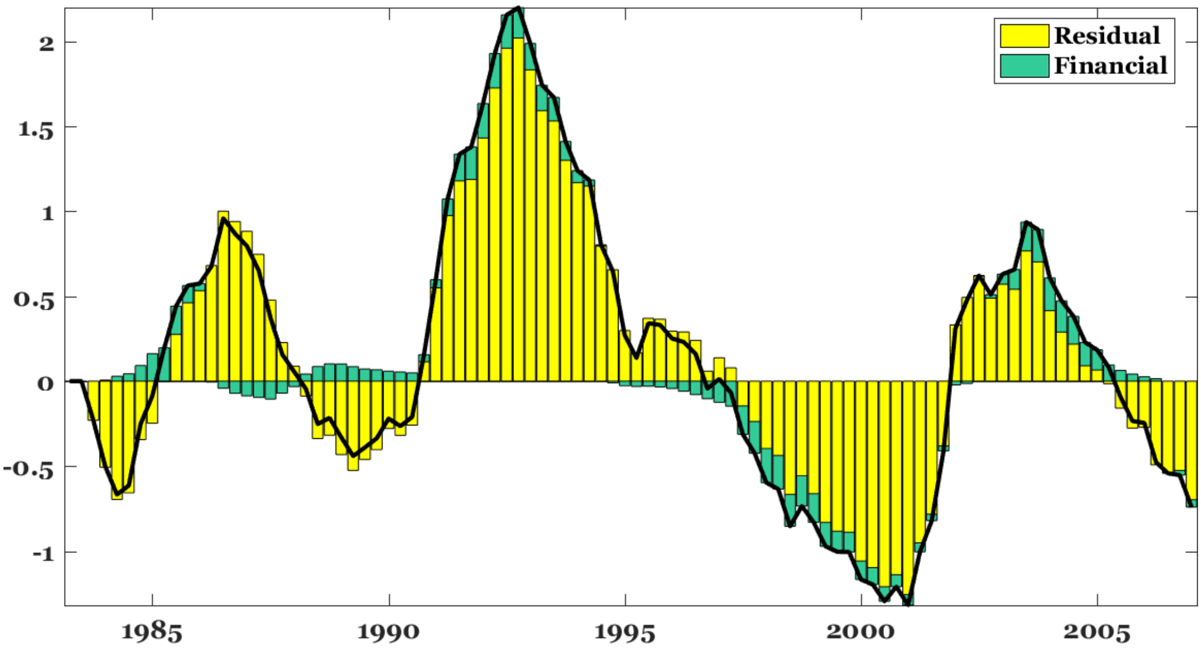

Figure 3.4: CVAR historical decomposition of unemployment, sample 1983Q1-2006Q4.

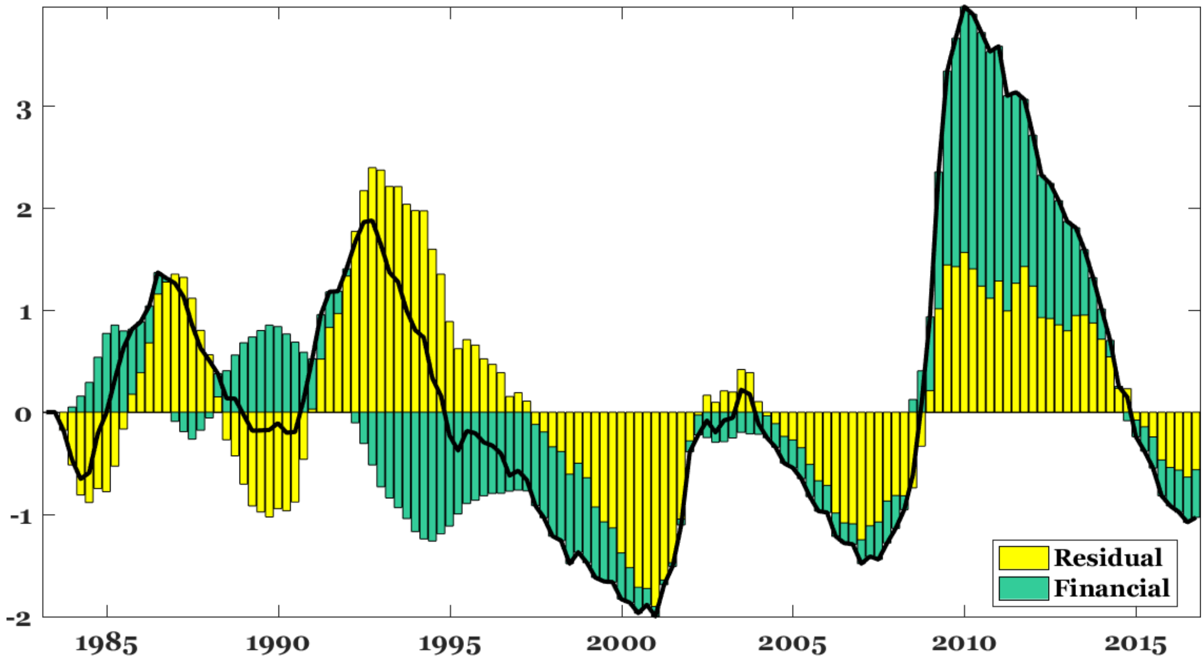

Figure 3.5: CVAR historical decomposition of unemployment, sample 1983Q1-2016Q3.

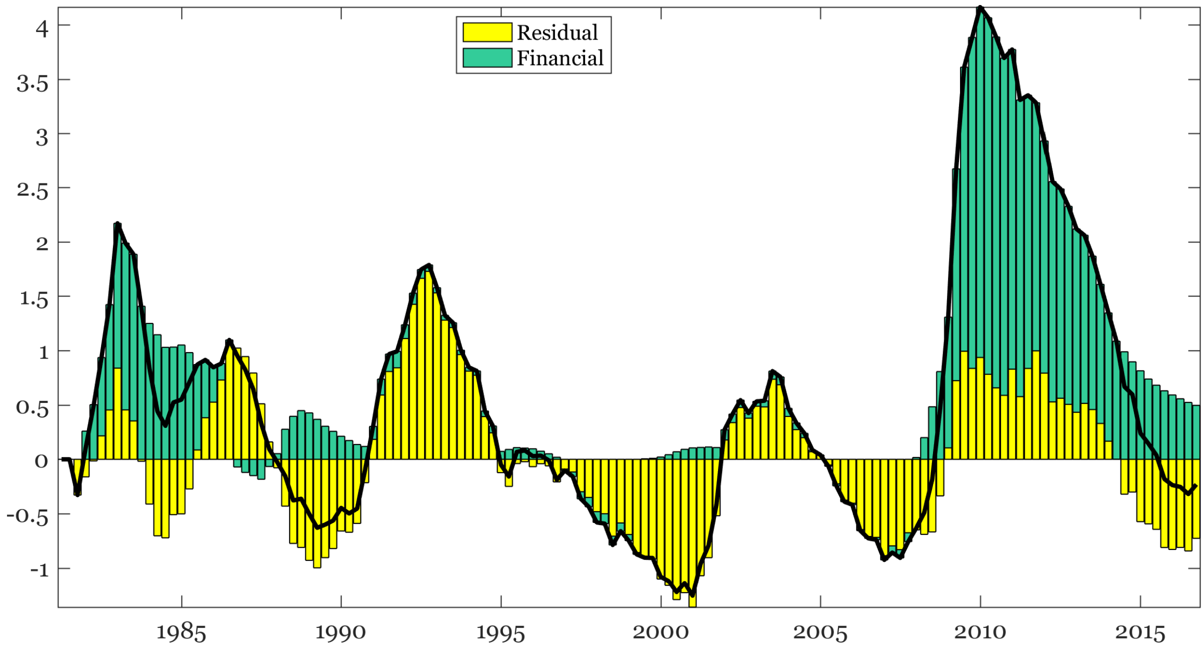

Figure 3.6: Historical decomposition of unemployment (TV-VAR-SV).

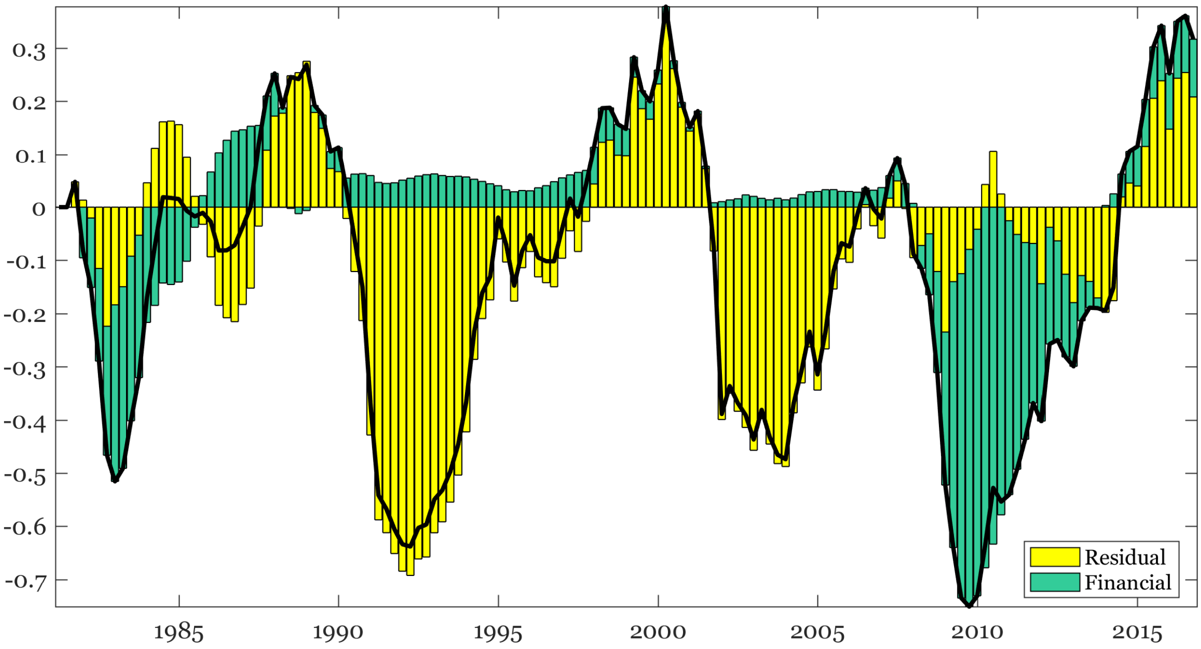

Figure 3.7: Historical decomposition of vacancies (TV-VAR-SV).

3.6 Robustness

In this section we perform two experiments to challenge the robustness of our results. First, we repeat the analysis using the credit spread index built by Gilchrist and Zakrajšek (2012). Second, we estimate the model by using monthly data. Most of the resulting figures for these robustness exercises are left in the Appendix.[19]

3.6.1 Excess Bond Premium

Gilchrist and Zakrajšek (2012) decompose their credit spread index in two components: the first one captures movements in expected defaults, the second one represents the excess bond premium (EB, henceforth) which measures cyclical changes in the relationship between default risk and credit spreads. In this subsection we verify the robustness of our results by using EB as financial variable, as in the VAR analysis of Gilchrist and Zakrajšek (2012); since the correlation between EB and NFCI is not so high (0.40), this represents a good test bench for our findings.[20] According to the CVAR historical decomposition, the 1990s were a period of positive financial shocks contribution. On the other hand, using a time-varying model, this positive contribution almost disappears, as in our benchmark specification.

Financial shock standard deviation is very low and pretty constant until the late 1990s, when it starts to increase, reaching a peak during the Great Recession. Impulse responses seem constant over time, when the impulse is standardized. Signs and sizes of responses are in line with the benchmark specification, except for the inflation response, which is negative but not statistically different from zero.

[19]Additional figures are available upon request.

[20]An empirical analysis in a time-varying framework using the GZ index has been conducted by Abbate and Marcellino (2016), who, however, do not consider the labor market.

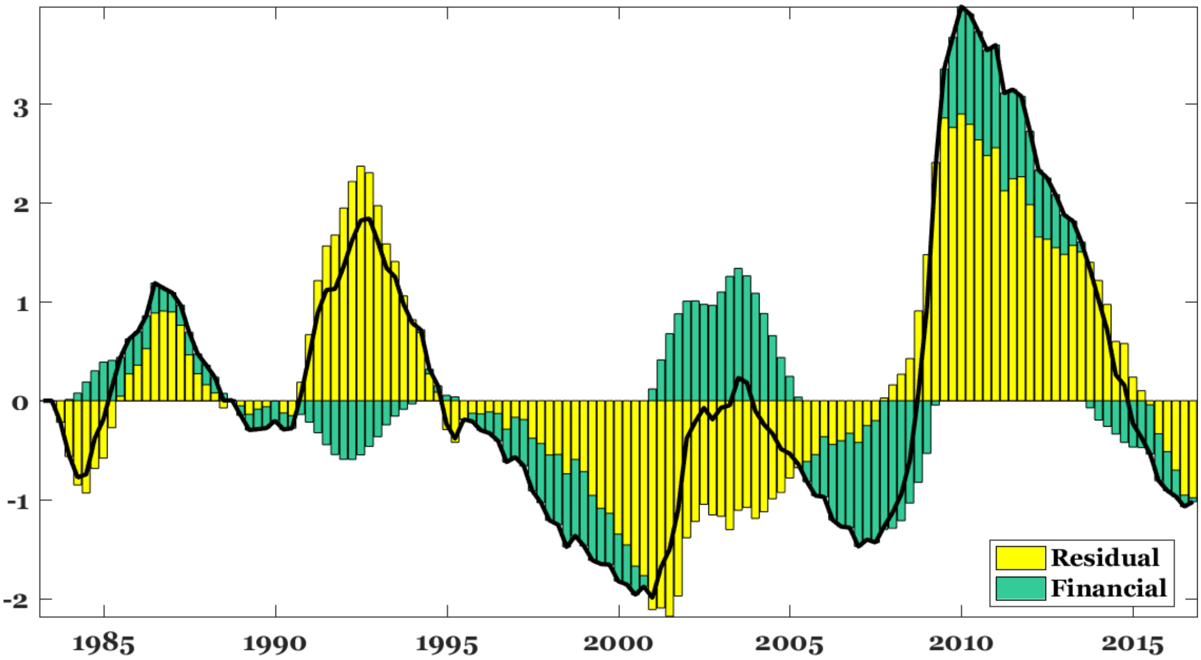

Figure 3.1: Historical decomposition of unemployment (EB specification, CVAR).

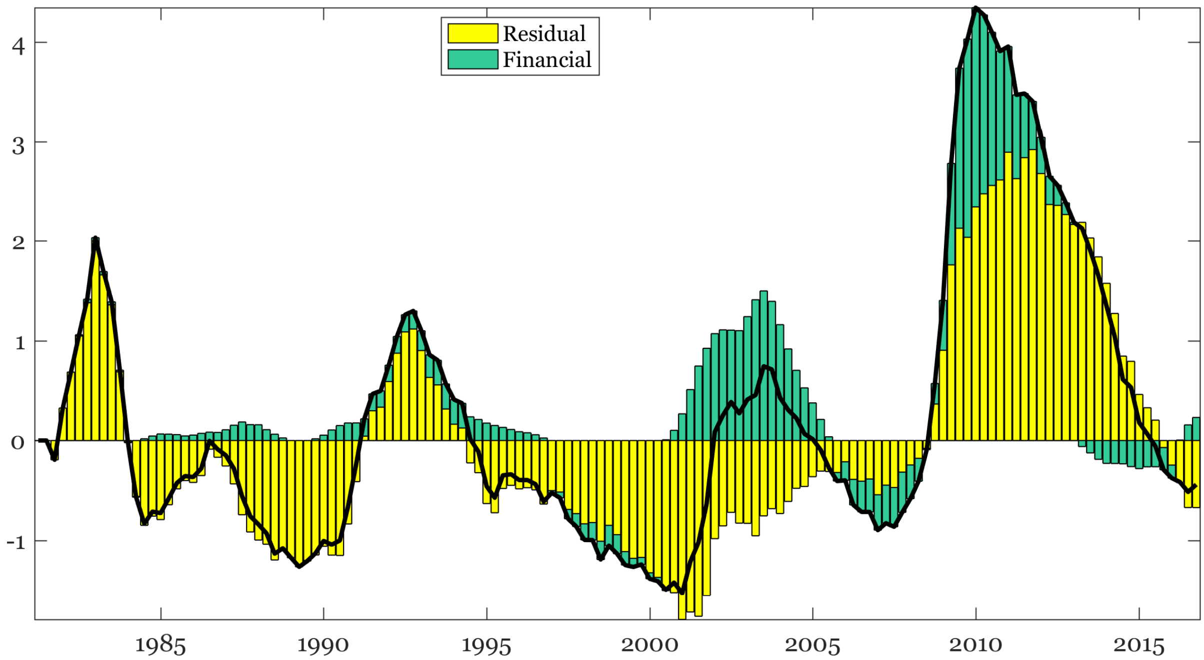

Figure 3.2: Historical decomposition of unemployment (EB specification, TV-SV-VAR).

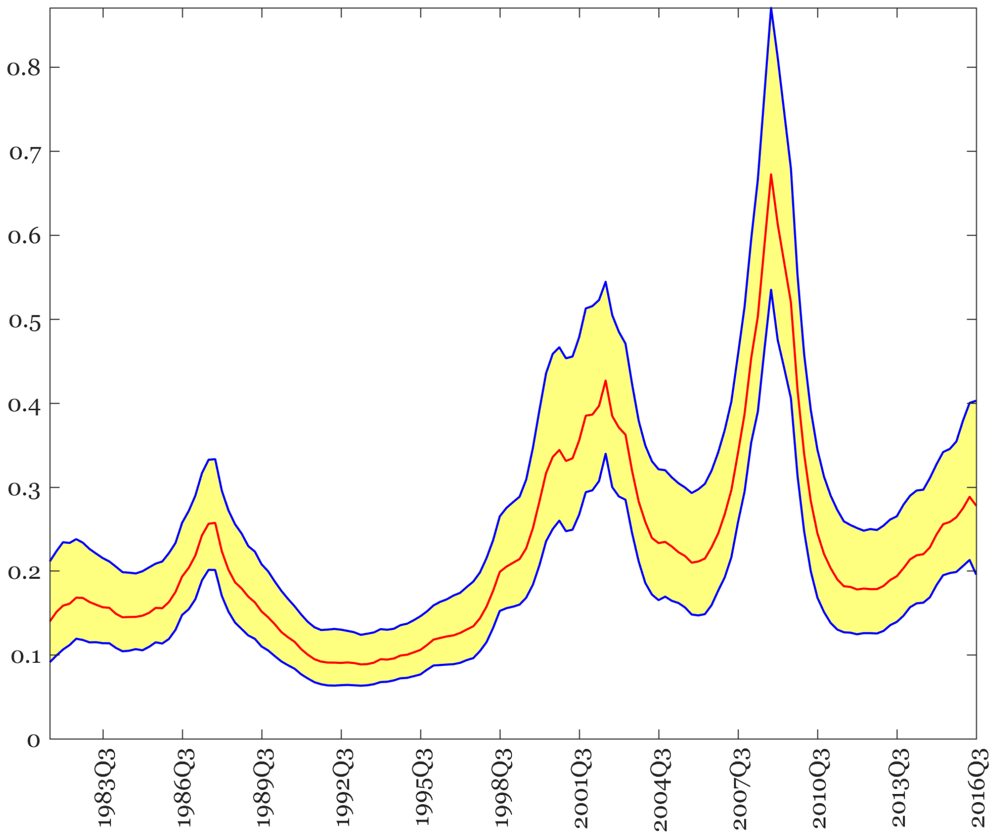

Figure 3.3: Stochastic volatility of the identified financial shock (EB specification).

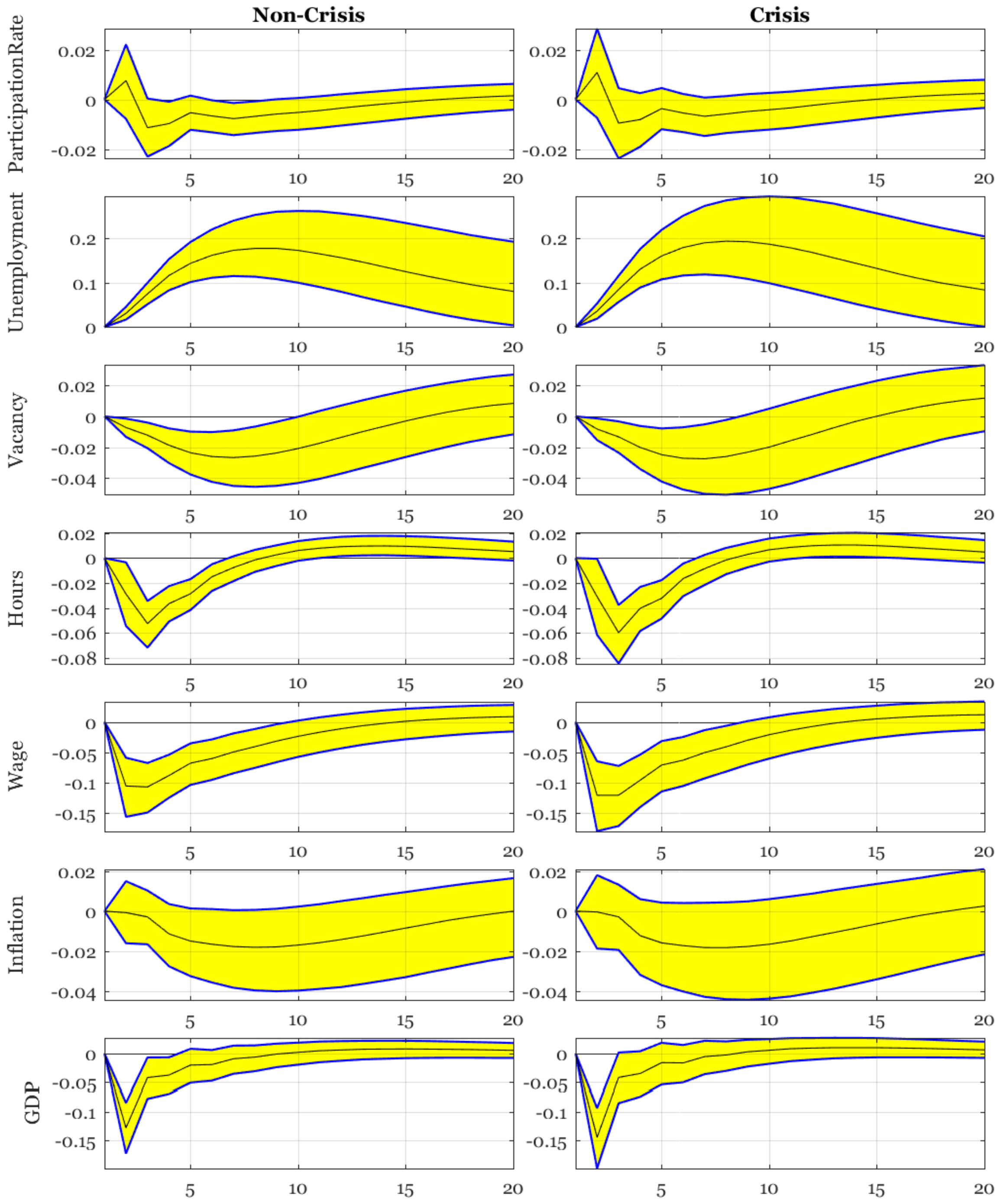

Figure 3.4: Time-varying impulse response functions to an EB (non-standardized) shock .

3.6.2 Fixed VAR Coefficients and Monthly Data

Our identification strategy is based on a short-run restriction: variables cannot contemporaneously react to an innovation in NFCI equation residuals. This assumption may seem questionable, if applied to quarterly data. In order to address this issue, we estimate the model using monthly data, keeping fixed the VAR coefficients, thus allowing time variation only in shocks' standard deviations. Indeed, when the model is estimated at monthly frequency, the number of coefficients to estimate gets huge. This is because, when the frequency switches from quarterly to monthly, the number of observations is multiplied by three, causing an increase in the number of lags p, as well as an increase of periods in which $k = n\,(np + 1)$ coefficients have to be estimated. However, since the benchmark specification does not find much time variation in VAR coefficients, a CVAR with stochastic volatility seems a good compromise.

The Gibbs Sampler to estimate a CVAR with stochastic volatility is a modification of the counterpart for the TV-VAR-SV described above, in which the coefficients' draw step is simply a Bayesian regression with informative prior, obtained by stacking the model in the following form:

$$\underbrace{Y}_{nT\times 1} = \underbrace{X}_{nT\times k} \cdot \beta + U, \qquad U \sim \mathcal{MN}\left(\mathbf{0},\ \underbrace{V_u}_{n\times n}\right)$$

where V_u is conditional on the history of stochastic volatilities drawn in the previous step. Prior information is incorporated in the posterior as suggested by Gelman et al. (2013).

Some of the series used in the baseline specification are not available at monthly frequency. The new series that we use are the following:

- Average hours of production and nonsupervisory employees in the private sector.
- Average hourly earnings of production and nonsupervisory employees in the private sector.
- The consumption price index.
- The industrial production.

The unemployment rate, the participation rate and the NFCI are available at monthly frequency, while the vacancy index is not and it is dropped from the estimation sample. All the transformations are the same of the baseline specification, except for hours worked that now are not divided for number of employees, being an average measure.

Results from this new specification do not change the picture: positive financial shocks have a mild impact on unemployment fluctuations and this result cannot be captured by a VAR with constant shocks' variance. The estimated stochastic volatility has a pattern similar to the correspondent graph of the quarterly baseline specification. The impulse response functions of unemployment, hours, GDP and inflation do not qualitatively differ from the baseline specification. Now nominal wage inflation grows on impact; nevertheless, given inflation response, the real wage decreases and this is consistent with a fall in labor demand by firms.

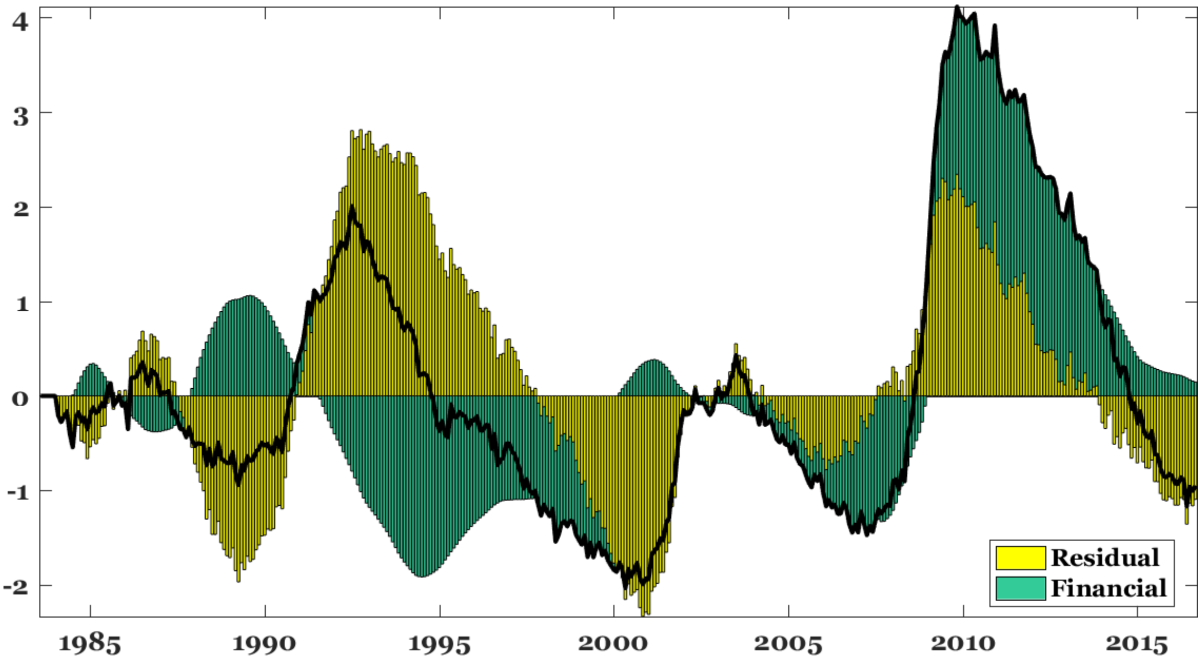

Figure 3.5: Historical decomposition of unemployment (CVAR, monthly specification).

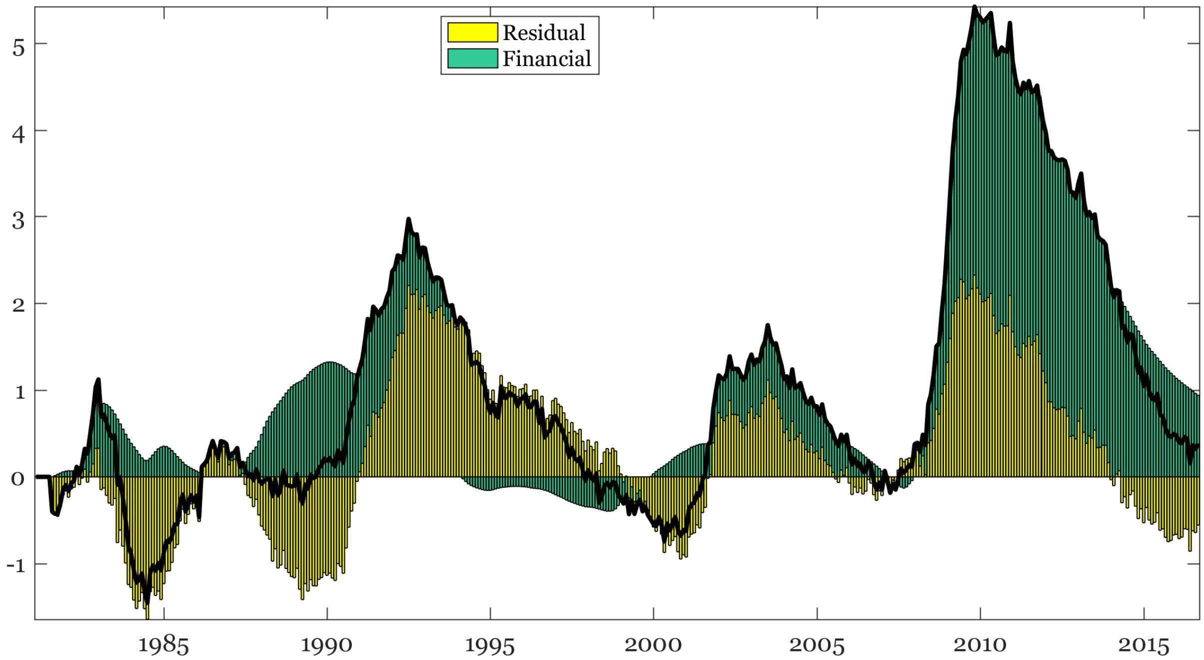

Figure 3.6: Unemployment historical decomposition (CVAR-SV, monthly specification).

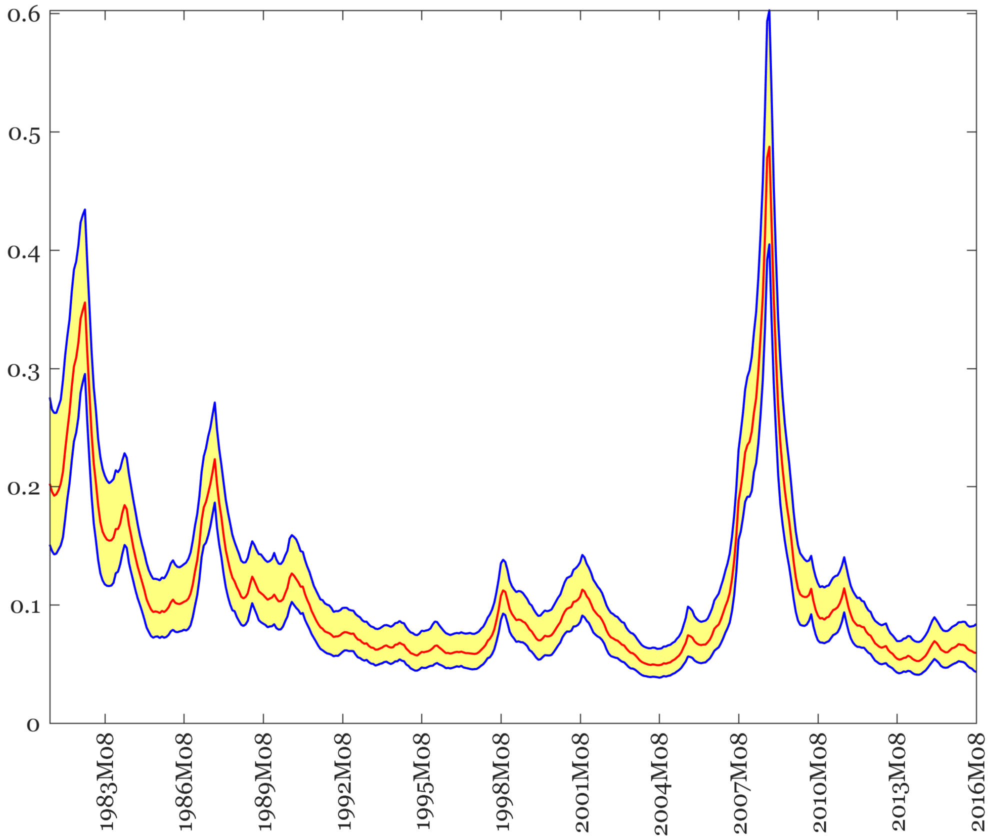

Figure 3.7: Stochastic volatility of the identified shock (monthly specification).

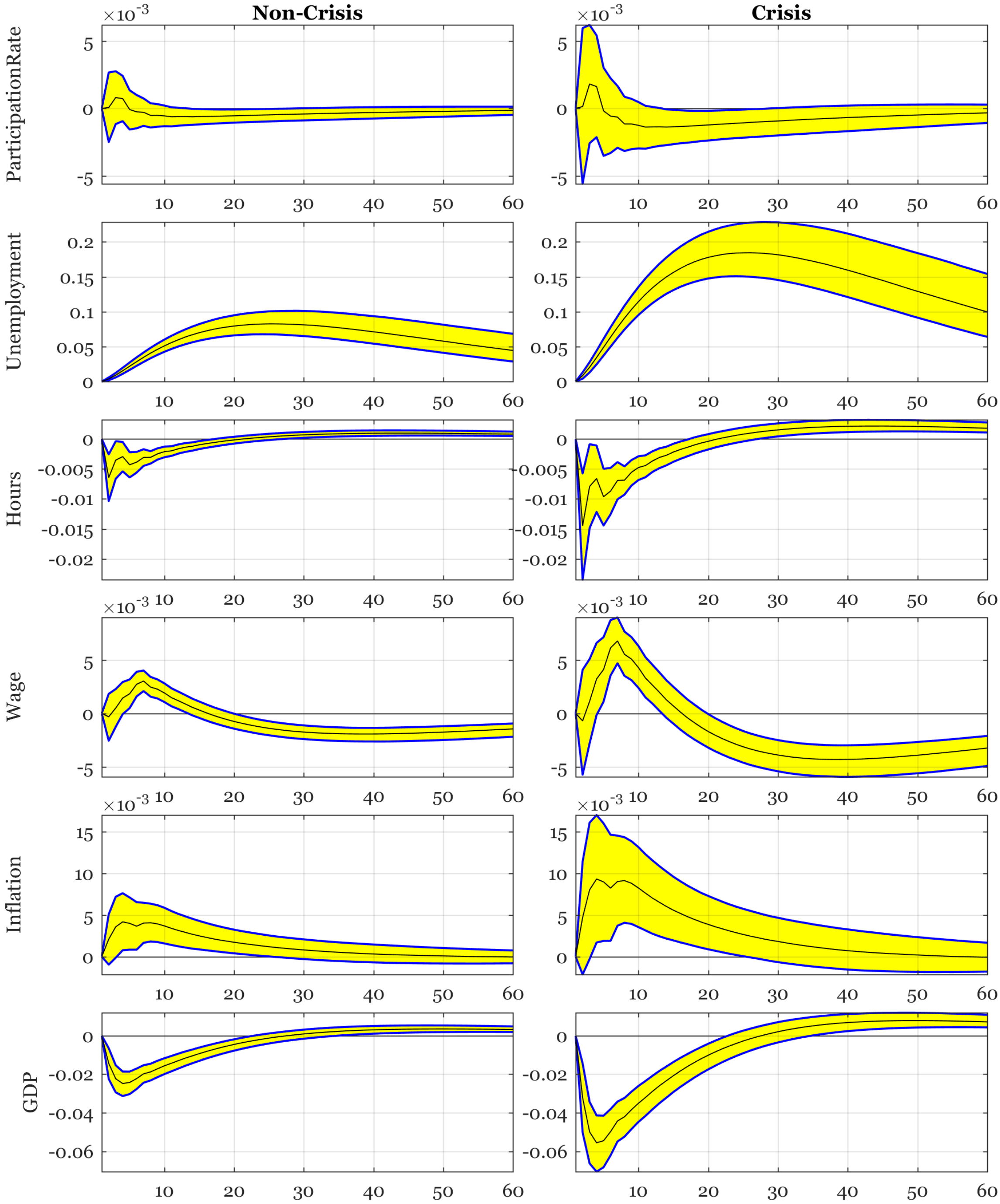

Figure 3.8: Impulse response functions (non-standardized, monthly specification).

3.7 Conclusions

In this paper we estimate a TV-VAR-SV in order to detect the effects of financial shocks on labor market variables, using the NFCI as financial indicator.

Differently from a CVAR framework, all the elements of a TV-VAR-SV are potentially time-varying: our findings report a relevant degree of time variation in the estimated financial shock's standard deviation, which is high in correspondence of periods of financial distress and low during the Great Moderation. However, our model does not find significant time variation in the transmission mechanism, since the estimated autoregressive coefficients are highly stable over time.

We show that positive financial shocks have been almost irrelevant in explaining unemployment fluctuations in the last three decades, while negative shocks have given a remarkable contribution. This result relies on the changing size of financial shocks, which is high during periods of financial turbulence, such as the Great Recession. This feature cannot be captured by a CVAR, which indeed finds both positive and negative contributions of financial shocks on the unemployment rate, in our estimation horizon.

In addition, we show that estimated response signs to an adverse financial impulse, identified with a short-run restriction, are reasonable and in line with the theoretical literature. A financial tightening generates a crisis in the labor market: firms reduce unemployment and per-capita hours worked to face the reduction in borrowing ability; they post less vacancies, so that resulting lower labor demand produces a fall in nominal wages; some unemployed workers get discouraged and the labor participation rate decreases; the response of real GDP is negative as well, due to a drop in labor input and a smaller demand of households, who become poorer. The response of inflation is positive but only borderline significant, reflecting both supply and demand effects at work.

From a policy perspective, our findings point out that macroprudential measures limiting the probability of a financial crisis may yield significant benefits to the economic activity via the labor market channel. Nonetheless, our model can not say anything about the effectiveness of these policies in reducing the standard deviation of financial shocks: thus, including a macroprudential indicator in macro-financial VARs with stochastic volatility seems an additional promising avenue to extend this line of research.

Appendix

3.A Additional Figures

3.A.1 Baseline Specification

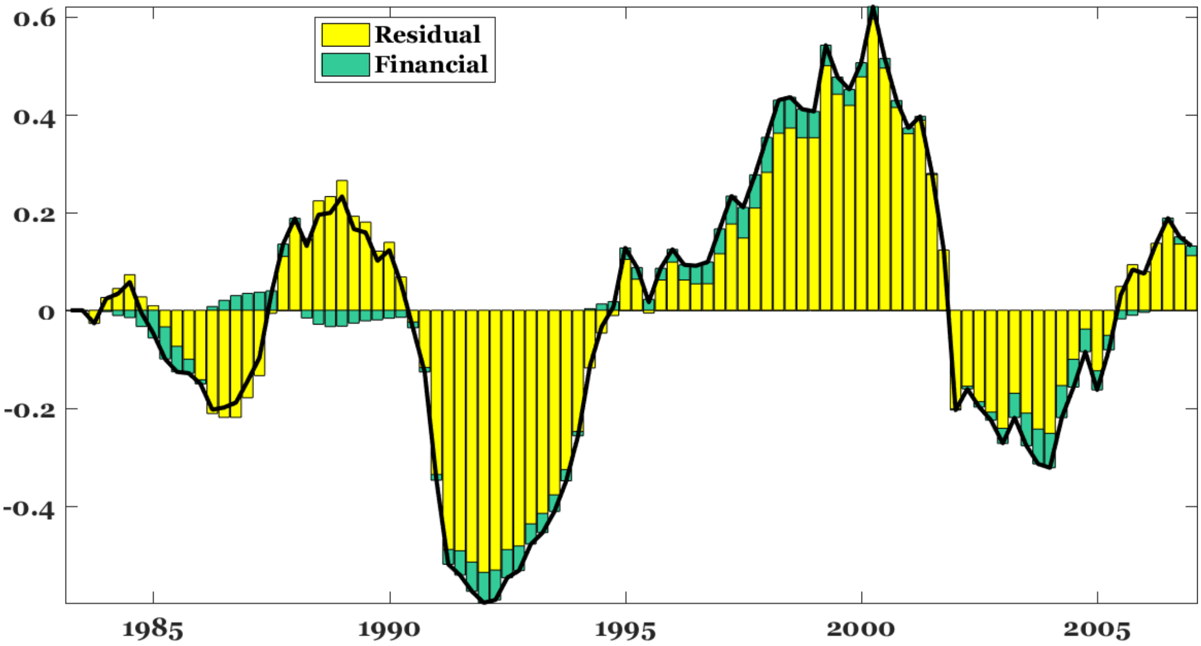

Figure A.1: CVAR historical decomposition of vacancy rate, sample 1983Q1-2006Q4.

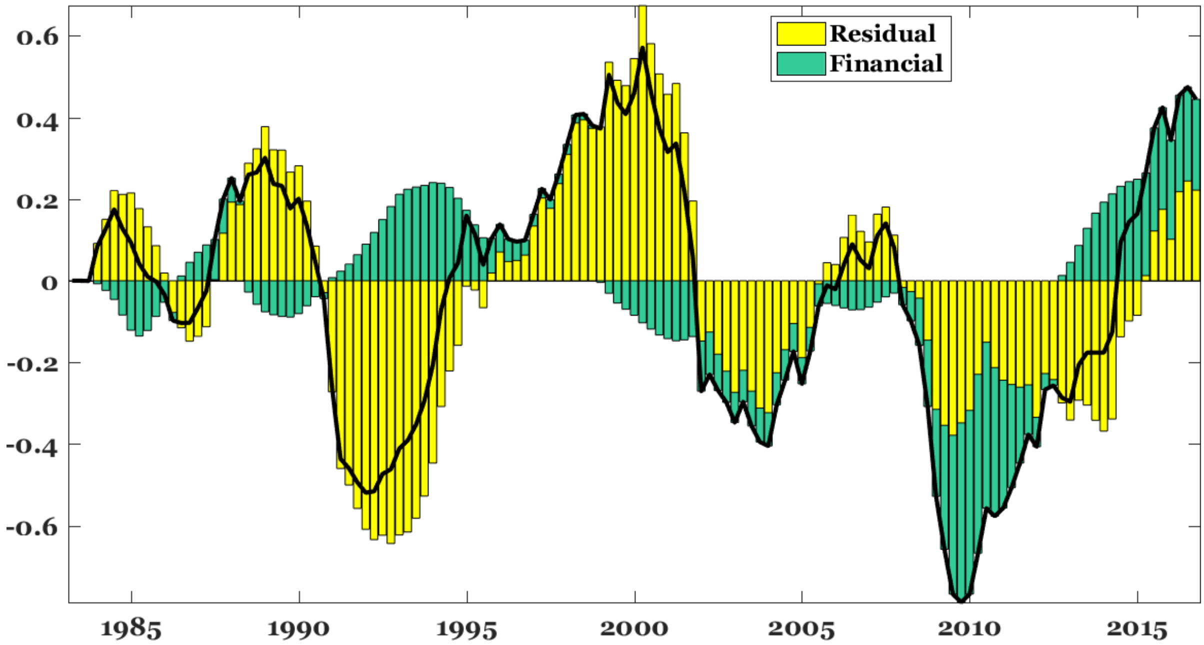

Figure A.2: CVAR historical decomposition of vacancy rate, sample 1983Q1-2016Q3.

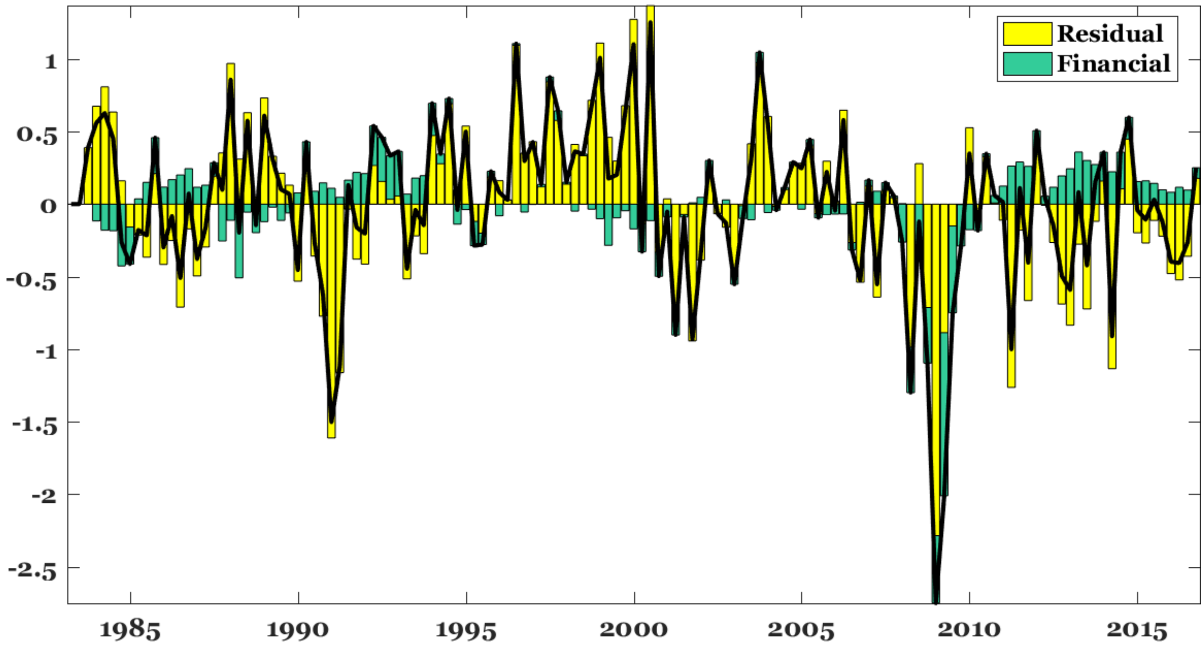

Figure A.3: Historical Decomposition of GDP (CVAR).

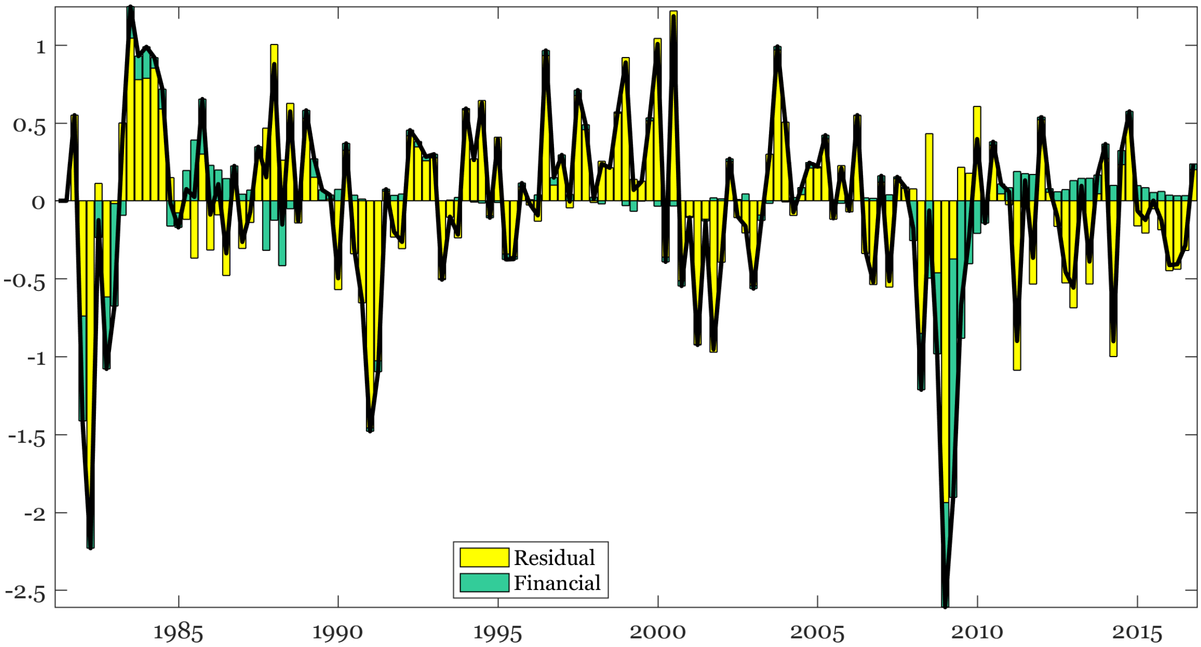

Figure A.4: Historical Decomposition of GDP (TV-VAR-SV).

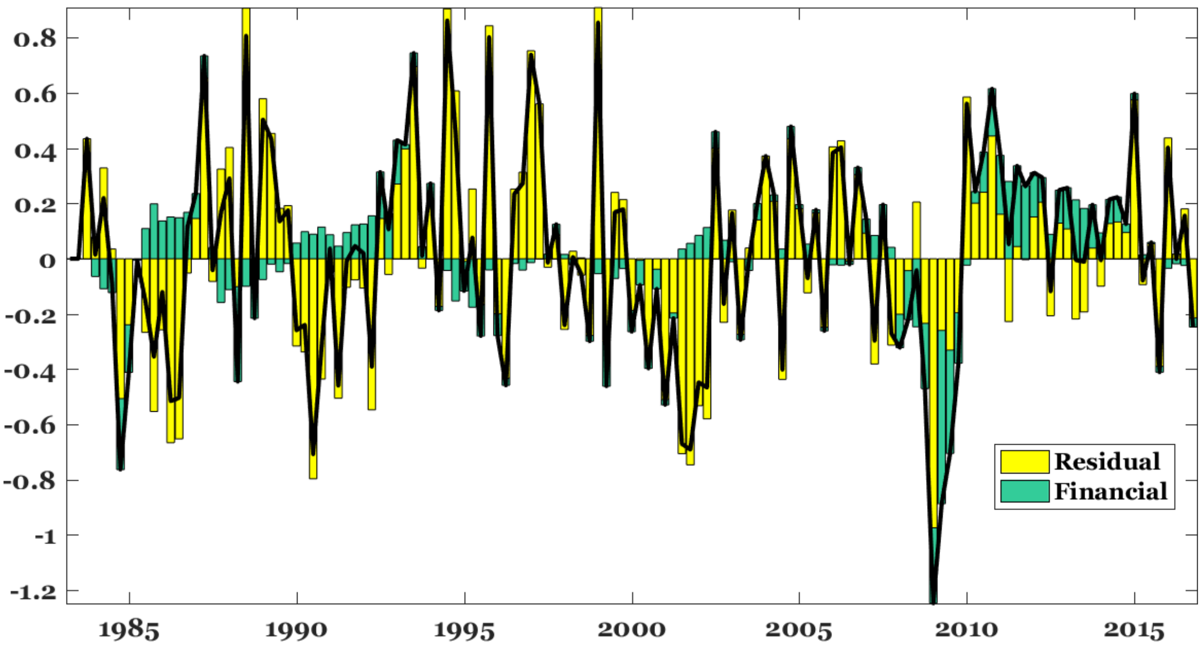

Figure A.5: Historical Decomposition of hours (CVAR).

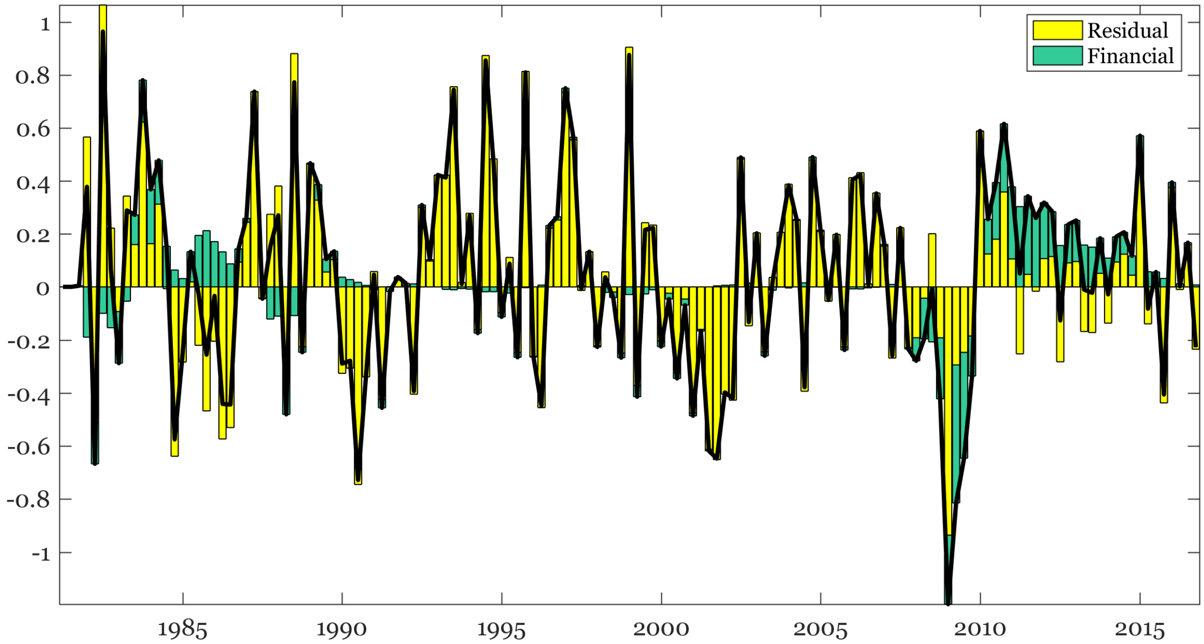

Figure A.6: Historical Decomposition of hours (TV-VAR-SV).

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