LIETUVOS BANKAS
EUROSISTEMA

THE MACROECONOMICS OF CARRY TRADE GONE WRONG: CORPORATE AND CONSUMER LOSSES IN EMERGING EUROPE

Working Paper Series

No 89 / 2021

ISSN 2029-0446 (online)

Working Paper Series
No 89 / 2021

THE MACROECONOMICS OF CARRY TRADE GONE WRONG: CORPORATE AND CONSUMER LOSSES IN EMERGING EUROPE

Eglė Jakučionytė[†]

Sweder van Wijnbergen[‡]

[†] Bank of Lithuania and Vilnius University, Lithuania. Email address: ejakucionyte@lb.lt.

[‡] Tinbergen Institute, CEPR and the University of Amsterdam, the Netherlands.

Gedimino pr. 6, LT-01103 Vilnius

www.lb.lt

Working papers describe research in progress by the author(s) and are published to stimulate discussion and critical comments.

The series is managed by the Applied Macroeconomic Research Division of the Economics Department and the Center for Excellence in Finance and Economic Research.

All papers in the series are refereed by internal and external experts.

ABSTRACT

This paper analyzes the macroeconomic consequences of foreign currency losses by banks, corporates and consumers in order to find whether some allocations of losses are better from a macroeconomic perspective than others. To that end, we construct a New Keynesian DSGE model with debt overhang for corporate borrowers, monitoring costs for household mortgage debt and leverage constraints for banks. The Hungarian experience at the end of 2008 and model estimation on Hungarian data motivate these financial frictions. Model simulation shows that making corporate borrowers bear currency risk results in worse macroeconomic outcomes than shifting currency mismatch losses to banks. Foreign currency mortgages to households, however, generate lower output than currency mismatch in the banking sector. The fact that households do not suffer from debt overhang, among other reasons, is driving this result.

Keywords: Currency mismatch, household debt, corporate debt, leveraged banks, small open economy, Bayesian estimation

JEL Classification: E44, G21, F41, P2.

1 Introduction

Currency mismatches (foreign currency liabilities in excess of foreign currency assets) make borrowers vulnerable to unexpected currency depreciation. Often borrowers face currency mismatch because lenders prefer to avoid exchange rate risk themselves.[1] However, shifting currency mismatch losses is not without costs for everyone involved in these debt contracts. For instance, although banks can decrease currency mismatch on their balance sheets by lending in foreign currency, this increases credit risk for the lending banks when carry trade goes wrong. This paper focuses on foreign currency carry trades gone wrong for households and firms. The paper distinguishes between corporate currency mismatch losses and household currency mismatch losses and asks whether shifting currency mismatch losses from households or firms to banks can lead to better macroeconomic outcomes.

The trade-off between currency mismatch for borrowers and currency mismatch for banks came to the fore in Emerging Europe when some local currencies depreciated by more than 30 percent in the beginning of 2009. In this way, a loss of investors' confidence in local currencies transmitted the financial crisis to this region. A prominent example is Hungary. Like in many other Emerging European countries Hungarian households and firms had extensively engaged in currency carry trade since 2002. When the Hungarian forint depreciated by more than 30 percent in 2009, the ratio of non-performing foreign currency loans soared. The Hungarian government responded by reversing the currency mismatch losses: it proposed a foreign currency mortgage repayment scheme that shifted currency mismatch losses from vulnerable household borrowers to banks.

The Hungarian consumer mortgage bailout after extensive currency mismatch losses by mortgage holders may have had many reasons, ranging from macroeconomic considerations to successful lobbying campaigns by consumers. In this paper we focus on the macroeconomic rationale for the bailout policies chosen. Although banks in Emerging Europe were not highly leveraged and did not engage in the sort of risky financial activities that triggered meltdowns in the US and Western Europe, the Great Recession in Emerging Europe was particularly deep and currency mismatch losses played an important role.

Currency mismatch losses varied across different countries, not only by size of accumulated foreign currency debt but also by borrower type. But most countries had high shares of foreign currency mortgages (IMF (2009), p. 21). In December 2008 Hungarian households and businesses had more than 60 percent of total credit denominated in foreign currency. In Poland foreign currency debt was mostly concentrated in the household sector and amounted to 40 percent of total household credit. Low incidence of corporate foreign currency debt obviously explains why bailing out corporates after currency mismatch losses or

[1] Basso et al. (2011) and Brown et al. (2010) report evidence that foreign owned banks in particular tend to issue foreign currency loans in Emerging Europe.

bailing in their bank lenders was not considered. But given the wide dispersion of incidence of currency mismatch losses and the differences in policies chosen in different countries, a comprehensive analysis of the macroeconomic impact of various bailout/bailin policies is surely called for. What are the macroeconomic consequences of bailing out consumers and/or corporates? How do they compare if instead their bank lenders are bailed in by shifting losses to them?

Before sketching the model setup, we should outline what we do not do. We explicitly confine ourselves to a macroeconomic *ex post* analysis of how to deal with the debt overhang that arises after carry trades have gone wrong, that is once the debt overhang has emerged after a collapse of the currency in the presence of extensive foreign currency denominated debt. Why the various actors in the country took on that exposure *ex ante* is not a question we try to answer here, whether that decision stems from myopia, legitimate hedging behavior, gambling on carry trade in the hope to get out before an eventual crash, or as a consequence of what Gennaioli et al. (2012) call "neglected risks". As such our paper is more a counterfactual exercise aimed at understanding the transmission channels and mechanisms through which currency losses by different agents in the economy and the way they are allocated affect macroeconomic performance.

We build and calibrate/estimate a New Keynesian DSGE model of a small open economy where firms, households and leveraged banks borrow in foreign currency, creating several potential currency mismatches. The paper uses the Hungarian recession in 2009 as a target environment. We estimate the model on Hungarian data for 2005:Q1-2016:Q4 and first test the relevance of the debt overhang friction. We incorporate debt overhang applying a variant of Merton's risk pricing model in Merton (1974) with predetermined debt as in Myers (1977) and compare that model setup to one that assumes costly state verification friction like in Bernanke et al. (1999). The model fits the data better with the (corporate) debt overhang structure. Occhino and Pescatori (2015) shows that debt overhang amplifies aggregate fluctuations more than the monitoring costs friction in Bernanke et al. (1999). Introducing household debt improves the model fit further, suggesting a large role of household debt in explaining aggregate fluctuations in Hungary.

We then take the model with corporate debt overhang, household debt and leveraged banks and construct different scenarios as to which sector is facing currency mismatch and compare aggregate outcomes after unexpected currency depreciation. Model simulation shows that shifting currency mismatch losses to banks has different implications dependent on whether households or production firms borrow in foreign currency. Our findings confirm potential gains from shifting currency mismatch losses from firms to banks. Domestic currency loans reduce corporate default risk so that incentives to invest become less distorted and boost economic activity. The boost is sufficient to counteract the fall in credit supply which stems from banks absorbing the currency mismatch losses.

Household currency mismatch losses, however, appear to have relatively small effects on output. If only household borrowers faced currency mismatch, shifting currency mismatch losses from banks to household borrowers leads to better macroeconomic outcomes, despite the elevated credit risk because of foreign currency mortgages and larger borrowers' consumption losses after unexpected depreciation. We explore several potential explanations for why shifting corporate losses to banks improves macroeconomic outcomes but shifting household losses to banks does not seem to lead to better (macroeconomic) outcomes.

The structure of the paper is as follows. Section 2 presents related literature. We discuss the model in detail in section 3, and describe model parametrization, data and Bayesian estimation results in section 4. The discussion of the loss allocation problem is in section 5. Section 6 concludes.

2 Related literature

This paper is at the intersection of several strands of literature. First, we use Myers' seminal model of corporate debt overhang (Myers, 1977). Second, there is a wide literature on the macroeconomic effects of liability dollarization as part of a more general open economy analysis of the impact of devaluations (see for an early discussion van Wijnbergen (1986)). Third, our paper relates to the household default literature and especially papers that analyzed household default from a business cycles perspective.

The idea that overindebted firms reject investment opportunities with positive net present values goes back to Myers (1977). There are a few studies that provide different reasons for why renegotiation fails, for instance, Jensen and Meckling (1976), Hart and Moore (1995) and Bhattacharya and Faure-Grimaud (2001). In our paper we assume that renegotiation fails to take place too, a necessary condition for debt overhang to persist, but we do not specify the reason behind the renegotiation failure, we are interested in its *ex post* consequences.

There a few macroeconomic studies analyzing the interactions of debt overhang in different sectors of the economy. Lamont (1995) shows how self-fulfilling pessimistic expectations of individual investors can create multiple equilibria if levels of debt are high. Philippon (2010) also finds multiple equilibria but as a consequence of debt overhang in households and banks. Moreover, he finds that bailing out households is inefficient, in contrast to bailing out out banks. This finding relies on the assumption that households own the banks. The gains from a bank bailout are then canceled by the higher taxes needed to finance the bailout.

Several studies analyze the interaction between debt overhang and inflation. Examples are Gomes et al. (2016) and Occhino and Pescatori (2014) who argue that unanticipated deflation worsens debt overhang for corporate borrowers and that monetary policy in the presence of debt overhang should therefore aim at increasing inflation. However, neither of these studies look at currency depreciation as a source of debt overhang through the magnification of the local currency value of foreign currency debt.

This latter effect has been looked at in the macroeconomic literature on devaluations. Céspedes et al. (2004), Devereux et al. (2006) and Gertler et al. (2007) include dollarized external debt but argue that depreciations increase output even in the presence of sizable foreign currency debt. van Wijnbergen (1986) and Cook (2004) arrive at the opposite conclusion because of a variety of channels, some affecting aggregate supply negatively in addition to the negative wealth effects of a devaluation in the presence of dollar debt. None of these authors explicitly model (corporate) debt overhang and its relevance for the macro-impact of devaluations in the presence of corporate dollar debt.

Household mortgage default has been a focus in the incomplete markets literature[2]. Although these studies shed light on the role of household debt in the presence of aggregate risk, they typically assume a closed economy framework precluding an analysis of exchange rate devaluations and its potential debt overhang consequences. Therefore, our approach to modeling household default comes the closest to a real business cycles model with household default in Clerc et al. (2015). In Clerc et al. (2015) household default is inefficient because of monitoring costs as in Bernanke et al. (1999). The setup also requires a high degree of consumption risk sharing to facilitate aggregation of household net worth and track aggregate net worth over time. In contrast to Clerc et al. (2015), we assume different financial frictions for other participants of the credit market, firms and banks, but use the same financial friction for households as Clerc et al. (2015). The rest of the literature that analyzes the role of housing over a business cycle follows the tradition of Iacoviello (2005) and assumes household borrowing constraints. Although we do not use borrowing constraints, we borrow the idea of two types of households in order to accommodate household borrowing and saving in the equilibrium from Iacoviello (2005).

3 Model

The model is at the core a standard New Keynesian DSGE model, with non-financial firms, banks, a government and two types of households: patient and impatient households. We introduce several sources of financial frictions in the model. Household debt prices in the possibility of default. To model the default premium, we introduce a monitoring costs friction like in Bernanke et al. (1999), because of the lack of empirical evidence for household debt overhang in Emerging Europe. However due to large and persistent investment losses in Emerging Europe, corporate borrowers did face an implicit debt overhang tax on

[2]This literature largely focuses on government policies for housing markets (Jeske et al., 2013) or on the macroeconomic impact of foreclosure (Chatterjee and Eyigungor, 2015, Corbae and Quintin, 2015, Garriga and Schlagenhauf, 2009). Nakajima and Rıos-Rull (2005) examine the effect of bankruptcy on amplifying aggregate shocks. Gordon (2015) evaluates the consequences of eliminating or restricting default in the presence and finds that aggregate risk substantially reduces welfare gains from eliminating default.

investment as in Myers (1977) (for a similar application within a DSGE model cf Occhino and Pescatori (2015)). Finally we introduce bank leverage constraints as in Gertler and Karadi (2011). Before turning to the model description, we briefly survey the evidence on financial frictions in Eastern Europe, to motivate the way we have introduced financial frictions in the model.

3.1 Empirical evidence on financial frictions in Emerging Europe

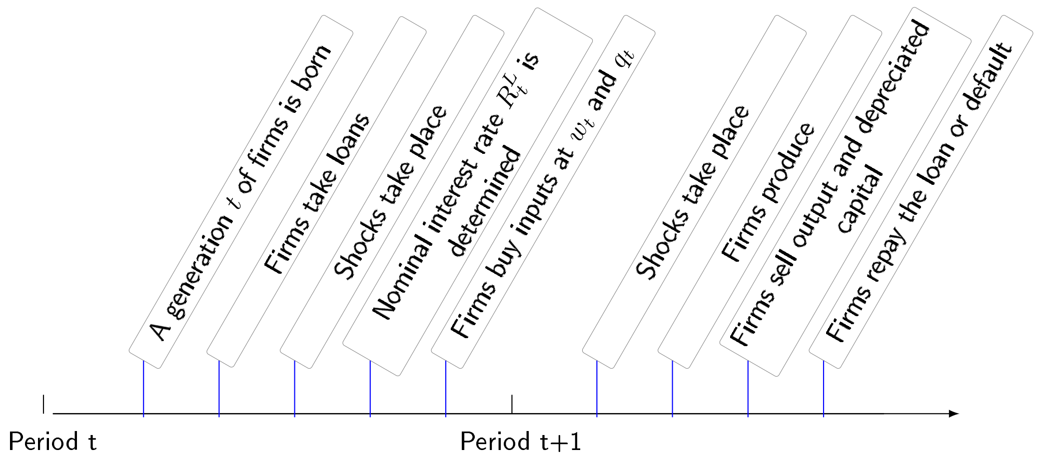
Sluggish investment recovery in Emerging Europe raised the question of debt overhang in the corporate sector. When, at the end of 2008, the Hungarian forint lost more than 30 percent of its value against the euro and the Swiss franc, this suddenly magnified the corporate debt burden with implications for firms' performance at both the micro and macro levels[3]. Moreover, Endrész et al. (2012) and Bodnár (2012) argue that firms in Hungary largely did not have access to natural hedges, which left them exposed to exchange rate risk once they had made the choice to borrow in foreign currency. Default rates rose. Vonnák (2018) shows that foreign currency denomination worsen loan performance in Hungary considerably, although other factors such as self-selection of low quality firms matter as well. Direct empirical evidence in favor of corporate debt overhang in Emerging Europe is scarce, but Kalemli-Özcan et al. (2018) provides evidence in favor corporate debt overhang in the core and periphery countries in Europe after the Lehman crisis.

Brown and Lane (2011) presents evidence against debt overhang in the household sector; we therefore chose a different type of financial friction for households. The external finance premium for household mortgages in this model occurs because of a costly state verification problem as in Bernanke et al. (1999). The default premium in this setup is positively related to household leverage.

Bank losses can impair credit provision if bank funding costs depend on bank performance. The banking system in Hungary was well-capitalized in 2008 (IMF, 2008), however liquidity shocks at the outbreak of the crisis affected bank funding costs Bakker and Klingen (2012). The sudden dry-up of foreign funding caused a tightening of leverage constraints. To capture this channel, we introduce market-value bank leverage constraints. We model it as an agency problem between banks and depositors following Gertler and Karadi (2011). Lower bank equity increases the moral hazard problem and bank funding costs which translates into lower bank credit supply. Empirical evidence in favor of currency mismatch driving changes in credit supply in Emerging Europe is reported in Fidrmuc and Kapounek (2020). Also, foreign banks that relied more on foreign funds than domestic banks responded to currency depreciation by cutting lending more than domestic banks.

[3]For a longer overview of the evidence on financial distress of Hungarian firms that borrowed in euros or Swiss francs and whether that could have had macroeconomic implications, see Jakucionyte and van Wijnbergen (2017).

Figure 1: Timing for financially constrained firms.



3.2 Financially constrained firms

We model several types of firms in the domestic economy. It takes five types of firms to produce domestic aggregate inputs for composite goods. First, capital producers invest to replenish depreciated capital. Second, there are the financially constrained firms that combine capital with labor to produce homogeneous goods. Third, the outputs of financially constrained firms are bought by retail firms that costlessly differentiate purchased goods and sell them as (local) monopolists, in Dixit-Stiglitz (1977) fashion. A similar group of firms called importers differentiate foreign (imported) goods. Fourth, a composite goods producer buys the differentiated home goods and aggregates them into an aggregate domestic good y_t^H with associated price p_t^H. The same composite goods producer also buys imported differentiated goods and aggregates them into a foreign aggregate good y_t^F. The corresponding aggregate price level of foreign goods is p_t^F. Finally there are two different aggregation technologies, one for consumption composite goods and another for investment composite goods. Each of them aggregates domestic aggregate goods with foreign aggregate goods to produce composite goods. Since the modeling of most of the layers of the production sector is standard, we only discuss financially constrained firms here and leave the rest for Appendix D.

To introduce debt overhang in the model, we assume that financially constrained firms cannot commit to their promised scale of output, use of factors of production or to specific promised investment levels, like in Myers (1977). Appendix C provides the detailed transformation of nominal variables to real variables and the solution to firm's optimization problem. Below we sketch the solution and the resulting model equations.

Financially constrained firms live for two periods. Every period there is a new-born generation of firms and the total number of firms always constitute a continuum of mass one. Figure 1 depicts the timing of decisions for a generation of firms born in period t. In the first period of their lives firms buy two types of inputs, capital k and labor n, and have to pay for it in advance, which generates a demand for working capital. Production takes place in the second period. To cover its working capital needs, a firm i born in period t borrows from the bank an amount $l_{i,t}$ that consists of both domestic currency funds $l^D_{i,t}$ and foreign currency denominated funds $l^F_{i,t}$ such that $l_{i,t} = l^D_{i,t} + rer_t l^F_{i,t}$, where rer_t is the real exchange rate. We assume that the share of foreign currency denominated funds is fixed and denoted by α^{FF}.

We assume that the firm decides how much to borrow before shocks hit and the prices of production inputs are revealed. The size of the loan is equal to the expected need for working capital to cover their inputs: $E_{t-1}\{l_{i,t}\} = E_{t-1}\{q_t k_{i,t} + w_t n_{i,t}\}$. q_t and w_t denote the real price of capital and the real wage respectively. After the loan is taken, shocks materialize. This may create debt overhang since the loan has already been taken out. The debt overhang in turn distorts the firm's incentives to invest in production inputs. The actual demand for working capital by the firm will generally not equal the loan amount received. We assume that in such cases households step in and transfer lump-sum funds $n^F_{i,t}$ to cover the difference as additional equity (a negative equity transfer would proxy for dividend payout).

Let the matured loan in units of composite goods be $R^L_{i,t}\left(\frac{l^D_{i,t}}{\pi_{t+1}} + rer_{t+1}\frac{l^F_{i,t}}{\pi^*_{t+1}}\right)$, where $R^L_{i,t}$ is the nominal gross interest rate on the loan. The bank sets interest rates on loans after the shocks take place, the loan rate adjusts to clear the loan market. The firm has to pledge a share κ of future revenue as collateral where $0 < \kappa \leq 1$. Then the contracted collateral is a fraction κ of firms' revenue from selling goods and depreciated capital in the next period, $p^L_{t+1}y^L_{i,t+1} + q_{t+1}(1-\delta)k_{i,t}$. p^L_{t+1} stands for the price of homogeneous goods, expressed in units of composite goods. The firm defaults when the collateral value falls below its interest inclusive loan repayment obligations, that is when

$$R^L_{i,t}\left(\frac{l^D_{i,t}}{\pi_{t+1}} + rer_{t+1}\frac{l^F_{i,t}}{\pi^*_{t+1}}\right) > \quad \kappa(p^L_{t+1}y^L_{i,t+1} + q_{t+1}(1-\delta)k_{i,t}) \tag{1}$$

So in the profit function of the firm the loan appears at face value plus a put option with the collateral as strike price.

The firm produces using the technology $y^L_{i,t+1} = z_{t+1}\theta_{i,t+1}k^\alpha_{i,t}\left(A_{t+1}n_{i,t}\right)^{1-\alpha}$ where z_{t+1} is a stationary aggregate technology shock, A_{t+1} is a non-stationary aggregate technology shock and $\theta_{i,t+1}$ is a stationary idiosyncratic technology shock.

Firm i born in period t maximizes profits taking the loan as given. Since firms are owned by patient households, we use the households' stochastic discount factor $\Lambda^P_{t,t+1}$ to discount future profits. The firm maximizes expected profits minus the equity transfer received in the first period, where expected profits are given by the expected sum of future revenue from selling goods and depreciated capital minus the debt it still needs to repay. Given that $n^F_{i,t} = q_t k_{i,t} + w_t n_{i,t} - l_{i,t}$, the maximization problem can be written as:

$$
\begin{aligned}
\max_{\{k_{i,t},n_{i,t}\}} & E_t\beta^P\Lambda^P_{t,t+1}\left\{p^L_{t+1}y^L_{i,t+1}+q_{t+1}(1-\delta)k_{i,t}\right\} \\
& - E_t\beta^P\Lambda^P_{t,t+1}\min\left\{R^L_{i,t}\left(\frac{l^D_{i,t}}{\pi_{t+1}}+rer_{t+1}\frac{l^F_{i,t}}{\pi^*_{t+1}}\right), \quad \kappa\left(p^L_{t+1}y^L_{i,t+1}+q_{t+1}(1-\delta)k_{i,t}\right)\right\} \\
& + l_{i,t}-(q_tk_{i,t}+w_tn_{i,t})
\end{aligned}
$$

s.t.

$$
E_{t-1}\left\{l_{i,t}\right\}=E_{t-1}\left\{q_tk_{i,t}+w_tn_{i,t}\right\}
$$

The first-order condition for capital reveals debt overhang implications for firm's choice to invest in capital. The first-order condition for labor has an analogous mechanism for labor demand, so we leave it for the Appendix. The first-order condition for capital presents the marginal cost of buying one more unit of capital (the left hand side) and the expected marginal benefit of using one more unit of capital in production (the right hand side):

$$
\begin{aligned}
q_t =& E_t\beta^P\Lambda^P_{t,t+1}\left\{p^L_{t+1}\frac{\partial y^L_{i,t+1}}{\partial k_{i,t}}+q_{t+1}(1-\delta)\right\} \\
& -\frac{\partial E_t\beta^P\Lambda^P_{t,t+1}\min\left\{R^L_{i,t}\left(\frac{l^D_{i,t}}{\pi_{t+1}}+rer_{t+1}\frac{l^F_{i,t}}{\pi^*_{t+1}}\right), \quad \kappa\left(p^L_{t+1}y^L_{i,t+1}+q_{t+1}(1-\delta)k_{i,t}\right)\right\}}{\partial k_{i,t}}
\end{aligned} \tag{2}
$$

The third term in equation (2) occurs because of the debt overhang friction. With this term, expected benefits from buying more capital are lower, because in case of default the firm shares the benefits with the bank. We further derive and present the final first-order conditions in C.1-C.2. The final conditions explicitly incorporate the default probability in otherwise standard demand functions for capital and labor. The default probability defined as $1-\Phi(d_{1,t})$ drives a wedge between the social and private benefits from investing. When the default probability increases, private benefits diminish and demand for labor and capital shrinks. Under-investment in working capital has negative and prolonged implications on aggregate variables, because lower investment today means less capital tomorrow.

The second implication of the first-order conditions relates to the option structure already referred to (the lender's short position in an implicit put option). The default probability directly depends on a volatility term $\sigma^2_{F,t}$ which captures the variance of future profits.

3.3 Banks

Banks are subject to an agency problem as in Gertler and Karadi (2011). At the end of every period, bankers can divert a fraction λ_t^B of assets, but if that happens the bank goes bankrupt.[4] Creditors take this possibility into account and lend only up to the point where the continuation value of the bank is equal to or higher than the value of what can be diverted. This condition acts as an incentive constraint for the bank and limits expansion of the balance sheet of the bank for a given amount of equity.

Domestic households own all banks that operate in the domestic economy and lend to financially constrained domestic firms. We assume that there is a continuum of these banks and every period there is a probability ω^B that a bank continues operating. If the bank does not continue, its remaining net worth is transferred to the owners of the bank, domestic households. We assume that banks give loans to firms and households out of accumulated equity n_t^B, domestic deposits d_t and foreign bank debt d_t^*.

A fraction of banks' foreign debt is denominated in foreign currency which exposes banks to currency mismatch. Lending in foreign currency would hedge the open currency position for banks, however, shifting exchange rate risk to borrowers increases the credit risk for banks. We consider two lending scenarios which have different implications for bank currency mismatch. First, banks lend in domestic currency only which creates currency mismatch on their balance sheets. The second scenario assumes that banks lend in both foreign and domestic currency. The model with loans denominated in both currencies is described here, while the model with lending in domestic currency only is described in Appendix F.2.

The balance sheet constraint of bank j, expressed in units of composite goods, is given by

$$n_{j,t}^B + d_{j,t} + rer_t d_{j,t}^* = l_{j,t} + m_{j,t}$$

Banks pay a nominal domestic interest rate R_t on deposits and a nominal foreign interest rate $R_t^* \xi_t$ on foreign debt. R_t^* follows a stationary AR(1) process. ξ_t denotes a premium on bank foreign debt. To ensure stationarity in the model, we assume that the premium depends on the level of foreign bank debt as in Schmitt-Grohé and Uribe (2003):

$$\xi_t = \exp\left(\kappa_\xi \frac{(rer_t d_t^* A_{t-1} - rer \cdot d^*)}{rer \cdot d^*} + \frac{\zeta_t - \zeta}{\zeta}\right),$$

where ζ_t is an exogenous shock that follows a stable AR(1) process.

Corporate loan performance directly affects bank profits. When the default probability $(1 - \Phi(d_{1,t}))$ for financially constrained firms increases, banks expect lower returns. High corporate leverage has similar consequences because it increases the size of loans for the same level of production and reduces firms'

[4] λ_t^B is an exogenous variable that can be affected by a stationary autoregressive process.

chances to repay. We define the expected return for the bank j as $\tilde{R}^L_{j,t}$. The definition makes use of the derivation of the expected loan payment (see Appendix C.2) and in its final expression directly incorporates the default probability on corporate loans:

$$E_t\left\{\frac{\tilde{R}^L_{j,t}}{\pi_{t+1}} l_{j,t}\right\} \equiv E_t \min\left\{R^L_{j,t}\left(\frac{l^D_{j,t}}{\pi_{t+1}} + rer_{t+1}\frac{l^F_{j,t}}{\pi^*_{t+1}}\right), \quad \kappa\left(p^L_{t+1} y^L_{j,t+1} + q_{t+1}(1-\delta)k_{j,t}\right)\right\}$$

$$\begin{aligned}\Rightarrow E_t\left\{\frac{\tilde{R}^L_{j,t}}{\pi_{t+1}} l_{j,t}\right\} \equiv E_t\Bigg\{&(1-\Phi(d_{1,t}))\,\kappa\left(p^L_{t+1} y^L_{j,t+1} + (1-\delta)q_{t+1}k_{j,t}\right) + \Phi(d_{2,t})R^L_{j,t}\frac{l^D_{j,t}}{\pi_{t+1}} \\ &+\Phi(d_{1,t})R^L_{j,t} rer_{t+1}\frac{l^F_{j,t}}{\pi^*_{t+1}}\Bigg\}\end{aligned}$$

In the impatient households section we will derive equation (8) to express the expected return on mortgages $\tilde{R}^M_{j,t}$. Given $\tilde{R}^L_{j,t}$ and $\tilde{R}^M_{j,t}$, we can define the optimization problem. The bank j we use the stochastic discount rate of patient households because they own the banks:

$$V_{j,t} = \max_{\left\{d_{j,t}, d^*_{j,t}, l_{j,t}, m_{j,t}\right\}} \quad E_t\left[\beta^P \Lambda^P_{t,t+1}\left\{(1-\omega^B)n^B_{j,t+1} + \omega^B V_{j,t+1}\right\}\right]$$

s.t.

$$V_{j,t} \geq \lambda^B_t \left(l_{j,t} + m_{j,t}\right), \qquad \textit{(Incentive constraint)}$$

$$n^B_{j,t} + d_{j,t} + rer_t d^*_{j,t} = l_{j,t} + m_{j,t}, \qquad \textit{(Balance sheet constraint)}$$

$$n^B_{j,t} = \frac{\tilde{R}^L_{j,t-1}}{\pi_t} l_{j,t-1} + \frac{\tilde{R}^M_{j,t-1}}{\pi_t} m_{j,t-1} - \frac{R_{t-1}}{\pi_t} d_{j,t-1} - \frac{R^*_{t-1}\xi_{t-1}}{\pi^*_t} rer_t d^*_{j,t-1} \qquad \textit{(LoM of net worth)}$$

The first-order conditions follow:

$$d_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1}\left\{(1-\omega^B) + \omega^B \nu_{2,t+1}\right\}\left(\frac{R_t}{\pi_{t+1}}\right) = \nu_{2,t} \tag{3}$$

$$d^*_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1}\left\{(1-\omega^B) + \omega^B \nu_{2,t+1}\right\}\left(\frac{R^*_t \xi_t}{\pi^*_{t+1}}\frac{rer_{t+1}}{rer_t}\right) = \nu_{2,t} \tag{4}$$

$$l_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1}\left\{(1-\omega^B) + \omega^B \nu_{2,t+1}\right\}\frac{\tilde{R}^L_{j,t}}{\pi_{t+1}} = \lambda^B_t \nu_{1,t} + \nu_{2,t} \tag{5}$$

$$m_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1} \left\{(1-\omega^B) + \omega^B \nu_{2,t+1}\right\} \frac{\tilde{R}^M_{j,t}}{\pi_{t+1}} = \lambda^B_t \nu_{1,t} + \nu_{2,t} \tag{6}$$

$\nu_{1,t}$ and $\nu_{2,t}$ are the Lagrangian multiplier to the incentive constraint and the Lagrangian multiplier to the balance sheet constraint combined with the law of motion for equity, respectively. The first-order conditions apply as do complementary slackness conditions.

Equations (3) and (4) cover the bank debt portfolio choice. Equation (3) presents the marginal cost to the bank from issuing one additional unit of deposits (the left hand side) in relation to the marginal benefit from increasing equity by one unit, $\nu_{2,t}$ (the right hand side). The marginal cost from issuing one additional unit of foreign bank debt is compared to the marginal benefit from increasing equity on the right hand side of equation (4) and is adjusted for changes in the exchange rate value. The structure of these choice rules implies that in equilibrium the bank is indifferent between taking deposits or issuing bank debt to foreign households.

Equations (5) and (6) link the marginal benefit to the bank from issuing one additional unit of loans (the left hand side) and the marginal cost (the right hand side). In equilibrium one additional unit of loans earns the discounted risk adjusted return on loans. This return has to increase in the marginal cost from issuing bank debt to finance the expansion of the balance sheet, $\nu_{2,t}$. Due to the endogenous bank leverage constraint, the risk adjusted bank return on loans increases in the share of divertable assets λ^B_t and the marginal loss to the bank creditor in the case of asset diversion, $\nu_{1,t}$. Both terms proxy for the marginal cost associated with the tighter incentive constraint. Moreover, the tighter leverage constraint increases the bank spread as well which translates into more credit tightening.

Like in Gertler and Karadi (2011) we assume that a fraction $(1-\omega^B)$ of banks exits every period and is replaced by the same number of new banks. New banks get an equity transfer households equal to $\iota^B n^B A_{t-1}$ to get started. Aggregate bank net worth evolves as:

$$n^B_t = \omega^B \left(\frac{\tilde{R}^L_{t-1}}{\pi_t} l_{t-1} + \frac{\tilde{R}^M_{t-1}}{\pi_t} m_{t-1} - \frac{R_{t-1}}{\pi_t} d_{t-1} - \frac{R^*_{t-1}\xi_{t-1}}{\pi^*_t} rer_t d^*_{t-1} \right) + \iota^B n^B A_{t-1} \tag{7}$$

3.4 Households

Simultaneous occurrence of household borrowing and household deposits requires household heterogeneity. We consider two types of households: impatient households with a higher discount factor than patient households. The latter save while impatient households borrow. Each dynasty has a continuum of measure-one members who are identical and differ only in idiosyncratic shocks ω_t *ex post*. If the *ex post* debt value exceeds the collateral value, impatient households default on their loans.

3.5 Patient households

Every member of the dynasty of patient households supplies labor of unique type which gives households monopolistic power in wage setting and allows us to introduce nominal rigidity for wages. First, we solve the dynasty's problem with respect to other choices the dynasty makes and later we elaborate on the monopolistic labor market and the modified first order condition for labor supply and wages.

In the beginning of each period the net worth of patient households is pooled resulting in complete intergenerational risk sharing. Given the pooled net worth, the patient dynasty chooses consumption c_t^P, housing stock h_t^P, and how much to save by putting deposits d_t and buying government bonds b_t such that her utility is maximized:

$$\max_{\{c_t^P, h_t^P, b_t, d_t\}} E_0 \sum_{t=0}^{\infty} \left(\beta^P\right)^t v_t \left(log\left(c_t^P\right) + A_h log\left(h_t^P\right) - A_n \frac{\left(n_t^P\right)^{1+\sigma_n}}{1+\sigma_n} \right),$$

where v_t is an exogenous preference shock. The dynasty maximizes utility subject to the budget constraint:

$$c_t^P + q_t^h \left(h_t^P - h_{t-1}^P\right) + b_t + d_t \leq w_t^P n_t^P + \frac{R_{t-1}}{\pi_t}\left(b_{t-1} + d_{t-1}\right) + \Pi_t$$

w_t^P is the real aggregate wage for patient households, q_t^h is the real housing price and n_t^P is labor demand. Π_t denotes profits from banks and all firms. This is an aggregate budget constraint, therefore, different labor types no do not show up separately, although it can be shown that an individual budget constraint leads to the aggregate budget constraint. In deriving optimal wages, we will focus on individual utility. Also, after deflating variables we get composite consumption goods inflation π_t. R_t denotes the domestic gross interest rate. First-order conditions follow:

$$c_t^P : \quad \lambda_t^P = v_t \frac{1}{c_t^P}$$

$$h_t^P : \quad v_t A_h \frac{1}{h_t^P} = \lambda_t^P q_t^h - \beta^P E_t \lambda_{t+1}^P q_{t+1}^h$$

$$b_t : \quad E_t \beta^P \frac{\lambda_{t+1}^P}{\lambda_t^P} \frac{R_t}{\pi_{t+1}} = 1$$

$$d_t : \quad E_t \beta^P \frac{\lambda_{t+1}^P}{\lambda_t^P} \frac{R_t}{\pi_{t+1}} = 1$$

λ_t^P is the Lagrange multiplier to the budget constraint, where $\Lambda_{t,t+1}^P \equiv \lambda_{t+1}^P / \lambda_t^P$.

Households set wages, however, only a share $(1 - \omega^W)$ of households will be allowed to adjust their wages in a given period. So households set wages by not only taking into account marginal disutility from work but also the probability of not being able to adjust wages in the future. This utility maximization problem described in section B.2 yields the optimal wage for patient households w_t^{P*} and the aggregate wage in period t that is w_t^P.

3.6 Impatient households

Impatient households borrow and can default on their mortgage debt, however, the dynasty of impatient households is not liable for the unpaid debt. In the beginning of every period the net worth of defaulted households is pooled with the net worth of non-defaulted households, leading to complete intergenerational consumption risk sharing. Given the pooled net worth, the dynasty maximizes utility of her members with respect to consumption c_t^I, housing stock h_t^I, mortgage size m_t and the optimal default threshold $\bar{\omega}_t$. The debt variables define the optimal debt contract as in Bernanke et al. (1999).

Household i uses its housing as collateral and finds it optimal to default if the collateral value is lower than the debt value. Given that a fixed fraction α^{FM} of the mortgage is in foreign currency, the household defaults if:

$$\omega_{i,t}\left(\zeta^h q_t^h h_{i,t-1}^I\right) \leq R_{t-1}^M\left(\frac{\alpha^{FM} rer_t}{\pi_t^*} + \frac{1-\alpha^{FM}}{\pi_t}\right) m_{i,t-1}$$

The left hand side of the inequality gives the value of the collateral, which is affected by the housing price q_t^h and an idiosyncratic shock ω_t. Parameter ζ^h is an exogenous loan-to-value ratio. The right hand side describes the value of debt. R_t^M is the nominal gross mortgage interest rate, rer_t denotes the real exchange rate and π_t and π_t^* denote consumer goods inflation in the domestic economy and the foreign inflation respectively. Exchange rate depreciation boosts the value of the household's debt and therefore has a positive effect on the default threshold, increasing the default rate.

The default threshold is given by the household-specific shock value ω_t such that:

$$\bar{\omega}_{i,t} \equiv \omega_{i,t} = \frac{R_{t-1}^M\left(\frac{\alpha^{FM} rer_t}{\pi_t^*} + \frac{1-\alpha^{FM}}{\pi_t}\right) m_{i,t-1}}{\zeta^h q_t^h h_{i,t-1}^I}$$

To derive the budget constraint of the dynasty, we define the fraction of defaulted impatient households as G_t and the fraction of housing seized by banks as Γ_t such that the bank on average gets $\Gamma_t \zeta^h q_{t+1}^h h_t^I$. We provide the definitions of G_t and Γ_t in Appendix B. Having introduced G_t and Γ_t, the budget constraint of the dynasty can be written as

$$c_t^I + q_t^h h_t^I \leq w_t^I n_t^I + (1-\zeta^h \Gamma_t) q_t^h h_{t-1}^I + m_t$$

The dynasty maximizes utility by choosing consumption, housing, level of mortgage debt and leverage subject to the budget constraint of the dynasty and banks' participation constraint. The latter ensures that housing attributed to the bank, net of monitoring costs, is in expectation equal to banks' expected return $E_t\tilde{R}_t^M$:

$$E_t\left[\left(\Gamma_{t+1}-\mu_H G_{t+1}\right)\zeta^h q_{t+1}^h h_t^I\right]=E_t\frac{\tilde{R}_t^M}{\pi_{t+1}}m_t \tag{8}$$

Parameter μ_H defines monitoring costs incurred by banks necessary to induce truth telling by borrowing households (as in Townsend (1979) and Bernanke et al. (1999)).

The maximization produces first-order conditions:

$$c_t^I: \quad \lambda_t^I=v_t\frac{1}{c_t^I}$$

$$h_t^I: \quad v_t A_h\frac{1}{h_t^I}=\lambda_t^I q_t^h-\beta^I E_t\lambda_{t+1}^I(1-\zeta^h\Gamma_{t+1})q_{t+1}^h-\Omega_t E_t\left(\Gamma_{t+1}-\mu_H G_{t+1}\right)\zeta^h q_{t+1}^h$$

$$\bar{\omega}_{t+1}: \quad \beta^I E_t\lambda_{t+1}^I\left(\Gamma_{t+1}\right)'\left(\zeta^h q_{t+1}^h h_t^I\right)=\Omega_t E_t\left(\left(\Gamma_{t+1}\right)'-\mu_H\left(G_{t+1}\right)'\right)\left(\zeta^h q_{t+1}^h h_t^I\right)$$

$$m_t: \quad \Omega_t E_t\frac{\tilde{R}_t^M}{\pi_{t+1}}=\lambda_t^I$$

The first-order conditions hold together with two slackness constraints:

$$\lambda_t^I\left(w_t n_t^I+(1-\zeta^h\Gamma_t)q_t^h h_{t-1}^I+m_t+t_t-c_t^I-q_t^h h_t^I\right)\geq 0, \quad \lambda_t^I\geq 0$$

$$\Omega_t\left(\left(\Gamma_{t+1}-\mu_H G_{t+1}\right)\zeta^h q_{t+1}^h h_t^I-E_t\frac{\tilde{R}_t^M}{\pi_{t+1}}m_t\right)\geq 0, \quad \Omega_t\geq 0$$

λ_t^I and Ω_t denote the Lagrange multiplier to the budget constraint and the banks' participation constraint respectively.

Impatient households, like patient households, have monopoly power in a labor market and can set wages. Similarly to patient households, we can derive optimal wage w_t^{I*}.

3.7 Capital producers

Capital producers sell capital to financially constrained firms at the real competitive price q_t and buy the depreciated capital stock back next period. Capital producers add investment i_t as additional inputs to the depreciated capital stock by using a technology subject to convex investment adjustment costs $\Gamma\left(\frac{i_t}{i_{t-1}}\right)$ and capital utilization shock u_t:

$$k_t=(1-\delta)k_{t-1}+\left(1-\Gamma\left(\frac{i_t}{i_{t-1}}\right)\right)u_t i_t$$

3.8 Imports and exports

Parallel to differentiated domestic goods, imported goods is yet another strand of differentiated goods in the economy that is used as an input for the production of domestic final goods. A set of firms called importers buy foreign goods from abroad and differentiate them. Importers exercise market power and set prices in the staggered way as in Calvo (1983), which allows for the incomplete exchange rate pass-through. Every period a share $(1-\omega^F)$ of importers set their prices to the optimal price. The remaining firms adjust past prices by the rate π_t^{adj}. The aggregate price level that prevails in the sector is denoted by p_t^F.

We assume that exports do not use imported inputs in the production. Exporters is a separate set of firms from importers and domestic retailers. Exporters demand y_t^{H*} units of the domestic aggregate good y_t^H, so the supply of the assembled production of domestic retailers has to satisfy both the demand of the composite goods producer and the demand of exporters. Exports are sold at a price p_t^H/rer_t which is the price of domestic aggregate goods expressed in units of foreign composite goods. The foreign demand for domestic aggregate goods is price-sensitive:

$$y_t^{H*} = \eta^* \left(\frac{p_t^H}{rer_t}\right)^{-\epsilon_*} y_t^*$$

Consistent with the small open economy assumption, P_t^* and y_t^* are assumed to evolve exogenously.

3.9 Monetary policy

The central bank conducts monetary policy by following a Taylor rule:

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\gamma_R} \left(\frac{y_t^H}{\bar{y}^H}\right)^{(1-\gamma_R)\gamma_Y} \left(\frac{\pi_t^H}{\bar{\pi}^H}\right)^{(1-\gamma_R)\gamma_\pi} \exp(mp_t)$$

where mp_t is a monetary policy shock and the domestic composite goods price inflation π_t^H can be expressed as $\pi_t^H = p_t^H/p_{t-1}^H \pi_t$.

3.10 Government

We assume exogenous government expenditure g_t. Taxes follow a simple rule that allows taxes to adjust proportionately to changes in government bonds ($0 < \kappa^B < 1$):

$$t_t = t + \kappa^B(b_{t-1} - b) + \tau_t$$

Finally the government has to satisfy its budget constraint:

$$g_t + \frac{R_{t-1}}{\pi_t} b_{t-1} = t_t + b_t$$

3.11 Current account

The trade balance in terms of domestic goods is given by:

$$tb_t = p_t^H y_t^{H*} - rer_t D_t^F y_t^F$$

We assume that only banks borrow from foreign households and issue foreign debt d_t^*. As a result, in equilibrium the stock of foreign debt changes either due to trade balance or payments on foreign bank debt.

The price of domestic currency (relative to foreign currency) adjusts to clear the foreign assets market. It follows that:

$$tb_t - \left(R_{t-1}^* \xi_{t-1} - 1\right) rer_t \frac{d_{t-1}^*}{\pi_t^*} = -\left(rer_t d_t^* - rer_t \frac{d_{t-1}^*}{\pi_t^*}\right)$$

3.12 Completing the model

The model is completed by a wage setting equation involving aggregate demand for labor derived from the firm's production decisions, and market clearing equations for the labor market and for the various domestically produced types of goods. The complete set of model equations is set up and presented in Appendix H.

4 Bringing the model to the data

Model simulation and estimation use a mixture of calibrated parameters and estimated parameters, since the sample size is too short to resort to a full fledged econometric estimation. Also, some parameters cannot be identified with macro data, for instance, the elasticity of substitution between varieties of goods. In what follows we discuss model calibration and estimation explaining our choices and results.

4.1 Calibration

We calibrate parameters that correspond to steady state ratios and model elasticities. The sources and values of parameters are listed in Table A1. In most cases, we resort to values used in models estimated on Hungarian data or used to simulate the Hungarian economy. Calvo parameters for domestic prices and wages are taken from a DSGE model estimated on Hungary data (Jakab and Kónya, 2016). We set Calvo parameters for import prices equal to the ones for domestic prices in Jakab and Kónya (2016), because they do not model sticky import prices. Elasticities of substitution are calibrated to the values chosen in a DSGE model estimated on Hungarian data in Jakab and Világi (2008). Labor supply elasticity among different types of labor is taken from Jakab and Világi (2008). Investment adjustment cost parameter is set following Jakab and Kónya (2016). Government spending to GDP ratio is taken from Jakab and Világi (2008). The Taylor rule is calibrated to Jakab and Világi (2008), but since they do not allow for the rate response to output, we set the response to output, denoted as γ_y in our model, to 0.1.

In some cases we rely on papers that do not focus on the Hungarian economy because Jakab and Világi (2008) or Jakab and Kónya (2016) either differ too much from our model. We calibrate household discount factors to values suggested in Iacoviello (2005), which is one of the first papers that introduced heterogeneous households and household borrowing in New-Keynesian DSGE models. The utility weight of housing in the utility function is also taken from Iacoviello (2005). Elasticity of substitution for exports is taken from Gali and Monacelli (2005). The banks' exit probability ω^B and the new equity parameter ι^B are calibrated as in Gertler and Karadi (2011). We calibrate the volatility of the idiosyncratic housing quality shock to approximately the value used in Clerc et al. (2015). They applied a monitoring costs friction to explain the household spread as we do in our model.

The housing stock is normalized to unity, so is the relative price of domestic aggregated goods p^H and the technology shock z. Non-stationary technology growth in the steady state is set to GDP growth net of population growth in Hungary over 2000:Q1-2016:Q3.

Several parameters in the model correspond to steady state values in data. We need a share of domestic goods in total consumption in Hungary. We take the share of imports to GDP in Hungary (73 percent) over the period 2002:Q1-2008:Q4 and adjust it given the average import share in the Hungarian exports (56 percent). For this we data on domestic value added in gross exports and import content of exports provided by OECD. In our model exports are assumed to be of domestic origin only, so we lower the observed import share in GDP by the amount of imports used in export production and get that the import share in domestic demand should constitute around 40 percent in our model. Thus we calibrate the share of domestic goods in consumption basket and investment basket (η_C and η_I respectively) to 0.6.

A few parameters are determined endogenously. A_n is chosen such that average working hours in the steady is 0.33. R follows from the Euler equation given β_P. R^* follows from satisfying the UIP condition in the steady state given the quarterly foreign inflation of 0.4 p.p. κ is endogenously determined to match the corporate loan spread of 0.6 p.p. The shares of foreign currency loans to households and firms are calibrated based on Hungarian data as of 2008:Q4 (Bank of Hungary, 2012). μ_H matches the average quarterly household loan spread of 1 p.p. in the data. λ^B is calibrated to match the bank spread of 0.3 p.p. in the data. The spreads are constructed using data provided by Bank of Hungary. We elaborate on this procedure in the next section when we present financial data used in model estimation.

Finally the utility function for patient households and impatient households is chosen such that the model preparation to match data would be easier. We elaborate on this in the next subsection.

4.2 Estimation

To carry on with the estimation exercise, we prepare the model to match observed variables. Usually the observed data cannot match the model variables, if a (stochastic) trend is present in the data. In our sample all variables are non-stationary, except for interest rates.[5]. To remedy the non-stationarity problem, we can match either growth rates of observed variables or HP-filtered levels of observed variables. Since HP-filter is criticized for creating rather than finding cyclical properties and deteriorating the prediction power of data, see for instance Hamilton (2017), we do not use HP filter. Instead we match growth rates of observed non-stationary variables and levels of stationary variables (as for instance Christiano et al. (2011)) and observation equations for non-stationary variables explicitly account for labor augmenting technology growth. Non-stationary variables are divided by labor augmenting technology level, yielding the set of equations listed in the Appendix H. Exceptions to this transformation and relevant notation are discussed there as well. This transformation has implications for the utility function. We choose a very simple utility function that assumes separately additive preferences. This facilitates model transformation to a stationary form considerably. For the same reason risk aversion parameters for consumption and housing are set to one and the Frisch elasticity for labor is set to one too.

We estimate parameters of the various stochastic processes using Hungarian macro and financial data from 2005:Q1-2016:Q4. The relatively short period is the result of short financial data series. The macro data set includes real GDP growth, consumption growth, investment growth, change in CPI inflation, change in the nominal gross interest rate, real exchange rate growth and change in the trade balance to GDP ratio. Financial variables include the corporate loan spread, the household spread and the bank spread. All quantities are in per capita terms. The model allows for one real trend growth rate. So, after computing growth rates (if necessary), we demean all variables because most of these variables have substantially different trend growth rates in the data.[6] Definitions of data series and data sources are listed in Table A3.

The full model with all three financial frictions is estimated using 13 shocks: stationary productivity shock, non-stationary productivity shock, government spending, monetary policy, capital utilization, pref-

[5]A large number of non-stationary variables can also be due to a small sample size though

[6]We follow Christiano et al. (2011).

erence, the country's risk premium, foreign interest rate, foreign inflation, foreign GDP growth, housing quality volatility shock $\sigma_{M,t}$, corporate profits volatility shock $\sigma_{F,t}$ and the bank leverage tightness λ_t^B. Model estimation also allows for measurement errors for all observed variables except interest rates. Measurement errors are calibrated to 10 percent of the observed variance of relevant time series. The size of measurement errors is on the conservative end of sizes used in Christiano et al. (2011) for Swedish data. We report measurement errors in Table A2.

A brief comment on financial data is needed. We use data provided by the Bank of Hungary. The household spread is defined as the interest rate premium of new housing loans to households in forints relative to 3-month BUBOR. The corporate spread is given by the interest rate premium of new loans to non-financial enterprises relative to 3-month BUBOR (3-month moving average). The loan rate of non-financial corporations is a floating rate with up to 1 year initial rate fixation. Only loans up to 1 million euros are considered. For both the household rate and the corporate rate we consider forint loans rather than euro loans due to data availability. To construct the bank spread, we take a difference between the average interest rates of unsecured forint interbank lending transactions (overnight rates) and the average household forint deposit rate with up to 1 year maturity.

We estimate autoregressive coefficients and standard deviations of shocks. The estimates are based on a double chain Metropolis-Hastings algorithm with 400,000 draws after a burn-in period of 200,000 draws and with the acceptance rate set to 0.21. Table A4 provides priors and posterior estimates. These estimates do not affect model simulation results, so we do not discuss them here and focus on model fit instead.

4.3 Endogenizing volatility

In regular DSGE models volatility effects are linearized away during solution. But in our model, the volatility of future profits appears in a non-linear fashion in the first order conditions of firms and banks in the derivative of the option prices implicit in modeling debt overhang. Thus our model is capable of studying volatility effects in ways that are not possible in regular DSGE models. Besides modeling a shock to volatility of firms' future profits, we can endogenize the volatility term by incorporating uncertainty about prices. We obtain the endogenized volatility value for future profits of financially constrained firms by iterating on the value for $\sigma_{F,t}$ until it converges. In this section we explain why the obtained volatility value is a better choice than an arbitrary calibrated value. We now briefly describe the simulation procedure as well.

The first order conditions that govern financially constrained firms' behavior contain a proxy for the default probability. The default probability depends not only on expected values of future revenue and liabilities but also on the variances of those future revenue and liabilities as well. And because prices are endogenous, the default probability is not only affected by stochastic components such as technology but also by (the volatility of) production prices and exchange rates. Therefore, we cannot postulate the variance of future output or future liabilities as an exogenous process dependent on technology and current state variables only. The variance of endogenous variables is unknown, but we can obtain an estimate from simulated series. In Appendix C.2 we derive the precise expression we need to be able to compute the default probability and simulate the model:

$$\sigma^2_{F,t} = var\left(\bar{y}_{t+1}\right) = var\left(\pi_{t+1}\left(\kappa\left(p^R_{t+1}y^R_{t+1} + q_{t+1}(1-\delta)k_t\right) - R^L_t rer_{t+1}\frac{l^F_t}{\pi^*_{t+1}}\right)\right) \tag{9}$$

To simulate the model we need a numerical value for $\sigma_{F,t} = \sqrt{\sigma^2_{F,t}}$.

To find a value for $\hat{\sigma}_{F,t}$ as close to the true value as possible we follow several steps:

1. Set a threshold level for convergence of the calibrated $\hat{\sigma}_{F,t}$ to the value of $\tilde{\sigma}_{F,t}$ that follows from the simulated time series generated by the model.
2. Choose an initial value for $\hat{\sigma}_{F,t}$.
3. Estimate the model with the chosen value for $\hat{\sigma}_{F,t}$.
4. Simulate the estimated model with the chosen value for $\hat{\sigma}_{F,t}$.
5. Compute $\tilde{\sigma}^2_{F,t}$ from simulated time series using the expression (9) and denote it by $\tilde{\sigma}^2_{F,t}$.
6. Compute the difference between the chosen value $\hat{\sigma}_{F,t}$ and the simulated value $\tilde{\sigma}_{F,t}$. If the difference is larger than the threshold value, set $\hat{\sigma}_F = \tilde{\sigma}_F$ and repeat steps 3-6.

This structure and procedure makes for a significantly richer model than can be obtained using regular DSGEs, allowing us to trace out the consequences of volatility shocks and resort more to estimation than to calibration in pinning down volatility processes.

4.4 Model fit

We bring the model closer to the macro and financial data in Hungary through Bayesian estimation. First, we estimate the model with different sets of financial frictions and assess the role of different frictions based on the model fit. Second, we evaluate the model performance by comparing the second moments and model responses to the data.

Monitoring costs is an alternative financial friction to debt overhang: financial distress for firms can arise from unobserved firm-specific productivity shocks and thus uniformly higher borrowing costs, like in Bernanke et al. (1999). If the monitoring costs explanation fits the data better than the debt overhang problem, the debt overhang friction should not be used. Although anecdotal evidence points to the relevance of debt overhang in Hungary, we also test this prediction by comparing the model with the debt overhang

Table 1: Marginal likelihood of different models.

Fin. friction for firms	Fin. friction for banks	Fin. shocks	Fin. data	Log-likelihood	σ_F
DO	-	$\sigma_{F,t}$, $\sigma_{M,t}$	firm and HH spreads	-780.0	0.018
DO	-	$\sigma_{F,t}$, $\sigma_{M,t}$	firm and HH spreads	-773.3	0.028
BGG	-	$\sigma_{F,t}$, $\sigma_{M,t}$	firm and HH spreads	-828.5	0.028
DO	GK	$\sigma_{F,t}$, $\sigma_{M,t}$, λ_t^B	firm, HH and bank spreads	-807.7	0.018
DO	GK	$\sigma_{F,t}$, $\sigma_{M,t}$, λ_t^B	firm, HH and bank spreads	-807.5	0.028
BGG	GK	$\sigma_{F,t}$, $\sigma_{M,t}$, λ_t^B	firm, HH and bank spreads	-818.4	0.028

Note: All estimations use macro data. Macro data includes: real GDP growth, consumption growth, investment growth, change in CPI inflation, change in the nominal gross interest rate, change in the trade balance to GDP ratio and real exchange rate growth. In the model the firm spread is the default spread on corporate loans defined as $R_t^L/\pi_{t+1} - R_t/\pi_{t+1}$. The household spread is the default spread and mortgages defined as $R_t^M/\pi_{t+1} - R_t/\pi_{t+1}$. The bank spread is defined as $\tilde{R}_{t+1}^L - R_t/\pi_{t+1}$.

Abbreviations: "Fin." stands for financial. "DO" means debt overhang, "BGG" means monitoring frictions as implemented in Bernanke et al. (1999). "GK" means the endogenous bank leverage constraint as implemented in Gertler and Karadi (2011).

friction to the one that features the monitoring costs friction for businesses instead. The latter follows a modeling tradition started in Bernanke et al. (1999). The description of this alternative model is provided in the Appendix G.

The estimated fit of the different models is presented in Table 1. The estimated log-likelihood values are based on a double chain Metropolis-Hastings algorithm with 400,000 draws after a burn-in period of 200,000 draws and with acceptance rate set to 0.21. The last column shows the volatility value for future profits of financially constrained firms in the steady state. The endogenized volatility value is 0.018, however, given the parameters, we cannot obtain the solution for the monitoring costs models with this volatility value and compare the models by choosing a slightly higher volatility value (0.028). We can see from Table 1, however, that the log-likelihood values for debt overhang models are very close to each other with both volatility values. In simulations and computing second moments we stick to the endogenized volatility value of 0.018.

We first test the fit of the debt overhang friction for the model without leveraged banks. We take these models to the data and estimate on the macro data set, the corporate spread data and the household spread data. the results reported in Table Table 1 show that the debt overhang friction explains aggregate fluctuations of real variables and financial variables better than the monitoring cost approach. The log-likelihood of the model with the debt overhang friction is higher. We also compare the fit of corporate frictions by allowing an interaction with bank leverage. Besides a financial friction for corporates, both models used for this comparison feature indebted households and leveraged banks. We take these models

Table 2: Second moments

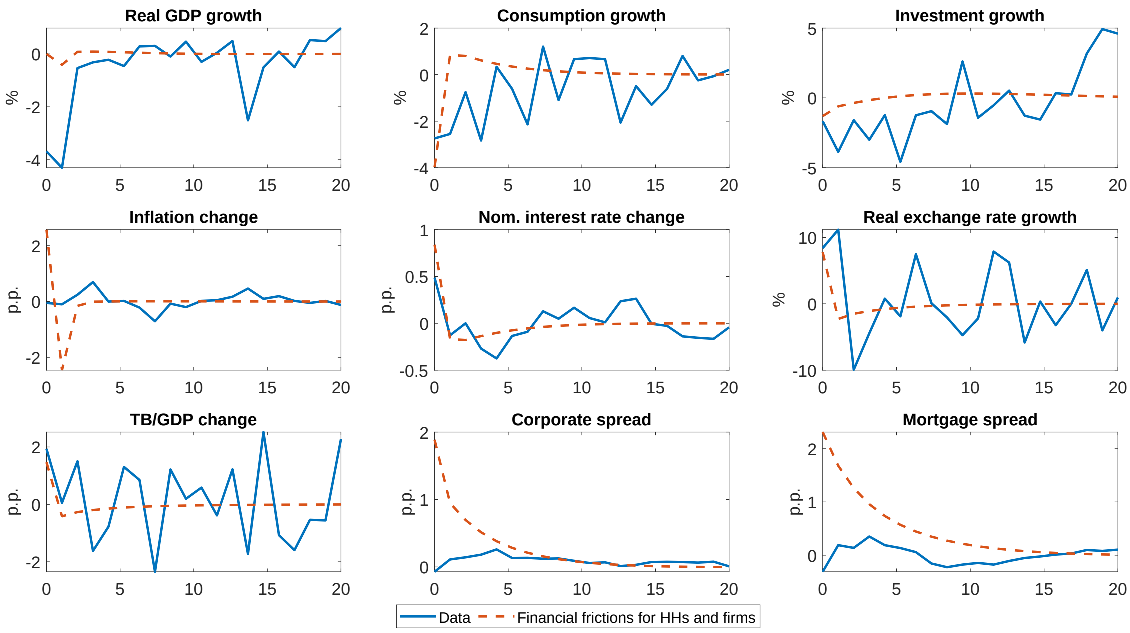
	Data	DO	DO-GK
		Standard deviation	
	(1)	(2)	(3)
Real GDP growth	1.0674	0.7823	1.0332
Consumption growth	1.1301	1.1650	1.3787
Investment growth	3.7019	3.8473	3.8008
Nominal interest rate change	0.1644	0.1876	0.1806
Inflation change	0.2327	0.9884	0.8922
TB/GDP change	1.4384	0.7229	0.7354
Real exchange rate growth	4.1177	1.7435	1.8575
Household spread	0.1546	0.2628	0.3766
Corporate spread	0.1225	0.1441	0.9855
Bank spread	0.1150	-	0.9925
		Autocorrelation	
Real GDP growth	0.4778	0.2076	0.2075
Consumption growth	0.3338	-0.0590	-0.0544
Investment growth	0.0503	0.2792	0.2299
Nominal interest rate change	0.4513	-0.0782	-0.0716
Inflation change	0.4004	-0.4854	-0.4929
TB/GDP change	-0.5573	-0.1177	-0.1942
Real exchange rate growth	0.0678	0.0164	-0.0213
Household spread	0.5737	0.7321	0.5075
Corporate spread	0.8917	0.4672	0.6658
Bank spread	0.3899	-	0.6711

Description: Means are not reported because all time series are demeaned following Christiano et al. (2011) in order to eliminate different trend growth rates. Table reports model moments computed with 400,000 simulation periods and data moments. Model "DO" includes borrowing households and firms with DO. Model "DO-GK" includes borrowing households, firms with DO and leveraged banks. In the model the firm spread is the default spread on corporate loans defined as $R_t^L/\pi_{t+1} - R_t/\pi_{t+1}$. The household spread is the default spread and mortgages defined as $R_t^M/\pi_{t+1} - R_t/\pi_{t+1}$. The bank spread is defined as $\tilde{R}_{t+1}^L - R_t/\pi_{t+1}$. Data spans from 2005:Q1 to 2016:Q4.

to the data and estimate them on the macro data set, the corporate spread data, the household spread data and the bank spread. The estimation results are presented in the last two rows of Table 1. The results show that, if the interaction between corporate financial inefficiency and banks' equity position is allowed, corporate debt overhang still performs better than the monitoring costs approach of Bernanke et al. (1999).

The estimated model generates second moments that are reasonably close to the data. Table 2 presents standard deviations and autocorrelation coefficients for the model with the debt overhang friction and bank frictions. Means are not reported because all time series are demeaned in order to eliminate different trend growth rates as in Christiano et al. (2011). Based on the standard deviations, the model with the debt overhang friction for firms matches GDP consumption, investment and interest rate data. However, the volatility of real exchange rate growth is too low and the standard deviation of the inflation change is too high. This discrepancy may be driven by relatively short time series and active policy intervention during

Figure 2: Model responses vs. data.



Note: The figure plots model IRFs to an unexpected increase in the country's premium by three p.p. and the Hungarian macroeconomic and financial data over the period 2008:Q4 to 2013:Q3. The model incorporates household leverage and firms with the debt overhang friction. Data series are demeaned.

the crisis, which may not be captured by our data. Besides this, the difficulty of matching may be caused by the fact that we attempt to match not the inflation rate but the change in the inflation rate. Including the bank frictions deteriorates the model fit in terms of credit spreads, suggesting to treat this model version with caution as we may overestimate the strength of financial frictions. Both models reasonably match autocorrelation coefficients of credit spreads, but do worse in matching autocorrelation coefficients of macro variables.

Finally we compare the model response to the country's risk premium shock to the data from 2008:Q4 to 2013:Q3. Figure 2 shows that the model responses have fewer fluctuations, which should not come as a surprise: we do not include other shocks that occurred in the beginning of the crisis in Hungary such as trade shocks or volatility shocks. Also, the risk premium shock decays in less than ten periods, whereas the data reflects that volatile macroeconomic environment in the Hungarian economy persisted up until the end of 2013. However, focusing on the country's risk premium answers the question of whether the shock to the country's premium can replicate a reasonable share of the fluctuations in the Hungarian economy during the crisis. The GDP growth and investment growth responses in the model are lower than in the data, suggesting that the role of other shocks is large in driving the real variables after 2008. The country's premium shock is sufficient to explain the increase in the nominal interest rate, the increase in the trade balance to GDP ratio and the rapid real exchange rate growth. However, the model largely overestimates the spikes in inflation and the credit spreads. Slower and milder adjustment of credit spreads in the data might reflect delayed bank responses and more versatile adjustment margins at banks' disposal than we allow for: banks could have rationed credit rather than simply adjusted credit prices or acted in anticipation of policy interventions aimed at preventing the credit crunch.

5 Results

This section analyzes the currency losses allocation problem. First, we explore how household debt denominated in foreign currency can lead to reduced output in times of currency depreciation and compare the outcomes to the downsides of corporate foreign currency loans. Currency mismatch in the household sector and currency mismatch in the corporate sector reduce output after a depreciation through different channels, which is why we first discuss these currency mismatches separately. In the next subsection we introduce bank leverage constraints to create wider ranging effects of bank currency mismatch losses and analyze different currency mismatch scenarios.

The following discussion uses selected output plots. A complete set of figures of each of the experiment is presented in the Appendix.

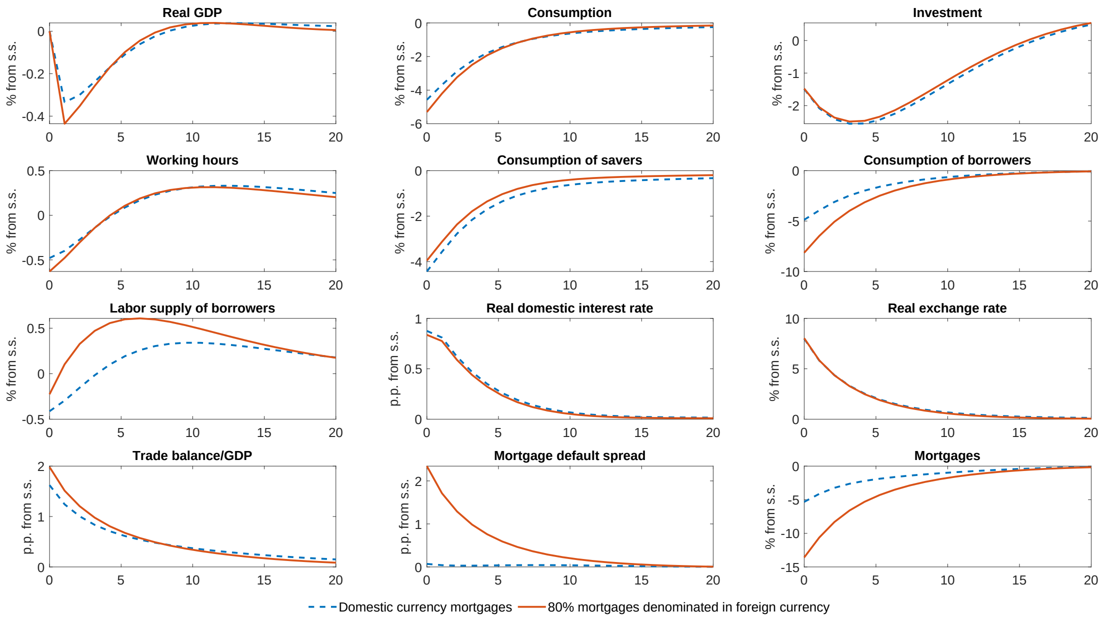
5.1 Household FX debt vs. corporate FX debt

Household FX mismatches

In this section we consider the consequences of foreign currency mortgages to households when an unexpected currency depreciation takes place. We assume 80 percent of mortgages in foreign currency; this was the share of foreign currency denominated mortgages in Hungary in 2008:Q4. The comparison is with a scenario with households borrowing in domestic currency only. The former scenario exposes households to currency mismatch, whereas in the latter scenario households would be insulated from exchange rate risk. Figure 3 presents the model simulation results for the two scenarios when unexpected currency depreciation is triggered by an increase in the country's risk premium by three percentage points. The figure plots aggregate real variables and financial variables that describe the financial situation of households and firms, namely default spreads and credit volume.

When the value of domestic currency declines, the domestic value of household debt increases, depleting household net worth. By assumption households do not have export revenue or any other hedge against

Figure 3: Country's premium shock and currency mismatch for households.



Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households and firms facing the debt overhang friction. Corporate loans in both cases are issued in domestic currency only.

currency risk, so an unexpected increase in the debt value is not offset by asset value gains. The reduction of household net worth makes households more willing to default and since banks do not observe idiosyncratic housing quality shocks, they contract lending for all household borrowers. The external household finance premium for households rises, reflecting banks' response to higher credit risk. Figure 3 shows that the presence of foreign currency debt increases the household default spread by two percentage points. This suggests that foreign currency debt exacerbates financial frictions on the households' side: without a hedge against exchange rate risk, the magnified debt value increases household leverage and makes household default more likely.

The reduction in household net worth creates a slump through two main channels: consumption and labor supply. Consumption decreases, but labor supply of borrowing households increases, see Figure 3. The consumption response is directly related to the decline in household net worth. The unexpectedly higher value of debt affects household net worth negatively, so borrowers have to cut consumption to meet debt payments and smooth housing purchases. The higher probability of default also raises borrowing costs and thus reduces the availability of mortgage credit, so impatient households have to use more of their net worth to acquire the same amount of housing or substitute some consumption goods for housing. As borrowers' demand for housing declines, housing prices fall (see Figure (A1) in the Appendix), which reinforces the decline in borrowers' net worth.

Borrowers adjust their labor supply in response to more expensive mortgage credit in order to smooth consumption and housing after the shock. This is why only impatient households increase their labor supply but not patient households, who are not directly affected by rising borrowing costs. However, higher labor supply is the second-order effect on equilibrium working hours. Lower aggregate demand reduces labor demand and this effect is stronger than the increase in labor supply of borrowers, resulting in the decline in total working hours.

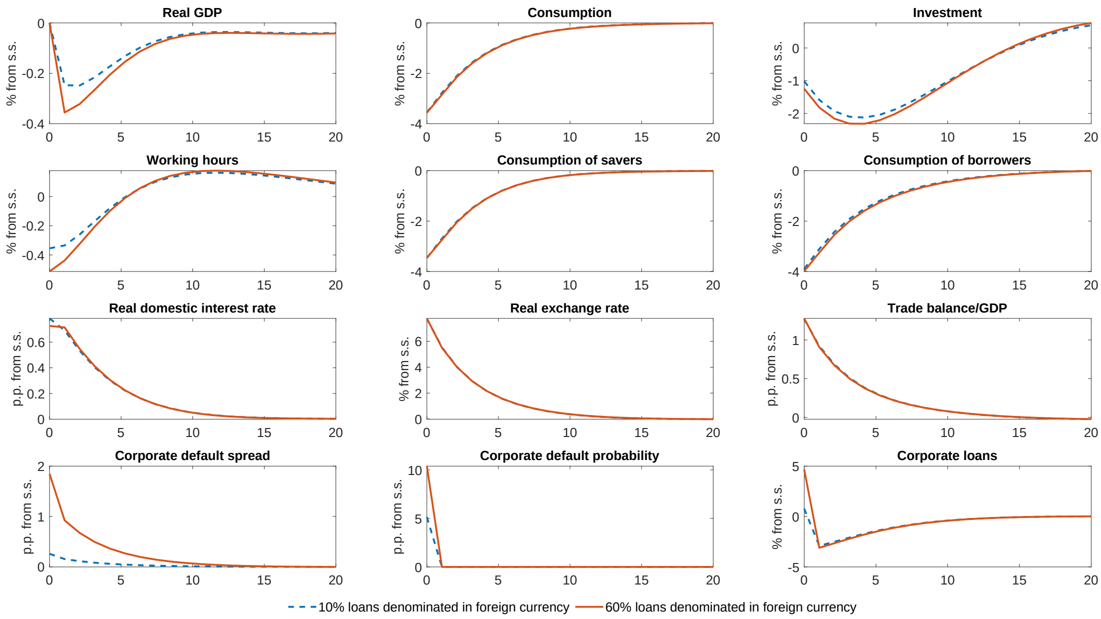
The negative effect on household net worth also has a dynamic side to it. We assume that the dynasty of impatient households pools the net worth of individual impatient households at the end of each period and then shares it equally among its members in the beginning of the next period. Hence, an instantaneous reduction in household net worth leads to lower total household net worth in the next period and thereafter more expensive mortgage credit. Borrowing costs rise for all borrowers due to asymmetric information between borrowers and lenders. So until total net worth has not recovered, all households would struggle to get mortgage credit in the future.

Lower net worth of household borrowers creates spillover effects to other sectors of the economy. First, depressed consumption translates into lower production. We observe that working hours decline, although the effect on investment is negligible. Second, as foreign currency debt makes households financially constrained, households consume fewer imported goods. Figure 3 shows that the trade balance increases relative to GDP by more, if household debt is denominated in foreign currency. Besides this difference driven by currency mismatch losses, the depreciation generates a traditional expenditure switching effect. The improved competitiveness of the economy creates higher demand for exports and domestic consumers also switch from more expensive imported goods to cheaper domestic products.

Corporate FX mismatches

When currency mismatch occurs in the corporate sector instead of the household sector, different transmission channels come into play. Financially constrained firms produce goods using capital and labor and finance working capital by taking loans denominated in foreign currency. Unexpected currency depreciation then slows down the economy because it worsens the financial situation of these firms rather than affecting consumption directly. To illustrate the impact of a depreciation in the presence of foreign currency corporate debt we again consider two scenarios. One scenario assumes that 60 percent of corporate debt is denominated in foreign currency, which was the share of foreign currency corporate debt in Hungary in 2008:Q4. In the comparison scenario, we assume a much lower 10 percent of debt denominated in foreign

Figure 4: Country's premium shock and currency mismatch for firms.



Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households and firms facing the debt overhang friction. Mortgages in both cases are extended in domestic currency only.

currency.[7] Figure 4 once again presents the simulation results of an unexpected increase in the country's premium, but now with only corporate FX denominated debt. The difference between the outcomes under the two scenario's indicates the impact of the presence of foreign currency debt.

Corporate currency mismatch affects investment more than other components of aggregate demand. Figure 4 shows that consumption barely reacts to the presence of corporate currency mismatch, since currency mismatch losses do not directly affect households' choices. However, currency mismatch in the corporate sector has a direct effect on capital purchases and labor hiring. The suddenly increased value of foreign currency reduces the distance to default and lowers the firms' incentives to invest, as one would expect given the emerging debt overhang. Figure 4 shows how corporate default spread increases by more, if firms face currency mismatch, and in turn firms cut their purchases of capital and labor hiring by more. The output loss due to corporate currency mismatch is small but positive. One of the reasons why corporate losses do not create larger spillovers to other sectors is that firms take one-period loans only and firms themselves cease to exist after two periods. These two assumptions limit the effect that overindebted firms can have on aggregate demand.

[7] We set 10 percent foreign currency share rather than zero because a zero share makes the model unstable.

The volume of corporate loans also indicates higher financial distress in the corporate sector when it is indebted in foreign currency. Initially the value of corporate loans increases because currency depreciation increases the debt value accordingly. However, in the second period after the shock, loans decline in response to higher corporate borrowing costs. The value of loans decreases in the second period as much as in the case with domestic currency loans despite a currency depreciation of around eight percent. Thus, the volume of loans must go down by almost five percent more with foreign currency corporate loans.[8]

Both types of households do not change their consumption response if corporate currency mismatch is introduced. As we show in Jakucionyte and van Wijnbergen (2017), the spillover effect would be stronger, if we introduce corporate equity that is pooled and transferred from exiting firms to new firms. Then higher debt value not only reduces profits and makes more firms default this period but also reduces funds for future firms. New firms need to borrow more to produce the same amount of goods and thus have to leverage up more. This would amplify the investment response but would not change the current ranking of outcomes.

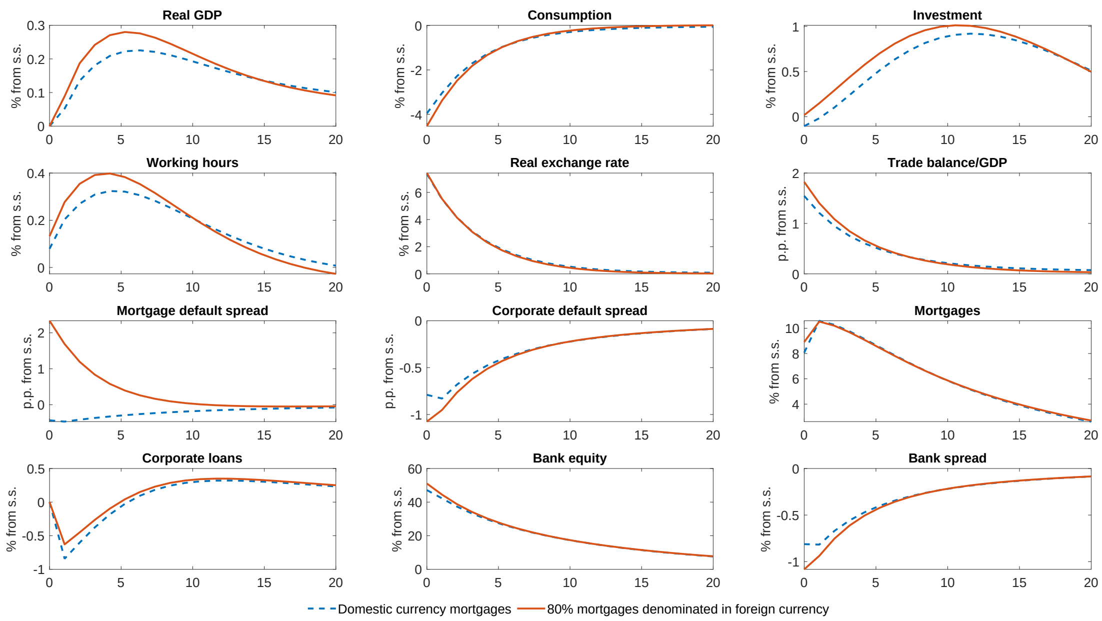
5.2 Allocating currency mismatch losses to banks

In this section we study the consequences of shifting currency mismatch losses to banks instead of to consumers or corporate borrowers. To analyze the impact of allocating currency mismatch losses, we introduce endogenous market-value based leverage constraints for banks as in Gertler and Karadi (2011). In their setup a decline in a bank's net worth creates a moral hazard problem: bankers become more likely to divert assets from shareholders. Bank depositors take this into account and require a compensation which increases bank borrowing costs and tightens bank leverage constraints. So after a decline in equity value, a fall in credit supply follows. In this way credit supply is directly linked to bank equity.

Currency mismatch losses can worsen the mortal hazard problem for bankers, regardless of whether banks or borrowers face currency mismatch. Currency mismatch losses for banks deplete bank net worth directly: when unexpected currency depreciation increases the value of bank liabilities but not the value of domestic currency loans to households or businesses, bank equity shrinks. The immediate decline in equity for banks worsens their moral hazard problem and tightens leverage constraints. As banks with tighter leverage constraints lend less, output losses become unavoidable. This way endogenous bank leverage constraints make shifting losses to banks a far less appealing option from a macroeconomic perspective. However, shifting losses to borrowers does not imply that bank leverage constraints will be unaffected in times of depreciation. If borrowers face exchange rate risk instead of banks, default rates of foreign currency

[8] We get 4.8 percent by taking eight percent currency depreciation and weighting it with a 60 percent share of foreign currency loans in total corporate loans.

Figure 5: Country's premium shock and currency mismatch for households with leverage-constrained banks.



Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households and firms facing the debt overhang friction and leveraged banks. Corporate loans in both cases are issued in domestic currency only.

loans will go up after a depreciation, eating up bank equity and tightening bank leverage constraints after all. In this section we consider both the credit risk and the valuation channels since both are embedded in our model. We show that in some cases shifting currency mismatch losses to banks is more costly in terms of output despite the fact that the alternative does not safeguard the bank entirely because it does lead to higher credit risk.

We start the analysis by focusing on household foreign currency debt as one of the ways to shift currency mismatch losses from banks to borrowers. By assumption banks borrow from both domestic households and foreign households, so they always have a share of liabilities denominated in foreign currency. Our calibration implies that when banks issue foreign currency mortgages, the share of their assets that is denominated in foreign currency becomes higher than the share of their foreign currency liabilities. For instance, the share of foreign currency liabilities in the banking sector matches the actual ratio of 0.3 in the banking system in Hungary before the crisis, however, foreign currency mortgages constitute 80 percent of total mortgages. This way unexpected currency depreciation creates gains for banks issuing foreign currency mortgages and their profits increase. We compare this scenario to the case when banks lend in domestic currency only and do not reap valuation gains from unexpected depreciation but face currency mismatch losses instead. Currency depreciation is triggered by an increase in the country's risk premium by three percentage points. Figure 5 plots the responses of aggregate real variables and financial variables to the country's risk premium shock for the two scenarios.

Results suggest that shifting depreciation losses to household borrowers has a positive effect on bank equity. Figure 5 shows that, if households borrow in foreign currency, bank equity increases by more. Therefore, bank valuation gains from foreign currency assets are large enough to offset losses from more frequent mortgage default. Relaxed bank leverage constraints result in a lower bank spread which is expressed as the difference between the expected real return on corporate loans and the real expected deposit rate.[9]

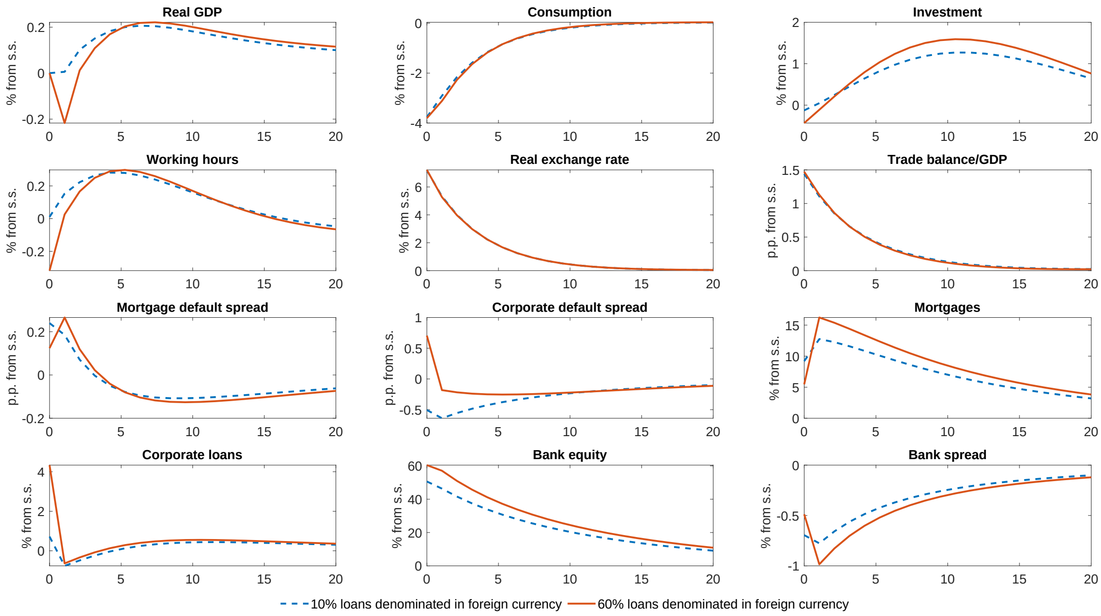
Of course household currency mismatch has a negative effect on borrowers' consumption, demand for housing and total consumption, as observed before. Currency depreciation erodes household net worth and leaves less cash available for consumption. Lower household net worth also makes mortgages more costly and households have to substitute consumption for housing. However, despite lower aggregate consumption, the financial situation in the banking sector is better, which results in higher total credit supply. Banks face lower borrowing costs and can extend loans more cheaply. So although they still price mortgages higher to reflect the higher credit risk, they extend loans to firms more freely. In Figure 5 corporate loans decrease by less and the corporate credit spread is lower, if households face currency mismatch. Investment decreases by less as now financially constrained firms can afford more working capital. Higher investment evidently offsets the negative effect of consumption on output. Hence, in this case shifting currency mismatch losses to household borrowers is beneficial from a macroeconomic perspective.

Bank leverage constraints play a smaller role in ranking macroeconomic outcomes, if firms instead of households borrow in foreign currency. Figure 6 shows that if businesses are not insulated from unexpected currency depreciation, output declines more. So although banks receive equity gains and looser bank leverage constraints allow banks to expand mortgage supply, this credit expansion is insufficient to offset the consequences of worsened debt overhang friction for firms.

There are several reasons why the presence of corporate foreign currency debt leads to larger output losses after a devaluation than the presence of foreign currency mortgages, even if direct bank losses are considered too. First, the debt overhang distortion generates a larger amplifications than monitoring costs (Occhino and Pescatori, 2015). In our model debt overhang does not distort households' incentives to consume and work, but debt overhang does weigh on aggregate investment and labor demand. Second, currency mismatch in the corporate sector has stronger effects on the supply side of the economy, not just on the demand side, because physical capital is a productive asset and housing is not. Third, although to

[9] In equilibrium the expected return on corporate loans is equal to the expected returns on mortgages.

Figure 6: Country's premium shock and currency mismatch for firms with leverage-constrained banks.

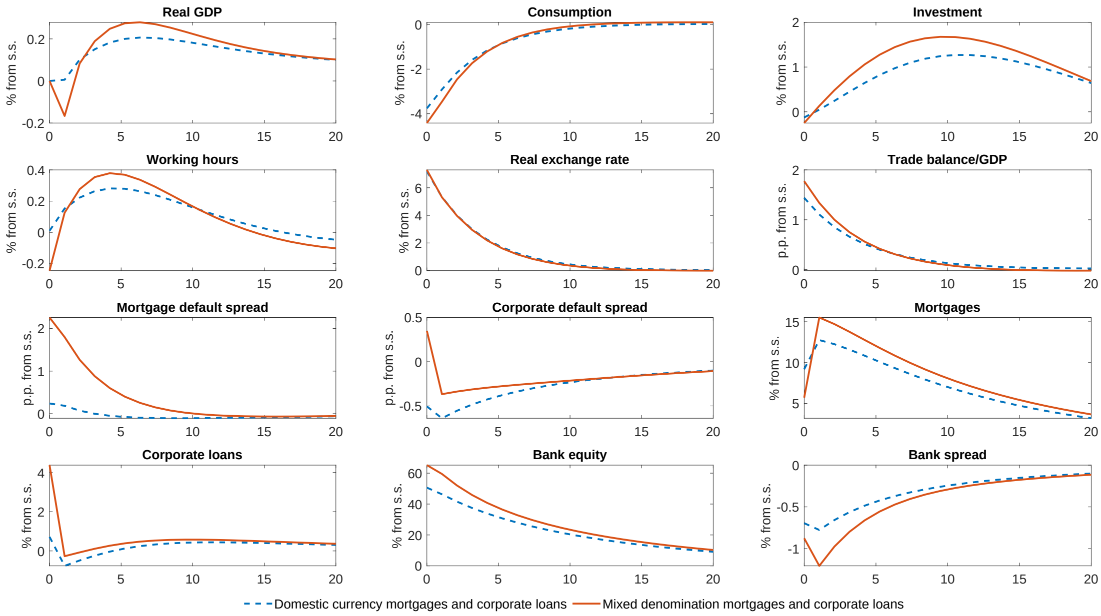


Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households and firms facing the debt overhang friction and leveraged banks. Mortgages in both cases are extended in domestic currency only.

produce one unit of investment goods or consumption goods takes the same proportion of imported goods, firms use only domestic labor as a production factor, which makes production overall less import-intensive than consumption. So when corporate losses occur, the consequences fall mostly on reduced demand for domestic factors rather than on demand for imports, with lower domestic output as a consequence. The fourth reason has to do with the calibrated ratio of foreign currency loans to firms and the associated potential upside for banks if they lend in foreign currency. Corporate loans constitute a smaller share of total bank credit than mortgages, so fixing 60 percent of corporate loans to be denominated in foreign currency is sufficient to hedge the bank open currency position but insufficient to make banks reap valuation gains after unexpected currency depreciation. It follows that the difference between bearing currency mismatch losses and shifting them to firms is smaller from the banks' perspective than it is with mortgages. So corporate financial frictions become more important in ranking macroeconomic outcomes than household financial frictions in ranking outcomes with foreign currency mortgages.

Finally we analyze the case where both corporate debt and household debt is partially denominated in foreign currency. On one hand, valuation gains should be even stronger as now the share of total assets

Figure 7: Country's premium shock and currency mismatch for all borrowers with leverage-constrained banks.



Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households and firms facing the debt overhang friction and leveraged banks. Mixed denomination mortgages and loans mean that 80 percent of mortgages and 60 percent of loans is dominated in foreign currency. In the domestic currency case, 10 percent corporate loans and zero of mortgages are denominated in foreign currency.

in foreign currency exceeds the share of foreign currency liabilities in the banking sector by a substantial margin. On the other hand, as we saw before, the presence of foreign currency loans to firms leads to larger macroeconomic losses after a depreciation. Figure 7 shows that, if we allow for both household and corporate debt to be partially denominated in foreign currency, output losses from unexpected depreciation are approximately the same regardless of who bears exchange rate risk. Thus, increasing the share of total foreign currency debt in the economy increases bank valuation gains to such an extent, that output outcomes are not worse or even better despite stronger debt overhang in the corporate sector and consumption losses.

Lower price stickiness could well result in different price and real exchange rate dynamics, affecting domestic consumers and producers. To test the role of price stickiness, we re-estimate the model with different Calvo parameters for prices. Figures A7-A10 show that the result is qualitatively the same: currency mismatch losses create larger output losses than leaving exchange rate risk on bank balance sheet.

To sum up, the only case where shifting currency mismatch losses to borrowers delivered worse output outcomes was with currency mismatch losses shifted to corporate borrowers. These results suggest that to limit the contractionary impact of depreciations through negative wealth effects and debt overhang, it is better for regulators to block shifting currency mismatch losses to corporate borrowers but allow banks to pass on losses to consumers.

6 Conclusions

In this paper we analyze whether shifting currency mismatch losses from household borrowers and corporate borrowers to banks is better from a macroeconomic point of view, that is with an eye on limiting the contractionary impact of a depreciation. With our model calibrated to match the Hungary's experience during the forint depreciation in 2009, we find that currency mismatch losses for corporate borrowers lead to a larger output decline than if banks lent in domestic currency and faced currency mismatch losses themselves. Foreign currency mortgages for households, however, lead to a lower decline than if banks issued mortgages in domestic currency and faced currency mismatch losses themselves.

Our findings follow from a medium-sized New-Keynesian DSGE model with three types of financial frictions and risky foreign currency debt. Bayesian estimation shows the relevance of corporate debt overhang in explaining Hungarian data. The debt overhang friction improves model fit considerably and performs better than a costly state verification friction as in Bernanke et al. (1999). So we adopt debt overhang to describe investment dynamics. However, in the absence of any evidence of debt overhang for households, we model household debt with a costly state verification friction. Debt overhang generates larger amplifications of aggregate shocks, so corporate debt overhang is one of the main reasons why corporate defaults result in larger output losses than household defaults do. We draw two clear conclusions from our analysis. First, adequately predicting the potentially contractionary output effects of a real depreciation requires careful modeling of both the nature of the financial frictions and of the interfaces where they occur. Second, who in the end bears the capital losses associated with the depreciation in the presence of foreign currency denominated debt is of crucial importance for the eventual macroeconomic impact of a depreciation.

References

BAKKER, M. B. B. AND M. C. KLINGEN (2012): *How Emerging Europe Came Through the 2008/09 Crisis: An Account by the Staff of the IMF's European Department*, International Monetary Fund.

BANK OF HUNGARY (2012): "Report on Financial Stability," *November 2012*.

BASSO, H. S., O. CALVO-GONZALEZ, AND M. JURGILAS (2011): "Financial dollarization: The role of foreign-owned banks and interest rates," *Journal of Banking & Finance*, 35, 794–806.

BERNANKE, B. S., M. GERTLER, AND S. GILCHRIST (1999): "The financial accelerator in a quantitative business cycle framework," *Handbook of Macroeconomics*, 1, 1341–1393.

BHATTACHARYA, S. AND A. FAURE-GRIMAUD (2001): "The debt hangover: Renegotiation with noncontractible investment," *Economics Letters*, 70, 413–419.

BODNÁR, K. (2012): "Exchange rate exposure of Hungarian enterprises – results of a survey," *MNB Working Papers No. 2009/80*.

BROWN, M., K. KIRSCHENMANN, AND S. ONGENA (2010): "Foreign currency loans-demand or supply driven?" *CEPR Discussion paper No. DP7952*.

BROWN, M. AND P. R. LANE (2011): "Debt Overhang in Emerging Europe?" *World Bank Policy Research Working Paper No. 5784*.

CALVO, G. A. (1983): "Staggered prices in a utility-maximizing framework," *Journal of Monetary Economics*, 12, 383–398.

CÉSPEDES, L. F., R. CHANG, AND A. VELASCO (2004): "Balance Sheets and Exchange Rate Policy," *American Economic Review*, 94, 1183–1193.

CHATTERJEE, S. AND B. EYIGUNGOR (2015): "A quantitative analysis of the US housing and mortgage markets and the foreclosure crisis," *Review of Economic Dynamics*, 18, 165–184.

CHRISTIANO, L. J., M. TRABANDT, AND K. WALENTIN (2011): "Introducing financial frictions and unemployment into a small open economy model," *Journal of Economic Dynamics and Control*, 35, 1999–2041.

CLERC, L., A. DERVIZ, C. MENDICINO, S. MOYEN, K. NIKOLOV, L. STRACCA, J. SUAREZ, AND A. VARDOULAKIS (2015): "Capital regulation in a macroeconomic model with three layers of default," *International Journal of Central Banking*, 11, 9–63.

COOK, D. (2004): "Monetary policy in emerging markets: Can liability dollarization explain contractionary devaluations?" *Journal of Monetary Economics*, 51, 1155–1181.

CORBAE, D. AND E. QUINTIN (2015): "Leverage and the foreclosure crisis," *Journal of Political Economy*, 123, 1–65.

DEVEREUX, M. B., P. R. LANE, AND J. XU (2006): "Exchange rates and monetary policy in emerging market economies," *The Economic Journal*, 116, 478–506.

ENDRÉSZ, M., G. GYÖNGYÖSI, AND P. HARASZTOSI (2012): "Currency mismatch and the sub-prime crisis: firm-level stylised facts from Hungary," *MNB Working Papers No. 2012/8*.

FIDRMUC, J. AND S. KAPOUNEK (2020): "The Risks and Financial Vulnerability of Foreign Bank Ownership in CEECs: Evidence from Exchange Rate Depreciation after the Financial Crisis," *Eastern European Economics*, 58, 34–48.

GALI, J. AND T. MONACELLI (2005): "Monetary policy and exchange rate volatility in a small open economy," *Review of Economic Studies*, 72, 707–734.

GARRIGA, C. AND D. E. SCHLAGENHAUF (2009): "Home equity, foreclosures, and bailouts," *Manuscript, Federal Reserve Bank of St. Louis*.

GENNAIOLI, N., A. SHLEIFER, AND R. VISHNY (2012): "Neglected risks, financial innovation and financial fragility," *Journal of Financial Economics*, 104, 452–468.

GERTLER, M., S. GILCHRIST, AND F. M. NATALUCCI (2007): "External constraints on monetary policy and the financial accelerator," *Journal of Money, Credit and Banking*, 39, 295–330.

GERTLER, M. AND P. KARADI (2011): "A model of unconventional monetary policy," *Journal of Monetary Economics*, 58, 17–34.

GOMES, J., U. JERMANN, AND L. SCHMID (2016): "Sticky Leverage," *American Economic Review*, 106, 3800–3828.

GORDON, G. (2015): "Evaluating default policy: The business cycle matters," *Quantitative Economics*, 6, 795–823.

HAMILTON, J. D. (2017): "Why You Should Never Use the Hodrick-Prescott Filter," *NBER Working Paper Series No. 23429*.

HART, O. AND J. MOORE (1995): "Debt and Seniority: An Analysis of the Role of Hard Claims in Constraining Management," *American Economic Review*, 85, 567–85.

IACOVIELLO, M. (2005): "House prices, borrowing constraints, and monetary policy in the business cycle," *American Economic Review*, 95, 739–764.

IMF (2008): "Hungary: 2008 Article IV Consultation—Staff Report," *Country Report No. 08/313*.

——— (2009): "Europe - Securing Recovery," *Regional Economic Outlook, October 2009*.

JAKAB, Z. AND I. KÓNYA (2016): "An Open Economy DSGE Model with Search-and-Matching Frictions: The Case of Hungary," *Emerging Markets Finance and Trade*, 52, 1606–1626.

JAKAB, Z. M. AND B. VILÁGI (2008): "An estimated DSGE model of the Hungarian economy," *MNB Working Papers No. 2008/9*.

JAKUCIONYTE, E. AND S. J. VAN WIJNBERGEN (2017): "Debt overhang and the macroeconomics of carry trade," *Tinbergen Institute Discussion Paper 2017-005/VI*.

JENSEN, M. C. AND W. H. MECKLING (1976): "Theory of the firm: Managerial behavior, agency costs and ownership structure," *Journal of Financial Economics*, 3, 305–360.

JESKE, K., D. KRUEGER, AND K. MITMAN (2013): "Housing, mortgage bailout guarantees and the macro economy," *Journal of Monetary Economics*, 60, 917–935.

KALEMLI-ÖZCAN, S., L. LAEVEN, AND D. MORENO (2018): "Debt overhang, rollover risk, and corporate investment: Evidence from the european crisis," *NBER Working Paper Series No. 24555*.

LAMONT, O. (1995): "Corporate-debt overhang and macroeconomic expectations," *American Economic Review*, 1106–1117.

MERTON, R. C. (1974): "On the pricing of corporate debt: The risk structure of interest rates," *Journal of Finance*, 29, 449–470.

MYERS, S. C. (1977): "Determinants of corporate borrowing," *Journal of Financial Economics*, 5, 147–175.

NAKAJIMA, M. AND J.-V. RIOS-RULL (2005): "Default and aggregate fluctuations in storage economies," *Frontiers in Applied General Equilibrium Modeling, Cambridge University Press*, 127–50.

OCCHINO, F. AND A. PESCATORI (2014): "Leverage, investment, and optimal monetary policy," *BE Journal of Macroeconomics*, 14, 511–531.

——— (2015): "Debt overhang in a business cycle model," *European Economic Review*, 73, 58–84.

PHILIPPON, T. (2010): "Debt overhang and recapitalization in closed and open economies," *IMF Economic Review*, 58, 157–178.

SCHMITT-GROHÉ, S. AND M. URIBE (2003): "Closing small open economy models," *Journal of International Economics*, 61, 163–185.

TOWNSEND, R. M. (1979): "Optimal contracts and competitive markets with costly state verification," *Journal of Economic Theory*, 21, 265–293.

VAN WIJNBERGEN, S. J. (1986): "Exchange Rate Management and Stabilization Policies in Developing Countries," *Journal of Development Economics*, 23, 227–247.

VONNÁK, D. (2018): "Why do firms default on their foreign currency loans? The case of Hungary," *Journal of International Money and Finance*, 86, 207–222.

Appendix

A Tables and figures

Table A1: Calibrated parameters.

Parameter	Description	Value	Source
β_P	Patient household's discount factor	0.99	Iacoviello (2005)
β_I	Impatient household's discount factor	0.95	Iacoviello (2005)
σ_n	Inverse of Frisch elasticity	1	-
A_n	Disutility weight of labor		matches $n = 0.33$
A_h	Utility weight of housing	0.1	Iacoviello (2005)
a	Non-stationary technology growth in SS	1.0141	GDP growth - population growth
α	Capital share in production	0.33	-
δ	Capital depreciation rate	0.025	-
γ	Investment adjustment cost parameter	13	Jakab and Kónya (2016)
ω^W	Calvo parameter, wages	0.62	Jakab and Kónya (2016)
ϵ_W	Labor supply elasticity among different types of labor	3	Jakab and Világi (2008)
ϵ^*	E.o.S. for exports	1.5	Gali and Monacelli (2005)
ω^H	Calvo parameter, domestic goods	0.87	Jakab and Kónya (2016)
ω^F	Calvo parameter, imported goods	0.87	-
ϵ_H	E.o.S. between domestic varieties	6	Jakab and Világi (2008)
ϵ_F	E.o.S. between imported varieties	6	Jakab and Világi (2008)
γ_R	Interest rate smoothing	0.766	Jakab and Világi (2008)
γ_π	Interest policy rule (inflation)	1.375	Jakab and Világi (2008)
γ_y	Interest policy rule (output)	0.1	-
κ_ξ	Elasticity of country risk to net asset position	0.01	-
ϵ_C	E.o.S. between domestic and imported consumption goods	3	Jakab and Világi (2008)
ϵ_I	E.o.S. between domestic and imported investment goods	3	Jakab and Világi (2008)
η_C	Share of domestic goods in consumption basket	0.6	based on domestic VA in exports and import content of exports
η_I	Share of domestic goods in investment basket	0.6	based on domestic VA in exports and import content of exports
π	Inflation in SS	1.017	average in data
p^H	Relative price of x^H in SS	1	-
S	Nominal exchange rate in SS	1	-
χ	Housing stock	1	-
R	Risk-free rate in SS	1.0304	matches $\pi = 1.017$
R^*	Foreign interest rate in SS	1.0072	matches $\pi^* = 1.004$
s^g	Gov. consumption/ GDP in SS	0.10	Jakab and Világi (2008)
π^*	Foreign inflation rate	1.004	from RER definition in SS
ξ	Risk premium on international bonds in SS	1.01	-
ζ_h	LTV	0.8	-
μ_H	Monitoring costs		matches household spread
α^{HF}	FX share in household mortgage debt	0.8	average in data
σ_M	Volatility of housing shocks in SS	0.11	Clerc et al. (2015) as guidance
ρ	Fraction of working capital to be paid in advance	0.8	-
α^{FF}	Share of FX loans	0.6	average in data
κ	Share of production revenue to be seized by creditors		matches corporate spread
σ_F	Volatility of firms' profits in SS	0.018	endogenized volatility value*
λ^B	Fraction of capital that can be diverted	0.43	matches bank spread
ω^B	Probability of bankers' survival	0.97	Gertler and Karadi (2011)
ι^B	Proportional transfer to the entering bankers	0.002	Gertler and Karadi (2011)

Note: * - The volatility in the model with monitoring costs is calibrated to 0.028, because with lower volatility values the model solution cannot be found.
Abbreviations: "SS" means steady state, "DO" – debt overhang, "BGG" – monitoring frictions as implemented in Bernanke et al. (1999).

Table A2: Calibrated shock parameters.

Parameter	Description	Value
	Shock processes	
ρ_g	Government spending shock autoregresive coeff.	0.3927
ρ_{y^*}	World demand shock autoregresive coeff.	0.8913
ρ_{π^*}	Foreign inflation shock autoregresive coeff.	0.8023
ρ_{R^*}	Foreign interest rate shock autoregresive coeff.	0.6550
σ_g	Government spending shock standard deviation	0.0249
σ_{y^*}	World demand shock standard deviation	0.0035
σ_{π^*}	Foreign inflation shock standard deviation	0.0012
σ_{R^*}	Foreign interest rate shock standard deviation	6.5810e-04
	Measurement errors	
σ_y	ME of GDP growth standard deviation	0.3375
σ_c	ME of consumption growth standard deviation	0.3574
σ_i	ME of investment growth standard deviation	1.1707
σ_π	ME of inflation change standard deviation	0.0736
σ_{tbgdp}	ME of TB/GDP change standard deviation	0.4549
σ_{rer}	ME of real exchange rate growth standard deviation	1.3021
σ_{spr^H}	ME of household spread standard deviation	0.0489
σ_{spr^F}	ME of corporate spread standard deviation	0.0387
σ_{spr^B}	ME of bank spread standard deviation	0.0363

Note: Autoregressive coefficients and standard deviations of shock processes are computed from the data by HP-filtering variables first. Measurement errors are computed as 10 percent of variance of observed variables. Observed variables are expressed in deviations from their means. Means are computed over the period 2005:Q1-2016:Q4.
Abbreviations: “ME” stands for measurement error.

Table A3: Data.

Variable	Definition in the used data	Data source, data series number (if available)
Real GDP growth*	Total Gross Domestic Product, National Currency, Quarterly, Seasonally Adjusted	FRED, NAEXKP01HUQ189S
Consumption growth*	Private Final Consumption Expenditure, National Currency, Quarterly, Seasonally Adjusted	FRED, NAEXKP02HUQ189S
Investment growth*	Gross Fixed Capital Formation, National Currency, Quarterly, Seasonally Adjusted	FRED, NAEXKP04HUQ189S
Government spending*	Government Final Consumption Expenditure, National Currency, Quarterly, Seasonally Adjusted	FRED, NAEXKP03HUQ189S
CPI inflation	Consumer Price Index: OECD Groups: All Items Non-Food and Non-Energy, Growth Rate Same Period Previous Year, Quarterly, Not Seasonally Adjusted	FRED, CPGRLE01HUQ659N
Nominal interest rate	3-Month or 90-day Rates and Yields: Treasury Securities for Hungary, Percent, Quarterly, Not Seasonally Adjusted	FRED, IR3TIB01EZQ156N
Real exchange rate	Real Broad Effective Exchange Rate, Index 2010=100, Monthly, Not Seasonally Adjusted	FRED, RBHUBIS
Trade balance to GDP	Exports of Goods and Services for Hungary - Imports of Goods and Services for Hungary Chained 2000 National Currency Units, Quarterly, Seasonally Adjusted	FRED, NAEXKP06HUQ652S, FRED, NAEXKP07HUQ652S
Foreign interest rate	Interest Rates, Government Securities, Government Bonds for Euro Area, Percent per Annum, Quarterly, Not Seasonally Adjusted	FRED, INTGSBEZQ193N
Foreign CPI inflation	HICP: All Items for Euro area All Items for Euro area Index 2015=100, Monthly, Not Seasonally Adjusted	FRED, CP0000EZCCM086NEST
Foreign GDP growth	Real Gross Domestic Product for Euro area, Millions of Chained 2010 Euros, Quarterly, Seasonally Adjusted	FRED, CLVMEURSCAB1GQEA19
Corporate loan spread	Interest rate premium of new loans to non-financial enterprises (over 3-month BUBOR, 3-month moving average) up to 1 year fixation	MNB Financial Stability Report
Household loan spread	Interest rate premium of new HUF loans to households (over 3-month BUBOR)	MNB Financial Stability Report
Bank spread	Diff. between monthly average interest rates of unsecured HUF interbank lending transactions and HUF deposits up to 1 year to households	MNB

* - Variables are expressed per capita by dividing with 'Working Age Population: Aged 15 and Over: All Persons for Hungary©, Persons, Quarterly, Seasonally Adjusted', FRED, series no. HOHWMN03HUQ065N.
Note: FRED: Federal Reserve Economic Data, available at https://fred.stlouisfed.org/series/. MNB: Magyar Nemzeti Bank, Statistical Time Series, available at https://www.mnb.hu/en/statistics/statistical-data-and-information/statistical-time-series/xi-money-and-capital-markets. We use MNB Financial Stability Report data from the reports in 2008 November and May 2017. They are available at https://www.mnb.hu/en/publications/reports/financial-stability-report.

Table A4: Estimated parameters.

Parameter	Shock description	Distr.	Prior mean	Prior s.d.	Posterior mean					
Model:					DO		BGG	DO-GK		BGG-GK
ρ_a	Non-stationary prod.	beta	0.5	0.2	0.4983	0.4531	0.0722	0.0561	0.0582	0.0612
ρ_z	Stationary prod.	beta	0.5	0.2	0.2695	0.2705	0.8848	0.3343	0.3480	0.9371
ρ_ζ	Risk premium	beta	0.5	0.2	0.7361	0.7156	0.5238	0.7576	0.7676	0.5641
ρ_u	Capital utilization	beta	0.5	0.2	0.1851	0.1789	0.1035	0.1817	0.1641	0.0468
ρ_v	Preferences	beta	0.5	0.2	0.5519	0.5559	0.4084	0.5684	0.5747	0.6094
ρ_{σ_M}	Housing quality vol.	beta	0.5	0.2	0.6642	0.6789	0.8202	0.6318	0.6027	0.8007
ρ_{σ_F}	Corporate profits vol.	beta	0.5	0.2	0.7033	0.6867	0.9737	0.6869	0.6793	0.9768
ρ_{λ^B}	Asset diversion vol.	beta	0.5	0.2				0.7930	0.7935	0.6753
σ_a	Non-stationary prod.	beta	0.01	∞	0.0052	0.0056	0.0144	0.0097	0.0097	0.0131
σ_z	Stationary prod.	beta	0.01	∞	0.0046	0.0045	0.0163	0.0047	0.0046	0.0136
σ_R	Monetary policy	beta	0.01	∞	0.0023	0.0023	0.0024	0.0023	0.0023	0.0023
σ_ζ	Risk premium	beta	0.01	∞	0.0025	0.0026	0.0021	0.0021	0.0021	0.0021
σ_u	Capital utilization	beta	0.01	∞	0.4462	0.4509	0.4037	0.4495	0.4540	0.3923
σ_v	Preferences	beta	0.01	∞	0.0080	0.0079	0.0150	0.0097	0.0097	0.0150
σ_{σ_M}	Housing quality vol.	beta	0.01	∞	0.0577	0.0554	0.0520	0.0459	0.0481	0.0490
σ_{σ_F}	Corporate profits vol.	beta	0.01	∞	0.0528	0.0416	0.0853	0.3519	0.2276	0.0816
σ_{λ^B}	Asset diversion vol.	beta	0.01	∞				0.0472	0.0469	0.0078
σ_F	Steady state profits vol.	-	-	-	0.018	0.028	0.028	0.018	0.028	0.028

Note: All estimations use macro data. Macro data includes: real GDP growth, consumption growth, investment growth, CPI inflation change, nominal gross interest rate change, real exchange rate growth, change in the trade balance to GDP ratio. All models also use household spread and corporate spread for estimation, but only models with financial frictions for banks (DO-GK and BGG-GK) use the bank spread for estimation as well.
Abbreviations: "Fin." stands for financial. "DO" means debt overhang, "BGG" means monitoring frictions as implemented in Bernanke et al. (1999). "GK" means the endogenous bank leverage constraint as implemented in Gertler and Karadi (2011).

B Households

B.1 Household debt contract

The household i finds it optimal to default, if the collateral value is lower than the debt value. Given that a fixed fraction α^{FM} of the mortgage is in foreign currency, the household defaults if:

$$\omega_{i,t}\left(\zeta^h q_t^h h_{i,t-1}^I\right) \leq R_{t-1}^M\left(\frac{\alpha^{FM} rer_t}{\pi_t^*} + \frac{1-\alpha^{FM}}{\pi_t}\right) m_{i,t-1}$$

Thus, the default threshold is given by the household-specific shock value ω_t such that:

$$\bar{\omega}_{i,t} \equiv \omega_{i,t} = \frac{R_{t-1}^M\left(\frac{\alpha^{FM} rer_t}{\pi_t^*} + \frac{1-\alpha^{FM}}{\pi_t}\right) m_{i,t-1}}{\zeta^h q_t^h h_{i,t-1}^I}$$

We can define the fraction of defaulted impatient households G_t:

$$G_t \equiv \int_0^{\bar{\omega}_t} \omega_t f\left(\omega_t\right) d\omega_t$$

Let the fraction of household net worth attributed to the bank be $\Gamma_t \zeta^h q_{t+1}^h h_t^I$, where

$$\Gamma_t \equiv \int_0^{\bar{\omega}_t} \omega_t f\left(\omega_t\right) d\omega_t + \bar{\omega}_t \int_{\bar{\omega}_t}^{\infty} f\left(\omega_t\right) d\omega_t$$

Given the extensive derivations for the optimal debt contract with monitoring costs provided in, for instance, the appendix of Devereux et al. (2006), it can be showed that

$$\Gamma_t = \bar{\omega}_t\left(1-\Phi\left(d_t^M\right)\right) + (1-\mu_F)\Phi\left(d_t^M - \sigma_t^M\right)$$

$$\Gamma_t' = \left(1-\Phi\left(d_t^M\right)\right) - \mu_F \Phi'\left(d_t^M\right)$$

$$G_t = 1-\Phi\left(d_t^M - \sigma_t^M\right) - \bar{\omega}_t\left(1-\Phi\left(d_t^M\right)\right)$$

$$G_t' = -\left(1-\Phi\left(d_t^M - \sigma_t^M\right)\right)$$

where

$$d_t^M = \frac{ln(\bar{\omega}_t) + 1/2\left(\sigma_t^M\right)^2}{\sigma_t^M}$$

B.2 Wage setting

Only a share $(1-\omega^W)$ of households will be allowed to adjust their wages in a given period. So households set wages by taking into account the probability of not being able to adjust wages in the future. This utility maximization problem can be formalized to

$$\max_{\{W_{t,i}^{P*}\}} E_t \sum_{k=0}^{\infty} \left(\beta^P \omega^W\right)^k U^P \left(c_{t+k,i}^P, h_{t+k,i}^P, n_{t+k,i}^P\right) \tag{B.1}$$

subject to the demand for labor of type i:

$$n_{t+k,i}^P = \left(\frac{W_{t,i}^{P*}}{W_{t+k}^P}\right)^{-\epsilon_W} n_{t+k}^P \tag{B.2}$$

n_t^P is aggregate labor supply of patient households, obtained by using the aggregation technology $n_t^P = \left(\int_0^1 \left(n_{t,i}^P\right)^{\frac{\epsilon_W - 1}{\epsilon_W}} di\right)^{\frac{\epsilon_W}{\epsilon_W - 1}}$. ϵ_W denotes labor supply elasticity among different types and W_t^P is aggregated nominal wage $W_t^P = \left(\int_0^1 \left(W_{t,i}^P\right)^{1-\epsilon_W} di\right)^{\frac{1}{1-\epsilon_W}}$. Labor demand for labor of type i can be derived from a perfectly competitive labor packer's profit maximization problem, where $w_t^P n_t^P - \int_0^1 w_{t,i}^P n_{t,i}^P di$ would be maximized with respect to $n_{t,i}^P$.

Solving the maximization problem described by (B.1) and (B.2) yields a first order condition for the optimal wage:

$$E_t \sum_{k=0}^{\infty} \left(\beta^P \omega^W\right)^k \left(U_c^P \left(1 + \frac{\partial n_{t+k,i}^P}{\partial W_{t,i}^{P*}} W_{t,i}^{P*}\right) \frac{W_{t,i}^P}{P_{t+k}} + U_n^P \frac{\partial n_{t+k,i}^P}{\partial W_{t,i}^{P*}} W_{t,i}^{P*}\right) = 0$$

where

$$\frac{\partial n_{t+k,i}^P}{\partial W_{t,i}^{P*}} = -\epsilon_W \left(\frac{W_{t,i}^{P*}}{W_{t+k}^P}\right)^{-\epsilon_W - 1} \frac{n_{t+k}^P}{W_{t+k}^P}$$

The optimal nominal wage W_t^{P*} is given by

$$\left(\frac{W_t^{P*}}{P_{t+k}}\right)^{1+\epsilon_W \sigma_n} = \frac{\epsilon_W}{\epsilon_W - 1} \frac{E_t \sum_{k=0}^{\infty} \left(\beta^P \omega^W\right)^k \left(A_n \left(W_{t+k}^P\right)^{\epsilon_W (1+\sigma_n)} \left(n_{t+k}^P\right)^{(1+\sigma_n)}\right)}{E_t \sum_{k=0}^{\infty} \left(\beta^P \omega^W\right)^k \left(\left(W_{t+k}^P\right)^{\epsilon_W} n_{t+k}^P \left(c_{t,i}^P\right)^{-\sigma_c}\right)}$$

After deflating this condition we obtain recursive expressions to describe wage setting of patient households (H.13)-(H.15).

Impatient households, like patient households, have monopoly power in a labor market and can set wages. Similarly to patient households, we can show that optimal wage setting will follow the conditions (H.19)-(H.21).

Labor supply of patient households and aggregated labor supply of impatient households is aggregated by the perfectly competitive labor that is described in section D.6.

C Financially constrained firms

C.1 Solving the financially constrained firms' profit maximization problem with FX loans

To pay in advance, a financially constrained firm i borrows from the bank an amount $L_{i,t}$ that consists of both domestic currency funds $L^D_{i,t}$ and foreign currency denominated funds $L^F_{i,t}$ such that $L_{i,t} = L^D_{i,t}+S_t L^F_{i,t}$ where S_t is the nominal exchange rate. We assume that the share of foreign currency denominated funds is fixed and denoted by α^{FF}, so that the firm can choose the size of the total loan but not the denomination structure. This assumption allows us to calibrate the open position of banks and is innocuous enough, since we study the consequences of foreign currency borrowing rather than the choice of the borrowing currency.

We assume that the firm decides how much to borrow before shocks arrive and the prices of production inputs are revealed. Then the demanded size of the loan is equal to the expected expenditure for working capital. It follows that in the beginning of period t the following condition holds:

$$E_{t-1}\left\{L_{i,t}\right\} = E_{t-1}\left\{(Q_t k_{i,t} + W_t n_{i,t})\right\}$$

Or, in units of composite goods associated with price P_t,

$$E_{t-1}\left\{l_{i,t}\right\} = E_{t-1}\left\{(q_t k_{i,t} + w_t n_{i,t})\right\}$$

q_t, w_t and rer_t denote the real price of capital, the real wage and the real exchange rate respectively. We express all three prices are expressed in units of composite goods. It follows that we define q_t as Q_t/P_t, w_t as W_t/P_t and the real exchange rate as $S_t P^*_t/P_t$ where S_t is the nominal exchange rate, P_t is the price of composite goods and P^*_t defines the price level of foreign composite goods. $l_{i,t}$ stands for the size of the total loan expressed in units of composite goods and is defined as $l_{i,t} \equiv L_{i,t}/P_t$. After the loan is taken, shocks materialize, however, the predetermined size of the loan creates the debt overhang effect by distorting firm's private incentives to invest in production inputs.

Because of the timing of new information, the actual demand for working capital by the firm will in most cases not equal the loan amount received. We assume that in such cases households step in and transfer lump-sum funds $N^F_{i,t}$ (where $n^F_{i,t} \equiv N^F_{i,t}/P_t$) to cover the difference. Importantly, these funds constitute residual funding and firms cannot rely on them as the main source of finance. These funds enter the domestic household's budget constraint as a lump-sum transfer and have no effect on either the household's or the firm's incentives.

Let the matured loan in units of composite goods be $R^L_{i,t}\left(\frac{l^D_{i,t}}{\pi_{t+1}} + rer_{t+1}\frac{l^F_{i,t}}{\pi^*_{t+1}}\right)$, where $R^L_{i,t}$ is the nominal gross interest rate on the loan. The bank sets interest rates on loans after the shocks take place, therefore, the loan rate adjusts to clear the loan market. We define real loans in different currencies as $l^D_{i,t} \equiv L^D_{i,t}/P_t$ and $l^F_{i,t} \equiv L^F_{i,t}/P^*_t$. To borrow, the firm has to pledge a share κ of future revenue as collateral where $0 < \kappa \leq 1$. Then the contracted collateral is a fraction κ of firms' revenue from selling goods and depreciated capital in the next period, $p^L_{t+1}y^L_{i,t+1} + q_{t+1}(1-\delta)k_{i,t}$. p^L_{t+1} stands for the price of homogeneous goods, expressed in units of composite goods ($p^L_{t+1} \equiv P^L_{t+1}/P_{t+1}$). Then the decision of the financially constrained firm i born in period t whether to default or not is determined by the lower value:

$$\min\left\{R^L_{i,t}\left(L^D_{i,t} + S_{t+1}L^F_{i,t}\right), \quad \kappa\left(P^L_{t+1}y^L_{i,t+1} + Q_{t+1}(1-\delta)k_{i,t}\right)\right\}$$

Deflating by P_{t+1} gives the expression in units of composite goods:

$$\min\left\{R^L_{i,t}\left(\frac{l^D_{i,t}}{\pi_{t+1}} + rer_{t+1}\frac{l^F_{i,t}}{\pi^*_{t+1}}\right), \quad \kappa\left(p^L_{t+1}y^L_{i,t+1} + q_{t+1}(1-\delta)k_{i,t}\right)\right\}$$

where $p^L_{t+1}y^L_{i,t+1} = p^L_{t+1}A_{t+1}\theta_{i,t+1}k^{\alpha}_{i,t}n^{1-\alpha}_{i,t}$.

The firm maximizes expected profits given by future revenue from selling goods and depreciated capital minus the debt payment minus the equity transfer, where $N^F_{i,t} = Q_t k_{i,t} + W_t n_{i,t} - L_{i,t}$:

$$\begin{aligned}\max_{\{k_{i,t},n_{i,t}\}} & E_t\beta^P\Lambda^P_{t,t+1}\frac{\{P^L_{t+1}y^L_{i,t+1} + Q_{t+1}(1-\delta)k_{i,t}\}}{P_{t+1}} \\ & - E_t\beta^P\Lambda^P_{t,t+1}\min\left\{\frac{R^L_{i,t}\left(L^D_{i,t} + S_{t+1}L^F_{i,t}\right)}{P_{t+1}}, \quad \frac{\kappa\left(P^L_{t+1}y^L_{i,t+1} + Q_{t+1}(1-\delta)k_{i,t}\right)}{P_{t+1}}\right\} \\ & + \frac{L_{i,t} + N^F_{i,t}}{P_t} - \frac{Q_t k_{i,t} + W_t n_{i,t}}{P_t}\end{aligned}$$

s.t.

$$\frac{E_{t-1}\{L_{i,t}\}}{P_t} = \frac{E_{t-1}\{Q_t k_{i,t} + W_t n_{i,t}\}}{P_t}$$

Using the previously introduced definitions yields

$$\begin{aligned}\max_{\{k_{i,t},n_{i,t}\}} & E_t\beta^P\Lambda^P_{t,t+1}\left\{p^L_{t+1}y^L_{i,t+1} + q_{t+1}(1-\delta)k_{i,t}\right\} \\ & - E_t\beta^P\Lambda^P_{t,t+1}\min\left\{R^L_{i,t}\left(\frac{l^D_{i,t}}{\pi_{t+1}} + rer_{t+1}\frac{l^F_{i,t}}{\pi^*_{t+1}}\right), \quad \kappa\left(p^L_{t+1}y^L_{i,t+1} + q_{t+1}(1-\delta)k_{i,t}\right)\right\} \\ & + l_{i,t} - (q_t k_{i,t} + w_t n_{i,t})\end{aligned}$$

s.t.

$$E_{t-1}\left\{l_{i,t}\right\} = E_{t-1}\left\{q_t k_{i,t} + w_t n_{i,t}\right\} \tag{C.1}$$

The resulting first-order conditions are:

$$\begin{aligned}
k_{i,t}: \quad & E_t \beta^P \Lambda^P_{t,t+1} \left\{ p^L_{t+1} \frac{\partial y^L_{i,t+1}}{\partial k_{i,t}} + q_{t+1}(1-\delta) \right\} \\
& - E_t \beta^P \Lambda^P_{t,t+1} \left\{ (1-\Phi(d_{1,t}))\kappa \left(p^L_{t+1} \frac{\partial y^L_{i,t+1}}{\partial k_{i,t}} + q_{t+1}(1-\delta) \right) \right\} \\
& - \frac{\partial cov \left(\beta^P \Lambda^P_{t,t+1}, \quad \min \left\{ R^L_{i,t} \left(\frac{l^D_{i,t}}{\pi_{t+1}} + rer_{t+1} \frac{l^F_{i,t}}{\pi^*_{t+1}} \right), \quad \kappa \left(p^L_{t+1} y^L_{i,t+1} + q_{t+1}(1-\delta) k_{i,t} \right) \right\} \right)}{\partial k_{i,t}} \\
& = q_t
\end{aligned}$$

$$\begin{aligned}
n_{i,t}: \quad & E_t \beta^P \Lambda^P_{t,t+1} \left\{ p^L_{t+1} \frac{\partial y^L_{i,t+1}}{\partial n_{i,t}} \right\} \\
& - E_t \beta^P \Lambda^P_{t,t+1} \left\{ (1-\Phi(d_{1,t}))\kappa \left(p^L_{t+1} \frac{\partial y^L_{i,t+1}}{\partial n_{i,t}} \right) \right\} \\
& - \frac{\partial cov \left(\beta^P \Lambda^P_{t,t+1}, \quad \min \left\{ R^L_{i,t} \left(\frac{l^D_{i,t}}{\pi_{t+1}} + rer_{t+1} \frac{l^F_{i,t}}{\pi^*_{t+1}} \right), \quad \kappa \left(p^L_{t+1} y^L_{i,t+1} + q_{t+1}(1-\delta) k_{i,t} \right) \right\} \right)}{\partial n_{i,t}} \\
& = w_t
\end{aligned}$$

where

$$d_{2,t} \equiv \frac{E_t \ln \left(\kappa \left(p^L_{t+1} y^L_{i,t+1} + q_{t+1}(1-\delta) k_{i,t} \right) - R^L_t rer_{t+1} \frac{l^F_{i,t}}{\pi^*_{t+1}} \right) - E_t \ln \left(R^L_{i,t} \frac{l^D_{i,t}}{\pi_{t+1}} \right)}{\sigma_{F,t}}, \qquad d_{1,t} = d_{2,t} + \sigma_{F,t}$$

The derivation of $d_{2,t}$ is given in the next subsection and results for the first-order conditions are given by equations (C.2) and (C.3). In deriving $d_{2,t}$, we largely follow Occhino and Pescatori (2015).

The first-order conditions hold together with the *ex ante* budget constraint provided in equation (C.1).

C.2 Derivation of the default probability

We need to compute the expected value of the firm's payment function (we abstract from indices i for the sake of brevity):

$$E_t \min \left\{ R_t^L \left(\frac{l_t^D}{\pi_{t+1}} + rer_{t+1} \frac{l_t^F}{\pi_{t+1}^*} \right), \quad \kappa \left(p_{t+1}^L y_{t+1}^L + q_{t+1}(1-\delta)k_t \right) \right\}$$

To simplify, we re-order the terms in the following way:

$$E_t \min \left\{ R_t^L \frac{l_t^D}{\pi_{t+1}}, \quad \kappa \left(p_{t+1}^L y_{t+1}^L + q_{t+1}(1-\delta)k_t \right) - R_t^L rer_{t+1} \frac{l_t^F}{\pi_{t+1}^*} \right\} + E_t R_t^L rer_{t+1} \frac{l_t^F}{\pi_{t+1}^*}$$

Further we focus on the first term only, since it defines the default decision and contains all necessary prices too:

$$E_t \min \left\{ R_t^L \frac{l_t^D}{\pi_{t+1}}, \quad \kappa \left(p_{t+1}^L y_{t+1}^L + q_{t+1}(1-\delta)k_t \right) - R_t^L rer_{t+1} \frac{l_t^F}{\pi_{t+1}^*} \right\}$$

Define $\bar{y}_{t+1} \equiv \pi_{t+1} \left(\kappa \left(p_{t+1}^L y_{t+1}^L + q_{t+1}(1-\delta)k_t \right) - R_t^L rer_{t+1} \frac{l_t^F}{\pi_{t+1}^*} \right)$, where

$$\bar{y}_{t+1} \sim \text{log-normal} \left(\mu_{\bar{y}_{t+1}}, \sigma_{F,t}^2 \right)$$

Then the modified minimum function can be re-written as

$$E_t \min \left\{ R_t^L l_t^D, \quad \bar{y}_{t+1} \right\}$$

Further,

$$
\begin{aligned}
E_t \min\left\{R_t^L l_t^D, \quad \bar{y}_{t+1}\right\} &= R_t^L l_t^D Pr\left(R_t^L l_t^D < \bar{y}_{t+1}\right) + \left(1 - Pr\left(R_t^L l_t^D < \bar{y}_{t+1}\right)\right) E_t\left(\bar{y}_{t+1} \mid \bar{y}_{t+1} < R_t^L l_t^D\right) \\
&= R_t^L l_t^D Pr\left(R_t^L l_t^D < \bar{y}_{t+1}\right) + \left(1 - Pr\left(R_t^L l_t^D < \bar{y}_{t+1}\right)\right) \int_0^{R_t^L l_t^D} \frac{\bar{y}_{t+1} dF\left(\bar{y}_{t+1}\right)}{1 - Pr\left(R_t^L l_t^D < \bar{y}_{t+1}\right)} \\
&= R_t^L l_t^D Pr\left(R_t^L l_t^D < \bar{y}_{t+1}\right) + \int_0^{R_t^L l_t^D} \bar{y}_{t+1} dF\left(\bar{y}_{t+1}\right) \\
&= R_t^L l_t^D \int_{R_t^L l_t^D}^{\infty} dF\left(\bar{y}_{t+1}\right) + \int_0^{R_t^L l_t^D} \bar{y}_{t+1} dF\left(\bar{y}_{t+1}\right) \\
&= R_t^L l_t^D \int_{R_t^L l_t^D}^{\infty} \frac{1}{\bar{y}_{t+1}\sigma_{F,t}\sqrt{2\pi}} e^{\frac{-\left(ln\left(\bar{y}_{t+1}\right)-\mu_y\right)^2}{2\sigma_{F,t}^2}} d\left(\bar{y}_{t+1}\right) \\
&+ \int_0^{R_t^L l_t^D} \frac{\bar{y}_{t+1}}{\bar{y}_{t+1}\sigma_{F,t}\sqrt{2\pi}} e^{\frac{-\left(ln\left(\bar{y}_{t+1}\right)-\mu_y\right)^2}{2\sigma_{F,t}^2}} d\left(\bar{y}_{t+1}\right) \\
&= R_t^L l_t^D \Phi\left(\frac{ln\left(\bar{y}_{t+1}\right) - \mu_y}{\sigma_{F,t}}\right) |_{R_t^L l_t^D}^{\infty} + \int_0^{R_t^L l_t^D} \frac{1}{\sigma_{F,t}\sqrt{2\pi}} e^{\frac{-\left(ln\left(\bar{y}_{t+1}\right)-\mu_y\right)^2}{2\sigma_{F,t}^2}} d\left(\bar{y}_{t+1}\right) \\
&= R_t^L l_t^D \left(1 - \Phi\left(\frac{ln\left(R_t^L l_t^D\right) - \mu_y}{\sigma_{F,t}}\right)\right) - \frac{1}{2} e^{\mu_y + \frac{\sigma_{F,t}^2}{2}} erf\left(\frac{-ln\left(\bar{y}_{t+1}\right) + \mu_y + \sigma_{F,t}^2}{\sqrt{2}\sigma_{F,t}}\right) |_0^{R_t^L l_t^D} \\
&= R_t^L l_t^D \Phi\left(\frac{\mu_y - ln\left(R_t^L l_t^D\right)}{\sigma_{F,t}}\right) + \frac{1}{2} E_t(\bar{y}_{t+1}) \left(erf\left(\frac{ln\left(R_t^L l_t^D\right) - \mu_y - \sigma_{F,t}^2}{\sqrt{2}\sigma_{F,t}}\right) + 1\right) \\
&= R_t^L l_t^D \Phi\left(\frac{\mu_y - ln\left(R_t^L l_t^D\right)}{\sigma_{F,t}}\right) + E_t(\bar{y}_{t+1}) \Phi\left(\frac{ln\left(R_t^L l_t^D\right) - \mu_y - \sigma_{F,t}^2}{\sigma_{F,t}}\right) \\
&= R_t^L l_t^D \Phi\left(\frac{\mu_y - ln\left(R_t^L l_t^D\right)}{\sigma_{F,t}}\right) + E_t(\bar{y}_{t+1}) \left(1 - \Phi\left(\frac{\mu_y - ln\left(R_t^L l_t^D\right)}{\sigma_{F,t}} + \sigma_{F,t}\right)\right)
\end{aligned}
$$

The expression can be simplified as

$$E_t \min\left\{R_t^L l_t^D, \quad \bar{y}_{t+1}\right\} = \left(1 - \Phi(d_{1,t})\right) E_t\left(\bar{y}_{t+1}\right) + \Phi(d_{2,t}) R_t^L l_t^D$$

where

$$d_{2,t} \equiv \frac{\mu_y - \ln\left(R_t^L l_t^D\right)}{\sigma_{F,t}}, \qquad d_{1,t} \equiv d_{2,t} + \sigma_{F,t}$$

where

$$\mu_y \equiv E_t \ln\left(\bar{y}_{t+1}\right)$$

or

$$d_{2,t} \equiv \frac{E_t \ln\left(\bar{y}_{t+1}/\pi_{t+1}\right) - \ln\left(R_t^L/\pi_{t+1} l_t^D\right)}{\sigma_{F,t}}, \qquad d_{1,t} \equiv d_{2,t} + \sigma_{F,t}$$

Recall that $\bar{y}_{t+1} \equiv \pi_{t+1}\left(\kappa\left(p_{t+1}^R y_{t+1}^R + q_{t+1}(1-\delta)k_t\right) - R_t^L rer_{t+1}\frac{l_t^F}{\pi_{t+1}^*}\right)$, so it can be substituted back.

It follows that $\sigma^2_{F,t} = var\left(\bar{y}_{t+1}\right) = var\left(\pi_{t+1}\left(\kappa\left(p^R_{t+1}y^R_{t+1} + q_{t+1}(1-\delta)k_t\right) - R^L_t rer_{t+1}\frac{l^F_t}{\pi^*_{t+1}}\right)\right)$.

To solve for the first-order conditions, we differentiate the expected loan payment w.r.t. k_t:

$$
\begin{aligned}
\frac{\partial E_t \min\left\{R^L_t l^D_t, \quad \bar{y}_{t+1}\right\}}{\partial k_t} &= (1-\Phi(d_{1,t}))\frac{\partial E_t\bar{y}_{t+1}}{\partial k_t} \\
&- E_t\bar{y}_{t+1}\frac{\partial\Phi(d_{1,t})}{\partial d_{1,t}}\frac{\partial d_{1,t}}{\partial k_t} + R^L_t l^D_t\frac{\partial\Phi(d_{2,t})}{\partial d_{2,t}}\frac{\partial d_{2,t}}{\partial k_t} \\
&= (1-\Phi(d_{1,t}))\frac{\partial E_t\bar{y}_{t+1}}{\partial k_t}
\end{aligned}
$$

where the proof of the last expression comes from by using $\frac{\partial d_{1,t}}{\partial k_t} = \frac{\partial d_{2,t}}{\partial k_t}$ and computing the following:

$$
\begin{aligned}
& -E_t\left(\bar{y}_{t+1}\right)\Phi'(d_{1,t}) + R^L_t l^D_t\Phi'(d_{2,t}) \\
=\ & -e^{\ln(E_t\bar{y}_{t+1})}\Phi'(d_{1,t}) + e^{\ln(R^L_t l^D_t)}\Phi'(d_{2,t}) \\
=\ & -e^{\ln(E_t\bar{y}_{t+1})}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{1,t}} + e^{\ln(R^L_t l^D_t)}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{2,t}} \\
=\ & -e^{\ln(E_t\bar{y}_{t+1})}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}\left(d^2_{2,t}+2d_{2,t}\sigma_{F,t}+\sigma^2_{F,t}\right)} + e^{\ln(R^L_t l^D_t)}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{2,t}} \\
=\ & -e^{\ln(E_t\bar{y}_{t+1})}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{2,t}}e^{-\left(d_{2,t}\sigma_{F,t}+\frac{1}{2}\sigma^2_{F,t}\right)} + e^{\ln(R^L_t l^D_t)}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{2,t}} \\
=\ & -e^{\ln(E_t\bar{y}_{t+1})}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{2,t}}e^{-E_t\left(\ln\bar{y}_{t+1}\right)-\ln(R^L_t l^D_t)+\frac{1}{2}\sigma^2_{F,t}} + e^{\ln(R^L_t l^D_t)}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{2,t}} \\
=\ & \frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{2,t}}\left[-e^{\ln(E_t\bar{y}_{t+1})}e^{-\left(\ln(E_t\bar{y}_{t+1})-\frac{1}{2}\sigma^2_{F,t}-\ln(R^L_t l^D_t)+\frac{1}{2}\sigma^2_{F,t}\right)} + e^{\ln(R^L_t l^D_t)}\right] \\
=\ & -\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{2,t}}e^{\ln(R^L_t l^D_t)} + e^{\ln(R^L_t l^D_t)}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}d^2_{2,t}} \\
=\ & 0,
\end{aligned}
$$

In this derivation we use the results for log-normal variables such as $E_t\ln\left(\bar{y}_{t+1}\right) = \ln\left(E_t\bar{y}_{t+1}\right) - \frac{1}{2}\sigma^2_{F,t}$ and and the definition of $d_{1,t}$. Substituting a definition for $\bar{y}_{t+1}$ back gives

$$
\begin{aligned}
&\frac{\partial E_t \min\left\{\frac{R^L_t}{\pi_{t+1}}l^D_t, \quad \kappa\left(p^L_{t+1}y^L_{t+1} + q_{t+1}(1-\delta)k_t\right) - R^L_t rer_{t+1}\frac{l^F_t}{\pi^*_{t+1}}\right\}}{\partial k_t} \\
&= (1-\Phi(d_{1,t}))\frac{\partial E_t\kappa\left(p^L_{t+1}y^L_{t+1} + q_{t+1}(1-\delta)k_t\right)}{\partial k_t} \qquad \text{(C.2)}
\end{aligned}
$$

Similarly it can be showed that

$$\frac{\partial E_t \min\left\{\frac{R_t^L}{\pi_{t+1}} l_t^D, \quad \kappa\left(p_{t+1}^L y_{t+1}^L + q_{t+1}(1-\delta)k_t\right) - R_t^L rer_{t+1}\frac{l_t^F}{\pi_{t+1}^*}\right\}}{\partial n_t} = (1-\Phi(d_{1,t}))\,\frac{\partial E_t \kappa\left(p_{t+1}^L y_{t+1}^L\right)}{\partial n_t} \tag{C.3}$$

C.3 Solving the financially constrained firms' profit maximization problem with domestic currency loans

Now the matured loan in units of composite goods is $R_{i,t}^L \frac{L_{i,t}}{P_{t+1}} \equiv R_{i,t}^L \frac{l_{i,t}}{\pi_{t+1}}$. The loan is denominated in domestic currency and $R_{i,t}^L$ is the nominal gross interest rate on the loan. The contracted collateral is a fraction κ of firms' revenue from selling goods and depreciated capital in the next period. In units of composite goods the contracted collateral can be expressed as $p_{t+1}^L y_{i,t+1}^L + q_{t+1}(1-\delta)k_{i,t}$. Then the decision of the financially constrained firm i born in period t whether to default or not is determined by the lower value:

$$\min\left\{R_{i,t}^L \frac{l_{i,t}}{\pi_{t+1}}, \quad \kappa\left(p_{t+1}^L y_{i,t+1}^L + q_{t+1}(1-\delta)k_{i,t}\right)\right\}$$

As previously, $p_{t+1}^L y_{i,t+1}^L = p_{t+1}^L A_{t+1}\theta_{i,t+1} k_{i,t}^{\alpha} n_{i,t}^{1-\alpha}$, $p_{t+1}^L \equiv P_{t+1}^L / P_{t+1}$ and $q_{t+1} \equiv Q_{t+1}/P_{t+1}$.

The maximization problem can be written as

$$\begin{aligned}\max_{\{k_{i,t}, n_{i,t}\}} & E_t \beta^P \Lambda_{t,t+1}^P \left\{\frac{P_{t+1}^L y_{i,t+1}^L + Q_{t+1}(1-\delta)k_{i,t}}{P_{t+1}}\right\} \\ & - E_t \beta^P \Lambda_{t,t+1}^P \min\left\{\frac{R_{i,t}^L L_{i,t}}{P_{t+1}}, \quad \frac{\kappa\left(P_{t+1}^L y_{i,t+1}^L + Q_{t+1}(1-\delta)k_{i,t}\right)}{P_{t+1}}\right\} \\ & + \frac{L_{i,t}}{P_t} - \frac{Q_t k_{i,t} + W_t n_{i,t}}{P_t}\end{aligned}$$

s.t.

$$\frac{E_{t-1}\left\{L_{i,t}\right\}}{P_t} = \frac{E_{t-1}\left\{Q_t k_{i,t} + W_t n_{i,t}\right\}}{P_t}$$

Using the previously introduced definitions yields

$$\begin{aligned}\max_{\{k_{i,t}, n_{i,t}\}} & E_t \beta^P \Lambda_{t,t+1}^P \left\{p_{t+1}^L y_{i,t+1}^L + q_{t+1}(1-\delta)\frac{k_{i,t}}{\pi_{t+1}}\right\} \\ & - E_t \beta^P \Lambda_{t,t+1}^P \min\left\{R_{i,t}^L \frac{l_{i,t}}{\pi_{t+1}}, \quad \kappa\left(p_{t+1}^L y_{i,t+1}^L + q_{t+1}(1-\delta)k_{i,t}\right)\right\} \\ & + l_{i,t} - (q_t k_{i,t} + w_t n_{i,t})\end{aligned}$$

s.t.

$$E_{t-1}\left\{l_{i,t}\right\} = E_{t-1}\left\{q_t k_{i,t} + w_t n_{i,t}\right\} \tag{C.4}$$

The resulting first-order conditions are:

$$\begin{aligned}
k_{i,t}: \quad & E_t \beta^P \Lambda^P_{t,t+1} \left\{ p^L_{t+1} \frac{\partial y^L_{i,t+1}}{\partial k_{i,t}} + q_{t+1}(1-\delta) \right\} \\
& - E_t \beta^P \Lambda^P_{t,t+1} \left\{ (1-\Phi(d_{1,t}))\kappa \left(p^L_{t+1} \frac{\partial y^L_{i,t+1}}{\partial k_{i,t}} + q_{t+1}(1-\delta) \right) \right\} \\
& = \frac{\partial cov\left(\beta^P \Lambda^P_{t,t+1}, \quad \min\left\{ R^L_{i,t} \frac{l_{i,t}}{\pi_{t+1}}, \quad \kappa\left(p^L_{t+1} y^L_{i,t+1} + q_{t+1}(1-\delta)k_{i,t} \right) \right\} \right)}{\partial k_{i,t}} \\
& + q_t
\end{aligned}$$

$$\begin{aligned}
n_{i,t}: \quad & E_t \beta^P \Lambda^P_{t,t+1} \left\{ p^L_{t+1} \frac{\partial y^L_{i,t+1}}{\partial n_{i,t}} \right\} \\
& - E_t \beta^P \Lambda^P_{t,t+1} \left\{ (1-\Phi(d_{1,t}))\kappa \left(p^L_{t+1} \frac{\partial y^L_{i,t+1}}{\partial n_{i,t}} \right) \right\} \\
& = \frac{\partial cov\left(\beta^P \Lambda^P_{t,t+1}, \quad \min\left\{ R^L_{i,t} \frac{l_{i,t}}{\pi_{t+1}}, \quad \kappa\left(p^L_{t+1} y^L_{i,t+1} + q_{t+1}(1-\delta)k_{i,t} \right) \right\} \right)}{\partial n_{i,t}} \\
& + w_t
\end{aligned}$$

where

$$d_{2,t} \equiv \frac{E_t \ln\left(\kappa\left(p^L_{t+1} y^L_{i,t+1} + q_{t+1}(1-\delta)k_{i,t} \right) \right) - E_t \ln\left(R^L_{i,t} \frac{l_{i,t}}{\pi_{t+1}} \right)}{\sigma_{F,t}}, \qquad d_{1,t} = d_{2,t} + \sigma_{F,t}$$

and $\sigma^2_{F,t} = var\left(\pi_{t+1}\kappa\left(p^L_{t+1} y^L_{t+1} + q_{t+1}(1-\delta)k_t \right) \right)$.

The first-order conditions hold together with the *ex ante* budget constraint provided in equation (C.4).

D Other firms

D.1 Retail firms

Homogeneous goods produced by financially constrained firms are sold to domestic retail firms. A domestic retail firm j differentiates purchased inputs at no cost and sells at a monopolistic price $p^H_t(j)$. We assume that only a fraction $(1-\omega^H)$ of domestic retail firms can adjust prices every period as in Calvo (1983). The fraction ω^H of remaining firms adjust past prices by the rate π_t^{adj}. The aggregate price level that prevails in the retail sector is denoted by p_t^H. Differentiated goods from the domestic retail sector, $y_t^H(j), \quad j \in (0,1)$, are purchased by the composite goods producer.

D.2 Importers

Parallel to differentiated domestic goods produced in the domestic retail sector, there is another strand of differentiated goods in the economy that is used as an input for the production of domestic final goods. In particular, we assume a set of importers that buy foreign goods from abroad and differentiate them. Importers exercise market power and set prices in the staggered way as in Calvo (1983), which allows for the incomplete exchange rate pass-through. Thus, $(1-\omega^F)$ of importers change their past prices to the optimal price at period t. The fraction ω^F of remaining firms adjust past prices by the rate π_t^{adj}. The aggregate price level that prevails in the retail sector is denoted by p_t^F.

D.3 Composite goods producer

We assume that the composite goods producer has access to an aggregation technology and can assemble differentiated goods at no cost. First, the composite goods producer assembles differentiated domestic goods $y_t^H(j)\forall j$ into domestic aggregate goods y_t^H and differentiated imported goods $y_t^F(j)\forall j$ into foreign aggregate goods y_t^F. She uses the following assembling technologies:

$$y_t^H = \left(\int_0^1 y_t^H(j)^{1-\frac{1}{\epsilon_H}}\,dj\right)^{\frac{\epsilon_H}{\epsilon_H-1}},$$

$$y_t^F = \left(\int_0^1 y_t^F(j)^{1-\frac{1}{\epsilon_F}}\,dj\right)^{\frac{\epsilon_F}{\epsilon_F-1}}$$

Aggregate goods can be used to produce consumption composite goods or investment composite goods. The producer combines domestic aggregate goods and foreign aggregate goods into consumption composite goods c_t with the aggregation technology that takes the taste parameter for foreign aggregate goods η_C as given:

$$c_t = \left(\eta_C^{\frac{1}{\epsilon_C}}\left(c_t^H\right)^{\frac{\epsilon_C-1}{\epsilon_C}} + \eta_c^{\frac{1}{\epsilon_C}}\left(c_t^F\right)^{\frac{\epsilon_C-1}{\epsilon_C}}\right)^{\frac{\epsilon_C}{\epsilon_C-1}}$$

Solving a perfectly competitive aggregator's profit maximization problem $c_t - p_t^H c_t^H - p_t^F c_t^F$ yields demand functions for domestic aggregate goods and foreign aggregate goods for consumption composites are as follows:

$$c_t^H = \eta_C \left(p_t^H\right)^{-\epsilon_C} c_t$$

$$c_t^F = (1-\eta_C)\left(p_t^F\right)^{-\epsilon_C} c_t$$

ϵ_C stands for elasticity of substitution between domestic aggregate goods and foreign aggregate goods. The composite consumption good has an associated price P_t.

Similarly, investment composite goods require a perfectly competitive aggregation technology where

$$i_t = \left(\eta_I^{\frac{1}{\epsilon_I}}\left(i_t^H\right)^{\frac{\epsilon_I-1}{\epsilon_I}} + \eta_I^{\frac{1}{\epsilon_I}}\left(i_t^F\right)^{\frac{\epsilon_I-1}{\epsilon_I}}\right)^{\frac{\epsilon_I}{\epsilon_I-1}}$$

Assuming that the associated price of investment composite goods is P_t^I, the respective demand function can be derived straightforwardly and are given by:

$$i_t^H = \eta_I\left(\frac{p_t^H}{p_t^I}\right)^{-\epsilon_I} i_t$$

$$i_t^F = (1-\eta_I)\left(\frac{p_t^F}{p_t^I}\right)^{-\epsilon_I} i_t$$

D.4 Capital producers

Capital producers sell capital to financially constrained firms at the real competitive price q_t and buy the depreciated capital stock back next period. To restore the depreciated capital, capital producers add composite goods (investment) i_t as additional inputs to the depreciated capital stock by using a technology subject to investment adjustment costs $\Gamma\left(\frac{i_t}{i_{t-1}}\right)$:

$$k_t = (1-\delta)k_{t-1} + \left(1-\Gamma\left(\frac{i_t}{i_{t-1}}\right)\right)u_t i_t$$

where adjustment costs Γ equal:

$$\Gamma\left(\frac{i_t}{i_{t-1}}\right) = \frac{\gamma}{2}\left(\frac{i_t}{i_{t-1}}u_t - a\right)^2$$

u_t is an exogenous capital utilization shock.

D.5 Exporters

We assume that perfectly competitive exporters demand y_t^{H*} units of the domestic aggregate good y_t^H, so the supply of the assembled production of domestic retailers has to satisfy both the demand of the composite goods producer and the demand of exporters. Exported goods consist of the domestic aggregate, so they do not use imported inputs.

Exports are sold at a price p_t^H/rer_t which is the price of domestic aggregate goods expressed in units of foreign composite goods. The foreign demand for domestic aggregate goods is price-sensitive:

$$y_t^{H*} = \eta^* \left(\frac{p_t^H}{rer_t}\right)^{-\epsilon_*} y_t^*$$

Consistent with the small open economy assumption, P_t^* and y_t^* are assumed to evolve endogenously.

D.6 Aggregation of labor

Financially constrained firms us labor supplied by both patient and impatient households. To aggregate over the labor supply, we assume that the following technology has to be applied:

$$n_t = \left(\left(n_t^P\right)^{\frac{\epsilon_N - 1}{\epsilon_N}} + \left(n_t^I\right)^{\frac{\epsilon_N - 1}{\epsilon_N}}\right)^{\frac{\epsilon_N}{\epsilon_N - 1}}$$

Solving a perfectly competitive aggregator's profit maximization problem $w_t n_t - w_t^P n_t^P - w_t^I n_t^I$ provides two demand functions for labor supplied by different types of households:

$$n_t^P = \left(\frac{w_t^P}{w_t}\right)^{-\epsilon_N} n_t$$

$$n_t^I = \left(\frac{w_t^I}{w_t}\right)^{-\epsilon_N} n_t$$

E Government

We abstract from normative analysis of government policies and take government spending as exogenous. We assume that to finance a stochastic stream of real government expenditure, g_t, the government collects lump-sum taxes t_t from the household and issues domestic bonds b_t. It has to satisfy the budget constraint:

$$g_t + \frac{R_{t-1}}{\pi_t} b_{t-1} = t_t + b_t$$

Taxes in units of domestic final goods follow this tax rule:

$$t_t = t + \kappa^B \left(b_{t-1} - b\right) + \tau_t$$

F Banks

F.1 Lending in foreign currency with a fixed denomination structure

The domestic household owns all banks that operate in the domestic economy and lend to financially constrained firms and impatient households. We assume that there is a continuum of these banks and every period there is a probability ω^B that a bank continues operating. Otherwise, the net worth is transferred to the owner of the bank, the domestic household. We assume that banks give loans out of accumulated equity N_t^B, deposits D_t and foreign debt D_t^*. The balance sheet constraint of a bank j, expressed in units of composite goods, is given by

$$\frac{N_{j,t}^B + D_{j,t} + S_t D_{j,t}^*}{P_t} = \frac{L_{j,t} + M_{j,t}}{P_t}$$

$L_{j,t}$ consists of both domestic currency funds $L_{j,t}^D$ and foreign currency denominated funds $L_{j,t}^F$ such that $L_{j,t} = L_{j,t}^D + S_t L_{j,t}^F$ where S_t is the nominal exchange rate. $M_{j,t}$ consists of both domestic currency funds $M_{j,t}^D$ and foreign currency denominated funds $M_{j,t}^F$ such that $M_{j,t} = M_{j,t}^D + S_t M_{j,t}^F$.

Banks pay a nominal domestic interest rate R_t on deposits and a nominal foreign interest rate $R_t^* \xi_t$ on foreign debt. R_t^* follows a stationary AR(1) process. ξ_t denotes a premium on bank foreign debt. To ensure stationarity in the model, we assume that the premium depends on the level of bank foreign debt (as in Schmitt-Grohé and Uribe, 2003):

$$\xi_t = \exp\left(\kappa_\xi \frac{(S_t D_t^* - S \cdot D^*)}{S \cdot D^*} + \frac{\zeta_t - \zeta}{\zeta}\right)$$

where ζ_t is an exogenous shock that follows a stable AR(1) process.

Banks are subject to an agency problem as in Gertler and Karadi (2011). At the end of every period, bankers can divert a fraction λ_t^B of assets, but if that happens the bank goes bankrupt (i.e. cannot continue). Creditors take this possibility into account and lend only up to the point where the continuation value of the bank is equal to or higher than the value of what can be diverted. This condition acts as an incentive constraint for the bank and eventually limits expansion of the balance sheet of the bank for given amount of equity.

The only asset on the banks' balance sheet is loans to financially constrained firms, thus, the expected nominal return of the bank j is defined as $R_{j,t}^L$ and given by:

$$E_t\left\{\tilde{R}_{j,t+1}^L L_{j,t}\right\} \equiv E_t \min\left\{R_{j,t}^L\left(L_{j,t}^D + S_{t+1} L_{j,t}^F\right), \quad \kappa\left(P_{t+1}^L y_{j,t+1}^L + Q_{t+1}(1-\delta)k_{j,t}\right)\right\}$$

Or, units of composite goods,

$$E_t\left\{\tilde{R}_{j,t}^L l_{j,t}\right\} \equiv E_t \min\left\{R_{j,t}^L\left(\frac{l_{j,t}^D}{\pi_{t+1}} + rer_{t+1}\frac{l_{j,t}^F}{\pi_{t+1}^*}\right), \quad \kappa\left(p_{t+1}^L y_{j,t+1}^L + q_{t+1}(1-\delta)k_{j,t}\right)\right\}$$

$$\Rightarrow E_t\left\{\tilde{R}^L_{j,t} l_{j,t}\right\} \equiv E_t\left\{(1-\Phi(d_{1,t}))\,\kappa\left(p^L_{t+1}y^L_{j,t+1}+(1-\delta)q_{t+1}k_{j,t}\right)+\Phi(d_{2,t})R^L_{j,t}\frac{l^D_{j,t}}{\pi_{t+1}}\right.$$
$$\left.+\Phi(d_{1,t})R^L_{j,t}rer_{t+1}\frac{l^F_{j,t}}{\pi^*_{t+1}}\right\}$$

We know the expression for the expected return on mortgages $\tilde{R}^M_{j,t}$ from the impatient households section. It is given by equation (8).

Then the optimization problem of the bank j can be written as:

$$V_{j,t} = \max_{\left\{D_{j,t},D^*_{j,t},L_{j,t},M_{j,t}\right\}} \quad E_t\beta^P\Lambda^P_{t,t+1}\left\{(1-\omega^B)\frac{N^B_{j,t+1}}{P_{t+1}}+\omega^B V_{j,t+1}\right\}$$

s.t.

$$V_{j,t} \geq \lambda^B_t\frac{L_{j,t}+M_{j,t}}{P_t}, \qquad \textit{(Incentive constraint)}$$

$$\frac{N^B_{j,t}+D_{j,t}+S_tD^*_{j,t}}{P_t} = \frac{L_{j,t}+M_{j,t}}{P_t}, \qquad \textit{(Balance sheet constraint)}$$

$$\frac{N^B_{j,t}}{P_t} = \frac{\tilde{R}^L_{j,t-1}}{P_t}L_{j,t-1}+\frac{\tilde{R}^M_{j,t-1}}{P_t}M_{j,t-1}-\frac{R_{t-1}}{P_t}D_{j,t-1}-\frac{R^*_{t-1}\xi_{t-1}}{P_t}S_tD^*_{j,t-1} \qquad \textit{(LoM of net worth)}$$

We define $rer_t \equiv P^*_tS_t/P_t$, $d^*_{j,t} \equiv D^*_{j,t}/P^*_t$, $d_{j,t} \equiv D_{j,t}/P_t$, $l_{j,t} \equiv L_{j,t}/P_t$, $m_{j,t} \equiv M_{j,t}/P_t$ and $n_{j,t} \equiv N^B_{j,t}/P_t$. It follows that

$$V_{j,t} = \max_{\left\{d_{j,t},d^*_{j,t},l_{j,t},m_{j,t}\right\}} \quad E_t\left[\beta^P\Lambda^P_{t,t+1}\left\{(1-\omega^B)n_{j,t+1}+\omega^B V_{j,t+1}\right\}\right]$$

s.t.

$$V_{j,t} \geq \lambda^B_t\left(l_{j,t}+m_{j,t}\right), \qquad \textit{(Incentive constraint)}$$

$$n^B_{j,t}+d_{j,t}+rer_td^*_{j,t} = l_{j,t}+m_{j,t}, \qquad \textit{(Balance sheet constraint)}$$

$$n^B_{j,t} = \frac{\tilde{R}^L_{j,t-1}}{\pi_t}l_{j,t-1}+\frac{\tilde{R}^M_{j,t-1}}{\pi_t}m_{j,t-1}-\frac{R_{t-1}}{\pi_t}d_{j,t-1}-\frac{R^*_{t-1}\xi_{t-1}}{\pi^*_t}rer_td^*_{j,t-1} \qquad \textit{(LoM of net worth)}$$

Lagrangian of the problem can be formulated as:

$$L = \quad (1+\nu_{1,t})E_t\beta^P\Lambda^P_{t,t+1}\left\{(1-\omega^B)\left(\frac{\tilde{R}^L_{j,t}}{\pi_{t+1}}l_{j,t}+\frac{\tilde{R}^M_{j,t}}{\pi_{t+1}}m_{j,t}-\frac{R_t}{\pi_{t+1}}d_{j,t}-\frac{R^*_t\xi_t}{\pi^*_{t+1}}rer_{t+1}d^*_{j,t}\right)+\omega^B V_{j,t+1}\right\}$$
$$-\nu_{1,t}\lambda^L\left(l_{j,t}+l_{j,t}\right)$$
$$+\nu_{2,t}\left(\frac{\tilde{R}^L_{j,t-1}}{\pi_t}l_{j,t-1}+\frac{\tilde{R}^M_{j,t-1}}{\pi_t}m_{j,t-1}-\frac{R_{t-1}}{\pi_t}d_{j,t-1}-\frac{R^*_{t-1}\xi_{t-1}}{\pi^*_t}rer_td^*_{j,t-1}-l_{j,t}-m_{j,t}+d_{j,t}+rer_td^*_{j,t}\right)$$

This gives the first-order conditions:

$$l_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1} \left\{ (1-\omega^B) \left(\frac{\tilde{R}^L_{j,t}}{\pi_{t+1}} \right) + \omega^B \frac{\partial V(.)}{\partial l_{j,t}} \right\} = \lambda^B_t \nu_{1,t} + \nu_{2,t}$$

$$m_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1} \left\{ (1-\omega^B) \left(\frac{\tilde{R}^M_{j,t}}{\pi_{t+1}} \right) + \omega^B \frac{\partial V(.)}{\partial l_{j,t}} \right\} = \lambda^B_t \nu_{1,t} + \nu_{2,t}$$

$$d_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1} \left\{ (1-\omega^B) \left(\frac{R_t}{\pi_{t+1}} \right) - \omega^B \frac{\partial V(.)}{\partial d_{j,t}} \right\} = \nu_{2,t}$$

$$d^*_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1} \left\{ (1-\omega^B) \left(\frac{R^*_t \xi_t}{\pi^*_{t+1}} rer_{t+1} \right) - \omega^B \frac{\partial V(.)}{\partial d^*_{j,t}} \right\} = \nu_{2,t} rer_t$$

with complementary slackness conditions:

$$\nu_{1,t} \Big(V_{j,t} - \lambda^B_t \left(l_{j,t} + m_{j,t} \right) \Big) = 0$$

$$\nu_{2,t} \left(\frac{\tilde{R}^L_{j,t-1}}{\pi_t} l_{j,t-1} + \frac{\tilde{R}^M_{j,t-1}}{\pi_t} m_{j,t-1} - \frac{R_{t-1}}{\pi_t} d_{j,t-1} - \frac{R^*_{t-1}\xi_{t-1}}{\pi^*_t} rer_t d^*_{j,t-1} - l_{j,t} - m_{j,t} + d_{j,t} + rer_t d^*_{j,t} \right) = 0$$

Further, the first-order conditions can be expressed as

$$l_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda_{t,t+1} \Big\{ (1-\omega^B) + \omega^B \nu_{2,t+1} \Big\} \left(\frac{R^L_{j,t}}{\pi_{t+1}} \right) = \lambda^B_t \nu_{1,t} + \nu_{2,t}$$

$$m_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1} \Big\{ (1-\omega^B) + \omega^B \nu_{2,t+1} \Big\} \left(\frac{\tilde{R}^M_{j,t}}{\pi_{t+1}} \right) = \lambda^B_t \nu_{1,t} + \nu_{2,t}$$

$$d_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1} \Big\{ (1-\omega^B) + \omega^B \nu_{2,t+1} \Big\} \left(\frac{R_t}{\pi_{t+1}} \right) = \nu_{2,t}$$

$$d^*_{j,t}: \quad (1+\nu_{1,t})\beta^P E_t \Lambda^P_{t,t+1} \Big\{ (1-\omega^B) + \omega^B \nu_{2,t+1} \Big\} \left(\frac{R^*_t \xi_t}{\pi^*_{t+1}} \frac{rer_{t+1}}{rer_t} \right) = \nu_{2,t}$$

Besides these first-order conditions, the set of equilibrium conditions includes the law of motion for aggregate net worth of banks and the bank incentive constraint. First, we formulate the law of motion for aggregate net worth. Aggregate net worth consists of the net worth of non-bankrupted banks and the new worth of new banks. Every period a fraction $(1-\omega^B)$ of banks bankrupt exogenously and are replaced by the same number of new banks. The new equity is injected by domestic households and is assumed to be of the size $\iota^B n^B A_{t-1}$. Then

$$n_t^B = \omega^B \left(\frac{R_{j,t-1}^L}{\pi_t} l_{t-1} - \frac{R_{t-1}}{\pi_t} d_{t-1} - \frac{R_{t-1}^* \xi_{t-1}}{\pi_t^*} rer_t d_{t-1}^* \right) + \iota^B n^B A_{t-1}$$

To include the incentive constraint in the equilibrium conditions, we have to redefine it by using the value of marginal utility from increasing assets by one unit and the value of marginal disutility from increasing debt by one unit. It follows from the previously derived results that the value of the bank j can also be defined as:

$$\begin{aligned} V_{j,t} &= \left(\lambda_t^B \tfrac{\nu_{1,t}}{1+\nu_{1,t}} + \tfrac{\nu_{2,t}}{1+\nu_{1,t}} \right) (l_{j,t} + m_{j,t}) - \tfrac{\nu_{2,t}}{1+\nu_{1,t}} d_{j,t} - \tfrac{\nu_{2,t}}{1+\nu_{1,t}} rer_t d_{j,t}^* \\ &= \tfrac{\nu_{2,t}}{1+\nu_{1,t}} \left(l_{j,t} + m_{j,t} - d_{j,t} - rer_t d_{j,t}^* \right) + \lambda^L \tfrac{\nu_{1,t}}{1+\nu_{1,t}} (l_{j,t} + m_{j,t}) \end{aligned}$$

$$\Rightarrow \quad V_{j,t} = \frac{\nu_{2,t}}{1+\nu_{1,t}} n_{j,t} + \lambda_t^B \frac{\nu_{1,t}}{1+\nu_{1,t}} (l_{j,t} + m_{j,t})$$

Then we can modify the incentive constraint as

$$\frac{\nu_{2,t}}{1+\nu_{1,t}} n_{j,t} + \lambda_t^B \frac{\nu_{1,t}}{1+\nu_{1,t}} (l_{j,t} + m_{j,t}) \geq \lambda_t^B (l_{j,t} + m_{j,t})$$

$$\Rightarrow \quad \nu_{2,t} n_{j,t} \geq \lambda_t^B (l_{j,t} + m_{j,t})$$

F.2 Lending in domestic currency only

Now the only asset on the banks' balance sheet is domestic currency loans extended to financially constrained firms, thus, the expected nominal return of the bank j is defined as $\tilde{R}_{j,t}^L$ and given by:

$$E_t \left\{ \tilde{R}_{j,t}^L L_{j,t} \right\} \equiv E_t \min \left\{ R_{j,t}^L L_{j,t}, \quad \kappa \left(P_{t+1}^L y_{j,t+1}^L + Q_{t+1}(1-\delta) k_{j,t} \right) \right\}$$

Or, in units of composite goods,

$$E_t \left\{ \frac{\tilde{R}_{j,t}^L}{\pi_{t+1}} l_{j,t} \right\} \equiv E_t \min \left\{ R_{j,t}^L \frac{l_{j,t}}{\pi_{t+1}}, \quad \kappa \left(p_{t+1}^L y_{j,t+1}^L + q_{t+1}(1-\delta) k_{j,t} \right) \right\}$$

$$\Rightarrow E_t \left\{ \frac{\tilde{R}_{j,t}^L}{\pi_{t+1}} l_{j,t} \right\} \equiv E_t \left\{ (1-\Phi(d_{1,t}))\, \kappa \left(p_{t+1}^L y_{j,t+1}^L + (1-\delta) q_{t+1} k_{j,t} \right) + \Phi(d_{2,t}) R_{j,t}^L \frac{l_{j,t}}{\pi_{t+1}} \right\} \qquad \text{(F.1)}$$

The rest of derivations for the bank's optimization problem remain the same.

G The monitoring costs friction for corporates

The model with monitoring costs for corporates is different in two main ways. First, we introduce two layers, intermediate firms and entrepreneurs that replace the sector of financially-constrained firms. Entrepreneurs transform new capital produced by capital goods producers into productive capital that can be used by intermediate firms. Entrepreneurs borrow to acquire capital and may default due to idiosyncratic shocks and aggregate shocks. Banks cannot observe idiosyncratic shocks unless they pay deadweight monitoring costs. Thus, the informational asymmetry takes the form of a costly state verification problem as in Bernanke et al. (1999). Intermediate firms buy capital from entrepreneurs and combine it with labor. They sell the new homogeneous product to retail firms.

We first describe the optimization problem of entrepreneurs. It solves for optimal debt contract as in Bernanke et al. (1999). The technology that entrepreneurs use to transform capital transforms k_t units of new capital into $\omega^F_{t+1}k_t$ units of capital available to rent to intermediate firms. The variable ω^F_{t+1} is log-normally distributed with $E(\omega^F_t) = 1$ and standard deviation $\sigma_{F,t}$. We assume that purchases of new capital $q_t k_t$ have to be financed by either loans from banks l_t or accumulated net worth n^F_t.

The gross interest rate on loans is denoted by R^L_t. The optimal debt contract specifies a cut-off value $\bar{\omega}^F_{t+1}$ such that if $\omega^F_{t+1} \geq \bar{\omega}^F_{t+1}$, the borrower pays $\bar{\omega}^F_{t+1}\left(r^K_{t+1} + (1-\delta)q_{t+1}\right)k_t$ to the bank and keeps $\left(\omega^F_{t+1} - \bar{\omega}^F_{t+1}\right)\left(r^K_{t+1} + (1-\delta)q_{t+1}\right)k_t$. While if $\omega^F_{t+1} < \bar{\omega}^F_{t+1}$, the borrower defaults. The bank gets total revenue from the project minus monitoring costs that is equal to a fraction μ_F of the total revenue. Thus, the bank obtains $(1-\mu_F)\,\omega^F_{t+1}\left(r^K_{t+1} + (1-\delta)q_{t+1}\right)k_t$. We assume that a fixed share of the loan α^{FF} is denominated in foreign currency. Then the loan repayment is given by $R^L_t\left(\frac{\alpha^{FF} rer_t}{\pi^*_{t+1}} + \frac{1-\alpha^{FF}}{\pi_{t+1}}\right)l_t$.

It follows that the interest rate can be expressed by using the cut-off value:

$$R^L_t\left(\frac{\alpha^{FF} rer_t}{\pi^*_{t+1}} + \frac{1-\alpha^{FF}}{\pi_{t+1}}\right) = \bar{\omega}^F_{t+1}\left(r^K_{t+1} + (1-\delta)q_{t+1}\right)\frac{k_t}{l_t}$$

Therefore, for the bank to be willing to lend it must be the case that the return on loans to entrepreneurs satisfies

$$\tilde{R}^L_t l_t \leq g\left(\bar{\omega}^F_{t+1}\right)\left(r^K_{t+1} + (1-\delta)q_{t+1}\right)k_t,$$

where

$$g\left(\bar{\omega}^F_{t+1}\right) = \bar{\omega}^F_{t+1}\left(1 - F\left(\omega^F_{t+1}\right)\right) + (1-\mu_F)\int_0^{\bar{\omega}^F_{t+1}} \omega^F_{t+1} f\left(\omega^F_{t+1}\right) d\omega^F_{t+1} \tag{G.1}$$

The first term in the right-hand side of equation G.1 is the share of total revenues that the bank obtains from non-defaulted entrepreneurs and the second term is the value of the assets seized from defaulted entrepreneurs.

Entrepreneurs' expected profits equals

$$E_t\left(h\left(\bar{\omega}_{t+1}^F\right)\left(r_{t+1}^K+(1-\delta)q_{t+1}\right)k_t\right)$$

where

$$h\left(\bar{\omega}_{t+1}^F\right)=\int_{\bar{\omega}_{t+1}^F}^{\infty}\omega_{t+1}^F f\left(\omega_{t+1}^F\right)d\omega_{t+1}^F-\bar{\omega}_{t+1}^F\left(1-F\left(\omega_{t+1}^F\right)\right), \tag{G.2}$$

equation G.2 represents the average share of total returns that is attributed to entrepreneurs conditional on not defaulting. The first term in the right-hand side of equation G.2 is the expected share of average revenue that entrepreneurs obtain. The second term is the expected loan repayment. It can be showed that the optimality condition for this debt contract is

$$E_t\left(\frac{\left(r_{t+1}^K+(1-\delta)q_{t+1}\right)}{q_t}\left(\frac{h'\left(\bar{\omega}_{t+1}^F\right)g\left(\bar{\omega}_{t+1}^F\right)}{g'\left(\bar{\omega}_{t+1}^F\right)}-h\left(\bar{\omega}_{t+1}^F\right)\right)\right)=E_t\left(\tilde{R}_{t+1}^L\frac{h'\left(\bar{\omega}_{t+1}^F\right)}{g'\left(\bar{\omega}_{t+1}^F\right)}\right)$$

The ratio $E_t\frac{\left(r_{t+1}^K+(1-\delta)q_{t+1}\right)}{q_t}/E_t\tilde{R}_{t+1}^L$ is known as the external finance premium and is increasing in entrepreneurs' leverage Bernanke et al. (1999).

We assume that a fraction ω^F of entrepreneurs survives every period[10], and an equal fraction enters the market. New entrepreneurs get an equity injection from patient households $\iota^F n^F A_{t-1}$. Given that the average share of total returns that is attributed to entrepreneurs at time t is defined by $h\left(\bar{\omega}_t^F\right)$, we get:

$$n_t^F=\omega^F\left(h(\tilde{\omega}_t^F)\left(r_t^K+(1-\delta)q_t\right)k_{t-1}\right)+\iota^F n^F A_{t-1}$$

Devereux et al. (2006) show in the appendix that with d_t^F where $d_t^F=\frac{ln(\bar{\omega}_t^F)+1/2\left(\sigma_t^F\right)^2}{\sigma_t^F}$, the following expressions follow:

$$g\left(\bar{\omega}_t^F\right)=\bar{\omega}_t^F\left(1-\Phi\left(d_t^F\right)\right)+(1-\mu_F)\Phi\left(d_t^F-\sigma_t^F\right)$$
$$g'\left(\bar{\omega}_t^F\right)=\left(1-\Phi\left(d_t^F\right)\right)-\mu_F\Phi'\left(d_t^F\right)$$
$$h\left(\bar{\omega}_t^F\right)=1-\Phi\left(d_t^F-\sigma_t^F\right)-\bar{\omega}_t^F\left(1-\Phi\left(d_t^F\right)\right)$$
$$h'\left(\bar{\omega}_t^F\right)=-\left(1-\Phi\left(d_t^F-\sigma_t^F\right)\right),$$

[10]This assumption prevents entrepreneurs from accumulating infinite net worth and not borrowing anymore.

H Equilibrium equations of the model with foreign currency debt and leverage-constrained banks

The model is described by 72 endogenous variables:

$$\Big\{\lambda_t^P, \lambda_t^I, c_t^P, c_t^I, h_t^P, h_t^I, w_t^P, w_t^I, n_t^P, n_t^I, b_t, d_t, R_t, m_t, m_t^F, m_t^H, q_t^h, R_t^M, \tilde{R}_t^M, \bar{\omega}_t, \Omega_t, d_{1,t}, d_{2,t}, R_t^L, \tilde{R}_t^L, l_t,$$
$$l_t^D, l_t^F, \pi_t, p_t^L, y_t^L, k_t, n_t, i_t, q_t, w_t, p_t^I, p_t^H, \tilde{p}_t^H, D_t^H, y_t^H, F_{1,t}^H, F_{2,t}^H, p_t^F, y_t^F, c_t, c_t^H, c_t^F, i_t^H, i_t^F, \tilde{p}_t^F, D_t^F, F_{1,t}^F, F_{2,t}^F,$$
$$\tilde{w}_t^P, D_t^{WP}, \Omega_t^{WP}, \Upsilon_t^{WP}, \tilde{w}_t^I, D_t^{WI}, \Omega_t^{WI}, \Upsilon_t^{WI}, y_t^{H*}, rer_t, d_t^*, n_t^B, \nu_{1,t}, \nu_{2,t}, t_t, S_t, tb_t, \xi_t\Big\}$$

The data fitting exercise requires accounting for non-stationary trends in the data, therefore, the model equations are expressed not only in real domestic currency terms, but also transformed into a stationary form with explicitly specified non-stationary growth components. This introduces non-stationary productivity growth variable a_t that occurs throughout the model description. It is defined as $a_t \equiv A_t/A_{t-1}$ where A_t is non-stationary productivity shock. Further, variables with hats denote non-stationary variables divided by A_{t-1} to obtain their stationary values, for instance, $\hat{c}_t = c_t/A_{t-1}$. There are a few exceptions: $\hat{\lambda}_t^P \equiv \lambda_t^P A_{t-1}$, $\hat{\lambda}_t^I \equiv \lambda_t^I A_{t-1}$, $\hat{\Omega}_t \equiv \Omega_t A_{t-1}$, $\hat{\Omega}_t^{WP} \equiv \Omega_t^{WP} A_{t-1}^{\epsilon_W - 1}$, $\hat{\Omega}_t^{WI} \equiv \Omega_t^{WI} A_{t-1}^{\epsilon_W - 1}$. Variables without hats are stationary.

They are given by 72 equilibrium equations below.

Patient households

$$\hat{\lambda}_t^P = v_t \frac{1}{\hat{c}_t^P} \tag{H.1}$$

$$v_t A_h \frac{1}{\hat{h}_t^P} = \hat{\lambda}_t^P q_t^h - \beta^P E_t \hat{\lambda}_{t+1}^P \frac{q_{t+1}^h}{a_t} \tag{H.2}$$

$$E_t \beta^P \frac{\hat{\lambda}_{t+1}^P}{\hat{\lambda}_t^P a_t} \frac{R_t}{\pi_{t+1}} = 1 \tag{H.3}$$

Impatient households

$$\hat{\lambda}_t^I = v_t \frac{1}{\hat{c}_t^I} \tag{H.4}$$

$$v_t A_h \frac{1}{\hat{h}_t^I} = \hat{\lambda}_t^I q_t^h - \beta^I E_t \hat{\lambda}_{t+1}^I (1 - \zeta^h \Gamma_{t+1}) \frac{q_{t+1}^h}{a_t} - \Omega_t E_t \left(\Gamma_{t+1} - \mu_H G_{t+1}\right) \zeta^h q_{t+1}^h \tag{H.5}$$

$$\frac{\beta^I}{a_t} E_t \hat{\lambda}_{t+1}^I \left(\Gamma_{t+1}\right)' = \Omega_t E_t \left(\left(\Gamma_{t+1}\right)' - \mu_H \left(G_{t+1}\right)'\right) \tag{H.6}$$

$$\hat{\Omega}_t E_t \tilde{R}_{t+1}^M = \hat{\lambda}_t^I \tag{H.7}$$

$$\hat{w}_t n_t^I + (1 - \zeta^h \Gamma_t) q_t^h \frac{\hat{h}_{t-1}^I}{a_{t-1}} + \hat{m}_t - \hat{c}_t^I - q_t^h \hat{h}_t^I = 0 \tag{H.8}$$

$$\left(\Gamma_{t+1}-\mu_H G_{t+1}\right)\zeta^h q^h_{t+1}\hat{h}^I_t = E_t \tilde{R}^M_{t+1}\hat{m}_t \tag{H.9}$$

$$\bar{\omega}_t = \frac{R^M_{t-1}\left(\frac{\alpha^{FM} rer_t}{\pi^*_t}+\frac{1-\alpha^{FM}}{\pi_t}\right)m_{t-1}}{\zeta^h q^h_t h^I_{t-1}} \tag{H.10}$$

$$\hat{m}^H_t + rer_t\hat{m}^F_t = \hat{m}_t \tag{H.11}$$

$$rer_t\hat{m}^F_t = \alpha^{FM}\hat{m}_t \tag{H.12}$$

Wage setting

$$\left(\hat{\tilde{w}}^P_t\right)^{1+\sigma_n\epsilon_W} = \frac{\epsilon_W}{\epsilon_W-1}\frac{\hat{\Omega}^{WP}_t}{\hat{\Upsilon}^{WP}_t} \tag{H.13}$$

$$\hat{\Omega}^{WP}_t = v_t A_n\left(\hat{w}^P_t\right)^{(1+\sigma_n)\epsilon_W}\left(n^P_t\right)^{(1+\sigma_n)} + \beta^P\omega^W\frac{\hat{\lambda}^P_{t+1}}{\hat{\lambda}^P_t a_t}\left(\frac{\pi}{\pi_{t+1}}\right)^{(1+\sigma_n)\epsilon_W}\hat{\Omega}^{WP}_{t+1}a_t^{\epsilon_W-1} \tag{H.14}$$

$$\hat{\Upsilon}^{WP}_t = \hat{\lambda}^P_t\left(\hat{w}^P_t\right)^{\epsilon_W} n^P_t + \beta^P\omega^W\frac{\hat{\lambda}^P_{t+1}}{\hat{\lambda}^P_t a_t}\left(\frac{\pi}{\pi_{t+1}}\right)^{\epsilon_W}\hat{\Upsilon}^{WP}_{t+1}a_t^{\epsilon_W-1} \tag{H.15}$$

$$\left(\hat{w}^P_t\right)^{\frac{1}{\epsilon_W-1}} = \left(1-\omega^W\right)\left(\hat{\tilde{w}}^P_t\right)^{\frac{1}{\epsilon_W-1}} + \omega^W\left(\frac{\hat{w}^P_{t-1}\pi}{a_{t-1}\pi_t}\right)^{\frac{1}{\epsilon_W-1}} \tag{H.16}$$

$$D^{WP}_t = \left(1-\omega^W\right)\left(\frac{\hat{w}^P_t}{\hat{\tilde{w}}^P_t}\right)^{(1+\sigma_n)\epsilon_W} + \omega^W\left(\frac{\hat{w}^P_{t-1}\pi}{\hat{w}^P_t\pi_t}\right)^{(1+\sigma_n)\epsilon_W}D^{WP}_{t-1} \tag{H.17}$$

$$n^P_t = \left(\frac{\hat{\tilde{w}}^P_t}{\hat{w}^P_t}\right)^{-\epsilon_W} n_t \tag{H.18}$$

$$\left(\hat{\tilde{w}}^I_t\right)^{1+\sigma_n\epsilon_W} = \frac{\epsilon_W}{\epsilon_W-1}\frac{\hat{\Omega}^{WI}_t}{\hat{\Upsilon}^{WI}_t} \tag{H.19}$$

$$\hat{\Omega}^{WI}_t = v_t A_n\left(\hat{w}^I_t\right)^{(1+\sigma_n)\epsilon_W}\left(n^I_t\right)^{(1+\sigma_n)} + \beta^I\omega^W\frac{\hat{\lambda}^I_{t+1}}{\hat{\lambda}^I_t a_t}\left(\frac{\pi}{\pi_{t+1}}\right)^{(1+\sigma_n)\epsilon_W}\hat{\Omega}^{WI}_{t+1}a_t^{\epsilon_W-1} \tag{H.20}$$

$$\hat{\Upsilon}_t^{WI} = \hat{\lambda}_t^I \left(\hat{w}_t^I\right)^{\epsilon_W} n_t^I + \beta^I \omega^W \frac{\hat{\lambda}_{t+1}^I}{\hat{\lambda}_t^I a_t} \left(\frac{\pi}{\pi_{t+1}}\right)^{\epsilon_W} \hat{\Upsilon}_{t+1}^{WI} a_t^{\epsilon_W - 1} \tag{H.21}$$

$$\left(\hat{w}_t^I\right)^{\frac{1}{\epsilon_W - 1}} = (1-\omega^W)\left(\hat{\tilde{w}}_t^I\right)^{\frac{1}{\epsilon_W - 1}} + \omega^W \left(\frac{\hat{w}_{t-1}^I \pi}{a_{t-1}\pi_t}\right)^{\frac{1}{\epsilon_W - 1}} \tag{H.22}$$

$$D_t^{WI} = (1-\omega^W)\left(\frac{\hat{w}_t^I}{\hat{\tilde{w}}_t^I}\right)^{(1+\sigma_n)\epsilon_W} + \omega^W \left(\frac{\hat{w}_{t-1}^I \pi}{\hat{w}_t^I \pi_t}\right)^{(1+\sigma_n)\epsilon_W} D_{t-1}^{WI} \tag{H.23}$$

$$n_t^I = \left(\frac{\hat{\tilde{w}}_t^I}{\hat{w}_t^I}\right)^{-\epsilon_W} n_t \tag{H.24}$$

$$\hat{w}_t = \left(\left(\hat{w}_t^P\right)^{1-\epsilon_W} + \left(\hat{w}_t^I\right)^{1-\epsilon_W}\right)^{\frac{1}{1-\epsilon_W}} \tag{H.25}$$

Financially constrained firms

$$E_t \beta^P \frac{\hat{\lambda}_{t+1}^P}{\hat{\lambda}_t^P a_t} \left\{(1-(1-\Phi(d_{1,t}))\kappa)\left(\alpha p_{t+1}^L z_{t+1} \left(a_{t+1} a_t\right)^{1-\alpha} \hat{k}_t^{\alpha-1} n_t^{1-\alpha} + q_{t+1}(1-\delta)\right)\right\} = q_t \tag{H.26}$$

$$E_t \beta^P \frac{\hat{\lambda}_{t+1}^P}{\hat{\lambda}_t^P a_t} \left\{(1-(1-\Phi(d_{1,t}))\kappa)\left((1-\alpha) p_{t+1}^L z_{t+1} \left(a_{t+1} a_t\right)^{1-\alpha} \hat{k}_t^{\alpha} n_t^{-\alpha}\right)\right\} = \hat{w}_t \tag{H.27}$$

$$E_{t-1}\left\{\hat{l}_t\right\} = E_{t-1}\left\{q_t \hat{k}_t + \hat{w}_t n_t\right\} \tag{H.28}$$

$$d_{2,t} \equiv \frac{E_t \ln\left(\kappa\left(p_{t+1}^L \hat{y}_{t+1}^L + q_{t+1}(1-\delta)\hat{k}_t\right) - R_t^L rer_{t+1} \frac{\hat{l}_t^F}{\pi_{t+1}^*}\right) - E_t \ln\left(R_t^L \frac{\hat{l}_t^D}{\pi_{t+1}}\right)}{\sigma_{F,t}} \tag{H.29}$$

$$\hat{y}_t^L = z_t \theta_t \left(a_{t-1}\right)^{-\alpha} \hat{k}_{t-1}^{\alpha} \left(a_t n_{t-1}\right)^{1-\alpha} \tag{H.30}$$

$$d_{1,t} \equiv d_{2,t} + \sigma_{F,t} \tag{H.31}$$

$$\hat{l}_t = \hat{l}_t^D + rer_t \hat{l}_t^F \tag{H.32}$$

$$\hat{l}_t^D = (1-\alpha^{Fl})\hat{l}_t \tag{H.33}$$

Capital producers

$$\hat{k}_t = (1-\delta)\frac{\hat{k}_{t-1}}{a_{t-1}} + \left(1 - \Gamma\left(\frac{\hat{i}_t}{\hat{i}_{t-1}}\right)\right) u_t \hat{i}_t \tag{H.34}$$

$$\begin{aligned}\frac{p_t^I}{q_t} = &\left(1 - \frac{\gamma}{2}\left(\frac{\hat{i}_t}{\hat{i}_{t-1}}a_{t-1} - a\right)^2\right) u_t - \gamma\left(\frac{\hat{i}_t}{\hat{i}_{t-1}}a_{t-1} - a\right)\frac{\hat{i}_t}{\hat{i}_{t-1}}a_{t-1} \\ &+ \gamma\beta^P E_t \frac{\hat{\lambda}_{t+1}^P}{\hat{\lambda}_t^P a_t}\frac{q_{t+1}}{q_t}\left(\frac{\hat{i}_{t+1}}{\hat{i}_t}a_t - a\right)\left(\frac{\hat{i}_{t+1}}{\hat{i}_t}a_t\right)^2 u_{t+1}\end{aligned} \tag{H.35}$$

Retail firms

$$1 = (1-\omega^H)\left(\tilde{p}_t^H\right)^{1-\epsilon_H} + \omega^H\left(\frac{p_{t-1}^H\left(\prod_{j=1}^{j=s}\pi_{t+j}^{adj}\right)}{p_t^H\pi_t}\right)^{1-\epsilon_H} \tag{H.36}$$

$$D_t^H = (1-\omega^H)\left(\tilde{p}_t^H\right)^{-\epsilon_H} + \omega^H\left(\frac{p_{t-1}^H\left(\prod_{j=1}^{j=s}\pi_{t+j}^{adj}\right)}{p_t^H\pi_t}\right)^{-\epsilon_H} D_{t-1}^H \tag{H.37}$$

$$\tilde{p}_t^H = \frac{\epsilon_H}{(\epsilon_H - 1)}\frac{\hat{F}_{1,t}^H}{\hat{F}_{2,t}^H} \tag{H.38}$$

$$\hat{F}_{1,t}^H = p_t^L\hat{y}_t^H + E_t\omega^H\beta^P\frac{\hat{\lambda}_{t+1}^P}{\hat{\lambda}_t^P}\left(\frac{p_{t+1}^H\pi_{t+1}}{p_t^H\left(\prod_{j=1}^{j=s}\pi_{t+j}^{adj}\right)}\right)^{\epsilon_H}\hat{F}_{1,t+1}^H \tag{H.39}$$

$$\hat{F}_{2,t}^H = p_t^H\hat{y}_t^H + E_t\omega^H\beta^P\frac{\hat{\lambda}_{t+1}^P}{\hat{\lambda}_t^P}\left(\frac{p_{t+1}^H\pi_{t+1}}{p_t^H\left(\prod_{j=1}^{j=s}\pi_{t+j}^{adj}\right)}\right)^{\epsilon_H - 1}\hat{F}_{2,t+1}^H \tag{H.40}$$

Exporters

$$\hat{y}_t^{H*} = \eta^*\left(\frac{p_t^H}{rer_t}\right)^{-\epsilon_*} y_t^* \tag{H.41}$$

Composite goods producer

$$\hat{c}_t = \left(\eta_C^{\frac{1}{\epsilon_C}}\left(\hat{c}_t^H\right)^{\frac{\epsilon_C - 1}{\epsilon_C}} + \eta_C^{\frac{1}{\epsilon_C}}\left(\hat{c}_t^F\right)^{\frac{\epsilon_C - 1}{\epsilon_C}}\right)^{\frac{\epsilon_C}{\epsilon_C - 1}} \tag{H.42}$$

$$\hat{c}_t^H = \eta_C\left(p_t^H\right)^{-\epsilon_C}\hat{c}_t \tag{H.43}$$

$$\hat{c}_t^F = (1-\eta_C)\left(p_t^F\right)^{-\epsilon_C}\hat{c}_t \tag{H.44}$$

$$\hat{i}_t = \left(\eta_I^{\frac{1}{\epsilon_I}} \left(\hat{i}_t^H\right)^{\frac{\epsilon_I - 1}{\epsilon_I}} + \eta_I^{\frac{1}{\epsilon_I}} \left(\hat{i}_t^F\right)^{\frac{\epsilon_I - 1}{\epsilon_I}} \right)^{\frac{\epsilon_I}{\epsilon_I - 1}} \tag{H.45}$$

$$\hat{i}_t^H = \eta_I \left(\frac{p_t^H}{p_t^I}\right)^{-\epsilon_I} \hat{i}_t \tag{I.45}$$

$$\hat{i}_t^F = (1 - \eta_I) \left(\frac{p_t^F}{p_t^I}\right)^{-\epsilon_I} \hat{i}_t \tag{H.46}$$

Definition of the real exchange rate

$$\frac{rer_t}{rer_{t-1}} = \frac{S_t}{S_{t-1}} \frac{\pi_t^*}{\pi_t} \tag{H.47}$$

Importers

$$1 = (1 - \omega^F) \left(\tilde{p}_t^F\right)^{1-\epsilon_F} + \omega^F \left(\frac{p_{t-1}^F \left(\prod_{j=1}^{j=s} \pi_{t+j}^{adj}\right)}{p_t^F \pi_t} \right)^{1-\epsilon_F} \tag{H.48}$$

$$D_t^F = (1 - \omega^F) \left(\tilde{p}_t^F\right)^{-\epsilon_F} + \omega^F \left(\frac{p_{t-1}^F \left(\prod_{j=1}^{j=s} \pi_{t+j}^{adj}\right)}{\pi_t p_t^F} \right)^{-\epsilon_F} D_{t-1}^F \tag{H.49}$$

$$\tilde{p}_t^F = \frac{\epsilon_F}{(\epsilon_F - 1)} \frac{\hat{F}_{1,t}^F}{\hat{F}_{2,t}^F} \tag{H.50}$$

$$\hat{F}_{1,t}^F = rer_t \hat{y}_t^F + E_t \omega^F \beta^P \frac{\hat{\lambda}_{t+1}^P}{\hat{\lambda}_t^P} \left(\frac{p_{t+1}^F \pi_{t+1}}{p_t^F \left(\prod_{j=1}^{j=s} \pi_{t+j}^{adj}\right)} \right)^{\epsilon_F} \hat{F}_{1,t+1}^F \tag{H.51}$$

$$\hat{F}_{2,t}^F = p_t^F \hat{y}_t^F + E_t \omega^F \beta^P \frac{\hat{\lambda}_{t+1}^P}{\hat{\lambda}_t^P} \left(\frac{p_{t+1}^F \pi_{t+1}}{p_t^F \left(\prod_{j=1}^{j=s} \pi_{t+j}^{adj}\right)} \right)^{\epsilon_F - 1} \hat{F}_{2,t+1}^F \tag{H.52}$$

Banks

$$E_t \left\{ \frac{\tilde{R}_t^L}{\pi_{t+1}} \hat{l}_t \right\} = E_t \left\{ (1 - \Phi(d_{1,t}))\, \kappa \left(p_{t+1}^L \hat{y}_{t+1}^L + (1-\delta) q_{t+1} \hat{k}_t \right) + \Phi(d_{2,t}) R_{j,t}^L \frac{\hat{l}_t^D}{\pi_{t+1}} + \Phi(d_{1,t}) R_{j,t}^L rer_{t+1} \frac{\hat{l}_t^F}{\pi_{t+1}^*} \right\} \tag{H.53}$$

$$(1 + \nu_{1,t}) E_t \beta^P \frac{\hat{\lambda}_{t+1}^P}{\hat{\lambda}_t^P a_t} \left\{ (1 - \omega) + \omega \nu_{2,t+1} \right\} \frac{\tilde{R}_t^L}{\pi_{t+1}} = \lambda^B \nu_{1,t} + \nu_{2,t} \tag{H.54}$$

$$(1+\nu_{1,t})E_t\beta^P\frac{\hat{\lambda}^P_{t+1}}{\hat{\lambda}^P_t a_t}\left\{(1-\omega)+\omega\nu_{2,t+1}\right\}\frac{\tilde{R}^M_t}{\pi_{t+1}}=\lambda^B\nu_{1,t}+\nu_{2,t} \tag{H.55}$$

$$(1+\nu_{1,t})E_t\beta^P\frac{\hat{\lambda}^P_{t+1}}{\hat{\lambda}^P_t a_t}\left\{(1-\omega)+\omega\nu_{2,t+1}\right\}\left(\frac{R_t}{\pi_{t+1}}\right)=\nu_{2,t} \tag{H.56}$$

$$(1+\nu_{1,t})E_t\beta^P\frac{\hat{\lambda}^P_{t+1}}{\hat{\lambda}^P_t a_t}\left\{(1-\omega)+\omega\nu_{2,t+1}\right\}\left(\frac{R^*_t\xi_t}{\pi^*_{t+1}}\frac{rer_{t+1}}{rer_t}\right)=\nu_{2,t} \tag{H.57}$$

$$\hat{n}^B_t=\frac{\omega^B}{a_{t-1}}\left(\frac{\tilde{R}^L_t}{\pi_t}\hat{l}_{t-1}+\frac{\tilde{R}^M_t}{\pi_t}\hat{m}_{t-1}-\frac{R_{t-1}}{\pi_t}\hat{d}_{t-1}-\frac{R^*_{t-1}\xi_{t-1}}{\pi^*_t}rer_t\hat{d}^*_{t-1}\right)+\iota^B n^B \tag{H.58}$$

$$\nu_{2,t}\hat{n}^B_t=\lambda^B\left(\hat{l}_t+\hat{m}_t\right) \tag{H.59}$$

$$\hat{n}^B_t+\hat{d}_t+rer_t\hat{d}^*_t=\hat{l}_t+\hat{m}_t \tag{H.60}$$

Monetary policy

$$\frac{R_t}{\bar{R}}=\left(\frac{R_{t-1}}{\bar{R}}\right)^{\gamma_R}\left(\frac{\hat{y}^H_t}{\bar{y^H}}\right)^{(1-\gamma_R)\gamma_Y}\left(\frac{p^H_t/p^H_{t-1}\pi_t}{\bar{\pi}}\right)^{(1-\gamma_R)\gamma_\pi}\exp(mp_t) \tag{H.61}$$

Government

$$\hat{g}_t+\frac{R_{t-1}}{\pi_t}\frac{\hat{b}_{t-1}}{a_{t-1}}=\hat{t}_t+\hat{b}_t \tag{H.62}$$

$$\hat{t}_t=\bar{t}+\kappa_b\left(\frac{\hat{b}_{t-1}}{a_{t-1}}-\bar{b}\right)+\tau_t \tag{H.63}$$

Market clearing

$$\hat{c}_t=\hat{c}^P_t+\hat{c}^I_t \tag{H.64}$$

$$h=\hat{h}^P_t+\hat{h}^I_t \tag{H.65}$$

$$\hat{y}_t=z_t\theta_t\left(\frac{\hat{k}_{t-1}}{a_{t-1}}\right)^{\alpha}(a_t n_{t-1})^{1-\alpha} \tag{H.66}$$

$$\hat{y}_t^H = \hat{c}_t^H + \hat{i}_t^H + \hat{g}_t \tag{H.67}$$

$$\hat{y}_t^F = \hat{c}_t^F + \hat{i}_t^F \tag{H.68}$$

$$\hat{y}_t = D_t^H \hat{y}_t^H + \hat{y}_t^{H*} \tag{H.69}$$

Trade balance

$$\hat{tb}_t = p_t^H \hat{y}_t^{H*} - rer_t D_t^F \hat{y}_t^F \tag{H.70}$$

Current account

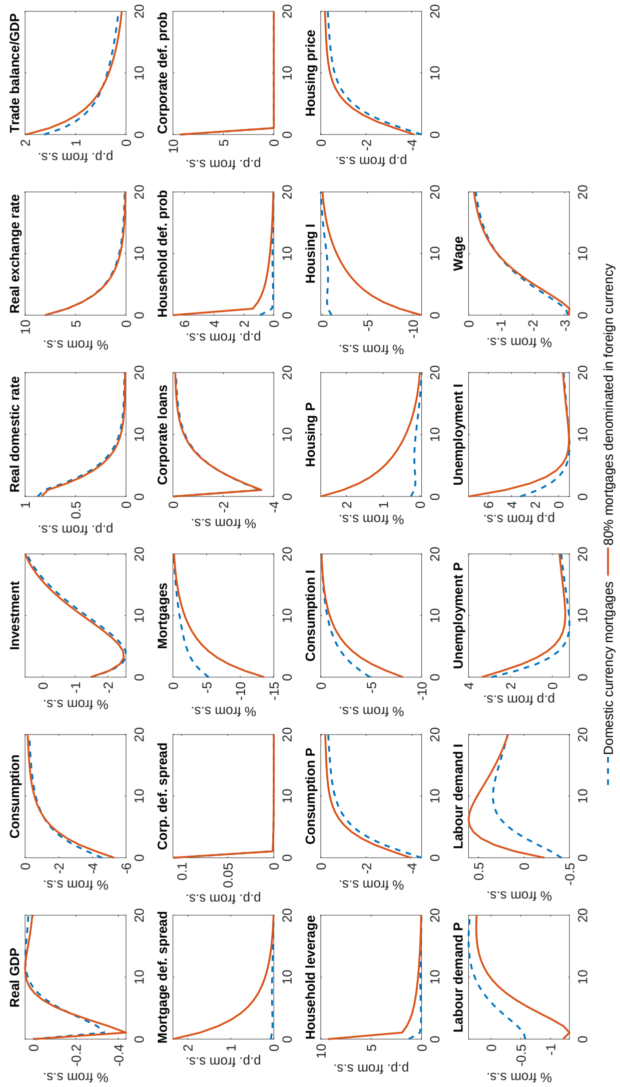
$$\hat{tb}_t - \left(R_{t-1}^* \xi_{t-1} - 1\right) rer_t \frac{\hat{d}_{t-1}^*}{\pi_t^* a_{t-1}} = -\left(rer_t \hat{d}_t^* - rer_t \frac{\hat{d}_{t-1}^*}{\pi_t^* a_{t-1}}\right) \tag{H.71}$$

$$\xi_t = \exp\left(\kappa_\xi \frac{\left(rer_t \hat{d}_t^* - rer \cdot d^*\right)}{rer \cdot d^*} + \frac{\zeta_t - \zeta}{\zeta}\right) \tag{H.72}$$

There are 15 exogenous variables:

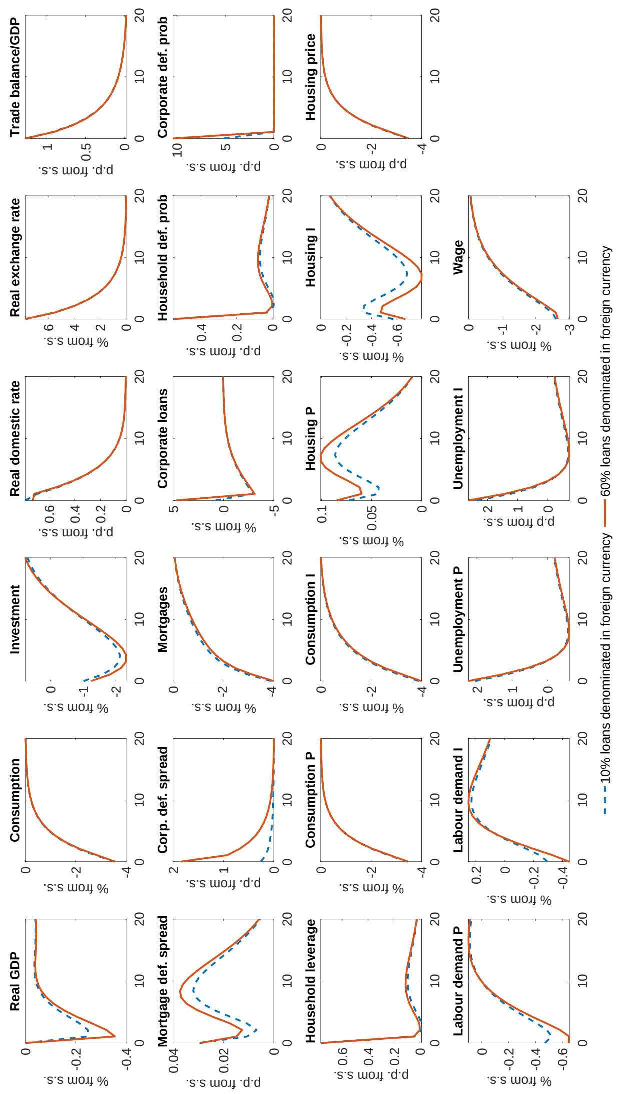
$$\left\{z_t, a_t, \theta_t, \pi_t^*, R_t^*, \zeta_t, y_t^*, mp_t, g_t, \tau_t, u_t, v_t, \sigma_{F,t}, \sigma_{M,t}, \lambda_t^B\right\}$$

Figure A1: Country's premium shock and currency mismatch for households.



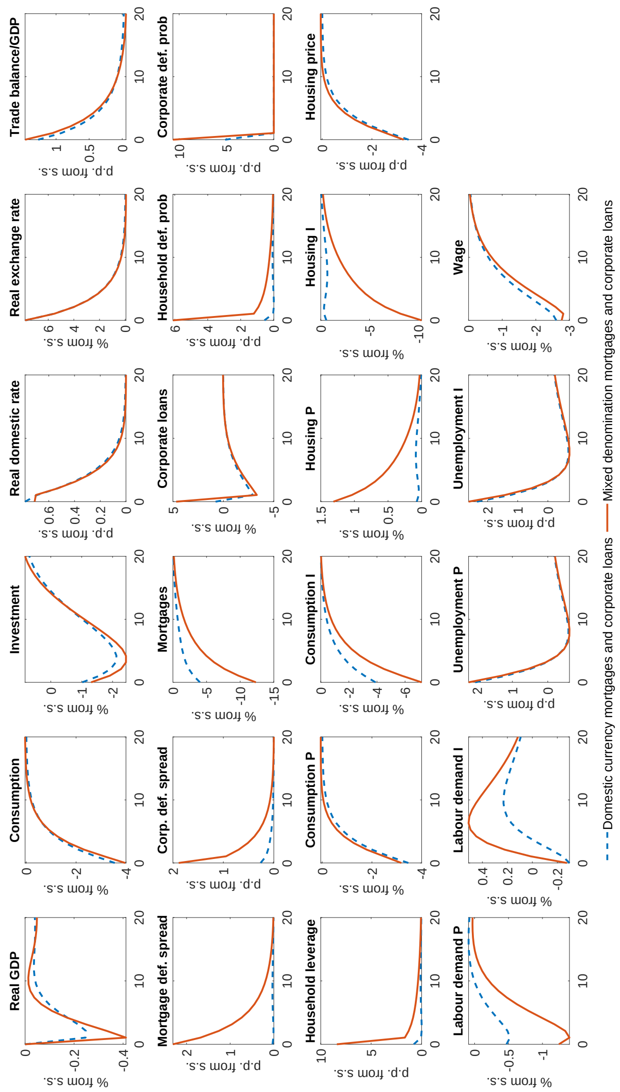
Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households and firms facing the debt overhang friction. Mixed denomination mortgages mean that 80 percent of mortgages is dominated in foreign currency. Corporate loans in both cases are issued in domestic currency only.

Figure A2: Country's premium shock and currency mismatch for corporates.



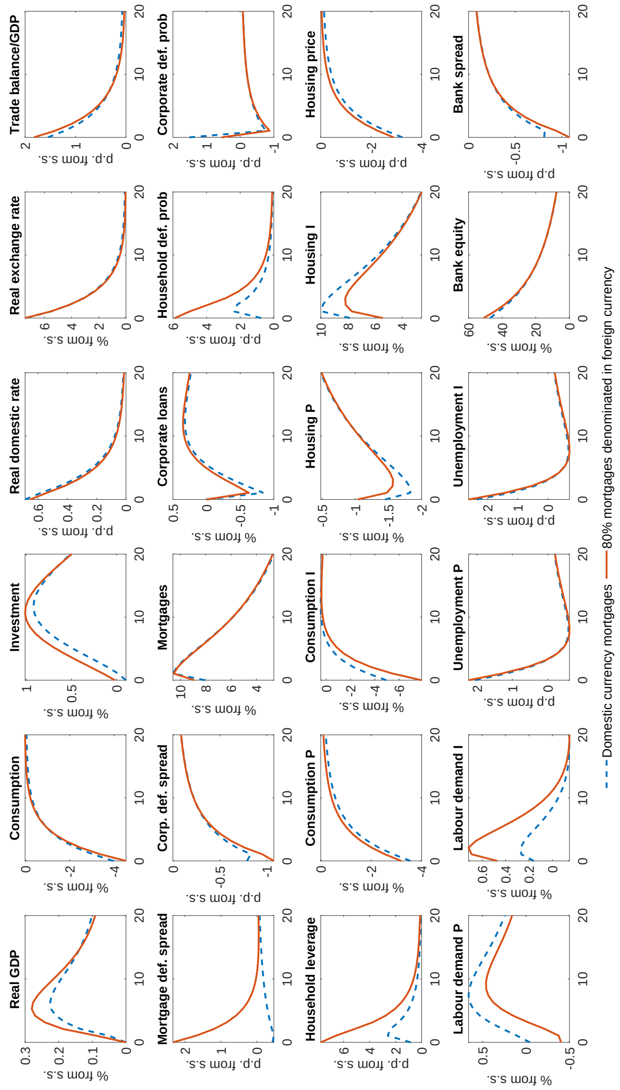
Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households and firms facing the debt overhang friction. Mortgages in both cases are issued in domestic currency only.

Figure A3: Country's premium shock and currency mismatch for households and corporates.



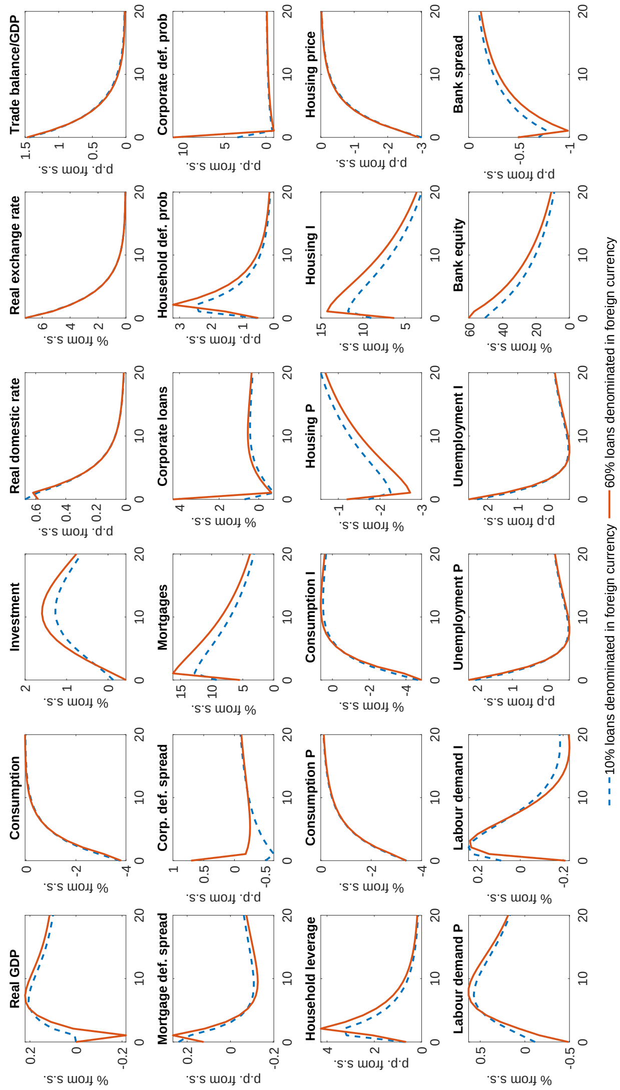
Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households and firms facing the debt overhang friction. Mixed denomination mortgages and loans mean that 80 percent of mortgages and 60 percent of loans is dominated in foreign currency. In the domestic currency case, 10 percent corporate loans and zero of mortgages are denominated in foreign currency.

Figure A4: Country's premium shock and currency mismatch for households with leveraged banks.



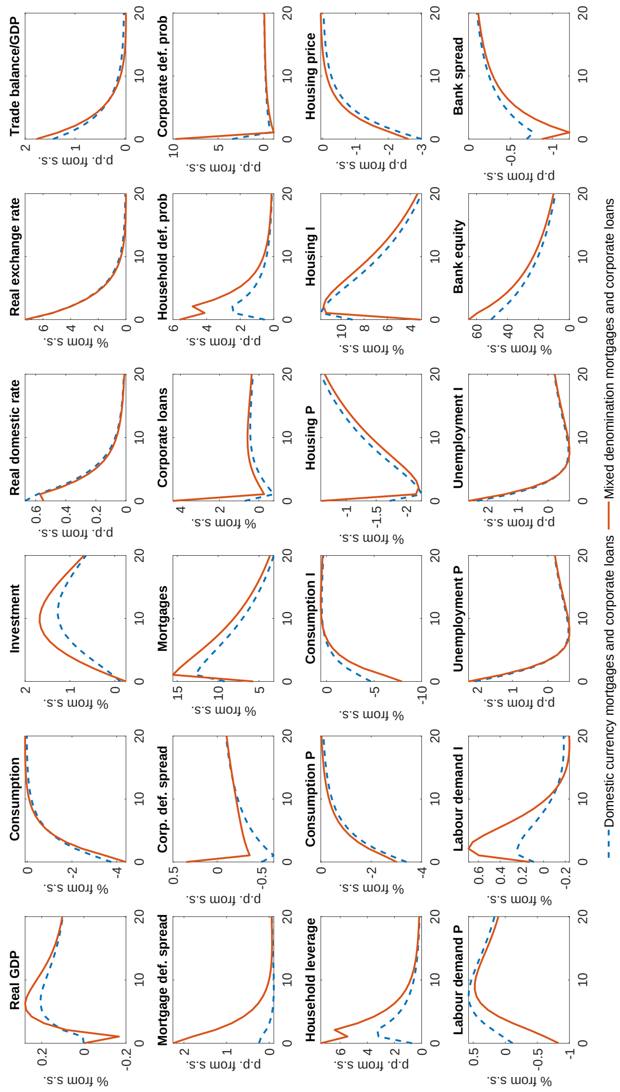
Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households, firms facing the debt overhang friction and leveraged banks. Mixed denomination mortgages mean that 80 percent of mortgages is dominated in foreign currency. Corporate loans in both cases are issued in domestic currency only.

Figure A5: Country's premium shock and currency mismatch for corporates with leveraged banks.



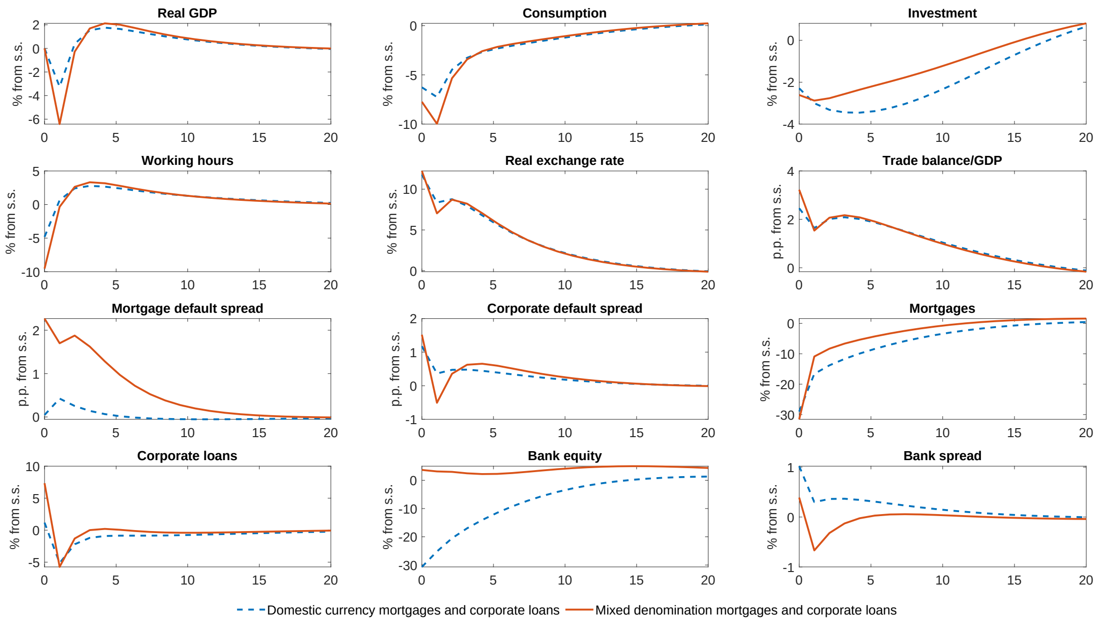
Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households, firms facing the debt overhang friction and leveraged banks. Mortgages in both cases are issued in domestic currency only.

Figure A6: Country's premium shock and currency mismatch for households and corporates with leveraged banks.



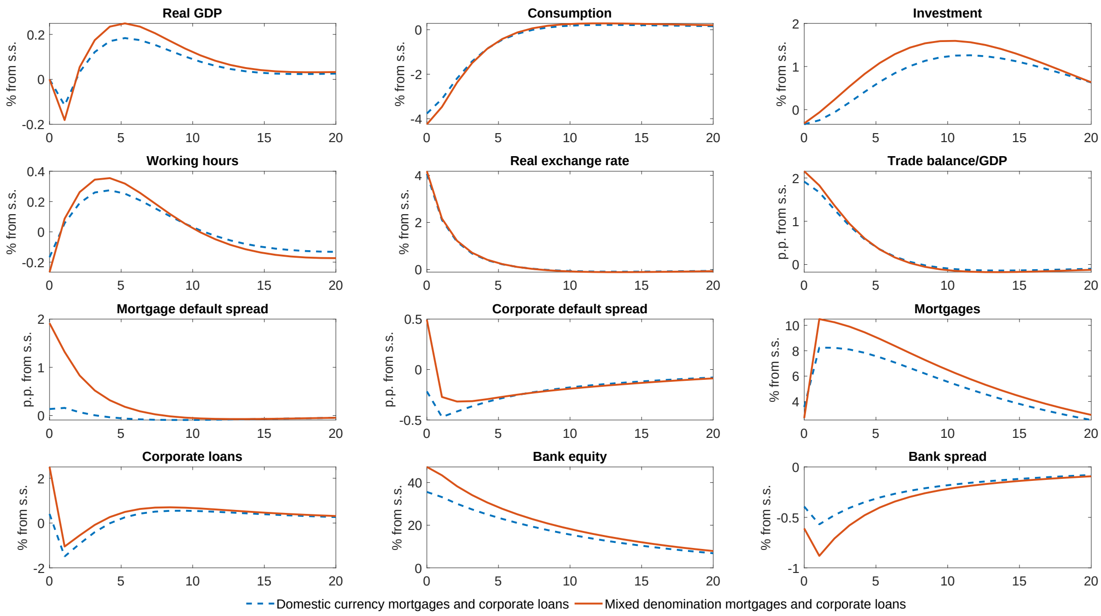
Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households, firms facing the debt overhang friction and leveraged banks. Mixed denomination mortgages and loans mean that 80 percent of mortgages and 60 percent of loans is dominated in foreign currency. In the domestic currency case, 10 percent corporate loans and zero of mortgages are denominated in foreign currency.

Figure A7: Country's premium shock and currency mismatch for corporates with leverage-constrained banks with $\omega^H = 0.5$.



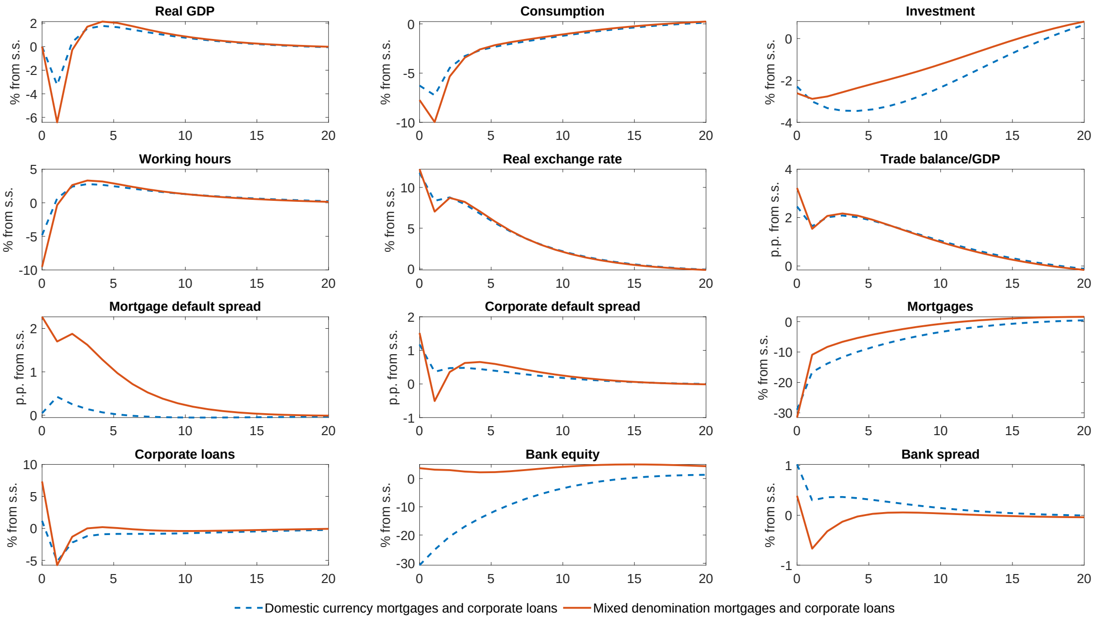
Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households, firms facing the debt overhang friction and leveraged banks when $\omega^H = 0.5$. To generate the IRFs, we first re-estimate the model with this value for price stickiness. Mortgages are denominated in domestic currency.

Figure A8: Country's premium shock and currency mismatch for corporates with leverage-constrained banks with ω^F=0.5.



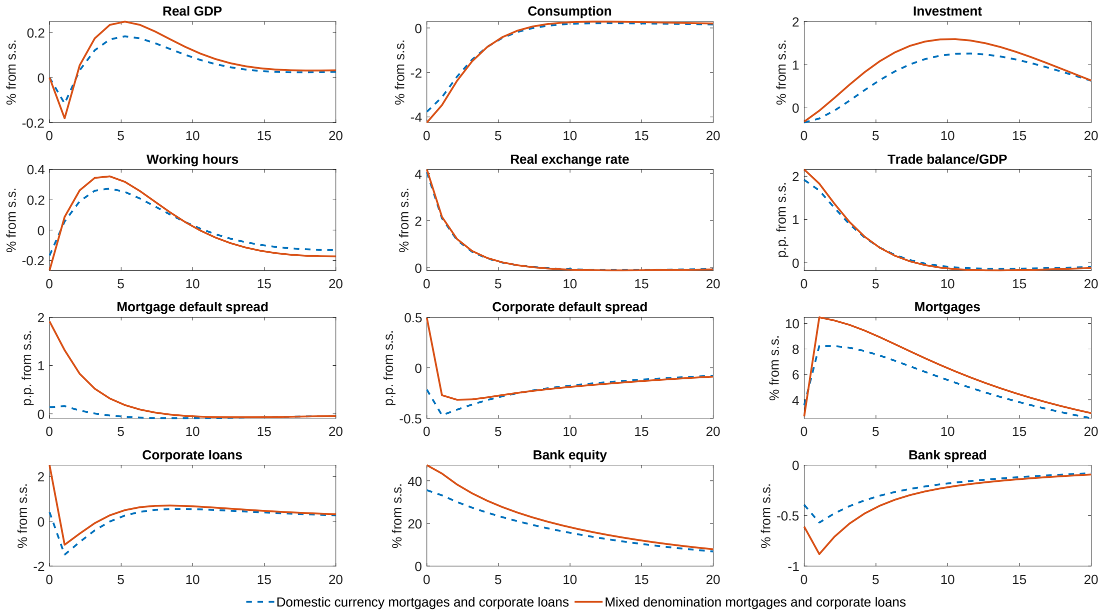
Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households, firms facing the debt overhang friction and leveraged banks when ω^F=0.5. To generate the IRFs, we first re-estimate the model with this value for price stickiness. Mortgages are denominated in domestic currency.

Figure A9: Country's premium shock and currency mismatch for all borrowers with leverage-constrained banks with $\omega^H = 0.5$.



Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households, firms facing the debt overhang friction and leveraged banks when $\omega^H = 0.5$. To generate the IRFs, we first re-estimate the model with this value for price stickiness. Mixed denomination mortgages and loans mean that 80 percent of mortgages and 60 percent of loans is dominated in foreign currency. In the domestic currency case, 10 percent corporate loans and zero of mortgages are denominated in foreign currency.

Figure A10: Country's premium shock and currency mismatch for all borrowers with leverage-constrained banks with ω^F=0.5.



Note: The figure plots IRFs to an unexpected increase in the country's premium by three p.p. in the model with leveraged households, firms facing the debt overhang friction and leveraged banks when ω^F=0.5. To generate the IRFs, we first re-estimate the model with this value for price stickiness. Mixed denomination mortgages and loans mean that 80 percent of mortgages and 60 percent of loans is dominated in foreign currency. In the domestic currency case, 10 percent corporate loans and zero of mortgages are denominated in foreign currency.