Macroeconomics of Carry Trade and Debt Overhang

Egle Jakucionyte* and Sweder J. G. van Wijnbergen†‡

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Abstract

The depreciation of the Hungarian forint in 2009 left Hungarian borrowers with skyrocketing value of foreign currency debt. The resulting allocation of currency mismatch losses to debt-ridden firms worsened debt overhang in Hungary and reduced bank returns. Therefore, even though Hungarian banks isolated their balance sheets from the exchange rate risk to some extent, they faced elevated credit risk. This is one of the examples of carry trade in emerging Europe that motivates the analysis of currency mismatch losses in different sectors in the economy, in particular, what are the macroeconomic consequences of shifting exchange rate risk from borrowers to banks. We develop a small open economy New Keynesian DSGE model that accounts for the implications of domestic currency depreciation for corporate debt overhang and an active banking sector. The model, calibrated to the Hungarian economy, shows that, in periods of unanticipated depreciation, allocating currency mismatch losses to the banking sector generates milder recession than if currency mismatch is placed at credit constrained firms. The government can intervene to reduce aggregate losses even further by recapitalizing banks and thus mitigating the effects of currency mismatch losses on credit supply.

Keywords: Debt overhang, foreign currency debt, leveraged banks, small open economy, Hungary.

1 Introduction

In the period leading up to the crisis Hungarian households and businesses exploited a favourable interest rate differential and piled on foreign currency debt. This carry trade was mostly supported by expectations of low exchange rate volatility and euro adoption in the near future. Both motives turned out to be wrong when in the first months in 2009 the Hungarian forint lost 26% of its value against the euro and even more against the Swiss franc[1]. The sharp depreciation of the

*Tinbergen Institute and the University of Amsterdam, the Netherlands.
†Tinbergen Institute and the University of Amsterdam, the Netherlands.
‡Corresponding author. Address: Roetersstraat 11, 1018 WB Amsterdam. Email address: s.j.g.vanwijnbergen@uva.nl (S.J.G. van Wijnbergen)

[1]By March 2009, compared to September 2008.

forint considerably magnified the debt value and the ratio of non-performing private loans rose. Therefore, even though shifting currency mismatch losses to borrowers saved Hungarian banks from the exchange rate risk on their balance sheets, the depreciation elevated the credit risk of foreign currency loans.

Even though we focus on Hungary as the most pronounced case of currency carry trade via corporate loans in emerging Europe, unhedged foreign currency borrowing in the private sector and substantial bank foreign debt were rather ubiquitous in the region (IMF, 2012b). This motivates our focus on the macroeconomic implications of currency mismatch losses, in particular, what are the macroeconomic consequences of shifting exchange rate risk from borrowers to banks. Thus, besides the allocation of currency mismatch losses that reasonably resembles the Hungary's case before 2009, we also study a counterfactual case with bank lending denominated in domestic currency only. In contrast to foreign currency loans, domestic currency denomination relieves domestic firms of currency mismatch and thus reduces potential debt overhang. However, banks with substantial funding from abroad are left with increased currency mismatch on their balance sheets. Resulting bank losses may impair the credit transmission channel as much as losses from non-performing loans in the former scenario. This trade-off offers scope for quantitative analysis.

This paper explores the macroeconomic consequences of allocating currency mismatch losses by developing a quantitative model with corporate debt overhang and an active banking sector. We confirm that avoiding direct exposure to exchange rate fluctuations does not save banks from losses in times of domestic currency depreciation and show that, in periods of unanticipated depreciation, the economy bears smaller aggregate losses, if firms' net worth is preserved by placing currency mismatch at banks. Banks are in a better position to absorb currency mismatch losses because, in contrast to firms, they do not face default risk. Even though banks are more leveraged than firms, unexpected bank losses affect borrowing conditions for firms and thus aggregate economic activity to a smaller extent than the investment distortion that can stem from a rising default probability in the firms' sector. This assumption relies on the fact that banks may expect to be rescued by either the government or parent banks, while a large number of financially constrained firms cannot expect to be nationalized or receive other types of financial support to prevent them from going bankrupt. The second reason why allocating currency mismatch losses to firms generates larger real losses is that excessive corporate debt affects firms' decisions and thus inflicts output losses directly, while bank losses affect aggregate economic activity with a lag and only after a share of the effect is absorbed by bank equity.

The currency mismatch situation in Hungary was unavoidably shaped by financial vulnerabilities developed prior to the forint depreciation. Our focus on debt overhang as triggered (or intensified) by the forint depreciation is supported by the data. In the run up to the crisis more than one half of private loans were taken in Swiss francs or euros (IMF, 2012b). Brown and Lane (2011) and Herzberg (2010) state that foreign currency borrowing in emerging Europe was not large-scale and concentrated among exporting firms. Studies with access to firm-level data in Hungary cast doubt on the firms' ability to hedge against the currency risk: Endrész et al. (2012) find that more than 82% of firms with foreign currency debt had no foreign currency revenue from exports, the survey of 698 Hungarian firms (Bodnár, 2009) discovers that also around 80% of foreign currency borrowers did not have a natural hedge. The weaker Hungarian forint resulted in significantly more bankruptcies among firms that borrowed in Swiss francs rather than Hungarian forints (Figure 2). Vonnák (2016) confirms that currency mismatch not the lending practices of Hungarian banks contributed the most to the riskiness of foreign currency borrowers.

After 2008, foreign currency borrowers in Hungary were more likely to default and reduce investment (Endrész et al., 2012). Foreign currency borrowers were not only riskier, but, as data analysis in Endrész et al. (2012) shows, also had sizable shares in aggregate variables such as investment and debt in Hungary. We notice that at the macro level the gap between private investment and profit shares in Hungary kept increasing: after 2008 investment declined by more and took longer to recover than the measure for corporate profitability (Figure 1). Therefore, Hungarian firms were unwillling to invest retained earnings for several years which is a strong suggestion of worsening debt overhang. In contrast to monitoring costs or uncertainty literature, the burden of accumulated debt can explain prolonged under-investment in the recovery environment. If firms perceive their chances to default on accumulated debt as sufficiently high, their private benefits from investing diminish. Recessions with investment falling below the socially optimal level of investment tend to be deeper and longer.

Currency mismatch both in the corporate sector and in the banking sector is at the heart of the problem. Both businesses and banks in Hungary borrowed in foreign currency (Hungarian bank association, 2012). The latter currency mismatch was reinforced by tight funding links between foreign parent banks and their subsidiaries in Hungary before the crisis. Moreover, isolation of currency mismatch losses in one sector is impossible due to the credit channel as banks act as the main source of credit in the economy. Banks are the main providers of credit in emerging Europe in particular as they intermediated even up to 80% of total credit (World Bank, 2015). Therefore, even if only borrowers face currency mismatch, domestic currency depreciation would deteriorate the quality of such loans and banks would shrink credit supply inducing far-reaching consequences for the whole economy. The credit provision channel constituted the core of the ECB critique for an early repayment scheme of foreign currency mortgages with an artificially strong exchange rate. In 2011, against the advice of the ECB (ECB, 2011), the Hungarian government adopted such a scheme to aid debt-ridden households and forced banks to take massive losses[2]. This might have posed a real threat of interrupting credit provision in Hungary and casted doubt on saving borrowers at the expense of lenders (even when lenders are foreign-owned). Even though this policy targeted households, we take it as evidence for the importance of credit channel.

For bank losses to impair credit provision, bank funding costs have to depend on bank performance. Indeed, banks are frequently leverage-constrained themselves during crises implying that access to funding depends on the riskiness of their balance sheets (e.g. Diamond and Rajan, 2009).

[2]The estimated total bank losses from the early repayment scheme were around 1.1 billion euros or around 10% of total bank capital in Hungary (Reuters, 2012; authors' calculations).

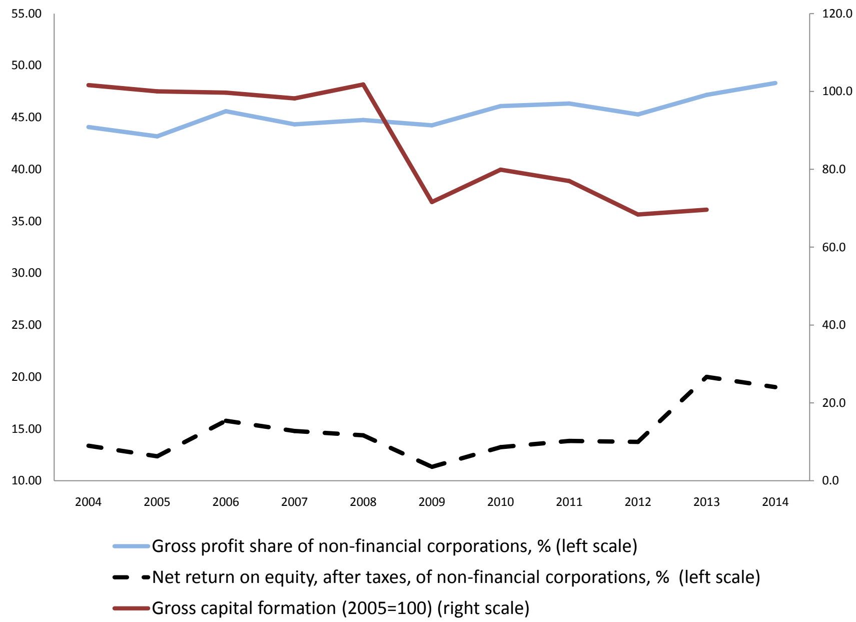


Figure 1: Profit share and private investment in Hungary.

Source: Eurostat.

The banking system in Hungary was well-capitalized in 2008 (IMF, 2008), however, liquidity shocks at the outbreak of the crisis changed the situation dramatically (IMF, 2012a). The sudden dry-up of foreign funding caused a tightening of leverage constraints. To capture this channel, we introduce the second financial friction in the banking sector, namely a leverage constraint. We model it as an agency problem between banks and depositors following Gertler and Karadi (2011). The agency problem prevents banks from unlimited expansion of their balance sheets in good times. In bad times, non-performing loans in the corporate sector deplete bank equity so that the leverage constraint becomes tighter and leads to higher borrowing costs for banks. Eventually, the endogenous leverage constraint amplifies the drop in lending and economic activity. The feedback in bank lending is what makes the model structure complete and suitable to answer the research question.

For a trigger of the debt overhang situation, we look at typical shocks at the onset of the crisis in Hungary that could have led to domestic currency depreciation and in turn magnified the domestic currency value of foreign currency loans. The chronology of the pre-crisis events in emerging Europe points to external triggers instead of shocks of a local origin: despite severe domestic imbalances in emerging Europe, depreciation of local currencies followed spill-overs from the looming economic crash in advanced economies rather than happened at the same time. Based on anecdotal evidence and data (IMF, 2012a) we choose to look at capital outflows, a drop in world demand for

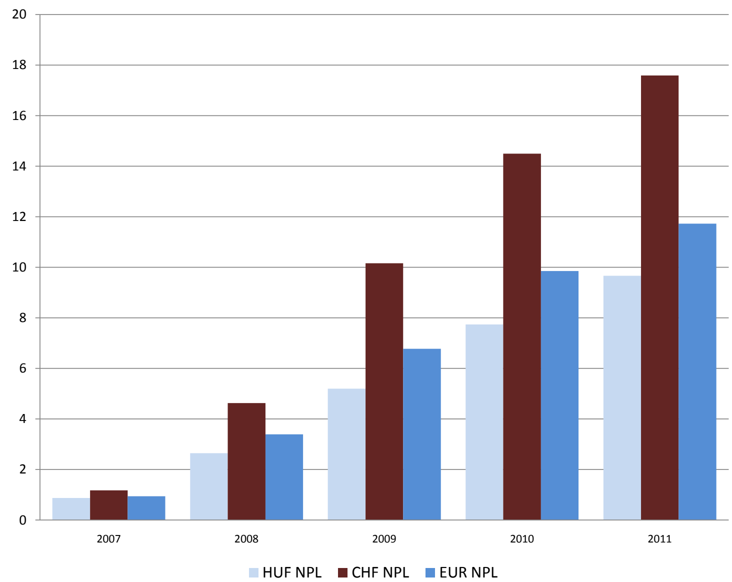


Figure 2: Ratio of non-performing corporate loans by currency in Hungary.

Source: Vonnák (2016).

domestic exports and an increase in volatility in the markets.

We feed shocks into a small open economy medium-sized New Keynesian model calibrated to the Hungarian data. The open sector of the model economy is essentially the extension of Galí and Monacelli (2002) as it is done in García-Cicco et al. (2014) and Adolfson et al. (2014). We introduce a financial friction of debt overhang which is the key element of the model next to the active banking sector as in Gertler and Karadi (2011). We generalize the debt overhang mechanism from Occhino and Pescatori (2015) to account for the default on corporate loans denominated in foreign currency.

Despite the used first-order approximation techniques, our model is capable of studying volatility effects. The volatility term in the financially constrained firms' optimization problem drives the wedge between social benefits from investing and private benefits from investing. Besides modeling a shock to volatility of firms' future profits, we endogenize volatility by incorporating uncertainty about prices: we simulate the theoretical model as long as the value converges. The obtained volatility value contains more information about the propagation of a particular shock in our model and thus is superior to an arbitrary calibrated value.

The debt overhang friction stems from particular features that we attribute to the debt contract in the model. Borrowing firms are subject to limited liability which distorts incentives towards taking too much risk and rules out a risk-free debt contract from the menu of optimal contracts. Second, banks cannot write a contract on how the issued loans will be used: the quantities of capital and labour are determined unilaterally by the firm. Following the literature we call this feature the assumption of non-contractible investment. Together, in the case of adverse shocks, these frictions may create debt overhang and distort the firms' choice of capital and labour demand.

The idea that risky debt makes firm to undergo valuable investment opportunities goes back to Myers (1977). Limited liability implies that issuing risky debt may incentivize a sub-optimal investment strategy and reduce the market value of a firm. However, the study does not explore how the reduced value of the firm would affect firm's borrowing costs. The idea that the default risk would feed into the credit spread is formalized in Merton (1974) that derives the credit spread as a put option on the future assets of a debtor. Our setup incorporates both seminal ideas: if debt is high enough, firms' incentives to invest diminish and a default spread goes up reinforcing the mechanism. Occhino and Pescatori (2015) is the first attempt to introduce debt overhang in the real business cycles model and our implementation of debt overhang largely relies on their work.

Out of several explanations how debt can reinforce business cycle fluctuations, only debt overhang is suitable for our research problem. The costly state verification framework does not explain borrowers' efforts to cope with excessive debt because it allows lenders and borrowers to contract on investment and thus eliminates the moral hazard problem. A default wedge as in Gourio (2014) introduces corporate default effects on input providers instead of lenders and thus abstracts from the credit channel which is crucial in the Hungarian story. This paper is the first attempt to use the non-contractible investment approach to explain the role of excessive debt and foreign currency debt in particular in the business cycle analysis.

The structure of the paper is as follows. We present related literature in Section 2 and discuss the model in detail in Section 3 and simulation settings in Section 4. We describe results in Section 5. Section 6 concludes.

2 Related literature

The lengthy corporate finance literature on debt overhang that starts with the seminal paper of Myers (1977). We contribute to the literature on macroeconomic consequences of debt overhang that were firstly examined in Lamont (1995). The paper shows that debt overhang can create strategic complementarities among investment of individual agents, thus, high debt can lead to multiple equilibria dependent on prevailing animal spirits in the economy. Differently, Philippon (2010) studies the interaction between different indebted sectors in the model economy. The paper argues that debt overhang can create strategic complementarities between different economic sectors, namely, households and banks. In a closed economy, bailing out banks is efficient, while bailing out insolvent households means transferring funds to households that made inefficient saving decisions. In an open economy, countries have an incentive to free ride on foreign recapitalization programs, therefore, international coordination is required. Besides the shared focus on the credit transmission channel in an indebted economy, we take beyond the analysis in Philippon (2010) and study the business cycle properties of the model economy and apply the concept of debt overhang to excessive foreign currency debt.

Our question comes close to Gomes, Jermann and Schmid (2013) and Occhino and Pescatori (2014) that analyze the conduct of monetary policy in an environment with nominal debt. However, instead of looking at the effects of unanticipated inflation, we focus on the debt overhang situation in the periods of domestic currency depreciation.

There is a vast literature that explores foreign currency debt effects in the costly state verification framework as implemented in Bernanke and Gertler (1989) and Bernanke, Gertler and Gilchrist (1999). Traditionally domestic currency depreciation invokes the expenditure switching effect that should stabilize demand for domestic goods. However, high foreign currency debt together with monitoring costs and sticky prices can potentially outweigh the expenditure switching effect and in turn make depreciations contractionary. Céspedes, Chang, and Vélasco (2004), Devereux, Lane and Xu (2006), and Gertler, Gilchrist, and Natalucci (2007) study the depreciation effects on firms in a small open economy setting. They incorporate a model of investment in which net worth affects the cost of capital and allow firms to borrow in foreign currency. They argue that even with high foreign currency debt depreciations remain expansionary. A similar model is considered in Cook (2004) where it leads to the opposite conclusion. Cook (2004) explains the discrepancy in findings by the type of price stickiness. If, as in Céspedes et al. (2004), input prices are sticky but output prices are not, domestic currency depreciation lowers real wages and increases revenues. Thus, the increase in firms' revenues might compensate for the soaring foreign currency debt and the depreciation remains expansionary. If, as in Cook (2004), output prices are sticky and input prices are not, revenues do not increase as fast as input costs and the depreciation can become contractionary. Despite the fact that these studies abstract from debt overhang, they emphasize the negative role of foreign currency debt and support our question too.

Empirical studies have established the relevance of financial frictions in explaining the macroeconomic outcomes. Without taking a stand on the prevalent financial friction, Towbin and Weber (2011) look at the data for 101 countries from 1974-2007 and show that high foreign currency debt increases the decline in investment in response to adverse external shocks. Kalemli-Özcan, Laeven and Moreno (2015) advance further by studying firm-bank-sovereign linkages in Europe to weigh the role of several financial frictions. They find that debt overhang is more important in explaining weak investment relative to weak bank and weak firm balance sheet channels. Therefore, debt overhang also has on average better chances in explaining poor investment performance in Hungary compared to other financial frictions.

Another branch of the literature that we relate to is centered upon volatility shocks. A recent contribution by Christiano, Motto and Rostagno (2014) attributes a significant share of business cycle fluctuations to idiosyncratic risk shocks fed through the time-varying idiosyncratic variance component. The variance component appears in the credit spread of entrepreneurs as in the costly state verification framework implemented in Bernanke et al. (1989). Thus the impact of the risk shock affects the credit spread rather than the default wedge in the firm's investment decision.

3 Model

Our main modeling contribution is the introduction of debt overhang friction along with an active banking sector in a small open economy model. While the contributions are necessary components of the problem in hand, the open sector with nominal rigidities generates realistic lending and output dynamics in the presence of foreign currency loans. We start the outline of the model by describing the novel sections and later briefly present sections which are standard to the New Keynesian DSGE tradition. More detailed derivations can be found in the supplementary appendix.

3.1 Financially constrained firms

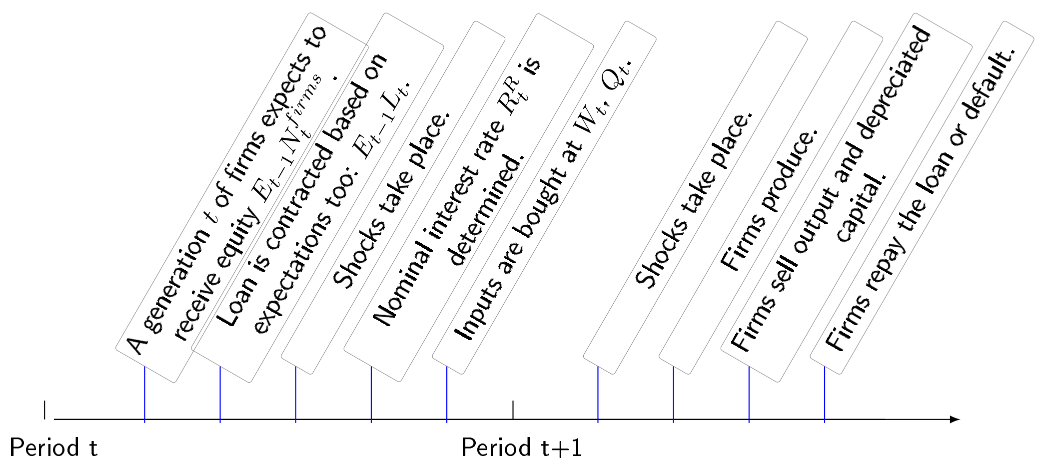


Figure 3: Timing for financially constrained firms.

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. In the first period firms buy two types of inputs, capital k and labour h, and have to pay for a fraction ρ of working capital in advance. Production takes place in the next period.

To pay in advance, a financially constrained firm i uses two types of financing. First, it receives equity from households, $N_{i,t}^{firms}$. Second, it borrows from the bank an amount $L_{i,t}$ that consists of both domestic currency funds $L_{i,t}^D$ and foreign currency denominated funds $L_{i,t}^F$ such that $L_{i,t} = L_{i,t}^D + S_t L_{i,t}^F$ where S_t is the nominal exchange rate. We assume that the share of foreign currency denominated funds is fixed and denoted by α^F, 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.

To borrow the firm pledges a share κ of future revenue, where $0 < \kappa \leq 1$. 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 minus the expected equity transfer from the household. It follows that in the beginning of period t the following condition holds:

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

where q_t, w_t and rer_t denote the real price of capital, the real wage and the real exchange rate respectively. We define the real exchange rate as $S_t P_t^*/P_t$ where S_t is the nominal exchange rate, P_t is the domestic consumer price level and P_t^* is the foreign price level. $n_{i,t}^{firms}$ stands for the real equity transfer from the domestic household, where $n_{i,t}^{firms} \equiv N_{i,t}^{firms}/P_t$. $l_{i,t}$ stands for the size of the total loan expressed in units of domestic 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.

The role of corporate equity is limited to the effect on firms' demand for funds and indirectly the distance to default. In bad times, a higher fraction of firms default decreasing the total value of corporate net worth. The household pools retained earnings and distributes them to new-born firms equally. New generations of firms receive lower equity from the household, therefore, to produce the same amount of goods, they have to leverage more and face higher chances to default. Noteworthy, firms die after two periods and do not take into account future profits which mutes the net worth effect to some extent. Also, the first generation of firms that enters the scene after the shock, makes its borrowing decision based on expectations about the value of its net worth. It follows that the net worth effect materializes for future generations of firms only.

In most cases actual firm's demand for working capital will not equal the received loan. We assume that in such cases the owner of the firm that is the domestic household steps in and transfers lump-sum funds $Z_{i,t}$ (where $z_{i,t} \equiv Z_{i,t}/P_t$) to cover the difference (as in Occhino and Pescatori, 2015). 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 has no effect on neither the household's nor the firm's incentives.

Let the matured loan in units of domestic goods be $R_{i,t}^R\left(\frac{l_{i,t}^D}{\pi_{t+1}} + rer_{t+1}\frac{l_{i,t}^F}{\pi_{t+1}^*}\right)$, where $R_{i,t}^R$ 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 $l_{i,t}^D \equiv L_{i,t}^D/P_t$ and $l_{i,t}^F \equiv L_{i,t}^F/P_t^*$. The contracted collateral is a fraction κ of firms' revenue from selling goods and depreciated capital in the next period, $p_{t+1}^R y_{i,t+1}^R + q_{t+1}(1-\delta)k_{i,t}$. Then the decision of the financially constrained firm i born in period t whether to default or not is determined by the lower value:

$$\min\left\{R_{i,t}^R\left(\frac{l_{i,t}^D}{\pi_{t+1}} + rer_{t+1}\frac{l_{i,t}^F}{\pi_{t+1}^*}\right), \quad \kappa\left(p_{t+1}^R y_{i,t+1}^R + q_{t+1}(1-\delta)k_{i,t}\right)\right\} \quad (2)$$

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

The firm i born in period t and endowed with corporate equity $n^{firms}_{i,t}$ maximizes profits taking the loan as given. The firm maximizes the expected sum of future revenue from selling goods and depreciated capital subtracted by the second fraction of working capital expenditure together with expenses related to the debt payment. Financial flows received in period t also enter the maximization problem and can be summarized as the difference between the loan plus equity (both $n^{firms}_{i,t}$ and $z_{i,t}$) and working capital expenditure:

$$
\begin{aligned}
\max_{\{k_{i,t},h_{i,t}\}} & E_t\beta\Lambda_{t,t+1}\left\{p^R_{t+1}y^R_{i,t+1} + q_{t+1}(1-\delta)k_{i,t} - (1-\rho)\frac{q_tk_{i,t}+w_th_{i,t}}{\pi_{t+1}}\right\} \\
& - E_t\beta\Lambda_{t,t+1}\min\left\{R^R_{i,t}\left(\frac{l^D_{i,t}}{\pi_{t+1}} + rer_{t+1}\frac{l^F_{i,t}}{\pi^*_{t+1}}\right), \quad \kappa\left(p^R_{t+1}y^R_{i,t+1} + q_{t+1}(1-\delta)k_{i,t}\right)\right\} \\
& + l_{i,t} + n^{firms}_{i,t} + z_{i,t} - \rho\left(q_tk_{i,t} + w_th_{i,t}\right)
\end{aligned}
$$

s.t.

$$
E_{t-1}\left\{l_{i,t}\right\} + E_{t-1}\left\{n^{firms}_{i,t}\right\} = E_{t-1}\left\{\rho\left(q_tk_{i,t} + w_th_{i,t}\right)\right\}
$$

The resulting first-order conditions are[3]:

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

[3]The derivation of the first-order conditions and the term $d_{2,t}$ in particular are provided in the supplementary appendix A1-A2.

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

where

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

The debt overhang friction introduces an additional term in otherwise standard demand functions for capital and labour: conditions incorporate a proxy for the default probability, $(1-\Phi(d_{1,t}))$, that reduces a marginal product of capital and a marginal product of labour. Thus in this problem the default probability is what drives the wedge between social benefits from investing and private benefits from investing. When the default probability increases, private benefits would diminish and demand for labour and capital would shrink resulting in a lower level of working capital than a socially optimal one. Under-investment in working capital has negative and prolonged implications on aggregate variables: we can distinguish between static debt overhang effects and dynamic debt overhang effects. Static debt overhang results from a decline in demand for working capital which depresses aggregate demand on impact. Dynamic debt overhang occurs, if the indebted sector uses capital as input. Then sub-optimally lower demand for capital shrinks demand for investment. Lower investment today decreases capital stock available for production tomorrow which prolongs the economic recovery.

The second implication of the first-order conditions relates to the option structure as reflected by the definition of the function argument $d_{2,t}$. The default probability directly depends on a volatility term σ^2_y which captures the variance of future profits. It can be showed that σ^2_y is given by $var\left(\pi_{t+1}\left(\kappa\left(p^R_{t+1}y^R_{i,t+1} + q_{t+1}(1-\delta)k_{i,t}\right) - R^R_t\frac{rer_{t+1}l^F_{i,t}}{\pi^*_{t+1}}\right)\right)$ and depends on exogenous productivity shocks, working capital and endogenous volatility of prices and exchange rate value in the domestic economy. The first-order conditions imply that increased uncertainty about of future collateral value reduces firms' chances to repay. Looming uncertainty during the latest crisis[4] high-

[4]The implied volatility indexes for both European markets and Poland rocketed in the end of 2008, see the plot in the Appendix (Figure 10). We do not have a measure for Hungary, however, the implied volatility index for Polish markets should serve as a satisfactory proxy for the markets' risk perception for the Hungarian economy.

lights the importance of the volatility term in explaining borrowing conditions for firms and firms' willingness to borrow and suggests that we cannot assume constant volatility without a loss of generality. Thus we model an exogenous shock to a volatility term to simulate increased uncertainty about financially constrained firms' performance in the future as one of possible triggers of debt overhang.

Noteworthy, the default probability varies not only with stochastic components such as technology but with expected prices and exchange rates as well. This motivates our simulation exercise in which we simulate the model until the endogenously implied volatility of firms' expected collateral value converges. This exercise allows us to incorporate the second-order characteristics of the economy and obtain a better estimate for the volatility term than an arbitrary calibrated value.

In the beginning of every period, after shocks take place and a fraction of firms default, the domestic household pools the remaining net worth from non-defaulted firms into aggregate net worth by following the aggregation rule:

$$\begin{aligned} n_t^{firms} = \quad & \omega^{firms}\left(p_t^R y_t^R + q_t(1-\delta)k_{t-1} - (1-\rho)\frac{q_{t-1}k_{t-1} + w_{t-1}h_{t-1}}{\pi_t}\right) \\ & - \omega^{firms}\left((1-\Phi(d_{1,t-1}))\,\kappa\left(p_t^R y_t^R + q_t(1-\delta)k_{t-1}\right) + \Phi(d_{2,t-1})R_{t-1}^R\frac{l_{t-1}^D}{\pi_t} + \Phi(d_{1,t-1})rer_t\frac{l_{t-1}^F}{\pi_t^*}\right) \\ & + \iota^{firms}\cdot n^{firms} \end{aligned}$$

Recall that $(1-\Phi(d_{1,t-1}))$ proxies for the default rate (by the law of large numbers this is equal to the share of defaulted firms in the economy). Then the first term on the right hand side is aggregate firms' revenue from production and selling depreciated capital minus the rest of the expenditure for working capital. The second term is the firms' aggregate expenditure for repaying loans. The difference between the two gives financially constrained firms' profits. The third term is the injection of new equity. We assume that the domestic households acts as distributor and cannot divert pooled equity funds anywhere else. Also the existing equity can be increased only by the amount $\iota^{firms}\cdot n^{firms}$ that is fixed and proportional to aggregate net worth in the steady state. Thus, this equity transfer does not depend on the household's decision. ω^{firms} is a fraction that is close but lower than unity. We assume that this parameter proxies for the equity management costs incurred by the household and use this parameter to calibrate the steady state corporate leverage to the one observed in the data.

3.2 Banks

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 that a bank continues operating. Otherwise, the net worth is transferred to the owners of the bank, domestic households.

We assume that banks give loans to firms out of accumulated equity n_t, domestic deposits d_t and foreign debt d_t^*. A fraction of banks' liabilities (foreign debt) is denominated in foreign currency which exposes banks to currency mismatch. Lending in foreign currency hedges the open currency position for banks[5]. However, shifting exchange rate risk to the credit constrained corporate sector 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 is described by bank lending in both foreign currency and domestic currency so that banks are relieved from currency mismatch. We will consider these two cases in the following discussion on shifting currency mismatch. The model with loans denominated in both currencies is described here, while the model with lending in domestic currency only is described in the supplementary appendix B2.

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

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

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):

$$\xi_t = \exp\left(\kappa_\xi \frac{(rer_t d_t^* - rer \cdot d^*)}{rer \cdot d^*} + \frac{\zeta_t - \zeta}{\zeta}\right) \tag{3}$$

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 every bank can divert a fraction λ^L of divertable assets. Creditors take this possibility into account and lend only up to the point where the continuation value of the bank is still larger or equal to what can be diverted. This condition acts as an incentive constraint for the bank and eventually limits expansion of the balance sheet.

The only asset on the banks' balance sheet is loans to domestic financially constrained firms, thus, loan performance directly affects bank profits. When the default probability $(1 - \Phi(d_{2,t}))$ for financially constrained firms increases, banks expect lower returns. High corporate leverage has similar consequences as it increases the size of loans for the same level of production and reduces firms' chances to repay *ceteris paribus*. We define the expected return for the bank j as $R_{j,t}^L$. The definition makes use of the derived expected loan payment (see the supplementary appendix A2) and in its final expression directly incorporates the default probability on corporate loans:

[5] We calibrate the share of loans denominated in foreign currency such that banks do not have a zero open currency position in that case. This allows us to distinguish between the credit risk effects and the exchange rate risk effects.

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

$$\Rightarrow E_t\left\{\frac{R^L_{j,t}}{\pi_{t+1}}l_{j,t}\right\}\equiv E_t\left\{(1-\Phi(d_{1,t}))\,\kappa\left(p^R_{t+1}y^R_{j,t+1}+(1-\delta)q_{t+1}k_{j,t}\right)+\Phi(d_{2,t})R^R_{j,t}\frac{l^D_{j,t}}{\pi_{t+1}}+\Phi(d_{1,t})R^R_{j,t}rer_{t+1}\frac{l^F_{j,t}}{\pi^*_{t+1}}\right\} \tag{4}$$

To facilitate further discussion, we define three spreads, expressed as differences in ex-ante real interest rates. The first is the default spread measured as the difference in the ex-ante interest rate on the loan and the ex-ante return on the loan: $E_t\left(R^R_{j,t}-R^L_{j,t}\right)/\pi_{t+1}$. The higher is the spread, the more the bank charges to compensate for the default risk. Secondly, we distinguish the bank spread that depends on the banking friction: it captures the premium that is to compensate for additional funding costs incurred due to the endogenous leverage constraint. This spread is given by the difference in the ex-ante return on the loan to financially constrained firms and the ex-ante bank funding costs: $E_t\left(R^L_{j,t}/\pi_{t+1}-R^*_t\xi_t/\pi^*_{t+1}\frac{rer_{t+1}}{rer_t}\right)$. Finally, the credit spread is the sum of the default spread and the bank spread and is given by $E_t\left(R^R_{j,t}/\pi_{t+1}-R^*_t\xi_t/\pi^*_{t+1}\frac{rer_{t+1}}{rer_t}\right)$. A higher credit spread reflects tighter borrowing conditions due to any or both of the financial frictions.

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

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

s.t.

$$V_{j,t}\geq\lambda^L l_{j,t}, \qquad \textit{(Incentive constraint)}$$

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

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

The first-order conditions follow:

$$d_{j,t}:\quad (1+\nu_{1,t})\beta E_t\Lambda_{t,t+1}\left\{(1-\omega)+\omega\nu_{2,t+1}\right\}\left(\frac{R_t}{\pi_{t+1}}\right)=\nu_{2,t} \tag{5}$$

$$d^*_{j,t}:\quad (1+\nu_{1,t})\beta E_t\Lambda_{t,t+1}\left\{(1-\omega)+\omega\nu_{2,t+1}\right\}\left(\frac{R^*_t\xi_t}{\pi^*_{t+1}}\frac{rer_{t+1}}{rer_t}\right)=\nu_{2,t} \tag{6}$$

$$l_{j,t}:\quad (1+\nu_{1,t})\beta E_t\Lambda_{t,t+1}\left\{(1-\omega)+\omega\nu_{2,t+1}\right\}\left(\frac{R^L_{j,t}}{\pi_{t+1}}\right)=\lambda^L\nu_{1,t}+\nu_{2,t} \tag{7}$$

$\nu_{1,t}$ 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.

Equations (5) and (6) govern the bank debt portfolio choice. Equation (5) 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 (6) and is adjusted for changes in the exchange rate value. The structure of these choice rules suggests that in equilibrium the bank has to be indifferent between taking deposits or issuing bank debt to foreign agents.

Equation (7) presents the relation between 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). We see that in equilibrium one additional unit of loans earns the discounted risk adjusted return on loans. Firstly, this return has to increase in the marginal cost from issuing bank debt to finance the expansion of the balance sheet, $\nu_{2,t}$. Secondly, due to the endogenous bank leverage constraint, the risk adjusted bank return on loans also increases in the share of divertable assets λ^L 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.

The first-order conditions hold together with complementary slackness conditions:

$$\nu_{1,t}: \quad \nu_{1,t}\left(V_{j,t} - \lambda^L l_{j,t}\right) = 0$$

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

The set of equilibrium conditions also 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. We assume that aggregate net worth consists of the net worth of non-bankrupted banks and the new worth of new banks. The new equity is injected by domestic households and is assumed to be of the size ιn. Then

$$n_t = \omega\left(\frac{R^L_{j,t-1}}{\pi_t} l_{t-1} - \frac{R_{t-1}}{\pi_t} d_{t-1} - \frac{R^*_{t-1}\xi_{t-1}}{\pi^*_t} rer_t d^*_{t-1}\right) + \iota n \tag{8}$$

3.3 Financial sector support

This segment of the model is dedicated for policy analysis and closely follows Kirchner and van Wijnbergen (2011). We assume that the government can intervene during the crisis by injecting capital τ^{FS}_t to the financial sector. We assign the following rule to the recapitalization of the financial intermediary j:

$$\tau_t^{FI} = \kappa_{FS}\left(shock_{t-l} - shock\right) n_{j,t-1}, \qquad \kappa_{FS} > 0, \quad l \geq 0$$

where $n_{j,t-1}$ is the net worth of the intermediary from the previous period. The recapitalization can be immediate ($l = 0$) or delayed ($l > 0$). We introduce a new variable $shock_t$ that coincides with the variable driving the crisis, e.g. the risk premium shock ($shock_t \equiv \xi_t$). We assume that the recapitalization is a gift from the government and does not have to be repaid.

Now the bank equity increases in the equity injection from the government besides being a function of loan returns and borrowing costs:

$$n_{j,t} = \frac{R_{j,t-1}^L}{\pi_t} l_{j,t-1} - \frac{R_{t-1}}{\pi_t} d_{j,t-1} - \frac{R_{t-1}^* \xi_{t-1}}{\pi_t^*} rer_t d_{j,t-1}^* + \kappa_{FS}\left(shock_{t-l} - shock\right) n_{j,t-1}$$

Bank's optimization problem would yield different results now. We present modified first-order conditions in the supplementary appendix B3.

3.4 Households

We assume a representative household. The household has two alternatives where to invest: put deposits d_t or buy domestic bonds issued by the government, b_t. The household supplies labour to a competitive labour market. The household has Greenwood–Hercowitz–Huffman (henceforth, GHH) preferences as in Greenwood et al. (1988) so that the labour supply decision does not depend on wealth. The household chooses a level of real consumption c_t and working hours h_t such that the following lifetime utility function is maximized:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\gamma} \left(c_t - \frac{\chi \left(h_t\right)^{1+\varphi}}{1+\varphi} \right)^{1-\gamma} \qquad \gamma, \chi, \varphi > 0 \tag{9}$$

where maximization takes place subject to the household's budget constraint:

$$c_t + b_t + d_t = w_t h_t + \frac{R_{t-1}}{\pi_t} b_{t-1} + \frac{R_{t-1}}{\pi_t} d_{t-1} + \Pi_t - T_t \tag{10}$$

π_t denotes consumer price inflation. We assume that the household is indifferent between buying domestic bonds and putting deposits, thus, R_t is nominal gross interest rate of both domestic bonds and deposits. The household owns all banks in the model economy and thus receives lump-sum dividends, Π_t. Taxes, t_t, enter the household's budget constraint in a lump-sum way as well. Lump-sum dividends from financially constrained firms are included in total profits and consists of firms' profits the household receives in the beginning in the period minus the household equity transfers to the firms in the beginning in the period.

3.5 Production and Pricing

There are several types of firms in the domestic economy. It takes three types of firms to produce domestic inputs for domestic final goods. First, there is an infinite set of financially constrained firms that combine purchased capital with labour and produce homogenous goods. Further we discuss other firms than financially constrained firms. More detailed derivations of optimization problems can be found in the supplementary appendix D.

3.5.1 Retail firms

Homogenous 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 $p_t^H(j)$. 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 final goods producer.

3.5.2 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.

3.5.3 Final goods producer

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

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

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

Then she combines domestic composite goods and foreign composite goods into domestic final goods y_t^C with the aggregation technology that takes the given taste parameter for foreign composite goods η as given:

$$y_t^C \equiv \left((1-\eta)^{\frac{1}{\epsilon}}(y_t^H - ex_t)^{\frac{\epsilon-1}{\epsilon}} + \eta^{\frac{1}{\epsilon}}(y_t^F)^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{11}$$

Domestic goods enter as a difference between all produced domestic goods and exports ex_t because we assume exports not to have imported content. Thus, exporters would export domestic composite goods rather than domestic final goods. ϵ stands for elasticity of substitution between domestically produced goods and imported goods. Domestic final goods are sold to the domestic household, the government and capital goods producers.

3.5.4 Capital producers

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

$$k_t = (1-\delta)k_{t-1} + \left(1 - \Gamma\left(\frac{i_t}{i_{t-1}}\right)\right) i_t \tag{12}$$

where

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

3.5.5 Exporters

For the purpose of exports, we model one more separate sector of firms operating in the domestic economy. We assume that perfectly competitive exporters demand ex_t units of domestic composite goods, therefore, supply of assembled production of domestic retailers has to satisfy both the demand of the final goods producer and demand of exporters. Also, it follows from the assumption about the composition of exported goods that exports have no imported inputs in their structure.

Exports are sold at a price $P_t^{H*} \equiv P_t^H/S_t$ which in relative terms can be expressed as $P_t^{H*}/P_t^* = P_t^H/(S_t P_t^*)$. The latter is the price of domestic composite goods expressed in units of foreign goods. Then the foreign demand for domestic composite goods follows:

$$ex_t = \eta^* \left(\frac{p_t^H}{rer_t}\right)^{-\epsilon_*} y_t^* \tag{13}$$

As it is common in the small open economy literature, P_t^* and y_t^* are assumed to evolve exogenously.

3.6 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, and the bank recapitalization program, τ_t^{FS}, the government collects lump-sum taxes t_t from the household and issues domestic bonds b_t. It has to satisfy the budget constraint:

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

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

$$t_t = t + \kappa^B \left(b_{t-1} - b\right) + \kappa^{FS} \tau_t^{FS} + e_t, \qquad 0 < \kappa^B \leq 1, \quad 0 \leq \kappa^{FS} \leq 1$$

The rule tells that a share κ^{FS} of the recapitalization expenditure is covered by increasing the lump-sum tax and the rest (a share $(1 - \kappa^{FS})$) is financed with new government debt.

3.7 Monetary policy

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

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\gamma_R} \left(\frac{y_t^H}{\bar{y}^H}\right)^{(1-\gamma_R)\gamma_Y} \left(\frac{\pi_t^H}{\bar{\pi}^H}\right)^{(1-\gamma_R)\gamma_\pi} \exp(mp_t) \tag{14}$$

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

3.8 Market clearing

The domestic household, the government and capital producers buy domestic final goods. Therefore, the supply of domestic final goods y_t^C has to satisfy the aggregate domestic demand:

$$y_t^C = c_t + i_t + g_t \tag{15}$$

3.9 Current account and its components

Trade balance expressed in units of domestic goods is given by:

$$tb_t = p_t^H ex_t - m_t$$

where m_t denotes the value of imports and can be expressed as $m_t \equiv rer_t D_t^F y_t^F$ (see the supplementary appendix J for details).

So the current account in real domestic terms is given by the sum of real trade balance and real net income from abroad:

$$ca_t = tb_t + ni_t \tag{16}$$

The domestic household owns banks that issue foreign debt d_t^*. Banks are the only agents to borrow from abroad. Also, we assume that nobody in the domestic economy lends to foreign agents. As a result, real net income from abroad is negative and equal to minus payments of bank foreign debt. It follows that

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

In equilibrium the current account has to equal the capital account balance which is given by the change in bank foreign debt. The equilibrium condition follows: We express this change in units of domestic goods as well and get:

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

4 Preliminaries to analyzing the model

4.1 Calibration

To employ the theoretical model for empirical simulation, all parameters are calibrated. We mostly used related studies on the Hungarian economy. We list calibrated parameter values and targeted steady state values in Table 2 in the Appendix. Parameters that are endogenously determined in steady state are $\beta, \chi, \eta^*, \kappa, \omega$ and π^*. χ is chosen such that average working hours in the steady is 0.3 as it is common in the literature. η^* is chosen such that the ratio between the steady state foreign output and the domestic output is equal to the share of the Hungarian GDP in the EU GDP, namely 0.007. π^* follows from satisfying the UIP condition in the steady state given the foreign nominal interest rate of 4.5 p.p. in annual terms. The most important ones of the rest of endogenously determined and calibrated parameters are discussed below.

The introduced financial frictions bring a few additional parameters to calibrate. The debt overhang friction depends substantially on the corporate default rate value in the steady state, $1-\Phi(d_2)$. Due to *de facto* non-existent corporate bond market in Hungary, we choose to calibrate the steady state default probability to an average default frequency of corporate loans in Hungary over the period 2002-2007 as reported by the Bank of Hungary. This makes $1-\Phi(d_2) \approx 0.03$. We choose the bankruptcy loss parameter κ such that the steady state default probability in the model matches the data counterpart. The banking friction relies on the fraction of capital that can be diverted, λ^L, the proportional transfer to the entering bankers, ι, and bank leverage in the steady state. We calibrate ι to 0.002 following the original paper of Gertler and Karadi (2011). Bank leverage matches the average bank leverage in the OECD data for year 2007. We make an adjustment to the average bank leverage of 8.6 in Hungary as reported by Bank of Hungary: we adjust for the average fraction of loans in total assets and get $8.6 \cdot 0.65 \approx 5.6$. The remaining parameter, λ^L, is chosen such that the lending spread in the steady state match the observed difference between nominal corporate loan interest rate and nominal corporate deposit rate in Hungary in 2001:Q1-2008:Q3 (data from the Bank of Hungary). Our computations yield an annual lending spread of 2.7 p.p. It follows that $\lambda^L = 0.45$.

We calibrate the share of foreign currency loans in total corporate loans to 0.6 to match the aggregate share of FX corporate loans in Hungary in 2007-2008 (Krekó and Endrész, 2010). For the model with loans of hybrid denomination we calibrate the steady state trade balance such that bank liabilities denominated in foreign currency would match foreign currency loans exactly.

We have also calibrated several steady state values using data from the Eurostat online database. The steady state annual inflation in Hungary over the period 2001:Q1-2008:Q3 was 5.9 p.p., we choose the discount factor β such that the steady state inflation in the model matches the data counterpart. The ratio of government spending to GDP, s^g, is set to 0.22. The ratio of imported goods in domestic consumption is computed in the following way. We take the share of imports to GDP in Hungary (72.7 percent) over the period 2002:Q1-2008:Q4 and adjust it given the average import share in the Hungarian exports (56 percent; OECD, 2015). Since in our model exports are assumed to be of domestic origin entirely, 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 37 percent in our model. Thus we calibrate η to 0.37 to achieve the desired steady state share. For simplicity we set the steady state level of the nominal exchange rate to unity.

4.2 Endogenizing volatility

As we pointed in the financially constrained firms' optimization problem, our model is capable of studying volatility effects. 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 simulating the theoretical model as long as the value converges. In this section we explain why the obtained volatility value is a better choice than an arbitrary calibrated value. We shortly describe the simulation procedure as well.

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 on variances of future revenue and liabilities as well and, as a result of endogenous prices, it varies not only with stochastic components such as technology but with production prices and exchange rates as well. Therefore, we cannot postulate the variance of future output or future liabilities to be an exogenous process dependent on technology and current state variables only. The variance of endogenous variables is unknown, but we can obtain an estimate

Debt denomination	Banking friction	Shock	Value
FX & domestic currency	No	Risk premium	0.1428
FX & domestic currency	No	World demand	0.0568
FX & domestic currency	No	All shocks	0.1459
Domestic currency	No	Risk premium	0.0678
Domestic currency	No	World demand	0.0591
Domestic currency	No	All shocks	0.0848
FX & domestic currency	Endogenous leverage constraint	Risk premium	0.2148
FX & domestic currency	Endogenous leverage constraint	World demand	0.0785
FX & domestic currency	Endogenous leverage constraint	All shocks	0.2117
Domestic currency	Endogenous leverage constraint	Risk premium	0.1216
Domestic currency	Endogenous leverage constraint	World demand	0.0768
Domestic currency	Endogenous leverage constraint	All shocks	0.1294

Table 1: Simulated standard deviations of expected profits for firms (σ_y)

from simulated series. In the supplementary appendix A2 we derive what variance exactly we are interested in to be able to compute the default probability and simulate the model:

$$\sigma^2_{y,t+1} = var\left(ln\left(\pi_{t+1}\left(\kappa\left(p^R_{t+1}y^R_{t+1} + q_{t+1}(1-\delta)k_t\right) - R^R_t rer_{t+1}\frac{l^F_{i,t}}{\pi^*_{t+1}}\right)\right)\right)$$

Hence to simulate the model we need a numerical value for $\sigma^2_{y,t+1}$ or, more precisely, $\sigma_{y,t+1}$, where $\sigma_{y,t+1} = \sqrt{\sigma^2_{y,t+1}}$. We assume $\sigma_{y,t+1}$ to be constant ($\sigma_{y,t+1} = \sigma_y$).

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

1. Set a threshold level for convergence of the calibrated $\hat{\sigma}_y$ to the value of $\tilde{\sigma}_y$ that follows from the simulated time series generated by the model.

2. Choose an initial value for $\hat{\sigma}_y$.

3. Simulate the model with the chosen value for $\hat{\sigma}_y$.

4. Compute volatility of $\bar{y}_{t+1}$ from simulated time series and denote it by $\tilde{\sigma}^2_y$.

5. Compute the difference between the chosen value $\hat{\sigma}_y$ and the simulated value $\tilde{\sigma}_y$. If the difference is larger than the threshold value, set $\hat{\sigma}_y = \tilde{\sigma}_y$ and repeat steps 3-5.

Converged values are presented in Table 1. We obtain estimates of the volatility value generated by capital outflows shocks and a drop in world demand only. The exogenous volatility shock sometimes prevents the simulation from converging because every new value shapes the results of the next simulation (the shock effect directly depends on the simulated value in the last period). So instead of simulating to obtain the volatility estimate generated by the exogenous volatility shock we use the average volatility retrieved after a set of shocks hit the economy: the productivity shock, the risk premium shock and the world demand shock.

5 Results

In the following section we dissect the interaction of financial distress in the firms' sector and losses in the banking sector. We begin by discussing the debt overhang friction in the firms' sector and its consequences in the periods of unanticipated depreciation. Next we add the banking friction to the setup to see how leverage-constrained banks can amplify the shocks even further. The relative importance of the frictions is analyzed by comparing two scenarios of allocating currency mismatch losses. Given immense foreign bank funding flows in emerging Europe, we assume that domestic banks issue debt denominated in foreign currency which creates currency mismatch unless banks match foreign currency liabilities with loans issued in foreign currency. In the latter case currency mismatch is shifted to domestic borrowers. We compare the model economy with bank lending in domestic currency and bank lending in both foreign currency and domestic currency to explore which currency mismatch situation generates larger macroeconomic losses.

More plots for every shock discussed in the following section can be found in the Appendix. Here we present graphs with main variables only.

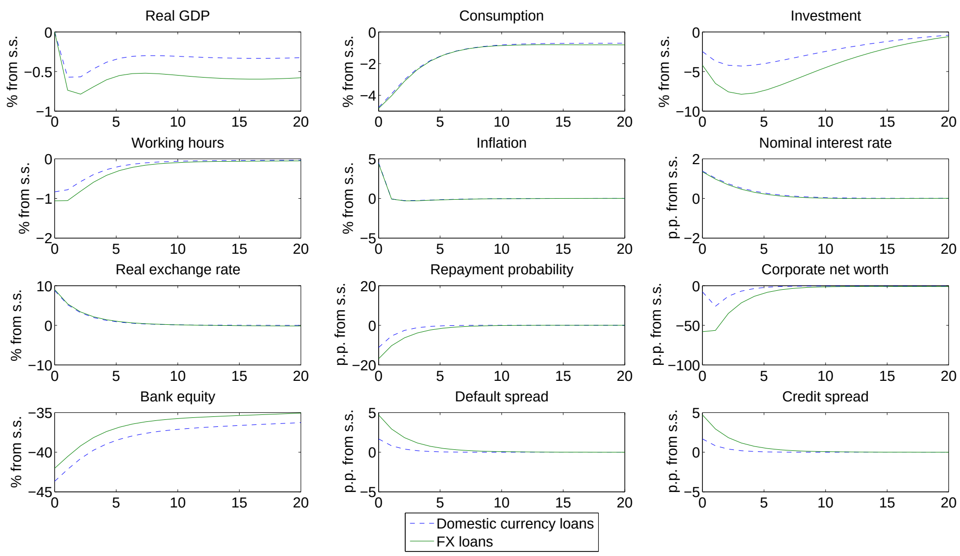
5.1 Debt overhang in the financially constrained firms' sector

Borrowing in foreign currency makes domestic financially constrained firms prone to debt overhang whenever the domestic currency depreciates. If the expected value of debt indeed exceeds the expected collateral value, the indebted firm faces a higher chance of losing its collateral (future revenue) to creditors. The firm's marginal benefits from investing diminish. In the setting with non-contractible investment, the rising possibility of default is enough to create a slump in output by decreasing investment. We consider exogenous events that may trigger domestic currency depreciation in a small open economy setup and thus increase the default probability: a country risk premium shock, a negative world demand shock and a shock to volatility of profits generated in the financially constrained firms' sector.

Regardless of the denomination of corporate debt, the listed shocks are expected to bring an economic downturn by either dampening aggregate demand or supply. Accumulated foreign currency debt makes the corporate default probability depend not only on the aggregate level of economic activity but the degree of currency mismatch as well. Thus, whenever the domestic currency depreciates, foreign currency debt opens an additional contractionary channel that operates through even higher default probabilities and thus more intense debt overhang in the financially constrained firms' sector.

Simulation results confirm our hypothesis that debt overhang amplifies adverse effects on aggregate variables more, if firms have their debt denominated in foreign currency rather than in domestic currency. In Figure 4 capital outflows, which we model by increasing a country risk premium on bank foreign debt, decrease demand for domestic currency and make it depreciate. To mute rising domestic inflation, the central bank responds by raising the domestic nominal interest

Figure 4: Country risk premium shock of 5 p.p. in the model without leverage-constrained banks.

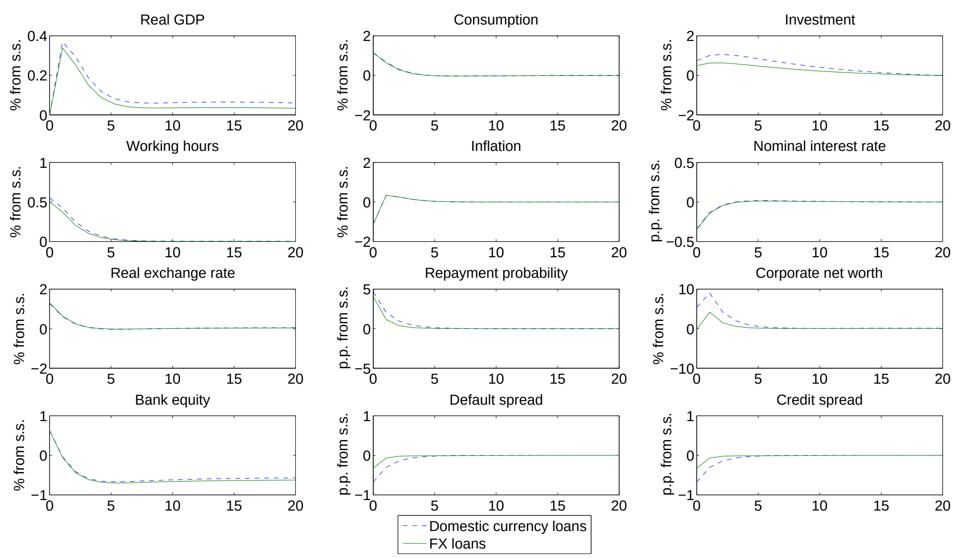


rate and in turn creates a recession. The main driver behind it is the decline in consumption driven by the substitution effect. Currency mismatch for firms makes the recession deeper as investment in working capital decreases not only due to lower aggregate demand but also due to debt burden weighing on firms' marginal benefits from investing. We observe that, if financially constrained firms borrow in foreign currency, a repayment probability is substantially lower, an interest rate on their loans rises higher and they post lower demand for labour and capital goods. Noteworthy, domestic currency depreciation not only distorts decisions ex-ante, but deprives firms of available funds ex-post: lower firms' profits result in lower corporate worth and thus higher dependence on external funds which come at a now high default spread.

A decline in world demand for domestic exports, as exhibited in Figure 5, results in deflation. Domestic prices have to decrease so that the drop in external demand would be compensated by increased competitiveness. Domestic currency depreciates. Interesting enough, financially constrained firms face a lower default probability. They do not experience losses in corporate net worth which also contributes to higher demand for labour and capital. Consequently the effect on output is positive. The paradoxical result partially owes to the predetermined demand for working capital as posted by financially constrained firms. When external demand for domestic goods declines, the domestic demand has to increase to absorb the idle output produced out of predetermined production inputs. Therefore, domestic prices drop sufficiently to make domestic consumers capable of consuming more. The increased domestic demand effect does not die immediately and the next period output grows to catch up with higher demand. To see that this is indeed the reason we modify the model so that labour demand can adjust immediately and output responds to changes in aggregate demand on impact (see the supplementary appendix A4 for modeling details). Figure 6 shows how the drop in world demand becomes contractionary once labour demand can shrink in response to fewer orders for domestic goods from abroad.

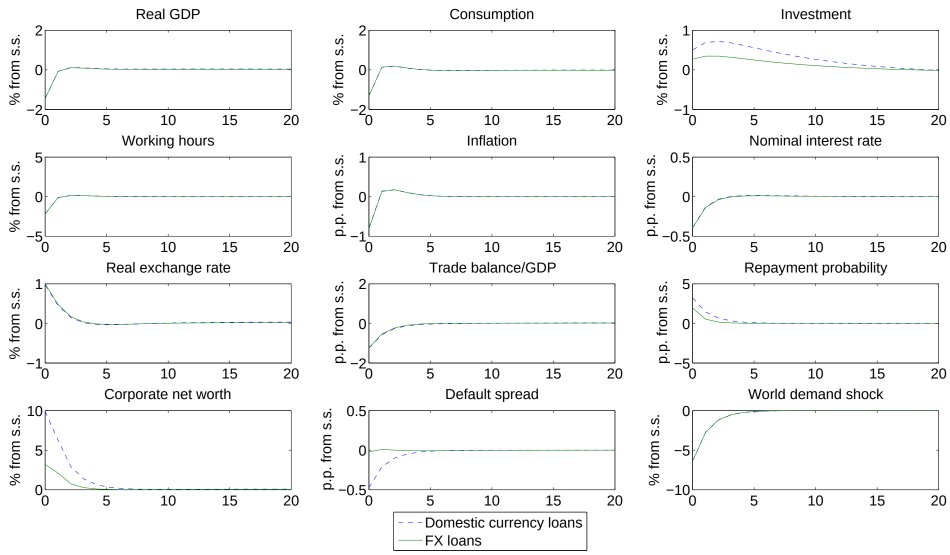
Currency mismatch brings in more negative effects, however, the difference is relatively small, see Figure 5. It turns out that the resulting domestic currency depreciation is too small to increase the wedge between the value of debt and the collateral value for financially constrained firms. A higher depreciation is needed due to a relatively restrictive version of the debt overhang model. First, we model short-term debt which, in contrast to long-term debt, makes debt overhang fade away after the first period. Second, the timing of the firm's optimization problem is such that firms learn about their net worth value after the borrowing amount is decided. Therefore, even though domestic currency depreciation triggers more defaults and thus reduces corporate net worth (Figure 5), the shock feedback through the corporate net worth comes with a delay. Third, firms die after two periods and do not take into account future profits which mutes the net worth effect to some extent as well. Shocks have to propagate through prices mostly and thus the exchange rate effect on firms' performance in the future is limited.

Figure 5: World demand shock of 6.4% in the model without leverage-constrained banks.



In contrast to other shocks, the volatility shock primarily affects not the demand side but the supply side of the economy by making the firms' future profits more uncertain. This has a direct effect on the default probability as the uncertainty magnifies the expected distance between the collateral value and the debt value. Then, for any debt burden and any productivity level, firms face lower chances to repay their debt and lenders respond by raising interest rates on corporate loans. Figure 7 depicts how in this case debt overhang weighs on the firms' incentives to invest

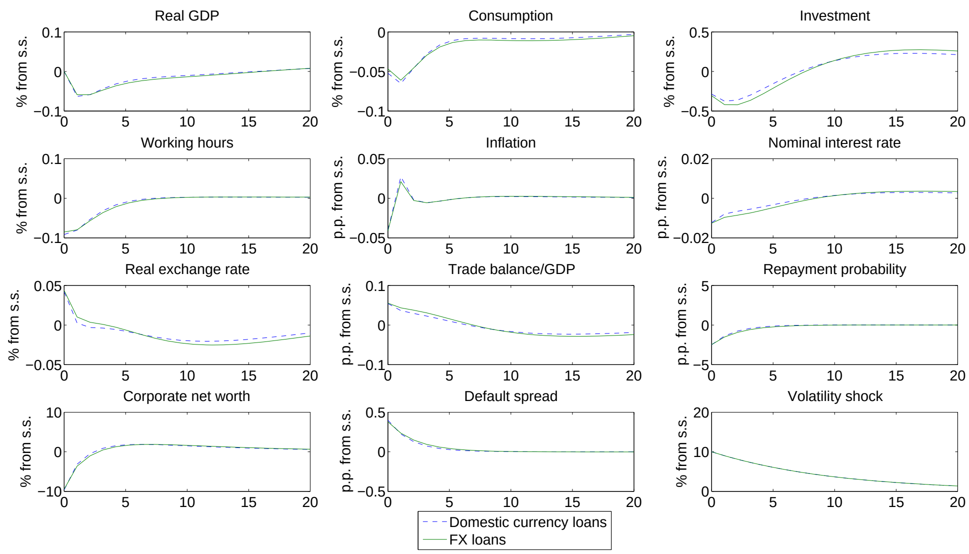
Figure 6: World demand shock of 6.4% in the model without leverage-constrained banks when labour demand is not predetermined.



and in turn the economy falls into a recession. The increased uncertainty of firms' future profits has an indirect effect on household consumption by lowering income: firms post lower demand for labour and wages decrease. The substitution effect stimulates consumption as the central bank copes with the slump and the corresponding deflation by cutting the policy rate, however, this effect appears to be negligible. Overall, the volatility shock generates responses of relatively large magnitude, changes in investment are particularly large. Initially, foreign currency debt generates more contraction than accumulated domestic currency debt, however, after two periods the real exchange rate depreciation in the former cases subsides and depreciation-driven debt overhang loses its influence completely. The difference between the case with borrower currency mismatch and without it is negligible. Besides the reasons mentioned before, the volatility shock directly hits firms' chances to repay and the depreciation effect becomes of the second order. In other words, the magnitude of the change in the default probability overshadows the risk related to the increased value of foreign currency debt.

Therefore, capital outflows can trigger domestic currency depreciation that increases currency mismatch in the corporate sector. Compared to firms borrowing in domestic currency only, the depreciation lands firms indebted in foreign currency in a more severe debt overhang situation. Under-investment and a deeper fall in output follow. The effects of the negative world demand shock and the increased exogenous uncertainty are less clear as they trigger an apparently insufficient loss in the domestic currency value. Also, the volatility shock increases firms' chances to default to an extent that depreciation effects get overshadowed and debt denomination loses its role in ranking the outcomes. The type of shocks appears to have important implications for the

Figure 7: Volatility shock of 10% in the model without leverage-constrained banks.



role of foreign currency debt and debt overhang.

5.2 Introducing leverage-constrained banks

The agency problem between banks and depositors generates an endogenous credit spread which tightens or improves borrowing conditions for banks depending on bank leverage. Highly leveraged banks face larger credit spreads on their debt. It follows that the credit spread moves countercyclically: in bad times non-performing loans deplete bank capital and bank leverage goes up.

Financial distress in the banking sector translates into worse borrowing conditions for the borrowing firms: the tighter endogenous leverage constraint and thus higher borrowing costs for banks make banks charge higher interest rates on loans issued to financially constrained firms. In bad times the binding bank leverage constraint amplifies initial losses in the economy.

In our experiment bank losses are triggered by currency mismatch losses placed in either the firms' sector or the banking sector. Bank debt denominated in foreign currency exposes the banking sector to currency mismatch, so that domestic currency depreciation has an immediate negative effect on bank equity and leverage. If the bank lends in foreign currency as much as it borrows in foreign currency, the depreciation increases the value of both sides of the bank balance sheet and bank earnings do not deteriorate *ceteris paribus*. However, domestic currency depreciation triggers large losses for domestic firms that borrowed in foreign currency. Lower firms' profits result in a higher ratio of non-performing loans and bank profits decline. Therefore, even if lending in foreign currency insulates the bank balance sheet from the exchange rate risk, a potentially higher increase in non-performing loans can still impair the credit transmission channel and worsen the recession.

This paper shows that, even if the model is enriched with the endogenous bank leverage constraint, aggregate losses are still smaller when corporate loans are denominated in domestic currency than when a share of debt is foreign currency loans.

Banks are in a better position to absorb currency mismatch losses because, in contrast to firms, they do not internalize default risk. Consequently, even though banks are more leveraged than firms, unexpected bank losses affect borrowing conditions for firms and thus aggregate economic activity to a smaller extent than the investment distortion that stems from the rising default probability in the firms' sector. This assumption relies on that fact that banks may expect to be rescued by either the government or parent banks, while a large number of firms cannot expect to be nationalized or receive other types of financial support to prevent them from going bankrupt. The second reason why allocating currency mismatch losses to firms generates larger real losses is that firms burdened with debt decrease aggregate output and demand directly, while banks affect aggregate economic activity with a lag and only after a share of the effect is absorbed by bank equity.

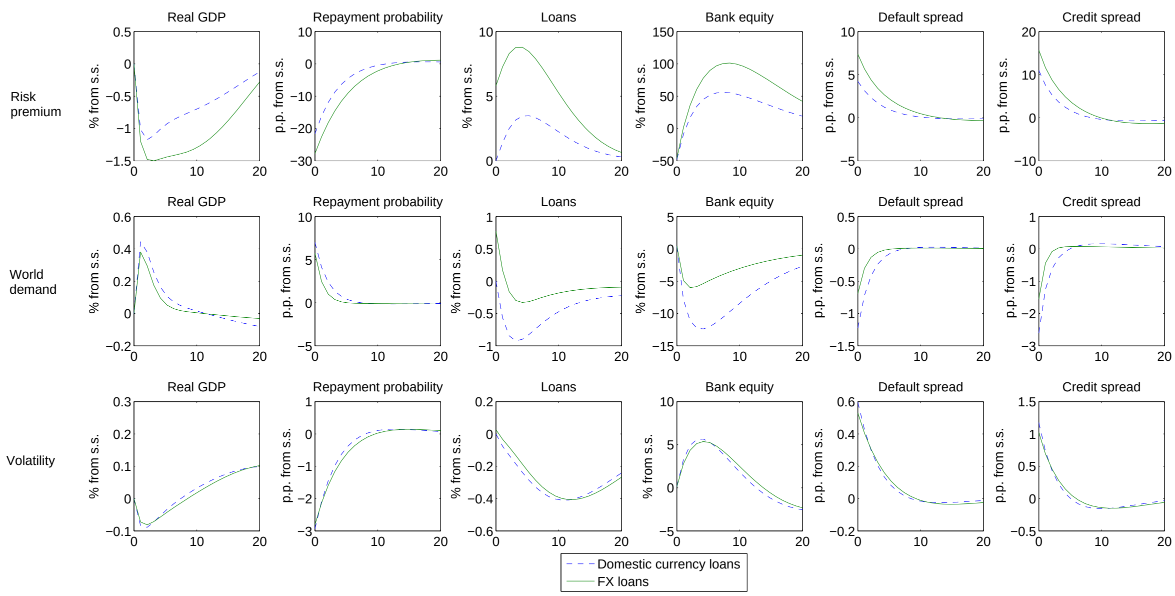
We arrive at the previously described conclusion after simulating the same set of shocks as before for the extended model. After the risk premium shock or the world demand shock, foreign currency debt worsens firms' chances to repay which generates larger output losses, see Figure 8. More non-performing loans deplete bank equity on impact and make banks ration credit for future borrowers. Over time, as the default frequency for firms goes down, banks replenish bank equity and the recession is contained. On the contrary, if banks face currency mismatch on their balance sheets, bank losses are smaller on impact but, since banks cannot switch to foreign currency lending later, the depreciation has a persistent negative effect on bank equity. Bank losses translate into persistent real losses for two additional reasons: bank cut lending to all firms rather than just troubled firms which constrains economic activity severely. Second, since banks accumulate equity out of retained earnings, even temporary bank losses can have a persistent effect on borrowing conditions in the economy. Nevertheless, we see that in the case of capital outflows magnified foreign currency debt and the related failures to repay offset bank gains from insulating their balance sheets from the exchange rate risk. Consequently foreign currency loans make domestic depreciation deepen the recession.

The drop in world demand for domestic goods also suggests that currency mismatch shifted to banks produce smaller aggregate losses in the short-run, however, it may generate a situation when currency mismatch in banking inflicts more recessionary outcomes in the future. However, this is not obvious. The volatility shock makes the default probability skyrocket and the role of foreign currency debt is limited in ranking the outcomes.

Simulations show that, in the first period after the shock, banks charge a substantially higher default spread. In subsequent periods changes in the default spread are approximately the same regardless of the allocation of currency mismatch losses. It follows that corporate default risk determines borrowing costs for firms in initial periods and the bank leverage constraint dominates the dynamics of costs further in the future.

In closing this section, it is important to note that the assumption of the financially constrained

Figure 8: IRFs in the model with leverage-constrained banks.



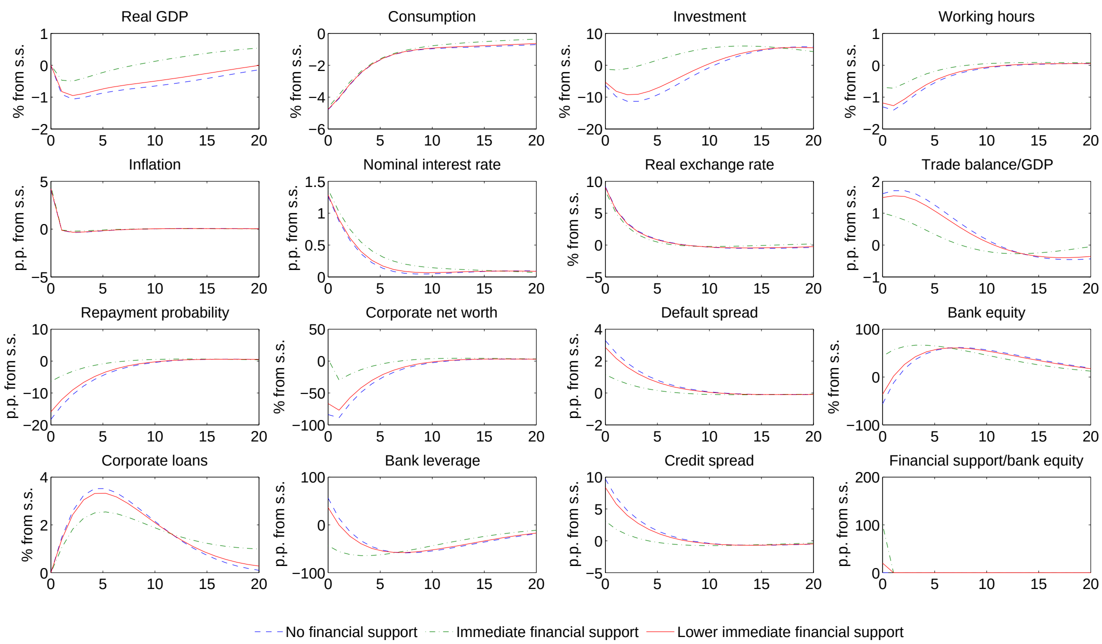
firms' exit after two-periods makes the effect of the debt overhang friction rather suspended in time. In contrast, banks incorporate their net worth dynamics in their optimization problem which makes bank losses have a prolonged effect on the economy. This can be considered as a bias towards the banking friction. The result that debt overhang nevertheless governs the dynamics of aggregate variables in the extended model lends more support to the importance of currency mismatch losses in the corporate sector in amplifying negative shocks than our model could offer. Even though the government should not underestimate the effects of bank losses derived from currency mismatch on the bank balance sheets, our simulations show that increasing currency mismatch for banks at the expense of lowering currency mismatch for borrowers is likely to result in lower macroeconomic losses.

5.3 Recapitalization

Shifting currency mismatch losses to banks reduces debt overhang and, as we showed before, leads to most likely less recessionary macroeconomic outcomes. However, this implies saving financially constrained firms at the expense of the banking sector. Further we study the efficiency of a government intervention that aims at compensating for bank losses. We study the scenario where bank losses stem from bearing the exchange rate risk while financially constrained firms avoid currency mismatch altogether.

Financial sector support is modeled as a gift from the government to banks given in the form of an equity injection. Consider the case of capital outflows which generated the largest economic

Figure 9: No government intervention vs. bank recapitalization.



downturn in the series of our experiments. Figure 9 shows how full recapitalization of the banking sector after the increase in the country risk premium immediately relaxes the endogenous bank leverage constraint and improves bank borrowing conditions. Banks cut credit supply by less and the economy undergoes a smaller recession than otherwise. Corporate loans increase by less in response to this policy because corporate net worth is replenished faster than the investment demand increases. The reason is the following. Financially constrained firms take the size of their net worth as given, therefore, higher net worth makes them demand fewer loans. However, investment demand is late to catch up with the increase in corporate net worth, because firms make borrowing decisions given their expectations of net worth value rather than the actual value. This assumption creates a lag in the net worth feedback to firms' working capital expenditure. Nevertheless, banks cut lending spreads as loans become less risky. Financial support of 20% bank equity would yield similarly positive but smaller changes in aggregate outcomes.

Therefore, currency mismatch in the banking sector can be efficiently alleviated ex-post. Noteworthy here we abstract from the potential negative implications of government interventions such as increasing public debt during times of fiscal distress (van der Kwaak and van Wijnbergen, 2014).

6 Conclusions

Hungary's experience after the fall in the domestic currency value in 2009 raised questions about the macroeconomic implications of allocating currency mismatch losses. We attempt to evaluate the consequences of shifting exchange rate risk from borrowers to banks: we weigh losses triggered by increased currency mismatch in the financially constrained firms' sector against losses for banks, if banks bear currency mismatch instead. As almost everywhere in emerging Europe banks heavily rely on foreign currency debt. This borrowing pattern exposes banks to currency mismatch, unless they lend in foreign currency and thus shift exchange rate risk to borrowers. Empirical evidence suggests that the forint depreciation amplified debt overhang in the private sector in Hungary and banks operating in Hungary were leverage-constrained. Therefore, to answer the research question, we develop a small open economy New Keynesian DSGE model with debt overhang in the corporate sector and the banking sector that operates under the endogenous leverage constraint.

The model, calibrated to the Hungarian economy, suggests that debt overhang in the corporate sector and losses at leverage-constrained banks are closely related and reinforce each other through the channel of credit provision. Nevertheless, we determine that capital outflows can trigger domestic currency depreciation that is large enough to strengthen debt overhang in the corporate sector and generate a large recession. Debt overhang and the related real losses dominate alternative losses from placing currency mismatch on the bank balance sheets. The result stems from the high power of the debt overhang distortion which, if strengthened, affects private investment to a larger extent than tighter borrowing conditions for firms that would alternatively result from currency mismatch losses attributed to highly leveraged banks. Besides this, firms burdened with debt decrease aggregate output and demand directly, while banks affect aggregate economic activity with a lag and only after a share of the effect is absorbed by bank equity. The results suggest that shifting exchange rate risk from borrowers to banks is most likely to have a positive effect on the depth and length of a recession.

To contain currency mismatch losses in the banking sector, the government can resort to bank recapitalization. We show that currency mismatch in the banking sector can be efficiently alleviated ex-post by injecting bank equity.

Our model abstracts from long-term debt and fully-fledged effects of corporate net worth which would potentially make the effects of adverse shocks more persistent and strengthen debt overhang in the corporate sector. Nevertheless, we still find macroeconomic outcomes to be in favour of placing currency mismatch in the banking sector rather than shifting to credit constrained firms. This context offers more support for our conclusions.

Our result should serve as an additional argument for why bank should bear currency risk besides such advantages as easier coordination of a few troubled banks than thousands of insolvent borrowers and the fact that, in contrast to firms in emerging Europe, banks can access foreign exchange markets for hedging purposes.

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Appendix

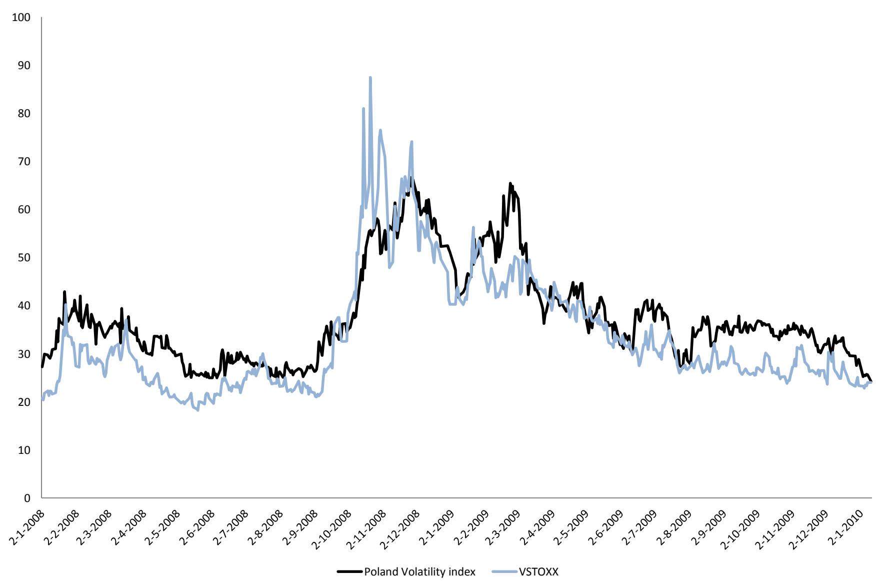

Figure 10: Implied volatility indexes.

Sources: EURO STOXX 50 Volatility Indices database and the courtesy of the blog 'Volatility Futures & Options', available at http://onlyvix.blogspot.nl/2013/03/polands-volatility-index.html.

Parameter	Description	Value	Source
	Calibrated parameters		
β	Household's discount factor	0.9970	to match $\pi = 1.059$
γ	Coefficient in GHH preferences	1.6	Jakab and Világi (2008)
ϕ	Labour supply elasticity	8	Jakab and Világi (2008)
α	Capital share in production	0.34	calibrated
δ	Capital depreciation rate	0.025	Jakab and Világi (2008)
ϵ	E.o.S. between domestic and imported goods	1.5	Gali and Monacelli (2002)
ϵ^H	E.o.S. between varieties of domestic goods	6	Jakab and Világi (2008)
ϵ^F	E.o.S. between varieties of imported goods	6	Jakab and Világi (2008)
ϵ^*	E.o.S. for exports	1.5	Gali and Monacelli (2002)
θ^H	Calvo parameter, domestic goods	0.75	Gali and Monacelli (2002)
θ^F	Calvo parameter, imported goods	0.75	calibrated
η	Share of x^F in y^C	0.37	to match average imports share of 37%
η^*	Share of ex in y^*	0.0033	calibrated
κ	Investment adjustment cost parameter	13	Jakab and Világi (2008)
κ_b	Tax feedback parameter for government debt	0.05	calibrated
z	Technology in SS	1	calibrated
π	Inflation in SS	1.059	average in the data in annual terms
p^H	Relative price of x^H in SS	1	calibrated
n	Working hours in SS	0.3	calibrated
S	Nominal exchange rate in SS	1	calibrated
y^*	Total foreign output in SS	104	calibrated
R	Risk-free rate in SS	1.073	average in the data in annual terms
R^*	Foreign interest rate in SS	1.045	calibrated
s^g	Gov. consumption/ GDP in SS	0.22	average in the data
π^*	Foreign inflation rate	1	from RER definition in SS
ξ	Risk premium on international bonds in SS	1.01	calibrated
κ_ξ	Elasticity of country risk to net asset position	0.001	Jakab and Világi (2008)
ζ	Exogenous shock to the bond premium in SS	1	calibrated
ρ_R	Interest rate smoothing	0.766	Jakab and Világi (2008)
α_π	Interest policy rule (inflation)	1.375	Jakab and Világi (2008)
α_y	Interest policy rule (output)	0.2	calibrated
ρ_σ	Volatility shock autoregr. coeff.	0.9	Occhino and Pescatori (2015)
ρ_{y^*}	World demand shock autoregr. coeff.	0.43	Konya and Jakab (2016)
ρ_ζ	Risk premium shock autoregr. coeff.	0.66	Konya and Jakab (2016)
	Financially constrained firms' parameters		
$1 - \Phi(d_2)$	Corporate default rate in SS	0.03	average in the data
ρ	Fraction of working capital to be paid in advance	0.8	-
α^F	Share of FX loans	0.6	average in the data
ι^{firms}	Proportional transfer to the entering firms	0.002	calibrated
lev^{firms}	Bank leverage in SS	3.3	average in the data
	Banking sector parameters		
λ^L	Fraction of capital that can be diverted	0.45	calibrated
ι	Proportional transfer to the entering bankers	0.002	Gertler and Karadi (2011)
lev	Bank leverage in SS	5.6	average in the data

Table 2: Parameters

Figure 11: Country risk premium shock in the model without leverage-constrained banks.

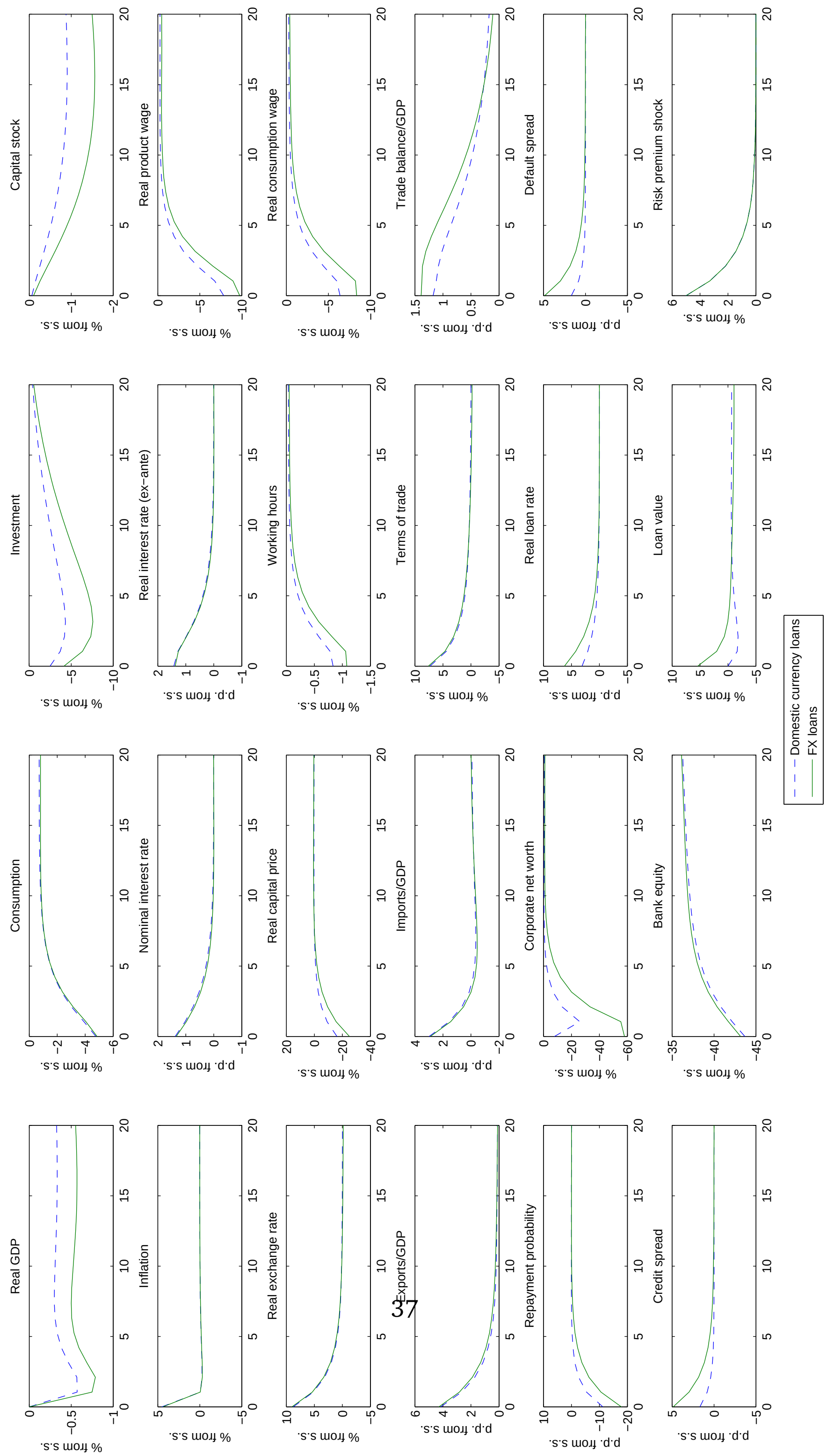

Figure 12: World demand shock in the model without leverage-constrained banks.

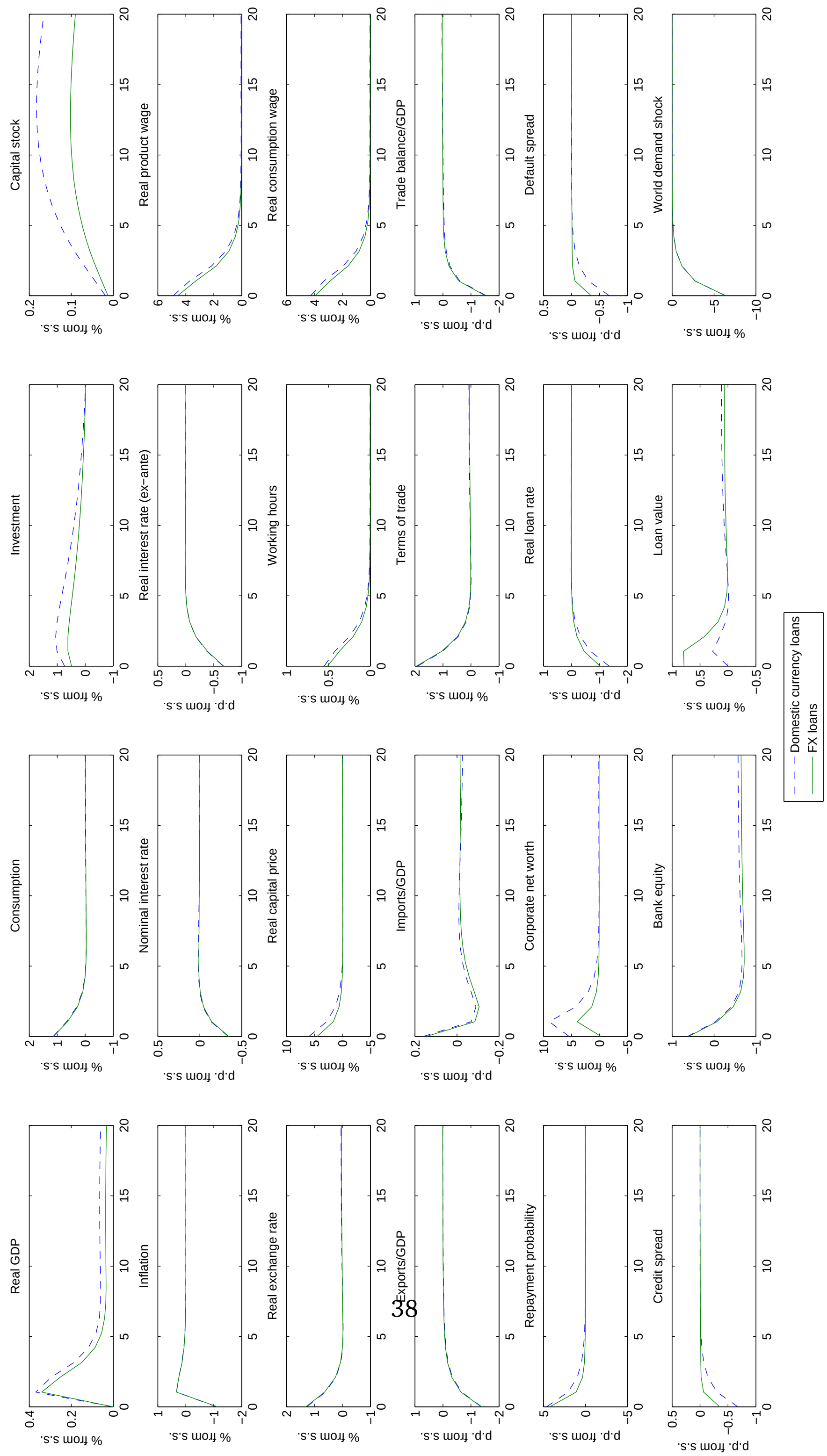

Figure 13: World demand shock in the model without leverage-constrained banks when labour demand is not predetermined.

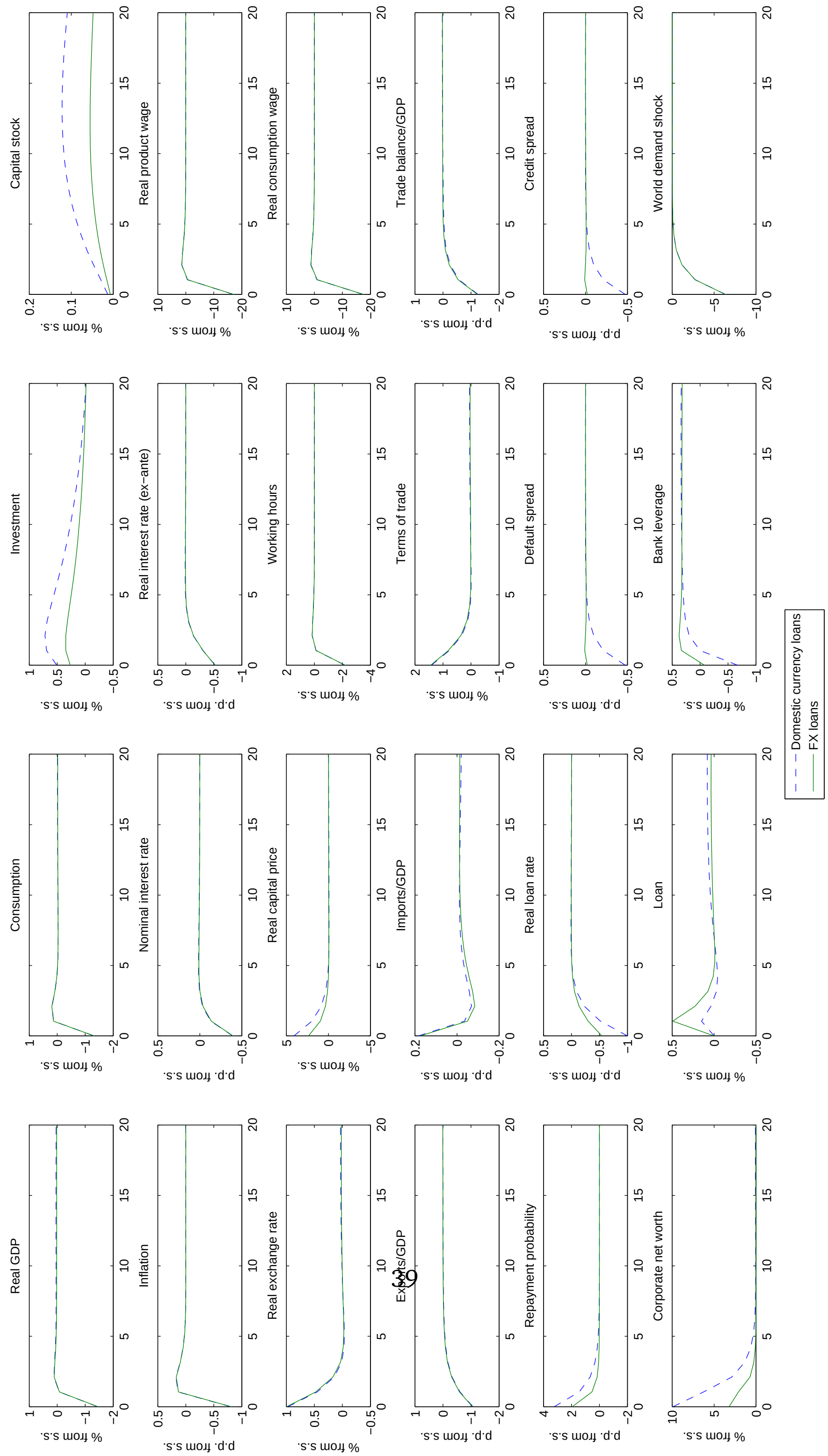

Figure 14: Volatility shock in the model without leverage-constrained banks.

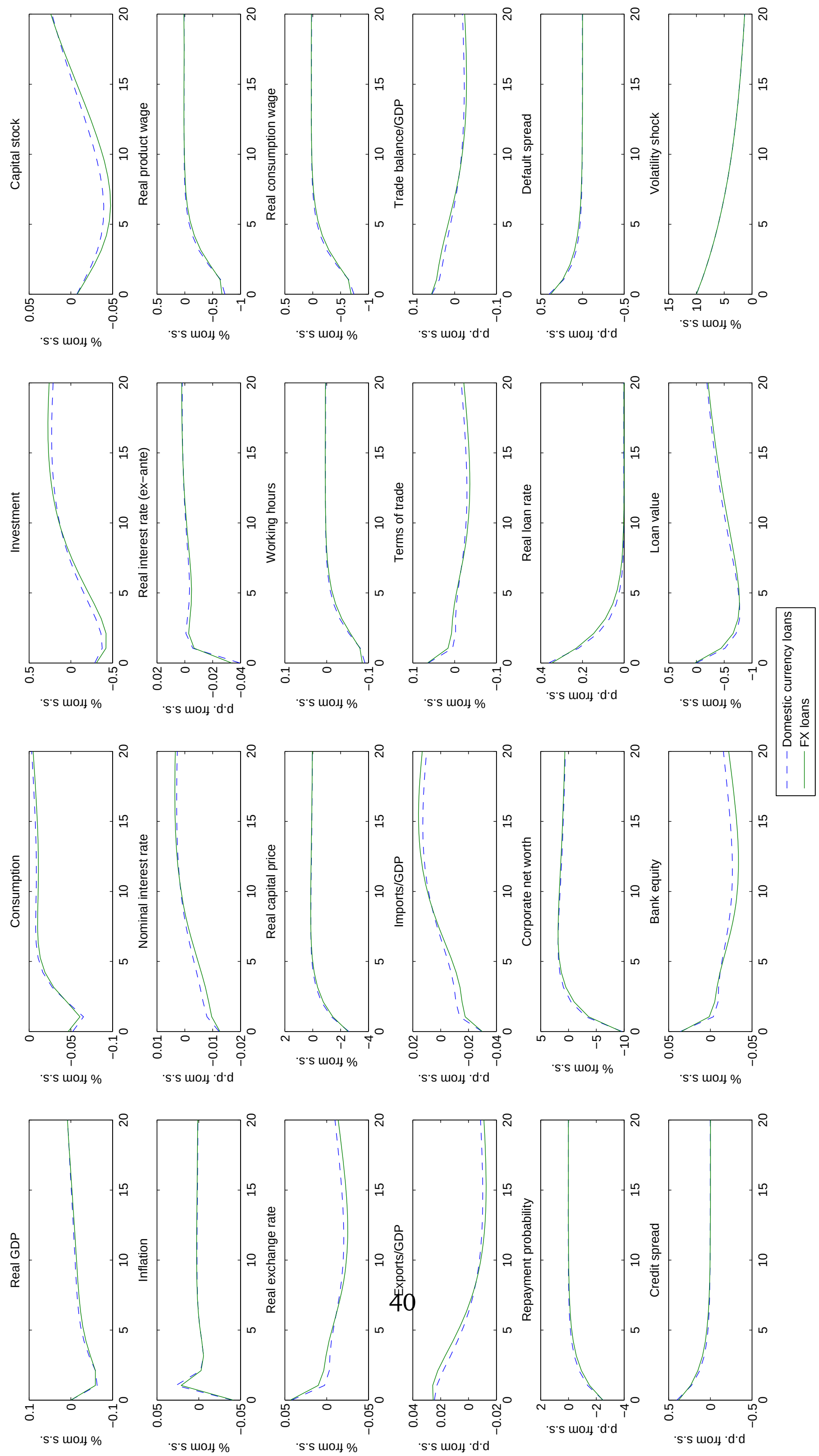

Figure 15: Country risk premium shock in the model with leverage-constrained banks.

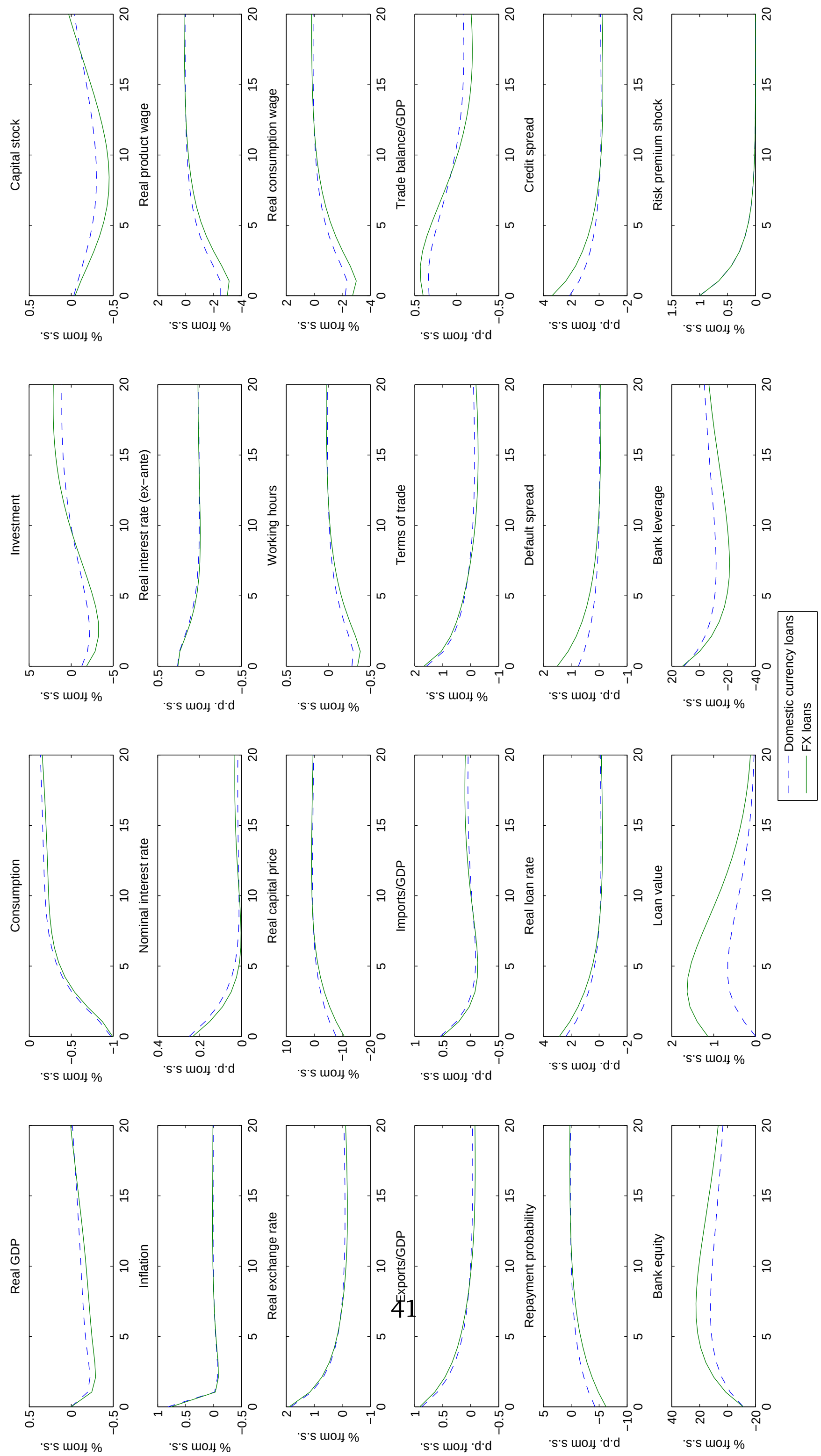

Figure 16: World demand shock in the model with leverage-constrained banks.

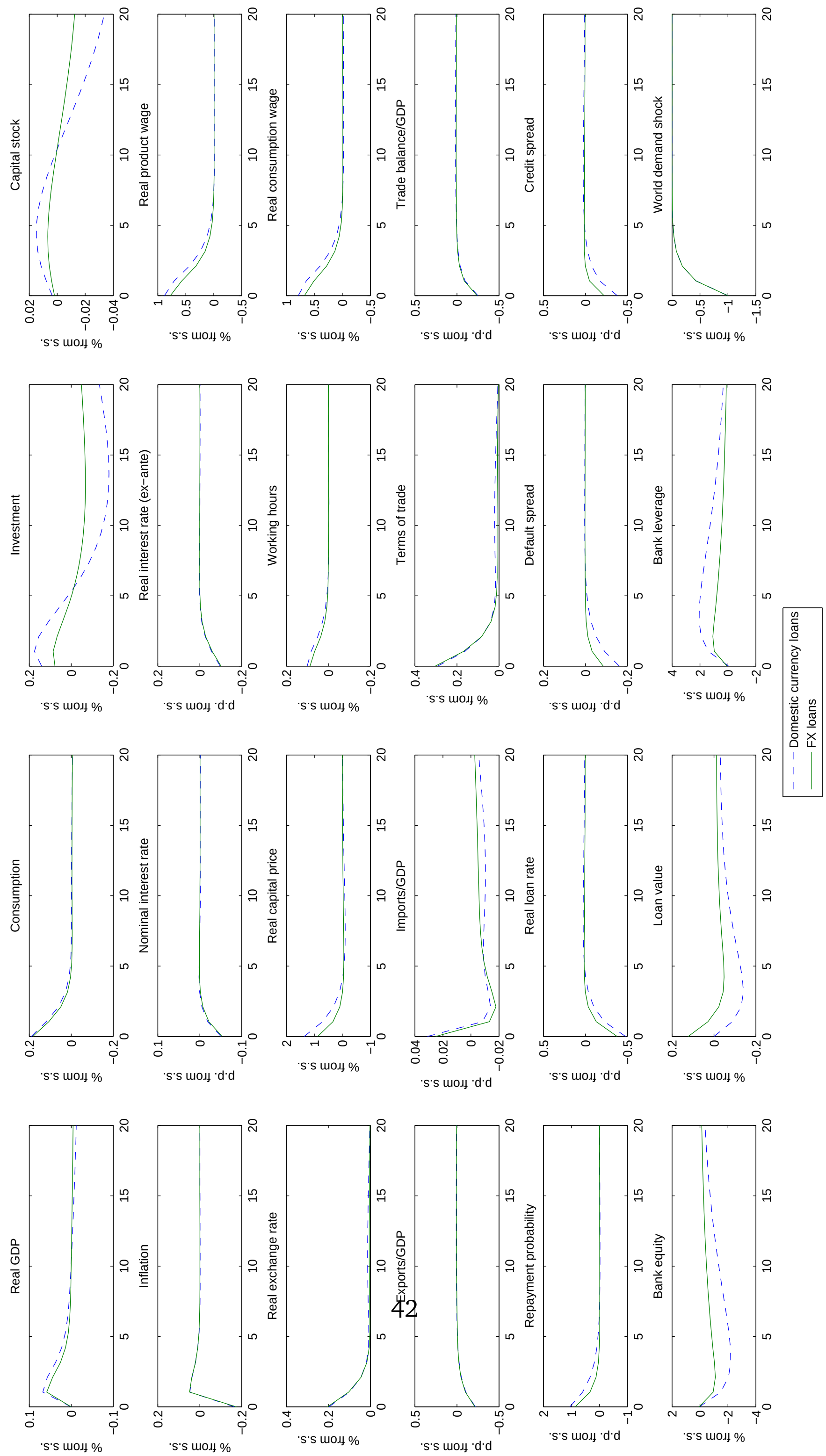

Figure 17: Volatility shock in the model with leverage-constrained banks.