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Monetary and macroprudential policy with foreign currency loans

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Abstract

In a number of countries a substantial proportion of mortgage loans is denominated in foreign currency. In this paper we demonstrate how their presence affects economic policy and agents' welfare. To this end we construct a small open economy model with housing loans denominated in domestic or foreign currency. The model is calibrated for Poland - a typical small open economy with a large share of foreign currency loans (FCL). We show that FCLs negatively affect the transmission of monetary policy. In contrast, their impact on the effectiveness of macroprudential policy is much weaker but positive. We also demonstrate that FCLs increase welfare when domestic interest rate shocks prevail and decrease it when risk premium (exchange rate) shocks dominate. Under a realistic calibration of the stochastic environment FCLs are welfare reducing. Finally, we show that regulatory policies that correct the share of FCLs may cause a short term slowdown.

JEL: E32, E44, E58

Keywords: foreign currency loans, monetary and macroprudential policy, DSGE models with banking sector

Non-technical summary

In a number of both emerging and advanced economies foreign currency loans (FCL) have become highly popular since the early 2000s. In the European Union this is the case for i.a. Bulgaria, Hungary, Romania, Poland and even Austria. As far as the former three countries are concerned, the FCLs in 2013 accounted for approximately 60% of loans to the non-banking sector. This number was a little lower in Poland (close to 30%) and in Austria (slightly below 20%). In the mortgage segment the share was even higher. While foreign currency loans offer some benefits to borrowers (lower interest rates and possibly longer maturities), they constitute an important source of systemic risk in the economy. In countries with a high share of FCLs, deep exchange rate depreciation generates a surge in servicing costs expressed in domestic currency, which may induce mass defaults and systemic banking crises.

Additionally, FCLs may substantially affect the monetary transmission mechanism. In particular, as evidenced by empirical research, they weaken the impact of domestic interest rates on the economy since borrowers with access to FCLs are less sensitive to the movements of the domestic interest rate. Moreover, understanding the relationship between FCLs and regulatory instruments becomes extremely important given the recently growing interest in macroprudential supervision. In contrast to monetary policy, there is no empirical evidence on the impact of FCLs on the effectiveness of regulatory or macroprudential policies. The recent decisions of policymakers in several countries to restrict foreign currency lending confirms that its presence is considered important and, given only scarce empirical and no structural evidence, requires further research.

In this paper we analyze the impact of FCLs through the lense of a dynamic stochastic general equilibrium (DSGE) model. While doing it we build on the theoretical literature on financial frictions as well as the empirical literature on the links between FCLs and macroeconomic policy. Our paper offers a quantitative perspective which is based on economic theory. More specifically, we design a microfounded small open economy model in which consumers have access to both domestic and foreign currency mortgage loans and use it to analyze the impact of FCLs on the working of monetary and macroprudential policies. While studying the effects of macroprudential policy, we focus not only on the LTV ratio applied to total borrowing, but also consider instruments that discriminate against (i.e. permanently lower the share of) FCLs. To the best of our knowledge, this is the first paper that analyzes this topic from the normative perspective and the first one that analyzes macroprudential policy in the context of foreign currency loans.

Our main findings are as follows. First, consistently with empirical evidence, foreign currency loans weaken the monetary transmission mechanism of domestic monetary policy. Second, their impact on the effectiveness of macroprudential policy is much weaker but positive. This follows from the fact that macroprudential policy has a relatively small impact on the interest rates and the exchange rate, while fluctuations of these variables are key for the difference in returns between foreign and domestic currency loans. Third, when domestic interest rate shocks are the main source of macroeconomic volatility, FCLs increase welfare. On the contrary, when risk premium shocks (shocks that primarily drive exchange rate movements) dominate, foreign currency lending affects welfare negatively. When all stochastic shocks are implemented simultaneously, we find FCLs to be welfare reducing. Given these findings, one may expect policymakers to be willing to reduce the share of foreign currency loans. In our final experiment we show that such policy may have a short term contractionary impact on the economy.

1 Introduction

Foreign currency loans (FCL) have become highly popular in many emerging and even some advanced economies since the early 2000s. In the European Union the problem affected i.a. Bulgaria, Hungary, Romania, Poland and even Austria. In the former three countries in 2013 FCLs accounted for approximately 60% of loans to the non-banking sector, in Poland this share was close to 30%, and in Austria slightly below 20% (SNB, 2013). In the mortgage segment the share was even higher. For instance, in Poland, for which our model is calibrated, over 50% of mortgage loans outstanding in 2013 were denominated in foreign currency. Foreign currency loans offer some advantages to borrowers, in particular lower interest rates and possibly longer maturities. At the same time, however, they constitute an important source of systemic risk in the economy. Sharp depreciations of the domestic exchange rate bring about a surge in servicing costs expressed in borrowers' domestic (income) currency, which may, in most extreme cases, lead to mass defaults and systemic banking crises (Yesin, 2013).

FCLs have also been recognized to affect the transmission of domestic monetary policy. In particular, the impact of domestic interest rates on the economy may be weaker when borrowers are able to substitute domestic currency loans (DCL) for FCLs in response to a rise in the domestic interest rate. Additionally, given the rapid expansion of macroprudential supervision, understanding the link between FCLs and regulatory instruments seems of particular importance as well. The impact of foreign currency lending on the economy has repeatedly gained attention of policymakers including microprudential (regulatory), macroprudential and monetary authorities (Dübel and Walley, 2010; ESRB, 2011; Bakker et al., 2012; Lim et al., 2011). In many countries lending in foreign currency has been restricted by the financial supervision over the last few years.

This paper analyzes the role of FCLs through the lens of a dynamic stochastic general equilibrium (DSGE) model. As such it connects two important streams in the literature: the modeling literature on financial frictions and the empirical literature on the relationship between FCLs and macroeconomic policy.

From the modeling perspective we build on the seminal papers of Kiyotaki and Moore (1997) and Iacoviello (2005) who developed a workhorse DSGE model with credit constraints and housing that serves as collateral. Models based on this framework have been successfully applied in the past to analyze a number of related issues like the impact of macroprudential policy on the business cycle or spillovers from the housing market to the economy (e.g. Gerali et al., 2010; Iacoviello and Neri, 2010). This framework fits also our needs since it contains the key ingredients given our research questions, i.e. mortgage loans and the possibility to introduce regulatory policy in the form of LTV requirements. Of course, this benchmark is modified in several directions. In particular, we extend it to a small open economy setting and introduce FCLs.

Regarding the main topic at hand, our study relates to the literature on foreign currency lending and its connections with monetary and macroprudential policies. This literature has a strong empirical flavor. As regards the links to monetary policy, the relationship between interest rates, exchange rates and FCLs is crucial. As documented in Magud et al. (2011), both fixed exchange regimes or high interest rate differentials increase the share of foreign currency loans. The latter finding has been confirmed in several other studies including Egert et al. (2007), Rosenberg and Tirpák (2009) and Brzoza-Brzezina et al. (2010), and is crucial to understand how FCLs can weaken the monetary transmission. Especially the last paper deals explicitly with this problem. Based on a panel of four Central European countries the study shows that after a monetary policy tightening, more than 50% of eliminated DCLs can return to the economy as FCLs.

Much less research has been conducted on the link between macroprudential policy and FCLs. The main question of interest so far has been whether appropriately designed regulation is able to reduce the share of FCLs in the economy. For instance, Lim et al. (2011) show that some regulatory actions targeted at limiting the amount of FCLs have been efficient in the past. However, to our knowledge, the impact of FCLs on the effectiveness of macroprudential policy has not been analyzed so far.

In contrast to the existing literature, this paper offers a more theoretical, but nevertheless quantitative, perspective on the subject. We construct a microfounded small open economy model with domestic and foreign currency loans. The model is calibrated to Poland, a typical small open economy with a relatively large share of FCLs. Next we apply the model to show how the presence of FCLs affects the monetary and macroprudential policy transmission. Finally, we analyze the welfare implications of foreign currency lending. To our knowledge, this is the first paper to analyze FCLs in mortgage markets from this normative perspective.[1] Moreover, as mentioned earlier, the implications of FCLs for macroprudential policy have not been analyzed before, either.

Our main findings are as follows. First, foreign currency loans negatively affect the transmission of monetary policy but do not significantly impact on the effectiveness of macroprudential policy. Second, we find that FCLs increase welfare when domestic interest rate shocks are strong and decrease it when risk premium (exchange rate) shocks dominate. Under a realistic calibration of the complete stochastic environment, FCLs are welfare reducing. Third, eliminating the described inefficiencies through regulation discriminating against FCLs may have a short-term contractionary impact on the economy.

The rest of the paper is structured as follows. Section two describes the model and section three its calibration. Section four discusses the impact of foreign currency loans

[1] In contrast, a number of papers have analyzed foreign currency lending in the corporate sector, see e.g. Elekdag and Tchakarov (2007), Gertler et al. (2007) or Kolasa and Lombardo (2014).

on the transmission of monetary and macroprudential policy and on welfare. Section five concludes.

2 Model

Our departure point is a standard New Keynesian framework for a small open economy, which we extend to incorporate credit in a way that allows us to accommodate both domestic and foreign currency denomination of loans. In what follows we describe in detail our extension, which concerns mainly the household sector, and provide only a brief summary of the model's remaining building blocks. A full list of model equations can be found in the Appendix.

2.1 Households

To introduce credit, we distinguish between two types of households whose preferences differ in the degree to which they discount the future utility flows. In this way we obtain a distinction between natural borrowers (impatient households) and lenders (patient households), denoted by I and P, respectively. Within each group, a representative agent $\iota \in \{I, P\}$ maximizes

$$\mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta_i^t \left[\log(c_{i,t}(\iota) - \xi c_{i,t-1}) + A_\chi \log \chi_{i,t}(\iota) - A_n \frac{n_{i,t}(\iota)^{1+\sigma_n}}{1+\sigma_n} \right] \right\} \tag{1}$$

with $\beta_I < \beta_P$. In the formula above, c_t is consumption, χ_t denotes housing stock and n_t is labor supply.

Patient households' maximization is subject to a standard budget constraint

$$\begin{aligned} P_t c_{P,t}(\iota) + P_{\chi,t}(\chi_{P,t}(\iota) - (1-\delta_\chi)\chi_{P,t-1}(\iota)) + P_{k,t}(k_t(\iota) - (1-\delta_k)k_{t-1}(\iota)) + D_t(\iota) \leq \\ \leq W_{P,t} n_{P,t}(\iota) + R_{k,t} k_{t-1}(\iota) + R_{t-1} D_{t-1}(\iota) + \Pi_t + T_{P,t} + \Xi_{P,t}(\iota) \end{aligned} \tag{2}$$

where k_t is physical capital, $R_{k,t}$ denotes its rental rate, Π_t is profits from monopolistically competitive firms and banks, $T_{i,t}$ is lump-sum net transfers, $\Xi_{i,t}$ stands for net payments from insurance policies traded between households of a given type and insulating them from idiosyncratic labor income risk, $P_{\chi,t}$ and $P_{k,t}$ denote housing and physical capital prices, $W_{i,t}$ is nominal wage while D_t stands for deposits denominated in domestic currency and paying risk-free rate R_t, fully controlled by the monetary authority.

Impatient households do not accumulate physical capital, do not hold any equity and can take loans both in domestic and foreign currency. Their budget constraint can be written as

$$P_t c_{I,t}(\iota) + P_{\chi,t}(\chi_{I,t}(\iota) - (1-\delta_\chi)\chi_{I,t-1}(\iota)) + R_{H,t-1}L_{H,t-1}(\iota) + S_t(1+\tau_{t-1})R_{F,t-1}L_{F,t-1}(\iota) \leq$$
$$\leq W_{I,t}n_{I,t}(\iota) + L_t(\iota) + T_{I,t} + \Xi_{I,t}(\iota) \quad (3)$$

where $L_{H,t}$ and $L_{F,t}$ are domestic and foreign currency loans, $R_{H,t}$ and $R_{F,t}$ denote interest paid on these loans, τ_t is a tax set by the macroprudential authority (to be explained in Section 4.4), S_t is the nominal exchange rate, and the loan aggregate is defined using the following constant elasticity of substitution (CES) function[2]

$$L_t(\iota) = \left[\eta_{L,t}^{\frac{1}{\phi_L}} L_{H,t}(\iota)^{\frac{\phi_L-1}{\phi_L}} + (1-\eta_{L,t})^{\frac{1}{\phi_L}} (S_t L_{F,t}(\iota))^{\frac{\phi_L-1}{\phi_L}}\right]^{\frac{\phi_L}{\phi_L-1}} \quad (4)$$

where $\eta_{L,t}$ denotes the share of domestic currency loans in total loans that is governed by a stochastic process. The formula above implies that we treat domestic and foreign currency loans as imperfect substitutes even in a non-stochastic environment. This modeling choice can be interpreted as a short-cut for households' preferences or implicit costs of changing the loan portfolio structure.

Additionally, impatient households' optimization is subject to the following collateral constraint

$$R_{H,t}L_{H,t}(\iota) + \mathbb{E}_t\{(1+\tau_t)R_{F,t}S_{t+1}L_{F,t}(\iota)\} \leq m_t(1-\delta_\chi)\mathbb{E}_t\{P_{\chi,t+1}\chi_{I,t}(\iota)\} \quad (5)$$

where m_t denotes the loan to value (LTV) ratio on total loans. We assume that it is set by the macroprudential authority.

2.2 Banks

Both types of loans are supplied by a continuum of monopolistically competitive banks indexed by j, who refinance them by collecting deposits from patient households and by borrowing from abroad. A representative bank maximizes

$$\mathbb{E}_0\left\{\beta_P \frac{u_{P,t+1}}{P_{t+1}}\left[R_{H,t}(j)L_{H,t}(j) + S_{t+1}R_{F,t}(j)L_{F,t}(j) - R_t D_t(j) - S_{t+1}\rho_t R_t^* D_t^*(j)\right]\right\} \quad (6)$$

[2]A similar functional form is used by Poutineau and Vermandel (2015) to aggregate loans from foreign and domestic banks. Additionally, to offset implicit transfers from impatient to patient households that arise from the loan aggregate L_t falling short of the financial flows generated by the banking sector $L_{H,t} + S_t L_{F,t}$, this difference is rebated back to impatient households in a lump sum manner and included in Ξ_t.

subject to the flow of funds constraint

$$L_{H,t}(j) + S_t L_{F,t}(j) = D_t(j) + S_t D_t^*(j) \tag{7}$$

and the demand for loans implied by the following Dixit-Stiglitz loan aggregators (for $h \in \{H, F\}$)

$$\int_0^{\omega_I} L_{h,t}(\iota) d\iota = \left[\int_0^1 L_{h,t}(j)^{\frac{1}{\mu_L}} dj \right]^{\mu_L} \tag{8}$$

where ω_I is the relative size of impatient households, $u_{\iota,t}$ is agents' ι marginal utility of real income, D_t^* is borrowing from abroad, R_t^* is the interest rate controlled by the foreign monetary authority and ρ_t is the risks premium that depends on foreign debt and risk premium shocks.[3]

2.3 Other building blocks

Since the rest of the model is fairly standard, we only briefly summarize its main components. Output is produced by monopolistically competitive firms that combine labor and capital services using the standard Cobb-Douglas technology. Their prices are set in a staggered fashion according to the Calvo scheme and are sticky in the consumers' currency (local currency pricing). Labor supplied by patient and impatient households is aggregated into labor services using a CES technology. Capital and housing are purchased by households from perfectly competitive capital and housing goods producers who combine the existing stocks with capital- and housing-specific investment, subject to adjustment costs and asset-specific shocks. Final consumption and capital investment goods are defined as CES aggregators of domestic and foreign goods while residential investment and government purchases are assumed to have only domestic content. As typically done in a small open economy setup, the foreign block is exogenous and the three key foreign variables (output, inflation and the interest rate) are assumed to follow first-order autoregressions with correlated innovations.

The model is closed by imposing a standard set of market clearing conditions and defining the rules for the fiscal, monetary and regulatory authorities. More specifically, the government spending is modeled as an exogenous process and the lump-sum taxes levied on households are adjusted such that the budget is balanced each period. The central bank adjusts its short-term interest rates according to a Taylor-like rule that allows for interest rate smoothing and includes i.i.d. monetary shocks. Finally, the LTV ratio set by the regulatory authority is assumed to be exogenous.

[3] The risk premium is introduced only to render the model stationary and calibrated such that it does not substantially affect the model dynamics.

3 Calibration

We calibrate the model to match the Polish data. Several parameters are set to match the key steady state ratios, reported in Table 1, using the 2000-2012 averages for Poland as the targets. Other parameters are taken from the literature. The calibrated values of structural parameters and stochastic shocks are summarized in Tables 2 and 3. Throughout, the unit of time is one quarter.

We choose 0.0054 as the housing stock depreciation rate and 0.56 as the housing weight in utility to match, respectively, the residential investment share in output equal to 2.8% and the steady state housing stock to output ratio of 1.3. The share of impatient households is calibrated at 0.75 to fit the mortgage loans to output ratio of 75%. Following Coenen et al. (2008), we choose transfers from patient to impatient agents so that consumption of the latter falls short of that of the former by no more than 25%. Finally, we calibrate the markup in the banking sector to match the average spread between the lending rate and the policy rate of 190 bp annually. Setting the weight of labor in utility to 110 allows us to match the share of working time of 32%. Finally, the share of FCLs in the loan aggregator (4) is calibrated at 0.5, roughly in line with the post-crisis data on lending to households.

While calibrating households' preferences, we follow the literature. Similarly to Iacoviello and Neri (2010), we set the discount factors for patient and impatient households to 0.993 and 0.985, respectively. The inverse of the Frisch elasticity as well as the inverse of the intertemporal elasticity of substitution in consumption are set to 2. Following Brzoza-Brzezina et al. (2014), we calibrate the degree of habit formation in consumption to 0.75. We pick 0.85 as the steady-state LTV ratio.

The steady state markups in the labor and product markets are set to 20%. The capital share in output is at the standard value of 0.32. Following Coenen et al. (2008), we set the elasticity of substitution between domestic and imported goods to 1.5 and the elasticity of substitution between patient and impatient households' labor to 6.[4]

We calibrate the degree of price stickiness in line with Brzoza-Brzezina et al. (2014), which additionally is supported by empirical evidence on price stickiness in Poland and the euro area presented in Macias and Makarski (2013) and Dhyne et al. (2006). The Calvo probabilities for domestic, import and export prices are all set to 0.75. The sensitivity of the risk premium is fixed at 0.02, which ensures that foreign debt is stabilized at zero in the long run without substantially affecting the model's short-run dynamics.

We parametrize the Taylor rule in line with the estimated DSGE models for Poland, i.e. interest rate smoothing equal to 0.75, the long-run response to inflation of 2 and that to output equal to 0.5. The steady state inflation rate is set to 0.5% quarterly, which is close to the inflation target in Poland.

[4] To be precise, Coenen et al. (2008) distinguish between Ricardian and rule-of-thumb agents.

One of the structural parameters that cannot be taken directly from the literature is the elasticity of substitution between foreign and domestic currency loans. We calibrate it somewhat arbitrarily at 6 but discuss the sensitivity of our results to some alternative values.

The parameters determining the evolution of stochastic shocks are calibrated to match the model moments to the data, all of which are detrended with the Hodrick-Prescott filter. More specifically, since foreign output, inflation and interest rates are exogenous to the rest of the model and directly observed, we use the data for the euro area and estimate the autoregressive processes that shape their behavior. We proceed similarly with government expenditure by fitting an AR(1) process to the Polish government consumption time series.

The remaining stochastic shocks as well as the elasticity of the residential and non-residential investment adjustment cost are calibrated so that the weighted distance between the selected moments from the data and their model-based counterparts is minimized. The procedure is similar to the simulated method of moments used e.g. in Ruge-Murcia (2012). The only difference is that in our case we do not run simulations but rather use the ergodic moments implied by the model solution.

More precisely, consider stationary data x_t. Denote the vector of moments computed from this data as $m(x_t)$. For any parameter $\theta \in \Theta$ (for which the solution to the model exists), we can compute the moments from the model $m(x(\theta))$. The parameters $\hat{\theta}$ are chosen as follows

$$\hat{\theta} = \arg\min_{\theta \in \Theta} [m(x_T) - m(x(\theta))]' \mathbf{W} [m(x_T) - m(x(\theta))]$$

where $\mathbf{W}$ is the diagonal matrix of the long-run variance of the moments computed using the Newey-West estimator with a Barlett kernel and bandwidth given by the integer of $4(T/100)^{2/9}$ and T denotes the sample size. As regards the moments collected in m, we use the standard deviations and first order autocorrelations of the following variables: output, consumption, non-residential investment, residential investment, inflation, interest rate, domestic currency mortgage loans, foreign currency mortgage loans and real exchange rate.

To show the workings of our model, in Table 4 we present the moments from the model against the ones from the data. We obtain an adequate data fit, except for the mismatch of correlation of inflation with output and underestimation of real exchange rate volatility. However, given that the former varies over time and the fact that exchange rate fluctuations are usually underestimated in this class of models, we consider our calibration satisfactory.

4 Results

4.1 Business cycle implications of foreign currency loans

Before we present the impact of FCLs on monetary and macroprudential policies and on welfare, we first discuss their implications for the business cycle. Table 5 presents the standard deviations and correlations with output of those key macrovariables that we also used to calibrate our model for various shares of FCLs.

The following observations can be made. First of all, if loans are taken in foreign currency, the economy becomes less stable. While the effect on output can be considered moderate as its standard deviation increases by just 5% if we move from zero to 100% share of FCLs, it is much stronger for those variables that can be considered important from the welfare perspective. In particular, the volatility of consumption more than doubles and that of housing investment increases significantly. A higher proportion of FCLs also implies a more volatile credit while, in contrast, inflation is hardly affected. The main reason for increased volatility in the economy is that, with a large share of FCLs, impatient households' balance sheets become very sensitive to fluctuations in the exchange rate, which significantly affects their consumption and housing demand. Moreover, since the central bank responds to fluctuations in output, an increase in their amplitude implies stronger adjustments of the short-term interest rate, which makes the exchange rate and hence borrowers' expenditures even more volatile.

Second, if the share of FCLs is sufficiently large, the real exchange rate becomes countercyclical. This means that depreciation of the exchange rate deteriorates the balance sheets of impatient households so strongly that the resulting decrease in their expenditures outweighs the positive effect of weaker currency on the country's net exports. This makes these agents suffer even more as their labor income is depressed following a slowdown in economic activity. Finally, it is worth noting that the effect of FCLs on aggregate volatility is non-linear: an increase in their share from zero to 50% has significantly lower impact than a move from 50% to 100%. Interestingly, the former shift has barely any effect on output volatility.

Overall, this discussion already suggests that lending in foreign currency to households might not be good for the aggregate welfare, and for that of impatient households in particular. We look at this issue more formally in subsection 4.3.

4.2 Foreign currency loans and effectiveness of monetary and macroprudential policies

We now check how foreign currency loans affect the transmission of monetary policy. The relevant impulse response functions are presented in Figure 1. As a benchmark we show the responses to a monetary policy shock in the absence of FCLs. In this case we have the standard financial accelerator at work, which, as known from the literature, amplifies the monetary transmission. Lower lending after the monetary policy shock drives down housing demand, lowers house prices and leads to a tightening of the collateral constraint. As a result, consumption further declines and so do output and inflation. If all loans are denominated in foreign currency, the financial accelerator is much weaker. This is because the relevant (i.e. foreign) interest rate does not change while the exchange rate appreciates, boosting impatient households' financial position. Finally, the impulse responses for our calibrated case (with 50% of FCLs) are located between these two extremes.

Our second experiment shows how the denomination of loans affects the potency of macroprudential policy. This is shown in Figure 2. It turns out that the difference between the impulse responses in the cases of domestic and foreign currency lending is much smaller. To see why, note that an LTV shock affects the real economy but has little effect on inflation, while the monetary authority responds mainly to the latter. As a result, the domestic interest rate moves only slightly (not reported) and hence the exchange rate movements are moderate. Actually, the fall in output caused by an LTV tightening implies a monetary policy easing and exchange rate depreciation, which hits impatient households' balance sheets if loans are denominated in foreign currency. Hence, the presence of FCLs amplifies the effects of macroprudential policy. However, as noted before, the magnitude of this amplification is not large.

Both implications of FCL for the business cycle and for the effectiveness of policies described above were derived for a given parametrization of the monetary policy rule and for an exogeneous LTV process. Now we go one step further and look at a wider set of policies. In particular, we optimize the behavior of both policymakers (one at a time) and analyze the trade-offs they face. Folowing much of the literature, the Taylor rule is assumed to respond to output y_t and inflation $\pi_t \equiv P_t/P_{t-1}$

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi} \left(\frac{y_t}{y}\right)^{\gamma_y}\right]^{1-\gamma_R} \tag{9}$$

where variables without time subscripts indicate the steady-state values. We next look at the trade-off between stabilizing these two variables.

Macroprudential policy still lacks such established standards and we decided to consider the trade-off between stabilizing the real and financial sides of the economy, represented by the volatility of output and credit, respectively. For this experiment, the LTV ratio is assumed to follow

$$\frac{m_t}{m} = \left(\frac{l_t}{l}\right)^{\gamma_{ml}} \left(\frac{y_t}{y}\right)^{\gamma_{my}} \tag{10}$$

where l_t denotes total real loans.

For both policies, we construct the efficient policy frontiers by finding optimal coefficients of the policy rules defined above for the simple loss functions with a full spectrum of weights on output vs. inflation or output vs. credit volatilities. In order to eliminate unrealisticaly volatile instruments, we introduced caps on the standard deviations of the interest rate and the LTV ratio at 2.5 p.p. (annualized) and 10 p.p., respectively. The obtained policy frontiers are plotted in Figures 3 and 4.

Both frontiers shows that our earlier findings about the business cycle implications of FCLs are robust to policy reaction. In all cases, the economy is more volatile with foreign than with domestic currency loans. Interestingly, the volatility increases only slightly for a relatively small share of FCLs and much more when it rises further. Another interesting finding is the steepening of the macroprudential policy frontiers with an increasing share of FCL. This means that with more FCLs it becomes relatively more difficult to stabilize the real economy using the LTV policy.

4.3 Welfare implications of foreign currency loans

We next show how foreign currency loans affect agents' welfare. We do this by comparing the model-consistent utility for different shares $\eta_{L,\chi}$ of DCLs in households' portfolio. We report the results separately for patient and impatient households, as well as using aggregate welfare computed as follows (see e.g. Lambertini et al., 2013; Rubio and Carrasco-Gallego, 2014)

$$U_t = \omega_P(1-\beta_P)U_{P,t} + \omega_I(1-\beta_I)U_{I,t}$$

where $U_{P,t}$ and $U_{I,t}$ are second-order approximations to the lifetime utility of patient and impatient households, respectively.

Welfare is presented as consumption equivalent, defined as percent of lifetime consumption that households would be willing to forgo to have only domestic currency loans in their portfolio (with total loans unchanged).The results are presented for three cases. First, we analyze the case where only domestic monetary policy shocks exist in the economy. Next, we move to the case with only risk premium (exchange rate) shocks. Finally, we show the welfare implications of FCLs in the complete stochastic environment.

Figure 5 shows the welfare effects of FCLs when domestic monetary policy is the only source of aggregate risk. It is intuitive that in such a case agents should dislike DCLs and prefer FCLs, since the latter generate less volatility in their consumption, housing and labor effort. Indeed, impatient agents' welfare can be raised by up to 0.18% if DCLs are substituted with FCLs. Also aggregate welfare can be raised by 0.15% in this case. Interestingly, the welfare function is not monotonic as the maxima are reached for a 13% share of DCLs in the portfolio. The reason is intuitive. Monetary policy shocks affect not only the domestic interest rate, but also the exchange rate. Fluctuations in the former discourage from holding DCLs, while those of the latter strongly affect impatient households' balance sheets when FCLs are held. Our welfare function solves the trade-off problem generated by these two effects, but gives a clear preference to FCLs.

An opposite case arises when only risk premium shocks are present. These move primarily the exchange rate and this effect clearly dominates any other spillovers. As evidenced in Figure 6, in this scenario DCLs are preferred unequivocally. If agents decide to hold only FCLs, their welfare loss is equivalent to 1.3% of lifetime consumption. The number for impatient agents is even higher, and goes up to almost 2%.

Finally, we show the results for the complete stochastic environment. As presented in Figure 7, again there is an internal optimum, although the peak is much less pronounced than in the first case. Welfare is maximized for a DCL share of 87%, but in fact the function if almost flat in the 70-100% region. However, for lower DCL shares welfare losses can be substantial, reaching 1.2% of lifetime consumption if agents hold only FCLs. For impatient agents the loss may attain 1.9%. This result clearly speaks in favor of holding a loan portfolio that primarily consists of domestic currency loans.

4.4 Using regulation to change the share of FCLs

In the preceding two subsections we documented that a substantial share of FCLs may decrease the effectiveness of monetary policy and negatively affect welfare. A natural question arises whether regulation can be used to reduce the share of FCLs and what is the cost of such an action. To check this we design two additional regulatory tools, whose role is to change the composition of the loan portfolio. The first tool targets directly the composition by setting the maximum share of DCLs in total loans to an exogenously defined value $\vartheta_t \equiv \frac{L_{H,t}}{L_t}$.

The second instrument works through the cost channel as it introduces a tax τ_t on foreign loans. This tax shows up in impatient households' budget constraint (3), raising effective cost of FCLs, as well as in the collateral constraint (5), raising the repayment value of debt. These two alternative instruments are applied separately and in a non-stochastic environment.

First, we document how the economy reacts if macroprudential policy is used to permanently lower the share of FCLs to ϑ_t. The experiment assumes that the share of FCLs is permanently reduced from 50% (our benchmark equal to the share desired by households) to 45% (imposed by the regulator). The results depend on the degree of substitutability between DCLs and FCLs. If the two types of loans are perfectly substitutable ($\phi_L = \infty$), the economy does not react to the shock. Households simply substitute FCLs with DCLs to the extent that keeps total lending and other variables unchanged. However, if FCLs and DCLs are imperfect substitutes ($\phi_L = 6$), the story becomes more interesting. Figure 8 presents the effects of this shock. Borrowers react to the lower imposed share of FCLs by increasing DCLs, though by less than they reduce FCLs. As a result, total loans decline. This leads to a reduction in residential investment. Even though consumption increases (crowding in effect), total output declines (by more in the short-run than in the long-run). Inflation initially goes up, but later declines as its behavior is determined by the central bank and hence it eventually returns to the inflation target.

In the second experiment the tax τ_t is permanently imposed by the regulator. If loans are perfectly substitutable, households eliminate FCLs from their portfolio completely and no other variables are affected. However, if loans are not perfectly substitutable, the result is quite different. As Figure 9 shows, after such policy is applied total loans decline (loans are not perfectly substitutable), which leads to lower residential investment and lower consumption. Here, and in contrast to the quantitative restriction policy, the imposition of a tax on FCLs increases debt payments of impatient households and therefore a reduction of consumption of impatient households is stronger. Since patient households increase their consumption (crowding in), total consumption eventually increases. Total output falls and its decline during the transition period is larger than in the long run. Inflation behaves similarly as in the first scenario.

5 Conclusions

Foreign currency loans play an important role in several economies, both advanced and emerging markets. They impact on the economy through several channels. First, they are a source of exchange rate risk for borrowers. Second, empirical evidence shows that they weaken the monetary policy transmission.

In this paper we analyze the role of foreign currency lending in a structural economic model. To this end we construct a small open economy DSGE model with financial frictions in the form of collateral constraints. Households accumulate housing and can take loans in domestic or foreign currency. In this framework we test how the presence of foreign currency lending affects the transmission of monetary and macroprudential policy. Furthermore, we analyze the welfare implications of foreign currency loans.

Our main findings are as follows. First, foreign currency loans impair the transmission of monetary policy but do not affect so much the effectiveness of macroprudential policy. Second, we find that FCLs increase welfare when domestic interest rate shocks are strong and decrease it when risk premium (exchange rate) shocks dominate. Under a realistic calibration of the complete stochastic environment, FCLs are welfare reducing. Third, we show that restoring the effectiveness of monetary policy or improving welfare through FCL discriminating regulation may have a (mainly short-run) negative impact on the economy.

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Tables and figures

Table 1: Steady state ratios

Steady state ratio	Value
Share of government expenditure	0.181
Import of consumer goods to output ratio	0.11
Import of capital investment goods to output ratio	0.14
Residential investment to output ratio	0.028
Capital investment to output ratio	0.177
Share of FCLs in total loans	0.5
Hours worked	0.32
Housing wealth to output ratio (annual)	1.3
Debt to output ratio (annual)	0.75
Spread (annualized)	0.019
Relative consumption of impatient HHs	0.77

Table 2: Calibration - parameters

Parameter	Value	Description
β_P	0.993	Discount factor, patient HHs
β_I	0.985	Discount factor, impatient HHs
δ_χ	0.0054	Housing stock depreciation rate
δ_k	0.02	Capital stock depreciation rate
ω_I	0.75	Share of impatient HHs
A_χ	0.56	Weight on housing in utility function
A_n	110	Weight on labor in utility function
σ_n	2	Inverse of Frisch elasticity of labor supply
ξ	0.75	Degree of external habit formation in consumption
θ_w	0.75	Calvo probability for wages
ϕ_n	6	Elasticity of substitution btw. labor of patient and impatient HHs
τ_I	0.35	Transfers to impatient HHs (relative to government spending)
μ	1.2	Steady state product markup
θ_H	0.75	Calvo probability for domestic prices
θ_F	0.75	Calvo probability for import prices
θ_H^*	0.75	Calvo probability for export prices
α	0.32	Output elasticity with respect to capital
κ_k	0.337	Capital investment adjustment cost
κ_χ	11.83	Housing investment adjustment cost
μ_L	1.0047	Loan markup
m	0.85	Steady state LTV ratio
η_L	0.5	Share of domestic currency loans in total loans
ϕ_L	6	Elasticity of substitution btw. domestic and foreign currency loans
π	1.005	Steady state inflation
ϱ	0.02	Elasticity of risk premium wrt. foreign debt
γ_R	0.75	Interest rate smoothing in Taylor rule
γ_π	2	Response to inflation in Taylor rule
γ_y	0.5	Response to output in Taylor rule
η_c	0.816	Share of domestic goods in consumption basket
η_k	0.205	Share of domestic goods in investment
ϕ_y^*	1.5	Price elasticity of exports
ϕ_c	1.5	Elasticity of substitution btw. home and foreign consumption goods
ϕ_k	1.5	Elasticity of substitution btw. home and foreign investment goods

Table 3: Calibration - stochastic shocks

Parameter	Value	Description
ρ_z	0.92	Productivity shock - autocorrelation
σ_z	0.007	Productivity shock - standard deviation
ρ_g	0.63	Government spending shock - autocorrelation
σ_g	0.011	Government spending shock - standard deviation
ρ_ρ	0.71	Risk premium shock - autocorrelation
σ_ρ	0.004	Risk premium shock - standard deviation
ρ_{η_L}	0.999	Shock to share of DCLs - autocorrelation
σ_{η_L}	0.003	Shock to share of DCLs - standard deviation
σ_R	0.002	Monetary shock - standard deviation
ρ_y^*	0.91	Foreign output - autocorrelation
σ_y^*	0.006	Foreign output - standard deviation
ρ_π^*	0.55	Foreign inflation - autocorrelation
σ_π^*	0.002	Foreign inflation - standard deviation
ρ_R^*	0.9	Foreign interest rate - autocorrelation
σ_R^*	0.001	Foreign interest rate - standard deviation
$r(\varepsilon_\pi^*, \varepsilon_y^*)$	0.48	Correlation of residuals from foreign inflation and output equations
$r(\varepsilon_\pi^*, \varepsilon_R^*)$	0.38	Correlation of residuals from foreign inflation and interest rate equations
$r(\varepsilon_R^*, \varepsilon_y^*)$	0.73	Correlation of residuals from foreign interest rate and output equations

Table 4: Moment matching

Variable	Standard dev.		Autocorrelation		Corr. with output	
	Data	Model	Data	Model	Data	Model
Output	1.3	0.95	0.91	0.93	1.00	1.00
Consumption	0.95	1.17	0.82	0.91	0.74	0.5
Non-Residential investment	5.96	6.13	0.94	0.92	0.92	0.38
Residential investment	5.11	5.3	0.82	0.99	0.67	0.61
Inflation	0.45	0.49	0.44	0.84	0.55	-0.71
Interest rate	1.7	2.12	0.92	0.87	0.60	-0.83
DCLs	8.97	8.95	0.88	0.90	0.55	0.13
FCLs	9.84	10.04	0.90	0.85	0.21	0.10
Real exchange rate	7.15	2.16	0.79	0.70	-0.25	0.09

Note: All variables are quarterly data for Poland for the period 2000-2012, detrended with the Hodrick-Prescott filter.

Table 5: Model-implied moments for various shares of FCLs

Variable	Standard dev.			Corr. with output		
	FCL: 0%	FCL: 50%	FCL: 100%	FCL: 0%	FCL: 50%	FCL: 100%
Output	0.96	0.95	1.01	1.00	1.00	1.00
Consumption	0.98	1.17	2.17	0.55	0.50	0.50
Non-Residential investment	6.92	6.13	6.67	0.30	0.38	0.17
Residential investment	5.15	5.3	6.05	0.63	0.61	0.51
Inflation	0.49	0.49	0.49	-0.69	-0.71	-0.67
Interest rate	2.09	2.12	2.29	-0.87	-0.83	-0.65
DCLs	8.28	8.95	-	0.11	0.13	-
FCLs	-	10.04	13.37	-	0.10	0.34
Real exchange rate	1.77	2.16	2.78	0.28	0.09	-0.19

Figure 1: Foreign Currency Loans and Monetary Policy

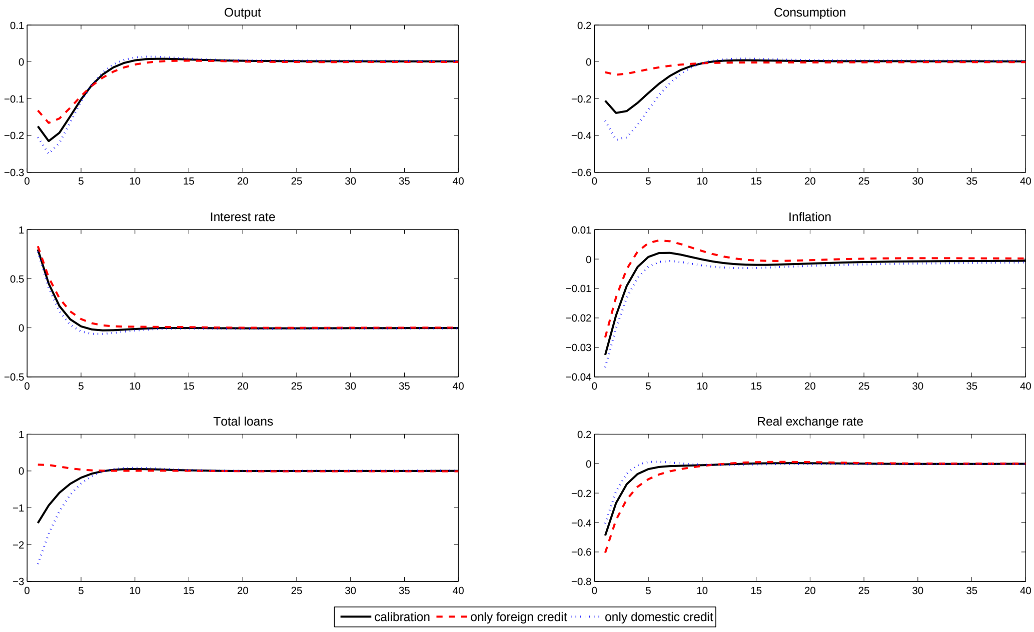


Figure 2: Foreign Currency Loans and Macroprudential Policy

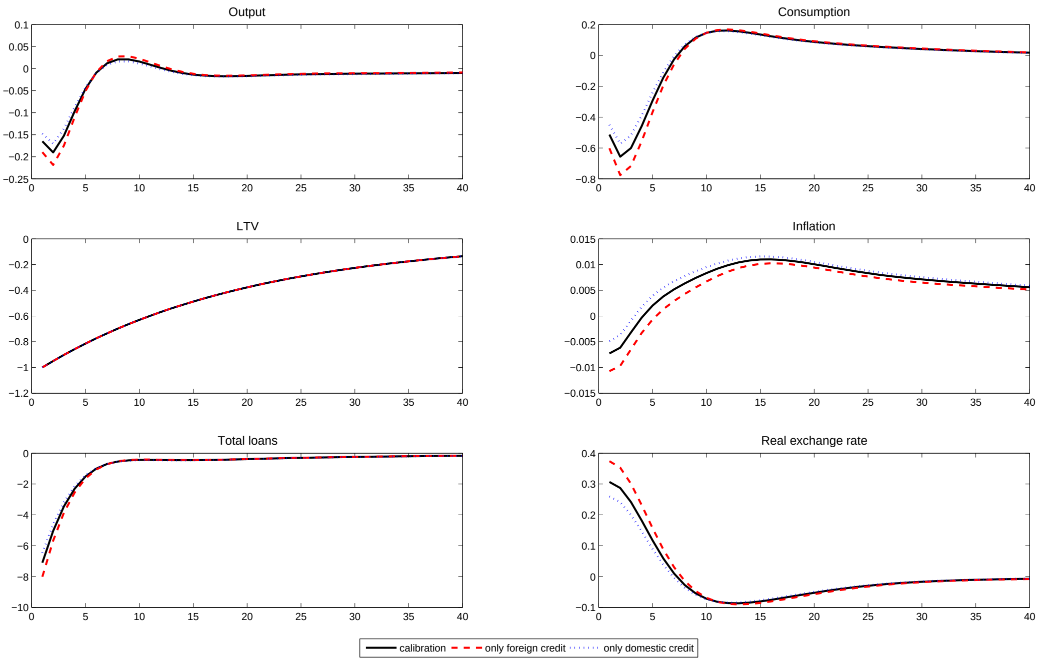


Figure 3: Monetary policy frontier

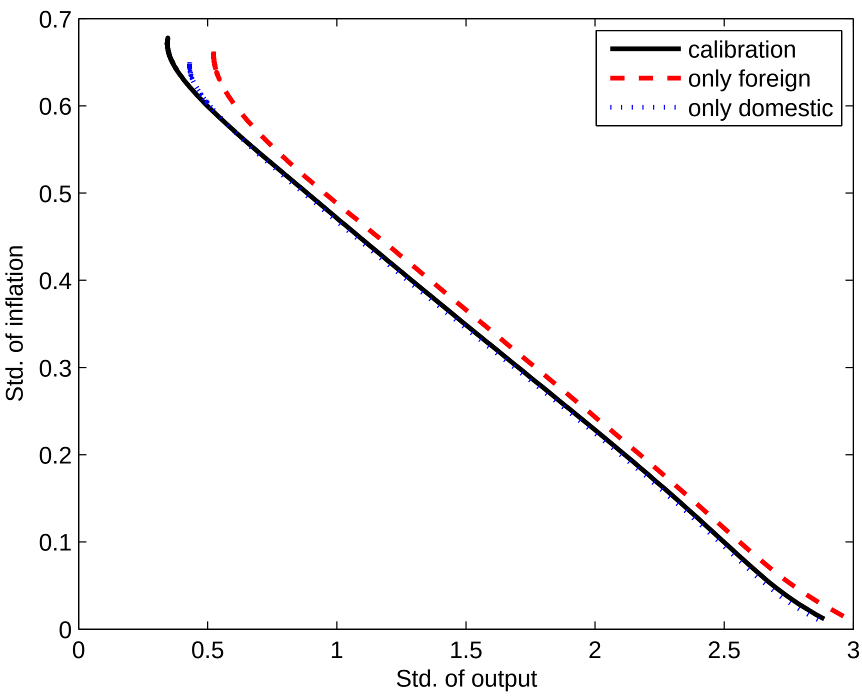


Figure 4: Macroprudential policy frontier

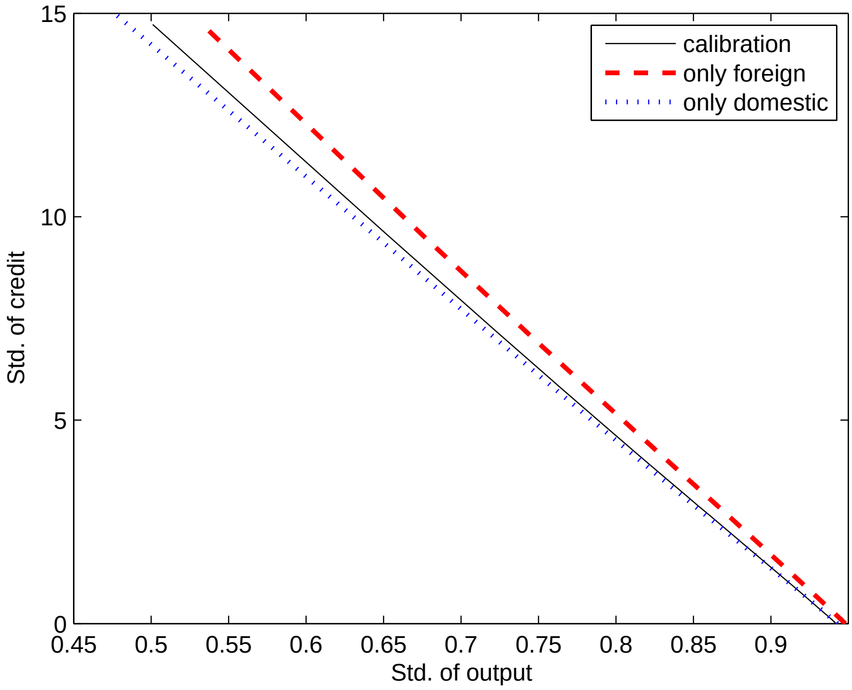


Figure 5: Welfare effects of domestic monetary policy shocks

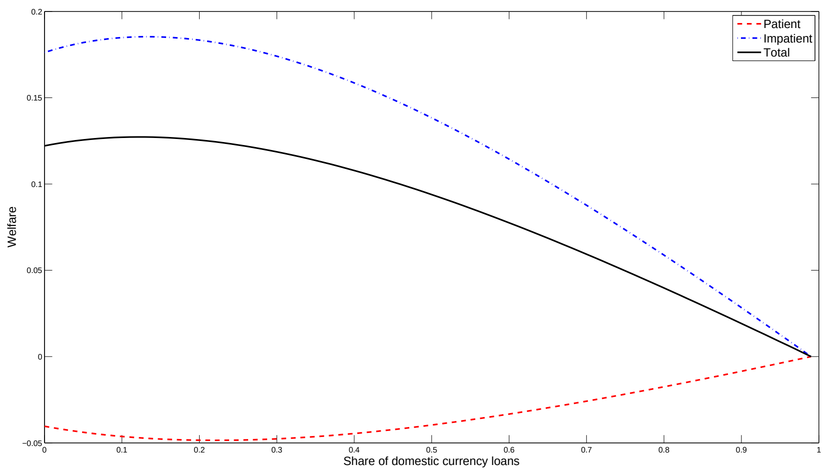


Figure 6: Welfare effects of risk premium shocks

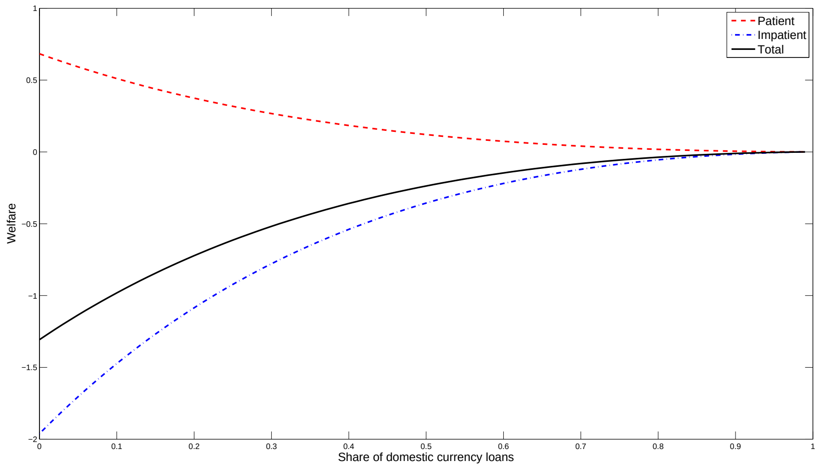


Figure 7: Welfare effects of full composition of shocks

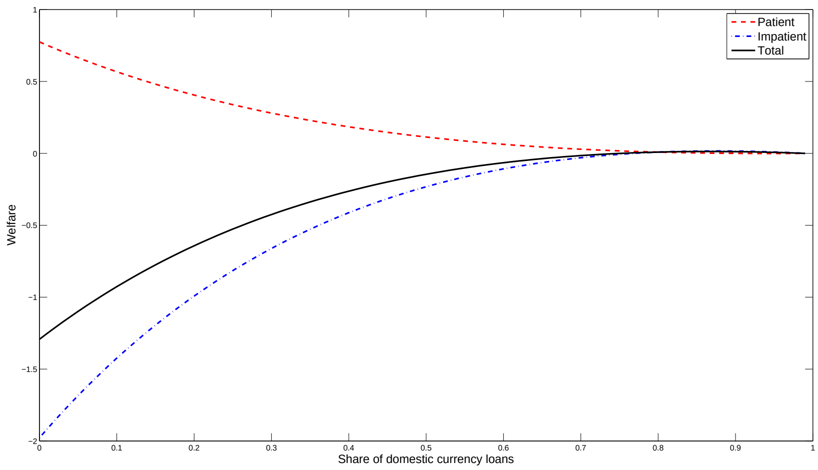


Figure 8: The effects of FCL discrimination under imperfect substitution

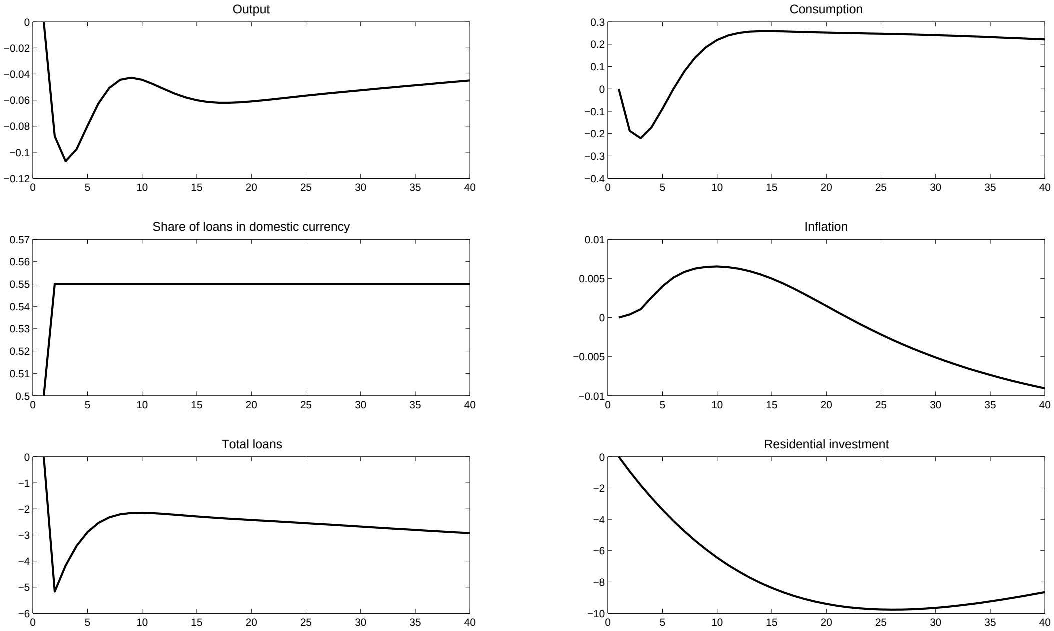
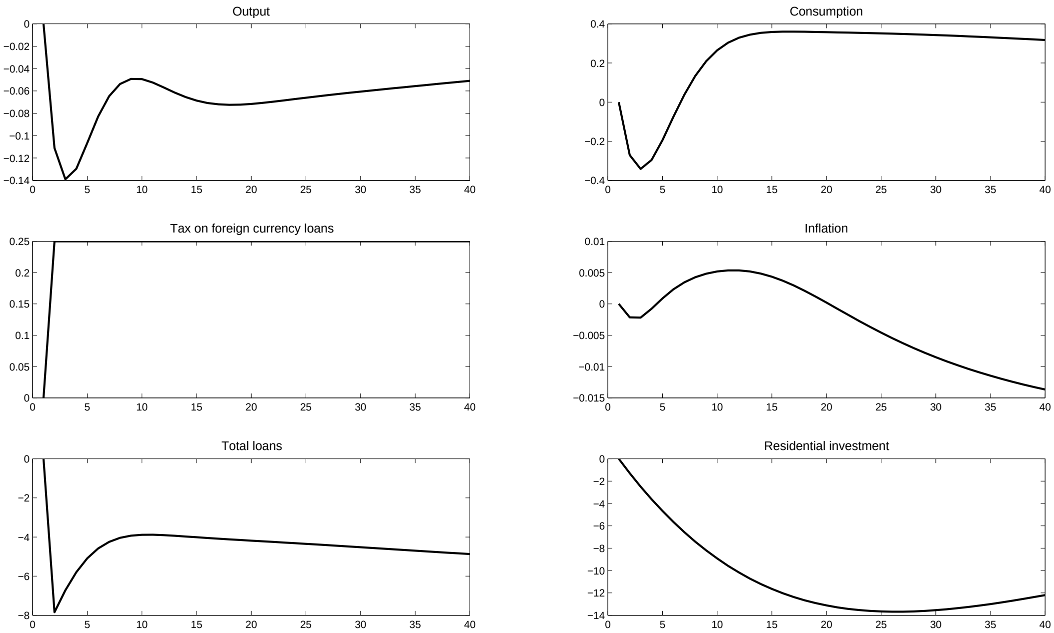


Figure 9: The effects of tax on FCL under imperfect substitution



Appendix: List of model equations

In this appendix we present a full list of equations making up our model. Lower-case letters are the real counterparts of the nominal variables defined in section 2. As regards the variables not showing up in the main text and not explicitly defined below, $q_t \equiv \frac{S_t P_t^*}{P_t}$ is the real exchange rate, $\pi_t \equiv \frac{P_t}{P_{t-1}}$ is the inflation rate, Θ_t is the Lagrange multiplier on the collateral constraint, $i_{\chi,t}$ and $i_{k,t}$ denote residential and capital investment and g_t is government spending. The variables without time subscripts denote the steady state.

Households

Marginal utilities (for $i = \{I, P\}$)

$$u_{i,t} = (c_{i,t} - \xi c_{i,t-1})^{-\sigma_c}$$

Euler equation for patient households

$$u_{P,t} = \beta_P \mathbb{E}_t \left\{ u_{P,t+1} \pi_{t+1}^{-1} \right\} R_t$$

Impatient households' budget constraint

$$c_{I,t}+p_{\chi,t}(\chi_{I,t}-(1-\delta_\chi)\chi_{I,t-1})+R_{H,t-1}l_{H,t-1}\pi_t^{-1}+q_t(1+\tau_{t-1})R_{F,t-1}(\pi_t^*)^{-1}l_{F,t-1} = w_{I,t}n_{I,t}+l_{H,t}+q_t l_{F,t}+t_{I,t}$$

Collateral constraint

$$R_{H,t}l_{H,t} + (1+\tau_t)R_{F,t}l_{F,t}\mathbb{E}_t \left\{ q_{t+1}\frac{\pi_{t+1}}{\pi_{t+1}^*} \right\} = m_t(1-\delta_\chi)\mathbb{E}_t \left\{ p_{\chi,t+1}\pi_{t+1}\chi_{I,t} \right\}$$

Euler equations for impatient households

$$u_{I,t} = \left(\frac{l_{H,t}}{\eta_{L,t} l_t} \right)^{\frac{1}{\phi_L}} \left(\beta_I \mathbb{E}_t \left\{ \frac{u_{I,t+1}}{\pi_{t+1}} \right\} R_{H,t} + \Theta_t R_{H,t} \right)$$

$$u_{I,t} = \left(\frac{q_t l_{F,t}}{(1-\eta_{L,t}) l_t} \right)^{\frac{1}{\phi_L}} \left(\beta_I \mathbb{E}_t \left\{ u_{I,t+1} \frac{q_{t+1}}{q_t \pi_{t+1}^*} \right\} R_{F,t} + \Theta_t (1+\tau_t) R_{F,t} \mathbb{E}_t \left\{ \frac{q_{t+1}}{q_t} \frac{\pi_{t+1}}{\pi_{t+1}^*} \right\} \right)$$

Loan aggregator

$$l_t = \left[\eta_{L,t}^{\frac{1}{\phi_L}} l_{H,t}^{\frac{\phi_L-1}{\phi_L}} + (1-\eta_{L,t})^{\frac{1}{\phi_L}} (q_t l_{F,t})^{\frac{\phi_L-1}{\phi_L}} \right]^{\frac{\phi_L}{\phi_L-1}}$$

Housing Euler equations

$$u_{P,t}p_{\chi,t} = A_\chi \chi_{P,t}^{-\sigma_\chi} + \beta_P(1-\delta_\chi)\mathbb{E}_t\left\{u_{P,t+1}p_{\chi,t+1}\right\}$$

$$\begin{aligned} u_{I,t}p_{\chi,t} &= A_\chi \chi_{I,t}^{-\sigma_\chi} + \beta_I(1-\delta_\chi)\mathbb{E}_t\left\{u_{I,t+1}p_{\chi,t+1}\right\} \\ &\quad +\Theta_t m_t(1-\delta_\chi)\mathbb{E}_t\left\{p_{\chi,t+1}\pi_{t+1}\right\} \end{aligned}$$

Capital Euler equation

$$u_{P,t}p_{k,t} = \beta_P E_t\left\{u_{P,t+1}\left[(1-\delta_k)p_{k,t+1} + r_{k,t+1}\right]\right\}$$

Total consumption

$$c_t = \omega_I c_{I,t} + (1-\omega_I)c_{P,t}$$

Labor market

Optimal wage set by reoptimizing households (for $i = \{I, P\}$)

$$(\tilde{w}_{i,t})^{1+\sigma_n\frac{\mu_w}{\mu_w-1}} = \frac{\Omega_{w,i,t}}{\Upsilon_{w,i,t}}$$

Auxiliary functions for optimal wages (for $i = \{I, P\}$)

$$\Omega_{w,i,t} = \mu_w A_n (w_{i,t})^{\frac{\mu_w}{\mu_w-1}(1+\sigma_n)} n_{i,t}^{1+\sigma_n} + \beta_i\theta_w\mathbb{E}_t\left\{\left(\frac{\pi}{\pi_{t+1}}\right)^{\frac{\mu_w}{1-\mu_w}(1+\sigma_n)}\Omega_{w,i,t+1}\right\}$$

$$\Upsilon_{w,i,t} = u_{i,t}(w_{i,t})^{\frac{\mu_w}{\mu_w-1}} n_{i,t} + \beta_i\theta_w\mathbb{E}_t\left\{\left(\frac{\pi}{\pi_{t+1}}\right)^{\frac{1}{1-\mu_w}}\Upsilon_{w,i,t+1}\right\}$$

Wage index (for $i = \{I, P\}$)

$$w_{i,t}^{\frac{1}{1-\mu_w}} = \theta_w\left(w_{i,t-1}\frac{\pi}{\pi_t}\right)^{\frac{1}{1-\mu_w}} + (1-\theta_w)\tilde{w}_{i,t}^{\frac{1}{1-\mu_w}}$$

Labor demand (for $i = \{I, P\}$)

$$n_{i,t} = \left(\frac{w_{i,t}}{w_t}\right)^{-\phi_n} n_t$$

Aggregate wage

$$w_t = \left[\omega_I w_{I,t}^{1-\phi_n} + (1-\omega_I) w_{P,t}^{1-\phi_n}\right]^{\frac{1}{1-\phi_n}}$$

Capital and housing producers

Capital accumulation

$$k_t = (1-\delta_k)\, k_{t-1} + \left(1 - \frac{\kappa_k}{2}\left(\frac{i_{k,t}}{i_{k,t-1}} - 1\right)^2\right) i_{k,t}$$

Price of capital

$$p_{ik,t} = p_{k,t}\left(1 - \frac{\kappa_k}{2}\left(\frac{i_{k,t}}{i_{k,t-1}} - 1\right)^2 - \kappa_k\left(\frac{i_{k,t}}{i_{k,t-1}} - 1\right)\frac{i_{k,t}}{i_{k,t-1}}\right) + \\ + \beta_P \mathbb{E}_t\left\{\frac{u_{P,t+1}}{u_{P,t}} p_{k,t+1}\kappa_k\left(\frac{i_{k,t+1}}{i_{k,t}} - 1\right)\left(\frac{i_{k,t+1}}{i_{k,t}}\right)^2\right\}$$

Housing accumulation

$$\chi_t = (1-\delta_\chi)\, \chi_{t-1} + \left(1 - \frac{\kappa_\chi}{2}\left(\frac{i_{\chi,t}}{i_{\chi,t-1}} - 1\right)^2\right) i_{\chi,t}$$

Price of housing

$$p_{H,t} = p_{\chi,t}\left(1 - \frac{\kappa_\chi}{2}\left(\frac{i_{\chi,t}}{i_{\chi,t-1}} - 1\right)^2 - \kappa_\chi\left(\frac{i_{\chi,t}}{i_{\chi,t-1}} - 1\right)\frac{i_{\chi,t}}{i_{\chi,t-1}}\right) + \\ + \beta_P \mathbb{E}_t\left\{\frac{u_{P,t+1}}{u_{P,t}} p_{\chi,t+1}\kappa_\chi\left(\frac{i_{\chi,t+1}}{i_{\chi,t}} - 1\right)\left(\frac{i_{\chi,t+1}}{i_{\chi,t}}\right)^2\right\}$$

Final goods producers

Aggregators

$$c_t = \left((1-\eta_c)^{\frac{1}{\phi_c}} c_{F,t}^{\frac{\phi_c-1}{\phi_c}} + \eta_c^{\frac{1}{\phi_c}} c_{H,t}^{\frac{\phi_c-1}{\phi_c}}\right)^{\frac{\phi_c}{\phi_c-1}}$$

$$i_{k,t} = \left((1-\eta_k)^{\frac{1}{\phi_k}} i_{kF,t}^{\frac{\phi_k-1}{\phi_k}} + \eta_k^{\frac{1}{\phi_k}} i_{kH,t}^{\frac{\phi_k-1}{\phi_k}}\right)^{\frac{\phi_k}{\phi_k-1}}$$

Demand equations

$$c_{F,t} = (1-\eta_c)\, p_{F,t}^{-\phi_c} c_t$$

$$c_{H,t} = \eta_c p_{H,t}^{-\phi_c} c_t$$

$$i_{kF,t} = (1-\eta_k)\left(\frac{p_{F,t}}{p_{ik,t}}\right)^{-\phi_k} i_{k,t}$$

$$i_{kH,t} = \eta_k \left(\frac{p_{H,t}}{p_{ik,t}}\right)^{-\phi_k} i_{k,t}$$

Intermediate goods producers

Marginal cost

$$mc_t = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \frac{1}{\varepsilon_{z,t}} r_{k,t}^\alpha w_t^{1-\alpha}$$

Optimal factor proportions

$$\frac{r_{k,t}}{w_t} = \frac{\alpha}{1-\alpha}\frac{n_t}{k_{t-1}}$$

Optimal prices set by reoptimizing firms for domestic market and exports

$$\tilde{p}_{H,t} = \mu \frac{\Omega_{H,t}}{\Upsilon_{H,t}}$$

$$\tilde{p}^*_{H,t} = \mu \frac{\Omega^*_{H,t}}{\Upsilon^*_{H,t}}$$

Auxiliary functions for optimal prices

$$\Omega_{H,t} = u_{P,t} mc_t p_{H,t}^{\frac{\mu}{\mu-1}} y_{H,t} + \beta_P \theta_H \mathbb{E}_t \left\{ \left(\frac{\pi}{\pi_{t+1}}\right)^{\frac{\mu}{1-\mu}} \Omega_{H,t+1} \right\}$$

$$\Omega^*_{H,t} = u_{P,t} mc_t (p^*_{H,t})^{\frac{\mu}{\mu-1}} y^*_{H,t} + \beta_P \theta^*_H \mathbb{E}_t \left\{ \left(\frac{\pi^*}{\pi^*_{t+1}}\right)^{\frac{\mu}{1-\mu}} \Omega^*_{H,t+1} \right\}$$

$$\Upsilon_{H,t} = u_{P,t} p_{H,t}^{\frac{\mu}{\mu-1}} y_{H,t} + \beta_P \theta_H \mathbb{E}_t \left\{ \left(\frac{\pi}{\pi_{t+1}}\right)^{\frac{1}{1-\mu}} \Upsilon_{H,t+1} \right\}$$

$$\Upsilon^*_{H,t} = u_{P,t} q_t (p^*_{H,t})^{\frac{\mu}{\mu-1}} y^*_{H,t} + \beta_P \theta^*_H \mathbb{E}_t \left\{ \left(\frac{\pi^*}{\pi^*_{t+1}}\right)^{\frac{1}{1-\mu}} \Upsilon^*_{H,t+1} \right\}$$

Price indexes for goods produced domestically and for exports

$$p_{H,t}^{\frac{1}{1-\mu}} = \theta_H \left(p_{H,t-1} \frac{\pi}{\pi_t} \right)^{\frac{1}{1-\mu}} + (1-\theta_H) \tilde{p}_{H,t}^{\frac{1}{1-\mu}}$$

$$(p_{H,t}^*)^{\frac{1}{1-\mu}} = \theta_H^* \left(p_{H,t-1}^* \frac{\pi^*}{\pi_t^*} \right)^{\frac{1}{1-\mu}} + (1-\theta_H^*) \left(\tilde{p}_{H,t}^* \right)^{\frac{1}{1-\mu}}$$

Importing firms

Optimal prices set by reoptimizing importers

$$\tilde{p}_{F,t} = \mu \frac{\Omega_{F,t}}{\Upsilon_{F,t}}$$

Auxiliary functions for optimal prices

$$\Omega_{F,t} = u_{P,t} q_t p_{F,t}^{\frac{\mu}{\mu-1}} y_{F,t} + \beta_P \theta_F \mathbb{E}_t \left\{ \left(\frac{\pi}{\pi_{t+1}} \right)^{\frac{\mu}{1-\mu}} \Omega_{F,t+1} \right\}$$

$$\Upsilon_{F,t} = u_{P,t} p_{F,t}^{\frac{\mu}{\mu-1}} y_{F,t} + \beta_P \theta_F \mathbb{E}_t \left\{ \left(\frac{\pi}{\pi_{t+1}} \right)^{\frac{1}{1-\mu}} \Upsilon_{F,t+1} \right\}$$

Price index for imports

$$p_{F,t}^{\frac{1}{1-\mu}} = \theta_F \left(p_{F,t-1} \frac{\pi}{\pi_t} \right)^{\frac{1}{1-\mu}} + (1-\theta_F) \tilde{p}_{F,t}^{\frac{1}{1-\mu}}$$

Banks

Interest on loans

$$R_{H,t} = \mu_L R_t$$

$$R_{F,t} = \mu_L \rho_t R_t^*$$

Uncovered interest rate parity

$$\mathbb{E}_t \left\{ u_{P,t+1} \left(\frac{R_t}{\pi_{t+1}} - \frac{q_{t+1}}{q_t} \frac{\rho_t R_t^*}{\pi_{t+1}^*} \right) \right\} = 0$$

Risk premium

$$\rho_t = 1 + \varrho \left[\exp \left(\frac{d_t^* q_t}{y_t} - \frac{d^* q}{y} \right) - 1 \right] + \epsilon_{\rho,t}$$

Fiscal and monetary authority

Taxes levied on impatient households

$$\omega_I t_{I,t} = \tau_I p_{H,t} g_t$$

Taylor rule

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\gamma_R} \left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi} \left(\frac{y_t}{y}\right)^{\gamma_y}\right]^{1-\gamma_R} \varepsilon_{R,t}$$

Market clearing

Production for domestic market

$$y_{H,t} = c_{H,t} + i_{kH,t} + i_{\chi,t} + g_t$$

Imports

$$y_{F,t} = c_{F,t} + i_{Fk,t}$$

Export demand

$$y^*_{H,t} = \eta^* \left(p^*_{H,t}\right)^{-\phi^*_y} y^*_t$$

Aggregate output

$$y_{H,t}\Delta_{H,t} + y^*_{H,t}\Delta^*_{H,t} \quad = \quad \varepsilon_{z,t} k^\alpha_{t-1} n^{1-\alpha}_t$$

GDP definition

$$y_t \quad = \quad y_{H,t}\Delta_{H,t} + y^*_{H,t}\Delta^*_{H,t}$$

Balance of payments

$$d^*_t = \Delta_{F,t} y_{F,t} - p^*_{H,t} y^*_{H,t} + \varrho_{t-1} R^*_{t-1} \frac{d^*_{t-1}}{\pi^*_t}$$

Price dispersion indexes

$$\Delta_{H,t} = \theta_H \left(\frac{p_{H,t}}{p_{H,t-1}}\right)^{\frac{\mu}{\mu-1}} \Delta_{H,t-1} \left(\frac{\pi}{\pi_t}\right)^{\frac{\mu}{1-\mu}} + (1-\theta_H)\left(\frac{\tilde{p}_{H,t}}{p_{H,t}}\right)^{\frac{\mu}{1-\mu}}$$

$$\Delta^*_{H,t} = \theta^*_H \left(\frac{p^*_{H,t}}{p^*_{H,t-1}}\right)^{\frac{\mu}{\mu-1}} \Delta^*_{H,t-1} \left(\frac{\pi^*}{\pi^*_t}\right)^{\frac{\mu}{1-\mu}} + (1-\theta^*_H)\left(\frac{\tilde{p}^*_{H,t}}{p^*_{H,t}}\right)^{\frac{\mu}{1-\mu}}$$

$$\Delta_{F,t} = \theta_F \left(\frac{p_{F,t}}{p_{F,t-1}}\right)^{\frac{\mu}{\mu-1}} \Delta_{F,t-1} \left(\frac{\pi}{\pi_t}\right)^{\frac{\mu}{1-\mu}} + (1-\theta_F)\left(\frac{\tilde{p}_{F,t}}{p_{F,t}}\right)^{\frac{\mu}{1-\mu}}$$

Housing market

$$\chi_t = \omega_I \chi_{I,t} + (1 - \omega_I)\chi_{P,t}$$

Wage dispersion indexes (for $i = \{I, P\}$)

$$\Delta_{w,i,t} = \theta_w \left(\frac{w_{i,t}}{w_{i,t-1}}\right)^{\frac{\mu_w}{\mu_w - 1}(1+\sigma_n)} \Delta_{w,i,t-1} \left(\frac{\pi}{\pi_t}\right)^{\frac{\mu_w}{1-\mu_w}(1+\sigma_n)} + (1 - \theta_w) \left(\frac{\tilde{w}_{i,t}}{w_{i,t}}\right)^{\frac{\mu_w}{1-\mu_w}(1+\sigma_n)}$$

Macroprudential Research Network
This paper presents research conducted within the Macroprudential Research Network (MaRs). The network is composed of economists from the European System of Central Banks (ESCB), i.e. the national central banks of the 27 European Union (EU) Member States and the European Central Bank. The objective of MaRs is to develop core conceptual frameworks, models and/or tools supporting macro-prudential supervision in the EU.
The research is carried out in three work streams: 1) Macro-financial models linking financial stability and the performance of the economy; 2) Early warning systems and systemic risk indicators; 3) Assessing contagion risks.
MaRs is chaired by Philipp Hartmann (ECB). Paolo Angelini (Banca d'Italia), Laurent Clerc (Banque de France), Carsten Detken (ECB), Simone Manganelli (ECB) and Katerina Šmídková (Czech National Bank) are workstream coordinators. Javier Suarez (Center for Monetary and Financial Studies) and Hans Degryse (Katholieke Universiteit Leuven and Tilburg University) act as external consultants. Fiorella De Fiore (ECB) and Kalin Nikolov (ECB) share responsibility for the MaRs Secretariat.
The refereeing process of this paper has been coordinated by a team composed of Gerhard Rünstler, Kalin Nikolov and Bernd Schwaab (all ECB).
The paper is released in order to make the research of MaRs generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the ones of the author(s) and do not necessarily reflect those of the ECB or of the ESCB.

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