Macroprudential reciprocity in the euro area in a high inflation environment

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Absent international coordination, macroprudential policy can lead to cross-border spillovers and leakages, which reduce its efficiency. In a high inflation environment, ensuring that macroprudential policy reaches its goal is even more crucial, because monetary policy is focused on fighting inflation. In the European Union, reciprocity of countercyclical capital buffers (CCyB) is mandatory among member states, while this is not the case for borrower-based measures. We build a core-periphery New Keynesian dynamic stochastic general equilibrium (DSGE) model for the euro area with domestic and foreign banks' lending to evaluate the optimality of macroprudential reciprocity in the presence of global cost-push shocks. We find that reciprocating a countercyclical rule on the loan-to-value ratio (LTV) is welfare-enhancing for the activating country when the domestic CCyB rule is not too responsive. Regarding the interaction with monetary policy, reciprocity becomes even more needed if monetary policy puts a high weight on stabilizing inflation. Our results show that in a situation of high inflation and a resulting tightening of monetary policy, reciprocity in macroprudential policy can facilitate the coordination of union-wide monetary policy and national macroprudential policies.

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"To be fully capable to influence the financial cycle, a robust regulatory and macro-prudential framework requires that national supervisors recognise or reciprocate the regulatory and policy measures of the other countries. If reciprocity is applied only selectively, the level playing field is at risk and regulatory arbitrage will generate unintended negative spillovers. I imagine that a wide range of macro-prudential measures would benefit from automatic and mandatory reciprocity". Speech by Vítor Constâncio, Vice-President of the ECB, at the joint conference organised by the European Commission and the European Central Bank "European Financial Integration and Stability", 27 April 2015.

1 Introduction

Macroprudential policies became a central cornerstone of global financial regulation over the last fifteen years. However, their nesting in institutional arrangements and the optimal degree of coordination with other policies remains challenging, both given the nature of the policy itself and the institutional level at which decisions are taken. This applies in particular to the euro area, where a range of borrower-based macroprudential measures are set by national regulatory authorities, while lender-based macroprudential measures such as capital requirements and guidance regarding the countercyclical capital buffer (CCyB) are largely determined at the global level by the Basel Committee. At the same time, monetary policy is conducted at the euro area-wide level by the Governing Council of the European Central Bank (ECB).

To alleviate inefficiencies in cross-border intermediation stemming from cross-country heterogeneity, macroprudential instruments enacted under the international Basel III framework – such as the countercyclical capital buffer (CCyB) – are subject to mandatory reciprocity. Up to the buffer rate of 2.5%, the domestic CCyB applies to both domestic and foreign bank exposures in a given country. On the contrary, other macroprudential tools, such as borrower-based instruments (e.g., the loan-to-value (LTV) ratio), do not automatically apply to foreign bank exposures in the activating country. In fact, European Union law does not impose reciprocity for these instruments, but leaves coordination to voluntary reciprocity agreements among Member States. Hence, absent international coordination, macroprudential policy can lead to cross-border spillovers and leakages, which reduce its efficiency (Rubio, 2020).

In a high inflation environment, ensuring that macroprudential policy is effective in preserving financial stability is particularly crucial, as monetary policy steered to fulfill a price stability mandate potentially has to respond forcefully to tame inflation. A rapid tightening of policy rates and financial conditions may come at the expense of increasing financial instability, as firms and households are suddenly confronted with higher financing costs and a deteriorating demand outlook. Rubio and Yao (2024) show that in the presence of cost-push shocks, new trade-offs between monetary and macroprudential policy emerge, which calls for monetary and macroprudential policy coordination. Thus, heterogeneity in national macroprudential policies might question the efficiency of such a coordination in the presence of large global inflationary shocks, strengthening the case for reciprocity in macroprudential measures.

In this paper, we study the macro-financial consequences of coordinating different macroprudential instruments and monetary policy in the presence of union-wide inflationary shocks. We build a two-country euro area (core vs. periphery) general equilibrium macro-financial model with financial frictions and domestic and foreign banks. Banks in each jurisdiction intermediate funds both domestically and abroad via home and foreign branches. Importantly, we assume that foreign banks face larger information asymmetries when assessing the solvency of domestic borrowers, resulting in higher costs to recover assets in case of default (Iacoviello and Minetti, 2006). Therefore, domestic borrowers face different collateralized borrowing constraints on domestic and foreign debt.

We introduce two countercyclical macroprudential tools to the model: a countercyclical loan-to-value (LTV) ratio in the household sector – as an archetype of borrower-based measures – and a countercyclical capital-to-asset ratio applied to the banking sector resembling the Basel III countercyclical capital buffer (CCyB). Both tools respond to deviations of the credit-to-GDP ratio from its long-run value, i.e., to the credit-to-GDP gap defined by the Basel Committee on Banking Supervision (Basel Committee on Banking Supervision, 2010). We use our model to derive the welfare-maximizing degree of reciprocity in the LTV ratio rule in response to global cost-push shocks. In line with current regulatory arrangements in the European Union, we assume full reciprocity in the CCyB, and account for the monetary policy response to the inflation surge by evaluating the optimal degree of reciprocity in macroprudential policies for different weights on inflation in the central bank's reaction function.

We find that reciprocating a countercyclical rule on the LTV ratio is welfare-enhancing for the activating country when the domestic CCyB rule is not too responsive. Regarding the interaction with monetary policy, we find that the optimal degree of reciprocity in the LTV ratio rule increases with the weight monetary policy puts on stabilizing inflation. The rest of the paper is organized as follows. Section 2 presents the related literature and Section 3 gives an overview of reciprocity agreements over the European Union and euro area. Section 4 presents the two-country general equilibrum model and Section 5 presents the dynamics of the model. Section 6 introduces countercyclical macroprudential policies and welfare analysis. Section 7 concludes.

2 Related Literature

Macroprudential policies emerged in response to the Global Financial Crisis (GFC) and have since been the subject of a vast theoretical academic literature in macroeconomics and finance. This literature mainly focused on assessing the efficiency of different macroprudential tools and the optimal coordination of macroprudential and monetary policies for promoting financial and business cycle stability. The optimality and the degree of coordination in setting such tools was studied against the backdrop of a variety of macro-financial factors such as different sources of shocks, heterogeneity in financial markets, or the implications of an effective lower bound (ELB) on nominal interest rates (Gerali et al., 2010; Angelini et al., 2014; Rubio and Yao, 2020; Gebauer and Mazelis, 2023). However, the issue of macroprudential reciprocity remained largely unaddressed in the theoretical literature, with Rubio (2020) and Agénor et al. (2024) being notable exceptions. Rubio (2020) shows that macroprudential reciprocity is welfare-improving when considering a countercyclical rule for setting the LTV ratio. However, the interaction of recipricty in the LTV with the setting of other macroprudential instruments and with monetary policy was not considered in this study. Agénor et al. (2024) study the optimality of reciprocating countercyclical capital requirements in response to expansionary monetary policy shocks. They show that reciprocity can be welfare-improving when regulatory spillovers are weak. However, they define reciprocity in countercyclical capital requirements by assuming that the value of the response parameter in the advanced economy's macroprudential policy rule is equally set in the emerging economy's policy rule relating to bank exposures in the advanced economy. In our paper, we use an alternative definition of reciprocity consistent with the European Systemic Risk Board (ESRB) reciprocity framework for the CCyB. In our setup, reciprocating a macroprudential tool implies that the measure also applies to foreign banks' exposures in the country that activated the tool (see Section 3).

In addition, empirical studies emphasized the importance of reciprocity against the backdrop of cross-border leakages and regulatory arbitrage in macroprudential policy (Aiyar et al., 2014; Forbes, 2021). For the euro area, Choi et al. (2023) show that more stringent macroprudential policies in core euro area countries imply leakages towards periphery countries. When mortgage credit standards are tightened in core countries, banks in those countries increase their cross-border lending in periphery countries, which affects financial risk in the latter.

While the empirical literature also finds that leakages in financial intermediation may be triggered by a tightening in both lender- and borrower-based macroprudential measures, theoretical studies focused on assessing reciprocity in one macroprudential instrument only so far (Rubio, 2020; Agénor et al., 2024). Thus, a theoretical assessment on the possibility that the optimal reciprocity in one instrument is conditional on the existing degree of reciprocity in another instrument is still lacking, and we aim to fill this gap in the literature. In doing so, our study is the first fully account for policy interactions stemming from the specific regulatory arrangements in the euro area characterized by mandatory reciprocity in the CCyB under EU law (see Section 3), voluntary reciprocity in other macroprudential instruments, and a common setting of monetary policy. Finally, our study is the first to study optimality of macroprudential reciprocity in response to large global cost-push shocks leading to a profound monetary policy tightening.

3 Institutional arrangements and empirical evidence

To put our analysis into perspective, we provide evidence on the institutional arrangements that are in place in the EU – and the euro area in particular – regarding reciprocity in macroprudential policy.

3.1 Institutional arrangements regarding macroprudential reciprocity

The European Union (EU) legal framework relies mostly on voluntary reciprocity, with a few exceptions. The most notable exception is the CCyB, for which the EU Capital Requirements Directive 2013/36/EU (CRD) [1] requires mandatory reciprocity up to a buffer rate of 2.5%, in line with the international Basel III framework. Therefore, when a financial institution operates in several countries, its CCyB is the average of the CCyB imposed by the countries in which this institution is exposed (both in the European Union and third party countries), weighted by the amount of exposure of this institution in each country.

Other macroprudential tools, such as borrower-side measures, do not automatically apply to foreign banks' exposures in the activating country. In this context, the European Systemic Risk Board (ESRB) established a coordinated framework for voluntary reciprocity in 2015 (ESRB/2015/2[2]) for the macroprudential instruments that are not subject to compulsory reciprocity. The ESRB provides recommendations on reciprocating specific national macroprudential measures through this framework. Reciprocity then depends on bilateral reciprocity agreements. The country initially activating a certain macroprudential policy measure can submit a formal request to the ESRB requiring reciprocation of that measure in other EU member states to ensure that an equivalent macroprudential measure is applied to exposures of foreign banks in the activating country either via foreign branches and/or direct cross-border exposures. Other member states can then decide whether to reciprocate the measure or not, but are required to formally explain their decision in case of rejection (for instance due to immaterial exposures). The fact that member states do not reciprocate some macroprudential measures implies that the same type of claims held by domestoc and foreign banks in a certain member state are subject to different regulatory treatments. This difference in regulatory treatment may ultimately lead to credit leakage and regulatory arbitrage as banks may find it optimal to circumvent the respective macroprudential measures.

[1] See the 2013/36/EU directive here.

[2] See the ESRB reciprocity framework here.

3.2 Evidence on reciprocity agreements in the European Union

The ESRB's Overview of National Macroprudential Measures database offers information about the implementation of national macroprudential instruments in European countries, and information about reciprocation agreements between European countries.[3]

Reciprocation of a macroprudential measure is activated once the financial authority in one member state adopts a macroprudential instrument that is either identical to or serving the same purpose as a comparable measure already implemented in another member state. In February 2024, the ESRB database recorded 101 voluntary reciprocity agreements, of which 39 agreements were still applicable, 61 were no longer active and 1 was classified as being applicable in the future.[4] There are 10 European countries that have macroprudential instruments that have been reciprocated by other member states: Belgium, Estonia, Finland, France, Germany, Lithuania, Luxembourg, the Netherlands, Norway and Sweden. The country whose macroprudential tools have been the most reciprocated in Europe is Norway, with 22 reciprocation agreements with other European countries, followed by Estonia, with 17, Belgium with 14, Sweden with 13, Finland with 8, France with 7, Luxembourg with 6, Germany and the Netherlands with 5 each, and finally Lithuania with 4.

There are 19 European countries that have reciprocated at least one macroprudential instrument of another European state: Luxembourg, the Netherlands, Croatia, Denmark, France, Lithuania, Norway, Portugal, Belgium, Cyprus, Czech Republic, Latvia, Slovakia, Sweden, Finland, Ireland, the United Kingdom, Italy, and Germany. The countries that reciprocate the most are France, with 15 reciprocation agreements, Lithuania with 12, Belgium with 11 and Sweden, Norway, and Denmark with 9 reciprocation agreements. Table 3 summarizes the macroprudential measures implemented by each country that have been reciprocated.

[3]The ESRB database contains information pertaining to the 27 EU member countries, as well as Iceland, Liechtenstein, Norway, and the United Kingdom.

[4]If a reciprocity agreement is no longer recorded as being "active", the macroprudential measure upon which the agreement was based has expired. Generally, a macroprudential measure that has expired gets extended by the reporting country, but the ESRB counts this as two distinct measures. An expired reciprocity agreement is thus most often replaced by an equivalent one.

Table 1: Macroprudential measures that have been reciprocated in Europe, by country and year (as of Q2 2024)

Activating country	Year	Measure	Status	Length (quarters)
Belgium	2013	Risk Weights RRE CRE	No longer active	14
Belgium	2018	Risk Weights RRE CRE	No longer active	17
Belgium	2022	SRB	Currently applicable	9
Belgium	2023	SRB	Currently applicable	2
Estonia	2016	SRB	No longer active	16
Estonia	2018	SRB	No longer active	Unknown
Finland	2017	Risk Weights RRE CRE	No longer active	13
France	2018	Large Exposures	No longer active	20
Germany	2022	SRB	Currently applicable	6
Lithuania	2021	SRB	Currently applicable	8
Luxembourg	2020	LTV	Currently applicable	14
Netherlands	2020	Risk Weights RRE CRE	No longer active	3
Netherlands	2022	Risk Weights RRE CRE	Currently applicable	7
Norway	2014	Risk Weights Mortgages	Currently applicable	38
Norway	2020	Risk Weights RRE CRE	No longer active	9
Norway	2020	SRB	No longer active	9
Norway	2022	SRB	Currently applicable	7
Norway	2022	Risk Weights (others)	Currently applicable	7
Sweden	2014	Pillar II	No longer active	Unknown
Sweden	2018	Risk Weights RRE CRE	No longer active	13
Sweden	2023	Risk Weights (others)	Currently applicable	3
Sweden	2023	Risk Weights RRE CRE	Currently applicable	4

Note: Risk Weights RRE and CRE refer to Residential Real Estate and Commercial Real Estate respectively. SRB refers to Systemic Risk Buffer. Large exposures mean... and "Pillar II" refers to...

3.3 Reciprocity in the high inflation environment

Several reciprocity agreements have been formed in Europe since 2022[5] or/and have remained applicable over the high inflation period, including borrower-based measures such as a LTV ratio in Luxembourg.

At the same time, CCyBs have been generally revised upwards in the euro area in the aftermath of the Covid-19 pandemic. Starting from the second quarter of 2022, all of the 20 national decisions on the CCyB rate taken in the euro area were an increase in the CCyB. With CCyB rates becoming effective one year after their announcement, the CCyB rate has now reached 1% in France and

[5]Out of the 101 reciprocity agreements, 37 have been activated after 2022 (15 in 2022, 20 in 2023, and 2 in 2024).

2% in the Netherlands and will reach 1% in Belgium in October 2024. National macroprudential authorities justified these decisions by high private sector debt levels, increased bank profitability in the context of interest rates hikes, and high economic uncertainty requiring the build up of bank reserves as insurance against possible future materializations of adverse risks.[6]

4 The model

Even though the reciprocity framework of the ESRB applies to all European Union countries, we focus in our theoretical exercise on the euro area. In doing so, we evaluate the optimality of reciprocity in a high inflation environment when monetary policy is common to all affected countries, while macroprudential policy is set nationally.[7] The model features two euro area countries: a core economy (country A, "domestic") and a periphery economy (country B, "foreign")[8]. Each country includes patient households (savers) and impatient ones (borrowers), domestic banks and branches of foreign banks, firms, and a national macroprudential authority. Monetary policy is set union-wide by a common monetary policy authority.

4.1 Households

4.1.1 Domestic patient households

Domestic patient households value consumption C'_t and housing services provided by real-estate assets h'_t and choose working hours l'_t. They make one-period deposits D_t in a domestic bank that pay off a risk-free gross nominal interest rate $R_{A,t}$ in the next period and invest in foreign bonds Z_t that pay a gross nominal rate of R_t. Patient households own the bank and thus earn the bank's profit net from initial capital provided to new banks; they also earn firms' profit. The sum of the profits earned by the households writes Π_t. The optimization problem of the representative

[6] See the ESRB reporting of EU CCyB decisions and rationales.

[7] Note that 48 out of the 101 reciprocity agreements collected from the ESRB dataset were reached among euro area countries.

[8] All variables in the periphery "foreign" economy are denoted with an asterisk. The core economy is interchangeably referred to as the domestic economy or country A throughout the paper, whereas the periphery economy is referred to as the foreign economy or country B.

domestic patient household writes as follows:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t (\ln C_t' + j \ln h_t' - \frac{1}{\eta} l_t'^{\eta})$$

s.t.

$$P_{A,t}C_{A,t}' + P_{B,t}C_{B,t}' + D_t + Z_t + Q_t(h_t' - h_{t-1}') + \frac{\psi}{2}\frac{Z_t^2}{P_{A,t}} = R_{A,t-1}D_{t-1} + R_{t-1}Z_{t-1} + W_t' l_t' + \Pi_t.$$

Consumption is a bundle of goods produced in both countries and defined as: $C_t' = C_{A,t}'^{n} C_{B,t}'^{(1-n)}$ with n denoting the relative size of country A. The prices of goods produced in country A and B are given by $P_{A,t}$ and $P_{B,t}$, respectively, and $\frac{\psi}{2}\frac{Z_t^2}{P_{A,t}}$ is a small quadratic cost of deviating from zero foreign borrowing.[9]

We divide the budget constraint by $P_{A,t}$ to rewrite it in terms of units of the domestic good:

$$C_{A,t}' + \frac{P_{B,t}}{P_{A,t}}C_{B,t}' + d_t + z_t + q_t(h_t' - h_{t-1}') + \frac{\psi}{2}z_t^2 = R_{A,t-1}\frac{d_{t-1}}{\pi_{A,t}} + R_{t-1}\frac{z_{t-1}}{\pi_{A,t}} + w_t' l_t' + \frac{\Pi_t}{P_{A,t}},$$

with $d_t = \frac{D_t}{P_{A,t}}$, $z_t = \frac{Z_t}{P_{A,t}}$, $q_t = \frac{Q_t}{P_{A,t}}$, $w_t' = \frac{W_t'}{P_{A,t}}$, and $\pi_{A,t} = \frac{P_{A,t}}{P_{A,t-1}}$ referring to goods price inflation in country A.[10]

We obtain the following first-order conditions:

$$\frac{C_{A,t}'}{C_{B,t}'} = \frac{nP_{B,t}}{(1-n)P_{A,t}}. \tag{1}$$

$$\frac{nq_t}{C_{A,t}'} = \frac{j}{h_t'} + \beta E_t[\frac{nq_{t+1}}{C_{A,t+1}'}]. \tag{2}$$

$$nw_t' = C_{A,t}' l_t'^{(\eta-1)}. \tag{3}$$

[9] We make this assumption to ensure the stationarity of foreign assets as in Schmitt-Grohé and Uribe (2003).

[10] Note that $\pi_{A,t}$ does not refer to the evolution of prices faced by consumers in country A, as they consume goods produced both in country A and country B, but to the evolution of the price of goods produced in country A and consumed in both country A and B. Therefore, our inflation measure refers to producer price inflation in country A rather than to consumer price inflation in country A.

$$R_{A,t} = \frac{R_t}{(1+\psi z_t)}. \quad (4)$$

The decision problem of foreign households is symmetric. To have comparable units in the two countries, we divide the budget constraint of foreign households by the price of the final good produced in country A $P^*_{A,t}$. We assume that the law of one price holds in a monetary union and therefore $P_{A,t} = P^*_{A,t}$ and $P_{B,t} = P^*_{B,t}$.

4.1.2 Domestic impatient households

We follow Iacoviello (2005) and assume that impatient households value present consumption by more than patient households, such that $\gamma < \beta$. Domestic impatient households value consumption $C_t = C^n_{A,t} C^{(1-n)}_{B,t}$ and housing services provided by real-estate assets h_t and choose working hours l_t. They can also borrow from both domestic banks (b^H_t) or from branches of foreign banks ($b^{F,D}_t$) to finance instantaneous consumption expenses. The representative impatient household faces the following optimization problem:

$$\max E_0 \sum_{t=0}^{\infty} \gamma^t (\ln C_t + j \ln h_t - \frac{1}{\eta} l^\eta_t)$$

s.t.

$$C_{A,t} + \frac{P_{B,t}}{P_{A,t}} C_{B,t} + q_t(h_t - h_{t-1}) + \tilde{R}^H_{t-1} \frac{b^H_{t-1}}{\pi_{A,t}} + \tilde{R}^F_{t-1} \frac{b^{F,D}_{t-1}}{\pi_{A,t}} = b^H_t + b^{F,D}_t + w_t l_t.$$

In doing so, domestic impatient households face different borrowing constraints on their domestic and foreign debt (Iacoviello and Minetti, 2006) as foreign banks are assumed to face larger information asymmetries when assessing the solvency of domestic borrowers, and thus higher costs to recover assets in case of loan default abroad. When seizing assets, the domestic lender pays a proportional cost whereas the foreign lender pays a convex cost, i.e. their monitoring technology is described by decreasing returns to scale. The borrowing constraints (divided by $P_{A,t+1}$) are thus as follows:[11]

$$E_t[\tilde{R}^H_t \frac{b^H_t}{\pi_{A,t+1}}] \leq E_t[m \alpha_t q_{t+1} h_t] \quad (5)$$

[11] We assume that the borrowing constraints are binding at all times and verify that this holds true in our simulations.

$$E_t[\tilde{R}_t^F \frac{b_t^{F,D}}{\pi_{A,t+1}}] \leq E_t[q_{t+1}(1-\alpha_t)h_t(1-\frac{1-z_h}{qh}(q_{t+1}(1-\alpha_t)h_t))] \tag{6}$$

α_t represents the share of collateral which is devoted to domestic borrowing. The impatient household's optimization problem yields the following first-order conditions:

$$\frac{C_{A,t}}{C_{B,t}} = \frac{nP_{B,t}}{(1-n)P_{A,t}} \tag{7}$$

$$\frac{n}{C_{A,t}}q_t = \frac{j}{h_t} + \gamma E_t[\frac{n}{C_{A,t+1}}q_{t+1}] + \mu_t E_t[m\alpha_t q_{t+1}] + \mu_t^F(E_t[q_{t+1}(1-\alpha_t) - 2h_t\frac{1-z}{qh}q_{t+1}^2(1-\alpha_t)^2]) \tag{8}$$

$$nw_t = C_{A,t}l_t^{(\eta-1)} \tag{9}$$

$$\frac{n}{C_{A,t}} = \gamma E_t[\frac{n}{C_{A,t+1}}\frac{\tilde{R}_t^H}{\pi_{A,t+1}}] + \mu_t E_t[\frac{\tilde{R}_t^H}{\pi_{A,t+1}}] \tag{10}$$

$$\frac{n}{C_{A,t}} = \gamma E_t[\frac{n}{C_{A,t+1}}\frac{\tilde{R}_t^F}{\pi_{A,t+1}}] + \mu_t^F E_t[\frac{\tilde{R}_t^F}{\pi_{A,t+1}}] \tag{11}$$

$$\mu_t m_h = \mu_t^F E_t[(1-2\frac{1-z_h}{qh}q_{t+1}(1-\alpha_t)h_t)]. \tag{12}$$

The problem is symmetric for foreign impatient households, but the we assume that the calibrated value of the loan-to-value ratio set by the foreign regulator on their own domestic lending, m_f, is different from m.

4.2 Firms

4.2.1 Domestic final goods producers

The final goods market is perfectly competitive. A continuum of final-goods firms aggregate intermediate goods according to the following production function: $Y_{A,t} = \int_0^1 (Y_{A,t(z)}^{\frac{\epsilon-1}{\epsilon}} dz)^{\frac{\epsilon}{\epsilon-1}}$, implying the price index $P_{A,t} = (\int_0^1 P_{A,t(z)}^{1-\epsilon} dz)^{\frac{1}{1-\epsilon}}$. The market for intermediate goods is monopolistically competitive. The demand for each intermediate good then writes: $Y_{A,t(z)} = (\frac{P_{A,t(z)}}{P_{A,t}})^{-\epsilon} Y_{A,t}$. The problem of foreign final-goods producers is symmetric.

4.2.2 Domestic intermediate goods producers

Intermediate goods are produced by a continuum of monopolistically competitive firms using labor from both patient households (l_t') and impatient households (l_t) as inputs, and following a Cobb-Douglas production technology for each good z:

$$Y_{A,t}(z) = Al_t(z)^{1-\nu} l_t(z)'^{\nu},$$

where A represents total factor productivity.

Firms minimize their production costs subject to the technology constraint, which yields the first-order conditions for labor demand:

$$w_t = \frac{A(1-\nu) l_t(z)^{-\nu} l_t(z)'^{\nu}}{X_{A,t}}.$$

$$w_t' = \frac{\nu A l_t(z)^{1-\nu} l_t(z)'^{(\nu-1)}}{X_{A,t}},$$

where $X_{A,t}$ is the mark-up (the inverse of the real marginal cost).

In setting their price, intermediate goods producers face standard Calvo-price nominal rigidities (see Appendix A). We introduce a cost-push shock $A_{p,t}$ to the inverse of the mark-up $X_{A,t}^1$ (or the real marginal cost). which follows an AR(1) process in logs and enters the Calvo framework in a non-linear way as in Harding et al. (2023). The shock enters the first-order condition of the price-setting problem of the firm as a multiplicative shifter of real marginal costs (see equation A2 in the intermediate good firm problem presented in Appendix A). The shock is common to both countries, so that it can be interpreted as a global inflationary cost-push shock.

By defining the relative reset price as $\pi_{A,t}^S = \frac{P_{A,t}^S}{P_{A,t}}$ with $P_{A,t}^S$ being the optimal reset price for firms able to change prices in period t, we obtain:

$$\pi^S_{A,t} = \frac{\epsilon}{\epsilon - 1}\frac{z_{1,t}}{z_{2,t}},$$

with

$$z_{1,t} = X^{-1}_{A,t}A_{p,t}Y_{A,t} + \theta E_t[\Lambda_{t,t+1}\pi^{\epsilon}_{A,t+1}z_{1,t+1}]$$

$$z_{2,t} = Y_{A,t} + \theta E_t[\Lambda_{t,t+1}\pi^{\epsilon-1}_{A,t+1}z_{2,t+1}].$$

4.3 Banks

4.3.1 Domestic banks

In the following, weshow the optimization program of a representative domestic bank, noting that the problem is symmetric for foreign banks. The bank b's balance sheet is given by:

$$b^H_{t,b} + b^{F,S*}_{t,b} = n_{t,b} + d_{t,b}$$

where $n_{t,b}$ is bank net worth (or retained earnings) divided by the price of the final good produced in country A ($n_{t,b} = \frac{N_{t,b}}{P_{A,t}}$), and $b^H_{t,b}$, $b^{F,S*}_{t,b}$, and $d_{t,b}$ are loans provided to domestic and foreign impatient households and deposits obtained from domestic households, respectively, all expressed in current units of the final good produced in A as well.

Following Gertler and Karadi (2011), each banker faces an exit probability of $1-\zeta$ in each period. When the banker exits, its accumulated net worth is distributed to the household that owns the bank as dividends. The banks that exit are replaced in each period by an equal number of new banks that start with a net worth of $(B^H + B^{F,S*})\omega$ provided by the household. The steady-state value of the domestic banking sector's assets expressed in units of the domestic final good is thus given by $b^H + b^{F,S*}$.

Following Millard et al. (2024), we assume that banks face a maximum leverage ratio *Lev* that they regard as an absolute maximum. They incur costs to avoid reaching this maximum that are larger as they get closer to the maximum leverage limit. The aggregate cost function is as follows:

$$(\frac{\phi_b}{Lev - \varphi_t} - \frac{\phi_b}{Lev - \varphi})N_t,$$

with ϕ_b the cost parameter, $\varphi_t = \frac{b_t^H + b_t^{F,S*}}{n_t}$ the leverage ratio and φ the steady-state leverage. Aggregating across individual banks, the law of motion determining the evolution of total banking sector net worth (in units of the domestic good) is given by:

$$n_t = \zeta(\tilde{R}_{t-1}^H \frac{b_{t-1}^H}{\pi_{A,t}} + \tilde{R}_{t-1}^{F*} \frac{b_{t-1}^{F,S*}}{\pi_{A,t}} - R_{A,t-1}\frac{d_{t-1}}{\pi_{A,t}} - (\frac{\phi_b}{Lev - \varphi_{t-1}} - \frac{\phi_b}{Lev - \varphi})\frac{n_{t-1}}{\pi_{A,t}}) + (1-\zeta)(b^H + b^{F,S*})\omega.$$

The representative bank aims at maximizing the expected present discount value of dividend flows to the household. It maximizes the expected present value of net worth upon closure:

$$V_{b,t} = \max E_t[\sum_{j=1}^{\infty} \Lambda_{t,t+j}\zeta^{j-1}(1-\zeta)N_{b,t+j}].$$

Following Gertler and Karadi (2011), we introduce the following agency problem: banks have the ability to divert a fraction of their assets for the personal use of their owners. They can divert up to a fraction θ_b of their loans in period t but they will be forced into bankruptcy at the beginning of period $t+1$. To make this decision, banks will compare the franchise value of the bank (discounted future value of continuing operations) $V_{b,t}$ with the gain of diverting funds $\theta_b(b_{t,b}^H + b_{t,b}^{F,S*})$.
Being aware of this, rational depositors will then require that the following incentive constraint (in real terms) is satisfied:

$$\theta_b(b_{b,t}^H + b_{b,t}^{F,S*}) \leq \frac{V_{b,t}}{P_{A,t}}.$$

Each period, the bank chooses b_b^H, $b_b^{F,S*}$ and d_b to maximize its franchise value, subject to the incentive compatibility constraint, the balance-sheet constraint and the law of motion of its net worth. The bank problem is detailed in Appendix B.
If the incentive compatibility constraint of the bank is not binding, the first-order condition of the

bank with respect to domestic and foreign leverage are:

$$\tilde{R}_t^H = R_{A,t} + \frac{\phi_b}{(Lev - \varphi_t)^2}, \tag{13}$$

and

$$\tilde{R}_t^{F,*} = R_{A,t} + \frac{\phi_b}{(Lev - \varphi_t)^2}. \tag{14}$$

In the model simulations, we assume and verify that the incentive-compatibility constraint is not binding for our set of parameter values.

4.4 Monetary policy

Following Quint and Rabanal (2014), the central bank of the monetary union follows a Taylor-type reaction function:

$$R_t = [\bar{R}(\frac{\pi_{A,t}^n \pi_{B,t}^{1-n}}{\bar{\pi}_A^n \bar{\pi}_B^{1-n}})^{\phi_\pi}(\frac{y_{A,t}^n y_{B,t}^{1-n}}{y_{A,t-1}^n y_{B,t-1}^{1-n}})^{\phi_y}]^{1-\rho_r} R_{t-1}^{\rho_r} \exp(e_{r,t}) \tag{15}$$

The central banks reacts to deviations in union-wide inflation and output governed by the relative size of both economies (n), with the policy parameters given by ϕ_π and ϕ_y, respectively. The rule accounts for interest rate smoothing and the monetary policy shock $\varepsilon_{R,t}$ is normally distributed with mean 0 and standard error σ_R.

4.5 Macroprudential Policy

4.5.1 Countercyclical macroprudential rules

We now introduce two countercyclical macroprudential instruments in the domestic country: a countercyclical loan-to-value ratio and a countercyclical capital buffer. They respond to deviations of the credit-to-GDP ratio from its long-run value, i.e., to the credit-to-GDP gap defined by the Basel Committee (Basel Committee on Banking Supervision, 2010).

The countercyclical rule on the loan-to-value ratio applied to domestic borrowing from *domestic* banks writes:

$$m_t = m_h - \xi_{m_h}\left(\frac{b_t^H + b_t^{F,D}}{Y_{A,t} + Y_{A,t-1} + Y_{A,t-2} + Y_{A,t-3}} - \frac{b^H + b^{F,D}}{4Y_A}\right), \tag{16}$$

with the term in parentheses representing the distance between the current credit-to-annual GDP ratio and its steady-state value.

Equivalently, the countercyclical rule on the loan-to-value ratio relative to domestic borrowing from *foreign* banks is given by:

$$z_t = z_h - \xi_{z_h}\left(\frac{b_t^H + b_t^{F,D}}{Y_{A,t} + Y_{A,t-1} + Y_{A,t-2} + Y_{A,t-3}} - \frac{b^H + b^{F,D}}{4Y_A}\right). \tag{17}$$

The countercyclical capital buffer (CCyB) rule writes as follows for domestic banks:

$$\begin{aligned} \frac{1}{Lev_t} = \frac{1}{Lev_h} &+ \xi_{lev_h}\frac{b_t^H}{b_t^H + b_t^{F,S*}}\left(\frac{b_t^H + b_t^{F,D}}{Y_{A,t} + Y_{A,t-1} + Y_{A,t-2} + Y_{A,t-3}} - \frac{b^H + b^{F,D}}{4Y_A}\right) + \\ &\xi_{lev_f}\frac{b_t^{F,S*}}{b_t^H + b_t^{F,S*}}\left(\frac{b_t^{H^*} + b_t^{F,D^*}}{Y_{B,t} + Y_{B,t-1} + Y_{B,t-2} + Y_{B,t-3}} - \frac{b_t^{H^*} + b_t^{F,D^*}}{4Y_B}\right), \end{aligned} \tag{18}$$

where $\frac{1}{Lev_t}$ is the inverse of the maximum leverage ratio Lev_t, i.e., the minimum capital-asset ratio imposed by the regulator. $\frac{1}{Lev_h}$ represents the steady-state value of the capital-asset ratio, ξ_{lev_h} measures the degree of reaction of the domestic capital-asset ratio to the domestic credit-to-annual GDP gap weighted by the share of domestic exposures in domestic banks' total exposures $\frac{b_t^H}{b_t^H+b_t^{F,S*}}$-, and ξ_{lev_f} measures the degree of reaction of the domestic capital-asset ratio to the foreign credit-to-GDP gap over a year weighted by the share of foreign exposures in domestic banks' total exposures $\frac{b_t^H}{b_t^H+b_t^{F,S*}}$.

This countercyclical capital buffer rule is in line with the mandatory reciprocity rule for CCyBs in the European Union as explained in Section 3. The global CCyB rate for the domestic bank is the weighted average of the CCyB rates in each of the countries the bank has exposures in, where the weights are given by the bank's exposures in each country.[12] Similarly, the CCyB rule for foreign

[12] Note that in our experiments, we focus on the implementation of the CCyB rule in the core "domestic" economy. Therefore, ξ_{lev_f} is set to zero in both domestic and foreign rules.

banks is given by:

$$\frac{1}{Lev_t^*} = \frac{1}{Lev_f} + \xi_{lev_h} \frac{b_t^{F,S}}{b_t^{H*} + b_t^{F,S}} \left(\frac{b_t^H + b_t^{F,D}}{Y_{A,t} + Y_{A,t-1} + Y_{A,t-2} + Y_{A,t-3}} - \frac{b^H + b^{F,D}}{4Y_A} \right) + \xi_{lev_f} \frac{b_t^{H*}}{b_t^{H^*} + b_t^{F,S}} \left(\frac{b_t^{H^*} + b_t^{F,D^*}}{Y_{B,t} + Y_{B,t-1} + Y_{B,t-2} + Y_{B,t-3}} - \frac{b_t^{H^*} + b_t^{F,D^*}}{4Y_B} \right). \quad (19)$$

Aggregation is detailed in Appendix C, while a summary of all the model equations is provided in Appendix D.

5 Model dynamics

In this section, we show dynamic model responses to a suite of shocks for illustrative purposes. In particular, we assess how common inflation shocks and monetary policy shocks propagate in the model.

5.1 Calibration

We calibrate the two-country model to account for core and periphery countries in the euro area. We assume the core to be approximated by the German economy (country A) and the periphery by the Spanish economy (country B), and calibrate the model accordingly. We set the parameters for the relative size (n) and for the domestic loan-to-value ratios in country A (m_h) and B (m_f) to the values estimated in Bosca et al. (2022) accordingly. As LTV ratios on foreign lending (z_h and z_f) can hardly be estimated from the data, we set both to 0.7. We therefore assume that foreign LTV ratios are slightly lower than domestic LTV ratios in both countries to account for the fact that domestic lenders have better liquidation technologies than foreign ones (Iacoviello and Minetti, 2006; Rubio, 2020). Parameters governing the banking sector, including that of the leverage penalty cost function, are set following Millard et al. (2024). Other parameters are calibrated in line with standard calibrations in the literature on 'Two-Agent New-Keynesian (TANK)' models, see e.g. Iacoviello (2005). The standard deviation of the cost-push shock is based on Smets and Wouters (2007) and the related literature. Table 2 provides a summary of the calibrated parameter values.

Table 2: Parameter values

Parameter	Description	Value
β	Patient household discount factor	0.99
γ	Impatient household discount factor	0.98
ν	Labor income share of patient households	0.64
j	Weight on housing in the utility function	0.1
m_h	Domestic LTV in country A	0.76
m_f	Domestic LTV in country B	0.8
z_h & z_f	Foreign LTV	0.7
η	Labour supply parameter	1.01
θ	Calvo probability of fixed price	0.75
ϕ_b	Parameter of the leverage penalty cost function	0.0526
θ_b	Proportion of assets that can be diverted	0.1
ζ	Bank survival rate	0.975
ω	Capital of newly-formed banks as a fraction of bank assets	0.05
ϵ	Elasticity of demand for differentiated intermediate goods	6
σ_e	Standard error of the cost-push shock	0.0014
ϕ_π	Coefficient on inflation in Taylor rule	0.5
ϕ_y	Coefficient on output in Taylor rule	0
ρ_r	Interest rate smoothing in Taylor rule	0.80
n	Size of country A	0.65
ρ_p	Persistence parameter of the cost-push shock	0.90

5.2 Impulse responses

In this subsection, we present model impulse responses for monetary policy shocks and cost-push shocks, the two key shocks in our analysis. While a monetary policy shock broadly proxies model responses to demand-side disturbances, the cost-push shock depicts an example of an aggregate supply-side shock pushing output and inflation in different directions. Note that we model union-wide shocks, i.e., both economies are exposed to the exact same shock at the same time, and we first look at the model dynamics without countercyclical macroprudential policy.

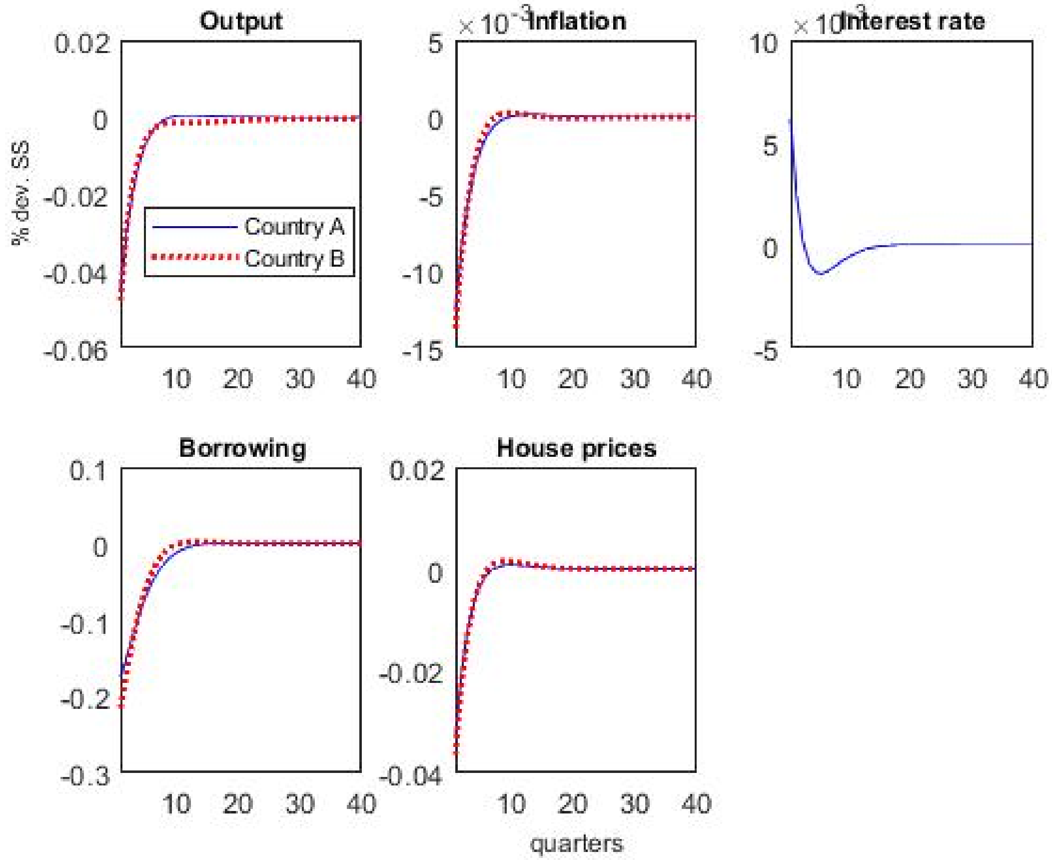

Figure 1: Impulse response functions to a monetary policy shock

Figure 1 shows model impulse responses to a 100bp tightening monetary policy shock.[13] In response to the shock, inflation, the output gap and total borrowing – including domestic and foreign borrowing – in each country decline, as commonly found in the literature. The effect of the monetary policy shock is amplified by falling house prices, triggering a tightening of borrowing constraints (equations (5) and (6)) as the value of collateral declines.[14]

[13]Note that inflation in country A (resp. in country B) represents the growth rate of prices of goods produced in country A (resp. in country B) and not inflation based on consumer prices in country A (resp. in country B).

[14]The drop in inflation is usually found to be more pronounced in a model with collateral constraints than in a model without this mechanism. See e.g. Rubio and Yao (2024).

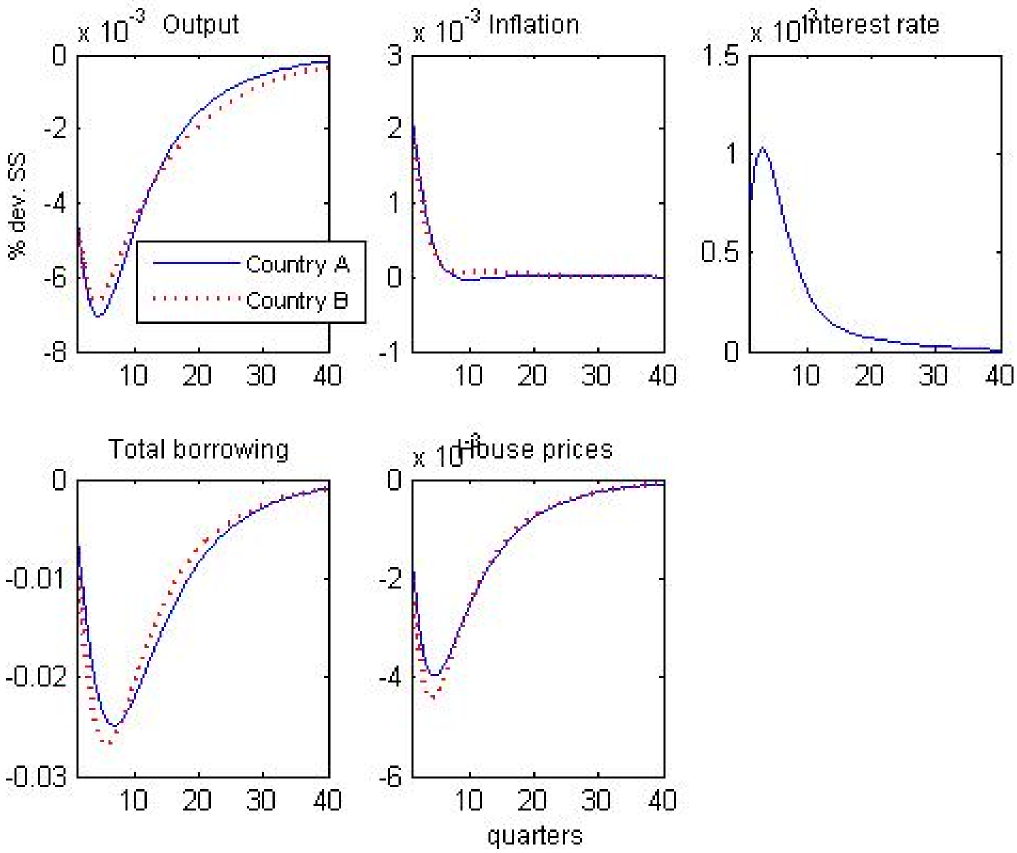

Figure 2: Impulse response functions to a cost-push shock

This is not the case, however, for the union-wide cost-push shock (Figure 2).[15] As commonly found, inflation rises while output declines in both countries in response to the cost-push shock. In line with falling activity and higher nominal interest rates, borrowing falls in both countries – and more so in the foreign economy in which the domestic LTV is higher – as borrowing constraints tighten, in turn aggravating the economic downturn. The collateral channel is amplifying the effects of the shock, as house prices fall in both countries. The decline in aggregate demand exerts a negative effect on inflation, which partially offsets the positive impact of the cost-push shock.

[15]The IRFs present the response to a one standard deviation*10 union-wide cost-push shock.

6 Reciprocity and welfare

6.1 Experiment

In this subsection, we evaluate the degree of reciprocity in the countercyclical loan-to-value ratio set by the domestic country (country A) that maximizes unconditional welfare in country A in the presence of global cost-push shocks. We optimize over the loan-to-value countercyclical rule parameter on foreign lending in country A (parameter ξ_{z_h} governing borrowing from foreign banks' branches in country A in equation (17)) for given national LTV and CCyB policies (i.e., given values for parameter ξ_{m_h} and ξ_{lev_h} in equations (16) and (18)). We consider that the domestic LTV policy is reciprocated when $\xi^*_{z_h}$ is greater than zero.

6.2 Welfare measure

Welfare in country A is defined as the sum of the welfare of patient households (savers) and impatient households (borrowers), weighted by their respective discount factors, as follows:[16]

$$W_t = (1-\beta)U'_t + (1-\gamma)U_t,$$

where U'_t is the individual welfare of patient households defined as:

$$U'_t = \max E_0 \sum_{t=0}^{\infty} \beta^t (\ln C'_t + j \ln h'_t - \frac{1}{\eta} l'^{\eta}_t)$$

and U_t is the individual welfare of impatient households defined as:

$$U_t = \max E_0 \sum_{t=0}^{\infty} \gamma^t (\ln C_t + j \ln h_t - \frac{1}{\eta} l^{\eta}_t).$$

This weighting of welfare implies that patient and impatient households get the same utility from a constant consumption flow. We evaluate welfare by using the solution to the second-order approximation of the structural equations of the model, relying on the recursive representation of the

[16] See e.g., Gebauer (2021), Rubio (2020).

individual welfare functions.[17]

6.3 Results

Table 3: Optimized foreign LTV reciprocity under different monetary and macroprudential policy regimes - Cost-push shock

	Foreign LTV rule ($\xi^*_{z_h}$)			
Taylor rule parameter (ϕ_π)	$\phi_\pi = 0.1$	$\phi_\pi = 0.5$	$\phi_\pi = 1$	$\phi_\pi = 1.5$
No CCyB ($\xi_{lev_h} = 0$)				
Low domestic LTV rule ($\xi_{m_h} = 1$)	0.82	1.28	1.37	1.38
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	2.05	3.01	3.29	3.35
High domestic LTV rule ($\xi_{m_h} = 10$)	3.64	5.26	5.75	5.87
Low CCyB ($\xi_{lev_h} = 0.5$)				
Low domestic LTV rule ($\xi_{m_h} = 1$)	0.24	0.60	0.65	0.64
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	1.57	2.44	2.67	2.70
High domestic LTV rule ($\xi_{m_h} = 10$)	3.19	4.72	5.16	5.25
Intermediate CCyB ($\xi_{lev_h} = 1$)				
Low domestic LTV rule ($\xi_{m_h} = 1$)	0	0	0	0
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	1.11	1.90	2.09	2.10
High domestic LTV rule ($\xi_{m_h} = 10$)	2.75	4.20	4.59	4.66
Additional intermediate CCyB ($\xi_{lev_h} = 5$)				
Low domestic LTV rule ($\xi_{m_h} = 1$)	0	0	0	0
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	0	0	0	0
High domestic LTV rule ($\xi_{m_h} = 10$)	0	0	0.32	0.26
High CCyB ($\xi_{lev_h} = 10$)				
Low domestic LTV rule ($\xi_{m_h} = 1$)	0	0	0	0
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	0	0	0	0
High domestic LTV rule ($\xi_{m_h} = 10$)	0	0	0	0

Table 3 shows optimal levels for the LTV reciprocity parameter $\xi^*_{z_h}$ (columns) for different levels of the parameter governing domestic LTV ratios ξ_{m_h} (rows). In addition, we distinguish results depending on the levels of CCyB (four separate blocks of rows) and monetary policy responsiveness in Taylor rule (equation (15)) (lower responsiveness in columns 2 and 3 vs. higher responsiveness in columns 4 and 5).

We consider the optimal degree of reciprocity under these variations in other policies for inflationary cost-push shocks. As commonly found, cost-push shocks imply trade-offs for steering

[17] We obtain the parameter of the foreign loan-to-value ratio rule in country A that maximizes unconditional welfare in country A, $\xi^*_{z_h}$, by realizing a grid search over the [0;15] interval, relying on the Matlab cmaes optimizer.

monetary policy if the weight on the output gap in reaction function (15) is non-zero, as monetary policy fails to perfectly stabilize output and inflation at the same time.[18] In such a situation, macroprudential policy could in principle be tailored to stabilize economic activity.[19]

Given that there is mandatory reciprocity in the CCyB, we consider several cases of aggressiveness in the CCyB rule in the domestic economy: an extreme case in which there is no CCyB ($\xi_{lev_h} = 0$), a case with a low responsiveness in the CCyB to credit dynamics ($\xi_{lev_h} = 0.5$), a case of intermediate responsiveness ($\xi_{lev_h} = 1$) and cases of high responsiveness ($\xi_{lev_h} = 5$ and $\xi_{lev_h} = 10$).[20] We then fix the parameter for the domestic LTV (ξ_{m_h}) also to different levels ($\xi_{m_h} = \{1, 5, 10\}$). Within this set of scenarios, we aim at finding the level of the foreign LTV rule coefficient that maximizes welfare in country A, i.e., to asses the extent to which reciprocating is optimal. If we find a welfare-maximizing level of the foreign LTV parameter which is different from zero, we conclude that it is optimal to reciprocate.

We find that reciprocation is only optimal for the domestic economy across all levels of domestic LTV ratios and weight on inflation in the monetary policy reaction function when the CCyB is deactivated or its responsiveness to credit is low ($\xi_{lev_h} = 0$ or $\xi_{lev_h} = 0.5$). For intermediate cases of CCyB responsiveness ($\xi_{lev_h} = 1$), it is optimal for the domestic country that the domestic LTV ratio is reciprocated only for the cases in which the domestic LTV rule is relatively active, that is, when the initial gap in policies applied to domestic and foreign branches is large. For higher intermediate CCyB responsiveness ($\xi_{lev_h} = 5$), reciprocity in the domestic LTV is optimal only for high responsiveness of the LTV rule and high responsiveness of monetary policy to inflation (i.e., $\phi_p i$ higher than 1). With high CCyB levels ($\xi_{lev_h} = 10$) applied in country A, reciprocity is not optimal for that country for all levels of domestic LTV ratios. As CCyBs are already acting reciprocally, the value added from aligning LTV policies is relatively low.

We furthermore find that for a given level of CCyBs, a more active domestic LTV policy (higher

[18]Optimal policy usually prescribes a "seeing-trough" strategy in the presence of cost-push shocks. However, a tighter policy stance in response to cost-push shocks can still contribute to keeping inflation expectations aligned with the central banks inflation target, and thus have an intermediate effect on inflation dynamics.

[19]This may require that focusing on real activity is optimal for the regulating authority. By deriving an optimal policy rule for CCyB, Gebauer (2021) finds that optimal capital requirements should be set taking real economic activity into account. See also Angelini et al. (2014) for a discussion of optimal coordination of monetary and macroprudential policies.

[20]The choice of the parameter values is illustrative.

values of ξ_{m_h}) implies that the coefficient on the foreign LTV turns out higher as well in all scenarios. This implies that reciprocity agreements are particularly welfare-enhancing if the domestic country is relying actively on LTV domestic ratios to regulate credit demand. By closing the gap in LTV policies applied to domestic and foreign branches, reciprocity agreements mitigate adverse effects from regulatory arbitrage, and are thus most effective if LTV regulation is used actively in the domestic economy. Inversely, if the domestic country does not actively rely on LTV ratios to set the domestic macroprudential stance, this gap turns out smaller such that the benefits from reciprocating are lower, ceteris paribus.

The coefficient that applies to foreign branches, that is the aggressiveness in reciprocation, is also changing with the aggressiveness of the Taylor rule towards inflation. When monetary policy fights inflation in a sensible range, there is an increasing need for reciprocity in the LTV. Considering that there is a common monetary policy for the union, a more aggressive policy is aligning countries in such way that macroprudential policies also need to be aligned. Table 5 in Appendix E shows that in general, reciprocity is not compromising or improving macroeconomic stability, but mainly affects financial stability. Closing policy gaps reduces the volatility of credit, and this is why it is optimal to do so. Increasing the aggressiveness of the CCyB rule also implies a benefit in terms of financial stability and this is why reciprocity in the LTV is not needed anymore for the purpose of reducing credit variance.

Table 4 reports welfare gains – expressed in consumption equivalents – of moving from the non-reciprocity case to the optimized case, i.e., the case in which the parameter of the rule on the domestic LTV ratio for foreign lending $\xi^*_{z_h}$ is set to the value that maximizes welfare.[21] We report total welfare gains as well as the disaggregated welfare gains of borrowers and savers separately. As already shown in Table 3, total welfare gains from reciprocity increase in the domestic LTV rule parameter, due to a narrowing of the policy gap. Inversely, they fall in the level of the CCyB. Borrowers benefit most from reciprocity in case domestic LTV ratios are high, while the opposite holds true for savers when there is no CCyB rule. When the CCyB rule becomes more aggressive, because there is already some reciprocity in place, welfare gains fade out, especially for savers.

[21]Consumption equivalents are expressed in percents. They are reported in absolute value and defined as follows: $| 1 - \exp(\text{weight} * (\text{Welfare reciprocity-Welfare benchmark}) |)$.

Table 4: Welfare gains from reciprocating (in consumption equivalents in %) for a given monetary policy ($\phi_\pi = 0.5$)

Consumption equivalents (%)	Total	Borrowers	Savers
No CCyB ($\xi_{lev_h} = 0$)			
Low domestic LTV rule ($\xi_{m_h} = 1$)	0.0004	0.0002	0.0002
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	0.0004	0.0003	0.0001
High domestic LTV rule ($\xi_{m_h} = 10$)	0.0004	0.0003	0.0001
Low CCyB ($\xi_{lev_h} = 0.5$)			
Low domestic LTV rule ($\xi_{m_h} = 1$)	0.0001	0.0001	0.0000
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	0.0003	0.0002	0.0001
High domestic LTV rule ($\xi_{m_h} = 10$)	0.0004	0.0003	0.0001
Intermediate CCyB ($\xi_{lev_h} = 1$)			
Low domestic LTV rule ($\xi_{m_h} = 1$)	-	-	-
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	0.0002	0.0001	0.0000
High domestic LTV rule ($\xi_{m_h} = 10$)	0.0003	0.0002	0.0001

7 Conclusion

In this paper, we provide an analytical framework to study the macroeconomic and financial stability consequences of coordination in different macroprudential instruments in the euro area.Relying on a two-country core-periphery DSGE model for the euro area in which impatient households can borrow from both domestic and foreign banks with different collateralized borrowing constraints, we show that reciprocating borrower-based macroprudential countercyclical measures under mandatory reciprocity in capital-based macroprudential measures can be welfare-improving in the activating country for low and intermediate values of the CCyB rule parameter. Indeed, reciprocity reduces cross-border leakages from macroprudential policy and diminishes credit volatility, and thus the cost of financial frictions associated with the collateralized borrowing constraints. In addition, the optimal degree of reciprocity increases with the monetary policy response to inflation. Reciprocation in macroprudential policy in the euro area can thus improve the coordination between the common monetary policy and national macroprudential policies.

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Appendix

A The intermediate good firm price-setting problem

Following Calvo (1983), in each period, the firm can reset its price $P_{A,t(z)}$ with probability $1-\theta$. Therefore, the problem of the firm in period t is to choose the price $P_{A,t(z)}$ that maximizes its expected inter-temporal profit (in terms of current units of good A), considering the probability θ^k that the price $P_{A,t(z)}$ is still in place in $t+k$:

$$\max_{P_{A,t(z)}} E_t[\sum_{k=0}^{\infty}\theta^k\Lambda_{t,t+k}(\frac{P_{A,t(z)}}{P_{A,t+k}}Y_{A,t+k}(z)-X^{-1}_{A,t+k}Y_{A,t+k}(z))], \tag{A1}$$

with $\Lambda_{t,t+k}=\beta\frac{C'_{A,t}}{C'_{A,t+k}}$ being the stochastic discount factor and $X_{A,t}$ being the mark-up.
Plugging in the demand function yields:

$$\max_{P_{A,t(z)}} E_t[\sum_{k=0}^{\infty}\theta^k\Lambda_{t,t+k}(\frac{P_{A,t(z)}}{P_{A,t+k}})^{1-\epsilon}Y_{A,t+k}-X^{-1}_{A,t+k}(\frac{P_{A,t(z)}}{P_{A,t+k}})^{-\epsilon}Y_{A,t+k})].$$

Following Harding et al. (2023), we introduce the cost-push shock $A_{p,t}$ directly into the first-order condition of the problem. The F.O.C. is given by:

$$P^S_{A,t}=\frac{\epsilon}{\epsilon-1}\frac{E_t[\sum_{k=0}^{\infty}\theta^k\Lambda_{t,t+k}X^{-1}_{A,t+k}A_{p,t}P^{\epsilon}_{A,t+k}Y_{A,t+k}]}{E_t[\sum_{k=0}^{\infty}\theta^k\Lambda_{t,t+k}P^{\epsilon-1}_{A,t+k}Y_{A,t+k}]}=\frac{\epsilon}{\epsilon-1}\frac{Z_{1,t}}{Z_{2,t}}, \tag{A2}$$

with

$$Z_{1,t}=X^{-1}_{A,t}A_{p,t}P^{\epsilon}_{A,t}Y_{A,t}+\theta E_t[\Lambda_{t,t+1}Z_{1,t+1}]$$

$$Z_{2,t}=P^{\epsilon-1}_{A,t}Y_{A,t}+\theta E_t[\Lambda_{t,t+1}Z_{2,t+1}].$$

If we define $z_{1,t}=\frac{Z_{1,t}}{P^{\epsilon}_{A,t}}$ and $z_{2,t}=\frac{Z_{2,t}}{P^{\epsilon-1}_{A,t}}$, we get:

$$\pi^S_{A,t}=\frac{\epsilon}{\epsilon-1}\frac{z_{1,t}}{z_{2,t}},$$

with

$$z_{1,t} = X_{A,t}^{-1} A_{p,t} Y_{A,t} + \theta E_t[\Lambda_{t,t+1} \pi_{A,t+1}^{\epsilon} z_{1,t+1}]$$

$$z_{2,t} = Y_{A,t} + \theta E_t[\Lambda_{t,t+1} \pi_{A,t+1}^{\epsilon-1} z_{2,t+1}].$$

B The bank's problem

Aggregating up across all banks, the aggregate Bellman equation for the banking sector's franchise value writes:

$$V_t(N_t) = \max E_t[\Lambda_{t,t+1}((1-\zeta)N_{t+1} + \zeta V_{t+1}(N_{t+1}))]$$

We assume that the value function V_t is linear in net worth: $V_t = \psi_t N_t$. Dividing both sides by P_{A_t}, this yields:

$$\psi_t n_t = E_t[\Lambda_{t,t+1}((1-\zeta)n_{t+1}\pi_{A,t+1} + \zeta\psi_{t+1}n_{t+1}\pi_{A,t+1})] = E_t[\Lambda_{t,t+1}(1-\zeta+\zeta\psi_{t+1})n_{t+1}\pi_{A,t+1}] =$$
$$E_t[\Lambda_{t,t+1}(1-\zeta+\zeta\psi_{t+1})(\tilde{R}_t^H b_t^H + \tilde{R}_t^{F*} b_t^{F,S*} - R_{A,t}d_t - (\frac{\phi_b}{Lev-\varphi_t} - \frac{\phi_b}{Lev-\varphi})n_t)].$$

s.t.

$$\theta_b(b_t^H + b_t^{F,S*}) \leq \psi_t n_t$$

$$b_t^H + b_t^{F,S*} = d_t + n_t.$$

We substitute the second constraint in the Bellman equation and divide both sides by n_t:

$$\psi_t = E_t[\Lambda_{t,t+1}(1-\zeta+\zeta\psi_{t+1})((\tilde{R}_t^H - R_A)\frac{b_t^H}{n_t} + (\tilde{R}_t^{F*} - R_A)\frac{b_t^{F,S*}}{n_t} + R_{A,t} - (\frac{\phi_b}{Lev-\varphi_t} - \frac{\phi_b}{Lev-\varphi}))].$$

We define domestic leverage: $\varphi_t^H = \frac{b_t^H}{n_t}$ and foreign leverage: $\varphi_t^F = \frac{b_t^{F,S*}}{n_t}$, with $\varphi = \varphi_t^H + \varphi_t^F$. The program of the bank can be rewritten as:

$$\psi_t = E_t[\Lambda_{t,t+1}(1-\zeta+\zeta\psi_{t+1})((\tilde{R}_t^H - R_A)\varphi_t^H + (\tilde{R}_t^{F*} - R_A)\varphi_t^F + R_{A,t} - (\frac{\phi_b}{Lev-\varphi_t} - \frac{\phi_b}{Lev-\varphi}))].$$

s.t.

$$\theta_b(\varphi_t^H + \varphi_t^F) \leq \psi_t.$$

We define λ_t the multiplier associated with the above incentive-compatibility constraint in period t. The complementary slackness condition is:

$$\lambda_t(\psi_t - \theta(\varphi_t^H + \varphi_t^F)) = 0$$

and the objective of the bank is:

$$\psi_t + \lambda_t(\psi_t - \theta(\varphi_t^H + \varphi_t^F)) = \psi_t(1+\lambda_t) - \lambda_t\theta_b(\varphi_t^H + \varphi_t^F).$$

We define domestic leverage: $\varphi_t^H = \frac{b_t^H}{n_t}$ and foreign leverage: $\varphi_t^F = \frac{b_t^{F,S*}}{n_t}$, with $\varphi = \varphi_t^H + \varphi_t^F$. The first-order conditions with respect to φ_t^H and $\varphi_t^{F,S*}$ write respectively:

$$E_t[\Lambda_{t,t+1}(1-\zeta+\zeta\psi_{t+1})(\tilde{R}_t^H - R_{A,t} - \frac{\phi_b}{(Lev-\varphi_t)^2})] = \theta_b\frac{\lambda_t}{1+\lambda_t}.$$

and

$$E_t[\Lambda_{t,t+1}(1-\zeta+\zeta\psi_{t+1})(\tilde{R}_t^H - R_{A,t} - \frac{\phi_b}{(Lev-\varphi_t)^2})] = \theta_b\frac{\lambda_t}{1+\lambda_t}.$$

The incentive-compatibility constraint is binding when $\lambda_t > 0$, i.e., when $E_t[\Lambda_{t,t+1}(1-\zeta+\zeta\psi_{t+1})(\tilde{R}_t^H - R_{A,t} - \frac{\phi_b}{(Lev-\varphi_t)^2})] > 0$, and in that case:

$$\theta\phi_t = \psi_t.$$

Otherwise, $\lambda_t = 0$ and the first-order condition of the bank is:

$$E_t[\Lambda_{t,t+1}(1-\zeta+\zeta\psi_{t+1})(\tilde{R}_t^H - R_{A,t} - \frac{\phi_b}{(Lev-\varphi_t)^2})] = 0 \Leftrightarrow \tilde{R}_t^H - R_{A,t} - \frac{\phi_b}{(Lev-\varphi_t)^2} = 0.$$

Similarly, the first-order condition with respect to $\varphi_t^{F,S*}$ writes:

$$E_t[\Lambda_{t,t+1}(1-\zeta+\zeta\psi_{t+1})(\tilde{R}_t^{F,*}-R_{A,t}-\frac{\phi_b}{(Lev-\varphi_t)^2})]=\theta_b\frac{\lambda_t}{1+\lambda_t}.$$

If $\lambda_t=0$, the first-order condition of the bank is:

$$\tilde{R}_t^{F,*}-R_{A,t}-\frac{\phi_b}{(Lev-\varphi_t)^2}=0.$$

In both cases, the optimal leverage does not depend on n_t and therefore ψ_t does not depend on n_t, which verifies the guess.

C Aggregation

Aggregate profits are redistributed to domestic patient households. Aggregate profits over all intermediate-goods producers in period t are given by:

$$\int_0^1[(\frac{P_{A,t(z)}}{P_{A,t}})^{1-\epsilon}Y_{A,t}-w_tl_t(z)-w_t'l_t'(z)]dz.$$

Hence, $\int_0^1 P_{A,t(z)}^{1-\epsilon}dz=P_{A,t}^{1-\epsilon}$ and $\int_0^1 l_t(z)dz=l_t$ and $\int_0^1 l_t'(z)dz=l_t'$ (market clearing on the labor market), so aggregate intermediate goods profits are equal to $Y_{A,t}-w_tl_t-w_t'l_t'$.

Profits from the exiting banks distributed to patient households as dividends in period t net from the starting value of new banks write:

$$(1-\zeta)(\tilde{R}_{t-1}^H\frac{b_{t-1}^H}{\pi_{A,t}}+\tilde{R}_{t-1}^{F*}\frac{b_{t-1}^{F,S*}}{\pi_{A,t}}-R_{A,t-1}\frac{d_{t-1}}{\pi_{A,t}}-(\frac{\phi_b}{Lev-\varphi_{t-1}}-\frac{\phi_b}{Lev-\varphi})\frac{n_{t-1}}{\pi_{A,t}}-\frac{n_{t-1}}{\pi_{A,t}}A_{n,t})-(1-\zeta)(b^H+b^{F,S*})\omega.$$

Therefore, total profits distributed to patient households in period t divided by $P_{A,t}$ write:

$$\frac{\Pi_t}{P_{A,t}}=Y_{A,t}-w_t(l_t+l_t')+(1-\zeta)(\tilde{R}_{t-1}^H\frac{b_{t-1}^H}{\pi_{A,t}}+\tilde{R}_{t-1}^{F*}\frac{b_{t-1}^{F,S*}}{\pi_{A,t}}-R_{A,t-1}\frac{d_{t-1}}{\pi_{A,t}}-$$
$$(\frac{\phi_b}{Lev-\varphi_{t-1}}-\frac{\phi_b}{Lev-\varphi})\frac{n_{t-1}}{\pi_{A,t}}-(1-\zeta)(b^H+b^{F,S*})\omega.$$

For foreign patient households, they write:

$$\frac{\Pi_t^*}{P_{A,t}} = \frac{P_{B,t}}{P_{A,t}} Y_{B,t} - \frac{P_{B,t}}{P_{A,t}} (w_t^* (l_t^* + l_t^{'*})) + (1-\zeta)(\tilde{R}_{t-1}^{H*} \frac{b_{t-1}^{H*}}{\pi_{A,t}} + \tilde{R}_{t-1}^{F} \frac{b_{t-1}^{F,S}}{\pi_{A,t}} - R_{B,t-1} \frac{d_{t-1}^*}{\pi_{A,t}} -$$

$$(\frac{\phi_b}{Lev^* - \varphi_{t-1}^*} - \frac{\phi_b}{Lev^* - \varphi^*}) \frac{n_{t-1}^*}{\pi_{A,t}}) - (1-\zeta)(b^{H*} + b^{F,S})\omega.$$

The housing markets clear:

$$h_t + h_t' = 1$$

$$h_t^* + h_t^{'*} = 1.$$

The market clearing condition on the domestically produced good market writes:

$$nY_{A,t} = nC_{A,t}^{'} + nC_{A,t} + (1-n)C_{A,t}^{'*} + (1-n)C_{A,t}^* + n(\frac{\phi_b}{Lev - \varphi_{t-1}} - \frac{\phi_b}{Lev - \varphi}) \frac{n_{t-1}}{\pi_{A,t}} + n\frac{\psi}{2} z_t^2.$$

The demand and supply of foreign bank loans are equal:

$$nb_t^{F,D} = (1-n) b_t^{F,S}$$

$$(1-n) b_t^{F,D^*} = n b_t^{F,S^*}$$

Foreign bonds are in zero-net supply:

$$nz_t + (1-n) z_t^* = 0.$$

Summing up the budget constraint of the households and the balance-sheet constraint of banks, and imposing the market clearing conditions yields the domestic net foreign asset position:

$$z_t = Y_{A,t} + b_t^{F,D} + R_{t-1} \frac{z_{t-1}}{\pi_{A,t}} + \tilde{R}_{t-1}^{F*} \frac{b_{t-1}^{F*,S}}{\pi_{A,t}} - C_{A,t}' - C_{A,t} -$$

$$\frac{P_{B,t}}{P_{A,t}} C_{B,t}' - \frac{P_{B,t}}{P_{A,t}} C_{B,t} - \tilde{R}_{t-1}^{F} \frac{b_{t-1}^{F,D}}{\pi_{A,t}} - b_t^{F,S*} - (\frac{\phi_b}{Lev - \varphi_{t-1}} - \frac{\phi_b}{Lev - \varphi}) \frac{n_{t-1}}{\pi_{A,t}} - \frac{\psi}{2} z_t^2.$$

Similarly, the foreign net foreign asset position writes, in terms of the country A produced good:

$$z_t^* = \frac{P_{B,t}}{P_{A,t}} Y_{B,t} + b_t^{F,D*} + R_{t-1} \frac{z_{t-1}^*}{\pi_{A,t}} + \tilde{R}_{t-1}^F \frac{b_{t-1}^{F,S}}{\pi_{A,t}} -$$

$$C_{A,t}^{\prime *} - C_{A,t} - \frac{P_{B,t}}{P_{A,t}} C_{B,t}^{\prime *} - \frac{P_{B,t}}{P_{A,t}} C_{B,t}^* - \tilde{R}_{t-1}^{F*} \frac{b_{t-1}^{F,D*}}{\pi_{A,t}} - b_t^{F,S} - (\frac{\phi_b}{Lev^* - \varphi_{t-1}} - \frac{\phi_b}{Lev^* - \varphi}) \frac{n_{t-1}^*}{\pi_{A,t}} - \frac{\psi}{2} z_t^{*2}.$$

Let's define the variable $P_{B_A,t} = \frac{P_{B,t}}{P_{A,t}}$, instead of having one law of motion for each price.

Its dynamic process is given by:

$$\frac{P_{B_A,t}}{P_{B_A,t-1}} = \frac{\pi_{B,t}}{\pi_{A,t}},$$

with $\pi_{B,t}$ and $\pi_{A,t}$ given by:

$$1 = \theta \pi_{A,t}^{\epsilon - 1} + (1 - \theta)(\pi_{A,t}^S)^{1-\epsilon}.$$

$$1 = \theta \pi_{B,t}^{\epsilon - 1} + (1 - \theta)(\pi_{B,t}^S)^{1-\epsilon}.$$

D Summary of the model's equilibrium conditions

D.1 Domestic patient households:

$$\frac{C'_{A,t}}{C'_{B,t}} = \frac{n}{(1-n)} P_{B_A,t}.$$

$$\frac{nq_t}{C'_{A,t}} = \frac{j}{h'_t} + \beta E_t[\frac{nq_{t+1}}{C'_{A,t+1}}].$$

$$nw'_t = C'_{A,t} l_t^{\prime(\eta-1)}.$$

$$\frac{1}{C'_{A,t}} = \beta E_t[\frac{1}{C'_{A,t+1}} \frac{R_{A,t}}{\pi_{A,t+1}}].$$

$$\frac{1 + \psi z_t}{C'_{A,t}} = \beta E_t[\frac{1}{C'_{A,t+1}} \frac{R_t}{\pi_{A,t+1}}].$$

D.2 Foreign patient households:

$$\frac{C_{A,t}^{\prime *}}{C_{B,t}^{\prime *}} = \frac{n}{(1-n)} P_{B_A,t}.$$

$$\frac{nq_t^*}{C_{A,t}'^*} = \frac{j}{h_t'^*} + \beta E_t[\frac{nq_{t+1}^*}{C_{A,t+1}'^*}].$$

$$nw_t'^* = C_{A,t}'^* l_t'^{*(\eta-1)}.$$

$$\frac{1}{C_{A,t}'^*} = \beta E_t[\frac{1}{C_{A,t+1}'^*}\frac{R_{B,t}}{\pi_{A,t+1}}].$$

$$\frac{1+\psi z_t^*}{C_{A,t}'^*} = \beta E_t[\frac{1}{C_{A,t+1}'^*}\frac{R_t}{\pi_{A,t+1}}].$$

D.3 Domestic impatient households:

$$\frac{C_{A,t}}{C_{B,t}} = \frac{n}{(1-n)} P_{B_A,t}.$$

$$\frac{n}{C_{A,t}} q_t = \frac{j}{h_t} + \gamma E_t[\frac{n}{C_{A,t+1}} q_{t+1}] + \mu_t E_t[m\alpha_t q_{t+1}] + \mu_t^F (E_t[q_{t+1}(1-\alpha_t) - 2h_t \frac{1-z}{qh} q_{t+1}^2 (1-\alpha_t)^2]).$$

$$nw_t = C_{A,t} l_t^{(\eta-1)}.$$

$$E_t[\tilde{R}_t^H \frac{b_t^H}{\pi_{A,t+1}}] = E_t[m\alpha_t q_{t+1} h_t].$$

$$E_t[\tilde{R}_t^F \frac{b_t^{F,D}}{\pi_{A,t+1}}] = E_t[q_{t+1}(1-\alpha_t)h_t(1 - \frac{1-z}{qh}(q_{t+1}(1-\alpha_t)h_t))].$$

$$\frac{n}{C_{A,t}} = \gamma E_t[\frac{n}{C_{A,t+1}}\frac{\tilde{R}_t^H}{\pi_{A,t+1}}] + \mu_t E_t[\frac{\tilde{R}_t^H}{\pi_{A,t+1}}].$$

$$\frac{n}{C_{A,t}} = \gamma E_t[\frac{n}{C_{A,t+1}}\frac{\tilde{R}_t^F}{\pi_{A,t+1}}] + \mu_t^F E_t[\frac{\tilde{R}_t^F}{\pi_{A,t+1}}].$$

$$\mu_t m = \mu_t^F E_t[(1 - 2\frac{1-z}{qh} q_{t+1}(1-\alpha_t)h_t)].$$

$$C_{A,t} + P_{B_A,t} C_{B,t} + q_t(h_t - h_{t-1}) + \tilde{R}_{t-1}^H \frac{b_{t-1}^H}{\pi_{A,t}} + \tilde{R}_{t-1}^F \frac{b_{t-1}^{F,D}}{\pi_{A,t}} = w_t l_t + b_t^H + b_t^{F,D}.$$

D.4 Foreign impatient households:

$$\frac{C_{A,t}^*}{C_{B,t}^*} = \frac{n}{(1-n)} P_{B_A,t}.$$

$$\frac{n}{C^*_{A,t}}q^*_t = \frac{j}{h^*_t} + \gamma E_t[\frac{n}{C^*_{A,t+1}}q^*_{t+1}] +$$

$$\mu^*_t E_t[m\alpha^*_t q^*_{t+1}] + \mu^{F,*}_t(E_t[q^*_{t+1}(1-\alpha^*_t) - 2h^*_t\frac{1-z}{q^*h^*}q^{*,2}_{t+1}(1-\alpha^*_t)^2]).$$

$$nw^*_t = C^*_{A,t}l^{*(\eta-1)}_t.$$

$$E_t[\tilde{R}^{H*}_t\frac{b^{H*}_t}{\pi_{A,t+1}}] = E_t[m\alpha^*_t q^*_{t+1}h^*_t].$$

$$E_t[\tilde{R}^{F*}_t\frac{b^{F,D*}_t}{\pi_{A,t+1}}] = E_t[q^*_{t+1}(1-\alpha^*_t)h^*_t(1-\frac{1-z}{qh}(q^*_{t+1}(1-\alpha^*_t)h^*_t))].$$

$$\frac{n}{C^*_{A,t}} = \gamma E_t[\frac{n}{C^*_{A,t+1}}\frac{\tilde{R}^{H*}_t}{\pi_{A,t+1}}] + \mu^*_t E_t[\frac{\tilde{R}^{H*}_t}{\pi_{A,t+1}}].$$

$$\frac{n}{C^*_{A,t}} = \gamma E_t[\frac{n}{C^*_{A,t+1}}\frac{\tilde{R}^{F*}_t}{\pi_{A,t+1}}] + \mu^{F*}_t E_t[\frac{\tilde{R}^{F*}_t}{\pi_{A,t+1}}].$$

$$\mu^*_t m = \mu^{F*}_t E_t[(1-2\frac{1-z}{qh}q^*_{t+1}(1-\alpha_t)^*h^*_t)].$$

$$C^*_{A,t} + P_{B_A,t}C^*_{B,t} + q^*_t(h^*_t - h^*_{t-1}) + \tilde{R}^{H*}_{t-1}\frac{b^{H*}_{t-1}}{\pi_{A,t}} + \tilde{R}^{F*}_{t-1}\frac{b^{F,D^*}_{t-1}}{\pi_{A,t}} = w^*_t l^*_t + b^{H*}_t + b^{F,D*}_t.$$

D.5 Domestic banks:

$$n_t = \zeta(\tilde{R}^H_{t-1}\frac{b^H_{t-1}}{\pi_{A,t}} + \tilde{R}^{F*}_{t-1}\frac{b^{F,S*}_{t-1}}{\pi_{A,t}} - R_{A,t-1}\frac{d_{t-1}}{\pi_{A,t}} - (\frac{\phi_b}{Lev-\varphi_{t-1}} - \frac{\phi_b}{Lev-\varphi})\frac{n_{t-1}}{\pi_{A,t}}) + (1-\zeta)(b^H + b^{F,S*})\omega.$$

$$b^H_t + b^{F,S*}_t = d_t + n_t.$$

$$\varphi_t = \frac{b^H_t + b^{F,S*}_t}{n_t}.$$

$$\tilde{R}^H_t = R_{A,t} + \frac{\phi_b}{(Lev-\varphi_t)^2}.$$

$$\tilde{R}^{F*}_t = R_{A,t} + \frac{\phi_b}{(Lev-\varphi_t)^2} = 0.$$

D.6 Foreign banks:

$$n^*_t = \zeta(\tilde{R}^{H*}_{t-1}\frac{b^{H*}_{t-1}}{\pi_{A,t}} + \tilde{R}^F_{t-1}\frac{b^{F,S}_{t-1}}{\pi_{A,t}} - R_{B,t-1}\frac{d^*_{t-1}}{\pi_{A,t}} - (\frac{\phi_b}{Lev^*-\varphi^*_{t-1}} - \frac{\phi_b}{Lev^*-\varphi^*})n^*_{t-1}) + (1-\zeta)(b^{H*} + b^{F,S})\omega.$$

$$b^{H*}_t + b^{F,S}_t = d^*_t + n^*_t.$$

$$\varphi_t^* = \frac{b_t^{H*} + b_t^{F,S}}{n_t^*}.$$

$$\tilde{R}_t^{H*} = R_{B,t} + \frac{\phi_b}{(Lev - \varphi_t^*)^2}.$$

$$\tilde{R}_t^{F} = R_{B,t} + \frac{\phi_b}{(Lev - \varphi_t^*)^2}.$$

D.7 Domestic intermediate-good firms

Labor-demand conditions:

$$w_t l_t = \frac{1-\nu}{X_{A,t}} v_{A,t}^P Y_{A,t}.$$

$$w_t' l_t' = \frac{\nu}{X_{A,t}} v_{A,t}^P Y_{A,t}.$$

D.8 Foreign intermediate-good firms

Labor-demand conditions:

$$w_t^* l_t^* = \frac{1-\nu}{X_{B,t}} v_{B,t}^P Y_{B,t}.$$

$$w_t^{'*} l_t^{'*} = \frac{\nu}{X_{B,t}} v_{B,t}^P Y_{B,t}.$$

D.9 Aggregate prices, aggregate output and monetary policy rule:

$$z_{1,t} = X_{A,t}^{-1} A_{p,t} Y_{A,t} + \theta\beta E_t[\frac{C_{A,t}^{'}}{C_{A,t+1}^{'}} \pi_{A,t+1}^{\epsilon} z_{1,t+1}].$$

$$z_{2,t} = Y_{A,t} + \theta\beta E_t[\frac{C_{A,t}^{'}}{C_{A,t+1}^{'}} \pi_{A,t+1}^{\epsilon-1} z_{2,t+1}].$$

$$z_{1,t}^* = X_{B,t}^{-1} A_{p,t} Y_{B,t} + \theta\beta E_t[\frac{C_{A,t}^{'*}}{C_{A,t+1}^{'*}} \pi_{B,t+1}^{\epsilon} z_{1,t+1}^*].$$

$$z_{2,t}^* = Y_{B,t} + \theta\beta E_t[\frac{C_{A,t}^{'*}}{C_{A,t+1}^{'*}} \pi_{B,t+1}^{\epsilon-1} z_{2,t+1}^*].$$

$$\pi^S_{A,t} = \frac{\epsilon}{\epsilon - 1}\frac{z_{1,t}}{z_{2,t}}.$$

$$\pi^S_{B,t} = \frac{\epsilon}{\epsilon - 1}\frac{z^*_{1,t}}{z^*_{2,t}}.$$

$$R_t = [\bar{R}(\frac{\pi^n_{A,t}\pi^{1-n}_{B,t}}{\bar{\pi}^n_A\bar{\pi}^{1-n}_B})^{\phi_\pi}(\frac{y^n_{A,t}y^{1-n}_{B,t}}{y^n_{A,t-1}y^{1-n}_{B,t-1}})^{\phi_y}]^{1-\rho_r}R^{\rho_r}_{t-1}\exp(e_{r,t}).$$

$$Y_{A,t}v^P_{A,t} = A_t l_t^{1-\nu} l_t'^{\nu}.$$

$$v^P_{A,t} = (1-\theta)(\pi^S_{A,t})^{-\epsilon} + \theta\pi^\epsilon_{A,t}v^P_{A,t-1}.$$

$$Y_{B,t}v^P_{B,t} = A^*_t l_t^{*(1-\nu)} l_t^{*'\nu}.$$

$$v^P_{B,t} = (1-\theta)(\pi^S_{B,t})^{-\epsilon} + \theta\pi^\epsilon_{B,t}v^P_{B,t-1}.$$

$$1 = \theta\pi^{\epsilon-1}_{A,t} + (1-\theta)(\pi^S_{A,t})^{1-\epsilon}.$$

$$1 = \theta\pi^{\epsilon-1}_{B,t} + (1-\theta)(\pi^S_{B,t})^{1-\epsilon}.$$

$$\frac{P_{B_A,t}}{P_{B_A,t-1}} = \frac{\pi_{B,t}}{\pi_{A,t}}.$$

D.10 Market clearing and resource constraints:

Housing market:

$$h_t + h'_t = 1.$$

$$h^*_t + h'^*_t = 1.$$

Domestic good market:

$$nY_{A,t} = nC'_{A,t} + nC_{A,t} + (1-n)C'^*_{A,t} + (1-n)C^*_{A,t} + n(\frac{\phi_b}{Lev - \varphi_{t-1}} - \frac{\phi_b}{Lev - \varphi})\frac{n_{t-1}}{\pi_{A,t}} + n\frac{\psi}{2}z_t^2.$$

Market clearing for domestic foreign loans:

$$nb_t^{F,D} = (1-n)b_t^{F,S}.$$

Market clearing for foreign foreign loans:

$$(1-n)b_t^{F,D^*} = nb_t^{F,S^*}.$$

Foreign bonds are in zero-net supply:

$$nz_t + (1-n)z^*_t = 0.$$

The domestic net foreign asset position is:

$$z_t = Y_{A,t} + b_t^{F,D} + R_{t-1}\frac{z_{t-1}}{\pi_{A,t}} + \tilde{R}^{F*}_{t-1}\frac{b_{t-1}^{F*,S}}{\pi_{A,t}} - C'_{A,t} - C_{A,t} -$$

$$\frac{P_{B,t}}{P_{A,t}}C'_{B,t} - \frac{P_{B,t}}{P_{A,t}}C_{B,t} - \tilde{R}^F_{t-1}\frac{b_{t-1}^{F,D}}{\pi_{A,t}} - b_t^{F,S*} - (\frac{\phi_b}{Lev - \varphi_{t-1}} - \frac{\phi_b}{Lev - \varphi})\frac{n_{t-1}}{\pi_{A,t}} - \frac{\psi}{2}z_t^2.$$

The foreign net foreign asset position is:

$$z_t^* = \frac{P_{B,t}}{P_{A,t}} Y_{B,t} + b_t^{F,D*} + R_{t-1} \frac{z_{t-1}^*}{\pi_{A,t}} + \tilde{R}_{t-1}^F \frac{b_{t-1}^{F,S}}{\pi_{A,t}} -$$
$$C_{A,t}^{\prime *} - C_{A,t}^* - \frac{P_{B,t}}{P_{A,t}} C_{B,t}^{\prime *} - \frac{P_{B,t}}{P_{A,t}} C_{B,t}^* - \tilde{R}_{t-1}^{F*} \frac{b_{t-1}^{F,D*}}{\pi_{A,t}} - b_t^{F,S} -$$
$$\left(\frac{\phi_b}{Lev^* - \varphi_{t-1}} - \frac{\phi_b}{Lev^* - \varphi}\right) \frac{n_{t-1}^*}{\pi_{A,t}} - \frac{\psi}{2} z_t^{*2}.$$

D.11 Shock process:

Common cost-push shock:

$$\ln(A_{p,t}) = \rho_j \ln(A_{p,t-1}) + \varepsilon_{p,t}.$$

E Changes in volatility related to macroprudential reciprocity

Table 5 provides the ratio of the volatility of the main variables in the core economy (country A) associated with the optimized results in Table 3 over the volatility of the same variables in the benchmark case (no reciprocity case). Therefore, a value lower than 1 means that the variable is less volatile under reciprocity in the LTV rule than under no-reciprocity, and conversely.

Table 5: Changes in volatility related to macroprudential reciprocity for given monetary policy ($\phi_\pi = 0.5$)

Volatility ratio	Output	Inflation	Credit	House prices
No CCyB ($\xi_{lev_h} = 0$)				
Low domestic LTV rule ($\xi_{m_h} = 1$)	1	1	0.95	1
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	1	1	0.97	1
High domestic LTV rule ($\xi_{m_h} = 10$)	1	1	0.96	1
Low CCyB ($\xi_{lev_h} = 0.5$)				
Low domestic LTV rule ($\xi_{m_h} = 1$)	1	1	0.98	1
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	1	1	0.97	1
High domestic LTV rule ($\xi_{m_h} = 10$)	1	1	1	1
Intermediate CCyB ($\xi_{lev_h} = 1$)				
Low domestic LTV rule ($\xi_{m_h} = 1$)	-	-	-	-
Intermediate domestic LTV rule ($\xi_{m_h} = 5$)	1	1	1	1
High domestic LTV rule ($\xi_{m_h} = 10$)	1	1	1	1