Cross-Border Risk Sharing and International Coordination of Macro-Prudential and Monetary Policies.*

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This version: June 2019

Abstract

We investigate the question of international coordination of monetary and macro-prudential policies using a two country general equilibrium model where monetary policy sets the cost of ex post liquidity and macro-prudential policy controls bank ex ante leverage. In this framework, we first show that coordinating macro-prudential policies, unlike monetary policy, leads to a Pareto improvement, i.e. countries are all better-off relative to the Nash equilibrium. The reason is the existence of a cross-border externality that macro-prudential policy makers fail to internalise in the Nash equilibrium, by which an economy can supply more risk sharing assets to the rest of the world when it is itself better insured/more diversified. Secondly however, we show that under cooperative monetary policies, the conduct of macro-prudential policy (Nash or cooperative) proves to be neutral for welfare.

*I would like to thank Meghana Ayyagari, Claudio Borio, Ester Faia, Giovanni Lombardo, Luiz Pereira, Hyun Shin, Cedric Tille as well as participants at the 8th IWH/INFER Workshop on International Capital Flows and Macroprudential Stability (August 2018), the 6th CBRT/ECB conference on Modelling macro-finance interaction (September 2018), the 4th Global Forum on International Macroeconomics and Finance (November 2018), the CAFRAL/Imperial College conference on Financial Intermediation in Emerging Economies (March 2019), Oxford NuCamp-Saïd Macro-finance Conference (April 2019) and the ABCDE world bank annual conference (June 2019) for useful comments and insights. The views expressed here are those of the author and do not necessarily reflect the views of the BIS.

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1 Introduction

The purpose of this paper is to provide a framework that lends itself the study of policy cross-border cooperation when policy makers hold different policy instruments to coordinate on. Specifically, we investigate the question of international coordination of monetary and macro-prudential policies in the context of a two region general equilibrium model. In this model, agents choose the optimal mix between ex ante and ex post liquidity. Ex ante liquidity comes in the form of cross-border borrowing, by which agents -henceforth banks- in one region can buy claims on projects run by banks of the other region. With returns on banks' projects being negatively correlated across regions, banks can ex ante sell claims on future output as a risk sharing device. Frictions affecting the market for risk sharing however limit how much insurance banks can sell. To get around these limitations, banks can rely on ex post liquidity through the market for ex post funding which opens once uncertainty has unraveled. On this market, banks in need for liquidity can issue and sell claims to banks holding excess liquidity.

We introduce monetary and macro-prudential policy by assuming that authorities in each region have two policy levers. Monetary policy affects the cost of ex post liquidityby setting the interest rate on an deposit -risk free- facility that any bank can access and deposit its funds into ex post, i.e. once uncertainty has unraveled. Macro-prudential policy consists in setting the maximum amount of claims domestic banks can sell ex ante on the market for risk sharing. It therefore limits or expands how much insurance, domestic banks can provide to the other region.

At the heart of the model is a set of trade-offs for policy makers that can be described as follows. For monetary policy, setting high interest rates allows on the one hand domestic banks to earn a larger return when they are on the lending side of the market for ex post funding. But on the other hand, with high interest rates, banks need to pay a higher cost for ex post liquidity when they are on the borrowing side of the market for ex post funding. And in addition, arbitrage implies the cost to selling insurance ex ante increases with the cost ex post liquidity. Interest rates set by monetary policy makers therefore tend to be lower when banks have issued more claims for risk sharing purposes, i.e. when banks are more leveraged. Turning to macro-prudential policy, the potential trade-off lies between ex ante bank borrowing and ex post

funding conditions. One the one hand, issuing risk sharing claims ex ante is profitable because such claims can be sold at a high price, given their risk sharing properties. On the other hand, allowing domestic banks to issue more risk sharing claims ex ante can crowd out the issuance (of risk sharing claims) by banks from the other region. If in turn such banks reduce their leverage and issue fewer risk sharing claims, this may lead monetary policy makers to set higher interest rates, which would reduce banks' profits.[1]

1.1 Main takeaways

In this framework, we derive two main results. First, unlike the coordination of monetary policies, coordinating macro-prudential policies delivers a Pareto improvement. When monetary policies are determined non-cooperatively, the cost of ex post liquidity that comes out of the game between the two central banks is optimal for one region but too high for the other one. This leaves one region in the position of the core, i.e. its characteristics determine global funding conditions and one region in the position of the periphery, i.e. it faces funding conditions that do not match the domestic economy needs. As a result, moving to cooperation -which shifts the cost of ex post funding down- benefits the periphery but is bound to hurt the core region.[2]

Conversely, both regions derive strictly positive gains from cooperative macro-prudential policies. The reason is the presence of a cross-border externality: when macro-prudential policy makers in one region allow domestic banks to issue more claims for risk sharing, then banks in the other region are better insured against future risks and this allows such banks in turn to supply more risk sharing claims. This *external effect*, which policy makers fail to internalize in the Nash equilibrium leads to inefficiently low levels of risk sharing with non-cooperative macro-prudential policies. Conversely under cooperative macro-prudential policy, each macro-prudential policy maker is willing to increase domestic banks supply for risk sharing, because even if, on its own, this were to reduce domestic profits, the spill-over to the other region and the spill-back -through lower insurance costs- are so large that they dominate any possible loss.

[1] Hence, notwithstanding the usual role assigned to macro-prudential policy in keeping systemic risk under control or ensuring banking and financial stability, this model stresses the trade-off facing macro-prudential policy in controlling financial conditions at the cost of possibly limiting beneficial trades with the rest of world.

[2] Note that irrespective of how cooperation shifts the equilibrium interest rate relative to the Nash case, the region for which the Nash equilibrium maximizes domestic profits is bound to lose. In this model cooperation shifts the equilibrium interest rate down, but a similar result would apply if cooperation led to a higher interest rate.

Second, under cooperative monetary policies, there are no gains to coordinating macro-prudential policies. The intuition is very simple: Under cooperative monetary policies, global funding conditions depend on banks global leverage, which each macro-prudential policy maker has only some limited influence on.[3] Hence the trade-off between manipulating funding conditions and allowing domestic banks to leverage up and sell more risk sharing claims always happens in favor of the latter as the opportunity cost of limiting bank leverage to affect funding conditions becomes too large. Hence, whether in Nash or in cooperative equilibrium, optimal macro-prudential policy always consists in maximizing banks' supply for risk sharing assets.

Last, we parametrize the model to quantify cooperation gains, starting with the global economy. We then slide and dice these gains by region and by policy. First, the median global welfare gain of moving from Nash to cooperative policies (monetary *and* macro-prudential) is slightly above 1%. Second, this median gain for the global economy hides significant asymmetry: for the core region, the median gain is about 0, while the median gain for the periphery region is around 2%. The relative modesty of global welfare gains also relates to the fact that global gains to monetary policy coordination (median at 0.75%) tend to outpace significantly those of macro-prudential policy coordination (median at 0.1%). Third and last, looking at welfare gains by region and policy confirms the main analytical result of the paper. While welfare gains to coordinating monetary policies are larger at the aggregate level than those accruing from coordinating macro-prudential policies, only the latter are always positive for both regions. Thus, the conclusions is that in the absence or coordinated monetary policies, macro-prudential policy coordination can be a second-best solution to reduce the global inefficiency of non-cooperative monetary policies.

1.2 Literature review

This paper relates to three different strands of literature. First, this paper relates to the literature on gains from cross-border policy coordination. While it has been established in the new open economy macro literature that benefits from monetary policy cooperation are rather limited (Obstfeld and Rogoff 2002),

[3] Pushing the argument to the limit, if the world economy was made of a large number of economies, each domestic macro-prudential policy maker would have virtually no influence on the global interest rate, which would end up being "almost" like an exogenous variable.

it is an open question as to whether such result still holds given recent significant changes in the conduct of monetary policy, e.g. the heavy use of unconventional monetary policy tools, or changing constraints and evolving limits on (the effectiveness of) monetary policy, as illustrated by the debate on dilemma vs. trilemma (Rey 2015). Moreover it remains equally open to figure out if the same type of result extends to macro-prudential policy. Last and not least, understanding how the benefits to cooperate on one policy lever depend on the conduct of other policies has remained largely an unexplored territory. Second, a growing body of empirical evidence has highlighted the sizeable cross-border impact of monetary and macro-prudential policies, particularly in the recent years where central banks in advanced economies have used extensively unconventional monetary policy tools. Bowman et al (2015) provide evidence that emerging market economies (EME) sovereign bond yields react strongly to the use of unconventional monetary policy in the US. For the ECB, Fratzscher et al. (2014) document that spillover from non-standard monetary policy measures include a positive impact on global equity markets in both advanced economies (AE) and EME as well as lower credit risk among banks and sovereigns. On the modelling side, Bagliano and Morana (2012) using a large macroeconometric model to show that asset prices as well as international trade are the key channels through which financial disturbances in the US transmit to the rest of the world. More specifically on macro-prudential policy, Cerutti et al. (2017) shows that usage of macro-prudential policy tools tend to be associated with lower credit growth, meanwhile cross-border borrowing tends to go up. Focusing on economies from the Asia-Pacific region, Bruno et al. (2017) find that capital flow management tools are effective in curbing banking and bond inflows, a finding that is very consistent with our modelling of macro-prudential policy.

Third our analytical framework builds on the seminal Hölmstrom and Tirole (1998) model of liquidity provision where firms may require the provision of outside liquidity -supplied by the government- to face aggregate shocks. In our model, such outside liquidity is provided by the rest of the world, hence giving rise to mutually advantageous cross-border capital flows. Our framework is also close in spirit to Jeanne and Korinek (2013) where macro-prudential policy comes ex ante as a constraint on agents' choices while monetary policy intervenes ex post, like in our framework, to set the price of liquidity on the market for ex post funding.

Theoretically, macro-prudential policy intervention is justified either as a response to aggregate demand externalities (Farhi and Werning (2013) and Korinek and Simsek (2016) or in the presence of pecuniary externalities (Gromb and Vayanos (2002), Caballero and Krishnamurthy (2003), Lorenzoni (2008), Jeanne and Korinek (2010), Stein (2012) or Bengui (2014)). In our framework - which belongs to the latter category-, the use of macro-prudential policy derives from three features of the model. First monetary policy makers choose to set interest rates ex post in relation to the composition of banks balance sheets. Affecting such balance sheets through macro-prudential policy can therefore help adjust funding costs in line with the needs of the economy. Second, because of the presence of a global capital market with frictionless arbitrage, countries may lose control of domestic financial conditions. Macro-prudential policy can therefore be useful as policy makers can recover some influence on domestic financial conditions by affecting the composition of domestic banks assets and liabilities and thereby affecting the equilibrium of the global market where banks exchange claims. Last the equilibrium on the market for ex post liquidity generates a positive cross-border externality in macro-prudential policy choices which is the source of welfare gains of coordinated policies.

The road map for the paper is as follows. The next section presents the analytical framework and its main assumptions. Section 3 derives the decentralized equilibrium for given monetary and macro-prudential policies. Then section 4 determines optimal monetary policies under the Nash and the cooperative equilibria while section 5 investigates optimal macro-prudential policies with and without cooperation. Welfare gains from policy cooperation are quantified in section 6 and finally conclusions are drawn in section 7.

2 Timing and Technology

2.1 Framework

We consider a world economy consisting of two regions -home and foreign, henceforth h and f-, lasting for three periods, 0; 1 and 2, and populated by risk neutral banks maximizing date-2 expected profits. At date 0, each bank starts with one unit of funds and can invest in a risky asset.

Investing in the risky asset at date 0 yields a unit return one period later with a probability $\frac{1}{2}$. But with

a probability $\frac{1}{2}$, the date-0 investment yields no output at date 1. Still, it can then deliver output at date 2 if reinvestment takes place at date 1, reinvestment having also a unit return. Banks whose risky assets pay-off (do not pay-off) at date 1 will be called *intact* (*distressed*) banks. Moreover, the shock to risky assets is observable, verifiable and perfectly correlated *within* regions. But, *across* regions, there is a perfect *negative* correlation: When risky assets pay-off in one region at date 1, then risky assets in the other region do not pay anything at date 1 and vice-versa.

2.2 Contracts

At date 0, banks can enter into cross-border risk sharing agreements. Banks from home can take shares in risky projects run by banks from foreign and vice-versa. L^h (L^f) denotes the amount of funds banks from home (banks from foreign) raise from banks from foreign (banks from home) at date 0 and R_1^h (R_1^f) denotes the return, banks from home (banks from foreign) pay at date 1 when intact, to banks from foreign (banks from home). Importantly when banks from region i pay a return R_1^i ($i = \{h; f\}$), banks from region $-i$ ($-i = \{f; h\}$) only earn βR_1^i, with $\beta < 1$, the difference $(1-\beta) R_1^i$ being a cost that scales the friction that the market for risk sharing suffers from.[4] Note finally that when banks are distressed, assets held on such banks are worthless.

At date 1, once uncertainty has unraveled, distressed banks can raise funds from intact banks to finance reinvestment. D^i ($i = \{h; f\}$) then denotes the funds a distressed bank from region i raise at date 1 and R_2^i denotes the return a distressed bank from region i pay at date 2 on liabilities raised at date 1. Last we assume a distressed bank from region i can borrow at date 1, at most an amount $1 - \lambda^i$.

2.3 Monetary and macro-prudential policies

We introduce monetary and macro-prudential policies as follows. In each region, monetary policy makers hold a -risk free- deposit facility, for which they can choose the interest rate paid on funds deposited at date

[4] For instance, this cost may be paid for ex ante certification or ex post verification purposes.

1.[5] We denote r^i the interest rate set by the central bank from region i ($0 < r^i < 1$). Turning to macro-prudential policy, authorities in each region determine the maximum amount of -risk sharing- liabilities that domestic banks can issue ex ante. They do so by choosing a parameter μ^i and imposing that liabilities issued at date 0 account at most for a fraction μ^i of date-0 investment.

Importantly macro-prudential authorities set their decision -on the maximum amount of liabilities banks can issue at date 0- first, i.e. before monetary policy makers choose the returns on their respective domestic deposit facilities. This is consistent with the timing of the model.

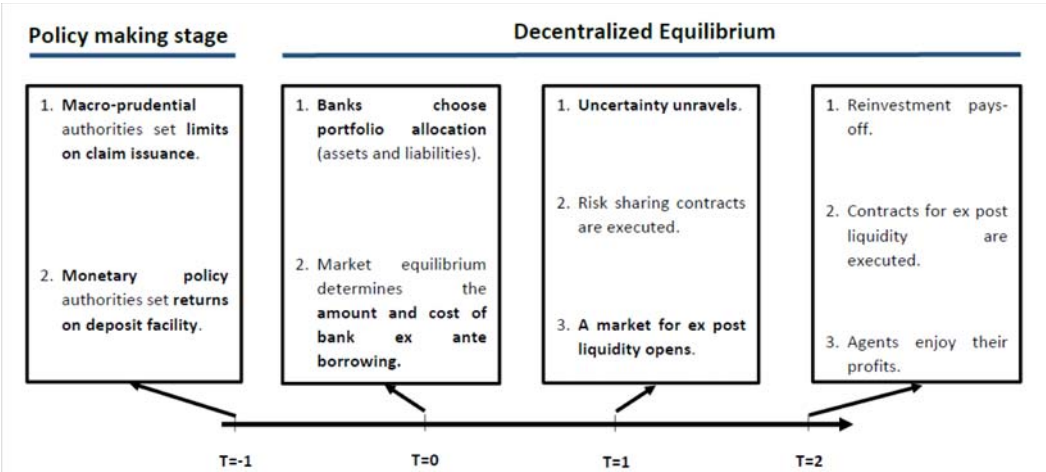

Figure 2: Timing of the model

Macro-prudential policy decisions are naturally taken ex ante, at date 0 given that the aim is to affect the extent of risk sharing. Conversely, monetary policy decisions can be made either at date 0, i.e. before uncertainty on risky assets is resolved or at date 1, once uncertainty on risky assets has unraveled.[6] Indeed, to simplify the analysis we will consider that monetary policy decisions are made ex ante at date 0 under perfect commitment.[7] Once these two sets of decisions are made in both regions, then banks determine their investment plans. They invest part of their endowment into the other region's risky assets; they also

[5] Limiting the deposit facility to date 1 ensures that monetary policy can influence the cost of capital without having full control on it. This amounts to assuming that the central bank can affect the return on risk free assets only in the short-run.

[6] In practise monetary policy essentially works by reacting to shocks affecting the economy. So in the context of the model, monetary policy decisions would be made at date 1. So it seems natural to assume that macroprudential policy is decided before monetary policy.

[7] The appendix section derives the model when monetary policy makers set interest rate at date 1, i.e. after uncertainty is resolved. It shows that the logic of the model can be preserved if the market for ex post liquidity is enriched with an adverse selection problem. In this case, the maximum interest rate that can be charged to borrowers depends negatively on the internal funds of the borrowers, hence replicating the trade-off for macro-prudential policy makers between allowing larger ex ante leverage and facing less favorable financial conditions ex post.

issue risk sharing claims and they invest in their domestic risky assets. Uncertainty then unravels, risky assets deliver output or not, risk sharing contracts are executed and a market for ex post liquidity opens. Distressed banks borrow from intact banks and reinvest in their risky assets. Finally distressed risky assets deliver output, distressed banks pay back intact banks and all banks enjoy their profits.

As is usual in this kind of model, we start by determining the decentralized equilibrium and its properties. Once this is established, we work out the optimal monetary policies under two different scenarios: the Nash and the cooperative equilibrium. Finally assuming some game for optimal monetary policies, we look at optimal macro-prudential policies. Here again, we consider the Nash and the cooperative solutions.

3 The decentralized equilibrium

3.1 Optimal portfolio allocation decisions.

At date 0, banks from region i $(i = \{h; f\})$ borrow L^i from banks from the other region $(-i)$. Banks from region i therefore invest $1 + L^i - L^{-i}$ in risky assets. With a probability $\frac{1}{2}$, risky assets pay early. In this case, banks from region i reap I at date 1 and pay $R_1^i L^i$ to banks of region $-i$. Profits at date 1, for intact banks from region i, write as:

$$\Pi_1^i = 1 + L^i - L^{-i} - R_1^i L^i \tag{1}$$

Alternatively, with a probability $\frac{1}{2}$, risky assets do not deliver at date 1. Distressed banks do not reap any output nor pay anything to bank from the other region. But, they can enjoy the proceeds of the claims held on risky assets of banks of the other region $\beta R_1^{-i} L^{-i}$ and use these funds as inside equity to reinvest. Since they borrow D^i at a cost R_2^i, profits under distress write as

$$\Pi_2^i = \beta R_1^{-i} L^{-i} + \left(1 - R_2^i\right) D^i \tag{2}$$

With these expressions for profits, we can now turn to solving the problem for banks. First, we start with optimal borrowing at date 1. Assuming it is profitable for distressed banks to borrow, i.e. $R_2^i \leq 1$, optimal

borrowing at date 1 satisfies $D^i = 1 - \lambda^i$. Then given optimal borrowing in case of distress, the problem for banks in region i consists in choosing the amount of assets L^{-i} they want to hold on risky assets of banks from region $-i$. This problem writes as:

$$\max_{L^{-i}} \left(1 - L^{-i} + \left(1 - R_1^i\right) L^i\right) R_2^{-i} + \beta R_1^{-i} L^{-i} + \left(1 - R_2^i\right)\left(1 - \lambda^i\right) \\ \text{s.t. } 0 \leq L^{-i} \leq 1 + L^i \tag{3}$$

The optimal demand by banks of region i for claims issued from banks from the other region simply write as:

$$L_d^{-i} = \mathbf{1}\left[\beta R_1^{-i} > R_2^{-i}\right]\left(1 + L^i\right) \tag{4}$$

Banks choose to hold claims on risky assets of banks from the other region when the marginal benefit of holding shares on risky assets of banks from the other region must be larger than the opportunity cost of doing so, hence the condition $\beta R_1^{-i} > R_2^{-i}$ for region i bank. Then given this optimal demand for claims, banks from region i choose the amount of claims L^i to issue to solve

$$\max_{L^i} \left(1 - L_d^{-i} + (1 - R_1) L\right) R_2^{-i} + (1 - R_2)(1 - \lambda) + \beta R_1^{-i} L_d^{-i} \\ \text{s.t. } L^i \leq \mu^i \left(1 + L^i - L_d^{-i}\right)$$

The constraint $L^i \leq \mu^i \left(1 + L^i - L_d^{-i}\right)$ imposed by the macro-prudential policy maker states that a bank from region i cannot sell to banks of the other region an amount of claims L^i which would exceed a fraction μ^i of the initial investment. Let us denote $m^i = \frac{\mu^i}{1-\mu^i}$.[8] the optimal supply L_s^i for claims by banks from region i simply write as:

$$L_s^i = \mathbf{1}\left[R_1^i \leq 1 \text{ and } \beta R_1^{-i} \leq R_2^{-i}\right] m^i \left(1 - L_d^{-i}\right) \tag{5}$$

[8] In what follows we will assume that the macro-prudential policy parameters m^h and m^f satisfy $0 < m^h; m^f < 1$. This ensures that banks respond to looser domestic macro-prudential policy by increasing and not cutting leverage.

3.2 Equilibrium cross-border capital flows.

Using the optimal demand and supply for cross-border claims on risky assets (4) and (5), we can derive the equilibrium amount of claims exchanged at date 0 as

$$L^h = m^h \frac{1-m^f}{1-m^f m^h} \text{ and } L^f = m^f \frac{1-m^h}{1-m^f m^h} \tag{6}$$

And assuming $R_1^h; R_1^f \leq 1$, the equilibrium return on these claims $(R_1^h; R_1^f)$ satisfy:

$$\beta R_1^h = R_2^h \text{ and } \beta R_1^f = R_2^f \tag{7}$$

3.3 Equilibrium of the market for funding.

After banks have raised funding and bought assets from abroad at date 0, they invest in risky assets. Then at date 1, uncertainty unravels and distressed banks can raise funds -to carry out reinvestment- from intact banks. Considering the case where banks from home are distressed and need to carry out reinvestment, the equilibrium of the market for funding at date 1 writes as

$$1 + L^f - L^h = \beta R_1^f L^f + 1 - \lambda^h \tag{8}$$

The supply for funds from intact banks (from foreign) lies on the left hand side of (8). For these banks, risky assets pay early. They hence earn at date 1 an output $1 + L^f - L^h$ which they can supply on the market for ex post funding. In addition, they have also access to the deposit facilities in home and foreign. They hence supply their funds on the market only if the return R_2^h they earn on the market for ex post funding is at least as good as their outside opportunity, hence the condition $R_2^h \geq r \equiv \max\left(r^h; r^f\right)$.

On the right hand side of (8), the demand for funds from Home banks is the sum of distressed banks initial funds $\beta R_1^f L^f$ and their borrowing $1 - \lambda^h$. But distressed banks raise funds for reinvestment only if it is profitable to do so, hence the condition $R_2^h \leq 1$. Hence using the pricing equation (7), when the funding

costs satisfy $r \leq R_2^h; R_2^f \leq 1$, the equilibrium cost of funds R_2^h satisfies:

$$R_2^h = \begin{cases} 1 \text{ if } L^h > \lambda^h + \left(1 - R_2^f\right) L^f \\ r \text{ if } L^h \leq \lambda^h + \left(1 - R_2^f\right) L^f \end{cases} \tag{9}$$

According to (9), the cost of raising liquidity ex post depends positively to the amount of claims the borrowing banks have issued ex ante. When banks of a given region turn out to be distressed, the larger the amount of claims they have issued ex ante, the lower the supply for funding available at date 1, hence the higher cost to borrow ex post.

3.4 Characterizing the decentralized equilibrium

Using expressions (7) and (9) for the return on cross-border capital flows and the cost of ex post funding, we can now determine the equilibrium funding costs $\left(R_2^h; R_2^f\right)$ and the equilibrium cross-border ex ante capital flows $\left(L^h; L^f\right)$ as a function of the primitives of the models, $\left(r^h; r^f\right)$ and $\left(m^h; m^f\right)$.

Proposition 1 *Assuming $\lambda^h; \lambda^f \geq 0$ and $r \equiv \max\left(r^h; r^f\right) \leq \beta$, there is a unique decentralized equilibrium where ex post funding costs satisfy $R_2^h = R_2^f = r$ and banks optimal claims issuance satisfies*

$$L^h = m^h \frac{1 - m^f}{1 - m^h m^f} \text{ and } L^f = m^f \frac{1 - m^h}{1 - m^h m^f} \tag{10}$$

if and only if

$$L^h \leq \lambda^h + (1 - r) L^f \text{ and } L^f \leq \lambda^f + (1 - r) L^h \tag{11}$$

Proof. First, cases where the funding costs satisfy $R_2^h = 1$ or $R_2^f = 1$ cannot be equilibria. Consider for instance the case where $R_2^h = 1$. Then banks from home prefer not to issue any claim on their risky assets, i.e. $L^h = 0$ and according to (9), this case requires $\lambda^h + \left(1 - R_2^f\right) L^f \leq 0$ which is not possible since $\lambda^h; L^f \geq 0$ and $R_2^f \leq 1$. There can hence be no decentralized equilibrium with $R_2^h = 1$. A similar argument can be made to show that there is no decentralized equilibrium with $R_2^f = 1$.

Second, when the funding costs satisfy $R_2^h = R_2^f = r$, then banks are better-off exchanging risk sharing

claims, i.e. $L^h; L^f > 0$ if $r \leq \beta$. When $r > \beta$, then according to (7), the costs of issuing claims ex ante satisfy $R_1^h > 1$ or $R_1^f > 1$, and banks do not exchange claims ex ante. Conversely, when $r \leq \beta$, banks exchange claims on risky assets L^h and L^f and this equilibrium holds if and only if the interest rate r and capital flows $\left(L^h; L^f\right)$ satisfy

$$r \leq \beta \text{ and } L^h \leq \lambda^h + (1-r)\, L^f \text{ and } L^f \leq \lambda^f + (1-r)\, L^h \tag{12}$$

Last when $r \leq \beta$, the constraints imposed by macro-prudential authorities in each region are binding. The total amount of claims issued by banks in each region hence satisfy $L^h = \mu^h \left(1 + L^h - L^f\right)$ and $L^f = \mu^f \left(1 + L^f - L^h\right)$. Solving for these two expressions yields (10). ■

The decentralized equilibrium has three important properties. First, there is always an excess supply of ex post funding, i.e. the funding costs $\left(R_2^h; R_2^f\right)$ are always at their lower bound r. According to (7), the return for banks to issuing claims ex ante should equate the return to ex post lending. As a result, when the latter goes up -because for instance of a scarcity of ex post funding-, then the former goes up one for one, but the cost to issuing claims ex ante needs to increase disproportionately (by $1/\beta > 1$). Thus, when ex post funding is scarce, banks prefer not to issue claims ex ante because it is just too costly. But if banks do not issue claims ex ante, then the demand for ex post funding falls and the scarcity of funding assumed at the beginning goes away. To put it in a nutshell, the friction β on the market for ex ante risk sharing prevents any scarcity of ex post funding at the equilibrium.[9]

Second, ex ante bank borrowing flows L^h and L^f are *negatively* related to each other through the macro-prudential policy parameters m^h and m^f: when macro-prudential policy in home is loosened, and m^h goes up, then banks of home issue a *larger* amount of claims L^h but banks from foreign are forced to issue a *lower* of amount of claims L^f. But conversely, ex ante borrowing flows L^h and L^f are *positively* related to each

[9] The reason for this paradox is relatively clear: introducing a friction on the market for risk sharing reduces the demand for ex post liquidity while it does not affect the supply, hence the lower likelihood of a scarcity of ex post funding. This can hold, for example, when the costs associated with cross-border risk sharing are only borne at the latest stage, so that the proceeds used to cover these costs are actually reinvested on the market for ex post liquidity. In this case, the supply for ex post liquidity would be unaffected by the presence of a friction on cross-border risk sharing while the demand for ex post would be reduced given that distressed banks which are credit constrained can borrow less.

other through the equilibrium conditions $L^h \leq \lambda^h + (1-r)\,L^f$ and $L^f \leq \lambda^f + (1-r)\,L^h$. When ex ante borrowing by home banks L^h goes up, and banks in foreign end up distressed, then both the funding supply $1 - L^f + L^h$ and the funding demand $\beta R_1^h L^h + 1 - \lambda^f$ go up as intact banks from home can provide more liquidity given that they invested more while distressed banks from foreign can also borrow more. However the supply for funding increases more than the demand for funding because the return on risky assets for banks from home is larger than the return they pay to banks from foreign through risk sharing contracts. As a result, the increase in home bank borrowing L^h exacerbates the situation of excess supply and home banks can afford to invest more in risky assets of banks from foreign, without compromising the excess supply on the market for ex post funding; hence the positive relationship between ex ante borrowing L^h and L^f. In other words, when banks in one region supply more risk sharing assets to the rest of the world, this in turn allows the rest of the world to issue more risk sharing assets.

Last, the equilibrium conditions $L^h \leq \lambda^h + (1-r)\,L^f$ and $L^f \leq \lambda^f + (1-r)\,L^h$ imply that larger ex ante borrowing can be sustained when interest rates $\left(r^h; r^f\right)$ are lower. Indeed, lower interest rates reduce the return on risk sharing assets and hence the demand for funding. As a result, the excess supply situation is compatible with larger cross-border risk sharing $\left(L^h; L^f\right)$.

4 Optimal interest rate policy.

We now move to the question of interest rate determination. To answer this question we consider two polar cases. First, the Nash equilibrium. In this equilibrium, a monetary authority sets in each region the interest rate on the domestic deposit facility, with the aim to maximize domestic welfare, taking as given the interest rate set in the other region. Second, we consider the case of cooperation in which interest rates are set to maximize global welfare, i.e. the sum of home and foreign banks profits.

4.1 The non-cooperative equilibrium.

In the non-cooperative equilibrium, each monetary authority determines the optimal domestic interest rate -that maximizes domestic banks' expected profits- as a best response to the other monetary authority's

interest rate decision. The problem for monetary authorities in region i ($i = \{h; f\}$) consists in choosing the interest rate r^i to solve

$$\begin{aligned} \max_{r^i} \quad & \pi^i\left(r^i\right) = \left[1 + \left(1 - \tfrac{r}{\beta}\right) L^i\right] r + (1 - r)\left(1 - \lambda^i\right) \\ \text{s.t. } & r = \max\left(r^h; r^f\right) \text{ and } L^h \leq \lambda^h + (1 - r) L^f \text{ and } L^f \leq \lambda^f + (1 - r) L^h \end{aligned} \tag{13}$$

The following proposition details the non-cooperative equilibrium in interest rates:

Proposition 2 *Denoting* $\frac{\lambda^n}{L^n} = \max\left\{\frac{\lambda^h}{L^h}; \frac{\lambda^f}{L^f}\right\}$, *optimal interest rates in the symmetric non cooperative equilibrium satisfy*

$$r^h = r^f = \min\{\beta; r_n\} \text{ with } r_n = \frac{\beta}{2}\left[1 + \frac{\lambda^n}{L^n}\right] \tag{14}$$

if and only if ex ante cross-border borrowing L^h *and* L^f *satisfy*

$$L^h \leq \lambda^h + (1 - \min\{\beta; r_n\}) L^f \text{ and } L^f \leq \lambda^f + (1 - \min\{\beta; r_n\}) L^h \tag{15}$$

Proof. The interest rates r^i which maximizes expected profits π^i writes as

$$r^i = \max\left\{r^{-i}; \frac{\beta}{2}\left[1 + \frac{\lambda^i}{L^i}\right]\right\}$$

Moreover, interest rates should satisfy $r^h; r^f \leq \beta$, so that the costs to issue liabilities ex ante satisfies $R_1^h; R_1^f \leq 1$ and banks are better-off issuing liabilities ex ante. Hence, the equilibrium interest rate when monetary policy makers play a Nash game writes as

$$r^h = r^f = \min\{\beta; r_n\} \text{ with } r_n = \frac{\beta}{2}\left[1 + \frac{\lambda^n}{L^n}\right]$$

Last, applying proposition 1, this situation is an equilibrium if and only if capital flows L^h and L^f are such that (15) holds. ■

Monetary authorities face a relatively simple trade-off: On the one hand, setting a high interest rate raises domestic banks' profits when domestic risky assets pay-off early, because domestic banks reap a higher return when lending to distressed banks from the other region. On the other hand, setting a high interest rate raises the cost to sell insurance which reduces the amount of liquidity banks can provide on the market for funding when their risky assets pay early and hence their profits. In addition, setting a higher interest rate reduces the profits of domestic banks when they are distressed.

Otherwise, the equilibrium interest rate is determined, everything else equal, in the region where banks issue less liabilities ex ante L^i. Setting a higher domestic interest rate raises the return paid on claims issued ex ante for risk sharing purposes. As a result, the larger the amount of claims issued ex ante, the lower the optimal interest rate. And with perfect arbitrage, the equilibrium interest rate is the largest one of the interest rates set in each region.[10] The equilibrium interest rate under the Nash equilibrium is therefore optimal for banks of one region but too high for banks of the other region. Turning to banks expected profits, assuming $r_n \leq \beta$, they write as

$$\pi_n^i = 1 - \lambda^i + r_n \left[\lambda^i + \left(1 - \frac{r_n}{\beta} \right) L^i \right] \tag{16}$$

4.2 The cooperative equilibrium.

In the cooperative equilibrium, each monetary authority still determines the optimal domestic interest rate as a best response to the other monetary authority's interest rate decision. The only difference with the non-cooperative equilibrium is that the two monetary authorities now maximize a common criterion, global welfare, i.e. the sum home anf foreign banks' expected profits. The problem in the cooperative equilibrium

[10] We will see that with endogenous macro-prudential policy, this result will be reversed: the "core" region, i.e. the region which sets the interest rate under Nash monetary policies will actually be the one issuing the larger not the lower amount of claims on risky assets ex ante, the reason being that optimal ex ante claim issuance L^i $(i = \{h; f\})$ will be increasing in λ^i.

therefore consists in choosing the interest rates r^h and r^f which solve

$$\begin{aligned} \max_{r^h;r^f} \quad & \pi\left(r^h;r^f\right) = \pi^h\left(r^h\right) + \pi^f\left(r^f\right) \\ \text{s.t. } r = \max\left(r^h;r^f\right) \text{ and } & L^h \leq \lambda^h + (1-r)\,L^f \text{ and } L^f \leq \lambda^f + (1-r)\,L^h \end{aligned} \tag{17}$$

The following proposition then details the cooperative equilibrium based on the solution to this problem.

Proposition 3 *Denoting* $\frac{\lambda^c}{L^c} = \frac{\lambda^h+\lambda^f}{L^h+L^f}$, *optimal interest rates in the cooperative equilibrium write as*

$$r^h = r^f = \min\{\beta; r_c\} \;\; \textit{with } r_c = \frac{\beta}{2}\left[1+\frac{\lambda^c}{L^c}\right] \tag{18}$$

if and only if ex ante cross-border borrowing L^h *and* L^f *satisfy*

$$L^h \leq \lambda^h + (1-\min\{\beta; r_c\})\,L^f \;\; \textit{and } L^f \leq \lambda^f + (1-\min\{\beta; r_c\})\,L^h \tag{19}$$

Proof. The interest rate r^i $(i = \{h; f\})$ which maximizes the sum of expected profits $\pi^h + \pi^f$ satisfies

$$r^i = \max\left\{r^{-i}; \frac{\beta}{2}\left[1+\frac{\lambda^c}{L^c}\right]\right\}$$

Moreover, as in the case of the Nash equilibrium, interest rates should satisfy $r^h; r^f \leq \beta$. As a result, the equilibrium interest rates when monetary policy makers play a cooperative game write as

$$r^h = r^f = \min\{\beta; r_c\} \;\; \text{with } r_c = \frac{\beta}{2}\left[1+\frac{\lambda^c}{L^c}\right] \tag{20}$$

Last applying proposition 1, this situation is an equilibrium if and only if bank ex ante borrowing L^h and L^f are such that (19) holds. ■

The optimal interest rate under cooperation r_c has three important properties. First, contrary to the optimal interest rate r_n in the Nash equilibrium which depends only on the characteristics of *one* region (at least locally), the optimal interest rate r_c in the cooperative equilibrium depends on the characteristics of

both regions. This difference is important because it has implications for how the macro-prudential policy parameters m^h and m^f affect the optimal interest rate, and thereby how macro-prudential policies affects financial conditions. Specifically, in the Nash equilibrium, assuming the optimal interest rate r_n is determined in home, looser macro-prudential policy in home, i.e. an increase in the policy parameter m^h, raises the amount of claims L^h issued by home banks and hence reduces the optimal interest rate r_n. Conversely, looser macro-prudential policy in foreign, i.e. an increase in the policy parameter m^f, cuts the amount of claims L^f issued by home banks and therefore raises the optimal interest rate r_n:

$$\frac{\partial r_n}{\partial m^h} \leq 0 \leq \frac{\partial r_n}{\partial m^f} \tag{21}$$

But in the case case of the cooperative equilibrium, an increase in either policy parameters m^h and/or m^f have a negative effect on the global interest rate r_c because under cooperation, the optimal interest rate depends (negatively) on the global amount of claims issued ex ante, which tends to increase in response to a positive change in either m^h or m^f.

$$\frac{\partial r_c}{\partial m^h} \leq 0 \text{ and } \frac{\partial r_c}{\partial m^f} \leq 0 \tag{22}$$

Second, the optimal interest rates set in the cooperative equilibrium are strictly lower than those set in the non-cooperative equilibrium. To see that, let us recall that when home sets the global interest rate in the Nash equilibrium -home is the core region and foreign is the periphery region-, then then the optimal interest rate is higher under the Nash than under the cooperative equilibria if and only if $\frac{\lambda^h}{L^h} \geq \frac{\lambda^h+\lambda^f}{L^h+L^f}$, which is equivalent to $\frac{\lambda^h}{L^h} \geq \frac{\lambda^f}{L^f}$, which holds by definition when home is the core region. Monetary authorities therefore set too high interest rates in the Nash equilibrium, this being due to the fact that monetary authorities in the core region fail to internalize the negative effect of their interest rate decision on expected profits of banks located in the periphery.

Third, denoting respectively π_c and π_n global expected profits under the cooperative and the Nash equilibrium and following on previous notation (region i is the core region), the gain in global welfare

stemming from cooperation writes as

$$\pi_c - \pi_n = (r_n - r_c)\left[\left[\frac{r_c + r_n}{\beta} - 1\right]\left(L^h + L^f\right) - \left(\lambda^h + \lambda^f\right)\right] = \frac{\beta}{4}\left[\frac{\lambda^h}{L^h} - \frac{\lambda^f}{L^f}\right]^2 \left[\frac{L^f}{L^h + L^f}\right]^2 \left[L^h + L^f\right] \tag{23}$$

According to (23), gains to monetary cooperation are decreasing in L^h but increasing in L^f. This is because larger borrowing from banks in the core region L^h tend to reduce the difference between the optimal interest rates under Nash and under cooperation $r_n - r_c$, while larger ex ante borrowing in the periphery region L^f tends to increase the difference between the optimal interest rates under Nash and under cooperation $r_n - r_c$. Next we investigate how gains to monetary policy cooperation are distributed among regions.

Proposition 4 *Banks from the core region are worse-off under cooperation.*

Proof. The change in expected profits for banks of region i, when comparing cooperation to Nash writes as

$$\pi_c^i - \pi_n^i = \left[\left[\frac{r_c + r_n}{\beta} - 1\right] L^i - \lambda^i\right](r_n - r_c)$$

Using the expressions for r_c and r_n, and assuming home is the core region, this expression writes for banks from home as

$$\pi_c^h - \pi_n^h = -\frac{\beta}{4}\left[\frac{\lambda^h}{L^h} - \frac{\lambda^f}{L^f}\right]^2 \left[\frac{L^f}{L^h + L^f}\right]^2 L^h$$

Banks from the core region therefore always lose when switching to the cooperative equilibrium. Turning to banks from the periphery, this quantity writes as

$$\pi_c^f - \pi_n^f = \frac{\beta}{4}\left[\frac{\lambda^h}{L^h} - \frac{\lambda^f}{L^f}\right]^2 \left[\frac{L^f}{L^h + L^f}\right]^2 \left[2L^h + L^f\right]$$

Banks from the periphery region therefore always benefit from monetary cooperation. ■

The Nash equilibrium is inefficient at the global level for two reasons: First competition on the market for ex post funding drives up the global interest rate to the maximum level of the two interest rates. Second, policy makers in the core region do not internalize the negative effect of high interest rates on banks from

the other region, which eventually leads to interest rates being too high. As a result, the global interest rate while optimal for banks from the core region, is too high for banks from the periphery region. Moving then to cooperation -which implies a lower equilibrium interest rate-, banks from the core region are necessarily worse-off while banks from the periphery are by definition, better-off.

5 Optimal macro-prudential policy.

Up to now, we have studied the problem of monetary authorities in each region choosing the interest rates r^h and r^f at which they can offer banks to park their funds. We now turn to the problem faced by macro-prudential authorities. As stated above, macro-prudential authorities can affect the amount of liabilities L^h and L^f banks issue and thereby the amount of cross-border risk sharing through the policy parameters m^h and m^f which limit banks' ability to leverage up.

5.1 Optimal risk sharing with non-cooperative interest rate setting.

In this section, we assume that interest rates are set in a Nash equilibrium. Under this assumption, we first look at the case of optimal macro-prudential policies in the non-cooperative equilibrium and then turn to determining optimal macro-prudential policies under cooperation.

5.1.1 Non-cooperative risk sharing.

When monetary and macro-prudential policies are determined in a Nash equilibrium, then, assuming home is the region which determines the global interest rate, i.e. the core region, the problem for macro-prudential authorities in region i ($i = \{h; f\}$) consists in solving:

$$\max_{m^i} \quad \pi^i\left(r_n; L^i\right) = 1 - \lambda^i + r_n\left[\lambda^i + \left(1 - \frac{r_n}{\beta}\right) L^i\right]$$
$$\text{s.t.} \begin{cases} r_n = \frac{\beta}{2}\left(1 + \frac{\lambda^h}{L^h}\right) \text{ and } \frac{\lambda^h}{L^h} \leq 1 \text{ and } \frac{\lambda^h}{L^h} \geq \frac{\lambda^f}{L^f} \\ L^h = \frac{m^h\left(1-m^f\right)}{1-m^f m^h} \text{ and } L^f = \frac{m^f\left(1-m^h\right)}{1-m^h m^f} \\ L^h \leq \lambda^h + \left(1 - r_n\right) L^f \text{ and } L^f \leq \lambda^f + \left(1 - r_n\right) L^h \end{cases} \tag{24}$$

In this problem, macro-prudential policy makers in region i control through the parameter m^i the amount of borrowing of their domestic banks. In addition, affecting their bank borrowing may change positively or negatively the global interest rate r_n depending on whether they are in the core or in the periphery.

Proposition 5 *When interest rates and ex ante bank borrowing are determined non-cooperatively and parameters satisfy $\lambda_h > \lambda_f$, then home is the core region; foreign is the periphery region and macro-prudential authorities set policies such that banks ex ante borrowing satisfies*

$$L^h = \lambda^h + (1 - r_n) L^f \text{ and } L^f = \min\left\{\lambda^f + (1 - r_n) L^h; L^n\right\} \tag{25}$$

where

$$L^n = \frac{2\lambda^h \lambda^f L^h + \left(L^h\right)^2 - \left(\lambda^h\right)^2}{\left(L^h\right)^2 + \left(\lambda^h\right)^2}$$

Proof. Let us assume that $\lambda_h > \lambda_f$ and home is the core. Expected profits of banks in home are then strictly increasing in m^h: Allowing banks to pledge a larger fraction of their initial investment in risky assets increases bank borrowing which is positive for banks' expected profits. Moreover this reduces the global interest rate r_n, but this has no effects on banks' expected profits given that r_n is by definition the profit maximizing interest rate:

$$\frac{\partial \pi^h}{\partial m^h} = \frac{\partial \pi^h}{\partial L^h}\frac{\partial L^h}{\partial m^h} + \underbrace{\frac{\partial \pi^h}{\partial r_n}}_{=0}\frac{\partial r_n}{\partial L^h}\frac{\partial L^h}{\partial m^h} > 0 \tag{26}$$

Macro-prudential authorities in the core region therefore choose to maximize capital inflows L^h. Given the upper bound on capital flows L^h, we have

$$L^h = \min\left\{\lambda^h + (1 - r_n) L^f; \frac{\lambda^h}{\lambda^f} L^f\right\} \tag{27}$$

Turning to the case of the periphery, banks expected profits π^f depend on the fraction m^f in two opposite ways. For one, a higher parameter m^f raises bank ex ante borrowing L^f which raises expected profits. But, this also has a negative effect on bank ex ante borrowing in the core L^h, which raises the global interest rate

r_n and thereby reduces expected profits for banks in the periphery as the Nash equilibrium interest rate is too high:

$$\frac{\partial \pi^f}{\partial m^f} = \left(1 - \frac{r_n}{\beta}\right) r_n \frac{\partial L^f}{\partial m^f} + \left[\lambda^f + \left(1 - \frac{2}{\beta} r_n\right) L^f\right] \frac{\partial r_n}{\partial L^h} \frac{\partial L^h}{\partial m^f} \tag{28}$$

Moreover one can easily check that banks expected profits π^f are concave in the macro-prudential policy m^f. As a result, macro-prudential policy makers in the periphery region set the parameter m^f such that $\frac{\partial \pi^f}{\partial m^f} = 0$. Then making use of the property that $L^h = m^h \left(1 - L^f\right)$, the optimality condition $\frac{\partial \pi^f}{\partial m^f} = 0$ writes as:

$$\frac{\beta}{4} \left[1 - \left(\frac{\lambda^h}{L^h}\right)^2 - 2 \left[\frac{\lambda^h}{L^h} - \frac{\lambda^f}{L^f}\right] \frac{\lambda^h}{L^h} \frac{L^f}{1 - L^f}\right] \frac{\partial L^f}{\partial m^f} = 0 \tag{29}$$

We then have two cases to look at.

If bank ex ante borrowing in the core satisfies $L^h = \frac{\lambda^h}{\lambda^f} L^f$ then expected profits in the periphery π^f are strictly increasing in m^f and optimal borrowing for banks in the periphery satisfies $L^f = \max\left\{\frac{\lambda^f}{\lambda^h} L^h; \lambda^f + (1 - r_n) L^h\right\}$. However for bank ex ante borrowing in the core to satisfy $L^h = \frac{\lambda^h}{\lambda^f} L^f$, the inequality $\frac{\lambda^h}{\lambda^f} L^f \leq \lambda^h + (1 - r_n) L^f$ must hold which requires $\lambda^f \geq \lambda^h$, but is impossible since we assumed $\lambda^h > \lambda^f$.

Conversely, if ex ante borrowing from home banks satisfies $L^h = \lambda^h + (1 - r_n) L^f$ then the first-order condition (29) which determines optimal ex ante borrowing from foreign banks then writes as

$$\left(\frac{L^h}{\lambda^h}\right)^2 = 1 + 2 \frac{L^f - \lambda^f \frac{L^h}{\lambda^h}}{1 - L^f} \tag{30}$$

Denoting L^n the value of L^f which satisfies (30), optimal bank ex ante borrowing under the Nash equilibrium therefore satisfies

$$L^h = \lambda^h + (1 - r_n) L^f \text{ and } L^f = \min\left\{\lambda^f + (1 - r_n) L^h; L^n\right\} \tag{31}$$

■

Macro-prudential authorities in the periphery region may refrain from maximizing bank ex ante borrowing. The reason is that larger borrowing on the one hand increases directly banks' expected profits but on the other hand, reduces expected profits through the effect on the global interest rate. Indeed when borrowing

by banks from the periphery increases, this reduces borrowing by banks in the core, which raises the global interest rate. However, the global interest rate in the Nash equilibrium is already too high for the periphery. As a result, raising it further reduces banks' expected profits. This is why macro-prudential authorities in the periphery actually limit domestic bank borrowing as this contributes to reduce the global interest rate and hence improve domestic welfare.

5.1.2 Cooperative risk sharing.

Let us now turn to optimal macro-prudential policies under cooperation. Assuming as in the previous section that monetary policy is conducted in a Nash game, the global planner chooses m^h and m^f to solve

$$\max_{m^h;m^f} \pi_c\left(r_n; L^h; L^f\right) = \pi^h\left(r_n; L^h\right) + \pi^f\left(r_n; L^f\right)$$
$$\text{s.t.} \begin{cases} L^h = m^h \frac{1-m^f}{1-m^f m^h} \text{ and } L^f = m^f \frac{1-m^h}{1-m^h m^f} \\ r_n = \frac{\beta}{2}\left(1 + \frac{\lambda^h}{L^h}\right) \text{ and } \frac{\lambda^h}{L^h} \leq 1 \text{ and } \frac{\lambda^h}{L^h} \geq \frac{\lambda^f}{L^f} \\ L^h \leq \lambda^h + (1-r_n) L^f \text{ and } L^f \leq \lambda^f + (1-r_n) L^h \end{cases} \tag{32}$$

We can derive the following proposition.

Proposition 6 *When interest rates are set non-cooperatively but ex ante capital flows are set cooperatively and parameters satisfy $\lambda^h > \lambda^f$, then home is the core region; foreign is the periphery region and macro-prudential authorities set policies such that bank ex ante borrowing L^h and L^f such that*

$$L^h = \lambda^h + (1-r_n) L^f \text{ and } L^f = \lambda^f + (1-r_n) L^h \tag{33}$$

Proof. Let us assume that $\lambda_h > \lambda_f$ and home is the core. Then expected profits π_c are strictly increasing in m^h since we have

$$\frac{\partial \pi_c}{\partial m^h} = \frac{\beta}{4}\left[\left(1-\left[\frac{\lambda^h}{L^h}\right]^2\right)\left(1-m^f\right)+2\left[\frac{\lambda_h}{L_h}-\frac{\lambda^f}{L^f}\right]\frac{L^f}{L^h}\frac{\lambda^h}{L^h}\right]\frac{\partial L^h}{\partial m^h} > 0 \tag{34}$$

When macro-prudential policy makers in the core allow domestic banks to issue more claims for risk sharing, global bank borrowing $L^h + L^f$ increases and so do global expected profits. Moreover given that monetary policy is conducted in a Nash game, the equilibrium interest rate is too high for the global economy. Hence larger borrowing for banks in the core -as it contributes to ease funding conditions on the market for ex post funding- further increases global expected profits. Optimal macro-prudential policy in the core region therefore still consists in the cooperative game in maximizing bank ex ante borrowing:

$$L^h = \min\left\{\frac{\lambda^h}{\lambda^f}L^f; \lambda^h + (1-r_n)\,L^f\right\} \tag{35}$$

Turning to optimal macro-prudential policy in the periphery, it is straightforward to note that global expected profits π_c are strictly increasing in m^h when $L^h = \frac{\lambda^h}{\lambda^f}L^f$. The optimal macro-prudential policy in the periphery would then satisfy $L^h = \lambda^h + (1-r_n)\,L^f$. However, as was mentioned above, this case is not possible because it requires $\lambda^h < \lambda^f$. We are hence left with the case where optimal macro-prudential policy in the core region is such that bank ex ante borrowing L^h satisfies $L^h = \lambda^h + (1-r_n)\,L^f$. We then have two possible cases. In the first one, optimal macro-prudential policy in the periphery is an interior solution. It then satisfies

$$\frac{\partial \pi_c}{\partial m^f} + \frac{dm^h}{dm^f}\frac{\partial \pi_c}{\partial m^f} = 0 \text{ with } \frac{dm^h}{dm^f} = \frac{1-m^h}{1-m^f}\frac{1-r_n+\left(1+\frac{\partial r_n}{\partial L^h}L^f\right)m_h}{(1-r_n)\,m^f+1+\frac{\partial r_n}{\partial L^h}L^f} \tag{36}$$

the second expression measuring how macro-prudential policy makers in the core respond to a change in macro-prudential policy in the periphery along the optimality condition $L^h = \lambda^h + (1-r_n)\,L^f$. Alternatively optimal macro-prudential policy in the periphery can be a corner solution and ex ante borrowing by banks in the periphery satisfies $L^f = \lambda^f + (1-r_n)\,L^h$. To solve for the case of the interior solution, we can use the

expressions for the first derivatives of global expected profits $\frac{\partial \pi_c}{\partial m^h}$ and $\frac{\partial \pi_c}{\partial m^f}$. Given that the latter writes as

$$\frac{\partial \pi_c}{\partial m^f} = \frac{\beta}{4}\left[\left(1-\left[\frac{\lambda^h}{L^h}\right]^2\right)\left(1-m^h\right) - 2\frac{L^f}{\lambda^h}\left[\frac{\lambda^h}{L^h}-\frac{\lambda^f}{L^f}\right]\left[\frac{\lambda_h}{L^h}\right]^2 m^h\right]\frac{\partial L^f}{\partial m^f} \tag{37}$$

And denoting A the positive scalar such that $\frac{dm^h}{dm^f} = \frac{1-m^h}{1-m^f}A$, the expression for the first order condition (36) simplifies as

$$1-\left[\frac{\lambda^h}{L^h}\right]^2 = 2\left[\frac{\lambda^h}{L^h}-\frac{\lambda^f}{L^f}\right]\frac{L^f}{L^h}\frac{\lambda^h}{L^h}\frac{m^h-A}{1-m^h+\left(1-m^f\right)A}$$

Yet given that $A > m^h$ this condition would imply that $L^h < \lambda^h$, which is not possible given that we have $L^h = \lambda^h + (1-r_n)L^f > \lambda^h$. There is hence no macro-prudential policy m^f which maximizes global expected profits π_c while being an interior solution. As a result, we a left with a single possibility: the macro-prudential policies which maximize global expected profits under cooperation satisfy

$$L^h = \lambda^h + (1-r_n)L^f \text{ and } L^f = \lambda^f + (1-r_n)L^h \tag{38}$$

And one can check that under such a solution we have $\frac{\partial \pi_c}{\partial m^f} + \frac{dm^h}{dm^f}\frac{\partial \pi_c}{\partial m^h} > 0$ so that the constraint $L^f \leq \lambda^f + (1-r_n)L^h$ is effectively binding. ■

Bank ex ante borrowing tends to be larger and the global interest rate tends to be lower under cooperative macro-prudential policies. To understand why, recall that with non-cooperative monetary policies, the equilibrium interest rate is optimal for banks in the core region, but too high for banks in the periphery. As a result, with non cooperative macro-prudential policies, the periphery is willing to restrict domestic bank borrowing with the aim that this will help banks in the core leverage up by more, which will eventually, give monetary policy makers in the core incentives to set a lower interest rate. Macro-prudential policy in the periphery therefore trades off the benefits of larger domestic bank borrowing against the cost of suboptimal funding conditions.

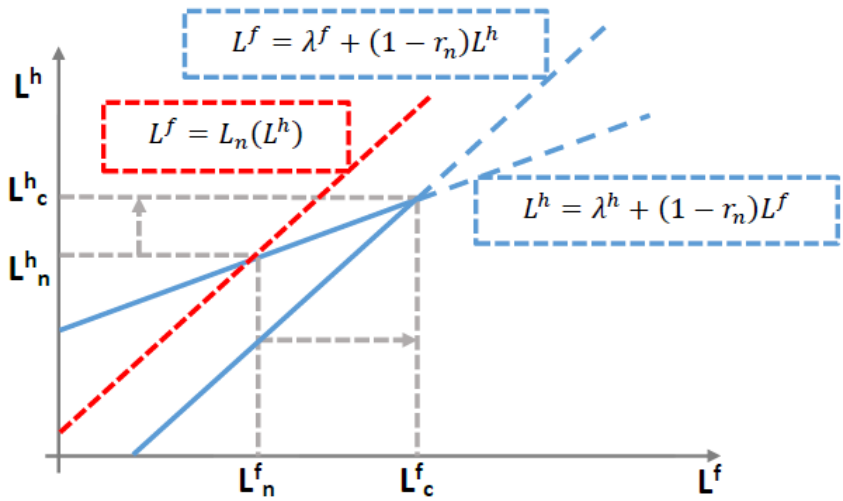

Figure 3: Optimal macro-prudential policies under Nash monetary policies.

But with cooperative macro-prudential policies, macro-prudential policy makers in the periphery internalise that leverage in the core is a positive not a negative function of leverage in the periphery. This is because as banks in the periphery leverage up and supply more risk sharing assets to banks in the core, banks in the core get more diversified. Being more diversified, banks in the core can in turn leverage up by more and supply more risk sharing assets to banks from the periphery. And by doing so, this gives incentives to monetary policy makers in the core to set a lower interest rate.

5.1.3 Gains to macro-prudential policy cooperation under Nash interest rate setting.

Comparing expected profits under cooperative macro-prudential policies with expected profits under Nash macro-prudential policies, we can easily compute the welfare gains each region enjoys as a result from cooperation. Denoting π_c^i (resp. π_n^i) expected profits of banks from region i under cooperative macro-prudential policies (resp. under Nash macro-prudential policies) when monetary policies are conducted in a Nash game, and assuming the home region is the core region, we have

$$\pi_s^i = 1 - \lambda^i + \left[\lambda^i + \left(1 - \frac{1}{\beta} r_n\left(L_s^h\right)\right) L_s^i\right] r_n\left(L_s^h\right) \text{ for } s = \{n; c\} \tag{39}$$

where L^n (resp. L_c^i) denotes borrowing from banks of region i when macro-prudential policy is Nash (resp. cooperative) and monetary policy is Nash, and the equilibrium interest rate r_n writes as

$$r_n = \min\left\{\beta; \frac{\beta}{2}\left(1 + \frac{\lambda^h}{L_s^h}\right)\right\} \tag{40}$$

Then assuming $L_s^i \geq \lambda^i$ for $i = \{h; f\}$ and $s = \{n; c\}$, this expression simplifies in the case of the interest rate setting region, as

$$\pi_c^h - \pi_n^h = \frac{\beta}{4}\left[1 - \frac{\lambda^h}{L^n}\frac{\lambda^h}{L_c^h}\right]\left(L_c^h - L^n\right) \tag{41}$$

As is clear, the increase in expected profits for banks in the core region is proportional to the increase in bank borrowing $\left(L_c^h - L^n\right)$, which is consistent with the fact that the global interest rate r_n being optimal for such banks, changes in this interest rate have no effect on expected profits in the core region. Turning to banks in the periphery, the change in expected profits when macro-prudential policies move from Nash to cooperation writes as:

$$\pi_c^f - \pi_n^f = \frac{\beta}{4}\left[1 - \frac{\lambda^h}{L_c^h}\frac{\lambda^h}{L^n}\right]\left(L_c^f - L^n\right) + \frac{\beta}{4}\frac{\lambda^h}{L^n}\left[\left(\frac{\lambda^h}{L^n} - \frac{\lambda^f}{L^n}\right)L_n^f + \left(\frac{\lambda^h}{L_c^h} - \frac{\lambda^f}{L_c^f}\right)L_c^f\right]\left(L_c^h - L_n^h\right) \tag{42}$$

This expression has two terms. The first term represents the increase in expected profits for banks of the periphery due to the increase in capital inflows under cooperative macro-prudential policies relative to the Nash equilibrium. It is similar to the expression for the change in expected profits for banks of the core region in the sense that it is equally proportional to the increase in domestic bank borrowing. The second term on the right hand side of expression (42) represents the increase in expected profits for banks of the periphery region stemming from the drop in the global interest rate under cooperation. As was noted above, when monetary policies are conducted non-cooperatively, the global interest rate is too high for banks of the periphery. Hence a lower interest rate is always positive for such banks. This is why banks from the periphery region benefit from macro-prudential policy coordination along two margins: larger borrowing and a lower global interest rate. So, unlike the case of monetary policy, coordinating on macro-prudential

policy is a Pareto improvement as both regions enjoy positive net gains, this being due to the presence of the positive (general equilibrium) externality in cross-border bank borrowing.

5.2 Optimal risk sharing with cooperative interest rate setting.

We now move to the case of optimal macro-prudential policy when interest rates are set cooperatively. Under this assumption, we first look at the case of optimal macro-prudential policies in the cooperative equilibrium and then turn to determining optimal macro-prudential policies under Nash.

5.2.1 Cooperative risk sharing.

When macro-prudential authorities play a cooperative game and the interest rate on the market for ex post funding is set cooperatively between central banks, the global planner chooses m^h and m^f to solve

$$\max_{m^h;m^f} \pi_c\left(r_c; L^h; L^f\right) = \pi^h\left(r_c; L^h\right) + \pi^f\left(r_c; L^f\right)$$
$$\text{s.t.} \begin{cases} r_c = \frac{\beta}{2}\left(1 + \frac{\lambda^h+\lambda^f}{L^h+L^f}\right) \text{ and } L^h + L^f \geq \lambda^h + \lambda^f \\ L^h = \frac{m^h\left(1-m^f\right)}{1-m^f m^h} \text{ and } L^f = \frac{m^f\left(1-m^h\right)}{1-m^f m^h} \\ L^h \leq \lambda^h + (1-r_c)\, L^f \text{ and } L^f \leq \lambda^f + (1-r_c)\, L^h \end{cases} \tag{43}$$

Proposition 7 *Denoting $\underline{r} = \frac{\beta}{2-\beta}$, when interest rates and bank borrowing are determined cooperatively then macro-prudential authorities choose bank borrowing L^h and L^f to satisfy:*

$$L^h = \lambda^h + (1-\underline{r})\, L^f \text{ and } L^f = \lambda^f + (1-\underline{r})\, L^h \tag{44}$$

Proof. Using the expression for r_c, it is straightforward to note that global expected profits are increasing in both m^h and m^f. As a result, macro-prudential policy makers in both regions maximize bank borrowing, i.e. $L^h = \lambda + (1-r_c)\, L^f$ and $L^f = \lambda^f + (1-r_c)\, L^h$. Solving from these two equations for L^h and L^f yields expressions in (44). ■

Macro-prudential policy makers choose to maximize capital inflows when monetary and macro-prudential policies are set cooperatively because there is no trade-off between managing capital flows and managing the global funding cost:by definition, the latter is set at the level which maximizes global expected profits, i.e. $\frac{\partial \pi_c}{\partial r_c} = 0$. It is therefore always welfare improving to increase bank borrowing as the global interest rate by construction adjusts so that it does not affect, at the margin, global expected profits. Macro-prudential policy makers therefore choose to maximize bank borrowing L^h and L^f, i.e. set them such that the conditions under which the decentralized equilibrium holds bind, i.e. $L^f = \lambda^f + (1 - r_c) L^h$ and $L^h = \lambda^h + (1 - r_c) L^f$, which yields expression (44). Let us now look at optimal macro-prudential policies under the Nash equilibrium.

5.2.2 Non-cooperative risk sharing.

Let us now turn to optimal macro-prudential policies under Nash. Assuming as in the previous section that monetary policy is conducted in a cooperative game, the macro-prudential policy maker in region i chooses m^i to solve

$$\max_{m^i} \pi^i \left(r_c; L^i\right)$$
$$\text{s.t.} \begin{cases} r_c = \frac{\beta}{2}\left(1 + \frac{\lambda^h + \lambda^f}{L^h + L^f}\right) \text{ and } L^h + L^f \geq \lambda^h + \lambda^f \\ L^h = \frac{m^h\left(1 - m^f\right)}{1 - m^f m^h} \text{ and } L^f = \frac{m^f\left(1 - m^h\right)}{1 - m^f m^h} \\ L^h \leq \lambda^h + (1 - r_c) L^f \text{ and } L^f \leq \lambda^f + (1 - r_c) L^h \end{cases} \tag{45}$$

We can now derive the following proposition.

Proposition 8 *Denoting $\underline{r} = \frac{\beta}{2-\beta}$, when interest rates are determined cooperatively but and ex ante bank borrowing are determined non-cooperatively then macro-prudential authorities choose*

$$L^h = \lambda^h + (1 - \underline{r}) L^f \text{ and } L^f = \lambda^f + (1 - \underline{r}) L^h \tag{46}$$

Proof. When macro-prudential policy makers in region i allow banks to increase ex ante borrowing, the change in expected profits writes as

$$\frac{\partial \pi^i \left(r_c; L^i\right)}{\partial m^i} = r_c \left(1 - \frac{1}{\beta} r_c\right) \frac{\partial L^i}{\partial m^i} + \frac{\partial r_c}{\partial \left(L^i + L^{-i}\right)} \frac{\partial \left(L^i + L^{-i}\right)}{\partial m^i} \left[\lambda^i + \left(1 - \frac{2}{\beta} r_c\right) L^i\right] \tag{47}$$

As is clear, the first term of the RHS expression $r_c\left(1-\frac{1}{\beta}r_c\right)\frac{\partial L^i}{\partial m^i}$ is always positive because allowing banks to issue more claims ex ante always contributes to raise expected profits. But the second term, which represents the effect on expected profits of a change in the interest rate r_c stemming from an increase in claims issued ex ante by banks in region i, could be either positive or negative. For instance, when $\frac{\lambda^h}{L^h} \geq \frac{\lambda^f}{L^f}$, this term is positive for banks from foreign but negative for banks from home. For the former, the equilibrium interest rate under cooperation r_c is too high relative to the domestically optimal interest rate. Hence reducing the interest rate r_c by allowing domestic banks to be more leveraged always raises domestic expected profits:

$$\frac{\partial \pi^f}{\partial m^f} = \frac{\beta}{4}\left[1-\left[\frac{\lambda^h+\lambda^f}{L^h+L^f}\right]^2 + 2\left[\frac{\lambda^h+\lambda^f}{L^h+L^f}\right]^2\left(1-m^h\right)\left[\frac{\lambda^h}{L^h}-\frac{\lambda^f}{L^f}\right]\frac{L^hL^f}{\lambda L}\right]\frac{\partial L^f}{\partial m^f} > 0 \tag{48}$$

Macro-prudential authorities in foreign therefore choose to set m^f such that

$$L^f = \lambda^f + (1-r_c)\,L^h \tag{49}$$

Conversely macro-prudential authorities in home face a trade-off when setting the optimal level of bank leverage since on the one hand increasing bank borrowing is positive for domestic welfare but on the other doing so reduces the equilibrium interest rate r_c which reduces welfare because, under the assumption that $\frac{\lambda^h}{L^h} \geq \frac{\lambda^f}{L^f}$, the interest rate r_c is too low from a domestic perspective:

$$\frac{\partial \pi^h}{\partial m^h} = \frac{\beta}{4}\left[1-\left[\frac{\lambda^h+\lambda^f}{L^h+L^f}\right]^2 - 2\left[\frac{\lambda^h+\lambda^f}{L^h+L^f}\right]^2\left(1-m^f\right)\left[\frac{\lambda^h}{L^h}-\frac{\lambda^f}{L^f}\right]\frac{L^hL^f}{\lambda L}\right]\frac{\partial L^h}{\partial m^h} \tag{50}$$

Now given that $\frac{\partial \pi^h}{\partial m^h}$ is increasing in m^h for $\frac{\partial \pi^h}{\partial m^h} = 0$, i.e. $\pi^h(r_c)$ is convex in m^h, macro-prudential authorities therefore choose either to minimize m^h and set L^h such that $L^h = \lambda^h + \lambda^f - L^f$ or they choose to maximize m^i and set $L^h = \min\left\{\lambda^h + (1-r_c)\,L^f; \frac{\lambda^h}{\lambda^f}L^f\right\}$. Comparing expected profits under this two different options shows that maximizing m^h is always the policy choice which maximizes expected profits.

Hence macro-prudential policy makers in home choose

$$L^h = \min\left\{\lambda^h + (1 - r_c)\, L^f; \frac{\lambda^h}{\lambda^f} L^f\right\} \tag{51}$$

Last if macro-prudential policy makers home set $L^h = \lambda^h + (1 - r_c)\, L^f$, then the validity condition $\lambda^h + (1 - r_c)\, L^f \leq \frac{\lambda^h}{\lambda^f} L^f$ turns into $\lambda^f \leq \lambda^h$ which always holds by definition. Optimal macro-prudential policies hence satisfy

$$L^f = \lambda^f + (1 - \underline{r})\, L^h \text{ and } L^h = \lambda^h + (1 - \underline{r})\, L^f \tag{52}$$

■

When interest rates are determined cooperatively, the optimal interest rate is too high for banks located in what would be the periphery with non-cooperative monetary policies and too low for banks located in what would be the core with non-cooperative monetary policies. For macro-prudential policy makers of this former (periphery) region, there is no trade-off between allowing domestic banks to borrow more and reducing the cost of ex post funding as more borrowing leads to a lower global interest rate, both of which contribute to increase expected profits. But in the latter (core) region, macro-prudential policy makers face a trade-off: allowing banks to borrow more has a positive direct effect on banks expected profits but it also carries a negative indirect effect as larger bank borrowing reduce the global interest rate which cuts domestic banks profits given that the global interest rate is too low from a domestic perspective. Yet, macro-prudential policy makers always choose to maximize bank borrowing. Why ? The reason is very simple: In the cooperative game, the equilibrium interest rate depends on *global* bank borrowing, which each macro-prudential policy maker has only limited influence on. As a result, the macro-prudential policy maker always prefers to maximize capital inflows, the cost of setting financial conditions in line with domestic needs being too large relative to the benefits of simply allowing banks to enjoy larger borrowing. When monetary policy makers play a cooperative game, the conclusion is hence that optimal macro-prudential policy always consists in maximizing bank borrowing, whether macro-prudential policy is decided cooperatively or not. In other words, gains to macro-prudential policy cooperation go away under cooperative monetary policies.

6 Quantifying the gains to policy coordination.

In this section, we aim at quantifying the model's findings to determine how large gains from policy cooperation can be. To do so, we focus on three parameters of the model. The first one is the β parameter which scales the friction on the market risk sharing. The second and the third are respectively the parameters λ^h and λ^f, each of which determines how much banks can borrow ex post. For each of these parameters we consider a range of possible values as follows. We assume the β parameter scaling the friction on the market for risk sharing ranges from 0.55 to 0.95. This means that between 5% and 45% of the return on assets traded on the market risk sharing is paid by the issuer without being earned by the buyer. Turning to the parameters λ^h and λ^f, we assume λ^h ranges between 0.4 and 0.8, while the parameter λ^f ranges between 0.0 and 0.4. Given that we always have $\lambda^h \geq \lambda^f$, home will be the core region while foreign will be the periphery region. For each combination of parameters $\left(\beta; \lambda^h; \lambda^f\right)$, we compute two different measures. We first derive welfare gains computed as the relative change in expected profits (global or regional) under alternative scenarios for monetary and macro-prudential policies.

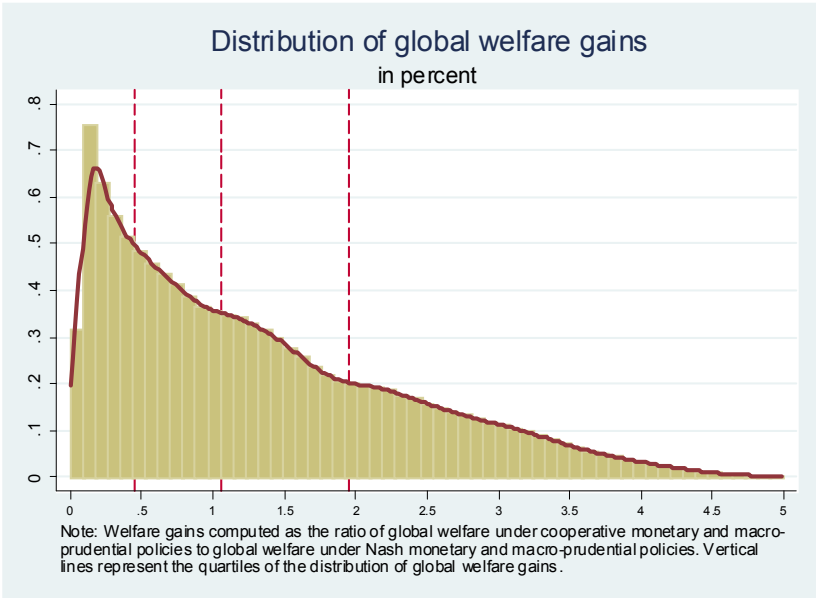

Figure 4: Distribution of global welfare gains.

First we compare global welfare under cooperative (monetary and macro-prudential) policies with global welfare under Nash (monetary and macro-prudential) policies. Figure 4 plots the distribution of these wel-

fare gains for all possible combinations of the parameters $\left(\beta; \lambda^h; \lambda^f\right)$ within the ranges described above. Global welfare gains range roughly from 0 to 4.5%, the median gain is around 1.06% and the inter-quartile range goes from around 0.5% to around 2%. Welfare gains at the global level therefore tend to exhibit a relatively wide dispersion.

With these first findings in mind, we decompose welfare gains at the global level into two different ways. First we split global welfare gains by region. To do so we compute welfare gains due to macro-prudential policy coordination assuming non-cooperative monetary policies and welfare gains due to monetary policy coordination assuming cooperative macro-prudential policies. The left hand panel in Figure 5 shows that the periphery region (green box) tends to grab a significantly larger part of coordination gains.

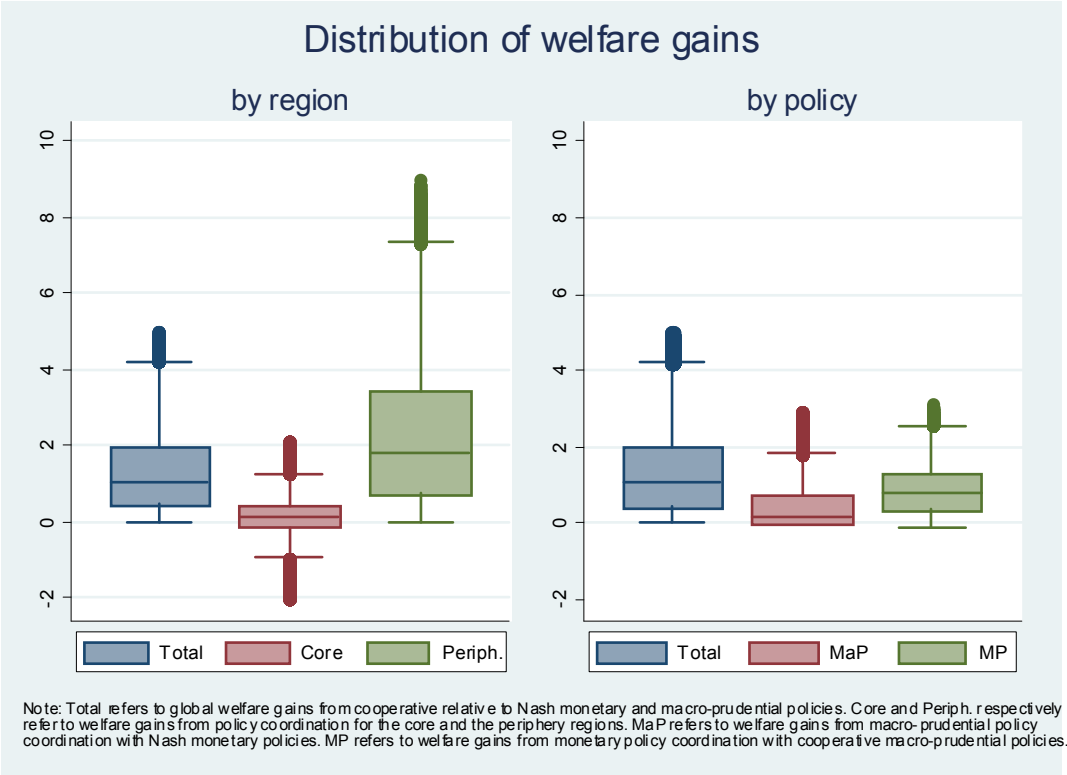

Figure 5: Distributions of welfare gains by region, by policy.

At the median, welfare increases globally by 1.06% (average increase is 1.3%) but this overwhelmingly comes from welfare gains in the periphery (whose median stands at 1.8% for an average welfare gain of 2.26%) while in the core region the median increase in welfare is only 0.10% (average at 0.16%). Moreover the

core region is actually worse-off under coordinated monetary and macro-prudential policies in more than one third of the different combinations of parameters (37.7% of the cases) with a an average welfare loss of 0.28% (median at 0.19%), something that never happens in the periphery which is always better-off under coordinated policies. As was highlighted above, the core region may suffer welfare losses because coordinating monetary policies implies abandoning its dominant role in setting the global interest rate and thereby moving from domestically optimal to domestically suboptimal funding conditions. By contrast, for the periphery coordinating monetary policies means that funding conditions, while still suboptimal from a domestic perspective will be less sub-optimal than in the case of Nash monetary policies. As a consequence, shifting to cooperative macro-prudential and/ monetary policies always delivers relatively larger gains.

Secondly we look at the contribution of coordinating each policy separately. To do so we first compute welfare gains due to macro-prudential policy coordination assuming non-cooperative monetary policies (red box) and then welfare gains due to monetary policy coordination assuming cooperative macro-prudential policies (green box). The right hand panel in Figure 5 shows the distribution of total welfare gains as well as those of each policy separately. Global welfare gains from monetary policy coordination typically tend to outweigh those from macro-prudential policy coordination. For example the average gain in global welfare is about 1.30% (median gain is 1.06%). But the contribution of monetary policy coordination is about two thirds of the total gain (0.87%), while that of macro-prudential policy coordination is only one third (0.43%).[11] This observation is not surprising: under coordinated monetary policy, funding conditions on the market for ex post funding are optimal from a global perspective and how macro-prudential policy is conducted is then irrelevant. By contrast coordinating macro-prudential policy under Nash monetary policies reduces the inefficiency from sub-optimal ex post funding conditions but is never able to eliminate it. And sometimes (with roughly a 25% probability), coordinating macro-prudential policy does not bring any welfare benefit. This is why global welfare gains from monetary policy coordination tend to outpace those from macro-prudential policy coordination.

Last, we look at welfare gains from policy coordination across policies and regions. Focusing first on the

[11] Looking at medians, total welfare gains are even more reliant on gains from monetary policy coordination: the latter represent about 73% of the former (0.78% out of 1.06%).

periphery region, the left hand panel in figure 6 shows that total welfare gains are mostly driven by monetary policy coordination. On average around 75% of total welfare gains come from coordinating monetary policies (1.62% out of 2.25%) while macro-prudential policy coordination only accounts for 25% of total welfare gains (0.63% out of 2.25%). Conversely, in the core region, total welfare gains tend to be much smaller (0.16% on average and 0.1% at the median), but they all come macro-prudential policy coordination (+0.19% on average) as monetary policy coordination yields no welfare gain on average (-0.03%). These findings confirm the conclusion derived analytically that macro-prudential policy coordination unlike monetary policy coordination is a Pareto improvement, as there are no cases where coordinating macro-prudential policy reduces welfare, neither in the core nor in the periphery region.

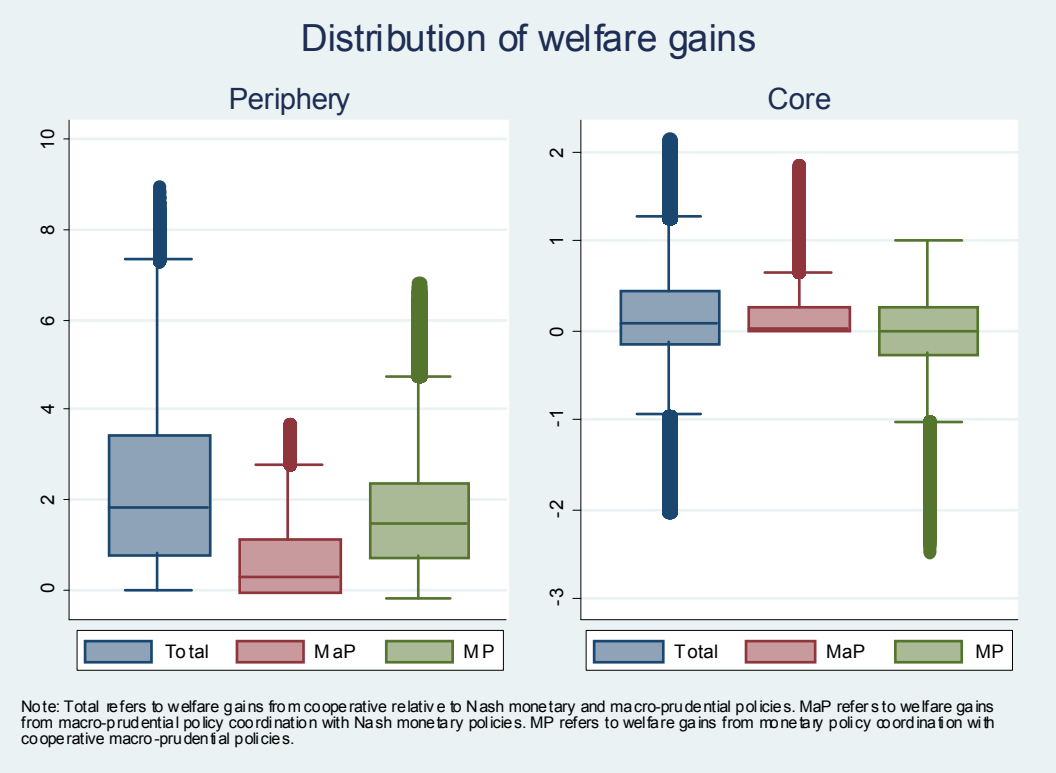

Figure 6: Welfare gains of policy coordination across regions.

Last, Figure 7 provides the correlations across regions in coordination gains and confirms that coordination gains that accrue to the periphery tend to exhibit relatively low correlation with the total gains that accrue to the core region. And these low correlations actually hide two sets of opposite correlations: on the one

hand, a positive and large correlation between gains from macro-prudential policy cooperation that accrue to the core region and cooperation gains that accrue to the periphery. But on the other hand a negative correlation between gains from monetary policy cooperation that accrue to the core region and cooperation gains that accrue to the periphery. These findings reinforce the general point that incentives to cooperate on macro-prudential policy are more aligned across regions than those to cooperate on monetary policy.

Core / Periphery	Total coordination gains	Gains from MaP coordination	Gains from MP coordination
Total coordination gains	0.174	0.766	-0.322
Gains from MaP coordination	0.212	0.919	-0.382
Gains from MP coordination	0.130	0.579	-0.245

Figure 7: Cross-region correlation matrix in welfare gains.

7 Conclusions

This paper provides a theoretical model which investigates the question of international coordination of monetary and macro-prudential policies in the context of a general equilibrium model with two regions where agents choose the optimal mix between ex ante and ex post liquidity. Its main conclusions are twofold. First, under non-cooperative monetary policies, macro-prudential policy coordination delivers strictly positive welfare gains that accrue to both regions. Coordinating on macro-prudential policy is therefore a Pareto improvement. Second, when monetary policy is cooperative, Nash and cooperative macro-prudential policies are similar to each other. Cooperation on monetary policy hence annihilates any gain to macro-prudential policy coordination. In sketching these results, the model highlights that macro-prudential policy can be a useful complement for policy makers because it allows them to affect domestic funding conditions, particularly when such conditions are not fully in line with domestic needs.

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Appendix: Allowing central banks to set state-contingent interest rates.

The model as presented, assumes that central banks need to announce at date $t = 0$ the interest rate, they propose on their respective deposit facilities between date $t = 1$ and date $t = 2$. This assumption therefore precludes central banks from setting state-contingent interest rates, which is at odds with reality. This section proposes to relax this assumption and show that the main intuitions of the model still go through in this more realistic framework. In particular, we will show that the trade-off for macro-prudential policy makers between allowing for larger cross-border risk sharing and controlling domestic financial conditions is still valid.

To do so, let us focus on distressed banks and assume that there are of two types: for some, reinvestment is variable-scale but for other reinvestment is typically fixed-scale. Moreover let us now assume that banks of the latter type can shirk and claim to be of the former type. When distressed banks hold a large amount of inside equity, claiming to hold a variable-scale reinvestment opportunity can be profitable because the amount of borrowing that can be raised is then a positive function of inside equity, while the amount of borrowing that can be raised by distressed banks with fixed-scale reinvestment opportunities is a negative function of inside equity. Specifically, let us normalize the upper bound on fixed-scale reinvestment to one and denote ϕ the fraction of inside equity that distressed banks with variable-scale reinvestment can borrow. Last let us assume that a distressed bank endowed with a fixed reinvestment scale obtain a return ρ but only with a probability $p < 1$. Considering the case where banks from home are distressed, and hold $\beta R_1^f L^f$ as inside equity, the incentive constraint which ensures that they disclose their true type then writes as

$$1 - \left(1 - \beta R_1^f L^f\right) R_2^h \geq \left[(1+\phi)\,\beta R_1^f L^f \rho - \phi \beta R_1^f L^f R_2^h\right] p \tag{53}$$

On the LHS lie the profit of a distressed bank with fixed scale reinvesment that reports its type thruthfull. This bank reinvests j and only borrows the difference between reinvestment j and its inside equity $\beta R_1^f L^f$ at a gross interest rate R_2^h. Turning to the RHS, a distressed bank with fixed scale reinvesment that wrongly claims to hold a variable scale reinvestment can borrow an amount $\phi \beta R_1^f L^f$. Its profit is hence the difference

between output from reinvestment $(1+\phi)\,\beta R_1^f L^f$ and debt repayment $\phi\beta R_1^f L^f R_2^h$. But the distressed bank earn this profit only with a probability p. With a probability $1-p$, reinvestment does not deliver any output and the distressed bank defaults on debt repayments. Assuming the probability p is sufficiently small, this incentive constraint translates into an upper bound the funding cost R_2^h which writes as:

$$R_2^h \leq \frac{1-p\rho\,(1+\phi)\,\beta R_1^f L^f}{1-(1+p\phi)\,\beta R_1^f L^f} \tag{54}$$

As is clear for this constraint to be relevant, we need that the return ρ to reinvestment for distressed banks wrongly reporting their type satisfies $\rho > \frac{1+p\phi}{p+p\phi}$. Otherwise, the incentive constraint (54) would always be satisfied since the RHS would be larger than one while R_2^h always satisfies $R_2^h \leq 1$. Note for instance that when reinvestment and the shirking alternative have the same expected returns $\rho p = 1$, then the condition $\rho > \frac{1+p\phi}{p+p\phi}$ is always met.

In addition, when the condition $\rho > \frac{1+p\phi}{p+p\phi}$ holds, the RHS in (54) **is decreasing** in the amount of inside equity $\beta R_1^f L^f$. When inside equity $\beta R_1^f L^f$ is larger, distressed banks with fixed scale reinvestment can borrow a lot more by wrongly claiming to hold a variable scale reinvestment opportunity. And on top of this, they only pay liabilities back with a probability p. They are hence willing to shirk even if the expected return under shirking is lower $\rho p < 1$. The only way to preclude this possibility is to cap the funding cost R_2^h and the more so the larger the inside equity $\beta R_1^f L^f$.

Then, using the property that $R_2^h = \beta R_1^h$ and $R_2^f = \beta R_1^f$, and using the property that the cost of ex post funding is equal to the interest rate set by the central bank, i.e. $R_2^h = r^f$ and $R_2^f = r^h$, the problem for monetary policy makers in region i in the non-cooperative game writes as

$$\begin{aligned} &\max_{r^i} \pi^i = \left(1+\left(1-\tfrac{1}{\beta}r^{-i}\right)L^i\right)r^i + \left(1-r^{-i}\right)\left(1-\lambda^i\right) \\ &\text{s.t. } r^i \leq \tfrac{1-p\rho(1+\phi)r^{-i}L^i}{1-(1+p\phi)r^{-i}L^i} \text{ and } r^{-i} \leq \tfrac{1-p\rho(1+\phi)r^{i}L^{-i}}{1-(1+p\phi)r^{i}L^{-i}} \end{aligned} \tag{55}$$

As is clear, expected profits π^i are strictly increasing in the interest rate set by the domestic central bank r^i and strictly decreasing in the interest rate set by the central bank from the other region $-i$. Central banks

therefore choose in the Nash equilibrium to maximize their respective interest rates r^h and r^f, which then satisfy

$$r^h = \frac{1 - p\rho\left(1+\phi\right) r^f L^h}{1 - \left(1 + p\phi\right) r^f L^h} \text{ and } r^f = \frac{1 - p\rho\left(1+\phi\right) r^h L^f}{1 - \left(1 + p\phi\right) r^h L^f} \tag{56}$$

The solution is therefore the fixed point to this system and writes for $i = \{h; f\}$ as

$$r^i = r^i\left(L^i; L^{-i}\right) \text{ with } \frac{\partial r^i\left(L^i; L^{-i}\right)}{\partial L^i} \leq 0 \leq \frac{\partial r^i\left(L^i; L^{-i}\right)}{\partial L^{-i}} \tag{57}$$

As a result, macro-prudential policy makers still face the same type of trade-off when determining the policy parameters m^h and m^f, i.e. how tight should the constraint be on domestic bank ex ante leverage. On the one hand, allowing banks to leverage up by more and allowing larger cross-border capital inflows improves banks expected profits, while on the other hand, this changes funding conditions for domestic banks in a way that is detrimental to expected profits as the interest rate domestic banks can charge on the market for ex post funding they act as lenders falls while the interest rate domestic banks pay for on the market for ex post funding they acts as borrowers increases.