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Too-international-to-fail? Supranational bank resolution and market discipline

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ABSTRACT

Supranational resolution of insolvent banks does not necessarily improve welfare. Supranational regulators are more inclined to bail-out banks indebted towards international creditors because they take into account cross-border contagion. When banks' creditors are more likely to be bailed out, market discipline decreases and risk-taking by indebted banks increases. Depending on the trade-off between giving the right incentives ex ante and limiting contagion ex post, both a national and a supranational resolution framework can be optimal. In particular, if market discipline is low under both national and supranational resolution mechanisms, supranational resolution improves welfare as it stimulates interbank trade.

1. Introduction

> *[The banking union]* is the most ambitious change in Europe since the launch of the euro: to transfer to European authorities the [..] power to wind up euro-zone banks, using a common European fund if necessary.
>
> [The Economist, December 2013]

Should international regulators resolve insolvent international banks? The global financial crisis revealed the fragility of integrated interbank markets: a high degree of international integration generates the potential for cross-border contagion. However, coordination between national regulators to limit the effects of contagion is hard to achieve. Consequently, a supranational regulator may be a more appropriate institution to resolve internationally integrated banks and contain systemic risk. In Europe the Single Resolution Mechanism (SRM) becomes operational in 2016[2]: It is designed to transfer bank resolution powers from a national to a centralized European level.

The impact of international bank resolution is not trivial. First, it can better contain cross-border contagion risks (International Monetary Fund, 2013), which are especially relevant in today's interconnected financial system. For example, between 2003 and 2013 banks in the Euro area held on average 5 trillion USD worth of assets in European countries other than the one in which they are headquartered. Within the same period, French and German banks had average international gross balances of more than 400 billion USD each against GIIPS (Greece, Italy, Ireland, Portugal, and Spain). The *net* exposure of France and Germany to the GIIPS represented four fifths of the gross balance, documenting a highly asymmetric European interbank market.[3] Large cross-border

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[1] The views expressed herein are those of the author and should not be attributed to the IMF, its Executive Board, or its management.

[2] The SRM is operational in all Euro zone countries and all other EU member states that decide to join the Banking Union. See the European Commission press release at http://europa.eu/rapid/press-release_MEMO-14-2764_en.htm from 19 December 2014.

[3] A prevailing view in the case of the banking union in Europe is that national resolution authorities would have more incentives to bail out defaulting banks than a supranational regulator (International Monetary Fund, 2013). This paper discusses an opposite hypothesis.

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exposures generate contagion risk: resolving a bank in one country implies losses for its foreign creditors as well – and potential multiple regulatory interventions in different countries.

Second, centralized resolution is expected to bypass protracted negotiations between national authorities (see the Dexia, Fortis bailouts). Finally, it should be free of the "domestic bias" of national regulators: Allen et al. (2011) argue that the latter "care first and foremost about domestic depositors," and thus do not take into account cross-border spillovers when resolving an insolvent bank. Section 2 offers background on the Icesave and Anglo-Irish Bank defaults, in 2008 and 2012 respectively: In both cases national regulators were reluctant to compensate foreign creditors from taxpayers' money. In sum, a supranational regulator may be relatively more inclined to bail out insolvent banks as it cares about the welfare in the whole supervised region.

This paper analyses the impact of supranational bank resolution. We build a two-country model of international banking with endogenous regulatory architecture. There is one bank and one regulator in each country: National regulators have the option to merge. Heterogeneity in banks' investment opportunities generates gains from trade; consequently, there is scope for an interbank market. Interbank contracts are the outcome of Nash bargaining between the two banks. If a bank defaults, the regulator either bails it out or liquidates its assets.

We introduce two frictions. First, there is moral hazard: Bank investments require costly monitoring. Second, liquidation of insolvent banks is inefficient. As a result, bailouts are always ex post efficient.

The main result is that a supranational resolution mechanism can reduce welfare. There is a trade-off between ex post resolution efficiency and ex ante monitoring incentives of banks. National regulators (NR) do not internalise the welfare of foreign agents and are more likely to liquidate an insolvent bank with large international liabilities. This is ex post inefficient, i.e. there is an underprovision of bailouts under NR. From an ex ante perspective however, excessive liquidation may generate a market discipline effect. Under NR international bank creditors bear counterparty risk: They receive only a part of their claims following a liquidation. Consequently, the lending terms depend on the monitoring strategies of the borrowing bank. As their default probability is higher, non-monitoring banks receive smaller loan sizes or pay higher interest rates, and therefore have lower expected profits. This offers debtor banks incentives to monitor their investments. However, market discipline under NR is only effective if monitoring costs are low enough.

The supranational regulator (SR) chooses the ex post efficient resolution, i.e. it bails out insolvent banks. The enhanced efficiency, however, comes at a price. Creditor banks bear no counterparty risk, and market discipline breaks down. For low monitoring costs, i.e. if market discipline is effective under NR, a supranational regulator decreases welfare. For high monitoring costs, however, the SR improves welfare: Worse borrowing terms under NR for non-monitoring banks are not enough to improve incentives. Therefore, market discipline breaks down also under national resolution. Depending on the potential gains from interbank trade, the SR welfare improvement is realized through either one of two channels: increasing *gains from trade* on the interbank market or improving *resolution efficiency*.

Heterogenous investment opportunities for the two banks generate gains from interbank trade. Supranational resolution may stimulate interbank trade, improving welfare. Under national resolution there is strategic credit rationing on the interbank market. For the creditor bank the potential interbank market profit is low relative to the loss from a contagion-triggered default. It therefore restricts interbank lending so that the debtor bank's regulator is indifferent between a bailout and a liquidation. Therefore, the debtor bank is always bailed out, and there is no contagion. It follows that the creditor bank bears no counterparty risk, and resolution policies are ex post efficient. However, credit rationing implies that the potential gains from trade are not fully realized. Under SR credit rationing is redundant since the supranational regulator always chooses ex post efficient bailouts. Consequently, SR increases gains from trade as it stimulates interbank lending. An interpretation of this result is that supranational resolution eliminates the "balkanisation" of interbank trading.[4] We refer to this as the *gains from trade* channel.

For high gains from interbank trade supranational resolution improves resolution efficiency. Potential interbank market profits are large. Therefore, the creditor bank is willing to bear the counterparty risk. Accordingly, it is compensated by a higher interest rate, i.e. one that includes a counterparty risk premium. There is no credit rationing under the NR. However, the resolution policy is suboptimal: The insolvent debtor bank is liquidated by the national regulator as bailouts involve large cross-border transfers. A supranational regulator improves welfare as it does not resort to inefficient liquidations. We refer to this as the *resolution efficiency* channel.

The paper generates one more result. If SR improves welfare, a merger of national regulators is always feasible. The resolution fund contributions of the two countries depend on the size of interbank trade. However, they do not necessarily depend on bank default probabilities, as the counterparty risk is priced in the interbank interest rates.

Policy implications. Perhaps the most salient prediction of our model is that a supranational resolution mechanism can amplify moral hazard. Therefore, a natural policy implication is a stricter Single Supervisory Mechanism (SSM). Stronger ex ante regulatory requirements limit the risk-taking behavior amplified by a more lenient ex post resolution policy. We formalise this intuition in Section 6.1. However, there are several caveats to a "tougher" SSM: Colliard (2013) and Carletti et al. (2015) argue agency frictions exist between local and joint bank supervisors. Further, Górnicka (2014) finds that banks respond to tougher capital requirements by moving risky assets off their balance sheets, while using taxpayer money to insure them.

Another policy response to the moral hazard problem is to implement a bail-in policy for cross-border bank creditors. We analyse such a policy in Section 6.2. We find that indeed, implementing bail-ins can reduce moral hazard and improve welfare. However, bail-ins are not optimal when they reduce the incentives for banks to make foreign loans.

A second insight is that the interbank market reveals the sign of the SR welfare impact. Under a welfare-improving SR the interbank lending terms ameliorate, i.e. transaction volumes increase or interest rates decrease.

Finally, the model shows that resolution fund contributions should take into account banks' cross-border net positions. This aspect is not taken into account by the current design of the European Single Resolution Fund, where contributions are proportional to the amount deposits covered by deposit insurance[5]: The model implies this system creates winners and losers, and might reduce the willingness of some states to join the SRM.

Related literature. Our paper is part of a rapidly growing literature on financial institution design and banking regulation. We contribute to this literature in the following ways.

First, the model focuses on the *interaction* between supranational resolution mechanisms and bank moral hazard. We find that

[4] Stopping the balkanisation of interbank markets is one of the goals of the European Banking Union. The Financial Times defines balkanisation as "a handy term for the breakdown of cross-border banking". See Patrick Jenkins (2012, September 10), *Banking union must halt Balkanisation*, Financial Times.

[5] See Art. 5 from Council Implementing Regulation (EU) 2015/81 from 19 December 2014.

supranational regulation can have a negative impact on market discipline. Second, regulatory architecture is endogenous; as a result the model can establish feasible member contributions to the supranational resolution fund.

Our paper is closest in spirit to Beck et al. (2013) and Niepmann and Schmidt-Eisenlohr (2013). Beck et al. (2013) show that bank resolution strategies of national regulators vary depending on the presence of foreign creditors and foreign debtors. In a similar way to our model, national supervisors' bailout incentives decrease in the share of foreign deposits. Our framework is more general as we consider the case of supranational regulation and distinguish between alternative regulatory interventions.

In Niepmann and Schmidt-Eisenlohr (2013) the interbank lending and borrowing is also the source of cross-border spillovers from bank defaults. In line with our setup, they argue that cooperation between national regulators can help mitigate contagion effects. Nevertheless, while allowing for additional inefficiencies of national regulation, such as the free-riding problem, the model abstracts from the interaction between supranational regulation and banks' risk-taking incentives.

In Beck et al. (2013), Niepmann and Schmidt-Eisenlohr (2013), as well as in our paper, it is the ex post inefficiency of national bank resolution strategies that motivates supranational regulation. Several other papers focus on supervision rather than resolution when looking at international regulatory coordination.

Colliard (2013) studies the optimal supervisory design in the presence of an agency problem between national and central supervisors. In the model, a local supervisor does not take into account the cross-border externalities of a bank's distress, and may thus prove to be too lenient. In a similar set-up, Carletti et al. (2015) show that even small differences in the objective functions between central and national supervisors may lead to poorer bank monitoring than in a fully-centralized or fully-national supervisory structures. The reason is that local supervisors sometimes prefer to remain ignorant rather than to potentially acquire information that would lead the central supervisor to decisions that are against local interests. Finally Foarta (2014) looks at the banking union from a political economy perspective and argues that, with imperfect electoral accountability, a banking union can encourage rent-seeking behavior for politicians in debtor countries and reduce welfare.

What distinguishes our paper from Colliard (2013) or Carletti et al. (2015) is the argument that the supranational regulator can actually distort banks' risk-taking incentives. The reason is the inability of the supranational regulator to commit to ex post inefficient bank liquidations.

We closely follow Acharya and Yorulmazer (2008) to model the weak commitment of regulators to liquidate insolvent banks, as they also link intervention rules to the ex post welfare functions. Other papers in this strand of literature include Mailath and Mester (1994), Freixas (1999), Perotti and Suarez (2002) for an analysis of the role of charter values, and Cordella and Yeyati (2003) for the relation with leverage. Allen et al. (2014) show that authorities with deeper pockets face a more severe commitment problem, even if governments can fail to provide full deposit insurance (giving rise to "fundamental panics"). Finally, while in our model bailouts of defaulting banks are always ex post efficient, there are papers that allow for inefficient bank bailouts, such as Acharya et al. (2014).

We rely on the Rochet and Tirole (1996) model of interbank lending when modeling the link between bank default contagion and moral hazard. In their set-up the borrowing bank invests in asset monitoring in order to improve the conditions of its interbank loan. The link with regulatory interventions emerges as bank bailouts lower the probability of the debtor's default. Carletti (1999) also shows market discipline is an effective tool to reduce moral hazard, but the model does not explicitly include a strategic regulator.

There are several papers that analyse this link more in detail. For example, Acharya and Yorulmazer (2007), Farhi and Tirole (2012) and Eisert and Eufinger (2013) argue that banks coordinate on risk and network choices to benefit from larger government guarantees, generating a "too-many-to-fail" problem. Farhi and Tirole (2014) discuss a double moral hazard problem: The bailout of banks by national regulators and of national regulators by supranational ones.

Last but not least, our paper contributes to the debate on the optimal design of a banking union in Europe, by providing a mechanism design perspective. A number of relevant policy papers analyse the European banking union from an empirical and institutional point of view: Schoenmaker and Gros (2012), Carmassi et al. (2012) and Ferry and Wolff (2012) for fiscal alternatives and Schoenmaker and Siegmann (2014) for an analysis of cross-border externalities. Avgouleas and Goodhart (2015) discuss the proposed bail-in policies and their effect on banking markets' balkanization.

The rest of the paper is structured as follows. Section 2 presents stylized facts on bank resolution in Europe during the 2007–2009 financial crisis and on the proposed Single Resolution Mechanism. Section 3 describes the model. Section 4 discusses the equilibrium under national resolution mechanisms. Section 5 focuses on the impact of supranational resolution. Particularly, we study welfare implications and optimal resolution fund shares. We extend our model and discuss several policy implications, such as the interaction with the Single Supervision Mechanism or the introduction of bail-ins, in Section 6. The empirical implications are detailed in Section 7. Section 8 concludes.

2. Stylized facts on European bank resolution

Bank resolution during the crisis. The Icelandic bank Icesave became insolvent in 2008. A bailout would have amounted to a 3.9 billion Euro contribution from Icelandic taxpayers to stop losses from spreading to the United Kingdom and the Netherlands, i.e. 12,000 Euro for each citizen.[6] A referendum in Iceland to repay foreign creditors of Icesave was rejected with a 58% vote against the bailout.

Another case is that of the Anglo-Irish Bank. Following its default in January 2012, the Central Bank of Ireland was willing to impose haircuts on creditors. Eventually, the European Central Bank (ECB) insisted that the Irish government repay senior debt in the Anglo-Irish bank at face value.[7]

In the view of Allen et al. (2011) the cases of Icesave and the Anglo-Irish Bank support the view that national resolution mechanisms do not internalise cross-border contagion losses. National regulators could be less favorable towards bailouts that imply large cross-border transfers. Engle et al. (2015) also document some European banks are "too-big-to-saved" as the cost for the taxpayer to rescue them is too high.

There are also cases where national regulators cooperate towards the resolution strategy, for example in the Franco-Belgian bailout of Dexia or the Dutch-Belgian resolution of Fortis. Even then though, the process is typically long-winded and inefficient due to different objectives and information asymmetries. The Basel Committee on Banking Supervision (2010) states about the Fortis resolution: "*the Dutch and Belgian supervisory authorities assessed the situation differently. Differences in the assessment of available information and the sense of urgency complicated the resolution*" (p. 11).

[6] See, for instance, the Deutsche Welle analysis at http://dw.de/p/10qlQ.

[7] See, for instance, the Reuters report from January 22, 2012: http://goo.gl/oZC9Pr.

The Single Resolution Mechanism. The Single Resolution Mechanism (SRM) and the Single Supervisory Mechanism (SSM) are the two pillars of the banking union in the European Union. The main goal of the SRM is to enable a more effective and timely management of bank crises, by centralizing the bank resolution mechanism for the participating member states.[8]

The decision to create the SRM was taken by the European Parliament and the European Council on July 15, 2014. The SRM will become operative on January 1, 2016.[9] Under the SRM, the resolution of troubled banks is entrusted to the Single Resolution Board (SRB), formed by representatives of the European Commission, national authorities, and the European Central Bank (ECB). In the case of bank distress, the SRB will propose a resolution strategy, to which the European Commission has a right to object. The SRM applies to all banks in the member states which also participate in the SSM, and identified by the Single Resolution Mechanism Regulation.

The availability of funding support will be guaranteed through the Single Resolution Fund (SRF) financed with contributions from financial institutions under the SSM. Contributions are established as a percentage of the amount of insured deposits. Appendix B provides more institutional details on the European banking union.

3. Model

3.1. Primitives

We consider an economy with four dates, $t \in \{-1, 0, 1, 2\}$, and two countries, labeled A and B. In each country there is one bank (BK_A and BK_B), one national regulator (NR_A and NR_B), and a unit measure of depositors.

Depositors. Depositors are risk-neutral and care about their $t = 2$ consumption only. Depositors receive a unit endowment at $t = 0$, which they can either store or deposit with the domestic bank. Depositors are fully insured by the regulator. Consequently, there is no bank run equilibrium and the net interest rate on deposits is zero.

Assets. The two banks have access to different investment opportunities. Bank BK_A can invest at $t = 0$ in a long-term project that yields a deterministic return of R_A. The return is realized in two stages: γ at $t = 1$, and $R_A - \gamma$ at $t = 2$. Bank BK_B can invest at $t = 1$ in a short-term, risky project that yields $\widetilde{R}_B \in \left\{R_B^H, R_B^L\right\}$ at $t = 2$, with $R_B^H > 1$ and $R_B^L < 1$.

The maximum investment in the long-term project is one unit, while there is no limit on the short-term investment. In addition, the banks have access to a zero-return cash storage technology.

Only domestic banks can directly invest in their country-specific opportunities, whereas foreign banks have to use them as an intermediary. One can think of this assumption as a form of local expertise.

Monitoring. There is moral hazard in the spirit of Rochet and Tirole (1996) and Holmstrom and Tirole (1997). Bank BK_B can choose whether to invest in monitoring technology at $t = 0$, before the investment takes place. The monitoring technology has cost C. If BK_B monitors, then its return is always R_B^H. If BK_B does not monitor, the investment is risky: it pays off $R_B^L < 1$ with probability p and R_B^H otherwise.

Assumption 1. The risky investment for BK_B has positive NPV, i.e. $(1 - p)R_B^H + pR_B^L > 0$.

Finally, Assumption 2 guarantees monitoring is socially optimal.

Assumption 2. Investing in the monitoring technology is socially optimal, i.e. $R_B^H - C \geqslant (1 - p)R_B^H + pR_B^L$. This is equivalent to $C \leqslant \overline{C}$, where

$$\overline{C} = p(R_B^H - R_B^L).$$

Interbank market. The interbank market opens at $t = 1$, when BK_A collects γ from its domestic investment. BK_A can either store the full amount until $t = 2$, or lend $\gamma_I \in (0, \gamma]$ to BK_B. Both the interbank loan size γ_I and the gross interest rate $r(\gamma_I)$ are the result of Nash bargaining between the two banks. We denote by $1 - \eta$ and η the bargaining power of BK_A and BK_B respectively, with $\eta \in (0, 1)$.

Regulators. The role of regulators in our model is to resolve banks in default, and to provide deposit insurance. A bank defaults whenever it is not able to repay its creditors at $t = 2$. The resolution strategies for the regulator are modeled as in Acharya and Yorulmazer (2008): The regulator chooses to either bailout or liquidate the insolvent bank.

In the case of a bailout, all creditors receive the face value of their claims. In the case of a liquidation, the regulator manages the bank assets itself, but not as efficiently as the original manager. Liquidation is costly: The regulator-as-bank-manager can only obtain $(1 - L)R_L^B$ at $t = 2$ per unit of investment, where $L \in (0, 1)$. The liquidation proceeds are then paid to both depositors and international creditors on a pro-rata basis relative to the original investment value.[10] The regulator provides additional liquidity such that depositors always receive the face value of debt. Importantly, the bank managers and the shareholders have a zero payoff upon default both after a liquidation or a bailout.

Supranational regulator. At $t = -1$ national regulators decide whether to merge into a supranational regulator SR. While a national regulator maximises the total welfare in its own country at $t = 2$, the supranational regulator maximises the joint welfare of both countries at $t = 2$. The welfare measure is defined as the sum of payoffs for all agents in the economy. The decision to form a SR is non-renegotiable.

Default contagion. Whenever the low return R_B^L is realized at the final date, bank BK_B defaults. Following the insolvency of BK_B, bank BK_A can also potentially default if it does not receive the face value of the interbank loan. For contagion to manifest, the interbank loan has to be sufficiently large. More precisely, for low enough γ, contagion is not possible, as BK_A never defaults, or BK_B is never liquidated. To rule out the trivial equilibria, we assume γ is large enough, i.e.

Assumption 3. $\gamma > \max\left\{\frac{LR_B^L}{1-R_B^L}, \frac{R_A-1}{1-R_B^L(1-L)}\right\}$.

For the regulator in country B the cost of bailing out the bank BK_B increases in the size of the foreign interbank loan γ_I. Assumption 3 guarantees that the funds available to the bank BK_A at $t = 1$ are sufficiently large such that i) the liquidation of BK_B is not always more expensive than a bailout, and ii) BK_A defaults following a liquidation of BK_B, if the full amount γ is lent to BK_B.

[8] See, for instance, the European Central Bank memo from April 2014: http://goo.gl/kRToUq.

[9] The Single Supervisory Mechanism came into force on August 19, 2014.

[10] The assumption that the pro-rata reimbursement is based on original investment at $t \in \{0, 1\}$ rather than the final claim value at $t = 2$ is made for tractability purposes. We assume in effect that the interest rate impact on the split of liquidation proceeds is second-order. With this assumption, following the liquidation of BK_B, BK_A receives $\frac{\gamma_I}{1+\gamma_I}R_B^L(1 - L)(1 + \gamma_I) = \gamma_I R_B^L(1 - L)$. If the pro-rata shares are based on final claims value, then the share of BK_A becomes $\frac{\gamma_I r_I}{1+\gamma_I r_I}R_B^L(1 - L)(1 + \gamma_I)$. The economic intuition is qualitatively the same: BK_A receives less than the face value of the debt following the liquidation of BK_A.

Timeline. The timeline is illustrated in Fig. 1. A list of all the model parameters is presented in Appendix A.

Market discipline. At $t = 0$, the creditor bank $\mathrm{BK_A}$ observes the monitoring decision of $\mathrm{BK_B}$ *before* the interbank contract is determined. Therefore, $\mathrm{BK_A}$ can condition the loan terms on the monitoring decision, i.e. demand a higher interest rate or reduce the loan size at $t = 1$ if $\mathrm{BK_B}$ did not monitor at $t = 0$.

3.2. First-best solution

We start our analysis with the first-best solution, which consists of (i) a monitoring decision for the bank $\mathrm{BK_B}$, (ii) the transfer γ_I from the bank $\mathrm{BK_A}$ to the bank $\mathrm{BK_B}$, and (iii) the resolution decision for the benevolent regulator following a default of the bank $\mathrm{BK_B}$ that jointly maximise the joint welfare in countries A and B. Lemma 1 summarises the first-best solution.

Lemma 1 (*First-best solution*). *The first best is given by:*

(i) *Bank* $\mathrm{BK_A}$ *transfers* $\gamma_\mathrm{I} = \gamma$ *to* $\mathrm{BK_B}$.
(ii) *Bank* $\mathrm{BK_B}$ *always invests in the monitoring technology*.
(iii) *There are no bank defaults.*

By Assumption 2 it is always socially optimal to invest in the monitoring technology. As a result the interbank lending is safe, and all funds available to $\mathrm{BK_A}$ at $t = 1$ are transferred to $\mathrm{BK_B}$. There are no bank defaults in the first-best.

4. Equilibrium with national regulators

In this section the equilibrium for an economy with national regulators is determined, i.e. we disallow the formation of a supranational regulator at $t = -1$. The equilibrium with a supranational regulator is considered in Section 5, along with the welfare impact and feasibility of a joint resolution mechanism.

The solution concept is subgame perfect Nash equilibrium. To determine the equilibrium, we use backward induction: We first solve for the regulators' decision at $t = 2$, then for the interbank loan size and interest rate at $t = 1$, and finally for the monitoring decision of $\mathrm{BK_B}$ at $t = 0$.

4.1. Optimal resolution policy

Bank $\mathrm{BK_B}$ defaults if and only if its return at $t = 2$ is R^L_B. As both depositors and international creditors require a gross return of at least one, the low return $R^\mathrm{L}_\mathrm{B} < 1$ is not enough to repay the debt in full. Conversely, $\mathrm{BK_B}$ never defaults if it obtains the high return $R^\mathrm{H}_\mathrm{B} > 1$.

If the regulator $\mathrm{NR_B}$ bails out $\mathrm{BK_B}$, the national welfare is

$$\mathrm{Welfare}^{\mathrm{bailout}}_\mathrm{B} = \underbrace{1}_{\text{Depositors}} - \underbrace{\left[\overbrace{1 + \gamma_\mathrm{I} r}^{\text{Debt}} - \overbrace{R^\mathrm{L}_\mathrm{B}(1 + \gamma_\mathrm{I})}^{\text{Assets}}\right]}_{\text{Regulator's cost}} \tag{1}$$

In the case of a bailout, domestic depositors and $\mathrm{BK_A}$ receive the full amount of their claims: 1 and $\gamma_\mathrm{I} r$ respectively. The term in square brackets is the additional amount $\mathrm{NR_B}$ needs to raise to repay all bank creditors. Since $R^\mathrm{L}_\mathrm{B} < 1$ and $r > 1$, the net cost for $\mathrm{NR_B}$ increases in the interbank loan size, γ_I.

The national welfare following liquidation of $\mathrm{BK_B}$ is

$$\mathrm{Welfare}^{\mathrm{liquidation}}_\mathrm{B} = \underbrace{1}_{\text{Depositors}} - \underbrace{\left[\overbrace{1}^{\text{Domestic debt}} - \overbrace{(1 - L)R^\mathrm{L}_\mathrm{B}}^{\text{Asset liquidation value}}\right]}_{\text{Regulator's cost}} \tag{2}$$

where the term $(1 - L)R^\mathrm{L}_\mathrm{B}$ in square brackets represents the proceeds from the sale of $\mathrm{BK_B}$'s assets net of the pro-rata payment to $\mathrm{BK_A}$, $\gamma_\mathrm{I}(1 - L)R^\mathrm{L}_\mathrm{B}$, and where 1 is the full repayment to insured domestic depositors. The repayment received by $\mathrm{BK_A}$ is always lower than the amount lent, as $(1 - L)R^\mathrm{L}_\mathrm{B} < 1$.

Finally, the need for regulatory intervention at $t = 2$ implies that $\mathrm{BK_B}$ did not monitor at $t = 0$; hence, there is no monitoring cost term in Eqs. (1) and (2).

If the interbank loan is not repaid in full $\mathrm{BK_A}$ may default on its depositors as well. In this case national regulator $\mathrm{NR_A}$ provides the missing funds and repays the insured depositors. Naturally, it is never optimal to liquidate $\mathrm{BK_A}$'s assets, since $\mathrm{BK_A}$ has no foreign creditors.

As a result, following a liquidation of $\mathrm{BK_B}$ and the consequent default of $\mathrm{BK_A}$ the welfare in country A is equal to

$$\mathrm{Welfare}^{\mathrm{default}}_\mathrm{A} = 1 - \underbrace{\left[1 - R_\mathrm{A} + \gamma_\mathrm{I}\left(1 - R^\mathrm{L}_\mathrm{B}(1 - L)\right)\right]}_{\text{Regulator's cost}}. \tag{3}$$

Lemma 2 describes the optimal resolution policy under national regulation in both countries.

Lemma 2 (*Optimal NR resolution*). *The national regulator* $\mathrm{NR_B}$ *bails out* $\mathrm{BK_B}$ *if:*

$$\gamma_\mathrm{I} < \frac{LR^\mathrm{L}_\mathrm{B}}{r - R^\mathrm{L}_\mathrm{B}} = \overline{\gamma}(r), \tag{4}$$

where $\overline{\gamma}(r)$ *decreases in r.*

Following a default of $\mathrm{BK_A}$ *the national regulator* $\mathrm{NR_A}$ *provides the missing funds to repay domestic depositors.*

From Lemma 2, $\mathrm{BK_B}$ is liquidated for large enough interbank loans. Note that Assumption 3 guarantees that $\gamma > \max_r \overline{\gamma}(r) = \overline{\gamma}(1)$, i.e. there exists an interbank loan threshold above which $\mathrm{BK_B}$ is indeed liquidated.

A bailout of $\mathrm{BK_B}$ by $\mathrm{NR_B}$ implies repaying the foreign claims in full. However, the national regulator does not internalise the welfare transfer abroad. As a larger γ_I implies a larger international transfer, the cost of a bailout increases in the size of the interbank market. As γ_I increases, the cost of a liquidation becomes lower than the cost of a bailout. Consequently, $\mathrm{BK_B}$ is liquidated.

The contagion mechanism and equilibrium resolution policies are further detailed in Fig. 2.

As Fig. 2 shows, the non-zero net exposure of the bank in country A to the bank in country B generates the potential for international spillovers from bank defaults. In the model the net international exposure follows from heterogeneity in investment opportunities between the countries. If domestic positive NPV projects are not in sufficient supply, the bank $\mathrm{BK_A}$ lends excess cash on the international interbank market to $\mathrm{BK_B}$, which can invest it profitably. The assumed asymmetry allow us to model the contagion mechanism in a clear and compact way; However, it is not crucial for our main results. For example, in a richer model, the spillovers from bank defaults could happen also between ex ante identical banks experiencing liquidity shocks of opposite signs in different periods.

4.2. Interbank market equilibrium

The interbank market loan size γ_I and the interbank rate r are simultaneously set through Nash bargaining. The bargaining power coefficients of $\mathrm{BK_A}$ and $\mathrm{BK_B}$ are $1 - \eta$ and η respectively.

Let $\tilde{p} \in \{p, 0\}$ be the probability that $\mathrm{BK_B}$ earns the low return R^L_B at $t = 2$; $\tilde{p}$ only depends on the monitoring technology investment at $t = 0$. The expected profit is conditional on all history until $t = 1$:

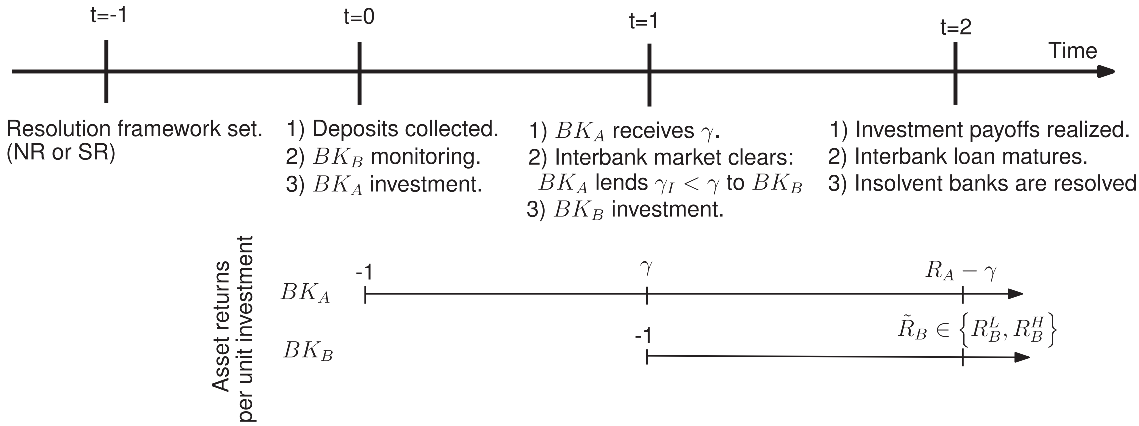
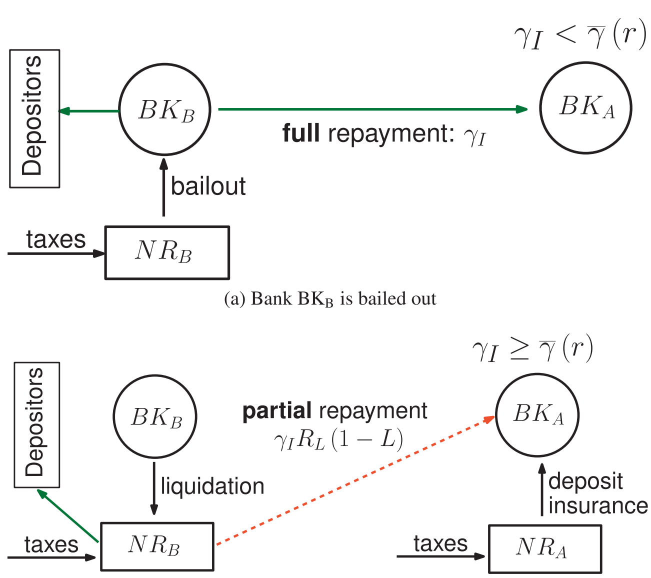


Fig. 1. Model timeline.



(b) Bank BK_B is liquidated

Fig. 2. Contagion mechanism following BK_B default. This figure shows the mechanism through which shocks are transmitted across borders in the model. For $\gamma \leqslant \overline{\gamma}(r)$, there is no spillover effect; if BK_B defaults, it is bailed out and can pay its short-term debt to BK_A. Conversely, if $\gamma > \overline{\gamma}(r)$, the national regulator liquidates BK_B and BK_A receives a pro-rata share of liquidation proceeds. The national regulator in country A needs to intervene as BK_A also defaults. Dashed, red lines correspond to partial repayments; green, continuous arrows correspond to full repayments. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

In particular the monitoring investment decision is already made (and the cost C already sunk). The conditional expected profit is then

$$\begin{aligned}\pi_B(\gamma_I, r|t=1) &= (1-\tilde{p})\left[R_B^H - 1 + \gamma_I\left(R_B^H - r\right)\right] \\ &\quad + \underbrace{\tilde{p}\max\left\{R_B^L - 1 + \gamma_I\left(R_B^L - r\right), 0\right\}}_{=0,\ \text{since } R_B^L<1} \\ &= (1-\tilde{p})\left[R_B^H - 1 + \gamma_I\left(R_B^H - r\right)\right]. \end{aligned} \tag{5}$$

when R_B^L is realized, the payoff of BK_B is zero: $R_B^L < 1$, and all creditors require return rates larger than one. However, if BK_B monitors the risky project it never defaults, as $\tilde{p} = 0$.

If BK_B is liquidated after a default the expected profit of BK_A, $\pi_A(\gamma_I, r, |t=1)$, is

$$\begin{aligned}\pi_A(\gamma_I, r|\gamma_I > \overline{\gamma}(r), t=1) \\ &= (1-\tilde{p})[R_A - 1 + \gamma_I(r-1)] \\ &\quad + \tilde{p}\max\left\{R_A - 1 + \gamma_I\left[R_B^L(1-L) - 1\right], 0\right\}. \end{aligned} \tag{6}$$

From Assumption 3, $R_A - 1 + \gamma\left[R_B^L(1-L) - 1\right] < 0$. If BK_A lends $\gamma_I = \gamma$ it always defaults upon the liquidation of BK_B.

If BK_B is bailed out upon default the expected profit of BK_A is riskless,

$$\pi_A(\gamma_I, r|\gamma_I \leqslant \overline{\gamma}(r), t=1) = (R_A - 1) + \gamma_I(r-1). \tag{7}$$

The interbank loan size and the interest rate solve the following Nash bargaining problem:

$$(\gamma_I, r) = \arg\max_{\gamma, i}[\pi_B(\gamma, i) - \pi_B(0,0)]^{\eta}[\pi_A(\gamma, i) - \pi_A(0,0)]^{1-\eta}. \tag{8}$$

From Eqs. (6) and (7), the expected profit of BK_A depends on the resolution strategy of NR_B. From Lemma 2 NR_B bails out BK_B if $\gamma_I \leqslant \overline{\gamma}(r)$, and liquidates BK_B otherwise. We consider the two cases below.

Interbank market for $\gamma_I \leqslant \overline{\gamma}(r)$. The interbank loan is risk free. Since both banks' profits increase in the loan size, BK_A lends the maximum amount, $\gamma_I = \overline{\gamma}(r)$. Further, the interest rate equals $r^{\text{Riskless}} = R_B^H(1-\eta) + \eta$.

At the same time, there is a risk transfer from BK_A to the national regulator NR_B in country *B*. A strategically low choice of interbank lending, $\overline{\gamma}(r)$ – which is lower than γ by assumption –, guarantees a bailout for BK_B and eliminates the counterparty risk for BK_A. On the other hand, the interbank loan size is lower than the first best, γ.

Interbank market for $\gamma_I > \overline{\gamma}(r)$. The interbank loan is risky as BK_B is liquidated upon default. Again, the expected profits of both BK_A and BK_B increase in γ_I, so the loan size is maximum possible, γ, regardless of the bargaining power η. If BK_A bears counterparty risk it has an incentive to lend the full amount to maximise its gain in the "good" state. The rate r depends on the counterparty risk, measured by p, and on the size of the loan, γ.

In general there are two ways to eliminate counterparty risk. First, the interbank loan size can be strategically low, i.e. $\gamma_I = \overline{\gamma}(r)$. Second, BK_B can eliminate the project risk by investing in the monitoring technology at $t = 0$. If BK_B monitors, all returns are deterministic, and the interbank equilibrium coincides with the first best. Thus, the equilibrium interbank contract $(\gamma_I(r), r)$ at $t = 1$ is a function of BK_B's monitoring investment at $t = 0$.

Let $\left(\gamma_I^{\text{Mon}}, r^{\text{Mon}}\right)$ and $\left(\gamma_I^{\text{NMon}}, r^{\text{NMon}}\right)$ be the equilibrium loan size and rate if BK_B monitors and does not monitor respectively. The possible equilibrium values are described by Lemma 3.

Lemma 3 (*Interbank market equilibrium under national regulation*). *If* BK_B *invests in monitoring technology at* $t = 0$, *the interbank equilibrium coincides with the first best,*

$$\left(\gamma_I^{\mathrm{Mon}}, r^{\mathrm{Mon}}\right) = \left(\gamma, r^{\mathrm{Riskless}}\right) = \left(\gamma, (1-\eta)R_B^H + \eta\right). \tag{9}$$

If BK_B *does not invest in monitoring technology at* $t = 0$,

$$\left(\gamma_I^{\mathrm{NMon}}, r^{\mathrm{NMon}}\right) \in \left\{\left(\overline{\gamma}\left(r^{\mathrm{Riskless}}\right), r^{\mathrm{Riskless}}\right), \left(\gamma, r^{\mathrm{Risk}}\right)\right\}, \tag{10}$$

where r^{Risk} *is*

$$r^{\mathrm{Risk}} = R_B^H(1-\eta) + \eta + \frac{\eta}{\gamma(1-p)} p(R_A - 1) > r^{\mathrm{Riskless}}. \tag{11}$$

4.3. Optimal monitoring

BK_B internalises the interbank market equilibrium when deciding on the monitoring technology investment at $t = 0$. The expected profit for BK_B if it monitors equals

$$\pi_B(\mathrm{monitor}) = \left[R_B^H - 1 + \gamma_I^{\mathrm{Mon}}\left(R_B^H - r^{\mathrm{Mon}}\right)\right] - C. \tag{12}$$

The expected profit for BK_B if it does not monitor is

$$\pi_B(\mathrm{not\ monitor}) = (1-p)\left[R_B^H - 1 + \gamma_I^{\mathrm{NMon}}\left(R_B^H - r^{\mathrm{NMon}}\right)\right]. \tag{13}$$

The monitoring condition follows from the comparison of Eqs. (12) and (13). Bank BK_B invests in monitoring technology if

$$\begin{aligned} C \leqslant\ & p\left(R_B^H - 1\right) + \gamma_I^{\mathrm{Mon}}\left(R_B^H - r^{\mathrm{Mon}}\right) \\ & - (1-p)\gamma_I^{\mathrm{NMon}}\left(R_B^H - r^{\mathrm{NMon}}\right). \end{aligned} \tag{14}$$

Market discipline. From the discussion in Sections 3.1 and 4.2, and Eq. (14), there are two ways BK_A can "discipline" BK_B through the interbank market. First, it can lend more if monitoring is observed, i.e. $\gamma_I^{\mathrm{Mon}} > \gamma_I^{\mathrm{NMon}}$. Second, a higher interest rate if BK_B does not monitor, $r^{\mathrm{NMon}} > r^{\mathrm{Mon}}$, also has a disciplining effect.

4.4. Equilibrium

We denote by $\Pi_{A,B}(\gamma_I, r)$ the Nash product of the two banks' profits. It is a function of the interbank loan size and the interbank interest rate,

$$\Pi_{A,B}(\gamma_I, r) = [\pi_A(\gamma_I, r) - \pi_A(0,0)]^{1-\eta}[\pi_B(\gamma_I, r) - \pi_B(0,0)]^{\eta}. \tag{15}$$

Let γ^* be the level of gains from trade that makes the banks indifferent between the $\left(\gamma, r^{\mathrm{Risk}}\right)$ and the $\left(\overline{\gamma}\left(r^{\mathrm{Riskless}}\right), r^{\mathrm{Riskless}}\right)$ interbank contracts. Therefore, γ^* is the unique solution of

$$\Pi_{A,B}\left(\gamma, r^{\mathrm{Risk}}\right) = \Pi_{A,B}\left(\overline{\gamma}, r^{\mathrm{Riskless}}\right). \tag{16}$$

The uniqueness of γ^* follows from the fact that both banks' profits when the interbank contract is $\left(\gamma, r^{\mathrm{Risk}}\right)$ monotonically increase in γ, whereas bank profits when the interbank contract is $\left(\overline{\gamma}\left(r^{\mathrm{Riskless}}\right), r^{\mathrm{Riskless}}\right)$ do not depend on γ.

Furthermore, we determine lower and upper bounds for γ^*:

$$\gamma^* \in \left[\gamma_I^{\eta=0}, \gamma_I^{\eta=0} + \underbrace{\frac{LR_B^L\left(pR_B^L + (1-p)R_B^H - 1\right)}{(1-p)\left(R_B^H - R_B^L\right)\left(1 - R_B^L\right)}}_{>0 \text{ due to positive NPV of } BK_B \text{ project}}\right], \tag{17}$$

and $\gamma_I^{\eta=0} = \frac{p(R_A-1)\left(R_B^H - R_B^L\right) + LR_B^L\left(R_B^H - 1\right)}{(1-p)\left(R_B^H - 1\right)\left(R_B^H - R_B^L\right)} > 0$, the interbank loan size when BK_B has zero bargaining power.

From Eq. (14) the monitoring decision of BK_B is a function of the interbank loan size and the interbank interest rate. We define a function $C^{NR}(\gamma)$ such that

$$C^{NR}(\gamma) = \begin{cases} p(R_B^H - 1)\left[1 + \frac{\eta}{p}\left(\gamma - (1-p)\overline{\gamma}\left(r^{\mathrm{Riskless}}\right)\right)\right] & \text{if } \gamma < \gamma^*, \\ p\left[(R_B^H - 1)(1 + \eta\gamma) + \eta(R_A - 1)\right] & \text{if } \gamma \geqslant \gamma^*. \end{cases} \tag{18}$$

Eq. (18) follows from (14) by substituting the interbank contract associated with the highest Nash product, i.e. $\left(\overline{\gamma}\left(r^{\mathrm{Riskless}}\right), r^{\mathrm{Riskless}}\right)$ for $\gamma < \gamma^*$ and $\left(\gamma, r^{\mathrm{Risk}}\right)$ or $\gamma \geqslant \gamma^*$.

Proposition 1 summarises the equilibrium strategies.

Proposition 1 (*National resolution equilibrium*). *If* $C < C^{NR}(\gamma), BK_B$ *invests in monitoring technology. From Lemma 3, the equilibrium loan contract is* $\left(\gamma, r^{\mathrm{Riskless}}\right)$. *The interbank rate does not include a counterparty risk premium, i.e.* $r^{\mathrm{Riskless}} = R_B^H(1-\eta) + \eta$. *There is no regulatory intervention.*

If $C > C^{NR}(\gamma), BK_B$ *does not invest in monitoring technology. The equilibrium loan contract is* $\left(\overline{\gamma}\left(r^{\mathrm{Riskless}}\right), r^{\mathrm{Riskless}}\right)$ *for* $\gamma < \gamma^*$ *and* $\left(\gamma, r^{Risk}\right)$ *if* $\gamma > \gamma^*$. *Regulator* NR_A *never liquidates* BK_A*'s assets; regulator* NR_B *liquidates* BK_B *for* $\gamma > \gamma^*$.

The function $C^{NR}(\gamma)$ gives the threshold cost for which BK_B is indifferent between monitoring or not. From Eq. (18) the threshold increases in γ. Bank BK_B is more likely to monitor if the potential gains from trade are high. Monitoring is also more likely for a higher default probability, as $C^{NR}(\gamma)$ increases in p.

If BK_B monitors its project the interbank loan bears no counterparty risk. Consequently, BK_A lends the full intermediate cashflow γ. With no bank defaults there are no interventions by national regulators.

On the other hand, if BK_B does not monitor, it may default. The creditor bank BK_A decides whether to bear counterparty risk by choosing the size of the interbank loan.

For low potential gains from trade, i.e. $\gamma < \gamma^*$, bank BK_A prefers the safe contract. If BK_A lends the full intermediate cashflow its interbank profit γr^{Risk} increases in γ. However, the limited scale of the interbank market – due to the low value of γ – translates into lower gains for BK_A. For $\gamma < \gamma^*$ potential interbank profits are lower than the default loss if counterparty risk materialises. As a result, whenever BK_B does not monitor its project, BK_A strategically limits its interbank loan to the level that guarantees an ex post bailout of BK_B by the regulator NR_B.

For high potential gains from trade, i.e. $\gamma \geqslant \gamma^*$, the expected profit from the interbank loan is large enough for BK_A to accept a positive counterparty risk. The interest rate includes a counterparty risk premium, and is thus higher than for $\gamma < \gamma^*$. As a result, it is optimal for BK_A to lend γ in the interbank market.

4.5. Welfare under national regulation

From Proposition 1, national regulators implement the joint first best if $C < C^{NR}(\gamma)$ as there is full investment and no default risk. The joint welfare is

$$\begin{aligned} &\mathrm{Welfare}^{NR} = \mathrm{Welfare}^{FB} = R_A + R_B^H + \gamma\left(R_B^H - 1\right) - C \\ &\text{if} \quad C < C^{NR}(\gamma). \end{aligned} \tag{19}$$

If $C \geqslant C^{NR}(\gamma)$ and $\gamma < \gamma^*$ all banks are bailed out given default. There are no liquidation losses, but there is under-investment as the interbank loan is scaled down. The joint welfare is

$$\text{Welfare}^{\text{NR}} = R_{\text{A}} + (1-p)R_{\text{B}}^{\text{H}} + pR_{\text{B}}^{\text{L}} + \overline{\gamma}(r^{\text{Riskless}})\left((1-p)R_{\text{B}}^{\text{H}} + pR_{\text{B}}^{\text{L}} - 1\right), \quad (20)$$

which is $(\gamma - \overline{\gamma}(r^{\text{Riskless}}))\left(R_{\text{B}}^{\text{H}} - 1\right)$ lower than the first best value.

If $C \geqslant C^{\text{NR}}(\gamma)$ and $\gamma > \gamma^*$ BK_{B} is liquidated given default. The joint welfare in this case is

$$\text{Welfare}^{\text{NR}} = R_{\text{A}} + (1-p)R_{\text{B}}^{\text{H}} + p(1-L)R_{\text{B}}^{\text{L}} + \gamma\left((1-p)R_{\text{B}}^{\text{H}} + p(1-L)R_{\text{B}}^{\text{L}} - 1\right). \quad (21)$$

There is no under-investment, as the interbank loan size is maximum, i.e. γ. However, welfare is below the first best as $R_{\text{B}}^{\text{H}} > (1-L)R_{\text{B}}^{\text{L}}$.

In sum, for $C \geqslant C^{\text{NR}}(\gamma)$, market discipline fails. There are two reasons why welfare is lower. First, the BK_{B} return is R_{B}^{L} with positive probability. Second, there are inefficient liquidations.

5. The impact of a supranational regulator

In this section national regulators are replaced by a single supranational regulator SR with resolution powers for both countries. Section 5.1 is concerned with the equilibrium strategy of SR. In Section 5.2 we analyse the welfare impact of the single regulator both relative to national regulation and to the first best. Finally, Section 5.3 discusses the feasibility of supranational regulation.

5.1. Equilibrium strategies

To determine the equilibrium under a single regulator for countries A and B, we use backward induction as in Section 4.

5.1.1. Optimal resolution policy

The objective function of the supranational regulator SR is to maximise the *joint* welfare in the two countries. From Eqs. (1)–(3) the relevant welfare functions are

$$\begin{aligned}
\text{Welfare}^{\text{SR}}_{\text{bailout B}} &= \underbrace{1 - \left[1 + \gamma_{\text{I}} r - R_{\text{B}}^{\text{L}}(1+\gamma_{\text{I}})\right] - \mathbb{I}_{\text{M}} \times C}_{\text{Country B}} + \underbrace{R_{\text{A}} + \gamma_{\text{I}}(r-1)}_{\text{Country A}} \text{ and} \\
\text{Welfare}^{\text{SR}}_{\text{liquidation B}} &= \underbrace{1 - \left[1 - (1-L)R_{\text{B}}^{\text{L}}\right] - \mathbb{I}_{\text{M}} \times C}_{\text{Country B}} + \underbrace{1 - \left[1 - R_{\text{A}} + \gamma_{\text{I}}\left(1 - R_{\text{B}}^{\text{L}}(1-L)\right)\right]}_{\text{Country A}}.
\end{aligned} \quad (22)$$

From a joint welfare perspective it is always optimal to bail out BK_{B} following a default as

$$\text{Welfare}^{\text{SR}}_{\text{bailout B}} - \text{Welfare}^{\text{SR}}_{\text{liquidation B}} = LR_{\text{B}}^{\text{L}}(1+\gamma_{\text{I}}) > 0. \quad (23)$$

Contrary to national regulators SR always bails out BK_{B}, independently of the size of the interbank market γ_{I}. The reason is that the supranational regulator internalises contagion; it optimally avoids the negative effect that a liquidation of BK_{B} has on BK_{A}. The welfare difference between a bailout and a liquidation increases in the size of the interbank loan, as the contagion effect is stronger.

5.1.2. Interbank market equilibrium

As BK_{B} is always bailed out, the expected profit for BK_{A} becomes, from Eq. (7),

$$\pi_{\text{A}}^{\text{SR}} = (R_{\text{A}} - 1) + \gamma_{\text{I}}(r-1). \quad (24)$$

From Eqs. (5) and (24) the expected profit for both banks increases in γ_{I}. Consequently, it is optimal to exchange the full intermediate cashflow, i.e. $\gamma_{\text{I}}^{\text{SR}} = \gamma$. Further, the equilibrium interest rate solves:

$$r^{\text{SR}} = \arg\max_i \left[(1-\tilde{p})\gamma_{\text{I}}\left(R_{\text{B}}^{\text{H}} - r\right)\right]^{\eta}\left[\gamma_{\text{I}}(i-1)\right]^{1-\eta} = R_{\text{B}}^{\text{H}}(1-\eta) + \eta = r^{\text{Riskless}}, \quad (25)$$

where $\tilde{p} \in \{0, p\}$ is the default probability for BK_{B}. Even though BK_{B} may default, it is always bailed out: The interbank loan bears no counterparty risk. The interest rate r^{SR} is equal r^{Riskless}.

5.1.3. Optimal monitoring

Under the supranational regulator neither the interest rate nor the interbank loan size depend on the monitoring strategy. From Eq. (14) BK_{B} monitors if:

$$C \leqslant p\left(R_{\text{B}}^{\text{H}} - 1\right) + p\gamma\left[R_{\text{B}}^{\text{H}} - \left(R_{\text{B}}^{\text{H}}(1-\eta) + \eta\right)\right] = p\left(R_{\text{B}}^{\text{H}} - 1\right)(1+\gamma\eta). \quad (26)$$

Note that BK_{B} is more likely to invest in monitoring technology for larger values of p, γ, and η. Large values of p imply a higher default risk; a higher γ suggests higher potential gains from trade. Finally, BK_{B}'s monitoring incentives are proportional to its bargaining power η, as it can capture a larger share of the surplus for a higher η.

5.1.4. Equilibrium

Proposition 2 summarises the equilibrium outcomes under the supranational regulator.

Proposition 2 (*Supranational regulation equilibrium*). *Under a supranational regulator,*

(i) BK_{B} *monitors at* $t = 0$ *if* $C < C^{\text{SR}}(\gamma)$, *where*

$$C^{\text{SR}}(\gamma) = p\left(R_{\text{B}}^{\text{H}} - 1\right)(1+\gamma\eta). \quad (27)$$

(ii) At $t = 1, \text{BK}_{\text{A}}$ *lends* γ *to* BK_{B} *at rate* $r^{\text{Riskless}} = R_{\text{B}}^{\text{H}}(1-\eta) + \eta$.

(iii) At $t = 2$, *the supranational regulator SR bails out any bank in default.*

We compare the monitoring threshold functions for the national and the supranational regulator, given by Eqs. (18) and (27). It follows that $C^{\text{SR}}(\gamma) < C^{\text{NR}}(\gamma)$ for all γ in the domain. Corollary 1 formally states this result.

Corollary 1. (Monitoring under SR and NR)
Monitoring incentives are (weakly) stronger under national regulation than under a supranational regulator.

Bank BK_{B} has weaker monitoring incentives under the supranational regulator. If $C < C^{\text{SR}}(\gamma)$, then $C < C^{\text{NR}}(\gamma)$; bank BK_{B} monitors under both regimes. If $C > C^{\text{NR}}(\gamma)$, then $C > C^{\text{SR}}(\gamma)$, and bank BK_{B} does not monitor under either national or supranational regulation.

From Corollary 1, there exists a cost region for which the supranational regulator SR distorts monitoring incentives. For $C \in \left[C^{SR}(\gamma), C^{NR}(\gamma)\right]$ the bank in country B monitors under national regulation, but does not monitor under the supranational regulator. For such values of the monitoring cost market discipline is destroyed by the introduction of SR.

Note that since $C^{NR} < C^{SR} \iff \min\left\{C^{NR}, \overline{C}\right\} < \min\left\{C^{SR}, \overline{C}\right\}$, the result that BK_B monitors *weakly* less under supranational than under national resolution carries through to the case where $C > \overline{C}$.

From Fig. 3 the monitoring incentives increase in the gains from trade under both resolution mechanisms. For $\gamma < \gamma^*$ market discipline is implemented through a cap on the interbank loan size. For $\gamma > \gamma^*$ market discipline is implemented through a counterparty risk premium. The higher slope of $C^{NR}(\gamma)$ for $\gamma < \gamma^*$ indicates that market discipline is more effective than for $\gamma \geqslant \gamma^*$: Incentives respond more to larger potential gains for trade if interbank lending is rationed.

Table 1 summarises the equilibrium outcomes for both national and supranational regulation. Note that the optimal interbank contract changes with the regulatory system only for a high monitoring cost, i.e. when market discipline breaks down both under national and supranational regulation.[11]

5.2. Welfare impact of the supranational regulator

To evaluate the welfare impact of the supranational regulator, we use the welfare under national regulation as a benchmark.

The SR welfare effect is not trivial ex ante. On the one hand, supranational regulation eliminates inefficient liquidations and cross-border contagion. Further, there is no under-investment as the full intermediate cashflow γ is traded on the interbank market. The potential gains from interbank trade are fully realized. On the other hand, SR may be too lenient: It resorts to bailouts in states of the world where national regulators liquidate an insolvent bank. This worsens moral hazard: Banks with large international exposures can take more risk. The disciplining role of the interbank market fails as the counterparty risk is borne by the joint regulator SR rather than creditors.

Proposition 3 presents the conditions under which joint resolution improves welfare.

Proposition 3 (*Welfare impact of SR*). *Relative to national regulation, a supranational regulator*

(i) ***improves welfare*** *for large monitoring cost values, i.e.* $C > C^{NR}(\gamma)$;
(ii) ***reduces welfare*** *for intermediate monitoring cost values, i.e.* $C \in \left[C^{SR}(\gamma), C^{NR}(\gamma)\right]$;
(iii) ***does not affect welfare*** *for low monitoring cost values, i.e.* $C < C^{SR}(\gamma)$.

Low moral hazard. If $C < C^{SR}(\gamma)$ moral hazard is low. Bank BK_B monitors both under SR and under NR. Introducing a supranational regulator does not distort monitoring incentives for BK_B. There are no bank defaults, and therefore no (inefficient) liquidations. The net welfare effect of the supranational regulator is zero. Both the national and supranational regulators can implement the first best welfare.

High moral hazard. If $C > C^{NR}(\gamma)$ moral hazard is high. Bank BK_B does not monitor neither under SR nor under NR. Again, monitoring incentives are not distorted by the supranational regulator. Market discipline breaks down in both regimes. Consequently, joint regulation is welfare-improving in this case. However, the improvement channel depends on whether γ is smaller or larger than γ^* as defined in Eq. (17).

For $\gamma < \gamma^*$ SR stimulates international trade. From Proposition 1, if the returns from international trade are low, BK_A optimally eliminates counterparty risk. It restricts the loan size such that it is relatively cheap for NR_B to bail out an insolvent BK_B. The default risk is borne by taxpayers in country B, and BK_A accepts a lower expected profit. There is no inefficient liquidation.

Under SR the loan size restriction is redundant. Since the single regulator internalises contagion, it always bails out BK_B, regardless of the interbank loan size. Consequently, interbank trading is stimulated under the supranational regulator. A natural interpretation of this result is that SR prevents the "balkanisation" of cross-border financial intermediation.

For $\gamma \geqslant \gamma^*$ SR eliminates inefficient liquidations. If returns from international trade are high, BK_A optimally bears counterparty risk. The national regulator NR_B liquidates an insolvent domestic bank. The liquidation is inefficient from a joint welfare perspective. The supranational regulator improves welfare as it eliminates cross-border spillovers. There is also a redistribution effect: The interbank interest rate is lower under SR as there is no counterparty risk premium. Consequently, the expected profit of BK_B increases due to lower funding costs.

However, even though SR improves welfare relative to national regulation, it does not achieve the first-best. The moral hazard friction cannot be eliminated.

Intermediate moral hazard. A supranational regulator distorts risk-taking incentives for bank BK_B if $C \in \left[C^{SR}(\gamma), C^{NR}(\gamma)\right]$. Under national regulation BK_B invests in monitoring technology as there is market discipline either through the loan size or the loan rate. There is no default under NR, and therefore no inefficient liquidation. National regulation can implement the first best. Under the supranational regulator however, BK_B is always bailed out. BK_A does not face counterparty risk, and the interbank contract does no longer depend on monitoring. Consequently, BK_B does not monitor; SR stimulates risk-taking. Welfare is lower than for national regulation and the first best.

Corollary 2. (First-best implementation)

For low moral hazard, i.e. $C < C^{SR}(\gamma)$, *both national and supranational regulators implement the first-best. For intermediate moral hazard, i.e.* $C \in \left[C^{SR}(\gamma), C^{NR}(\gamma)\right]$, *only the national regulator implements the first-best. For high moral hazard, i.e.* $C > C^{NR}(\gamma)$, *neither mechanism can implement the first-best.*[12]

5.3. Resolution fund contributions

In this section, national regulators endogenously decide whether to merge into SR at $t = -1$. As a result, the supranational regulator emerges only if it is individually optimal for both regulators to give up resolution powers. Two main results follow from our analysis: First, whenever SR improves welfare, the joint

[11] The model could be extended to allow for positive (exogenous) continuation values at $t = 2$. In this case, bank A would have additional incentives to restrict interbank lending under national regulation, i.e. to avoid a costly bankruptcy. However, in the current setting the $t = 2$ payoff $R_A - \gamma$ can be thought of as BK_A's continuation value. Bank A effectively restricts its lending to avoid counterparty risk. Under supranational resolution the amount exchanged on the interbank market is γ irrespective of the continuation value, as BK_A bears no counterparty risk.

[12] One solution to implement the first best when $C > C^{NR}(\gamma)$ could be a Pigouvian tax (see, e.g., Acharya et al., 2012; Masciandaro and Passarelli, 2013; Perotti and Suarez, 2011). The tax level is set to make bank B indifferent between monitoring or not, i.e. to $C - C^{NR}(\gamma)$. A Pigouvian tax achieves the first best if it can be implemented without frictions.

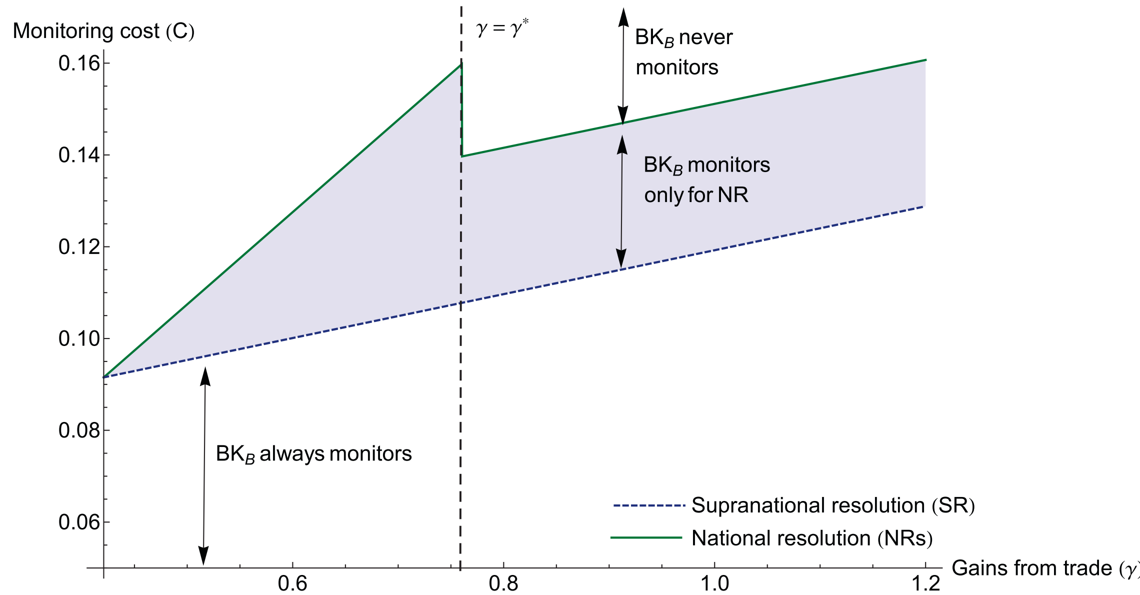


Fig. 3. Equilibrium monitoring for BK_B under national and supranational regulation. This figure displays the monitoring indifference curves for BK_B under national and supranational regulation, $C^{NR}(\gamma)$ and $C^{SR}(\gamma)$ respectively. In the shaded region, BK_B monitors only under national regulation; incentives are worse under a supranational regulator.

Table 1
Equilibrium comparison. This table presents the equilibrium monitoring decision of BK_B, resolution policy, and interbank market contract for both national and supranational regulation. We distinguish between different regions for the gains from trade γ and the monitoring cost C. The threshold γ^* is defined as the unique solution of

$$\left[\frac{\pi_B(\gamma, r^{\text{Risk}}) - \pi_B(0,0)}{\pi_B(\overline{\gamma}, r^{\text{Riskless}}) - \pi_B(0,0)}\right]^{\eta} = \left[\frac{\pi_A(\overline{\gamma}, r^{\text{Riskless}}) - \pi_A(0,0)}{\pi_A(\gamma, r^{\text{Risk}}) - \pi_A(0,0)}\right]^{1-\eta}.$$

The highlighted cells point out the differences between national and supranational resolution systems.

γ range	National regulator			Supranational regulator		
	Monitor	Bailout	Contract	Monitor	Bailout	Contract
Low monitoring cost: $C < C^{SR}(\gamma)$						
all	yes	yes	$(\gamma, r^{\text{Riskless}})$	yes	yes	$(\gamma, r^{\text{Riskless}})$
Intermediate monitoring cost: $C \in \left[C^{SR}(\gamma), C^{NR}(\gamma)\right]$						
$\gamma < \gamma^*$	yes	yes	$(\gamma, r^{\text{Riskless}})$	**no**	yes	$(\gamma, r^{\text{Riskless}})$
$\gamma > \gamma^*$	yes	no	$(\gamma, r^{\text{Riskless}})$	**no**	**yes**	$(\gamma, r^{\text{Riskless}})$
High monitoring cost: $C > C^{NR}(\gamma)$						
$\gamma < \gamma^*$	no	yes	$(\overline{\gamma}, r^{\text{Riskless}})$	no	yes	$(\gamma, r^{\text{Riskless}})$
$\gamma > \gamma^*$	no	no	$(\gamma, r^{\text{Risk}})$	no	**yes**	$(\gamma, r^{\text{Riskless}})$

resolution fund is feasible. Second, the resolution fund share of the creditor country A increases in the gains from trade γ.

For simplicity, we focus on linear resolution fund contracts: NR_A supports a share $\beta \in (0,1)$ of all intervention costs, whereas NR_B supports $1-\beta$. Thus, if a bailout requires a liquidity injection ℓ, country A pays $\beta \times \ell$, and country B will pay $(1-\beta) \times \ell$.

The goal of the analysis is to determine the feasible range for β that offers incentives to both regulators to join SR. The following participation constraints should hold simultaneously:

$$\mathbb{E}\left[\text{Welfare}_A^{SR} - \text{Welfare}_A^{NR}\right] \geqslant 0 \text{ and}$$
$$\mathbb{E}\left[\text{Welfare}_B^{SR} - \text{Welfare}_B^{SR}\right] \geqslant 0. \tag{28}$$

The SR improves welfare if and only if $C > C^{NR}(\gamma)$, i.e. if bank BK_B does not monitor under both national and joint regulation. In this section, we focus on the case where SR improves welfare: For any given value of the gains from trade γ, we assume the monitoring cost C is large enough such that $C > C^{NR}(\gamma)$.

Proposition 4 (*Endogenous SR participation*). *There exists $\beta \in (0,1)$ such that it is optimal for both national regulators to merge into a supranational regulator.*

From Proposition 4 national regulators always merge at $t = -1$ if SR improves welfare.

Fig. 4 illustrates that both the lower and upper bounds for β increase with γ. First, when $\gamma < \gamma^*, NR_A$ is better off by joining the SR as the size of the interbank market increases from $\overline{\gamma}(r^{\text{Riskless}})$ to γ, i.e. there are higher gains from interbank trade. In contrast, NR_B is less willing to join the SR for a higher γ, as its expected bailout costs increase by a factor of $\frac{\gamma - \overline{\gamma}(r^{\text{Riskless}})}{\overline{\gamma}(r^{\text{Riskless}})}$. Consequently, NR_B requires NR_A to pay a higher share of the bailout costs.

Second, when $\gamma \geqslant \gamma^*, NR_A$ does not bear contagion risk if it joins SR, as the supranational regulator is efficient ex post. Under national regulation, NR_A's expected loss due to contagion is proportional to the size of the interbank loan γ. Therefore, NR_A contributes more to the resolution fund for a higher γ. In contrast, upon joining SR, NR_B loses the option to liquidate and to partly transfer the losses abroad. Consequently, for a higher γ, NR_B is less willing to contribute to the resolution fund.

Corollary 3 (Comparative statics). *Define $\underline{\beta}(\gamma)$ and $\overline{\beta}(\gamma)$ such that national regulators choose to merge if and only if $\beta \in \left(\underline{\beta}(\gamma), \overline{\beta}(\gamma)\right)$, the "feasible SR interval".*

If $\gamma < \gamma^*$, the size of the interval, i.e. $\overline{\beta}(\gamma) - \underline{\beta}(\gamma)$ increases in γ and decreases in p. If $\gamma \geqslant \gamma^*$, the size of the interval, i.e. $\overline{\beta}(\gamma) - \underline{\beta}(\gamma)$ decreases in γ and does not change in p.

If the supranational regulator improves welfare through boosting interbank trade, i.e. for $\gamma < \gamma^*$, it is easier to form the SR if the potential boost in the interbank market size (γ) is larger, and if the

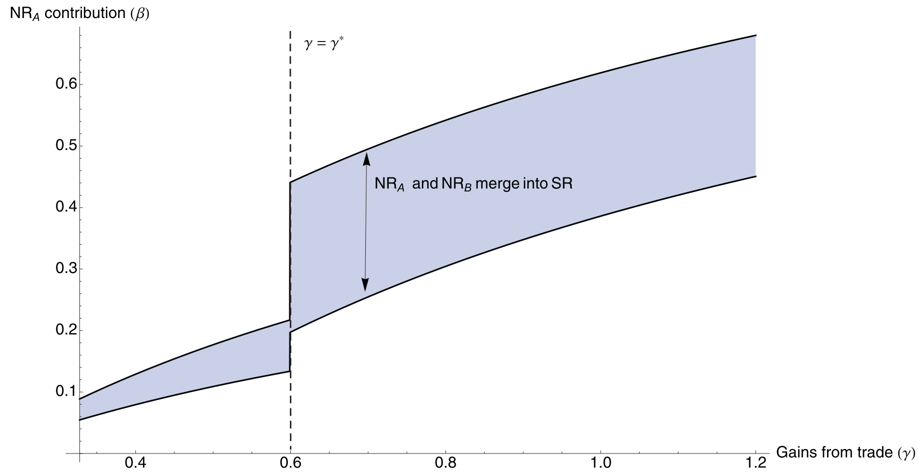


Fig. 4. Feasible resolution fund contributions. This figure depicts feasible linear resolution fund contributions as a function of the potential gains from trade γ. Country A pays a share β of any regulatory contribution; Country B pays $1-\beta$. The two national regulators merge at $t=0$ for values of β in the shaded region.

project backing the interbank loan has a large NPV (the default probability p is small). The shaded region in Fig. 4 widens with γ for $\gamma < \gamma^*$.

If the supranational regulator improves welfare through eliminating inefficient liquidations, i.e. for $\gamma \geqslant \gamma^*$, it is easier to form the SR if the potential gains from the interbank market are small. This is due to the fact that for $\gamma \geqslant \gamma^*$, the supranational resolution mechanism does not alter the size of interbank trading relative to national regulation: there are no additional gains from trade. The total bailout costs increase in γ, and therefore the feasible range for β is narrower.

Since counterparty risk is taken into account also under national regulation through a higher interbank interest rate, it does not influence the feasible SR region.

Corollary 4. *The minimum resolution fund contribution for country A, $\underline{\beta}(\gamma)$, jumps upwards at $\gamma = \gamma^*$:*

$$\lim_{\gamma \nearrow \gamma^*} \underline{\beta}(\gamma) < \lim_{\gamma \searrow \gamma^*} \underline{\beta}(\gamma). \tag{29}$$

The intuition for this result, as in the discussion above, is that for $\gamma > \gamma^*$ NR$_B$ is able to partly transfer abroad the domestic default costs since foreign claims are not covered in full. Under supranational regulation NR$_B$ loses this ability. Therefore, from Corollary 4, it is less willing to contribute to the resolution fund and requires a higher contribution from NR$_A$.

6. Policy implications

The analysis in Section 5 suggests that a supranational resolution mechanism does not necessarily improve welfare, as a result of worse market discipline. To counteract the risk-shifting incentives of banks under SR, other policy instruments are required. In this section, we study how centralized supervision, the bail-in of uninsured creditors, or ex post transfer between regulators can improve or substitute for market discipline and alleviate moral hazard.

6.1. Interaction of single resolution and single supervision mechanisms

Another natural extension of the model is to allow for ex ante bank supervision. We introduce supervision as follows: At $t = -\frac{1}{2}$, the regulator (either national or supranational) makes effort $\lambda > 0$ to monitor the activity of BK$_B$. As a result, the monitoring cost for bank B becomes $Ce^{-\lambda}$. Consequently, the higher the intensity of regulatory supervision, the smaller the bank's incentive to shirk.

Since bank supervision is costly, the optimal regulatory effort λ^* is either zero or such that BK$_B$'s incentive compatibility constraint binds. That is,

$$\begin{aligned} &\text{for the national regulator}: Ce^{-\lambda^{NR}} = C^{NR}(\gamma) \Rightarrow \lambda^{NR} = \log\left(\frac{C}{C^{NR}(\gamma)}\right) \text{ and} \\ &\text{for the supranational regulator}: Ce^{-\lambda^{SR}} = C^{SR}(\gamma) \Rightarrow \lambda^{SR} = \log\left(\frac{C}{C^{SR}(\gamma)}\right). \end{aligned} \tag{30}$$

Since $C^{NR}(\gamma) > C^{SR}(\gamma)$ it follows immediately that $\lambda^{SR} > \lambda^{NR}$. For regulator $R \in \{SR, NR\}$, any supervision effort $\lambda \in (0, \lambda^R)$ has a positive cost but does not improve bank incentives and any supervision effort $\lambda > \lambda^R$ is redundant ("over-supervision").

If the monitoring costs are low, i.e. $C < C^{SR}(\gamma)$, neither the national nor the supranational regulator actively supervise. The bank BK$_B$ monitors its investment even without regulatory control. Consequently, $\lambda^{SR} = \lambda^{NR} = 0$.

For intermediate monitoring costs, i.e. $C \in \left[C^{SR}(\gamma), C^{NR}(\gamma)\right]$, the national regulator does not invest in supervision as BK$_B$ monitors its investment. The supranational regulator, however, makes supervision effort λ^{SR} if it improves welfare:

$$\begin{aligned} &\underbrace{R_A + R_B^H + \gamma\left(B^H - 1\right) - C^{SR}(\gamma) - \log\left(\frac{C}{C^{SR}(\gamma)}\right)}_{\text{Total welfare for } \lambda^{SR} = \log\left(\frac{C}{C^{SR}(\gamma)}\right)} \\ &\geqslant \underbrace{R_A - \gamma + \left(R_B^L + (1-p)R_B^H\right)(1+\gamma)}_{\text{Total welfare for } \lambda^{SR}=0}. \end{aligned} \tag{31}$$

Equivalently, the supranational regulator makes supervision effort λ^{SR} if the monitoring cost is low enough, i.e.

$$C^{SR}(\gamma) < C < C^{SR}(\gamma)e^{C^{SR}(\gamma) + p\left(R_B^H - R_B^L\right)(1+\gamma)}. \tag{32}$$

For high monitoring costs, i.e. $C > C^{NR}(\gamma)$, it is ambiguous whether the national or the supranational regulator supervises more. In particular, the national regulator $\mathrm{NR_B}$ takes into account the domestic share of the interbank market gains, which are netted out in the supranational welfare function. Also, under national regulation, supervision can prevent inefficient liquidations upon default, which is never the case under SR. While the positive effort condition for SR is still given by (32), the equivalent condition for the national regulator crucially depends on the bargaining power η and the liquidation loss L.

To sum up, if the supranational resolution mechanism reduces market discipline, it optimally compensates through a higher ex ante effort to supervise banks subject to moral hazard. The net welfare effect of a supranational regulator crucially depends on the assumed supervision cost function. For example, as Colliard (2013) and Carletti et al. (2015) argue, cross-border agency conflicts in supranational bank regulators tend to augment supervision costs. Therefore, a supranational regulator does not necessarily improve welfare, even if it monitors more ex ante.

6.2. Bail-ins

A crucial assumption of the model is that a regulator chooses between a full bailout and a liquidation of a defaulting bank. In this section we extend the baseline set-up and incorporate a *bail-in* of uninsured bank creditors.

We define the *bail-in* as an ex ante commitment technology, through which the regulator is obliged to write down claims of the uninsured bank's creditors following a default. The regulator decides whether to commit to a bail-in at $t = -\frac{1}{2}$, i.e. before $\mathrm{BK_B}$'s monitoring decision. If $\mathrm{BK_B}$ does not monitor and defaults, then the country B depositors are repaid, but not $\mathrm{BK_A}$. As a consequence, $\mathrm{BK_A}$ also defaults, while depositors in country A are repaid by the regulator.

In what follows we focus on the consequences of the new policy for the supranational regulator. We then briefly discuss the implications of the bail-in for the case with national regulators.

Resolution comparison. It immediately follows that, if $\mathrm{BK_B}$ does not monitor,[13] for any given interbank loan size γ_I the supranational regulator is indifferent between a bail-in and a bail-out, since it will have to repay insured depositors in country A in both cases:

$$\begin{aligned} \text{Welfare}^{\text{Bail-in}} &= \text{Welfare}^{\text{SR}} \\ &= (1-p)\left[R_A + R_B^H + \gamma_I\left(R_B^H - 1\right)\right] \\ &\quad + p\left[R_A + R_B^L(1+\gamma_I) - \gamma_I\right]. \end{aligned} \tag{33}$$

Interbank contract. The intuition is the same as in Lemma 3. In contrast to the equilibrium in Section 4, however, strategically restricting the interbank loan size to $\overline{\gamma}$ by $\mathrm{BK_A}$ does not trigger a bailout if SR is committed to a bail-in. Therefore, banks choose between exchanging the maximum amount γ or zero.

If the supranational regulator commits to a bail-in and $\mathrm{BK_B}$ does not monitor, the interbank contract is $(\gamma, r^{\text{Risk}})$ for $\gamma \geqslant \gamma^{**}$ and $(0, r^{\text{Riskless}})$ for $\gamma < \gamma^{**}$, where γ^{**} solves $\mathrm{BK_A}$'s participation constraint,

$$\pi_A(\gamma^{**}, r^{\text{Risk}}) - \pi_A(0,0) = 0. \tag{34}$$

From Eqs. (16) and (34) it follows that $\gamma^{**} < \gamma^{*}$. If $\mathrm{BK_B}$ monitors its loan, the interbank contract is unchanged, i.e. $(\gamma, r^{\text{Riskless}})$.

Market discipline. The *bail-in* policy restores market discipline without a loss of welfare – from Eq. (33). For $\gamma \geqslant \gamma^{**}$, $\mathrm{BK_A}$ requires a higher interest rate than under the bailout policy, $r^{\text{Risk}} > r^{\text{Riskless}}$, if $\mathrm{BK_B}$ does not monitor. For $\gamma < \gamma^{**}$, the interbank market breaks down: no interbank loan compared to a loan of γ under the bailout policy. In both cases, this deters the risk-taking incentives of $\mathrm{BK_B}$.

Monitoring. Bank $\mathrm{BK_B}$ monitors its project if and only if $C < C^{\text{Bail-in}}(\gamma)$, where

$$C^{\text{Bail-in}}(\gamma) = \begin{cases} p\left[\left(R_B^H - 1\right) + \gamma\left(R_B^H - r^{\text{Riskless}}\right)\right] & \text{if } \gamma < \gamma^{**}, \\ p\left[(R_B^H - 1)(1+\eta\gamma) + \eta(R_A - 1)\right] & \text{if } \gamma \geqslant \gamma^{**}. \end{cases} \tag{35}$$

By comparing (35) with (27) it follows that $C^{\text{Bail-in}} > C^{\text{SR}}$ for all admissible γ: Commitment to the bail-in always improves monitoring incentives under the supranational regulator.

Welfare effects of bail-ins. For $\gamma > \gamma^{**}$ the supranational regulator committed to bail-in implements the same interbank contracts as the national regulator in Proposition 1 for $\gamma > \gamma^{*}: (\gamma, r^{\text{Risk}})$ or $(\gamma, r^{\text{Riskless}})$, depending on $\mathrm{BK_B}$'s monitoring decision. In particular, the maximum amount γ is exchanged on the interbank market. Since from Eq. (35) the bail-in commitment also improves incentives, it follows that bail-ins always (weakly) improve welfare, and the supranational regulator wants to commit to a bail-in ex ante.

For $\gamma < \gamma^{**}$ the welfare impact of bail-in commitments depends on the monitoring cost. In particular, for $C > C^{\text{Bail-in}}$, there is no interbank loan as $\mathrm{BK_A}$ participation constraint (34) is not met. Consequently, the bail-in commitment reduces welfare by $\gamma\left[(1-p)R_B^H + pR_L^H\right]$. Naturally, a welfare-reducing commitment is not optimal.

To sum up, bail-ins can improve incentives and welfare. However, it is not always optimal for SR to commit to a bail-in: For low gains from trade γ and high monitoring costs C, bail-ins discourage interbank trading and reduce welfare.

Bail-ins by national regulators. If the national regulator $\mathrm{NR_B}$ commits to a bail-in, monitoring thresholds for the bank $\mathrm{BK_B}$ are the same as for the supranational regulator, i.e. given by Eq. (35). Intuitively, the two regulatory regimes (supranational and national) do not differ any more from the perspective of the lending bank $\mathrm{BK_A}$.

Ex post, if $\mathrm{BK_B}$ does not monitor, a bail-in of foreign bank creditors is always preferred by the national regulator $\mathrm{NR_B}$, since on the one hand it limits intervention costs compared to a bail-out, and on the other hand it does not involve efficiency losses, L, associated with a liquidation.

Ex ante, however, the national regulator might prefer not to commit to a bail-in. As for the supranational regulator, this is the case for sufficiently low gains from interbank lending, $\gamma < \gamma^{**}$, when the interbank market breaks down following the commitment to a bail-in.

In practice, it is likely that bail-ins are also easier to implement by a supranational agency, as it eliminates conflicts of interest between national regulators associated with cross-border liability transfers.

6.3. Regulatory cooperation

An alternative to setting up a single resolution mechanism is relying on an ex post fund transfer from $\mathrm{NR_A}$ to $\mathrm{NR_B}$. As follows from the Coase (1960) theorem, both arrangements implement the ex post optimal outcome.[14]

[13] If the bank in country B monitors its loan, then no intervention is needed.

[14] The national regulator in country A would agree to pay any transfer T that improves welfare. There exists T that satisfies $\mathrm{NR_A}$'s participation constraint, since

$$\underbrace{R_A + \gamma(r^{\text{Risk}} - 1) - T}_{\text{Welfare}_A \text{ after transfer}} > \underbrace{R_A - \gamma\left(1 - R_B^L(1-L)\right)}_{\text{Welfare}_A \text{ after liquidation of } \mathrm{BK_B}} \iff T < \underbrace{\gamma\left(r^{\text{Risk}} - 1 - R_B^L(1-L)\right)}_{>0}.$$

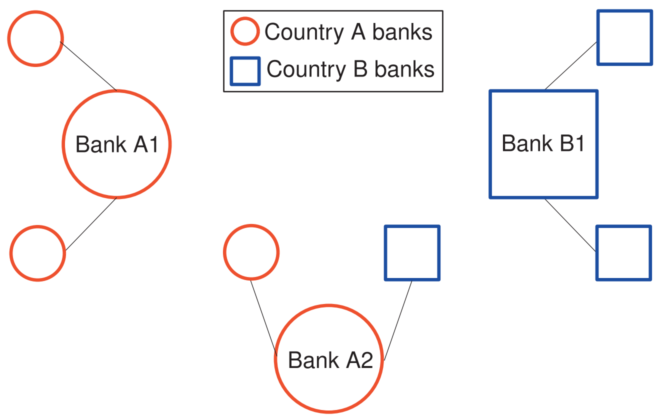


Fig. 5. International bank network. This figure depicts a stylized interbank network structure with two countries, A and B. Links between banks represent payment relationships.

However, in practice ex post transfers can be difficult to implement due to different objectives of national regulators and information asymmetries between regulators (Holthausen and Ronde, 2004). One example of information asymmetry is the costly verification of a cross-border default. Also, the international exposure of banks is difficult to measure, especially if complex instruments are involved. Informational asymmetries complicate the bargaining process, potentially increasing liquidation costs and delaying resolution.

7. Empirical implications

There are a number of predictions of the model that could be empirically tested. First, following the announcement and implementation of the European SRM, banks with strong international links are more likely to be bailed out due to potential cross-border spillovers – at least as implied by market beliefs. Secondly, they should have a higher appetite for risk, thus pointing to a moral hazard problem.

Testing the two hypotheses should take into account the network structure of the European interbank market. In particular, to identify a "too-European-to-fail" effect, one needs to decompose network centrality into a national and an international (cross-border) component. In Fig. 5, bank $A1$ is connected with two domestic banks, whereas bank $A2$ is connected with one domestic and one foreign bank. Therefore, banks $A1$ and $A2$ are identical from the point of view of the whole network, but different from a national network perspective. Assuming their default triggers the insolvency of connected smaller banks, they are equally systemically important for the supranational regulator. However, the national country A regulator is more concerned about a $A1$ default (3 out of 5 banks become insolvent) than about a $A2$ default (2 out of 5 banks become insolvent).

Concretely, the empirical implications of our model are that following the introduction of the SRM, banks with a higher European network centrality ($A2$ rather than $A1$).

1. have a higher bailout likelihood as implied by CDS, bond, or put option prices, and
2. shift their portfolios towards riskier assets.

The bailout likelihood is proportional with the value of implicit guarantees: this can be extracted either from CDS prices (Merton et al., 2015) or using an explicit measure, such as the Fitch Support Ratings. The risk-taking behavior of banks can be measured either from balance sheet data (Rajan, 2006) or market data (Laeven and Levine, 2009).

8. Conclusion

This paper studies the impact of supranational bank resolution. A natural interpretation of the SR in our model is the Single Resolution Mechanism, as recently introduced in European Union. From this perspective, our paper contributes to the recent European debate on the banking union. We study the welfare impact of a supranational regulator and make policy proposals for the structure of the resolution fund.

From an ex post perspective, supranational resolution is optimal as it eliminates cross-border contagion. However, ex post optimal policies come at the price of reduced market discipline. This is particularly the case if monitoring costs are low, e.g. banks hold few opaque assets – as opaque assets are likely to have high monitoring costs (e.g. higher expertise needed to manage complex derivatives portfolios, or worse agency problems for more opaque borrowers). If banks' monitoring costs are high, a supranational resolution mechanism improves welfare. One channel is higher resolution efficiency. National regulators may prefer inefficient liquidations of insolvent banks as they involve lower cross-border wealth transfers. Contrastingly, the supranational regulator resorts to efficient bailouts, as it internalises contagion effects. A second channel is higher gains from trade. Supranational resolution mechanism stimulates interbank trade, as it provides contagion insurance. The "balkanisation" of interbank markets is reversed under the SRM.

There are two main policy implications. First, if a supranational resolution mechanism has a negative effect on bank incentives, either bail-ins or a more restrictive ex ante supervision of banks might be needed to compensate for the additional moral hazard. However, it is not always optimal for supranational regulators to commit to bail-ins. Second, the resolution fund contributions depend on international positions of banks. In the current regulatory proposals, contributions are only related to the size of the deposit base. Our model suggests that some countries benefit from this system, while others are disadvantaged. If cross-border positions are taken into account when setting up resolution fund shares, more countries could be willing to join the banking union.

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Appendix A. Notation summary

Model parameters and interpretation

Parameter	Definition
γ	Intermediate return for BK_A at $t=1$.
R_A	Deterministic return for BK_A at $t=2$.
$\widetilde{R}_B \in \left\{R_B^H, R_B^L\right\}$	Stochastic return for BK_B at $t=2$.
p	Default probability of BK_B if it does not monitor.
C	Cost of monitoring technology for BK_B.
L	Project value percentage loss upon liquidation: $L \in (0,1)$.
β	Resolution fund share for country A.

Appendix B. The road to a banking union in Europe

Initial response to the global financial crisis. Initially, the response of European authorities to the destabilizing situation in the financial system was carried out within two funding programs: the European Financial Stability Facility and the European Financial Stabilization Mechanism, established on May 10, 2010. The two programs had the authority to raise up to EUR 500 billion, guaranteed by the European Commission and the EU member states. The mandate of the European Financial Stability Facility and the European Financial Stabilization Mechanism was to "safeguard financial stability in Europe by providing financial assistance" to Eurozone member countries.

Financial help from the two facilities could be obtained only after a request made by a Eurozone member state and was conditional on implementation of a country-specific program negotiated with the European Commission and the International Monetary Fund.

In September 2012, the two programs were replaced by the European Stability Mechanism. The European Stability Mechanism support, again conditional on acceptance of a structural reform program, was designed also for direct bank recapitalization.

Path to the banking union. On June 29, 2012, during the Eurozone summit, European leaders called for a Single Supervisory Mechanism (SSM) of national financial systems within the ECB. On September 12, 2012, in response to the Eurozone summit debate, the European Commission proposed that the ECB become the direct supervisor of all EU banks (with the right to grant and retract banking licenses). In the first half of 2013, the key elements of the European banking union took shape. Two main pillars were proposed: the SSM (on March, 19) and the Single Resolution Mechanism (on June, 27).

SSM. According to the proposals as of January 2014, participation in the SSM will be mandatory for all Eurozone countries, and optional only for other EU member states. Within the SSM, only banks viewed as "systemically important" will be supervised by the ECB directly. Approximately 150 institutions are included that satisfy at least one of five following requirements:

1. The assets' value exceeds EUR 30 billion.
2. The assets' value exceeds EUR 5 billion and 20% of the GDP of the given member state.
3. The institution is among top three largest banks in the country of the location.
4. The institution is characterized by intense cross-border activities.
5. The institution receives support from the EU bailout programs.

All other banks will remain under the direct supervision of national regulators, with the ECB keeping the overall supervisory role. The supreme body of the SSM will be the Supervisory Board consisting of national regulators — members of the SSM — and representatives of the ECB. The Supervisory Board, although administratively separated, will, however, remain legally subordinate to the Governing Council of the ECB.

Single resolution mechanism (SRM). The resolution of troubled banks identified in accordance with the SRM regulation will be entrusted to the Single Resolution Board (SRB), consisting of representatives from the ECB and the European Commission, and relevant national authorities. In the case of bank distress, the SRB will propose a resolution strategy, to which the European Commission has a right to object.

The resolution tools made available to the SRB include: the sale of business, setting up a bridge institution with the purpose of asset sales in the future, separation of assets with the use of asset management vehicles, and bail-ins, in which the claims of unsecured bank creditors will be converted into equity or written down.

The availability of funding support will be guaranteed through the Single Resolution Fund (SRF). The SRF will be financed with contributions from financial institutions under the SSM. Each participating institution will be required to add an equivalent of 1% of its covered deposits to the joint fund within eight years from the establishment of SRF. As a result, the total value of the SRF should reach around EUR 55 billion. The use of the SRF will be restricted to 5% of the total liabilities of the distressed institution and will be made conditional on the bail-in of at least 8% of total liabilities.

Appendix C. Proofs

Lemma 1. Given a default of the bank BK_B it is always optimal to bail it out, since

$$\underbrace{R_A + R_B^L + \gamma_I(R_B^L - 1)}_{\text{Ex post total welfare after bailout of } BK_B} \geqslant \underbrace{R_A + R_B^L + \gamma_I(R_B^L - 1) - LR_B^L(1+\gamma_I)}_{\text{Ex post total welfare after liquidation of } BK_B}. \tag{C.1}$$

The total welfare when BK_B invests in monitoring is

$$\text{Welfare}^M = R_A + R_B^H + \gamma_I(R_B^H - 1) - C, \tag{C.2}$$

which is increasing in γ_I, thus in equilibrium $\gamma_I = \gamma$. As BK_B is always bailed out following a default, the joint welfare when BK_B does not monitor is

$$\begin{aligned}\text{Welfare}^{NM} = (1-p)\left[R_A + R_B^H + \gamma_I(R_B^H - 1)\right] \\ + p\left[R_A + R_B^L + \gamma_I(R_B^L - 1)\right].\end{aligned} \tag{C.3}$$

Welfare^{NM} increases in γ_I when $(1-p)(R_B^H - 1) - p(1 - R_B^L)$ is larger than zero, i.e. $p \leqslant \bar{p}$ where $\bar{p} = \frac{R_B^H - 1}{R_B^H - R_B^L}$. It is optimal to set $\gamma_I = \gamma$. When $p > \bar{p}$ there is no interbank transfer in the first-best.

Finally, investing in the monitoring technology is welfare-maximizing when

$$\text{Welfare}^M \geqslant \text{Welfare}^{NM} \iff \begin{cases} C \leqslant p(1+\gamma)(R_B^H - R_B^L) = \overline{C}_1 & \text{if } p \leqslant \bar{p} \\ C \leqslant p(R_B^H - R_B^L) + \gamma(R_B^H - 1) = \overline{C}_2 & \text{if } p > \bar{p}. \end{cases} \tag{C.4}$$

By Assumption 2 both $\overline{C}_1$ and $\overline{C}_2$ are larger than $\overline{C}$. Thus in the first-best equilibrium BK_B invests in the monitoring technology and $\gamma_I = \gamma$.

Lemma 2. In country B, welfare is larger after bailout than after liquidation if

$$\text{Welfare}_B^{\text{bailout}} - \text{Welfare}_B^{\text{liquidation}} = \gamma_I\left(R_B^L - r\right) + LR_B^L$$
$$> 0 \iff \gamma_I < \frac{LR_B^L}{r - R_B^L}. \tag{C.5}$$

Lemma 3. *Case 1:* BK_B *invests in the monitoring technology*. The interbank loan is risk free. The expected profit for BK_A is $(R_A - 1) + \gamma(r^M - 1)$, and for BK_B it is $R_B^H - 1 + \gamma\left(R_B^H - r^M\right)$. Since both profit functions increase in γ, it is optimal to lend the maximum amount, $\gamma_I = \gamma$. The interbank interest rate then solves

$$r^M = \arg\max_i \left[\gamma\left(R_B^H - i\right)\right]^\eta [\gamma(i-1)]^{1-\eta}, \tag{C.6}$$

and is equal

$$r^M = (1-\eta)R_B^H + \eta = r^{\text{Riskless}}. \tag{C.7}$$

Case 2: BK_B *does not invest in the monitoring technology*. If the loan size $\overline{\gamma}(r)$, the interbank loan is risk free. BK_A's expected payoff is $(R_A - 1) + \overline{\gamma}(r^{NM})(r^{NM} - 1)$, and BK_B's expected payoff is $(1-p)\left(R_B^H - 1 + \overline{\gamma}(r^{NM})(R_B^H - r^{NM})\right)$. Using the definition of $\overline{\gamma}(r) = \frac{LR_B^L}{r - R_B^L}$, the interbank interest rate solves

$$r^{NM} = \arg\max_i \left[(1-p)\frac{LR_B^L}{i - R_B^L}\left(R_B^H - i\right)\right]^\eta \left[\frac{LR_B^L}{i - R_B^L}(i-1)\right]^{1-\eta}, \tag{C.8}$$

and is again equal to

$$r^{NM} = (1-\eta)R_B^H + \eta = r^{\text{Riskless}}. \tag{C.9}$$

Note that any loan size $\gamma_I < \overline{\gamma}(r)$ is suboptimal: the loan is still risk-free, but not all the gains from trade are realized. At the same time, any loan size $\gamma_I \in (\overline{\gamma}(r), \gamma)$ is Pareto-dominated by $\gamma_I = \gamma$. Conditional that bank BK_A does not eliminate counterparty risk and bank BK_B does not eliminate default risk, a higher loan size increases both banks' profits.

If Bank BK_A decides to lend γ, the interbank loan is risky. BK_A's expected payoff is equal to $(1-p)\left[R_A - 1 + \gamma(r^{NM} - 1)\right]$, and BK_B's expected payoff is $(1-p)(R_B^H - 1 + \gamma\left(R_B^H - r^{NM}\right)$. The interbank interest rate solves

$$r^{NM} = \arg\max_i \left[(1-p)\gamma\left(R_B^H - i\right)\right]^\eta [(1-p)(R_A - 1 + \gamma(i-1)) - (R_A - 1)]^{1-\eta}, \tag{C.10}$$

and is equal

$$r^{NM} = R_B^H(1-\eta) + \eta + \frac{\eta}{\gamma(1-p)}p(R_A - 1) > r^{\text{Riskless}}. \tag{C.11}$$

Proposition 1. First, compare payoffs to BK_A from alternative investment policies. If BK_B monitors the risky project, it is always weakly preferred to invest in the interbank market rather than store cash, as for $\eta \in [0,1]$:

$$R_A - 1 + \gamma(r^{\text{Riskless}} - 1) \geqslant R_A - 1. \tag{C.12}$$

If BK_B does not monitor, BK_A can invest $\overline{\gamma}(r^{\text{Riskless}})$ for the interest rate r^{Riskless}, or γ for r^{Risk}, defined in Lemma 3. The interbank contract $(\gamma, r^{\text{Risk}})$ is preferred to $(\overline{\gamma}(r^{\text{Riskless}}), r^{\text{Riskless}})$ if the joint marginal profits of the two banks, weighted by their bargaining power, is larger:

$$\left[\frac{\pi_B(\gamma, r^{\text{Risk}}) - \pi_B(0,0)}{\pi_B(\overline{\gamma}, r^{\text{Riskless}}) - \pi_B(0,0)}\right]^\eta \geqslant \left[\frac{\pi_A(\overline{\gamma}, r^{\text{Riskless}}) - \pi_A(0,0)}{\pi_A(\gamma, r^{\text{Risk}}) - \pi_A(0,0)}\right]^{1-\eta}. \tag{C.13}$$

Let γ^* be a solution of (C.13). Since the left-hand side and the right-hand side of (C.13) increases, respectively decreases in γ, the solution γ^* is unique.

Consider the case when $\gamma < \gamma^*$. BK_B monitors the risky project if

$$C \leqslant p\left(R_B^H - 1\right) + \gamma\left(R_B^H - r^{\text{Riskless}}\right) - (1-p)\overline{\gamma}(r^{\text{Riskless}})\left(R_B^H - r^{\text{Riskless}}\right) \iff$$
$$C \leqslant p(R_B^H - 1)\left[1 + \tfrac{\eta}{p}(\gamma - (1-p)\overline{\gamma}(r^{\text{Riskless}}))\right]. \tag{C.14}$$

When $\gamma < \gamma^*$ and BK_B monitors, the interbank contract is $(\gamma, r^{\text{Riskless}})$. If BK_B does not monitor, the interbank contract is $(\overline{\gamma}(r^{\text{Riskless}}), r^{\text{Riskless}})$.

Consider the case when $\gamma \geqslant \gamma^*$. BK_B monitors the risky project if

$$C \leqslant p\left(R_B^H - 1\right) + \gamma\left(R_B^H - r^{\text{Riskless}}\right) - (1-p)\gamma\left(R_B^H - r^{\text{Risk}}\right) \iff$$
$$C \leqslant p\left[(R_B^H - 1)(1 + \eta\gamma) + \eta(R_A - 1)\right]. \tag{C.15}$$

When $\gamma \geqslant \gamma^*$ and BK_B monitors, the interbank contract is $(\gamma, r^{\text{Riskless}})$. If BK_B does not monitor, the interbank contract is $(\gamma, r^{\text{Risk}})$.

Proposition 2. From Eq. (23), the SR always bails out a defaulting bank, and from Eq. (25), the interest rate r^{SR} is equal r^{Riskless}. The interbank loan is risk free, thus BK_A always lends the maximum amount γ. BK_B monitors if:

$$C \leqslant p\left(R_B^H - 1\right) + p\gamma\left[R_B^H - \left(R_B^H(1-\eta) + \eta\right)\right]$$
$$= p\left(R_B^H - 1\right)(1 + \gamma\eta) = C^{SR}(\gamma). \tag{C.16}$$

Corollary 1. For $\gamma < \gamma^*$ the comparison of the monitoring thresholds $C^{NR}(\gamma)$ and $C^{SR}(\gamma)$ yields:

$$C^{NR}(\gamma) - C^{SR}(\gamma) = p(R_B^H - 1)\left[1 + \frac{\eta}{p}(\gamma - (1-p)\overline{\gamma}(r^{\text{Riskless}}))\right]$$
$$- p\left(R_B^H - 1\right)(1 + \gamma\eta) \tag{C.17}$$
$$= (R_B^H - 1)\left[\eta(\gamma - (1-p)\overline{\gamma}(r^{\text{Riskless}})) - p\eta\gamma\right] \tag{C.18}$$
$$= (R_B^H - 1)(1-p)\eta(\gamma - \overline{\gamma}(r^{\text{Riskless}})) > 0.$$

For $\gamma \geqslant \gamma^*$ the comparison yields:

$$C^{NR}(\gamma) - C^{SR}(\gamma) = p\left[(R_B^H - 1)(1 + \eta\gamma) + \eta(R_A - 1)\right]$$
$$- p\left(R_B^H - 1\right)(1 + \gamma\eta) \tag{C.19}$$
$$= p\eta(R_A - 1) > 0.$$

Proposition 3. *High moral hazard.* First, let $C > C^{NR}(\gamma)$. Bank BK_B does not monitor under either national or supranational regulation. If $\gamma \geqslant \gamma^*$, then at $t = 1$ BK_A lends γ on the interbank market. If BK_B is insolvent, the national regulator liquidates it and the supranational regulator bails it out. The welfare functions under national and supranational regulation are

$$\begin{aligned}\text{Welfare}^{\text{NR}} &= (1-p)\left[R_A + R_B^H + \gamma\left(R_B^H - 1\right)\right] \\ &\quad + p\left[R_A - \gamma\left(1 - R_B^L(1-L)\right) + (1-L)R_B^L\right], \\ \text{Welfare}^{\text{SR}} &= (1-p)\left[R_A + R_B^H + \gamma\left(R_B^H - 1\right)\right] \\ &\quad + p\left[R_A + R_B^L(1+\gamma) - \gamma\right].\end{aligned} \tag{C.20}$$

The SR welfare impact is

$$\text{Welfare}^{\text{SR}} - \text{Welfare}^{\text{NR}} = pLR_B^L(1+\gamma) > 0, \tag{C.21}$$

and therefore supranational resolution improves welfare. If $\gamma < \gamma^*$, then at $t = 1$ BK_A lends γ on the interbank market under SR and $\overline{\gamma}(r^{\text{Riskless}})$ under NR. Both the national and supranational regulator bail out BK_B following default. The welfare functions become:

$$\begin{aligned}\text{Welfare}^{\text{NR}} &= (1-p)\left[R_A + R_B^H + \overline{\gamma}(r^{\text{Riskless}})\left(R_B^H - 1\right)\right] \\ &\quad + p\left[R_A + R_B^L(1+\gamma) - \gamma\right], \\ \text{Welfare}^{\text{SR}} &= (1-p)\left[R_A + R_B^H + \gamma\left(R_B^H - 1\right)\right] \\ &\quad + p\left[R_A + R_B^L(1+\overline{\gamma}(r^{\text{Riskless}})) - \overline{\gamma}(r^{\text{Riskless}})\right].\end{aligned} \tag{C.22}$$

The SR welfare impact is

$$\text{Welfare}^{\text{SR}} - \text{Welfare}^{\text{NR}} = (\gamma - \overline{\gamma}(r^{\text{Riskless}}))\left[(1-p)R_B^H + pR_B^L - 1\right] > 0, \tag{C.23}$$

as long as the risky project has positive net present value (NPV). Again, supranational resolution improves welfare.

Intermediate moral hazard. Let $C \in \left[C^{\text{SR}}(\gamma), C^{\text{NR}}(\gamma)\right]$. Bank BK_B monitors under national regulation and does not monitor under supranational regulation. Bank BK_B never defaults under national regulation; under SR, if it defaults it is always bailed out. For both NR and SR, BK_A lends γ on the interbank market. The welfare functions are:

$$\begin{aligned}\text{Welfare}^{\text{NR}} &= R_A + R_B^H + \gamma\left(R_B^H - 1\right) - C, \\ \text{Welfare}^{\text{SR}} &= (1-p)\left[R_A + R_B^H + \gamma\left(R_B^H - 1\right)\right] + p\left[R_A + R_B^L(1+\gamma) - \gamma\right].\end{aligned} \tag{C.24}$$

Using Assumption 2 the SR welfare impact is

$$\text{Welfare}^{\text{SR}} - \text{Welfare}^{\text{NR}} = p\left(R_B^L - R_B^H\right)(1+\gamma) + C < 0. \tag{C.25}$$

Therefore, for $C \in \left[C^{\text{SR}}(\gamma), C^{\text{NR}}(\gamma)\right]$ the supranational regulator reduces welfare.

Low moral hazard. Finally, let $C < C^{\text{SR}}(\gamma)$. Bank BK_B monitors under both national and supranational regulation. There is never a need for regulatory intervention and BK_A lends γ on the interbank market. The welfare functions are:

$$\begin{aligned}\text{Welfare}^{\text{NR}} &= R_A + R_B^H + \gamma\left(R_B^H - 1\right) - C, \\ \text{Welfare}^{\text{SR}} &= R_A + R_B^H + \gamma\left(R_B^H - 1\right) - C.\end{aligned} \tag{C.26}$$

The introduction of SR has no impact on welfare.

Corollary 2. The joint first best welfare is

$$\text{Welfare}^{\text{FB}} = R_A + R_B^H + \gamma\left(R_B^H - 1\right) - C. \tag{C.27}$$

From Eq. (C.26), both the national and the supranational regulator implement the first best if $C < C^{\text{SR}}(\gamma)$.

From Eq. (C.24), only the national regulator implement the first best if $C \in \left[C^{\text{SR}}(\gamma), C^{\text{NR}}(\gamma)\right]$.

From Eqs. (C.20) and (C.22), neither the national or the supranational regulator implement the first best if $C > C^{\text{NR}}(\gamma)$.

Proposition 4. First, consider the case that $\gamma < \gamma^*$. The welfare functions under national regulation for the two countries are

$$\begin{aligned}\text{Welfare}_A^{\text{NR}} &= (1-p)(R_A + \overline{\gamma}(r^{\text{Riskless}})(r^{\text{Riskless}} - 1)) \\ &\quad + p(R_A + \overline{\gamma}(r^{\text{Riskless}})(r^{\text{Riskless}} - 1)) \text{ and} \\ \text{Welfare}_B^{\text{NR}} &= (1-p)\left(R_B^H(1 + \overline{\gamma}(r^{\text{Riskless}})) - \overline{\gamma}(r^{\text{Riskless}})r^{\text{Riskless}}\right) \\ &\quad + p\left(R_B^L(1 + \overline{\gamma}(r^{\text{Riskless}})) - \overline{\gamma}(r^{\text{Riskless}})r^{\text{Riskless}}\right).\end{aligned} \tag{C.28}$$

The welfare functions under the SR for the two countries are

$$\begin{aligned}\text{Welfare}_A^{\text{SR}} &= (1-p)(R_A + \gamma(r^{\text{Riskless}} - 1)) \\ &\quad + p\left(R_A + \gamma(r^{\text{Riskless}} - 1) - \beta\left(1 + \gamma r^{\text{Riskless}} - R_B^L(1+\gamma)\right)\right) \text{ and} \\ \text{Welfare}_B^{\text{SR}} &= (1-p)\left(R_B^H(1+\gamma) - \gamma r^{\text{Riskless}}\right) \\ &\quad + p\left(1 - (1-\beta)\left(1 + \gamma r^{\text{Riskless}} - R_B^L(1+\gamma)\right)\right).\end{aligned} \tag{C.29}$$

The participation constraint for NR_A is

$$\begin{aligned}\text{Welfare}_A^{\text{SR}} > \text{Welfare}_A^{\text{NR}} &\iff \beta < \overline{\beta}_1 \\ &= \frac{(\gamma - \overline{\gamma}(r^{\text{Riskless}}))\left[r^{\text{Riskless}} - 1\right]}{p\left(1 + \gamma r^{\text{Riskless}} - R_B^L(1+\gamma)\right)}.\end{aligned} \tag{C.30}$$

The participation constraint for NR_B is

$$\begin{aligned}\text{Welfare}_B^{\text{SR}} > \text{Welfare}_B^{\text{NR}} &\iff \beta > \underline{\beta}_1 \\ &= \frac{(\gamma - \overline{\gamma}(r^{\text{Riskless}}))\left[r^{\text{Riskless}} - \left((1-p)R_B^H + pR_B^L\right)\right]}{p\left(1 + \gamma r^{\text{Riskless}} - R_B^L(1+\gamma)\right)}.\end{aligned} \tag{C.31}$$

It follows that $\overline{\beta}_1 > \underline{\beta}_1$, so that the interval $\left(\underline{\beta}_1, \overline{\beta}_1\right)$ exists, if and only if $(1-p)R_B^H + pR_B^L > 1$. Moreover, $\overline{\beta}_1 > 0$, such that there exists β for which BK_A joins the SR.

Regulator NR_B joins the SR if $\underline{\beta}_1 < 1$. Note that

$$\frac{\partial \underline{\beta}_1}{\partial p} = -\frac{\left(R_B^H - r^{\text{Riskless}}\right)\left(r^{\text{Riskless}} - R_B^L\right)(\gamma - \overline{\gamma}(r^{\text{Riskless}}))}{p^2\left(r^{\text{Riskless}} - R_B^L\right)\left(1 - R_B^L + \gamma\left(r^{\text{Riskless}} - R_B^L\right)\right)} < 0. \tag{C.32}$$

The boundary value $\underline{\beta}_1$ decreases in p. It follows that $p = 0$ gives an upper bound for $\underline{\beta}_1$:

$$\underline{\beta}_1 < \frac{(\gamma - \overline{\gamma}(r^{\text{Riskless}}))\left(r^{\text{Riskless}} - R_B^L\right)}{1 + \gamma r^{\text{Riskless}} - R_B^L(1+\gamma)} < 1. \tag{C.33}$$

Therefore, $\underline{\beta}_1 < 1$. Since $\underline{\beta}_1 < 1$ and $\overline{\beta}_1 > 0$, there always exists $\beta \in (0,1)$ such that the national regulators join the S.

Next, consider the case that $\gamma \geqslant \gamma^*$. The welfare functions under national regulation for the two countries are

$$\begin{aligned}\text{Welfare}_A^{\text{NR}} &= (1-p)(R_A + \gamma(r^{\text{Risk}} - 1)) + p\left(R_A - \gamma\left(1 - R_B^L(1-L)\right)\right) \text{ and} \\ \text{Welfare}_B^{\text{NR}} &= (1-p)\left(R_B^H(1+\gamma) - \gamma r^{\text{Risk}}\right) + p(1-L)R_B^L.\end{aligned} \tag{C.34}$$

The welfare functions under the SR for the two countries are the same as in (C.29).

The participation constraint for NR_A is

$$\text{Welfare}_A^{SR} > \text{Welfare}_A^{NR} \iff \beta < \overline{\beta}_2 = \frac{\gamma\left[r^{\text{Riskless}} - \left((1-p)r^{\text{Risk}} + pR_B^L(1-L)\right)\right]}{p\left(1+\gamma r^{\text{Riskless}} - R_B^L(1+\gamma)\right)}. \tag{C.35}$$

The incentive compatibility constraint for NR_B is

$$\text{Welfare}_B^{SR} > \text{Welfare}_B^{NR} \iff \beta > \underline{\beta}_2 = \frac{\gamma\left[r^{\text{Riskless}} - \left((1-p)r^{\text{Risk}} + p\frac{R_B^L(\gamma+L)}{\gamma}\right)\right]}{p\left(1+\gamma r^{\text{Riskless}} - R_B^L(1+\gamma)\right)}. \tag{C.36}$$

It follows that $\overline{\beta}_2 > \underline{\beta}_2$, so that the interval $\left(\underline{\beta}_2, \overline{\beta}_2\right)$ exists.

It also follows that $\overline{\beta}_2 > 0$ if and only if

$$(1-p)\left(r^{\text{Risk}} - r^{\text{Riskless}}\right) < p\left(r^{\text{Riskless}} - R_B^L(1-L)\right). \tag{C.37}$$

Note that $\underline{\beta}_2 < 1$ since

$$\underline{\beta}_2 - 1 = -\frac{1-(1-L)R_B^L + \eta(R_A - 1)}{1+\gamma r^{\text{Riskless}} - R_B^L(1+\gamma)} < 0. \tag{C.38}$$

From Assumption 3, since $\gamma > \frac{R_A - 1}{1-R_B^L(1-L)}$, it follows that

$$\begin{aligned}\frac{r^{\text{Riskless}} - \left((1-p)r^{\text{Risk}} + pR_B^L(1-L)\right)}{p} &= \left[R_B^H(1-\eta) + \eta - \frac{\eta}{\gamma}(R_A-1) - R_B^L(1-L)\right] \\ &> \left[R_B^H(1-\eta) + \eta - \frac{\eta\left(1-R_B^L(1-L)\right)}{R_A-1}(R_A-1) - R_B^L(1-L)\right] \\ &= \left(R_B^H - R_B^L(1-L)\right)(1-\eta) > 0.\end{aligned} \tag{C.39}$$

From (C.39), $\overline{\beta}_2 > 0$ since

$$\begin{aligned}\overline{\beta}_2 &= \frac{\gamma\left[r^{\text{Riskless}} - \left((1-p)r^{\text{Risk}} + pR_B^L(1-L)\right)\right]}{p\left(1+\gamma r^{\text{Riskless}} - R_B^L(1+\gamma)\right)} \\ &> \frac{\gamma\left(R_B^H - R_B^L(1-L)\right)(1-\eta)}{\left(1+\gamma r^{\text{Riskless}} - R_B^L(1+\gamma)\right)} > 0.\end{aligned} \tag{C.40}$$

Since $\underline{\beta}_2 < 1$ and $\overline{\beta}_2 > 0$, there always exists $\beta \in (0,1)$ such that the national regulators join the SR.

Corollary 3. First, consider the case $\gamma < \gamma^*$. The partial derivative of $\overline{\beta}_1 - \underline{\beta}_1$ with respect to p is:

$$\frac{\partial\left(\overline{\beta}_1 - \underline{\beta}_1\right)}{\partial p} = -\frac{\left(R_B^H - 1\right)\left(\gamma - \overline{\gamma}\left(r^{\text{Riskless}}\right)\right)}{p^2\left(1 - R_B^L + \eta\left(r^{\text{Riskless}} - R_B^L\right)\right)} < 0. \tag{C.41}$$

The partial derivative of $\overline{\beta}_1 - \underline{\beta}_1$ with respect to γ is:

$$\frac{\partial\left(\overline{\beta}_1 - \underline{\beta}_1\right)}{\partial \gamma} = \frac{\left(1-(1-L)R_B^L\right)\left((1-p)R_B^H + pR_B^L - 1\right)}{p\left(1 - R_B^L + \eta\left(r^{\text{Riskless}} - R_B^L\right)\right)^2} > 0, \tag{C.42}$$

as long as $(1-p)R_B^H + pR_B^L - 1 > 0$. Consequently, the size of the feasible SR interval decreases in p and increases in γ if $\gamma < \gamma^*$.

Next, we consider the case $\gamma \geqslant \gamma^*$. The partial derivative of $\left(\overline{\beta}_2 - \underline{\beta}_2\right)$ with respect to p is zero, as neither $\overline{\beta}_2$ nor $\underline{\beta}_2$ are functions of p (see proof of Proposition 4).

The partial derivative of $\overline{\beta}_2 - \underline{\beta}_2$ with respect to γ is:

$$\frac{\partial\left(\overline{\beta}_2 - \underline{\beta}_2\right)}{\partial \gamma} = \frac{(\eta-1)\left(R_B^H - 1\right)LR_B^L}{\left(1 - R_B^L + \eta\left(r^{\text{Riskless}} - R_B^L\right)\right)^2} < 0. \tag{C.43}$$

Consequently, the size of the feasible SR interval decreases in γ if $\gamma \geqslant \gamma^*$.

Corollary 4. From Eqs. (C.31) and (C.36) it follows that

$$\underline{\beta}_2(\gamma^*) - \underline{\beta}_1(\gamma^*) = \frac{1}{1+\gamma^* r^{\text{Riskless}} - R_B^L(1+\gamma^*)} \frac{\eta LR_B^L\left(R_B^H - 1\right)}{r^{\text{Riskless}} - R_B^L} > 0. \tag{C.44}$$

Therefore,

$$\underline{\beta} = \begin{cases} \underline{\beta}_1 & \text{if} \quad \gamma < \gamma^* \\ \underline{\beta}_2 & \text{if} \quad \gamma \geqslant \gamma^* \end{cases} \tag{C.45}$$

jumps at $\gamma = \gamma^*$.

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