Optimal Supervisory Architecture and Financial Integration in a Banking Union*

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Abstract

Both in the United States and in the Euro Area, bank supervision is the joint responsibility of local and central supervisors. I study a model in which local supervisors do not internalize as many externalities as a central supervisor. Local supervisors are more lenient, but banks also have weaker incentives to hide information from them. These two forces can make a joint supervisory architecture optimal, with more weight put on centralized supervision when cross-border externalities are larger. Conversely, more centralized supervision endogenously encourages banks to integrate more cross-border. Due to this complementarity, the economy can be trapped in an equilibrium with both too little central supervision and too little financial integration, when a superior equilibrium would be achievable.

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1 Introduction

Following the increasing integration of banking systems in the past decades, the boundaries of a bank's activities can stretch significantly further than the mandate of its supervisor. As a result, supervisors can lack either the power or the incentives to properly monitor banks. For instance, Agarwal, Lucca, Seru, and Trebbi (2014) show that bank supervision in the United States is systematically more lenient at the State level than at the Federal level. In Europe, the European Commission proposed the creation of a "Single Supervisory Mechanism" (SSM) in September 2012, so as to improve the supervision of Euro Area banks and promote the integration of European banking markets.[1] Both areas now have a joint supervisory architecture, relying both on State/Federal or national/supranational agencies.

This paper adopts an organization theory perspective to study the architecture of bank supervision. Banks can be monitored either by a local supervisor or a central supervisor. Central supervision is preferable *ex post* as only the central supervisor takes into account cross-border externalities. However, a more lenient local supervisor gives banks weaker incentives to hide problems, which can be desirable *ex ante*. Due to these two forces, a joint architecture can be optimal. I show that centralized supervision and cross-border integration are complements: more integration increases the externalities and the need for centralized supervision, while centralized supervision fosters integration and increases cross-border externalities. Because of this complementarity, an economy may be "stuck" in a suboptimal equilibrium with local supervision and little integration. Instead, the optimal architecture should be forward-looking and take into account how the market adapts to supervision.

[1] The preamble of the Council Regulation No 1024/2013 of 15 October 2013 mentions market integration as one of the primary motivations for setting up the SSM.

In the model, a bank can have bad loans that it is reluctant to liquidate. Bank supervisors conduct on-site inspections in order to learn the quality of the bank's loans, and may order a liquidation if necessary. A central supervisory authority decides the frequency with which inspections are conducted by a local supervisor or a central supervisor. The mix between both types of inspections is called a supervisory architecture.

The bank can invest resources in order to decrease the probability that a supervisory inspection leads to a liquidation (e.g., lobbying, revolving doors...). This investment depends on the supervisory architecture. The local supervisor does not take into account the cross-border externalities of a bank's distress, which makes him soft on the bank. Conversely, the central supervisor internalizes all the losses triggered by the bank's default, making her tougher.[2] Even though the central supervisor always prefers to be responsible for inspections ex post, a joint architecture acts as a commitment to being more lenient with the bank. This reduces incentives for the bank to avoid inspections ex ante, which can lead to a more efficient outcome than fully centralized supervision.[3]

This simple theory of supervisory architectures has implications on the optimal level of centralization for a given bank. In particular, financial integration and centralized supervision reinforce each other. On the one hand, when a bank relies more on foreign funding the cross-border externalities are stronger, the local supervisor is more lenient and there is more scope for centralized supervision. On the other hand, centralized supervision reduces the risk for foreign investors to lend to the bank, which allows the bank to borrow more from them.

[2]I will refer to the central supervisor with the female pronoun "she" and to the local supervisor with the male pronoun "he".

[3]A related idea in the corporate finance literature is that a company's board can commit to being soft with the manager so as to increase her incentives to collect and communicate information (e.g., Burkart, Gromb, and Panunzi (1997) and Adams and Ferreira (2007)).

This complementarity can generate multiple equilibria. When looking at a bank with few foreign creditors, the central supervisor concludes that the bank is best left to local authorities. Precisely for this reason, few foreign investors lend to the bank. Centralizing supervision would generate more lending by foreigners, making central supervision necessary. If the supervisory architecture does not internalize this impact, which I call being "passive," the economy can be trapped in an equilibrium with both too little central supervision and too little market integration, when a superior equilibrium is achievable.[4] As an example, supervision by the European Central Bank (ECB) is triggered by a number of sufficient criteria that are backward-looking in nature.

The paper delivers some insights into which criteria should be used to allocate a bank to the central supervisor, the most important one in the model being the extent of cross-border externalities. Interestingly, some of the other criteria used in practice have an ambiguous effect in the model. Bank size, a key criterion for the SSM, scales up both the costs and benefits of centralizing supervision. The expected riskiness of the bank, whose increase can allow the Federal supervisor to take over supervision in the United States, also has an ambiguous impact. If a bank has very poor prospects, even the local supervisor will intervene. Central supervision is useful for banks that are likely to be weak enough to warrant liquidation from the perspective of the central supervisor, but not from the perspective of the local supervisor.

In addition to normative implications about the organization of bank supervision, the paper also delivers empirical implications on the impact of changes in the supervisory architecture on banks. The main mechanism is that banks supervised at the central level should

[4] A parallel can be made with the endogeneity of optimal currency areas (Frankel and Rose (1998)).

increase their cross-border activities and find it easier to borrow from foreign sources than comparable banks supervised at the local level. Importantly, this mechanism only operates when investors are uncertain about the quality of a bank's assets, for instance in crisis times. The implementation of the SSM at the end of 2013, when investors were concerned about a number of European banks, is a good example of a situation in which the effects studied in the model can be expected to materialize.

This paper contributes to the theoretical literature on bank supervision, which includes papers such as Mailath and Mester (1994), Kahn and Santos (2005), and Eisenbach, Lucca, and Townsend (2016). Whereas these papers consider a bank operating in only one area, a limited number of theoretical studies have considered the supervision of cross-border activities, such as Dalen and Olsen (2003), Holthausen and Ronde (2004), Calzolari and Loranth (2011), and Hardy and Nieto (2011). My setup differs from this literature as I look at the "vertical" problem of a central supervisor delegating to a local supervisor instead of the "horizontal" interaction between equal national supervisors. This vertical dimension is the one that seems relevant to understand the recent U.S. based empirical evidence, and also reflects the new situation in the Euro Area.

Recent studies have shown the empirical relevance of frictions in supervision. Beck, Todorov, and Wagner (2013) show both theoretically and empirically (on European data) that supervisory incentives react to the nationality of a bank's shareholders, creditors, and assets. I build on this idea to study how best to organize supervision in the presence of such incentives. Fiordelisi, Ricci, and Saverio Stentella Lopes (2017) show that European banks part of the SSM reduced their lending so as to increase their capitalization. In addition to the already mentioned Agarwal, Lucca, Seru, and Trebbi (2014), other relevant papers in the empirical literature include for instance Kang, Lowery, and Wardlaw (2015), Rezende (2014), and Gopalan, Kalda, and Manela (2017).

More broadly, this paper is related to the literature on competition and coordination among regulators, as studied in, e.g., Acharya (2003), Dell'Ariccia and Marquez (2006), and Morrison and White (2009). Note that both in the United States and in the European Union regulation is already fully integrated, while supervision can be conducted at a local level.

The development of the European Banking Union has spurred a number of theoretical papers deriving new economic mechanisms that are important to understand the challenges of supranational supervision.[5] Beck and Wagner (2016) study the costs and benefits of supranational supervision in the presence of a trade-off between cross-border externalities and heterogeneity of national preferences regarding financial stability. Importantly, externalities are exogenous in their model, whereas the main mechanism of my paper relies on externalities being endogenous to supervision. Calzolari, Colliard, and Loranth (2016) show that centralized supervision can induce multinational banks to expand abroad through branches rather than subsidiaries, thereby increasing potential losses for deposit insurance funds. Boyer and Ponce (2012) caution that a central supervisor will be weaker against lobbying efforts than separate supervisors. Górnicka and Zoican (2016) and Foarta (2014) focus on the impact of bail-outs and recapitalizations in the Banking Union, thus complementing this paper's analysis of common supervision with a study of bank resolution. Carletti, Dell'Ariccia, and Marquez (2016) consider a situation in which local supervisors are responsible for collecting

[5] See also Vives (2001) for an early discussion of the challenges for financial integration and common regulation in Europe.

information about banks, while intervention decisions are taken by a central supervisor. Centralized decision-making then lowers the local supervisor's incentives to collect information. In some cases, this makes centralized supervision less efficient at controlling the bank's risk-taking. This is an important caveat for the current design of the SSM. My paper focuses on a different friction, as I assume that the central supervisor can conduct inspections herself.[6]

Finally, this paper can be seen as an application of organization theory to the topic of banking supervision. Consistent with actual supervisory arrangements, I assume that it is legally infeasible to use monetary transfers to control the local supervisor's incentives, so that a supervisory architecture simply consists in allocating the authority to inspect and close a bank to either a local or a central supervisor. This is formally related to the delegation problems studied in, e.g., Aghion and Tirole (1997). An interesting specificity of bank supervision is that the supervisory architecture itself affects market outcomes and thus the bias of the agent. This key feature of the present paper generates new challenges for designing an optimal supervisory architecture.

The remainder of the paper is organized as follows. Section 2 introduces the assumptions of the model. Section 3 solves for the optimal supervisory architecture, taking the structure of the banking system as given. This structure is then endogeneized in Section 4. Section 5 summarizes the policy and empirical implications of the model.

[6]This is the case in the U.S. In the Euro Area, SSM inspections are conducted by "joint supervisory teams" involving both national supervisors and supervisors from the ECB. I consider the polar case in which the team's objectives are aligned with the central supervisor, while Carletti, Dell'Ariccia, and Marquez (2016) consider the other polar case, the reality being probably somewhere in between.

2 Framework

The economy: I consider a simple intermediation model in which banks stand between borrowers and investors. All agents are price-takers and risk-neutral.

- A continuum of penniless *borrowers* can invest in risky projects that require one unit of investment. A successful project returns $1 + \rho$. The returns are heterogeneous across borrowers: For a given r, there are $q(r)$ borrowers with $\rho > r$, with $q'(r) < 0$. With probability p, all projects are successful, otherwise they fail and return 0.[7] Under these assumptions, for a given net interest rate r the demand for loans is equal to $q(r)$.

At $t = 0$, all agents only know the distribution of the success probability, $p \hookrightarrow F(.)$ over $[0, 1]$, with a continuous density $f(.)$. The actual p is privately revealed to the bank only in $t = 2$, at which date the project can be liquidated. A liquidated project yields $(1 - \ell)$.

- *Banks* extend a quantity L of loans to borrowers at rate $1+r$, with $L = q(r)$ in equilibrium. On the liability side, banks have a given quantity D_h of domestic debt and no capital.[8] In order to lend $L > D_h$, banks need to borrow $D_f = L - D_h$ from foreign investors. Banks are price-takers when borrowing, and take as given the rate $1 + i$ at which they can borrow. On the lending side they also compete in prices, but borrowers face a switching cost s, so that banks can charge an intermediation margin equal to s and in equilibrium we have $r = i + s$.

- *Foreign investors* stand ready to lend to banks at rate $1 + i$ as long as this rate gives them an expected return above the risk-free return, normalized to 1. *Home investors* can lend up to D_h at the same rate. All investors are uninsured. If a bank defaults, its assets are

[7] p thus represents the probability of a negative macroeconomic shock, whereas diversifiable shocks are already included in the average return ρ.

[8] This assumption models in a stylized way a bank with a high leverage. The model can be extended to the case of positive capital, as shown in the Online Appendix.

distributed pro-rata to its creditors.

Finally, throughout the paper I will make the assumption that demand is always higher than D_h, so as to exclude uninteresting cases in which the bank does not need to borrow from foreign investors at all. Formally, this corresponds to the following assumption, where i_{max} is the maximum interest rates that banks can pay in equilibrium:

$$q(i_{max} + s) > D_h, \text{ with } i_{max} \text{ such that } (1 + i_{max})\mathbb{E}(p) = 1. \tag{H1}$$

Supervision and inspections: By construction, the liquidation value of loans is not enough for banks to repay their debt, so that due to limited liability they never voluntarily liquidate the loans. Investors cannot observe p, for instance because they are individually too small for such monitoring to be efficient. In line with Dewatripont and Tirole (1994), the bank supervisor monitors the bank in lieu of the other agents and can force liquidation.

A supervisor can conduct *inspections* in $t = 2$. Inspections are imperfect and difficult to conduct. There is a probability $1 - d$ that an inspection is *informative*, in which case the supervisor learns the exact value of p, and decides whether the bank's loans should be liquidated. With probability d instead, the inspection is *uninformative*, and the supervisor doesn't learn the value of p. It is assumed that, for informational and legal reasons, it is impossible to liquidate the bank's projects without inspecting the bank, and without the inspection being informative.

The probability d is interpreted as the *inspection difficulty*, and it can be affected by the bank. The bank can pay a non-pecuniary cost $C(d)$ per unit of loan in order to increase the difficulty from 0 to d, with C increasing, convex, and $C(0) = C'(0) = 0$. Increasing inspection difficulty can be interpreted as making the bank more complex, lobbying the supervisory authorities, practicing a “revolving door policy”, or any other action that makes supervisors less likely to liquidate the bank's assets.[9] To avoid the uninteresting case in which the bank can entirely avoid inspections, I assume that C' is sufficiently large in $d = 1$:

$$C'(1) > s \int_0^{1-\ell} p dF(p). \tag{H2}$$

Supervisory architecture: There are two risk-neutral supervisors. The *local supervisor* aims at maximizing the welfare of local agents, and the *central supervisor* at maximizing total welfare in the economy. Local welfare is denoted $\hat{W}_1$, $\hat{W}_0$, $\hat{W}_\ell$, depending on whether loans are successful, failing, or liquidated, respectively. Similarly, total welfare is equal to W_1, W_0, or W_ℓ. Local welfare includes the borrowers' surplus, the banks' profit, and the payoff to home investors. Total welfare additionally includes the foreign investors' payoff.

With frequency λ (e.g., once every $1/\lambda$ years), the central supervisor is tasked with conducting the inspection in $t = 2$, whereas the local supervisor is in charge with frequency $1-\lambda$. λ is chosen by the central supervisor and represents the supervisory architecture. The cases $\lambda = 0$ and $\lambda = 1$ correspond to fully local and fully central supervision.

Timeline: I consider two possible timings of the model. In the *passive architecture* case, I consider an equilibrium in which the central supervisor takes the assets and liabilities of the bank as given and optimally reacts to them when choosing the frequency of central inspections, while banks and investors optimally react to the supervisory architecture. The

[9] See Lambert (2017) and Lucca, Seru, and Trebbi (2014) for recent evidence on lobbying and revolving doors, respectively.

central supervisor does not take into account that in the long-run changing the architecture is going to affect the market equilibrium. The timing is then:

-$t = 0$: Investors choose the interest rate $1 + i$ at which they lend to banks, banks choose the quantity L they lend to borrowers, and borrow D_f from foreign investors. The central supervisor chooses the frequency λ with which she will be responsible for inspecting the bank.

-$t = 1$: Banks choose the inspection difficulty d, at cost $L \times C(d)$.

-$t = 2$: p is realized. The central supervisor inspects the bank with frequency λ, and with frequency $1 - \lambda$ the local supervisor does it. The supervisor who inspects the bank learns p with probability $1 - d$, in which case he or she can force the liquidation of the project.

-$t = 3$: If the projects were not liquidated in $t = 1$, they succeed with probability p and banks are repaid $(1 + r)L$. The banks repay $(1 + i)D_h$ to home investors and $(1 + i)D_f$ to foreign investors. With probability $1 - p$ the loans fail, banks and investors obtain a zero payoff.

I also consider a *forward-looking architecture* case: the central supervisor takes into account that she can influence market participants through her choice of λ (she acts as a Stackelberg leader). Formally, there is a new period $t = -1$ at which the central supervisor sets λ, while investors and banks still set L and i in $t = 0$.

The timeline with a passive architecture is summed up in Fig. 1.

Discussion: The model is meant to capture in a stylized way "federal" or two-layered supervisory systems, the two main examples being the Euro Area and the United States. In the Euro Area, the supervision of banks under the SSM relies on a partition of the banking system into two groups. The "most significant credit institutions" are supervised directly by the ECB. Although the national supervisors play a role in the inspections, the ultimate

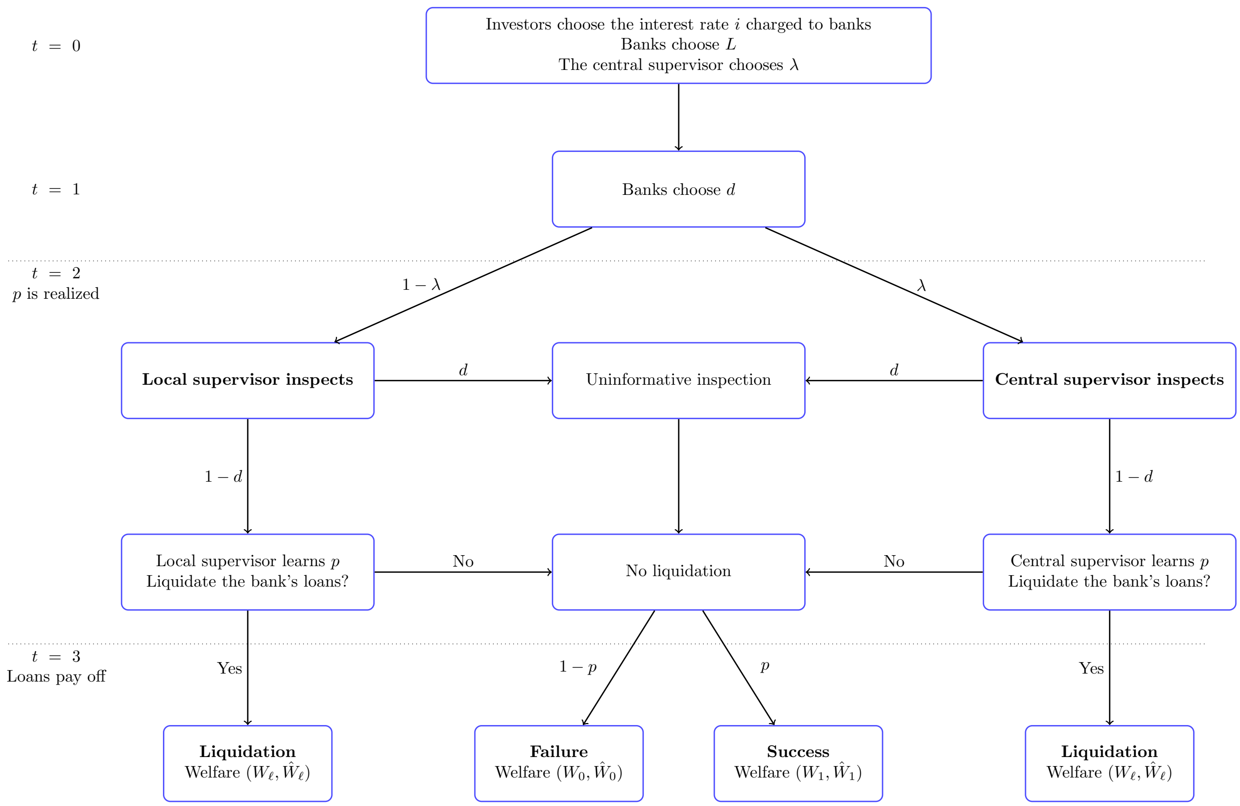

Figure 1: Timeline - Market equilibrium and choice of a supervisory architecture.

decision lies with the ECB, which corresponds to the case $\lambda = 1$. Conversely, while the ECB does some offsite monitoring of the less significant banks, the on-site supervision is entirely left to national authorities, which corresponds to the case $\lambda = 0$ in the model. As discussed below in Section 5, the criteria used to determine the most significant credit institutions are by nature backward-looking, which corresponds to the case of a "passive architecture". In the United States, almost all State-chartered commercial banks are supervised both by a State supervisor and a Federal supervisor. The frequency of inspections by the Federal supervisor depends on the significance of the bank, and is represented by λ in the model.

In order to have a tractable equilibrium model in which supervision and market forces interact, I assume a specific market structure. However, several assumptions made for tractability are not necessary to obtain the main results of the paper.

- The assumptions on the structure of the economy model a situation in which a region with financing needs relies on foreign capital flows. This structure creates a wedge between the two supervisors. While I assume that funding in the bank's home country is capped at D_h in order to focus on the impact of supervision on foreign investors, the model can be extended to have elastic investors in both countries (see the Online Appendix). Similar results can also be obtained if the bank has more foreign assets than foreign liabilities, as long as there is some imbalance (see Beck, Todorov, and Wagner (2013) for a general treatment of this question, and the Online Appendix for an extension with foreign assets).

- The bank's liabilities are uninsured. One can think of these liabilities as wholesale funding, in particular for foreign debt. It is important in the model that foreign investors react to the probability that the bank will be liquidated, so that they must be uninsured, or imperfectly insured. However, it doesn't matter whether domestic liabilities are insured or not. Hence, one can easily adapt the model and interpret D_h as insured deposits.

- The presence of switching costs for bank borrowers is necessary to ensure that banks make a strictly positive profit. If $s = 0$, then banks make a null profit and never invest in the inspection avoidance technology. Other assumptions can be made about the competition between banks without changing the key intuitions of the model (e.g., differentiated competition). However, assuming switching costs is realistic (see, e.g., Kim, Kliger, and Vale (2003)), represents a small departure from a competitive model so that the results are not driven by imperfect competition effects, and gives tractable analytical solutions.

- The only cost of central supervision in this model is that it endogenously makes the bank invest more in inspection avoidance. However, the main results of the model rely on the benefits of central supervision, and the fact that they increase with financial integration.

These results still obtain for other costs of central supervision, as long as they do not increase too quickly with financial integration.[10]

- The parameter λ is interpreted as the frequency with which the central supervisor inspects the bank. While the model has only one inspection stage and λ is mathematically a probability, it is straightforward to extend the model to several identical periods representing an inspection cycle, and λ is the proportion of periods in which the central supervisor inspects. It is important for this interpretation to be correct that the bank chooses d for an entire inspection cycle, and cannot re-optimize between inspections. In other words, the avoidance technology used by the bank corresponds to a long-run investment. Finally, one can easily consider the more restrictive case in which λ has to be equal to either 0 or 1, and show that the main results of the paper below would still be valid.

3 Optimal delegation of supervisory powers

This section solves for the optimal supervisory architecture, taking the interest rates i and $r = i + s$ and thus the banks' assets $L = q(r)$ and foreign debt $D_f = q(r) - D_h$ as given.

3.1 Liquidation decisions and inspection difficulty

Proceeding by backward induction, we can first solve for the optimal decision taken by a supervisor at $t = 2$. In case the bank is liquidated, the total surplus is equal to $(1 - \ell)L$, and

[10]For instance, an earlier version of this paper assumed that the local supervisor had more local expertise and could inspect at a lower cost. While this is a relevant concern for the Euro Area, this effect may weaken over time as the ECB gains experience. In Beck and Wagner (2016), the cost of centralized supervision is that it is a "one-size-fits all" policy that neglects cross-country heterogeneity. In Carletti, Dell'Ariccia, and Marquez (2016), the cost is that local supervisors are less diligent at collecting information when the final decision is taken by a central supervisor with different objectives.

is shared between domestic and foreign investors proportionally to their claims on the bank, D_h and D_f, while the borrowers and the bank's shareholders receive zero. The total welfare from the perspective of the central supervisor is $W_\ell = (1-\ell)L$. As the local supervisor neglects the foreign investors, the local welfare is only $\hat{W}_\ell = (1-\ell)D_h$.

If the bank is not liquidated, its loans are repaid with probability p. In that case, denoting $S = \int_r^{+\infty} q(x)dx + (1+r)L$ the total Marshallian surplus from the loans, the borrowers receive $S - (1+r)L$, the bank $(1+r)L - (1+i)(D_h + D_f) = sL$, domestic investors $(1+i)D_h$, and foreign investors $(1+i)D_f$. The central supervisor thus considers the social surplus to be $W_1 = S$. From the perspective of the local supervisor, the social surplus is the same amount, minus the payoff accruing to foreign investors, that is $\hat{W}_1 = S - D_f(1+i)$. Finally, when loans are not repaid, all agents receive a zero payoff and we have $W_0 = \hat{W}_0 = 0$.

Knowing the loans' success probability p, the central supervisor receives W_ℓ if she liquidates the loans, against an expected welfare of $pW_1 + (1-p)W_0$ if she does not. Liquidation thus occurs when p is lower than the *central supervisor's intervention threshold* p_c. Similarly, the local supervisor intervenes when p is lower than the *local supervisor's intervention threshold* p_l. The thresholds are equal to:

$$p_c = \frac{W_\ell}{W_1} = \frac{(1-\ell)L}{S}, p_l = \frac{\hat{W}_\ell}{\hat{W}_1} = \frac{(1-\ell)D_h}{S - D_f(1+i)}. \tag{1}$$

Using that $S > (1+r)q(r) = (1+r)L$, we have $p_l \leq p_c$ in equilibrium: The local supervisor intervenes less than the central supervisor. This is due to the local supervisor neglecting the losses borne by foreign investors when the bank's projects fail.

We can now solve for the bank's optimal choice of inspection difficulty in $t = 1$. If the bank expects to be liquidated when $p < x$, its expected profit per loan can be written as:

$$\pi(x) = s \times \int_x^1 p dF(p). \tag{2}$$

Thus, the bank expects to receive $\pi(0)$ per loan if the inspection is uninformative, and $\pi(p_l)$ and $\pi(p_c)$ for informative inspections by the local and the central supervisors, respectively. Since $p_c \geq p_l$ and $\pi'(x) \leq 0$, we have $\pi(p_c) \leq \pi(p_l)$. All else equal, an informative central inspection implies that the bank survives in fewer states of the world and thus receives a lower expected profit than with an informative local inspection. To determine the bank's choice of inspection difficulty, using Fig. 1 we can write its expected profit $\Pi(d, \lambda)$ as:

$$\Pi(d, \lambda) = L\left(\underbrace{d\pi(0)}_{\text{Uninformative inspection}} + \underbrace{\lambda[1-d]\pi(p_c)}_{\text{Central inspection}} + \underbrace{(1-\lambda)[1-d]\pi(p_l)}_{\text{Local inspection}} - \underbrace{C(d)}_{\text{Cost}}\right). \tag{3}$$

Increasing the inspection difficulty d makes it more likely that the bank won't be liquidated even for low values of p, but is costly. Differentiating Π with respect to d gives us:[11]

Lemma 1. *The bank's optimal inspection difficulty $d^*(\lambda)$ is given by:*

$$\Pi_1(d^*(\lambda), \lambda) = L[\pi(0) - \lambda\pi(p_c) - (1-\lambda)\pi(p_l) - C'(d^*(\lambda))] = 0. \tag{4}$$

$d^*(\lambda)$ increases in the frequency λ with which the central supervisor conducts the inspection:

$$d^{*\prime}(\lambda) = \frac{\pi(p_l) - \pi(p_c)}{C''(d^*(\lambda))} \geq 0. \tag{5}$$

[11] All proofs not in the text can be found in the Appendix.

Thus, centralized supervision gives banks an incentive to respond by increasing inspection difficulty. Indeed, as the central supervisor is tougher on the bank, investing to decrease supervisory efficiency is more profitable when central supervision is more likely. This effect creates an incentive for the central supervisor to delegate inspections to the local level.

3.2 Optimal supervisory architecture

We can now solve for the optimal choice of λ, for given values of p_c and p_l. The total expected welfare in the economy, denoted $\mathcal{W}(\lambda)$, is equal to:

$$\underbrace{d^*(\lambda)\mathbb{E}(p)W_1}_{\text{Uninformative}} + (1-d^*(\lambda))\left(\underbrace{\lambda\left[F(p_c)W_\ell + \int_{p_c}^{1} pW_1 dF(p)\right]}_{\text{Central}} + \underbrace{(1-\lambda)\left[F(p_l)W_\ell + \int_{p_l}^{1} pW_1 dF(p)\right]}_{\text{Local}}\right). \tag{6}$$

Welfare is the sum of three terms. With an uninformative inspection, welfare is equal to pW_1, summed over all realizations of p. With frequency $\lambda(1-d^*)$, the central supervisor conducts an informative inspection, and welfare is equal to W_ℓ instead of pW_1 if $p \leq p_c$. With frequency $(1-\lambda)(1-d^*)$, the local supervisor conducts an informative inspection and the intervention threshold is p_l instead of p_c. Replacing W_ℓ with $W_1 p_c$ using equation (1), we can rewrite total welfare as:

$$\mathcal{W}(\lambda) = W_1\left[\mathbb{E}(p) + (1-d^*(\lambda))\left(\lambda\int_0^{p_c}(p_c - p)dF(p) + (1-\lambda)\int_0^{p_l}(p_c - p)dF(p)\right)\right]. \tag{7}$$

To determine the optimal level of central inspections λ, the following quantity plays an important role:

$$\chi = \frac{\int_{p_l}^{p_c}[p_c - p]dF(p)}{\int_0^{p_c}[p_c - p]dF(p)}. \tag{8}$$

This ratio measures the ex-post benefit of central inspections: the denominator is the additional welfare obtained with a central inspection rather than a local inspection, and the numerator is the welfare obtained with a central inspection. Marginally increasing λ has a positive impact on welfare if and only if:

$$\mathcal{W}'(\lambda) \geq 0 \Leftrightarrow \underbrace{[1 - d^*(\lambda)]\chi}_{\text{Ex-post}} - \underbrace{d^{*\prime}(\lambda)[1 - (1 - \lambda)\chi]}_{\text{Ex-ante}} \geq 0. \tag{9}$$

Increasing the frequency of inspections by the central supervisor has two effects. The first term is a positive ex-post effect: for a given inspection difficulty, it is always better to have the central supervisor conduct the inspection, as the local supervisor is biased towards leniency. The second term measures a negative ex ante effect of central supervision: more frequent inspections by a tougher supervisor incentivize the bank to increase inspection difficulty, so as to avoid being liquidated more often. A joint system with both local and central inspections can be optimal, with the optimal frequency of inspections λ^* balancing the ex-post effect (which depends on χ) and the ex-ante effect (which depends on $d^{*\prime}$ and hence on C''):

Proposition 1. *For given values of p_c and p_l, a joint supervisory architecture with $\lambda^* \in (0,1)$ is optimal if $C''(d^*(0))[1-d^*(0)] > s\frac{1-\chi}{\chi}\int_{p_l}^{p_c} pdF(p)$ and $C''(d^*(1))[1-d^*(1)] < \frac{s}{\chi}\int_{p_l}^{p_c} pdF(p)$. In this case, λ^* is such that (9) holds with an equality.*

The optimal architecture is determined by three different elements: the cost function

$C(.)$ the distribution of types $F(.)$, and the supervisors' intervention thresholds p_c and p_l. Whereas the functions $C(.)$ and $F(.)$ are exogenous, p_c and p_l are endogenous variables that depend on the interest rate i, which itself depends on the supervisory architecture.

4 Optimal supervision and market equilibrium

I now close the model by solving for the optimal reaction of market participants to the supervisory architecture. As explained in Section 2, there are two possibilities: a passive architecture or a forward-looking architecture.

4.1 Equilibrium with a passive architecture

With a passive architecture, market participants take their decisions based on their anticipation of what the central supervisor's decision is. As we need to solve for the equilibrium interest rate i in $t = 1$, it is convenient to express all the equilibrium quantities as functions of i.[12] The equilibrium rate i makes investors indifferent between lending to the bank and receiving the risk-free return. Conditional on p, an investor receives $(1 - \ell)$ on each unit he lent to the bank in case of liquidation, $(1 + i)$ with probability p and 0 with probability $1 - p$ if the loans are not liquidated. Denoting $u(i, x)$ the expected return on one unit lent to the bank at interest rate i if the bank is liquidated when $p < x$, we have:

$$u(i, x) = (1 - \ell)F(x) + (1 + i)\int_x^1 pdF(p). \tag{10}$$

[12] We have $r = i + s$, $L = q(i + s)$, $S = S(i + s)$, $D_f = q(i + s) - D_h$. The thresholds $p_c(i)$ and $p_l(i)$ are given by (1) and (1), the bank's profit $\Pi(d, \lambda, i)$ by (3), the optimal inspection difficulty $d^*(\lambda, i)$ by (4), expected welfare $\mathcal{W}(\lambda, i)$ by (7), the benefit of central inspections $\chi(i)$ by (8), and the optimal frequency of local inspections $\lambda^*(i)$ by Proposition 1.

Note that for a given i the payoff $u(i, x)$ is maximized in $x = p_d$, with:

$$p_d(i) = \frac{1-\ell}{1+i}. \tag{11}$$

As $i \leq r$, it is immediate to show that $p_d(i) > p_c(i)$: investors want more liquidation than even the central supervisor, since they do not take into account the bank's profit and the borrower's surplus associated with the loans. This also implies that, for a given inspection difficulty, investors prefer the tougher central inspections to the local inspections.

We can compute the creditors' expected payoff on one unit lent to the bank:

$$U(i,\lambda) = \underbrace{d^*(\lambda,i)u(i,0)}_{\text{Uninformative}} + \underbrace{\lambda[1-d^*(\lambda,i)]u(i,p_c)}_{\text{Central}} + \underbrace{(1-\lambda)[1-d^*(\lambda,i)]u(i,p_l)}_{\text{Local}}. \tag{12}$$

For a given λ, the equilibrium interest rate is the lowest one such that $U(i, \lambda) = 1$.

Lemma 2. *Denote:*

$$i^*(\lambda) = \min\{i \geq 0,\ s.t.\ U(i,\lambda) = 1\}. \tag{13}$$

$i^*(\lambda)$ is uniquely defined for any $\lambda \in [0, 1]$, and $i^*(\lambda) \in [i_{min}, i_{max}]$, where i_{min} is defined in the Appendix.

The Lemma shows that an equilibrium interest rate exists, and gives useful bounds corresponding to the case in which there is no informative inspection (i_{max}) and the case in which all inspections are informative and maximize the creditors' payoff (i_{min}). We can now define an equilibrium:

Definition 1. *An equilibrium with a passive architecture is a pair (i^*, λ^*) such that $i^* = i^*(\lambda)$*

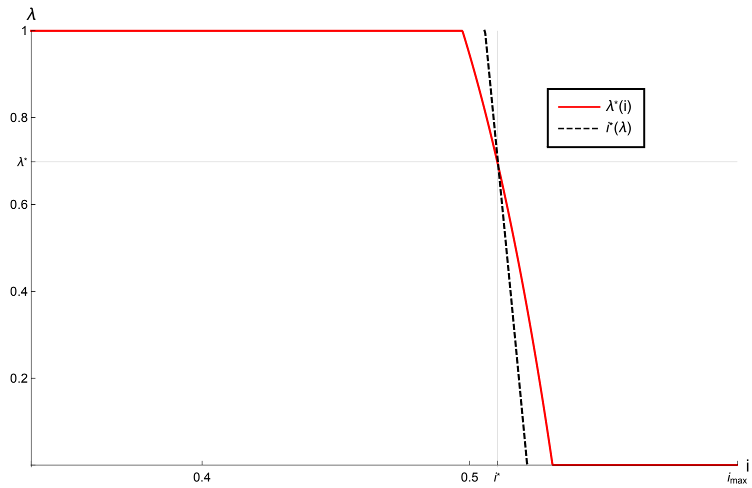

Figure 2: Example with a unique equilibrium.

and $\lambda^* = \lambda^*(i)$.

An equilibrium with a passive architecture can be seen as the intersection of the two curves $i^*(\lambda)$, the equilibrium interest rate for a given level of supervision, and $\lambda^*(i)$, the optimal level of supervision for a given interest rate. Fig. 2 shows an example in which there is a unique, interior equilibrium.[13]

The possibility of multiple equilibria comes from the fact that both $i^*(\lambda)$ and $\lambda^*(i)$ can be decreasing. For $i^*(\lambda)$ we have:

Proposition 2. $i^*(\lambda)$ *is decreasing in* λ *near any equilibrium pair* (i^*, λ^*).

When λ increases, there are more inspections by the central supervisor, who takes into account the foreign investors' payoff. Thus, all else equal, increasing λ has a positive impact on the foreign investors' payoff $U(i, \lambda)$ for a given i, and thus reduces the equilibrium i.

Conversely, a higher interest rate can lower the central supervisor's incentives to inspect. The main mechanism behind this result comes from the following observation:

[13]The parameters for all the figures are given in the Appendix A.13.

Lemma 3. *p_l is increasing in i, whereas p_c is decreasing in i. As a consequence, the benefit of central inspections $\chi(i)$ decreases in i.*

Intuitively, when i increases r is higher, so that the surplus per loan is higher and the central supervisor is less likely to liquidate them. At the same time, $D_f = q(i+s) - D_h$ is lower, so that a higher proportion of the liquidation proceeds go to domestic agents. This makes the local supervisor more likely to intervene. These two effects go in the same direction of making central inspections less useful relative to local inspections ex-post. In the limit, if both i and s are very small then $p_l \to 0$ and $\chi = 1$: liquidation only benefits foreign agents, so that the local supervisor never liquidates. Conversely, if i is so high that $q(i+s) = D_h$, then $p_l = p_c$ and $\chi = 0$: the bank only relies on domestic investors and the conflict of objectives between the two levels of supervision disappears, making central supervision unnecessary.

Lemma 3 has two opposite consequences. On the one hand, when i decreases the central supervisor has more incentives to intervene ex-post, which increases λ^*. On the other hand, since the central supervisor becomes tougher, the bank also has more incentives to avoid inspections, so that the ex-ante effect of λ can go in the other direction. The relative strength of the two effects depends on the convexity of the cost function C, which determines how strongly inspection difficulty reacts to changes in supervision. To see this, consider the following particular functional form for C:

$$C(d) = \frac{c}{2}d^2, \tag{14}$$

so that c measures the convexity of the cost function. We have:

Proposition 3. *There exists $\bar{c} \geq 0$ such that if $c \geq \bar{c}$ then $\lambda^*(i)$ is decreasing in i for any*

$i \in [i_{min}, i_{max}]$.

Propositions 2 and 3 show that foreign lending and centralized supervision can reinforce each other. More centralized supervision increases foreign lending, more foreign lending increases the conflict of objectives, and a higher conflict of objectives increases the incentives for central supervision. This complementarity between foreign lending and centralized supervision can lead to a multiplicity of equilibria.

Proposition 4. *For any parameterization of $q(.)$, $F(.)$, ℓ, s, and D_h, there is a cost function C such that there are two equilibria $(\lambda^*, i^*) = (1, i_1)$ and $(\lambda^*, i^*) = (0, i_2)$, with $i_1 < i_2$.*

The Proposition is illustrated in Fig. 3. It shows that one can obtain two extreme equilibria, one with only central supervision, and one with only local supervision. Moreover, the interest rate i can be higher either in the first or in the second equilibrium (equivalently, cross-border flows $D_f = q(i + s) - D_h$ can be lower in either equilibrium). In the equilibrium with only central supervision, investors ask for a low interest rate. Given this low interest rate, cross-border flows are large and the local supervisor would be very lenient on the bank, so that fully centralized supervision is optimal. Under the same parameters, there is another equilibrium with only local supervision in which investors ask for a high interest rate, so that the local supervisor's bias is small and the gains of centralized supervision are low. Moreover, if the central supervisor were to inspect the bank with a positive frequency, the bank would increase inspection difficulty a lot, so the cost of centralized supervision is high. Hence, it is optimal to have only local supervision.

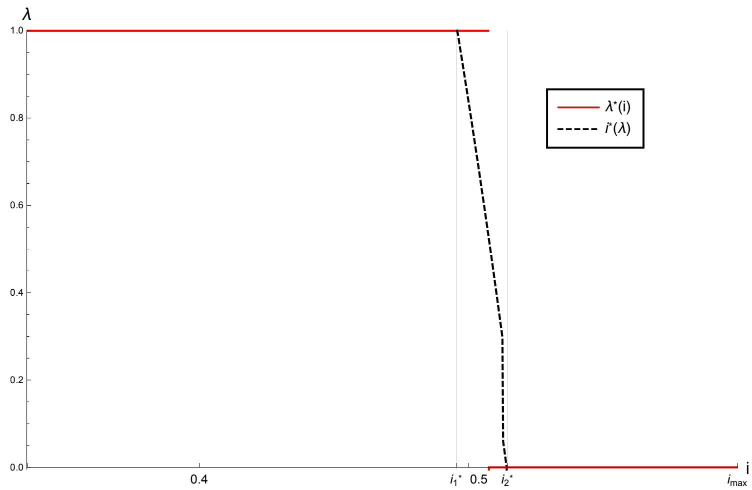

Figure 3: Example with two extreme equilibria.

4.2 Equilibrium with a forward-looking architecture

I now consider the case in which the central supervisor takes into account that she can affect the bank's structure. For a given λ, the equilibrium interest rate still satisfies $i^* = i^*(\lambda)$, but the supervisor now maximizes welfare taking into account that λ affects i^* instead of taking i^* as given. Due to this effect, the central supervisor may not play the static best response to the equilibrium value of i.

Formally, the central supervisor chooses λ so as to maximize $\mathcal{W}(\lambda, i^*(\lambda))$. To see the different forces at play, we can use equation (7) to differentiate welfare with respect to λ. After rearranging, and denoting $i^* = i^*(\lambda)$ and $p_c^* = p_c(i^*)$, we obtain:

$$\begin{aligned}
\frac{d\mathcal{W}(\lambda, i^*)}{d\lambda} &= \mathcal{W}_1(\lambda, i^*) + i^{*\prime}(\lambda)\mathcal{W}_2(\lambda, i^*), \\
\text{with } \mathcal{W}_2(\lambda, i^*) &= W_1'(i^*)\frac{\mathcal{W}(\lambda, i^*)}{W_1(i^*)} - W_1(i^*)d_2^*(\lambda, i^*)\int_0^{p_c^*}[p_c^* - p]dF(p)[1-(1-\lambda)\chi(i^*)] \\
&+ W_1(i^*)[1-d^*(\lambda, i^*)]\left[p_c'(i^*)F(p_c^*)[1-(1-\lambda)\chi(i^*)] - (1-\lambda)\chi'(i^*)\int_0^{p_c^*}[p_c^* - p]dF(p)\right].
\end{aligned}$$

In addition to the effect $\mathcal{W}_1(\lambda, i^*(\lambda))$ already present with a passive architecture, we have three new effects coming from the fact that a marginal increase in λ reduces the interest rate $i^*(\lambda)$. First, this lower interest rate increases the total surplus of loans and thus welfare as well. Second, the lower interest rate affects the level of difficulty chosen by the bank. The sign of this effect depends on $d_2^*(\lambda, i^*(\lambda))$, and can be either positive or negative. Third, a lower interest rate increases cross-border externalities, which for a given λ reduces welfare.

There is no general closed-form expression for the optimal λ in this case. Because the three effects are of different signs and their magnitudes depend on the distribution F, the optimal λ with a forward-looking architecture can in general be either higher or lower than in an equilibrium with a passive architecture. Moreover, the optimal λ with a forward-looking architecture has to be such that welfare is at least as large as in any equilibrium with a passive architecture. This observation has an interesting consequence in the special case of Proposition 4:

Proposition 5. *If the cost function C is as in Proposition 4, $\lambda = 0$ cannot be chosen in the case with a forward-looking architecture, even though it is a possible equilibrium outcome with a passive architecture.*

As an example, Fig. 4 plots the welfare $\mathcal{W}(\lambda, i^*(\lambda))$ for the same parameters as used in Fig. 3. In this example, the equilibrium with fully centralized supervision happens to be also the optimal choice of a forward-looking supervisor.

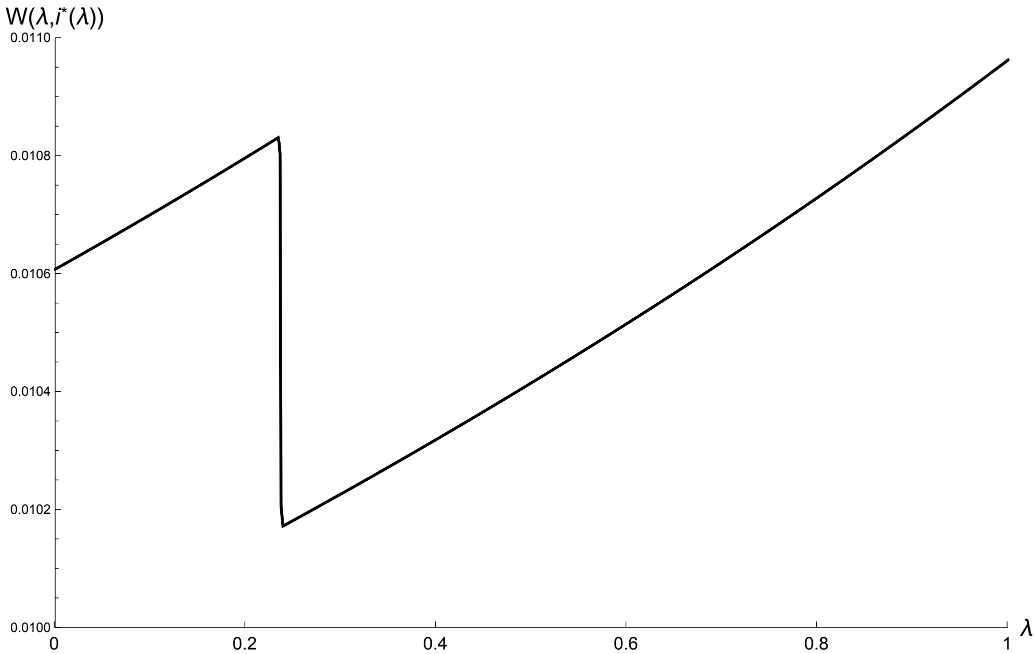

Figure 4: Welfare $\mathcal{W}(\lambda, i^*(\lambda))$ as a function of λ. The parameters are the same as in Fig. 3.

5 Implications

This section summarizes the policy conclusions and testable implications of the paper. When a result depends on the convexity of the cost function $C(.)$, I use the square functional form (14) to clarify the impact of cost convexity, which is measured by the parameter c.

5.1 Optimal supervisory architecture

Architecture. The previous sections give two general policy conclusions regarding the optimal architecture of supervision. From Proposition 1, we have:

Implication 1. *Despite local inspections being inefficient ex-post, a joint architecture relying on both local and central inspections can be optimal. More precisely, there exist* $\underline{c}$ *and* $\overline{c}$ *such that joint supervision is optimal for* $c \in [\underline{c}, \overline{c}]$.

Implication 1 gives a potential rationale for two-layered banking supervision systems.

Even when central inspections are strictly more efficient than local inspections ex post, they give banks more incentives to hide information ex ante. In particular, observing conflicts of objectives between different supervisors, as in Agarwal, Lucca, Seru, and Trebbi (2014), can be compatible with a second-best architecture.

More broadly, this implication shows that having a closer relationship between banks and supervisors may have costs and benefits. Interestingly, there is empirical evidence for both. Gopalan, Kalda, and Manela (2017) study the impact on bank risk of the geographic distance between a bank and its supervisor (a branch of the U.S. Office of the Comptroller of the Currency). The authors find that increasing this distance leads to higher bank leverage and risk. Conversely, Behn, Haselmann, Kick, and Vig (2015) study the bail-out decisions taken by German politicians who also sit on the board of failing banks. The proximity of the politician with the bank gives him or her more information, but introduces a bias. The authors show that the second effect is stronger, so that proximity leads to inefficient bail-outs.

Proposition 5 implies the following:

Implication 2. *A central supervisor in a passive architecture may be stuck in an equilibrium with either too little or too much central supervision.*

This implication underlines the necessity to decide on the supervisory architecture in a forward-looking manner, taking into account how this choice affects market integration in the long-run. In the Euro Area, criteria for a bank to be centrally supervised are *not* forward-looking. For instance, a bank should be supervised by the ECB if the "ratio of its cross-border assets/liabilities in more than one other participating Member State to its total assets/liabilities is above 20%". This criterion neglects the fact that ECB supervision may itself increase this ratio (fostering integration is actually one of the objectives of the SSM).

Frequency of inspections. Focusing on the case in which $\lambda^* \in (0,1)$, we can derive comparative static results from Proposition 1, in order to shed light on which types of banks should be supervised more centrally. This "ceteris paribus" analysis assumes a small change in one parameter when the economy is already in the neighborhood of an equilibrium (λ^*, i^*). Fig. 5 below illustrates some of the implications.

Implication 3. *The benefit of central inspections $\chi(i)$ decreases in the amount of domestic debt D_h. For a sufficiently large c, the optimal frequency of central inspections λ^* decreases in D_h.*

As already shown in Lemma 3, a lower proportion of domestic debt makes the local supervisor more lenient, as liquidating the bank benefits more foreign agents, which increases the benefit of centralized supervision. This observation is made more generally and supported empirically in Beck, Todorov, and Wagner (2013). In my model, this effect translates into a higher optimal frequency of central inspections, but only if the cost function C is sufficiently convex, so that the ex-ante effect of central inspections is not too strong.

In line with the idea that externalities are important, access to Federal deposit insurance in the United States automatically implies that a bank must have a Federal supervisor, as the bank's default triggers losses beyond the State. Similarly, a Euro Area bank falls under ECB supervision if it has requested assistance from the European Stability Mechanism or the European Financial Stability Facility, or has a high-ratio of cross-border assets or liabilities.

Implication 4. *The optimal frequency λ^* of central inspections increases in c.*

The cost of central inspections in the model is that they give the bank higher incentives to avoid inspections. If the cost of avoiding inspections is more convex, the bank reacts less to an increase in central inspections, and the frequency of central inspections can be increased. In practice, the cost function is likely to reflect both the ease with which the bank can hide or misreport information, and the skill of the supervisor at discovering such attempts. The parameter c should thus be higher in countries with a better quality of supervision (as measured in Cihak and Tieman (2008) or Barth, Caprio, and Levine (2013)).

The allocation of supervision in the Euro Area and in the U.S. goes in the opposite direction: larger and more complex banking groups are more likely to be supervised centrally, even though they may have more opportunities to lobby or capture the supervisors. A reason for this allocation is that the benefit of inspections may increase with bank size. Interestingly, however, in the model inspection avoidance scales with size as well, so that bank size plays no role to determine the optimal frequency of central inspections:

Implication 5. *For a given interest rate i and for any scalar α, the optimal frequency of central inspections λ^* is the same for a bank with D_h deposits and a demand function $q(.)$ and a bank with αD_h deposits and a demand function $\alpha q(.)$.*

This implication shows that size is not a relevant criterion for central supervision in the model. It is true that the benefits of central inspections increase with size, as more welfare gains are at stake. However, the incentives for the bank to avoid inspections increase with size as well. Both increase linearly, so that size is irrelevant. This is of course a knife-edge result. Empirically, it is key to estimate which component increases more quickly with size.[14]

[14] Eisenbach, Lucca, and Townsend (2016) present evidence for economies of scale in bank supervision, which is in line with the idea that the cost function C increases more than proportionally with size, in which case larger banks should indeed face more central inspections. Another element going in the same direction is that supervision costs may increase more quickly with size for local supervisors than for central supervisors, as suggested in Rezende (2011).

Implication 6. *If $F(.)$ is such that $F(p_l) = 1$ or $F(p_c) = 0$, then any frequency of central inspections leads to the same outcome.*

This implication shows that bank risk has an ambiguous impact on the optimal frequency of inspections. In the United States, a bank that receives a bad enough CAMELS rating automatically becomes supervised by a Federal supervisor. Similarly, the ECB has discretion to take over supervision of a "less significant institution," an option that will presumably be used if bad signals are received about a bank. However, it is clear in the model that the relevant question is not whether a bank has a low success probability p, but whether p is likely to be between p_l and p_c, that is, in the region in which the central supervisor wants to liquidate the bank but the local supervisor does not. Indeed, if the bank is so bad that p is almost surely below p_l, then the local supervisor's incentives are aligned with the central supervisor's, and there is no benefit in centralizing. Importantly, this Implication also illustrates that finding the optimal *architecture* of supervision is not the same problem as finding the optimal *level* of supervision. Indeed, riskier banks should be supervised more (see Eisenbach, Lucca, and Townsend (2016)), but not necessarily more centrally.

5.2 Testable implications

The recent implementation of the SSM in Europe can be interpreted as a change from fully local supervision ($\lambda = 0$) to fully central supervision ($\lambda = 1$) for a subset of the banking system. The previous section shows that this can result in better supervision and lower interest rates, but only when the bank cannot react by increasing the difficulty of inspections:

Implication 7. *For c sufficiently large, moving from local supervision ($\lambda = 0$) to central*

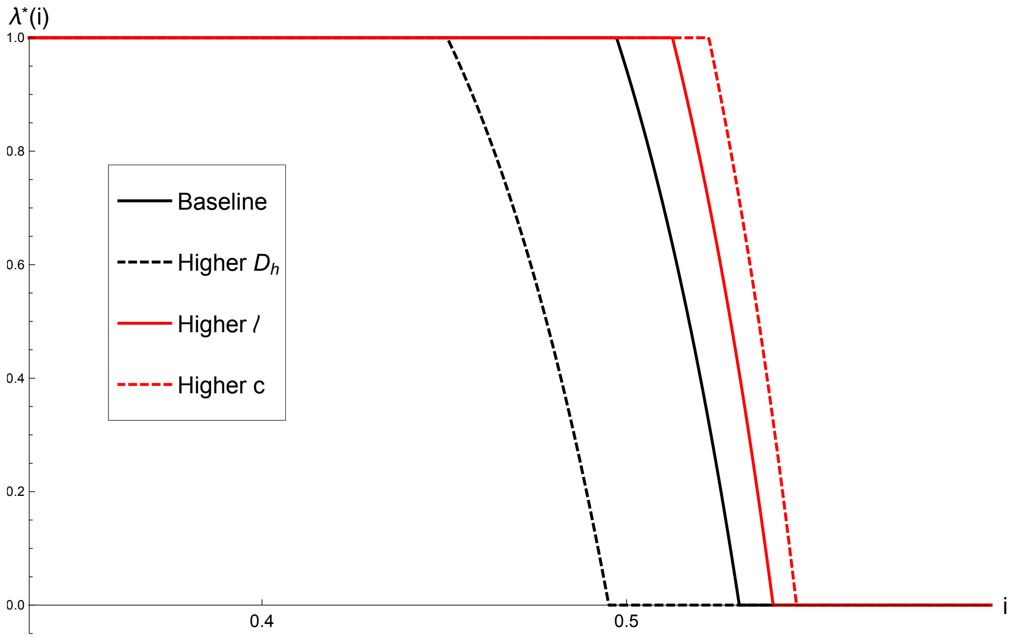

Figure 5: Optimal inspection frequency $\lambda^*(i)$ for different parameters. From left to right: higher home deposits D_h, Baseline parameters, higher liquidation discount ℓ, higher cost c.

supervision ($\lambda = 1$) *decreases the interest rate* i^* *and increases cross-border flows* D_f.

This implication shows that increasing central supervision, as done in the Euro Area with the SSM, can indeed contribute to restoring market integration, which is one of the objectives stated by the European Commission. However, the possible strategic reaction of banks to more supervision needs to be taken into account. In particular, the new central supervisor has to be so efficient that a bank cannot hide information without incurring large costs.

Note that for this effect to materialize in practice it is important that p belongs to $[p_l, p_c]$ with some probability (Implication 6). In quiet times, investors may perceive the probability that $p < p_c$ to be quite low, and even banks supervised locally can borrow heavily from foreign investors. The architecture of supervision becomes an issue mostly in crisis times, such as the European sovereign debt crisis, during which investors were uncertain about the quality of many European banks and banks' cross-border liabilities dropped.[15] A prediction

[15] It is well documented that the share of foreign funding of European banks dropped during the crisis

of the model is that banks supervised centrally should see a lower increase in their funding costs during a crisis than banks supervised locally, and should see a lower drop of foreign funding, even controlling for the quality of their assets.

The launch of the SSM gives a perfect opportunity to test the impact of centralizing supervision, given that most European banks are still supervised at the local level and form a control group (see Fiordelisi, Ricci, and Saverio Stentella Lopes (2017) for such an analysis). Implication 7 suggests that treated and untreated banks should diverge over time in a predictable way. Banks directly supervised by the ECB should be able to borrow at lower rates on wholesale markets, compared to similar banks under national supervision, and find it easier to borrow cross-border.

6 Conclusion

This paper develops a framework to analyze optimal supervisory architectures in a federal/international context in which local supervisors neglect cross-state/cross-border externalities and are too forbearant. Having a tougher central supervisor inspecting the bank is optimal ex post, but also gives the bank a strong incentive to hide information ex ante so as to avoid liquidation. This framework rationalizes the range of solutions observed in the United States and the Euro Area: Local supervision, central supervision, or joint supervision.

The model shows that a more centralized supervisory architecture allows the bank to use more foreign funding, while conversely more foreign funding makes the local supervisor

(see, e.g., Allen, Beck, Carletti, Lane, Schoenmaker, and Wagner (2011), p. 24), due both to cross-border interbank loans (Heider, Garcia-de Andoain, Frutos de Andres, and Papsdorf (2016), Abbassi, Brauning, Fecht, and Peydro (2017)) and to cross-border deposits (Bank for International Settlements (2011)). See also Santos (2017) for a detailed account of the Spanish banking crisis of 2008-2012, in particular pp. 21-22.

more lenient, which increases the benefits from central supervision. This complementarity can generate multiple equilibria. In particular, it is possible to be stuck in an equilibrium in which market integration and centralization are both low, when another equilibrium in which both are high would be possible and welfare-improving. The choice of a supervisory architecture should thus anticipate how the market will react to the new supervision framework.

A Appendix

A.1 Proof of Lemma 1

Equation (4) gives the first-order condition associated with the optimal value of d. The second-order condition follows from the convexity of C. One can check for the corner solutions $d = 0$ and $d = 1$. Since $C'(0) = 0$, we always have $\Pi_1(0, \lambda) > 0$, so that $d = 0$ cannot be optimal. In $d = 1$ we have:

$$\Pi_1(1, \lambda) = [\pi(0) - \lambda\pi(p_c) - (1 - \lambda)\pi(p_l)] - C'(1). \tag{A.1}$$

We have $p_l \leq p_c \leq 1-\ell$, so that $\pi(0)-\lambda\pi(p_c)-(1-\lambda)\pi(p_l) \leq \pi(0)-\pi(1-\ell) = s\int_0^{1-\ell} pdF(p)$. Assumption (H2) then implies that $\Pi_1(1, \lambda) < 0$.

Finally, the marginal benefit of increasing inspection difficulty is increasing in λ:

$$\Pi_{1,2}(d, \lambda) = L[\pi(p_l) - \pi(p_c)] \geq 0. \tag{A.2}$$

(5) follows from (4) using implicit differentiation. ∎

A.2 Proof of Proposition 1

The result follows straightforwardly from using (9) to write $\mathcal{W}'(0)$ and $\mathcal{W}'(1)$, and replacing $d^{*\prime}(\lambda)$ by its expression (5). The sufficient conditions given in the Proposition are equivalent to $\mathcal{W}'(0) > 0$ and $\mathcal{W}'(1) < 0$, which ensure that the optimal λ is an interior solution. ∎

A.3 Proof of Lemma 2 and Proposition 2

Proof of Lemma 2. Define i_{min} such that:

$$(1 - \ell)F(p_d(i_{min}))\int_{p_d(i_{min})}^{1} pdF(p) = 1. \tag{A.3}$$

We know that even if the bank were always liquidated so as to maximize the creditors' payoff, for $i < i_{min}$ we necessarily have $U(i, \lambda) < 1$. Conversely, $u(i, p_c) \geq u(i, p_l) \geq u(i, 0)$, and

$u(i_{max}, 0) = 1$, so that for $i > i_{max}$ we necessarily have $U(i, \lambda) > 1$. Between these two bounds, there is a smallest value of i at which $U(i, \lambda)$ becomes larger than 1. ■

Proof of Proposition 2. As $i^*(\lambda)$ is the smallest i satisfying $U(i, \lambda) = 1$, near an equilibrium point, $U(i, \lambda)$ is necessarily increasing in i. To prove the Proposition, we need to show that $U(i, \lambda)$ is also increasing in λ. We can write $U_2(i, \lambda)$ as:

$$U_2(i, \lambda) = (1 - d^*(\lambda, i))[u(i, p_c(i)) - u(i, p_l(i))] + d_1^*(\lambda, i)[u(i, 0) - \lambda u(i, p_c(i)) - (1-\lambda)u(i, p_l(i))]. \tag{A.4}$$

Remember that at an equilibrium point the first-order condition of the supervisor imposes that (9) is null. Using this condition in (A.4) and rearranging gives:

$$U_2(i, \lambda^*(i)) = \frac{d_1^*(\lambda^*(i), i)}{\chi(i)} \left[u(i, p_c(i)) - u(i, p_l(i)) - \chi(i)(u(i, p_c(i)) - u(i, 0)) \right]. \tag{A.5}$$

Developing and rearranging, we obtain:

$$U_2(i, \lambda^*(i)) \geq 0 \Leftrightarrow \chi(i) \leq \frac{u(i, p_c(i)) - u(i, p_l(i))}{u(i, p_c(i)) - u(i, 0)} = \frac{\int_{p_l(i)}^{p_c(i)} [p_d(i) - p] dF(p)}{\int_0^{p_c(i)} [p_d(i) - p] dF(p)}. \tag{A.6}$$

Define:

$$h(x) = \frac{\int_{p_l(i)}^{p_c(i)} [x - p] dF(p)}{\int_0^{p_c(i)} [x - p] dF(p)}. \tag{A.7}$$

Observing that $\chi(i) = h(p_c(i))$ and $p_d(i) \geq p_c(i)$, in order to show that $U_2(i, \lambda^*(i)) \geq 0$ it is sufficient to show that $h(x)$ is increasing in x. The quantity $h'(x)$ is positive if and only if:

$$\frac{\int_0^{p_c(i)} [x - p] dF(p)}{F(p_c(i))} \geq \frac{\int_{p_l(i)}^{p_c(i)} [x - p] dF(p)}{F(p_c(i)) - F(p_l(i))} \Leftrightarrow \mathbb{E}(x - p | p \leq p_c(i)) \leq \mathbb{E}(x - p | p_l(i) \leq p \leq p_c(i)), \tag{A.8}$$

and this last statement is necessarily true. Hence, $U(i, \lambda)$ increases in λ near $\lambda^*(i)$, which concludes the proof. ■

A.4 Proof of Lemma 3 and Proposition 3

Proof of Lemma 3. Differentiating (1) with respect to i gives:

$$\begin{aligned} p_l'(i) &= \frac{(1-\ell)D_h[q(i+s)-D_h-sq'(r)]}{[S(i+s)-(q(i+s)-D_h)(1+i)]^2} \geq 0 \\ p_c'(i) &= \frac{(1-\ell)q'(i+s)[S(i+s)-(1+i+s)q(i+s)]}{S(i+s)^2} \leq 0. \end{aligned}$$

From (8), in order to prove the lemma we need to check that χ decreases in p_l and increases in p_c. The first property is obvious from (8). For the second one, differentiate (8) with respect to p_c to obtain:

$$\frac{\partial \chi(i)}{\partial p_c(i)} \geq 0 \Leftrightarrow [F(p_c(i))-F(p_l(i))]\int_0^{p_c(i)}(p_c(i)-p)dF(p)-F(p_c(i))\int_{p_l(i)}^{p_c(i)}(p_c(i)-p)dF(p) \geq 0. \tag{A.9}$$

This inequality is equivalent to $\mathbb{E}(p_c(i)-p|p \leq p_c(i)) \geq \mathbb{E}(p_c(i)-p|p_l(i) \leq p \leq p_c(i))$, which is true. ■

Proof of Proposition 3. To show the Proposition it is enough to differentiate (9) in i and show that the resulting expression is negative for c sufficiently large. That is, we need to show that:

$$\chi'(i)[1-d^*(\lambda,i)+d_1^*(\lambda,i)(1-\lambda)]-d_{12}^*(\lambda,i)[1-(1-\lambda)\chi(i)]-d_2^*(\lambda,i)\chi(i) \leq 0. \tag{A.10}$$

Lemma 3 shows that the first term is indeed negative. As c does not enter into $\chi(i)$ and $[1-d^*(\lambda,i)+d_1^*(\lambda,i)(1-\lambda)]$ converges to 1 as $c \to +\infty$, it is sufficient to show that $d_2^*(\lambda,i)$ and $d_{12}(\lambda,i)$ can be made arbitrarily small in absolute value when c is sufficiently large.

First, computing $d_1^*(\lambda,i)$ using (5) with a square form for C gives:

$$d_1^*(\lambda,i) = \frac{s\int_{p_l(i)}^{p_c(i)} pdF(p)}{c}. \tag{A.11}$$

Differentiating (A.11) with respect to i, we have:

$$d_{12}^*(\lambda,i) = \frac{s}{c}[p_c'(i)p_c(i)f(p_c(i))-p_l'(i)p_l(i)f(p_l(i))], \tag{A.12}$$

which is negative and goes to zero as $c \to +\infty$.

Second, computing $d_2^*(\lambda, i)$ using (4) with a square form for C, gives:

$$d_2^*(\lambda, i) = \frac{s}{c}[\lambda p_c'(i)p_c(i)f(p_c(i)) + (1-\lambda)p_l'(i)p_l(i)f(p_l(i))], \tag{A.13}$$

which has an ambiguous sign and goes to zero as $c \to +\infty$. Hence, there is a value $\bar{c}$ such that for $c \geq \bar{c}$ we have $\mathcal{W}_{12}(\lambda, i) \leq 0$. ∎

A.5 Proof of Proposition 4

Consider a cost function C such that $C(0) = 0$, $C(d) = \bar{c}$ if $d \leq \bar{d}$, and $C(d)$ is arbitrarily large for $d > \bar{d}$. Hence, the bank will optimally choose either $d = 0$ or $d = \bar{d}$. Assume that in equilibrium 1 we have $\lambda^* = 1, i^* = i_1, d = \bar{d}$, and in equilibrium 2 we have $\lambda^* = 0, i^* = i_2, d = 0$. We want to find sufficient conditions on $\bar{c}$ and $\bar{d}$ for these two outcomes to be equilibria and have $i_1 < i_2$.

Consider equilibrium 1, and denote $p_{c1} = p_c(i_1), p_{l1} = p_l(i_1)$. We need the bank to prefer $d = \bar{d}$ over $d = 0$, which gives:

$$\bar{d}\pi(0) + (1-\bar{d})\pi(p_{c1}) - \bar{c} \geq \pi(p_{c1}) \Leftrightarrow \bar{c} \leq \bar{d}[\pi(0) - \pi(p_{c1})]. \tag{A.14}$$

We also need the central supervisor to find it optimal to choose $\lambda = 1$. The only choice that could potentially dominate $\lambda = 1$ would be to choose $\lambda = \lambda'$, with λ' such that the bank chooses difficulty $d = 0$ instead of $d = \bar{d}$. The level λ' is defined by:

$$\bar{d}[\pi(0) - \pi(p_{l1})] + \lambda'[\pi(p_{l1}) - \pi(p_{c1})] = \bar{c} \Leftrightarrow \lambda' = \frac{\bar{c} - \bar{d}[\pi(0) - \pi(p_{l1})]}{\bar{d}[\pi(p_{l1}) - \pi(p_{c1})]}. \tag{A.15}$$

Using (7), the central supervisor prefers $\lambda = 1, d = \bar{d}$ over $\lambda = \lambda', d = 0$ if and only if:

$$(1-\bar{d})\int_0^{p_{c1}}[p_{c1} - p]dF(p) \geq \lambda' \int_0^{p_{c1}}[p_{c1} - p]dF(p) + (1-\lambda')\int_0^{p_{l1}}[p_{c1} - p]dF(p). \tag{A.16}$$

After rearranging, this gives us:

$$\lambda' \leq 1 - (\bar{d}/\chi(i_1)). \tag{A.17}$$

Consider now equilibrium 2, and denote $p_{c2} = p_c(i_2), p_{l2} = p_l(i_2)$. It has to be the case that with $\lambda = 0$ the bank is indifferent between $d = 0$ and $d = \bar{d}$. Otherwise, the central supervisor would find it optimal to choose a larger λ. This gives us:

$$\pi(p_{l2}) = \bar{d}\pi(0) + (1 - \bar{d})\pi(p_{l2}) - \bar{c} \Leftrightarrow \bar{c} = \bar{d}[\pi(0) - \pi(p_{l2})]. \tag{A.18}$$

We also need the central supervisor to prefer $\lambda = 0$ to $\lambda = 1$. The computation is the same as in (A.17), replacing λ' with 0 and reversing the sign of the inequality, which gives:

$$0 \geq 1 - (\bar{d}/\chi(i_2)). \tag{A.19}$$

From this preliminary analysis, we conclude that necessary and sufficient conditions to have the two equilibria we are looking for is to find $\bar{c}$ and $\bar{d}$ satisfying (A.14), (A.17), (A.18), and (A.19), and $i_1 \leq i_2$. Note that an extra difficulty here is that i_1 and i_2 are both endogenous. However, we can use the fact that i_1 depends on $\bar{c}$ and $\bar{d}$, but not i_2.

To construct the cost function, we can first solve (implicitly) for i_2, which is the minimum value satisfying:

$$F(p_l(i_2))(1 - \ell) + (1 + i_2) \int_{p_l(i_2)}^{1} p dF(p) = 1. \tag{A.20}$$

We then define $\bar{c}$ by (A.18). Then, pick the lowest $\bar{d}$ such that (A.19) holds, that is:

$$\bar{d} = \chi(i_2). \tag{A.21}$$

These values of $\bar{d}$ and $\bar{c}$ define the interest rate i_1 as the smallest value satisfying:

$$\bar{d}(1 + i_1) \int_0^1 p dF(p) + (1 - \bar{d}) \left[F(p_c(i_1)(1 - \ell) + (1 + i_1) \int_{p_c(i_1)}^{1} p dF(p) \right] = 1. \tag{A.22}$$

It remains to show that $i_1 < i_2$ and that (A.14) and (A.17) hold.

Let us first show that $i_1 < i_2$. For this it is sufficient to show that replacing i_1 with i_2 in the left-hand side of (A.22) gives a payoff larger than 1. Replacing $\bar{d}$ using (A.21), we need:

$$\chi(i_2)(1+i_2) \int_0^1 p dF(p) + (1 - \chi(i_2)) \left[F(p_c(i_2))(1 - \ell) + (1 + i_2) \int_{p_c(i_2)}^{1} p dF(p) \right] > 1. \tag{A.23}$$

The 1 on the right-hand side can be replaced by the left-hand side of (A.20). Rearranging, this gives:

$$\frac{\int_0^{p_{c2}}(p_{c2}-p)dF(p)}{F(p_{c2})}\left[1-\ell-(1+i_2)\int_{p_{l2}}^{p_{c2}}\frac{pdF(p)}{F(p_{c2})-F(p_{l2})}\right] > \frac{\int_{p_{l2}}^{p_{c2}}(p_{c2}-p)dF(p)}{F(p_{c2})-F(p_{l2})}\left[1-\ell-(1+i_2)\int_0^{p_{c2}}\frac{pdF(p)}{F(p_{c2})}\right]. \tag{A.24}$$

This can be reexpressed as:

$$[p_{c2}-\mathbb{E}(p|p\leq p_{c2})][1-\ell-(1+i_2)\mathbb{E}(p|p_{l2}\leq p\leq p_{c2})] > [p_{c2}-\mathbb{E}(p|p_{l2}\leq p\leq p_{c2})][1-\ell-(1+i_2)\mathbb{E}(p|p\leq p_{c2})], \tag{A.25}$$

which is equivalent to:

$$[\mathbb{E}(p|p_{l2}\leq p\leq p_{c2})-\mathbb{E}(p|p\leq p_{c2})][1-\ell-p_{c2}(1+i_2)]>0. \tag{A.26}$$

This last inequality is true: the first term in brackets is positive, and it is easily shown that $p_c(i)<\frac{1-\ell}{1+i}$. This proves that $i_1<i_2$.

To prove that (A.14) holds, using (A.18) we just need to prove that $\pi(p_{c1})\leq\pi(p_{l2})$, which is equivalent to $p_{l2}\leq p_{c1}$. Remember that $p_l(i)$ is increasing in i, while $p_c(i)$ is decreasing. Moreover, for $i=\bar{i}$ such that $q(\bar{i}+s)=D_h$, we have $p_c(i)=p_l(i)$. This implies that under assumption H1, for any i_1 and i_2 in $[i_{min},i_{max}]$, we have $p_l(i_2)\leq p_c(i_1)$, so that (A.14) is satisfied.

Finally, we need to prove (A.17). Using (A.15) and (A.18), we can reexpress λ' as:

$$\lambda'=\frac{\pi(p_{l1})-\pi(p_{l2})}{\pi(p_{l1})-\pi(p_{c1})}, \tag{A.27}$$

so that

$$1-\lambda'=\frac{\int_{p_{l2}}^{p_{c1}}pdF(p)}{\int_{p_{l1}}^{p_{c1}}pdF(p)}. \tag{A.28}$$

Using (A.21) and (A.28), we need to show the following inequality:

$$\frac{\int_{p_{l2}}^{p_{c1}}pdF(p)}{\chi(i_2)}-\frac{\int_{p_{l1}}^{p_{c1}}pdF(p)}{\chi(i_1)}\geq 0. \tag{A.29}$$

Note that this holds with an equality when $i_1=i_2$. As we have just shown that $i_1<i_2$,

it is sufficient to show that the left-hand side of (A.29) increases in i_2. Differentiating with respect to i_2, this is equivalent to:

$$-p_l'(i_2)p_{l2}f(p_{l2})\chi(i_2) - \chi'(i_2)\int_{p_{l2}}^{p_{c1}} pdF(p) \geq 0. \tag{A.30}$$

We know from Lemma 3 that $\chi'(i_2)$ is negative. Since $i_1 < i_2$, we have $p_{c1} > p_{c2}$, so that in order to prove inequality (A.30) it is sufficient to show that it holds replacing p_{c1} with p_{c2}. Moreover, i_2 enters $\chi(i_2)$ only through $p_{c2} = p_c(i_2)$ and $p_{l2} = p_l(i_2)$. We know from the proof of Lemma 3 that $\chi(i_2)$ increases in $p_c(i_2)$, so that $-\chi'(i_2)$ is greater than $-\frac{\partial\chi(i_2)}{\partial p_l(i_2)}p_l'(i_2)$. Taking these two facts into account, (A.30) necessarily holds if:

$$-p_l'(i_2)p_{l2}f(p_{l2})\chi(i_2) + p_l'(i_2)f(p_{l2})\frac{(p_{c2}-p_{l2})}{\int_0^{p_{c2}}[p_{c2}-p]dF(p)}\int_{p_{l2}}^{p_{c2}} pdF(p) \geq 0. \tag{A.31}$$

Using the explicit expression of $\chi(i_2)$ and rearranging, (A.31) is equivalent to:

$$-p_{l2}[F(p_{c2}) - F(p_{l2})] + \int_{p_{l2}}^{p_{c2}} pdF(p) \geq 0. \tag{A.32}$$

This is equivalent to $p_{l2} \leq \mathbb{E}(p|p_{l2} \leq p \leq p_{c2})$, which is true. Hence, (A.30) is satisfied, which shows that the values $\bar{d}$ and $\bar{c}$ we have considered satisfy (A.17) as well as all the other conditions for the two equilibria to obtain, which concludes the proof. ■

A.6 Proof of Proposition 5

Using (7), the welfare in both equilibria writes as:

$$\begin{aligned}
\mathcal{W}(1,i_1) &= W_1(i_1)\left[\int_0^1 pdF(p) + (1-\bar{d})\int_0^{p_c(i_1)}(p_c(i_1)-p)dF(p)\right] && \text{(A.33)}\\
\mathcal{W}(0,i_2) &= W_1(i_2)\left[\int_0^1 pdF(p) + \int_0^{p_l(i_2)}(p_c(i_2)-p)dF(p)\right]. && \text{(A.34)}
\end{aligned}$$

We want to show that $\mathcal{W}(1,i_1) > \mathcal{W}(0,i_2)$, which will prove that the central supervisor never chooses $\lambda = 0$, since this solution is at least dominated by $\lambda = 1$. Since $i_1 < i_2$ we have

$W_1(i_1) > W_1(i_2)$, so we need to show that:

$$(1-\bar{d})\int_0^{p_c(i_1)}(p_c(i_1)-p)dF(p) \geq \int_0^{p_l(i_2)}(p_c(i_2)-p)dF(p). \tag{A.35}$$

Using (A.21) that defines $\bar{d}$ and rearranging, this is equivalent to:

$$\int_0^{p_c(i_1)}(p_c(i_1)-p)dF(p) \geq \int_0^{p_c(i_2)}(p_c(i_2)-p)dF(p). \tag{A.36}$$

This inequality is true if and only if $p_c(i_1) \geq p_c(i_2)$, which is the case as $i_1 \leq i_2$. This shows that $\mathcal{W}(1,i_1) > \mathcal{W}(0,i_2)$ and proves that the central supervisor never chooses $\lambda = 0$. ■

A.7 Proof of Implication 1

Using (4) and (14), we have:

$$d^*(\lambda,i) \quad = \quad \frac{s}{c}\left[\int_0^{p_l} pdF(p) + \lambda\int_{p_l}^{p_c} pdF(p)\right]. \tag{A.37}$$

Using this equation and $C''(d^*(\lambda,i)) = c$, the sufficient conditions given in Proposition 1 to ensure an interior λ^* are equivalent to:

$$s\left(\frac{1-\chi(i)}{\chi(i)}\int_{p_l}^{p_c} pdF(p) + \int_0^{p_l} pdF(p)\right) \leq c \leq s\left(\frac{1}{\chi(i)}\int_{p_l}^{p_c} pdF(p) + \int_0^{p_c} pdF(p)\right), \tag{A.38}$$

which gives the values $\underline{c}$ and $\overline{c}$ mentioned in the Implication. ■

A.8 Proof of Implication 3

Note that D_h enters the model only through $p_l(i)$, and that $p_l(i)$ increases in D_h. This directly implies that $\chi(i)$ decreases in D_h. Next, we need to differentiate (9) with respect to p_l and show that the resulting expression is negative for a large enough c, that is:

$$\frac{\partial\chi(i)}{\partial p_l}[1-d^*(\lambda,i)+d_1^*(\lambda,i)(1-\lambda)] - \frac{\partial d^*(\lambda,i)}{\partial p_l}\chi(i) - \frac{\partial d_1^*(\lambda,i)}{\partial p_l}[1-(1-\lambda)\chi(i)] \leq 0. \tag{A.39}$$

The first term is negative. For the second term, we have:

$$\frac{\partial d^*(\lambda, i)}{\partial p_l} = \frac{s(1-\lambda)p_l f(p_l)}{c} \geq 0, \tag{A.40}$$

so that the second term is negative as well. For the third term, we have:

$$\frac{\partial d_1^*(\lambda, i)}{\partial p_l} = \frac{-s p_l f(p_l)}{c}. \tag{A.41}$$

This equation shows that the last term is positive, but can be made arbitrarily small when c is large, whereas the first term of (A.39) does not go to zero. This shows that λ^* decreases in D_h for a large enough c. ■

A.9 Proof of Implication 4

Equations (A.11) and (A.37) immediately imply that $d_1^*(\lambda, i)$ and $d^*(\lambda, i)$ are both decreasing in c. Since c does not enter the other terms in (9), it immediately follows that λ^* increases in c. ■

A.10 Proof of Implication 5

If the demand function is $\alpha q(.)$ then the economic surplus is represented by $\alpha S(.)$. Thus, using (1), neither p_l nor p_c depend on α, so that $d^*(\lambda, i)$ and $\lambda^*(i)$ are independent of α as well. ■

A.11 Proof of Implication 6

Obvious from equations (4) and (7) that define $d^*(\lambda, i)$ and $\mathcal{W}(\lambda, i)$. ■

A.12 Proof of Implication 7

When c is sufficiently large, for any i both $d^*(0, 1)$ and $d^*(1, i)$ can be made arbitrarily close to zero. From (12) it is then clear that $U(i, 1) > U(i, 0)$ for any i, which implies using (13) that $i^*(1) < i^*(0)$. Since $D_f = q(i+s) - D_h$, this also implies that centralizing supervision increases cross-border borrowing. ■

A.13 Parameters used in the figures

All figures use $q(r) = (1+r)^{-2}$, F is a Beta distribution with parameters $(a,b) = (2, 1.2)$. In addition, the baseline parameterization is $s = 0.001, \ell = 0.1, D_h = 0.33, C(d) = \frac{1.7*10^{-4}}{2} d^2$.

Fig. 2: Baseline parameters.

Fig. 3 and 4: Baseline parameters, with $s = 0.0001$ and $C(d)$ corresponding to the specification of Proposition 4, that is, $C(d) = 0$ for $d \leq \bar{d} = 0.0536$, $C(d) = \bar{c} = 8.58 * 10^{-8}$ for $d = \bar{d}$ and $C(d)$ infinitely large for larger values of d.

Fig. 5: "Baseline" - baseline parameters; "Higher D_h" - baseline parameters with $D_h = 0.34$; "Higher ℓ" - baseline parameters with $\ell = 0.11$; "Higher c" - baseline parameters with $C(d) = \frac{1.8*10^{-4}}{2} d^2$.

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B Supplementary Appendix for "Optimal Supervisory Architecture and Financial Integration in a Banking Union"

For online publication only.

B.1 Extension: Banks with positive capital

I consider a simple extension of the model in which banks have non-zero capital and study the impact of capital on the supervisors' incentives.

Assume that a bank has raised K units of capital from local shareholders. The bank thus has L units of loans, financed by K in capital and $L - K$ in debt at an interest rate of i. If, after learning p, the bank liquidates its loans, it receives a payoff equal to:

$$\max(0, L(1-\ell) - (L-K)(1+i)) = \max(0, K(1+i) - L(\ell+i)). \tag{B.1}$$

Denoting $\kappa = K/L$ the bank's capital ratio, this payoff is positive if and only if:

$$\kappa > \frac{\ell + i}{1+i}. \tag{B.2}$$

I assume that this condition is violated, so that the bank never liquidates voluntarily, as in the original model.[16] If the bank is not liquidated, its expected profit conditionally on p is:

$$p[sL + K(1+i)] + (1-p) \times 0. \tag{B.3}$$

To determine the supervisors' incentives, we need to compute the quantities $W_1, W_\ell, \hat{W}_1, \hat{W}_\ell$. The total welfare quantities W_1 and W_ℓ are simply equal to the value of the bank's assets, as in the original model, and are independent of K, so that p_c is still given by (1). Local welfare under liquidation is equal to $(1-\ell)D_h$, as local shareholders get zero. Finally, local

[16] One can still consider the model under the assumption that (B.2) holds. The bank will then liquidate when $p \leq p_b$, where p_b is a threshold lower than p_l. Thus, supervision remains useful even when the bank is sufficiently capitalized to survive the liquidation of its assets.

welfare when loans are repaid is $\hat{W}_1 = S(r) - (1+i)(L - K - D_h)$. As a result, we have:

$$p_l = \frac{(1-\ell)D_h}{S(r) - (1+i)(L(1-\kappa) - D_h)}. \tag{B.4}$$

This quantity is decreasing in κ: the local supervisor becomes *more* forbearant when the bank is better capitalized. This is due to the proportion of local shareholders being larger than the proportion of local creditors (see Beck, Todorov, and Wagner (2013)). When this is the case, the quantity $\chi(i)$ is larger than in the original model, so that the ex-post effect that drives all the results is actually stronger.

Interestingly, additional capital has an ambiguous impact on the bank's optimal choice of inspection difficulty. We can rewrite (3) as:

$$\Pi(d, \lambda, i) = L[s+\kappa(1+i)] \left[d \int_0^1 p dF(p) + (1-d)\lambda \int_{p_c}^1 p dF(p) + (1-d)(1-\lambda) \int_{p_l}^1 p dF(p) \right] - LC(d). \tag{B.5}$$

Differentiating with respect to d and κ yields:

$$\frac{\partial \Pi_1(d, \lambda, i)}{\partial \kappa} = L(1+i) \left[\int_0^{p_l} p dF(p) + \lambda \int_{p_l}^{p_c} p dF(p) \right] + L[s+\kappa(1+i)] p_l f(p_l)(1-\lambda) \frac{\partial p_l}{\partial \kappa}. \tag{B.6}$$

The first effect is positive: As shareholders have more money at stake, they have more incentives to increase inspection difficulty so as to avoid what they see as excessive liquidation conducted by the bank supervisors. The second effect goes in the opposite direction. Since the presence of domestic shareholders makes the local supervisor more lenient, this reduces the bank's incentives to increase inspection difficulty. Note that this second effect disappears when supervision is fully centralized, in which case additional capital unambiguously increases d.

B.2 Extension: Supply of savings

Consider a more general specification for the supply of savings by home and foreign investors. The home country is denoted by index h, and the foreign country by f. Investors in country $i \in \{h, f\}$ have a wealth M_i, and can lend D_i to banks. The amount $M_i - D_i$ that is not lent to banks yields a utility $V(M_i - D_i)$, with $V' \geq 0, V'' \leq 0$.

I briefly show that Proposition 2 and Lemma 3, which bear on the main economic mechanisms of the model, still obtain in this setup.

In equilibrium, investors in both countries must be indifferent between lending a marginal unit to the bank or keeping it. For a given interest rate i and for a given λ, the endogenous values of D_h and D_f are given by:

$$V'(M_h - D_h) = V'(M_f - D_f) = U(i, \lambda). \tag{B.7}$$

Notice in particular that $M_h - D_h = M_f - D_f$. This gives the value of D_h and D_f as functions of i:

$$D_h(i) = M_h - V'^{-1}(U(i, \lambda)), D_f(i) = M_f - V'^{-1}(U(i, \lambda)). \tag{B.8}$$

To close the equilibrium, we also need to have $D_h(i) + D_f(i) = q(i+s)$, so that the equilibrium i satisfies:

$$q(i^* + s) + 2V'^{-1}(U(i^*, \lambda)) - M_h - M_f = 0. \tag{B.9}$$

Using implicit differentiation, this equation gives us:

$$\frac{di^*}{d\lambda} = \frac{-U_2(i^*, \lambda)}{V''(M_h - D_h(i^*))q'(i^* + s) + 2U_1(i^*, \lambda)}. \tag{B.10}$$

As U_1 and U_2 are both positive, V'' and q' both negative, this shows that i^* decreases in λ, which is the result of Proposition 2.

Turning to Lemma 3, $\chi(i)$ has the same definition as in the original model, and we want to show that it decreases in i. It is still increasing in $p_c(i)$ and decreasing in $p_l(i)$. The definition of $p_c(i)$ is the same as before, and we still have $p_c'(i) \leq 0$. The only thing that remains to show is that $p_l'(i) \geq 0$. We have:

$$p_l(i) = \frac{(1 - \ell)D_h(i)}{S(i + s) - D_f(i)(1 + i)}. \tag{B.11}$$

Differentiating with respect to i and observing that $D'_f(i) = D'_h(i)$, $p'_l(i) \geq 0$ if and only if:

$$D'_h(i)[S(i+s) - (1+i)(D_h(i) + D_f(i))] - D_h(i)[S'(i+s) - D_f(i)]. \tag{B.12}$$

We have $D'_h(i) = -U_1(i, \lambda)/V''(M_h - V_h(i)) \geq 0$, $S(i+s) > (1+i+s)q(i+s) > (1+i)(D_h(i) + D_f(i))$, and $S'(i+s) \leq 0$. These inequalities imply that equation (B.12) is positive. This shows that $p'_l(i) \geq 0$, and hence that $\chi'(i) \leq 0$ and that Lemma 3 still obtains.

The conclusion from this extension is that the simple modeling used in the paper allows to focus on the impact of supervision on foreign investors by assuming that domestic debt is inelastic, but the main economic forces of the model are still at play if investors in both countries are treated symmetrically.

B.3 Symmetric case of a bank lending abroad

The original model is designed to study the impact of centralized supervision on a bank borrowing from a foreign country. If it borrows from foreign banks, one may ask whether the effects studied in the model also obtain for the foreign banks. I study in this appendix a simple extension that shows that more market integration leads to centralized supervision being more desirable in the foreign country (as is shown in Proposition 3 in the original model).

Consider a bank with only local deposits, that lends both in its home country and in a foreign country. To simplify, the borrowers in the two countries are identical and are represented by a demand function $q(.)$ as in the original model. Denote α the proportion of local borrowers in the bank's portfolio. The central supervisor's threshold p_c does not depend on α and is the same as in the original model. Since all the bank's creditors are local, we have $\hat{W}_\ell = W_\ell = (1-\ell)L$. Finally, when the loans are successful, the local supervisor takes into account a proportion α of the borrowers' surplus $S(r) - (1+r)L$, plus the bank's profit sL, plus $(1+i)L$ paid to the local depositors. This gives:

$$\hat{W}_1 = \alpha S(r) + (1-\alpha)(1+r)L, \;\; p_l = \frac{(1-\ell)L}{\alpha S(r) + (1-\alpha)(1+r)L}. \tag{B.13}$$

Importantly p_l decreases in α, and is equal to p_c for $\alpha = 1$. Hence, symmetrically to the original model, we have $p_l \geq p_c$: the local supervisor liquidates the bank too often, as he does not internalize the loss of the foreign borrowers' surplus. When the share of local borrowers increases, this effect is weaker. Expected total welfare is still defined by Equation (7), and we have:

$$\mathcal{W}_1(\lambda, i) = -d_1^*(\lambda, i)\left[\int_0^{p_c}(p_c - p)dF(p) - (1-\lambda)\int_{p_c}^{p_l}(p - p_c)dF(p)\right] + (1 - d^*(\lambda, i))\int_{p_c}^{p_l}(p - p_c)dF(p). \tag{B.14}$$

The proportion of local deposits α only appears in p_l, and we have:

$$\frac{\partial \mathcal{W}_1(\lambda, i)}{\partial p_l} = [d_1^*(\lambda, i)(1-\lambda) + (1 - d^*(\lambda, i))](p_l - p_c)f(p_l). \tag{B.15}$$

When C is sufficiently convex the term $d_1^*(\lambda, i)$ can be made arbitrarily small, so that this expression is positive, meaning that the marginal impact of λ on welfare decreases in α. This shows that, as in the original model, more market integration increases the incentives to centralize supervision. While studying the converse statement would require a more developed equilibrium model with assets in two countries, one would also expect that more centralized supervision can foster market integration. Indeed, when the bank lends abroad and supervision is local the bank exposes itself to the risk of premature liquidation. If supervision is more centralized, the bank is not penalized for lending abroad so that the equilibrium share of foreign borrowers should increase.