

# Supervisory Incentives in a Banking Union\*

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December 17, 2015

## Abstract

We explore the behavior of supervisors in a “hub-and-spokes” regime: one in which a supranational agency has legal power over all decisions regarding banks, but has to rely on local supervisors to collect the information necessary to act. This institutional design entails a principal-agent problem between the central and local supervisors to the extent that their objective functions differ. Information collection will be inferior to what would happen in a model with fully independent local supervisors or one where the centralized agency directly collects information. The reason is that local agents will, in some states of the world, prefer to remain ignorant rather than to potentially learn information that would lead the central supervisor to decisions that are against the local agents’ interests. This, in turn, may lead to poorer ex ante incentives for regulated banks.

## 1 Introduction

The global financial crisis laid bare the limitations of a financial architecture in which nation-bound supervisors oversaw increasingly integrated financial markets and institutions. Supervisory fragmentation hindered the monitoring and understanding of cross-border linkages before the crisis, and led to often locally-driven and globally-inefficient policy actions after the crisis started. Against this background, the nascent banking union in Europe represents an important step in the direction of limiting the negative effects of the existing fragmentation. Yet, the move to supranational supervision raises new questions about its internal governance, its relationship with local supervisors, and ultimately, the way it will affect the behavior of the financial institutions under its jurisdiction. And, while the need for and benefits from a more internationally integrated supervisory regime have been discussed at length (Schoenmaker, 2011, Obstfeld, 2014), its costs and challenges have received much less attention.

This paper is a theoretical exploration of the tensions inherent in a “hub-and-spokes” supervisory regime: one in which a supranational agency has legal power over all decisions regarding banks, but has to rely on local

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\*The views expressed in this paper are those of the authors and do not necessarily represent those of the IMF or its Executive Board.

supervisors to collect the information necessary to act. In particular, we focus on how this institutional design affects supervisors' incentives to collect information; and on how this, in turn, influences bank behavior. Our framework is inspired by the supervisory reform in Europe.<sup>1</sup>

We model an economy in which banks, protected by limited liability and operating under asymmetric information, tend to take on excessive risk in the absence of effective supervision. As in many related models, banks are levered and do not take into account the losses they impose on depositors and debt holders (and taxpayers when deposits are insured) when they fail (e.g., Hellmann et al., 2000, Matutes and Vives, 2000, Repullo, 2004, and Dell'Ariccia and Marquez, 2006). In our framework, bank risk taking is not directly observable, and the informational asymmetries this engenders prevents investors from pricing risk at the margin. The result is more risk taking than is socially optimal. Bank supervision is designed to improve over this *laissez-faire* equilibrium.

Under independent supervision, local supervisors invest resources to collect information about bank risk taking and, upon obtaining it, they can intervene a bank and force it to invest in the portfolio deemed optimal by the supervisor, which is typically a safer portfolio. Intervention, however, comes at a cost. This can be seen as a reputational cost for the supervisor, the loss associated with the removal of a national (and private) champion, and/or it could represent a loss in efficiency associated with the transfer of the bank to the public sector.

Under centralized supervision, local supervisors retain control of information collection, but are mandated to transmit to the central agency what they learn. Then, the central supervisor can act on the information and has full control over the decision of whether or not to intervene a bank, and what portfolio to implement conditional on intervention. Critically, local supervisors have utility functions that are different, perhaps just slightly, from that of the central agency, and are in general less inclined to intervene in banks. Such reluctance to intervene may stem from greater costs that are borne at the local level for the supervisor, such as the aforementioned reputational costs and/or fiscal costs, or may reflect some degree of regulatory capture to which a central supervisor would not be subjected (see Agarwal et al., 2014, Acharya et al., 2013, and Bolton and Jeanne, 2011). This generates a principal-agent problem between the central and local supervisors, in addition to that between supervisors and banks, that is at the core of our model. Information collection will be distorted away from what would happen in a model with fully independent local supervisors

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<sup>1</sup>In its simplicity, our model cannot do justice to the many checks and balances and corrective procedures existing in a real-world supervisory mechanism. Rather, the model is meant to highlight some of the tensions that the new supervisory regime will have to take into account in order to operate effectively.

or one where the centralized agency directly collects information. The reason is that local agents will, in some states of the world, prefer to remain ignorant rather than to potentially learn information that would lead the central supervisor to decisions that are against their own interests.

This poorer information collection entails costs. The problem for the central agency is obvious. But the lack of information can also lead to results that are undesirable for local supervisors, and may lead to inefficient outcomes in terms of bank resolution. This, in turn, may lead to poorer ex ante incentives for regulated banks. A lower probability of having its actions discovered will make it more attractive for banks to take risk in excess of that desired by the regulator. That said, to the extent that a centralized supervisor imposes tighter standards (tolerates less risk taking) than local ones, for some banks this effect will be partly offset by a lower threshold for intervention.

Building on this result, the paper delves into what factors make the conflict more or less relevant and what policies the central supervisor can enact to correct it. The starting point of the analysis is that the local and the central supervisors have different utility functions and, consequently, can take different decisions. In other words, there are some states of the world for which the local supervisor would allow certain banks to operate while the central agency would prefer to intervene and resolve them. This stems from two main forces: First, banks may be systemic at the national but not the supranational level. Second, central supervisors internalize the cost of resolution, which may have negative externalities for other international institutions, more than the local agency. Based on this setup we expect the conflict to be greater for: 1) Regional banks that are systemic for individual countries but not for the broader banking union as a whole. 2) Local supervisors in fiscally weak countries that are more reluctant to bear the cost of resolution but that have internationally important banks. 3) Concentration: in small countries, a more concentrated banking system increases the probability of having locally systemic but not globally systemic banks. In large countries, this may not be true.

The paper is relevant for the nascent banking union in Europe. As of November 2014, the Single Supervisory Mechanism (SSM), which will reside within the European Central Bank, will be the primary supervisor of the Eurozone's biggest banks. It will supervise directly the largest 128 banks in the Eurozone, accounting for approximately 85 percent of banking assets in the Eurozone, and indirectly all the banks in the Eurozone. Yet, at least for a prolonged transition period, one can realistically assume that the SSM will have to rely heavily on local supervisors for the collection and processing of on-site information. Then, our paper suggests

that internal mechanisms need to be devised to guarantee that the spokes, which may have different objective functions from the hub, act according to the centralized mandate. Various elements of the new institutional design go in this direction. For instance, the SSM retains the right to bring any bank (in addition to the top 128) under its direct supervision. In our model, this kind of threat would act as a discipline device for local regulators. The ECB also plans to appoint multi-country teams headed by SSM's officials to conduct on-site inspections at the largest banks; again a move that facilitates the exchange of information between the spokes and the hub.

This paper contributes to the literature on the benefits and challenges of centralized bank regulation and supervision. In this respect the paper is related to Dell'Ariccia and Marquez (2006), Calzolari and Loranth (2011), Holthausen and Rønde (2004), Goyal et al. (2013), and the discussions in Basel Committee on Banking Supervision (2010) and IMF (2010).

The paper proceeds as follows. Section 1 describes the basic model with a local independent supervisor. Section 2 derives the bank's portfolio choice in the case of no supervision. Section 3 derives the equilibrium in the case of an independent local supervisor, while Section 4 discusses the effects of centralizing supervision.

## 2 Model

Consider a simple one-period economy with banks, investors and a local supervisor. Each bank has access to a risky investment portfolio and needs external funds to finance it. The supervisor may observe the bank's portfolio and decide to intervene the bank or let it operate. Finally, the bank's portfolio returns are realized and the bank either succeeds or fails.

Specifically, the bank's investment portfolio requires 1 unit of funds. Each bank is endowed with an amount of capital  $k \in [0, 1]$  and raises an amount of deposits  $1 - k$  from outside investors. Bank capital is distributed according to the cumulative distribution  $F(k)$ , with density  $f(k)$ .

The opportunity cost of capital is  $r_E \geq 1$  per unit. Depositors receive a promised (per unit) return  $r_D$  and have a total per unit (normalized) opportunity cost of 1. The deposit market is perfectly competitive so that the bank will always set  $r_D$  at the level required for depositors to recover their opportunity cost of funds and be willing to participate. For simplicity, we consider that deposits are fully insured so that  $r_D = 1$ .

The bank chooses a portfolio on the efficient frontier, where that frontier is defined as follows: if a portfolio with probability of repayment  $q$  is chosen, the return on the portfolio is  $R - \frac{1}{2}cq$ . In other words,

the bank can choose the level of risk it likes, with the implication that a higher risk (i.e., lower  $q$ ) portfolio has a higher return if successful. This gives a familiar risk-return tradeoff.

The local supervisor may decide to inspect the bank and observe the quality of the bank's portfolio. Specifically, the supervisor chooses initially an inspection effort  $e$  at a cost  $\frac{d}{2}e^2$ , which represents the probability of observing the portfolio  $q$  chosen by the bank, as well as the bank's level of capital (i.e., the supervisor observes the bank's balance sheet). Conditional on the result of the inspection, the supervisor decides whether to intervene the bank or let it operate independently. If intervened, the bank is put under receivership with probability  $\eta$ . In this case, at a cost  $A_L$  (think about reputation costs or costs associated with the loss of a national champion), the supervisor takes control over the bank's investment choice and chooses the investment portfolio that maximizes total social surplus. Existing bank shareholders are expropriated. We discuss later an alternative assumption under which shareholders of intervened banks retain ownership of the bank and its profits, but lose control of its portfolio choices. The parameter  $\eta$  represents a measure of the banks's ability to challenge the intervention decision of the supervisor, possibly through lobbying activities or through the courts.

Irrespective of whether it has intervened the bank, the supervisor provides deposit insurance. In other words, the supervisor repays depositors when, with probability  $1 - q$ , the bank's investment returns 0 at the end of the game. Bank failure is socially costly, and is reflected in a (per unit) cost  $\psi_L \geq 1$  borne by the supervisor when the bank fails and the supervisor is required to repay depositors. The cost  $\psi_L$  may represent the cost of externalities associated with bank failure, which grow with the size of the realized losses to bank depositors.

The timing of the model is as follow. In stage 0, a bank with capital  $k$  chooses its investment portfolio and the local supervisor chooses the inspection effort  $e$ . In stage 1, with probability  $e$ , the supervisor observes  $q$  and  $k$ , and decides whether to intervene. If intervened, with probability  $\eta$  the bank is put under receivership and the supervisor's preferred investment portfolio is chosen. If not intervened, with probability  $(1 - e\eta)$ , the bank continues with its prior choice of portfolio quality  $q$ . In either case, in stage 2, the investment portfolio returns are realized, and depositors obtain their promised return  $r_D$  either from the bank or the supervisor. Capital providers obtain the remaining profits from the bank's portfolio after repaying depositors when the bank is not intervened and the portfolio succeeds. Otherwise, they obtain zero. In order for them to be willing to participate, shareholders must obtain at least  $r_E$  in expectation.

### 3 The bank's investment choice in the case of no supervision

We start by considering the bank's optimal investment under laissez-faire, that is in the absence of regulation.

The bank chooses the quality of the investment portfolio  $q$  so as to maximize expected profits.

If the bank were fully equity financed, its objective function would be:

$$\max_q q \left( R - \frac{1}{2}cq \right) - r_E.$$

The optimal choice of  $q$  solves:

$$R - cq = 0$$

and thus equals:

$$q^* = \frac{R}{c}.$$

We denote this as the first best investment portfolio since the decision internalizes the cost of failure (i.e., there is no risk shifting on to depositors). We assume  $R < c$  so that an internal solution is guaranteed,  $q^* < 1$ .

Now consider the case of a levered institution: The bank has some capital  $k$  and must finance the rest with deposits. The bank's objective function reflects the fact that it is protected by limited liability:

$$\max_q q \left( R - \frac{1}{2}cq - (1 - k) \right) - kr_E,$$

that is the bank pays back its depositors,  $1 - k$ , only when its investment is successful, which occurs with probability  $q$ . Thus, in the absence of regulation, the bank chooses an investment portfolio of quality  $\hat{q}(k)$ , where

$$\hat{q}(k) = \frac{R - (1 - k)}{c}. \tag{1}$$

The bank chooses  $\hat{q}(k) < q^*$  when levered because of limited liability: the bank does not internalize the losses that accrue to depositors (or taxpayers given the assumption of deposit insurance) in case of failure. Note that the chosen quality of the investment portfolio is a function of the capital  $k$  a bank has and, in particular, it is increasing in  $k$ . This "skin-in-the-game" effect implies that high capital banks will choose lower risk portfolios, and low capital banks will choose higher risk portfolios. Importantly, high capital banks will choose portfolios that are closer to the first best choice  $q^*$ .

This framework implies a moral hazard problem in the choice of the investment portfolio quality when the bank raises a positive amount of deposits, and it is the justification for regulation in this framework.

The quality of the investment portfolio may be so low that it may be welfare enhancing for the supervisor to intervene and take over control of the bank's investment. This is precisely what we analyze next, starting with the case when there is only a local supervisor that chooses both the inspection effort and the intervention strategy. For simplicity we proceed first with the basic case where there is no differential cost between equity and debt financing, so that  $r_E = 1$ .

## 4 Equilibrium in the case of an independent local supervisor

In this section, we consider the case where there is a local supervisor that chooses an inspection effort  $e$  and an intervention strategy, which amounts to an intervention threshold and a portfolio choice for the bank upon intervention. The model is solved backward. We first analyze the supervisor's intervention decision conditional on its inspection having been successful, and then look at the choice of  $e$ .

### 4.1 Intervention choice of the local supervisor

Upon learning the bank's portfolio - asset allocation  $q$  and liabilities, including capital  $k$  - the supervisor chooses whether to intervene so as to maximize total surplus, which includes financial as well as possible non-pecuniary returns. Given a portfolio choice  $q$  by a bank with capital  $k$ , if the supervisor decides not to intervene, its payoff is given by:

$$q \left( R - \frac{1}{2}cq - (1 - k) \right) - (1 - q)(1 - k)\psi_L - k. \quad (2)$$

The first term reflects that with probability  $q$  the bank's portfolio succeeds and produces a surplus  $R - \frac{1}{2}cq - (1 - k)$  after repaying 1 to the  $(1 - k)$  depositors. The second term is the payoff when with probability  $1 - q$  the bank's portfolio fails and returns 0. In this case, the  $1 - k$  of deposits are repaid through deposit insurance at the per unit cost  $\psi_L$ . The last term is the opportunity cost of capital  $k$  that is employed in the investment portfolio.

In case the supervisor decides to intervene, the supervisor's payoff is instead given by

$$\eta \left( -A_L + q_L^* \left( R - \frac{1}{2}cq_L^* - (1 - k) \right) - (1 - q_L^*)(1 - k)\psi_L \right) + (1 - \eta) \left( q \left( R - \frac{1}{2}cq - (1 - k) \right) - (1 - q)(1 - k)\psi_L \right) - k \quad (3)$$

where

$$q_L^* = \frac{R + (1 - k)(\psi_L - 1)}{c} \quad (4)$$

is now the investment portfolio quality chosen by the supervisor to maximize its payoff in the case of intervention, i.e., it is the portfolio quality that maximizes (3). Note that  $q_L^* > q^*$  as the supervisor takes into account the greater cost of failure associated with the higher shadow cost  $\psi_L > 1$  while a fully equity financed bank does not when choosing  $q^*$ . Also, note that  $\frac{\partial q_L^*}{\partial k} < 0$  since deposit insurance outlays conditional on failure decrease with the bank's capitalization. At the limit, if  $k = 1$  so that the bank is all equity financed,  $q_L^* = q^* = \hat{q}$ , and there is no need for intervention.

The first term in (3) represents the payoff to the supervisor when intervention is successful. In this case, which occurs with probability  $\eta$ , the supervisor pays the cost of intervention  $-A_L$  and obtains a net expected surplus from investing in a portfolio of quality  $q_L^*$ . With probability  $q_L^*$  the investment yields a return net of depositors' repayment of  $R - \frac{1}{2}cq_L^* - (1 - k)$ , and with probability  $1 - q_L^*$  it fails and the  $1 - k$  deposits are repaid through deposit insurance at the per-unit cost  $\psi_L$ . The second term in (3) represents instead the payoff to the supervisor when, with probability  $1 - \eta$ , the intervention is not successful and the bank continues to operate with its original portfolio. The last term is again the opportunity cost of the capital  $k$  employed in the bank's investment.

Let  $I(q_L^*, q, k)$  indicate the difference between the intervention and no intervention payoffs for the supervisor when he implements  $q_L^*$  under intervention, under no intervention the bank chooses  $q$ , and the bank has a level of capital  $k$ . Assuming the local supervisor chooses  $q_L^*$  when he intervenes, we have:

$$I_L(q_L^*, q, k) = \eta \left( -A_L + q_L^* \left( R - \frac{1}{2}cq_L^* - (1 - k) \right) - (1 - q_L^*) (1 - k) \psi_L \right) - \eta \left( q \left( R - \frac{1}{2}cq - (1 - k) \right) - (1 - q) (1 - k) \psi_L \right). \quad (5)$$

In what follows, we assume  $-A_L + q_L^* (R - \frac{1}{2}cq_L^* - 1) - (1 - q_L^*) \psi_L > 0$  so that, at least for banks with zero capital, intervention does not entail any social loss. Moreover, we also assume that intervention is always desirable for banks with no capital. Formally, this means  $I_L(q_L^*, q, k) > 0$  for  $k = 0$ . After substituting the expression for  $q_L^*$  into (5), this boils down to requiring that  $\psi_L > \sqrt{2cA_L}$ . We have then the following immediate result.

**Proposition 1** *When acting independently, the local supervisor chooses to intervene a bank with capital  $k$  if  $q < \tilde{q}_L(k)$ , where*

$$\tilde{q}_L(k) = \frac{1}{c} \left( R + (1 - k)(\psi_L - 1) - \sqrt{2cA_L} \right). \quad (6)$$



It follows that  $\frac{\partial \tilde{q}_L(k)}{\partial k} < 0$ ,  $\frac{\partial \tilde{q}_L(k)}{\partial \psi_L} > 0$  and  $\frac{\partial \tilde{q}_L(k)}{\partial A_L} < 0$ .

**Proof.** Substituting the expression for  $q_L^*(k)$  as in (4) into (5) and solving it equal to zero gives

$$\tilde{q}_L(k) = \frac{1}{c} \left( R + (1-k)(\psi_L - 1) \pm \sqrt{2cA_L} \right).$$

We take the negative root for  $\tilde{q}_L$  as otherwise  $\tilde{q}_L(k) > q_L^*(k)$ , which cannot be optimal given that it would imply an intervention threshold for  $q$  above the optimal portfolio quality chosen by the supervisor in case of intervention. It is immediate to see that for  $\psi_L > 1$ ,  $\frac{\partial \tilde{q}_L}{\partial k} = -\frac{1}{c}(\psi_L - 1) < 0$ ,  $\frac{\partial \tilde{q}_L}{\partial \psi_L} = \frac{1}{c}(1-k) > 0$  and  $\frac{\partial \tilde{q}_L}{\partial A_L} = -\frac{1}{\sqrt{2cA_L}} < 0$ .  $\square$   $\blacksquare$

The proposition states that the local supervisor will intervene when the quality of the bank's portfolio is too low relative to its capitalization. Indeed, the intervention threshold  $\tilde{q}_L(k)$  is a function of a bank's actual level of capital. In fact,  $\tilde{q}_L(k)$  defines a schedule of thresholds as a function of  $k$ , with  $\tilde{q}_L$  decreasing in  $k$ . This implies that a supervisor is willing to be more lenient with better capitalized banks in the sense of allowing a bank with more capital to operate with a riskier portfolio. The reason is that the social cost of providing public funds in case of failure,  $(1-k)(\psi_L - 1)$ , is lower the more capital the bank has. This leads the supervisor to be less inclined to intervene more capitalized banks.<sup>2</sup> This result reminds of risk-weighted capital requirements: banks with riskier portfolios are required to hold more capital. In practice, regulatory measures such as CARs are justified on the basis of the loss absorbing capacity of bank capital. The intuition for our result is similar: upon failure, better capitalized banks entail lower costs in terms of deposit insurance outlays.

It follows from the arguments above that, for a given level of capital  $k$ , the threshold  $\tilde{q}_L(k)$  increases with the supervisor's shadow cost of funds  $\psi_L$  so that an increase in  $\psi_L$  makes the supervisor more prudent. This means that the prospect of more costly deposit insurance outlays in case of failure, or simply more costly externalities associated with failure, leads to a more aggressive "prompt corrective action" stance.

Finally, for any given level of capital  $k$ , the critical portfolio quality  $\tilde{q}_L$  below which a bank is intervened is lower than the supervisor's choice of investment quality  $q_L^*$  because of the intervention cost  $A_L$ . This implies that banks with investment portfolios of quality  $q \in (\tilde{q}_L, q_L^*]$  are not intervened. In the absence of the intervention cost (i.e., if  $A_L = 0$ ),  $\tilde{q}_L = q_L^*$ . It follows that the supervisor becomes laxer in its intervention decisions as the cost  $A_L$  increases.

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<sup>2</sup>As we show below, however, this will nevertheless translate into a unique capital threshold below which intervention occurs, and above which the bank is allowed to continue. The decreasing nature of  $\tilde{q}_L$  with respect to  $k$  does, however, influence bank behavior, as we discuss further below.

Note that in this section we have characterized the subgame perfect intervention strategy (that is, the strategy that will prevail when the supervisor cannot commit ex ante to a specific intervention threshold). Put differently, the strategy is ex-post optimal, and as such fully credible. But, ex-ante, the supervisor might prefer to commit to different intervention standards since they may provide better incentives for banks under its jurisdiction. We will assume throughout the analysis that supervisors are unable to commit to standards other than those ex-post optimal. In an extension, we discuss how the equilibrium changes when regulators can commit to non-subgame-perfect intervention thresholds.

## 4.2 Bank portfolio choice

Now consider how the bank's portfolio choice changes once we introduce the possibility of regulatory action. For a choice of portfolio quality  $q$ , the bank's profit function can be rewritten as

$$\Pi = \begin{cases} q(R - \frac{1}{2}cq - (1 - k)) - k & \text{for } q \geq \tilde{q}_L \\ (1 - e\eta)q(R - \frac{1}{2}cq - (1 - k)) - k & \text{for } q < \tilde{q}_L. \end{cases} \quad (7)$$

The first expression in (7) represents the expected profit for a bank with portfolio quality  $q \geq \tilde{q}_L$ . The second line is instead the profit for a bank with  $q < \tilde{q}_L$ , which obtains a positive payoff only when, with probability  $1 - e\eta$ , it is not intervened and can continue the investment, returning  $q(R - \frac{1}{2}cq - (1 - k))$ .

It is immediate to see that the threat of regulatory intervention may affect a bank's portfolio choice. In particular, banks with a level of capital  $k$  such that their laissez-faire optimal portfolio  $\hat{q}(k)$ , as defined in (1), is greater than the intervention threshold  $\tilde{q}_L(k)$ , as defined in Proposition 1, will not be affected by the threat of regulatory intervention and will continue to choose their desired portfolio  $\hat{q}(k)$ . By contrast, banks whose capital  $k$  is such that  $\hat{q}(k) < \tilde{q}_L(k)$  will now have to take into account that, with probability  $e\eta$ , they will be intervened and lose their franchises. This implies that some of these banks, and in particular those with a level of capital such that the difference  $\tilde{q}_L(k) - \hat{q}(k)$  is small enough, may now opt for the portfolio  $\tilde{q}_L$  in order to avoid the risk of intervention.

To see this formally, we proceed in steps. We first recall that the regulatory threshold  $\tilde{q}_L(k)$  for intervention decreases with  $k$  while the laissez faire choice  $\hat{q}$  increases with  $k$ . This implies that the difference  $\tilde{q}_L(k) - \hat{q}(k)$  is decreasing in  $k$  and there is a unique level of bank capital  $k$ , denoted  $\tilde{k}_L$ , at which  $\tilde{q}_L(k) = \hat{q}(k)$ . Equating (1) and (6) and solving for  $k$  gives

$$\tilde{k}_L = \left(1 - \frac{1}{\psi_L} \sqrt{2cA_L}\right). \quad (8)$$

Under the assumption that  $\psi_L > \sqrt{2cA_L}$ , which, as argued above, guarantees that intervention is at least sometimes optimal, we have  $\tilde{k}_L \in (0, 1)$ . It follows that banks with  $k \geq \tilde{k}_L$  will continue finding it optimal to choose their laissez-faire portfolio  $\hat{q}(k)$  and won't be intervened since this portfolio is already safer than the intervention threshold  $\tilde{q}_L(k)$ . These banks are thus unaffected by the presence of a supervisor. By contrast, banks with capital  $k < \tilde{k}_L$ , and thus  $\hat{q}(k) < \tilde{q}_L(k)$ , will now compare their expected profit when choosing  $\hat{q}(k)$  with that when switching to  $\tilde{q}_L(k)$ . Using (7), the expected profit is given by

$$\Pi(\hat{q})|_{k < \tilde{k}_L} = (1 - e\eta)\hat{q}\left(R - \frac{1}{2}c\hat{q} - (1 - k)\right) - k \quad (9)$$

in the former case and by

$$\Pi(\tilde{q}_L)|_{k < \tilde{k}_L} = \tilde{q}_L\left(R - \frac{1}{2}c\tilde{q}_L - (1 - k)\right) - k \quad (10)$$

in the latter. Define  $D(k) = \Pi(\tilde{q}_L)|_{k < \tilde{k}_L} - \Pi(\hat{q})|_{k < \tilde{k}_L}$ . Then, clearly, a bank with a given level of capital  $k < \tilde{k}_L$  will choose to switch to the supervisory intervention threshold  $\tilde{q}_L(k)$  if  $D(k) > 0$ , and will stick to the laissez-faire portfolio  $\hat{q}(k)$  otherwise. We have the following result.

**Lemma 2** *For a given level of supervisory effort  $e$ , there exists a level of capital  $\bar{k}_L(e)$  such that banks with  $k < \bar{k}_L(e)$  choose the laissez-faire portfolio quality  $\hat{q}(k)$ , while banks with  $k \geq \bar{k}_L(e)$  switch to a portfolio of quality  $\tilde{q}_L(k)$ , where*

$$\bar{k}_L(e) = \left(1 - \frac{R\sqrt{e\eta} + \sqrt{2cA_L}}{\psi_L + \sqrt{e\eta}}\right) < \tilde{k}_L. \quad (11)$$

*It follows that  $\frac{\partial \bar{k}_L(e)}{\partial e} < 0$ ,  $\frac{\partial \bar{k}_L(e)}{\partial \psi_L} > 0$  and  $\frac{\partial \bar{k}_L(e)}{\partial A_L} < 0$ .*

**Proof.** Substituting the expression for  $\tilde{q}_L(k)$  as in (6) into (10) and that for  $\hat{q}$  as in (1) into (9) and solving  $D(k) = \Pi(\tilde{q}_L)|_{k < \tilde{k}_L} - \Pi(\hat{q})|_{k < \tilde{k}_L} = 0$  with respect to  $k$  gives  $\bar{k}_L(e)$  as in 11. Using the expression for  $\tilde{k}_L$  as in (8) it is easy to see that  $\bar{k}_L(e) < \tilde{k}_L$ . Moreover, from (11) we have  $\frac{\partial \bar{k}_L(e)}{\partial e} = -\frac{\psi_L R - \sqrt{2cA_L}}{2\sqrt{e\eta}(\psi_L + \sqrt{e\eta})^2} < 0$ ,  $\frac{\partial \bar{k}_L(e)}{\partial \psi_L} = \frac{R\sqrt{e\eta} + \sqrt{2cA_L}}{(\psi_L + \sqrt{e\eta})^2} > 0$  and  $\frac{\partial \bar{k}_L(e)}{\partial A_L} = -\frac{c}{\sqrt{2cA_L}(\psi_L + \sqrt{e\eta})} < 0$ . The proposition follows.  $\square$  ■

The lemma shows that, for a given regulatory effort, the threat of intervention affects the portfolio choice of banks with capital in an intermediate range,  $k \in [\bar{k}_L(e), \tilde{k}_L)$ , as it induces them to switch from their laissez-faire portfolio quality  $\hat{q} < \tilde{q}_L(k)$  and meet the supervisor's standards. The threshold level  $\bar{k}_L(e)$  is decreasing in the supervisory effort  $e$ , meaning that banks with increasingly lower levels of capital will choose to meet the supervisory standards as  $e$  increases.

Moreover,  $\bar{k}_L(e)$  increases with the shadow cost of public funds  $\psi_L$ , while it decreases with the cost of regulatory intervention  $A_L$ . This means that a decrease in  $\psi_L$  (or an increase in  $A_L$ ) induces banks with even

lower levels of capital to meet the supervisory standards. The reason for these results is that, for a given level of supervisory effort  $e$ , these parameters affect the intervention threshold  $\tilde{q}_L(k)$ , as stated in Proposition 1. When  $\tilde{q}_L(k)$  decreases, as for example as a result of a decrease in  $\psi_L$  or an increase in  $A_L$ , the supervisor is more lenient in that it allows banks with lower portfolio quality to continue. This will induce banks with lower capital to choose  $\tilde{q}_L(k)$  as the difference between this and their laissez-faire optimal  $\hat{q}(k)$  is reduced.

To guarantee that supervisory intervention is meaningful in the model, in what follows we will restrict parameters so that the threshold  $\bar{k}_L(e)$  is positive. This implies that there will always be banks with capital  $k < \bar{k}_L$  that will choose  $\hat{q} < \tilde{q}_L$  and will be intervened with probability  $e$ ; banks with  $k \in [\bar{k}_L(e), \tilde{k}_L]$  that will instead choose  $\tilde{q}_L$  to avoid being intervened; and, finally, banks with  $k \in [\tilde{k}_L, 1]$  that will continue to play their laissez-faire portfolio,  $\hat{q} \geq \tilde{q}_L$ . Assuming  $\bar{k}_L(e) > 0$  requires the parameters  $R, \psi_L, A_L$  and  $c$  to be such that in equilibrium the supervisor will choose an inspection effort  $e < \bar{e}_L$  where, by setting (11) equal to zero, we have

$$\bar{e}_L = \frac{(\psi_L - \sqrt{2cA_L})^2}{\eta(R-1)^2} \quad (12)$$

Figure 1 summarizes graphically the relationship between the bank portfolio choice as a function of  $k$  for a given supervisory effort  $e$ . As the figure illustrates, banks choose their laissez-faire portfolio quality  $\hat{q}$  for  $k < \bar{k}_L(e)$  and for  $k > \tilde{k}_L$ . In the former case,  $\hat{q}$  is less than  $\tilde{q}_L$  and banks risk to be intervened with probability  $e\eta$ , while in the latter case  $\hat{q} > \tilde{q}_L$  and thus these banks will always be allowed to continue operating. Banks with  $k \in [\bar{k}_L(e), \tilde{k}_L]$  deviate from their laissez-faire portfolio as a result of the threat of intervention.

Lemma 2 above characterizes a bank's behavior for a given anticipated supervisory effort the  $e$  and level of capital  $k$ . Note, however, that since the threshold value  $\bar{k}_L$  is a function of effort  $e$ , the point at which a bank switches from its laissez faire choice  $\hat{q}$  to the supervisory threshold  $\tilde{q}_L$  is also a function of  $e$ . An alternative way of viewing the relationship between bank portfolio choice and supervisory effort is to consider the bank's portfolio choice directly as a function of  $e$  by solving  $D(k) = 0$  for  $e$ , given a particular level of  $k$ . Specifically, for  $k < \tilde{k}_L$  there exists a level of supervisory effort  $\hat{e}(k)$  such that  $D(k) = 0$ .

Viewed this way, we can now write the bank's reaction function  $\hat{q}_L(k, e)$  at the individual bank level in the case of a local supervisor as

$$\hat{q}_L(k, e) = \begin{cases} \hat{q}(k) & \text{for } e < \hat{e}(k) \text{ and } k < \tilde{k}_L \\ \tilde{q}_L(k) & \text{for } e \geq \hat{e}(k) \text{ and } k < \tilde{k}_L \\ \hat{q}(k) > \tilde{q}_L(k) & \text{for } k \geq \tilde{k}_L, \end{cases}$$

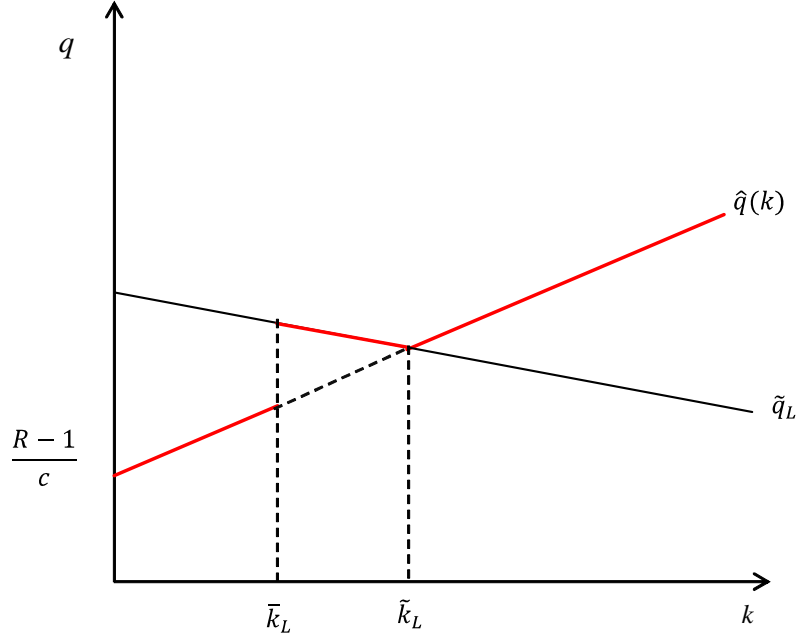


Figure 1: Bank portfolio choice  $q$  as a function bank capital  $k$ , for a given supervisory effort  $e$ .

where  $\hat{q}(k)$  is as in (1) and  $\tilde{q}_L(k)$  is given by (6). Thus, a bank with capital  $k > \tilde{k}_L$  is not affected by the threat of regulatory intervention and will always choose its laissez-faire portfolio, while a bank with capital  $k < \tilde{k}_L$  will choose its laissez-faire portfolio level only if the supervisor exerts a level of effort below  $\hat{e}(k)$ , and will meet the supervisory standard  $\tilde{q}_L(k)$  for  $e > \hat{e}(k)$ . Note that, relative to more capitalized banks, less capitalized banks have riskier laissez faire portfolios (lower  $\hat{q}$ ) but are forced into safer portfolios of quality  $\tilde{q}_L$  once supervised.

Figure 2 below represents graphically the relationship between bank portfolio choice,  $\hat{q}_L$ , and supervisory effort,  $e$ , for banks with  $k < \tilde{k}_L$ , for two different levels of capital,  $k_1$  and  $k_2$ . For  $e < \hat{e}(k_i)$ ,  $i = 1, 2$ ,  $\hat{q}_L = \hat{q}$ . At  $e = \hat{e}(k_i)$ , the bank with capital  $k_i$  switches to the higher quality portfolio  $\tilde{q}_L$ . Since  $k_1 < k_2$ , we also have that  $\tilde{q}_L(k_1) > \tilde{q}_L(k_2)$  reflecting our argument above that the supervisor is more lenient with better capitalized banks.

Having derived the bank portfolio choice as a function of the supervisory effort  $e$ , we can now turn to study the supervisor's optimal effort choice as a function of the distribution of capital across banks in the economy. Before doing this, we note that although we have derived it as an individual bank's choice, the threshold  $\bar{k}_L(e)$  described in Lemma 2 can be seen as characterizing the set of banks that will be intervened

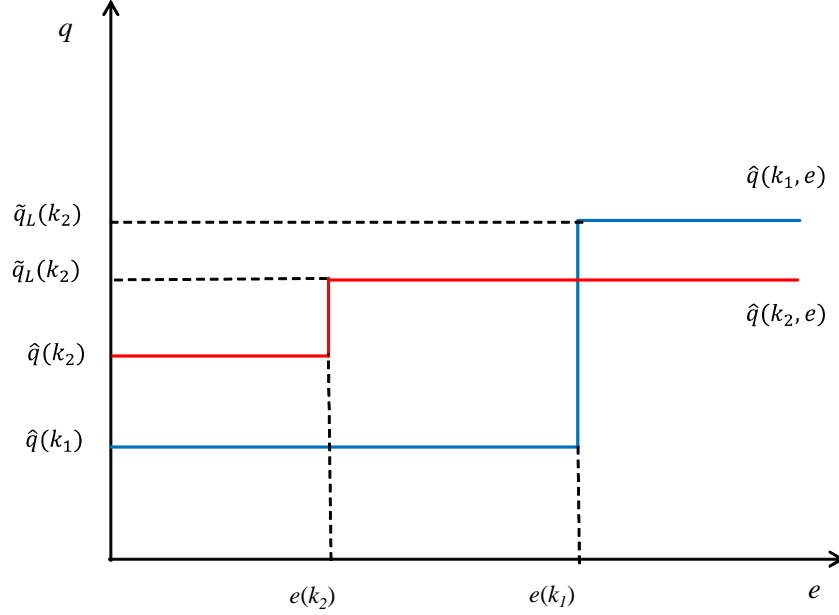


Figure 2: Bank's portfolio choice as a function of the supervisory effort  $e$ , for given levels of capital  $k_1$  and  $k_2$ , with  $k_2 > k_1$ .

if discovered by the supervisor (those with  $k < \bar{k}_L(e)$ ) as well as those whose behavior/portfolio choice will be affected by supervision (those with  $k \in [\bar{k}_L(e), \tilde{k}_L]$ ). In this sense, the threshold  $\bar{k}_L(e)$  can be viewed as an aggregate reaction function to the supervisory effort  $e$ , with  $\frac{d\bar{k}_L(e)}{de} < 0$ , as argued above. In other words, the banking system's reaction function for the critical value  $\bar{k}_L$  is downward sloping in  $e$ .

### 4.3 Inspection effort of the local supervisor

We can now turn to the choice of the local regulator concerning the effort  $e$  to exert to inspect the bank.

Given the decision to intervene for  $q < \tilde{q}_L(k)$ , the supervisor's objective function is

$$\begin{aligned}
\max_e SW_L &= \Pr(q > \tilde{q}_L) E\left[q \left(R - \frac{1}{2}cq - (1-k)\right) - (1-q)(1-k)\psi_L - k \mid q > \tilde{q}_L\right] \\
&+ e\eta \Pr(q < \tilde{q}_L) E\left[-A_L + q_L^* \left(R - \frac{1}{2}cq_L^* - (1-k)\right) - (1-q_L^*)(1-k)\psi_L - k \mid q < \tilde{q}_L\right] \\
&+ (1-e\eta) \Pr(q < \tilde{q}_L) E\left[q \left(R - \frac{1}{2}cq - (1-k)\right) - (1-q)(1-k)\psi_L - k \mid q < \tilde{q}_L\right] - \frac{d}{2}e^2, \quad (13)
\end{aligned}$$

where  $\tilde{q}_L < q_L^*$  is the intervention threshold as given in (6) and  $q_L^*$  is the bank portfolio the supervisor implements upon successful intervention, as given by (4). The first term represents the expected social surplus when the bank chooses an investment portfolio of quality  $q > \tilde{q}_L$  and is allowed to continue. The second term represents the case when the supervisor inspects the bank, intervenes it and takes over its

portfolio choice. The third term is the payoff when the supervisor is unsuccessful in its inspection or intervention and the bank can continue its investment project despite having chosen a portfolio with  $q < \tilde{q}_L$ . Finally, the last term represents the cost of inspection.

For simplicity we can rewrite the supervisor's objective function as

$$SW_L = E[q \left( R - \frac{1}{2}cq - (1-k) \right) - (1-q)(1-k)\psi_L - k] + e\eta \Pr(q < \tilde{q}_L) E[I_L(q_L^*, q, k) | q < \tilde{q}_L] - \frac{d}{2}e^2, \quad (14)$$

where  $I_L(q_L^*, q, k)$  is the net gain from intervention for the supervisor as defined in (5). Clearly, only the last two terms depend on the supervisor's inspection effort. This means that the supervisor will choose the inspection effort taking into account that this will affect only banks with portfolios of quality  $q < \tilde{q}_L$  or, equivalently, those with  $k < \bar{k}_L(e)$  as defined in Lemma 2. We can then derive the supervisor's optimal effort as follows.

**Lemma 3** *Given the bank's optimal behavior as described in Lemma 2, under independence, the local supervisor chooses a level of effort  $e_L(\bar{k}_L)$  given by*

$$e_L(\bar{k}_L) = \min \left\{ \int_0^{\bar{k}_L} I_L(q_L^*, \hat{q}, k) f(k) dk, \bar{e}_L \right\}. \quad (15)$$

It follows that  $\frac{\partial e_L(\bar{k}_L)}{\partial \bar{k}_L} > 0$ .

**Proof.** Differentiating (14) with respect to  $e$  and recalling we have restricted  $e$  to be less than  $\bar{e}_L$  as in (12) gives

$$e_L = \min \{ \Pr(\hat{q} < \tilde{q}_L) E[I_L(q_L^*, \hat{q}, k) | \hat{q} < \tilde{q}_L], \bar{e}_L \}. \quad (16)$$

Further, from Lemma 2, it follows that in equilibrium  $\Pr(\hat{q} < \tilde{q}_L) = \Pr(k < \bar{k}_L(e)) = F(\bar{k}_L)$  and  $E[I_L(q_L^*, \hat{q}, k) | \hat{q} < \tilde{q}_L] = \frac{1}{F(\bar{k}_L)} \int_0^{\bar{k}_L} I_L(q_L^*, \hat{q}, k) f(k) dk$ . Substituting these into the expression above for  $e_L$  gives (15). Differentiating this with respect to  $\bar{k}_L$  gives  $\frac{\partial e_L}{\partial \bar{k}_L} = I_L(q_L^*, \hat{q}(\bar{k}_L), \bar{k}_L) f(\bar{k}_L) > 0$ .  $\square$   $\blacksquare$

The lemma describes the supervisor's reaction function in the case of local supervision. The supervisory effort depends positively on the threshold  $\bar{k}_L$  characterizing banks' behavior. The higher  $\bar{k}_L$ , (the greater the fraction of banks with  $k < \bar{k}_L$  that will choose  $\hat{q} < \tilde{q}_L$ ), the higher the supervisory effort.

## 4.4 Equilibrium

Having characterized the reaction functions for the supervisor and the banks, we can now characterize the equilibrium.

**Proposition 4** For given intervention cost  $A_L$  and shadow cost of public funds  $\psi_L$ , there is a unique equilibrium  $(e_L^*, \bar{k}_L^*, \tilde{q}_L, \hat{q}_L)$  in supervisory effort, intervention strategy, and bank portfolio choices such that:

1) The supervisor will intervene (upon obtaining actionable information) any bank with  $q < \tilde{q}_L(k)$ , where  $\tilde{q}_L(k)$  is as in (6);

2) Banks that choose not to meet the supervisor's standards,  $\tilde{q}_L(k)$ , choose their laissez-faire optimal portfolios  $\hat{q}(k)$ ;

3) The optimal supervisory effort  $e_L^*$  and capital threshold  $\bar{k}_L^*$  below which banks choose not to meet supervisory standards satisfy:  $e_L(\bar{k}_L^*) = e_L^*$  and  $\bar{k}_L(e_L^*) = \bar{k}_L^*$ .

**Proof.** To establish the existence and uniqueness of an equilibrium, recall first that we can focus on the equilibrium as a function of the supervisory effort  $e$  and capital threshold level  $\bar{k}_L$ , rather than portfolio choice  $q(k)$ , since, as described in Lemma 2,  $\bar{k}_L$  provides a summary statistic of how supervisory effort affects bank risk taking behavior. Furthermore, from the lemmas above we have  $\frac{\partial \bar{k}_L}{\partial e} < 0$  and  $\frac{\partial e_L}{\partial \bar{k}_L} > 0$ , so that the two reaction functions will intersect at most once.

For  $e = 0$ , the function  $\bar{k}_L(e)$  equals the regulatory threshold  $\tilde{k}_L$ , since for  $e = 0$  only banks with  $k \geq \tilde{k}_L$  will choose  $q > \tilde{q}_L$ . Conversely,  $\bar{k}_L(e)$  will equal 0 at  $\bar{e}_L$  as defined in (12). It follows that the two functions can only cross once and that  $\bar{k}_L^* \in (0, \tilde{k}_L)$  and  $e_L^* \in (0, \bar{e}_L)$ . To show that the solution must be strictly interior, note that  $e_L^* = \bar{e}_L$  cannot be an equilibrium as then  $\bar{k}_L(\bar{e}_L) = 0$  and all banks would choose  $q \geq \tilde{q}_L$ . Given this, it cannot be optimal for the supervisor to choose  $e_L^* = \bar{e}_L$  since all banks are meeting the regulatory standards. Likewise,  $\bar{k}_L^* = 0$  cannot be an equilibrium as then the supervisor's optimal response would be to choose  $e = 0$ , which would make the proposed solution of  $\bar{k}_L^* = 0$  not optimal for the banks. Therefore, the equilibrium must be strictly interior. ■

Proposition 4 establishes that a unique equilibrium exists where the supervisor exerts a strictly positive level of effort in identifying which banks may have portfolios that it views as excessively risky, and some (but not all) banks adjust their behavior to conform to the supervisory standards. Figure 3 illustrates the result (for bank capital uniformly distributed between 0 and 1). The downward sloping line represents the banks' reaction function,  $\bar{k}_L(e)$ , as a function of supervisory effort. The upward sloping line represents the supervisor's reaction function  $e_L(\bar{k})$  as a function of the threshold level of capital below which banks choose their laissez-faire portfolios. The point where they intersect is the equilibrium, and implies a strictly positive level of effort,  $e_L^*$ , as well as a threshold level of capital  $\bar{k}_L^*$  strictly less than  $\tilde{k}_L$ , meaning that supervision



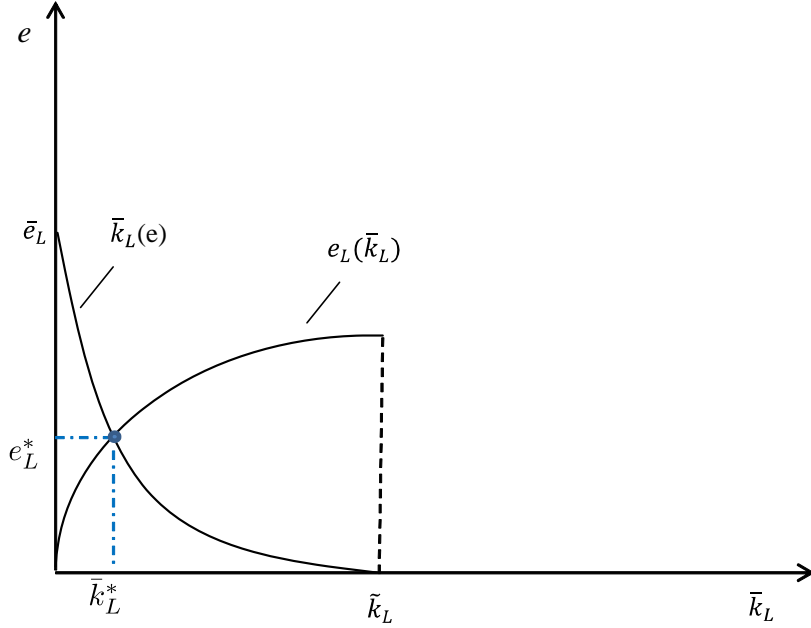


Figure 3: Equilibrium with local supervision. The figure describes the bank’s reaction function  $\bar{k}_L(e)$  and the local supervisor’s reaction function  $e_L(\bar{k}_L)$  as functions of supervisory effort  $e$  and capital threshold  $\bar{k}_L$ , respectively.

leads a strictly positive measure of banks to move away from their most preferred portfolio  $\hat{q}$  and instead adhere to the regulatory standard  $\tilde{q}_L$ .

## 5 The centralization of bank supervision

So far, we have considered the case where there is only a single, local supervisor, and studied the implications of that supervisor’s intervention decision on the bank’s choice of portfolio risk. Here, we introduce a central supervisor who has the power to mandate intervention, but who must rely on the local agency to obtain actionable information before it can intervene.

Consider therefore the following extension to the model. A central supervisor has interest in maintaining a healthy banking sector and minimizing the need for costly intervention, much as the local regulator, but faces somewhat different tradeoffs. In particular, the central supervisor perceives the cost of intervention as  $A_C \neq A_L$  and/or the shadow cost of funds as  $\psi_C \neq \psi_L$ , so that it is more/less willing to intervene than the local regulator. This difference in the perceived costs may represent the central supervisor’s internalization of bank failures on the overall financially integrated area, or may simply reflect that the local supervisor is partially “captured” by local constituents, including banks, while the central supervisor is less likely to

attach much weight to local political economy considerations. Regardless, the implication is that the central supervisor may mandate intervention by the local supervisor in situations where the local supervisor would prefer to forbear and allow the bank to operate unimpeded, or vice versa. The rest of the model remains unchanged.

We can now study the central supervisor's intervention decision. As in Section 4.1, if the local supervisor successfully obtained information about a given bank's portfolio, the central supervisor must decide whether it is optimal to intervene the bank or not. The central supervisor compares intervening, which, if successful, entails the cost  $A_C$  but gives a payoff:

$$\eta \left( -A_C + q_C^* \left( R - \frac{1}{2} c q_C^* - (1-k) \right) - (1-q_C^*) (1-k) \psi_C - k \right) + (1-\eta) \left( q \left( R - \frac{1}{2} c q - (1-k) \right) - (1-q) (1-k) \psi_C - k \right)$$

where:

$$q_C^* = \frac{R + (1-k) (\psi_C - 1)}{c}$$

is the central supervisor's preferred bank portfolio conditional on intervention, and allowing the bank to continue with its initial portfolio choice  $q$  and gives the supervisor a payoff equal to:

$$q \left( R - \frac{1}{2} c q - (1-k) \right) - (1-q) (1-k) \psi_C - k.$$

It is straightforward to see that the comparison is the same as that in (5), only with a different intervention cost  $A_C$  and shadow cost of funds  $\psi_C$ . Therefore, following the analysis in Section 4.1, we can define:

$$I_C(q_C^*, q, k) = \eta \left( -A_C + q_C^* \left( R - \frac{1}{2} c q_C^* - (1-k) \right) - (1-q_C^*) (1-k) \psi_C \right) - \eta \left( q \left( R - \frac{1}{2} c q - (1-k) \right) - (1-q) (1-k) \psi_C \right), \quad (17)$$

and find the optimal intervention threshold for the central supervisor below which intervention will occur as given by

$$\tilde{q}_C(k) = \frac{1}{c} \left( R + (1-k) (\psi_C - 1) - \sqrt{2cA_C} \right). \quad (18)$$

It is worth noting that, as for the case of independent supervision,  $\tilde{q}_C(k)$  represents a subgame perfect solution when the central supervisor cannot precommit to an intervention threshold involving a time inconsistency. If the central supervisor were able to precommit to non-subgame-perfect intervention thresholds, it would have an effect not only on bank behavior, but also on the local regulator's choice of

effort. As in the previous section, throughout the analysis, we assume that the only credible alternative to the subgame perfect strategy is to allow the local regulator to operate fully independently. Later, in an extension we consider the commitment case.

As in the previous section, we require  $\tilde{q}_C(k)$  to be positive at least for some values of  $k$ , for which assuming that  $\psi_C > \sqrt{2cA_C}$  is sufficient.

The relative position of the central,  $\tilde{q}_C(k)$ , and local,  $\tilde{q}_L(k)$ , intervention thresholds (and their slope with respect to  $k$ ) will depend on the relative magnitude of the parameters that determine the cost of intervention and eventual deposit insurance outlays:  $A_C$ ,  $A_L$ ,  $\psi_C$ , and  $\psi_L$ . Any  $\tilde{q}_C \neq \tilde{q}_L$  may entail inefficient information collection by the local regulator, but the nature of the inefficiency may be different depending on whether  $\tilde{q}_C > \tilde{q}_L$  or  $\tilde{q}_C < \tilde{q}_L$ , that is on whether the central supervisor is tougher or more lenient than the local one. Looking at the expressions given in (6) and (18) gives the following immediate result.

**Lemma 5** *(1) Assume that  $\psi_C = \psi_L$ , so that both supervisors face the same shadow cost of funds. Then, the central supervisor is tougher in his intervention policy than the local supervisor if he faces a lower intervention cost, i.e.:  $\tilde{q}_C(k) > \tilde{q}_L(k)$  if  $A_C < A_L$ , and is more lenient otherwise. (2) Assume that  $A_C = A_L$ , so that both supervisors bear the same cost of intervention. Then, the central supervisor is tougher if he faces a higher shadow cost of funds, i.e.,  $\tilde{q}_C(k) > \tilde{q}_L(k)$  if  $\psi_C > \psi_L$ , and is more lenient otherwise.*

Note that the case where  $\psi_C > \psi_L$  implies also that the central supervisor will choose, upon intervention, a higher portfolio quality for the bank than the local supervisor, i.e.,  $q_C^* > q_L^*$ . The intuition is simple. If the central supervisor faces a higher shadow cost of repaying depositors when the bank fails, or internalizes externalities associated with a bank's failure, he will want to prevent bank failure more than the local supervisor and will therefore choose to implement a higher portfolio quality upon intervention.

In what follows, we focus on the case where the central supervisor is tougher and we analyze the implications this has for bank risk taking and supervisory effort in equilibrium.

## 5.1 An unambiguously tougher central supervisor

Assume that the central regulator has a tougher intervention policy,  $\tilde{q}_C(k) > \tilde{q}_L(k)$ , either because of a lower intervention cost  $A_C < A_L$  or because of a higher shadow cost of funds,  $\psi_C > \psi_L$ . We can now turn to the bank's portfolio decision choice and the supervisory effort, which is undertaken by the local supervisor. The analysis follows similar steps to those in the case of the local supervisor.

To see how the threat of regulatory intervention affects banks' choice of portfolio risk, we first find the threshold  $\tilde{k}_C$  at which banks independently would choose a portfolio  $\hat{q}(k)$  which is sufficiently safe not to be intervened:  $\hat{q}(k) = \tilde{q}_C(k)$ . Equating (1) and (18) and solving for  $k$  gives

$$\tilde{k}_C = \left(1 - \frac{1}{\psi_C} \sqrt{2cA_C}\right). \quad (19)$$

Again, we assume that  $\tilde{k}_C > 0$ , which is true if  $\psi_C > \sqrt{2cA_C}$ . Note also that  $\tilde{k}_C > \tilde{k}_L$  if either  $\psi_C > \psi_L$  or  $A_C < A_L$ , meaning that, when the central regulator is tougher, banks are less likely to choose voluntarily a portfolio sufficiently safe to satisfy the supervisor, i.e., that has a quality  $q$  at least equal to the supervisory intervention threshold  $\tilde{q}_C(k)$ .

We can now see how the threat of intervention affects the choice of banks with capital below the threshold  $\tilde{k}_C$ . Following the same analysis as in Section 4.2, we obtain the following.

**Lemma 6** *For a given level of supervisory effort  $e$ , there exists a level of capital  $\bar{k}_C(e)$  such that banks with  $k < \bar{k}_C(e)$  choose the laissez-faire portfolio quality  $\hat{q}(k)$ , while banks with  $k \in [\bar{k}_C(e), \tilde{k}_C]$  switch to a portfolio of quality  $\tilde{q}_C(k) > \hat{q}(k)$ , where*

$$\bar{k}_C(e) = \left(1 - \frac{R\sqrt{e\eta} + \sqrt{2cA_C}}{\psi_C + \sqrt{e\eta}}\right) < \tilde{k}_C. \quad (20)$$

*It follows that  $\frac{\partial \bar{k}_C(e)}{\partial e} < 0$ ,  $\frac{\partial \bar{k}_C(e)}{\partial \psi_C} > 0$  and  $\frac{\partial \bar{k}_C(e)}{\partial A_C} < 0$ .*

**Proof.** The proof follows the same steps as the proof of Lemma 2. A bank with  $k < \tilde{k}_C$  will choose to switch from a portfolio of quality  $\hat{q}$  to one of quality  $\tilde{q}_C(k)$  if it has higher expected profit from doing so. The relevant expressions to compare are (10) using  $\tilde{q}_C(k)$  in place of  $\tilde{q}_L(k)$  and (9). Substituting the expression for  $\tilde{q}_L(k)$  as in (18) into (10) and  $\hat{q}$  as in (1) into (9), setting the difference equal to zero, and solving for  $k$  gives  $\bar{k}_C(e)$  as in (20). Comparing this to  $\tilde{k}_C$  as in (19) gives  $\bar{k}_C(e) < \tilde{k}_C$ . Moreover, it follows easily  $\frac{\partial \bar{k}_C(e)}{\partial e} = -\frac{\psi_C R - \sqrt{2cA_C}}{2\sqrt{e\eta}(\psi_C + \sqrt{e\eta})^2} < 0$ ,  $\frac{\partial \bar{k}_C(e)}{\partial \psi_C} = \frac{R\sqrt{e\eta} + \sqrt{2cA_C}}{(\psi_C + \sqrt{e\eta})^2} > 0$  and  $\frac{\partial \bar{k}_C(e)}{\partial A_C} = -\frac{c}{\sqrt{2cA_C}(\psi_C + \sqrt{e\eta})} < 0$ . The lemma follows.  $\square$   $\blacksquare$

The lemma identifies the banks whose portfolio choice is affected by the threat of intervention when a central supervisor is present. As in Section 4.2, the function  $\bar{k}_C(e)$  can in fact be seen both as an individual bank's reaction function for given supervisory effort  $e$  and as an aggregate reaction function characterizing the proportion of banks with  $k < \bar{k}_C(e)$  that will be intervened if discovered and those with  $k \in [\bar{k}_C(e), \tilde{k}_C]$  whose portfolio choice is affected by supervision.

As before, for the supervisory intervention to be meaningful in the model, we assume that  $\bar{k}_C(e) > 0$ . Setting (20) equal to zero and solving for  $e$ , this means requiring the parameters  $R, \psi_C$  and  $A_C$  are such that in equilibrium the local supervisor will choose an inspection level  $e < \bar{e}_C$ , where

$$\bar{e}_C = \frac{(\psi_C - \sqrt{2cA_C})^2}{\eta(R-1)^2}. \quad (21)$$

Comparing the expressions for  $\bar{k}_C(e)$  and  $\bar{k}_L(e)$  as in (20) and (11), we obtain the following result.

**Lemma 7** *If the central supervisor is tougher than the local supervisor, i.e., if  $A_C < A_L$  for  $\psi_C = \psi_L$ , or if  $\psi_C > \psi_L$  for  $A_C = A_L$ , so that  $\tilde{q}_C(k) > \tilde{q}_L(k)$ , then the bank's reaction function  $\bar{k}_C(e)$  lies above the reaction function under independence:  $\bar{k}_C(e) > \bar{k}_L(e)$  for all  $e$ .*

The lemma establishes that, for a given supervisory effort  $e$ ,  $\bar{k}_C(e) > \bar{k}_L(e)$ , meaning that there will be banks with  $k \in (\bar{k}_L(e), \bar{k}_C(e)]$  that will no longer comply with the minimum supervisory portfolio quality under central supervision and will therefore risk being intervened. Put differently, as standards get tougher, absent increased regulatory effort there will be fewer banks who meet the minimum requirements. This, however, does not mean that there are fewer banks that alter their behavior in response to regulation. Indeed, we also have  $\tilde{k}_C > \tilde{k}_L$ . To examine when the supervisory threat has a greater effect on banks' behavior, we compare  $\tilde{k}_C - \bar{k}_C(e)$  with  $\tilde{k}_L - \bar{k}_L(e)$ , the range of banks who deviate from their preferred portfolios to avoid being intervened under centralization and under local supervision, respectively. Substituting all the relevant expressions, we have

$$\tilde{k}_C - \bar{k}_C(e) = \frac{\sqrt{e\eta}(R\psi_C - \sqrt{2cA_C})}{\psi_C(\psi_C + \sqrt{e\eta})}$$

and

$$\tilde{k}_L - \bar{k}_L(e) = \frac{\sqrt{e\eta}(R\psi_L - \sqrt{2cA_L})}{\psi_L(\psi_L + \sqrt{e\eta})}.$$

For the case where both supervisors have the same shadow cost,  $\psi_C = \psi_L$ , but the central supervisor has a lower cost of intervention,  $A_C < A_L$ , the expressions above show that  $\tilde{k}_C - \bar{k}_C(e) > \tilde{k}_L - \bar{k}_L(e)$ , so that there is a larger range of banks for which the threat of supervisory intervention leads them to adjust their portfolio upward when there is a tougher supervisor. The reason is simple: since the supervisor is more likely to intervene, more banks prefer to adjust their portfolios in order to avoid being caught and intervened.

Given the bank's portfolio choice for a given level of supervisory effort  $e$ , we can now study the local supervisor's effort problem when the central supervisor decides whether to intervene or not, but must rely on

the information collected by the local supervisor in order to act. In the case when he was acting independently, the local supervisor's effort problem was given by (14). Essentially, the intervention decision of the local supervisor,  $\tilde{q}_L$ , partitioned the mass of banks into two regions, and effort was a function of the mass of banks with  $q < \tilde{q}_L$  and the average benefit from intervention in that region,  $E[I_L(q_L^*, q, k)|q < \tilde{q}_L]$ . Here, however, since the two supervisors have different intervention thresholds ( $\tilde{q}_C > \tilde{q}_L$ ), there may be a region where the supervisor's effort is in fact decreasing in the set of banks that are subject to being intervened. This is because, for banks in the  $(\tilde{q}_L, \tilde{q}_C)$  region, the local supervisor is against intervention and intervention can only occur when information is collected.

Moreover, to the extent that the portfolio quality that will be implemented upon intervention,  $q_C^*$ , is different under centralization than that under independence,  $q_L^*$ , the local supervisor's incentives to exert effort will be reduced further.

When the central supervisor is tougher than the local one, banks will be partitioned into three groups. For  $q \geq \tilde{q}_C$ , learning the bank's type  $(q, k)$  brings no benefit to the local supervisor because those banks are not intervened. For  $q < \tilde{q}_L$ , banks are intervened as under independent local supervision. However, if  $q_C^* \neq q_L^*$  the local supervisor's benefits are not the same as before, and are in fact lower since  $q_C^*$  instead of  $q_L^*$  will be implemented. This will imply a loss for the local supervisor relative to the case of independence, implying that even for banks that would otherwise choose  $\hat{q}$  close to  $\tilde{q}_L$ , the local supervisor will incur a loss (recall that  $\hat{q} = \tilde{q}_L$  is the point where the local supervisor is exactly indifferent between intervening and not when intervention calls for choosing the portfolio  $q_L^*$ ). We define the point at which the local supervisor is indifferent between intervention and not under central supervision as  $\tilde{q}(q_C^*)$ , and note that  $\tilde{q}(q_C^*) = \tilde{q}_L$  if  $q_C^* = q_L^*$ . In other words, for  $\tilde{q}(q_C^*) \leq q < \tilde{q}_C$ , learning the bank's type entails a loss equal to  $I_L(q_C^*, q, k) < 0$  for the local regulator. This is because he would rather let these banks continue than intervene them and instead is forced to intervene.

The argument above implies that the local supervisor's problem now becomes

$$\begin{aligned}
\max_e SW_L^C &= \Pr(q > \tilde{q}_C) E[q \left( R - \frac{1}{2}cq - (1-k) \right) - (1-q)(1-k)\psi_L - k | q > \tilde{q}_C] \\
&+ e\eta \Pr(q < \tilde{q}(q_C^*)) E[-A_L + q_C^* \left( R - \frac{1}{2}cq_C^* - (1-k) \right) - (1-q_C^*)(1-k)\psi_L - k | q < \tilde{q}(q_C^*)] \\
&+ e\eta \Pr(\tilde{q}(q_C^*) \leq q < \tilde{q}_C) E[-A_L + q_C^* \left( R - \frac{1}{2}cq_C^* - (1-k) \right) - (1-q_C^*)(1-k)\psi_L - k | \tilde{q}(q_C^*) \leq q < \tilde{q}_C] \\
&(1-e\eta) \Pr(q < \tilde{q}(q_C^*)) E[q \left( R - \frac{1}{2}cq - (1-k) \right) - (1-q)(1-k)\psi_L - k | q < \tilde{q}(q_C^*)] \\
&+ (1-e\eta) \Pr(\tilde{q}(q_C^*) \leq q < \tilde{q}_C) E[q \left( R - \frac{1}{2}cq - (1-e) \right) - (1-q)(1-k)\psi_L - k | \tilde{q}(q_C^*) \leq q < \tilde{q}_C] - \frac{d}{2}e^2.
\end{aligned}$$

This reduces to

$$\begin{aligned}
\max_e SW_L^C &= E[q \left( R - \frac{1}{2}cq - (1-k) \right) - (1-q)(1-k) - k] \\
&+ e\eta \Pr(q < \tilde{q}(q_C^*)) E[I_L(q_C^*, q, k) | q < \tilde{q}(q_C^*)] \\
&+ e\eta \Pr(\tilde{q}(q_C^*) \leq q < \tilde{q}_C) E[I_L(q_C^*, q, k) | \tilde{q}(q_C^*) \leq q < \tilde{q}_C] - \frac{d}{2}e^2.
\end{aligned} \tag{22}$$

Given that  $E[I_L(q_C^*, q, k) | q < \tilde{q}(q_C^*)] < E[I_L(q_C^*, q, k) | q < \tilde{q}(q_C^*)]$  if  $q_C^* \neq q_L^*$  and  $E[I_L(q_C^*, q, k) | \tilde{q}(q_C^*) \leq q < \tilde{q}_C] < 0$ , the expression for  $SW_L^C$  above is smaller than the expression for  $SW_L$  in (14). Analogously to above, we define  $\tilde{k}(q_C^*)$  as the value of  $k$  for which  $\hat{q}(k) = \tilde{q}(q_C^*)$ . Assuming that the banks behave as above, choosing either  $\hat{q}$  or  $\tilde{q}_C$ , we obtain the following.

**Lemma 8** *If the central regulator is tougher than the local regulator, that is if  $A_C < A_L$  for  $\psi_C = \psi_L$ , or if  $\psi_C > \psi_L$  for  $A_C = A_L$  so that  $\tilde{q}_C(k) > \tilde{q}_L(k)$  and  $q_C^* \geq q_L^*$ , the local supervisor's reaction function, as given by*

$$e_C(\bar{k}_C) = \min \left\{ \int_0^{\min(\bar{k}_C, \tilde{k}(q_C^*))} I_L(q_C^*, \hat{q}, k) f(k) dk + \mathbf{1}_{\bar{k}_C > \tilde{k}(q_C^*)} \int_{\tilde{k}(q_C^*)}^{\bar{k}_C} I_L(q_C^*, \hat{q}, k) f(k) dk, \bar{e}_C \right\}, \tag{23}$$

*lies (weakly) below the reaction function under independence:  $e_C(\bar{k}) \leq e_L(\bar{k})$ .*

The lemma characterizes the local supervisor's reaction function under central supervision. As it shows, we can decompose the reaction function as

$$e_C = \left\{ \begin{array}{l} \int_0^{\bar{k}_C} I_L(q_C^*, \hat{q}, k) f(k) dk \text{ for } \bar{k}_C \leq \tilde{k}(q_C^*) \\ \int_0^{\tilde{k}(q_C^*)} I_L(q_C^*, \hat{q}, k) f(k) dk + \int_{\tilde{k}(q_C^*)}^{\bar{k}_C} I_L(q_C^*, \hat{q}, k) f(k) dk \text{ for } \bar{k}_C > \tilde{k}(q_C^*), \end{array} \right\} \tag{24}$$

where  $I_L(q_C^*, \hat{q}, k) f(k) dk > 0$  for  $\bar{k}_C \leq \tilde{k}(q_C^*)$  and  $I_L(q_C^*, \hat{q}, k) < 0$  for  $\bar{k}_C > \tilde{k}(q_C^*)$ . Given that

$$\frac{\partial e_C}{\partial \bar{k}_C} = \left\{ \begin{array}{l} I_L(q_C^*, \hat{q}, \bar{k}_C) f(\bar{k}_C) \text{ for } \bar{k}_C \leq \tilde{k}(q_C^*) \\ I_L(q_C^*, \hat{q}, \bar{k}_C) f(\bar{k}_C) \text{ for } \bar{k}_C > \tilde{k}(q_C^*), \end{array} \right\}, \quad (25)$$

it follows that the reaction function  $e_C(\bar{k}_C)$  is positively sloped for  $\bar{k}_C \leq \tilde{k}(q_C^*)$  and negatively sloped for  $\bar{k}_C > \tilde{k}(q_C^*)$ .

The lemma establishes that, for a given  $\bar{k}_C$ , when supervisory powers are centralized, the local supervisor will be, all things equal, (weakly) less diligent in trying to uncover excessive risk taking on the side of the banks under its jurisdiction. This occurs for the simple reason that once any hard information is uncovered, the central supervisor can use that to intervene if the bank is discovered to have chosen a riskier portfolio than what the supervisor desires. In some of these instances, the local supervisor would prefer not to intervene because it faces a larger intervention cost relative to the benefit it perceives from adjusting the bank's portfolio, but does not have the authority to make this decision. As a consequence, the local supervisor instead chooses to reduce the likelihood that any damning evidence is found, meaning that it reduces its effort relative to what it would find individually optimal to do.

Having characterized the reaction function  $\bar{k}_C(e)$  of the banks and that of the supervisor  $e_C(\bar{k}_C)$ , we can now turn to characterize the equilibrium. For exposition, we distinguish the analysis into two cases: the case where the central regulator has lower intervention cost than the local regulator ( $A_C < A_L$ ) but equal shadow cost ( $\psi_C = \psi_L$ ), and the case where the central regulator has higher shadow cost than the local regulator ( $\psi_C > \psi_L$ ) but it has the same intervention cost ( $A_C = A_L$ ). In both cases the central regulator is tougher in that it intervenes at a higher level of portfolio quality,  $\tilde{q}_C > \tilde{q}_L$ , than the local regulator. However, in the former case  $q_C^* = q_L^*$  so that the supervisory portfolio quality does not vary with centralized supervision, while in the latter  $q_C^* > q_L^*$ . This affects the equilibrium values  $(e_C^*, \bar{k}_C^*)$  differently as we will see below.

In both cases we analyze below, we focus on understanding whether the centralization of supervision leads to higher or lower inspection effort and whether it leads to higher or lower risk in the banking sector. To capture this, we define two measures of the quality of banks' portfolios. The first is the average portfolio quality  $q$  chosen by banks under each regulatory regime  $I$ :

$$Q_I = \int_0^1 \hat{q}(k) f(k) dk + \int_{\bar{k}_I}^{\tilde{k}_I} [\tilde{q}_I(k) - \hat{q}(k)] f(k) dk \text{ for } I = L, C. \quad (26)$$

The second is the average portfolio quality  $q$  expected to prevail after the regulatory intervention:

$$Q_I^* = \int_0^1 \hat{q}(k) f(k) dk + e_I^* \eta \int_0^{\bar{k}_I} [q_I^*(k) - \hat{q}(k)] f(k) dk + \int_{\bar{k}_I}^{\tilde{k}_I} [\tilde{q}_I(k) - \hat{q}(k)] f(k) dk, \text{ for } I = L, C. \quad (27)$$



## 5.2 Lower intervention cost for the central regulator: $A_C < A_L$ and $\psi_C = \psi_L$

We start with the case where  $A_C < A_L$  and  $\psi_C = \psi_L$ , so that the central supervisor has a lower intervention threshold and thus is tougher, but since she has the same shadow cost of funds she chooses the same portfolio conditional on intervention as the local supervisor. Using the notation from the model, this means  $\tilde{q}_C > \tilde{q}_L$  but  $q_C^* = q_L^*$ . It follows from Lemmas 7 and 8 that the local supervisor's reaction function under centralization coincides with the one under local supervision (15) for  $\bar{k}_C \leq \tilde{k}_L$ , while the bank's reaction function  $\bar{k}_C(e)$  under centralization remains strictly above the one under local supervision,  $\bar{k}_L(e)$ .

We can now turn to analyze the equilibrium levels of the supervisory effort and banks' choice of portfolio risk, as well as the equilibrium risk level of the banking sector's portfolio. In what follows we restrict our attention the case where bank capital is uniformly distributed between 0 and 1, i.e.,  $k \sim U[0, 1]$ . We have the following result.

**Proposition 9** *Suppose that  $\psi_C = \psi_L$ . There is a value  $\delta > 0$  such that, for  $0 < A_L - A_C < \delta$ , the local supervisor exerts more effort under centralization than when independent,  $e_C^* > e_L^*$ , and banks' average portfolio quality is higher:  $Q_C^* > Q_L^*$  and  $Q_C > Q_L$ .*

**Proof.** Since  $\psi_C = \psi_L$ , at  $A_L = A_C$  we have  $e_C^* = e_L^*$ . Also, since at  $e_L^*$  the regulator's reaction function is upward sloping and  $\frac{\partial \bar{k}_C}{\partial A_C} < 0$ , we have that  $\frac{\partial e_C^*}{\partial A_C} < 0$ . By continuity, there exists a  $\delta > 0$  such that for all  $A_C \in (A_L - \delta, A_L)$ ,  $e_C^* > e_L^*$ .

Now turn to banks' portfolio quality. From the discussion following Lemma 7 we know that for constant effort  $\tilde{k}_C - \bar{k}_C(e) > \tilde{k}_L - \bar{k}_L(e)$ , which in turn implies that  $Q_C > Q_L$  and  $Q_C^* > Q_L^*$ . The latter is a fortiori true here since  $e_C^* > e_L^*$ , which increases the weight of the second term in the definition of  $Q_I^*$  (equation 27).

□ ■

The proposition establishes that when the conflict between the local and the central supervisor is relatively small, meaning that their respective costs of intervention are not very different, centralizing bank supervision leads to an increase in the effort exerted by the local supervisor in detecting banks' portfolio choices, and consequently also leads to safer portfolios. The reason is simply that the tighter standards of the central supervisor induce banks to choose safer portfolios to avoid being intervened. The local supervisor, while not always fully in agreement with the central supervisor, exerts more effort in order to try to catch the banks

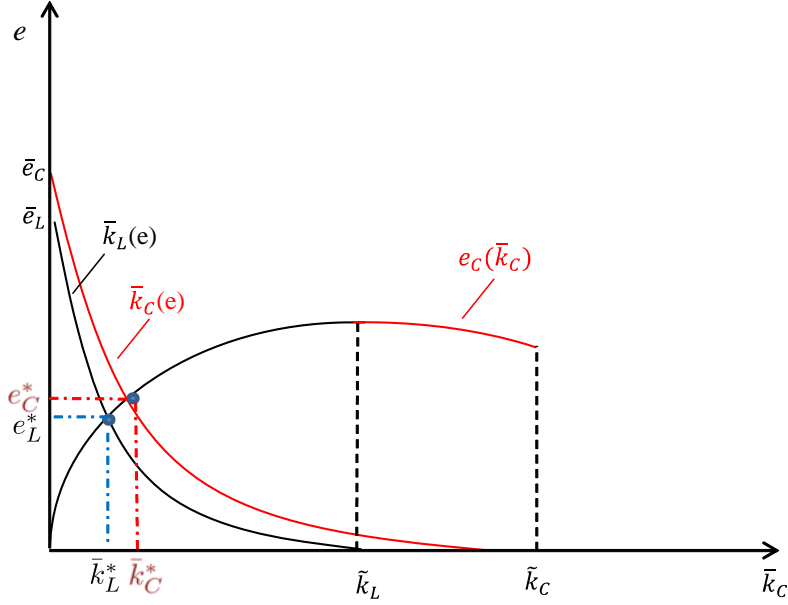


Figure 4: Equilibrium with central supervision in the case of a tougher central regulator. The figure describes the bank's reaction function  $\bar{k}_C(e)$  and the local supervisor's reaction function  $e_C(\bar{k}_C)$  as a function of supervisory effort  $e$  and bank capital threshold  $\bar{k}_C$ , respectively.

that would have behaved in the absence of a central supervisor, but now find it too onerous to do so given the tougher standard.

However, centralization of supervision creates an agency problem vis á vis the local supervisor who must collect actionable information about the banks' operations. As the following result shows, this may lead to less diligence on the part of the local supervisor when the conflict with the central supervisor is sufficiently large. To show this, again we restrict our attention to the case where bank capital is uniformly distributed, i.e.,  $k \sim U[0, 1]$ . In this case, the reaction function of the supervisor can be expressed as

$$e_I(\bar{k}) = \left( \frac{(2\psi_L - \psi_C)\psi_C}{2c} \left( \bar{k} - \bar{k}^2 + \frac{\bar{k}^3}{3} \right) - \bar{k} \cdot A_L \right) \frac{\eta}{d}. \quad (28)$$

The reaction function of the banks can also be written explicitly as

$$\bar{k}_I(e) = 1 - \frac{(R\sqrt{e\eta} + \sqrt{2cA_I})}{(\psi_I + \sqrt{e\eta})} \quad (29)$$

for  $I = L, C$ . We have the following result.

**Proposition 10** *Suppose that  $\psi_C = \psi_L$  and  $A_C \leq \frac{1}{8c} \left( \sqrt{3(8cA_L - \psi_L^2)} - \psi_L \right)^2$ . Then, there exists an equilibrium under centralization which entails a supervisory effort  $e_C^* = 0$  and lower bank portfolio quality:*

$$Q_C^* < Q_L^* \text{ and } Q_C < Q_L.$$

**Proof.** Setting (28) equal to zero and solving for  $\bar{k}$ , and taking the smallest root which gives a positive value for  $\bar{k}$  gives

$$\bar{k}_0 = \frac{1}{(2\psi_L - \psi_C)\psi_C} \left( (3\psi_L - \psi_C)\psi_C - \frac{1}{2}\psi_C^2 - \frac{1}{2}\sqrt{3}\sqrt{(2\psi_L - \psi_C)\psi_C(8cA_L - \psi_C(2\psi_L - \psi_C))} \right).$$

When  $\psi_C = \psi_L$  this simplifies to

$$\bar{k}_0 = \frac{3}{2} - \frac{1}{2\psi_L}\sqrt{3(8cA_L - \psi_L^2)}.$$

We then compare  $\bar{k}_0$  and  $\tilde{k}_C$  as given by (19). We have that  $\bar{k}_0 \leq \tilde{k}_C$  if

$$\frac{1}{2} - \frac{1}{2\psi_L}\sqrt{3(8cA_L - \psi_L^2)} \leq -\frac{1}{\psi_L}\sqrt{2cA_C}$$

or, equivalently, if

$$A_C \leq \frac{1}{8c} \left( \sqrt{3(8cA_L - \psi_L^2)} - \psi_L \right)^2. \quad (30)$$

When (30) is satisfied, the regulator's reaction function is positive for  $\bar{k} < \bar{k}_0 < \tilde{k}_C$  and zero for  $\bar{k}_0 \leq \bar{k} \leq \tilde{k}_C$ . This, together with the fact that the bank's reaction function  $\bar{k}_C(e)$  crosses the  $e = 0$  axis at  $\tilde{k}_C$ , implies that an equilibrium with  $(e_C^*, \bar{k}_C) = (0, \tilde{k}_C)$  exists.

When  $e_C^* = 0$ , the central supervisor never intervenes and thus banks always choose their preferred portfolio quality  $\hat{q}$ . From the comparison of the expressions for  $Q_I$  and  $Q_I^*$  for  $e_L^* > 0$  and  $e_C^* = 0$  given in (26) and (27), it follows  $Q_C^* < Q_L^*$  and  $Q_C < Q_L$  for  $e_C^* = 0$ .  $\square$   $\blacksquare$

The intuition for the last result is that, when the divergence between the objectives of the central and the local supervisors is sufficiently large, the local supervisor's incentives to exert effort are sufficiently muted that an equilibrium with zero information collection emerges. This is one of the multiple equilibrium of the model as long as the reaction function of the banks and that of the regulator intersect before the tangency point. Beyond that point, the  $e_C^* = 0$  equilibrium is the only surviving.

Notably, the parameter space for which this equilibrium exists increases in  $A_L$  and decreases with  $\psi_L$ , that is it is unequivocally broader for laxer local regulators. Intuitively, these are exactly the regulators for whom the agency problem vis a vis the central regulator is the greatest.

When there are multiple equilibria, there is at least another equilibrium with positive effort. This level of effort can be greater than the effort level under local supervision, but it may also be lower if the bank's reaction function intersects the regulator's reaction function in the downward sloping section. Moreover, the different equilibria cannot be Pareto-ranked since both the local and the central supervisor prefer the

equilibrium with positive effort, whereas the banks always prefer the equilibrium with no effort,  $e = 0$ , and thus no chance of being intervened.

### 5.2.1 Numerical simulations

Propositions 9 and 10 show that the centralization of supervision may lead to less information being collected in equilibrium if the conflict between the supervisors is sufficiently big. This results in a weaker intervention threat for banks since it is less likely that actionable information will be obtained. The consequence is that, despite the tougher regulatory standards, the equilibrium with central supervision may be worse than the equilibrium with local supervision both in terms of social welfare and in terms of banks' overall portfolio quality.

We show this with the help of a numerical example. We start by showing that there is a value of  $A_C$  such that there is an equilibrium with  $e_C^* = e_L^*$  and both  $Q_C^* > Q_L^*$  and  $Q_C > Q_L$ . Then, we show that by decreasing  $A_C$  further, it is possible to have an equilibrium under centralization with a positive but lower supervisory effort than under local supervision and greater risk:  $e_C^* < e_L^*$ ,  $Q_C^* < Q_L^*$  and  $Q_C < Q_L$ .

For this example, we assume the following values:  $R = 2.5$ ,  $c = 3$ ,  $d = 0.04$  and  $\eta = 0.2$ . Moreover, we set the intervention cost and the social cost of bank failure in the case of local supervision equal to  $A_L = 0.25$  and  $\psi_L = 1.5$ . This set of parameters ensures that the portfolio quality  $q_L^*$  chosen by the regulator upon intervention given in (4) is an interior solution for all values of bank capital  $k \in [0, 1]$ . It follows that the intervention quality  $\tilde{q}_L$  and banks' laissez-faire quality  $\hat{q}$  given, respectively, in (6) and (1) are interior solutions as well.

For this set of parameters, the equilibrium under local supervision entails a level of supervisory effort  $e_L^* = 0.04085$ . This intervention threat induces banks with capital  $k$  between  $\bar{k}_L^* = 0.08782$  and  $\tilde{k}_L = 0.18350$  to choose the intervention threshold  $\tilde{q}_L$ , while banks with  $k < \bar{k}_L^*$  and with  $k > \tilde{k}_L$  choose the laissez-faire quality  $\hat{q}$ . The average portfolio quality chosen by banks defined in (26) is  $Q_L = 0.00229$ , the one prevailing after the regulatory intervention defined in (27) equals  $Q_L^* = 0.00263$ .

We now consider the case of central supervision. For this, we set  $\psi_C = \psi_L = 1.5$ , while we reduce the intervention cost of the central regulator to  $A_C = 0.13929$ .

Figure : Equilibrium with positive equilibrium effort under local and central supervision for  $A_C = 0.13929 < A_L = 0.25$ .

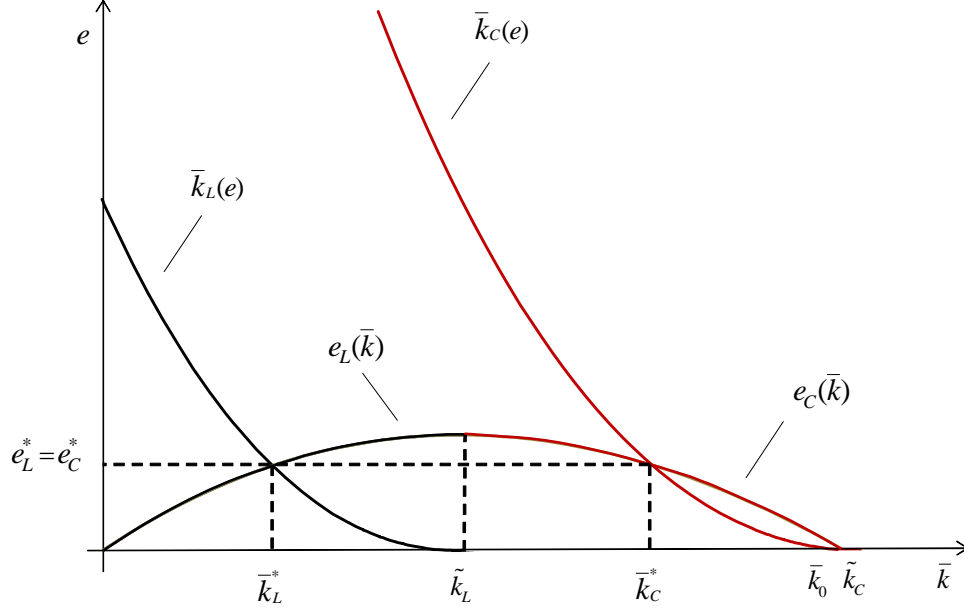


Figure 5:

Figure 5.2.1 illustrates the case under centralization and compares it with the equilibrium under local supervision. As it can be seen, a lower  $A_C$  modifies both the banks' reaction function and supervisor's reaction function relative to the case with local supervision. The former shifts up to the right; the latter coincides with the one with local supervision for  $k < \tilde{k}_L$  and it becomes downward sloping beyond that point.

There exist two equilibria under centralization. One entails the same level of effort as with local supervision,  $e_C^* = e_L^* = 0.04085$  but  $\bar{k}_C^* = 0.28308 > \bar{k}_L^*$ ; the other features  $e = 0$  and  $\bar{k}_C^* = \tilde{k}_C$ . In the equilibrium with positive effort, the average bank portfolio quality is given by  $Q_C = 0.00289 > Q_L$  and  $Q_C^* = 0.00388 > Q_L^*$ . Centralization reduces the risk of the banking sector relative to the case with local supervision because the high regulatory standards  $\tilde{q}_C > \tilde{q}_L$  induces more banks to comply with regulation, that is  $\tilde{k}_C - \bar{k}_C^* > \tilde{k}_L - \bar{k}_L^*$  in the case  $\psi_C = \psi_L$ .

The second equilibrium under centralization features  $e_C^* = 0$  and  $\bar{k}_C^* = \tilde{k}_C$ . As stated in Proposition 10, in this case the average quality of banks' portfolio is lower than under local supervision, both before and after taking regulatory intervention.

We now turn to another example to show that centralization can lead to an equilibrium with a positive supervisory effort which is lower than under local supervision, and with a higher level of risk in terms of

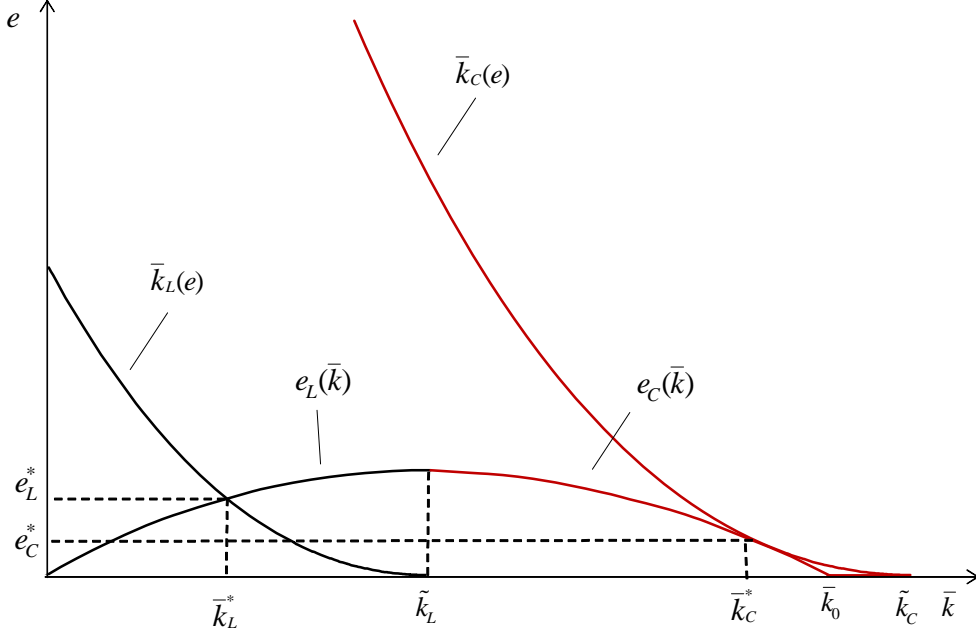


Figure 6:

banks' average quality. For this example, we reduce the intervention cost of the central supervisor further to  $A_C = 0.12637$ , while keeping all other parameters as before.

Figure : Equilibrium with positive regulatory effort under local and central supervision for  $A_C = 0.12637 < A_L = 0.25$ .

As illustrated in Figure 5, the new lower value for  $A_C$  increases  $\tilde{k}_C$  further, pushing further up to the right the reaction function of banks and down to the left the reaction function of the central regulator. The case with central supervision has now three equilibria, two with positive supervisory effort and one with no supervisory effort. In all equilibrium, the supervisor exerts a lower effort than the case where he acts independently. The equilibrium under central supervision with the highest effort features  $e_C^* = 0.01514 < e_L^*$  and  $\bar{k}_C^* = 0.35158 > \bar{k}_L^*$ . The corresponding average portfolio quality equals  $Q_C = 0.00115 < Q_L$  and  $Q_C^* = 0.00159 < Q_L^*$ . This shows that when the conflict between the two supervisors as represented by the difference  $A_L - A_C$  is strong enough, the solution under centralized supervision is worse than under independence in terms of supervisory effort and risk of the banking system.

### 5.3 Higher cost of bank failure for the central regulator: $A_C = A_L$ and $\psi_C > \psi_L$

We now investigate the case where the central supervisor faces the same intervention cost as the local supervisor  $A_C = A_L$ , but faces a higher cost in case of bank failure  $\psi_C > \psi_L$ . This implies again  $\tilde{q}_C > \tilde{q}_L$ , but also that  $q_C^* > q_L^*$  so that the supervisor is now tougher in terms of both having a higher intervention threshold and adopting a higher standard conditional on intervention. It follows from Lemma 7 that the local supervisor's reaction function under centralization lies strictly below the one under local supervision (15) for  $\bar{k}_C \leq \tilde{k}_L$  because  $I_L(q_C^*, \hat{q}, k) < I_C(q_L^*, \hat{q}, k)$  for any  $\bar{k}_C \leq \tilde{k}_L$ . Also from Lemma 7, the bank's reaction function  $\bar{k}_C(e)$  under centralization remains strictly above the one under local supervision  $\bar{k}_L(e)$ .

**Lemma 11** *When  $A_C = A_L$  and  $\psi_C > \psi_L$ , the local supervisor's reaction function under centralization is strictly below the reaction function under independence:  $e_C(\bar{k}) < e_L(\bar{k})$  for all  $\bar{k} < \tilde{k}_C$ .*

**Proof.** Recall that the reaction function under centralization is given by

$$e_C(\bar{k}_C) = \min \left\{ \int_0^{\min(\bar{k}_C, \tilde{k}(q_C^*))} I_L(q_C^*, \hat{q}, k) f(k) dk + \mathbf{1}_{\bar{k}_C > \tilde{k}(q_C^*)} \int_{\tilde{k}(q_C^*)}^{\bar{k}_C} I_L(q_C^*, \hat{q}, k) f(k) dk, \bar{e}_C \right\},$$

where  $\tilde{k}(q_C^*) \leq \tilde{k}_L$ . Given that  $E[I_L(q_C^*, \hat{q}, k) | \hat{q} < \tilde{q}(q_C^*)] < E[I_L(q_L^*, \hat{q}, k) | \hat{q} < \tilde{q}(q_C^*)]$  if  $q_C^* \neq q_L^*$ , this establishes that  $e_C(\bar{k}) < e_L(\bar{k})$  for  $\bar{k} < \tilde{k}(q_C^*) < \tilde{k}_L$ . For  $\bar{k} > \tilde{k}(q_C^*)$ , we have that  $E[I_L(q_C^*, \hat{q}, k) | \tilde{q}(q_C^*) \leq \hat{q} < \tilde{q}_C] < 0$ , so the result trivially follows also for  $\bar{k} > \tilde{k}(q_C^*)$ .  $\square$   $\blacksquare$

The lemma, which is a special case of Lemma 8, establishes that when the central supervisor is tougher because he internalizes a higher cost of bank failure, the local supervisor will react by, *ceteris paribus*, exerting less effort. The reason is simply that the difference in the failure costs translates into a difference in the portfolios that each supervisor would like to see implemented conditional on intervention,  $q_C^*$  and  $q_L^*$ , so that even in cases where the local supervisor would like to intervene (because the bank has chosen an excessively risky portfolio), he does not get to implement his preferred portfolio. This conflict between the two supervisors reduces the incentives of the local supervisor to exert effort at identifying high-risk banks.

Figure 7 illustrates the result from Lemma 11. The red curve labeled  $e_C$  represents the local supervisor's reaction function for effort when the central supervisor has a higher shadow cost of funds. In particular,  $e_C$  is strictly below  $e_L$  for all levels of the capital threshold  $\bar{k}$ , reflecting that, *ceteris paribus*, the local supervisor prefers to put in less effort than he would under independence. The curve labeled  $\bar{k}_C$ , however, represents the banks' reaction to the tougher standards, and is shifted out relative to the case of an independent local supervisor, much as in Section 5.2. Now, however, the implications of having a tougher central supervisor

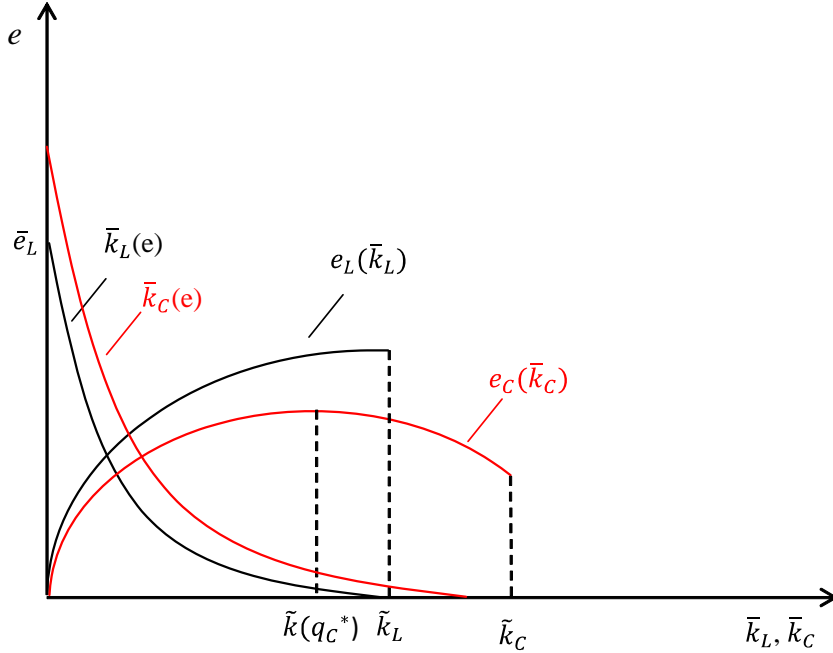


Figure 7: Equilibrium with central supervision when supervisors have different shadow costs of funds. The figure describes the bank's reaction function  $\bar{k}_C(e)$  and the local supervisor's reaction function  $e_C(\bar{k}_C)$  as a function of supervisory effort  $e$  and bank capital threshold  $\bar{k}_C$ , respectively.

are more ambiguous: while banks respond by themselves adopting higher quality portfolios for a given level of effort, the supervisor responds by exerting less effort. In principle, this can lead to either more or less effort being exerted in equilibrium.

To see when centralization of supervision entails lower effort in the case with different costs of bank failures, we first note that the condition for the equilibrium with zero supervisory effort in Proposition 10 is still valid in that there still exists an equilibrium under centralization with  $e_C^* = 0$  in the case where  $\psi_C > \psi_L$  if  $A_C \leq \frac{1}{8c} \left( \sqrt{3(8cA_L - \psi_L^2)} - \psi_L \right)^2$ . The reason is simply that the assumption  $\psi_C > \psi_L$  shifts further out the banks' reaction function, while shifting further down the regulator's reaction function. This implies that the condition  $A_C \leq \frac{1}{8c} \left( \sqrt{3(8cA_L - \psi_L^2)} - \psi_L \right)^2$  is sufficient to have  $e_C^* = 0$  also in the case when  $\psi_C > \psi_L$ .

### 5.3.1 Numerical Simulations

We now turn to analyze with the help of some numerical examples whether in the case when  $A_C = A_L$  and  $\psi_C > \psi_L$ , under centralization there still exist equilibria with positive but lower-than-under-independence supervisory effort. Similarly to before, we first show that there is a value of  $\psi_C$  such that there is an



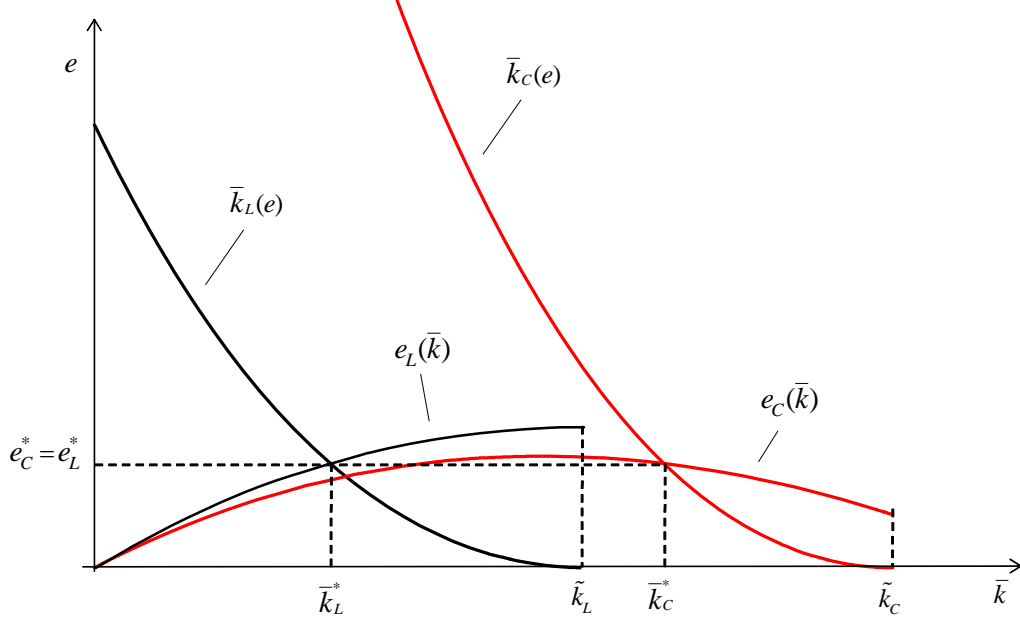


Figure 8:

equilibrium with  $e_C^* = e_L^*$ . Then we show that by increasing  $\psi_C$  further a (unique) equilibrium with lower effort and greater risk emerges:  $e_C^* < e_L^*$ ,  $Q_C^* < Q_L^*$  and  $Q_C < Q_L$ .

For this example, we slightly modify the parameters we used in the previous section. In particular, we maintain  $R = 2.5, c = 3, d = 0.04$  and  $\eta = 0.2$ , while we now set  $A_L = 0.13$  and  $\psi_L = 1.15$ . This set of parameters ensures again that all portfolio qualities described in (4), (6) and (1) are interior solutions for all  $k \in [0, 1]$ .

For this set of parameters, the equilibrium under local supervision entails a level of supervisory effort  $e_L^* = 0.03716$  and banks with  $k > \bar{k}_L^* = 0.11124$  choose a portfolio quality at least equal to  $q_L$  to avoid being intervened. The average portfolio quality chosen by banks defined in (26) is  $Q_L = 0.00280$ , and the one prevailing after the regulatory intervention defined in (27) equals  $Q_L^* = 0.00309$ .

We now consider the case of central supervision and we set  $A_C = A_L = 0.13$  and increase the social cost of bank failures to  $\psi_C = 1.41536 > \psi_L = 1.15$ .

Figure : Equilibrium with local and central supervision with positive and equal regulatory inspection effort for  $\psi_C = 1.41536$

Figure 5.3.1 shows the new equilibrium under centralization and compares it with the equilibrium under local supervision. As it can be seen easily, this parameter set gives a unique equilibrium with the same

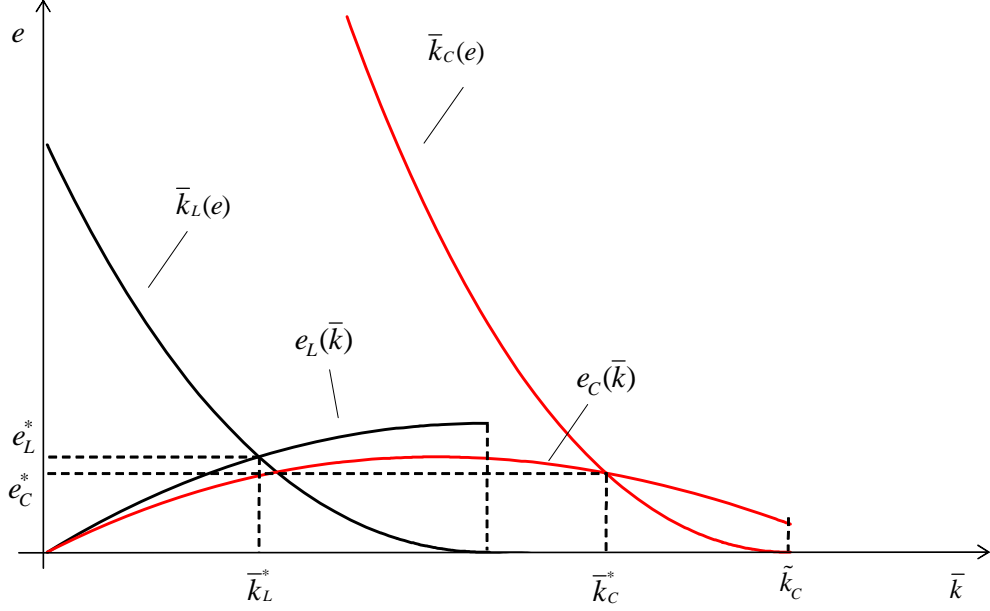


Figure 9:

regulatory effort as under independence,  $e_C^* = e_L^* = 0.03716$ , and  $\bar{k}_C^* = 0.26830 > \bar{k}_L^*$ . Similarly to the cases analyzed in the previous subsections, the equilibrium lies in downward sloping part of the regulator's reaction function, but it is now the only equilibrium as the regulator's reaction function remains positive for all  $k \in [0, \tilde{k}_C]$ . In terms of risk, banks are of slightly lower quality on average than under centralization with  $Q_C = 0.00274 < Q_L$  but of higher quality after the regulatory intervention with  $Q_C^* = 0.00355 > Q_L^*$  thanks to the stricter standards  $q_C^* > q_L^*$  that the regulator implements upon intervention.

As  $\psi_C$  is further increased to 1.45, there is still a unique equilibrium but now with lower supervisory effort and higher bank risk. This is illustrated in Figure 5.3.1 where again the regulator's reaction function remains positive for all values of  $k \in [0, \tilde{k}_C]$ , and the equilibrium with  $e_C^* = 0.03081 < e_L^*$ ,  $\bar{k}_C^* = 0.29380 > \bar{k}_L^*$ ,  $Q_C = 0.00228 < Q_L$  and  $Q_C^* = 0.00302 < Q_L^*$ .

Figure : Equilibrium with local and central supervision with positive regulatory inspection effort for  $\psi_C = 1.45 > \psi_L =$

## 6 Conclusion

This paper develops a simple model to analyze supervisory incentives and bank behavior in a stylized hub-and-spokes regulatory framework. In the model, levered banks protected by limited liability invest in

portfolios that are too risky from a social welfare perspective. Local supervisors are tasked with the day to day job of monitoring banks and identifying which have risky portfolios and are poorly capitalized, but the regulatory actions associated with identifying such banks are under the control of a central supervisor who may have different objectives.

We first show that the threat of regulatory intervention provides discipline against moral hazard by causing some banks to adjust their investment decisions and choose safer portfolios than they would otherwise. That said, in equilibrium, there will be banks (the least capitalized ones) for which moral hazard is stronger than regulatory discipline. These will not comply with regulatory standards and will instead stick with their preferred portfolios; even at the risk of being intervened and losing the returns from their investments.

In our stylized hub-and-spokes framework, the local regulator's incentives to collect information decrease relative to when she operates under full independence. The reason is that, the information she collects might be used by the center to take actions that she dislikes. This agency conflict can lead to less information being collected and, as a result, worse quality portfolios on aggregate despite the higher regulatory standards.

Our analysis has bearing on the current debate and implementation of the Single Supervisory Mechanism (SSM) in the eurozone, where bank supervision is being centralized but local supervisors still represent - and will likely do so for some time - the "boots on the ground," being the parties that actually have greater contact with local financial institutions and are thus in the best position to evaluate banks' portfolios. Our analysis shows that centralization is likely to raise supervisory standards and deal with the perceived laxness and unwillingness to intervene that preceded the recent crisis.

However, it also highlights the governance challenges inherent in a hub-and-spoke supervisory framework. To the extent that the parties in charge of information collection and implementation continue to have different objectives, absent corrective mechanisms, the tougher standards may in fact lead to even greater risk taking and consequently an increased chance of systemic problems. Further, the agency problems at the source of this issue are the larger the laxer the local regulator. Hence, the problem may be the most severe exactly for those cases that could in principle benefit the most from centralized supervision. The design of the SSM implicitly takes into account these risks. First, the SSM retains the right to take any bank in the eurozone under direct supervision. In our model, this would act as a threat to the local regulator and increase its payoff from exerting effort. Second, the new design entails that all locally systemic banks will be under direct SSM supervision. This will likely minimize the difference between the local and central

supervisor utility functions. Indeed, banks that are locally systemic but not systemic for the eurozone as a whole are those for which views are most likely to differ. The fact that all euro level systemic banks will also be under direct supervision has a similar effect, since these are the banks for which the externality from failure is likely to be valued differently by local and central supervisors. Third, internal governance practices such as having SSM employees heading on-site inspection teams and rotating staff of different nationality on these teams will contribute to limit conflicts.

## Appendix

Proof of Lemma 8: Differentiating (22) with respect to  $e$  and recalling we have restricted  $e$  to be less than  $\bar{e}_C$  as given in (21) gives

$$e_C(\bar{k}_C) = \min\{\Pr(\hat{q} < \tilde{q}(q_C^*)) E[I_L(q_C^*, \hat{q}, k) | \hat{q} < \tilde{q}(q_C^*)] + \Pr(\tilde{q}(q_C^*) \leq \hat{q} < \tilde{q}_C) E[I_L(q_C^*, \hat{q}, k) | \tilde{q}(q_C^*) \leq \hat{q} < \tilde{q}_C], \bar{e}_C\}.$$

This differs from (16) in two respects. First, if  $q_C^* > q_L^*$ , as is the case if  $\psi_C > \psi_L$ , then  $E[I_L(q_C^*, \hat{q}, k) | \hat{q} < \tilde{q}(q_C^*)] < E[I_L(q_L^*, \hat{q}, k) | \hat{q} < \tilde{q}(q_C^*)]$ . Second,  $E[I_L(q_C^*, \hat{q}, k) | \tilde{q}(q_C^*) \leq \hat{q} < \tilde{q}_C] < 0$ , meaning that relative to (16) there is now an extra negative term in the supervisor's equation for effort choice. This implies that the reaction function  $e_C(\bar{k}_C)$  lies weakly below  $e_L(\bar{k}_L)$ .

To characterize  $e_C(\bar{k}_C)$ , recall first that under laissez-faire banks choose  $\hat{q} < \tilde{q}_L$  if  $k < \tilde{k}_L$  and that under centralization they choose  $\hat{q} < \tilde{q}_C$  if  $k < \bar{k}_C$ , with  $\tilde{q}_C > \tilde{q}_L$ . We can then distinguish the case where  $\bar{k}_C < \tilde{k}_L$  and the case where  $\bar{k}_C > \tilde{k}_L$ . The same argument applies here replacing  $\tilde{k}_L$  and  $\tilde{q}_L$  with  $\tilde{k}(q_C^*)$  and  $\tilde{q}(q_C^*)$ , respectively. In the first case,

$$\Pr(\hat{q} < \tilde{q}_L) E[I_L(q_C^*, \hat{q}, k) | \hat{q} < \tilde{q}_L] = F(\bar{k}_C) \frac{1}{F(\bar{k}_C)} \int_0^{\bar{k}_C} I_L(q_C^*, \hat{q}, k) f(k) dk = \int_0^{\bar{k}_C} I_L(q_C^*, \hat{q}, k) f(k) dk$$

and  $\Pr(\tilde{q}_L \leq q < \tilde{q}_C) E[I_L(q_C^*, \hat{q}, k) | \tilde{q}_L \leq \hat{q} < \tilde{q}_C] = 0$ . In the second case, when  $\bar{k}_C > \tilde{k}_L$ ,

$$\Pr(\hat{q} < \tilde{q}(q_C^*)) E[I_L(q_C^*, \hat{q}, k) | \hat{q} < \tilde{q}(q_C^*)] = F(\tilde{k}(q_C^*)) \frac{1}{F(\tilde{k}(q_C^*))} \int_0^{\tilde{k}(q_C^*)} I_L(q_C^*, \hat{q}, k) f(k) dk = \int_0^{\tilde{k}(q_C^*)} I_L(q_C^*, \hat{q}, k) f(k) dk$$

and

$$\begin{aligned} \Pr(\tilde{q}(q_C^*) \leq q < \tilde{q}_C) E[I_L(q_C^*, \hat{q}, k) | \tilde{q}(q_C^*) \leq q < \tilde{q}_C] &= \left[ F(\bar{k}_C) - F(\tilde{k}(q_C^*)) \right] \frac{1}{F(\bar{k}_C) - F(\tilde{k}(q_C^*))} \int_{\tilde{k}(q_C^*)}^{\bar{k}_C} I_L(q_C^*, \hat{q}, k) f(k) dk \\ &= \int_{\tilde{k}(q_C^*)}^{\bar{k}_C} I_L(q_C^*, \hat{q}, k) f(k) dk. \end{aligned}$$

The lemma follows.

Proof of Proposition 9: From Proposition 4, we know that there is a unique equilibrium  $(e_L^*, \bar{k}_L^*)$  for the case where there is only a local supervisor. This equilibrium is interior, i.e.,  $e_L^* < \bar{e}_L$  and  $\bar{k}_L^* < \tilde{k}_L$ , with both  $e_L^*$  and  $\bar{k}_L^*$  being strictly positive. This equilibrium also holds for the case of a central supervisor if  $\psi_C = \psi_L$  and  $A_C = A_L$ , so that the central and the local supervisors share the same objectives and there is no conflict between. Moreover, for  $A_C < A_L$  and  $\psi_C = \psi_L$ ,  $e_C(\bar{k}) = e_L(\bar{k})$  for  $\bar{k} \leq \tilde{k}_L$ , as implied in Lemma 7.

Now consider the case where  $A_C = A_L - \epsilon$ . From Lemma 7 we know that the banks' reaction function will lie above the one for the case of independence, with  $\bar{k}_C(e) \rightarrow \bar{k}_L(e)$  as  $\epsilon \rightarrow 0$ . Therefore, for  $\epsilon$  small the equilibrium point - where  $\bar{k}_C(e)$  intersects  $e_C(\bar{k})$  - can be arbitrarily close to the solution under independence, but with a strictly higher level of effort.

The result that average portfolio quality improves follows: with higher equilibrium effort and an increase in the supervisory standard,  $\tilde{q}_C(k) > \tilde{q}_L(k)$ , along with an increase in the set of banks whose behavior is affected by the tougher standards, i.e.,  $\tilde{k}_C - \bar{k}_C(e) > \tilde{k}_L - \bar{k}_L(e)$  when  $A_C < A_L$  and  $\psi_C = \psi_L$ , we have  $\tilde{q}_C(\tilde{k}_L) - \bar{k}_C(e_C^*) > \tilde{q}_L(\tilde{k}_L) - \bar{k}_L(e_L^*)$ , which implies that  $\int_0^1 q_C(k) f(k) dk > \int_0^1 q_L(k) f(k) dk$  for  $f(k) = 1$ , as desired.

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