Centre for
Economic and
Business Research

CEBR

Discussion Paper 2007-01

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June 2006

Abstract

We study the optimal regulation of banking groups ("banks"), taking both minimum capital requirements and legal structure into account. A bank can set up either as one legal unit facing limited liability jointly (branch structure) or as a bank holding company with subsidiaries (subsidiary structure). Banks are exposed to risk from their unobservable asset choices and to exogenous risk from their environment. We show that banks with branches are more prudent in normal times than banks with subsidiaries, but are also less prudent when problems arise. A regulator that observes banks' exogenous risk should optimally determine both capital requirements and legal structure. If the exogenous risk is private information to banks, it can be optimal to screen banks according to risk by setting capital requirements appropriately, and letting banks choose their legal structure.

JEL Classifications: G21; G28; L51.

Keywords: banking groups; capital requirements; legal structure.

*An earlier version of this paper was included in Harr's Ph.D. thesis (University of Copenhagen). We thank Thomas Barnebeck Andersen, Elena Carletti, Xavier Freixas, Henrik Jensen, Robert Marquez, Birgitte Sloth, Lucy White and seminar participants at EARIE 2005, NORIO V, CEPR/ECB Conference on Competition, Stability and Integration in European Banking, LEFIC conference: Issues in implementation, regulation and supervision, Stockholm School of Economics (SITE), University of Copenhagen, University of Helsinki for valuable comments.

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1 Introduction

During the last 20 years European and US banking has gone through a period of consolidation. In Europe, the main bulk of the M&A activity has been domestic (Berglöf et al., 2000; ECB, 2000). In the US, the consolidation process has been within states but also across states, due to the Riegle-Neal Act in 1994 that lifted the ban on interstate M&As. On both continents the M&A activity has led to the emergence of either "big banks" with a series of branches, or bank holding companies with subsidiaries.

Alongside the consolidation process, the regulation of banking groups has received increased attention. Several new issues arise here compared to "standalone" banks. Among the regulatory concerns are that capital requirements could be boosted artificially through stock purchase loans among members of the group; bad loans could be shifted around to avoid attention from regulators; and risks could "spill over" from one member to another (BIS, 2003).

In spite of many open questions of great practical importance, the academic literature has only recently started to study the regulation of banking groups. Furthermore, it has mainly looked at multinational banking groups and problems related to the division of supervisory powers (Calzolari and Loranth, 2004; Holthausen and Rønde, 2004; Repullo, 2001). In this paper we take a different approach and study regulation from the point of view of a single, benevolent regulator. This allows us to focus on a problem intrinsic to banking groups, namely risk spillovers. The analysis applies therefore directly to national banking groups, but also constitutes a natural benchmark in an international context.

We consider a setup where a banking group (the "bank") consists of two units with common ownership. Each unit collects deposits, which are covered by a deposit insurance scheme, and invests them into assets. The bank is subject to two types of risk, exogenous and endogenous risk. The exogenous risk is the probability that some of its investments will fail for reasons outside the control of the management whereas the endogenous risk stems from the asset choices made. A key ingredient of the analysis is the choice of legal structure. The bank can set up either as a "big bank" with two branches (a branch structure) or as a bank holding company with subsidiaries (a subsidiary structure). The difference is that the units are jointly liable for deposits in the branch structure but not in the subsidiary structure.

The regulator has two instruments available when regulating banking groups. The first instrument is capital requirements, which have the standard effect of reducing banks' incentive to gamble by increasing the loss of shareholders in the case of default (Rochet, 1992 and Hellman et al., 2000). The second instrument is the legal structure. A main contribution of this paper is that we consider both these instruments at the same time when deriving the optimal regulation. We therefore determine the optimal capital regulation of banking groups taking the endogenous choice of legal structure into account. Indeed, the optimal regulation not only determines which banks choose which legal structure, but also who takes this decision (the banks or the regulator). This paper presents to the best of our knowledge the first analysis that endogenizes these important dimensions in the regulation of banking groups.

We show that the branch and the subsidiary structure have different advantages from a regulatory point of view. A bank with a branch structure is less prone to risk-taking in normal times, because the downside of a gamble is carried by both units. However, if one of the units of the banking group is in trouble, it increases the other unit's incentive to gamble only within the branch structure. We will refer to this problem as "risk spillovers", and it is very similar to the debt-overhang problem analyzed in the corporate finance literature (Myers, 1977) and to the gambling for resurrection behavior studied in the banking literature (Kane, 1989). Due to these effects, a lower capital requirement is needed to ensure prudent investment by banks with a branch structure in normal times. In order to stop gambling also in bad times, banks with a branch structure must face a higher capital requirement than banks with a subsidiary structure.

First, we consider a situation where the regulator observes a bank's exogenous risk (its "type"). It is shown that due to the problem of risk spillovers, capital requirements for banks with a branch structure should be more sensitive to the overall financial situation of the banking group than for banks with a subsidiary structure. More generally the analysis shows that if the regulator observes the exogenous risk to which the banking group is exposed, the regulator should determine both the capital requirements and the legal structure. The optimal regulation takes the following form: risky types should set up as a branch structure and face a high capital requirement, which is the combination that minimizes the use of expensive public funds for deposit insurance. Safe types should also set up as a branch structure, but should face a low capital requirement to economize on private funds in the form of bank capital. Finally, it can be optimal to let intermediate risk types set up as a subsidiary structure. This represents an intermediate solution in terms of the use of both private and public funds.

In the second part of the paper we look at different extensions of the basic framework. First and foremost we determine the optimal regulation when a bank's type is private information to the owners. Since the optimal legal structure depends on the type, the regulation should try to exploit the banks' private information. The regulator therefore announces two capital requirements, one for each structure, after which the banks choose their legal structure. Capital requirements play here the dual role of curbing risk-taking incentives and screening banks according to type.

The subsidiary structure has the advantage of “double limited liability” for the banks: a loss in one unit is not carried by the other unit. To induce at least some banks to set up as a branch structure, it is necessary to give banks with a branch structure a capital requirement discount compared to banks with a subsidiary structure. Since double limited liability is more valuable to higher risk types, the banks self-select in the desired way: safe types, for whom risk spillovers are not a major regulatory concern, choose the branch structure, while riskier types choose the subsidiary structure. We show, however, that screening is costly, because the capital requirement for the branch structure has to be increased beyond the optimal level in order to discourage risky types from choosing it. Therefore it may sometimes be welfare enhancing to impose the same capital requirements and legal structure on all banks.

Our analysis has several important policy implications. The existing Basel capital rules (Basel I) do not take into account banks’ liability structure. Our model suggests they should. Specifically, the capital requirements for banks with a branch structure should be more sensitive to the overall financial condition of the bank than for banks with a subsidiary structure. Within the new capital rules for credit institutions, Basel II, banks’ legal structure could for example be taken into account in pillar 2 - the supervisory review process.

In circumstances where the regulator is not well-informed about the risks to which the banks are exposed, it can be optimal to let banks themselves choose their legal structure. Banks with a branch structure should then in general face lower capital requirements than banks with a subsidiary structure. This is in accordance with practitioners’ argument that “big banks” should receive a capital requirement discount. However, their argument is based on diversification benefits whereas our result stems from incentive effects. An attractive feature of this regulation that induces screening is its low informational requirements. We show that subsidiaries of bank holding companies should be treated like standalone banks. A banking group only receives a capital requirement discount if it chooses the branch structure, thereby revealing the members of the group. Hence the regulation does not require the regulator to actively identify members of banking groups. This is particularly important in an international context, where it is often difficult to identify banks with common ownership, so-called parallel-owned banks (BIS, 2003).

Finally, we look at two additional extensions to our baseline model: i) a source of strength policy, as it has been introduced in the US in the late 1980s, that establishes some degree of cross-liability within the subsidiary structure, and ii) a third possible legal structure where one unit is a fully owned subsidiary of the other unit. We show that within our framework neither of these possibilities improve upon the regulation already derived.

Besides the already mentioned works, our analysis is related to a few more papers. In a parallel work, Loranth and Morrison (2004) study the capital regulation of multinational banks. They show that capital requirements should balance banks' incentives to over and underinvest, and find that optimal capital requirements should always be lower for the branch than for the subsidiary structure. We argue that this depends on the underlying risk of the bank. Moreover, Loranth and Morrison do not consider the interplay between capital requirements and the choice of banks' legal structure in the design of optimal regulation.

Kahn and Winton (2004) consider the optimal legal structure of financial institutions in a quite general framework. They show among other things that the subsidiary structure may be optimal due to the risk spillovers that arise in a branch structure. However, Kahn and Winton do not consider applying this to banking regulation. Therefore they do not look at capital requirements. Nor do they study the screening of financial institutions according to risk, which plays an important role in our analysis.

The rest of the paper is organized as follows: section 2 outlines the model. Section 3 analyzes optimal regulation in our baseline setup, where the regulator observes the banks' exogenous risk but not their asset choices. Section 4 contains the analysis of the case where there is also asymmetric information about the banking groups' exogenous risk. In section 5 we look at a source of strength policy and the legal structure with a fully owned subsidiary. Section 6 concludes.

2 The Model

2.1 The Bank

A bank consists of two units with common owners. Each unit has access to one unit of deposits that is invested into projects. The gross deposit rate is normalized to 1. The asset choices are made so as to maximize the profits of the entire bank and are unobservable to outsiders.

Before entering further into the model, it is useful to sketch the timing. We assume that the investment opportunities of the bank arrive sequentially. The two units are equally likely to invest first, and we denote the first unit to invest by "unit-1". The other unit ("unit-2") invests afterwards, but before this investment decision is made, the bank receives a perfect and private signal about the return on the assets of unit-1. This timing captures a natural occurrence: the bank receives private information about its financial health and can react to it. This possibility would arise in any dynamic model where the bank has private information about the quality of its assets and where investment opportunities arise continuously over time. Our timing allows us to introduce it into a simple, one-period model.[1]

Endogenous and Exogenous Risk The bank is exposed to two types of risks, endogenous and exogenous risk. The endogenous risk stems from the asset choices made by the bank while the exogenous risk arises from events outside the control of the bank, for example, an adverse shock to specific industries in which the bank has specialized.

The exogenous risk is modelled in the following manner: with probability $\widetilde{\theta}$, there is no shock and the bank is only exposed to the endogenous risk. With probability $1-\widetilde{\theta}$, unit-1 is subject to an exogenous shock and loses all its investment return.[2] We assume that $\widetilde{\theta}$ is drawn from $[\eta, 1]$ according to a distribution function $F(\widetilde{\theta})$ with a continuous density function $f(\widetilde{\theta})$. The bank observes the realization of $\widetilde{\theta}$, θ. We refer to θ as the bank's "type". One interpretation of θ is that the bank's day-to-day business provides it with information about the risks that its borrowers face and about the probability of a severe, adverse shock to its portfolio of loans.

Turning to the endogenous risk, each of the two units of the bank can invest into two different assets: a gambling asset and a prudent asset. Suppose that the bank is not hit by an exogenous shock. The gambling asset then pays $R > 2$ per unit invested with probability p and 0 with probability $1-p$. A bank that gambles successfully is therefore able to pay back the deposits. The prudent asset pays α per unit invested with certainty. All returns are realized at the end of the game. We make the following assumptions concerning the two assets:

Assumption 1. *i)* $\alpha > pR$, *ii)* $p(R-1) > \alpha - 1$.

Assumption 1 *i)* implies that the prudent asset has the highest expected payoff. Nevertheless, due to Assumption 1 *ii)*, a bank protected by limited liability and faced with no capital requirements would prefer to invest in the gambling asset. Assumption 1 i) and ii) are the standard assumptions in banking models that introduce a risk-shifting problem.

[1] A two-period model where the two units invest simultaneously each period would, for example, give rise to very similar effects. The basic insights of our analysis would remain unchanged but the analysis would be more cumbersome.

[2] It is essential that the shock can hit office 1, because this creates the possibility of risk spillovers, but our results would not change qualitatively if both units could be hit by a shock.

Legal Structure After observing the type, it is decided whether the bank will set up as a branch or as a subsidiary structure. The difference between these two legal structures is the liability for the deposits collected.[3] Within a subsidiary structure each unit functions as a separate legal entity with limited liability. Hence if one unit becomes insolvent, the other unit is not liable. If instead the bank sets up as a branch structure, the two units are one legal entity and are jointly liable for the deposits.

2.2 The Regulatory Environment

Deposit Insurance The depositors of the bank are fully protected by a deposit insurance scheme. The deposit insurance scheme is financed by public funds.[4] The social cost of one unit of public funds is $1+\lambda$, $\lambda > 0$. The cost λ can be thought of as the overhead costs of running the deposit insurance scheme, deadweight loss of taxation, etc.[5]

Capital Requirements We study prudential regulation from the perspective of a benevolent regulator that maximizes social welfare. To curb risk-taking incentives, the regulator requires banks to hold a certain minimum amount of capital per unit of deposits. In order to simplify expressions, it is assumed that the capital cannot be invested. The opportunity cost of bank capital is κ per unit where $\kappa > \alpha$. The cost of bank capital can be explained by 1) informational dilution costs when there is asymmetric information between existing and new equity holders (Myers and Majluf, 1984), and by 2) liquidity costs as bank equity is a bad medium of exchange (Gorton and Pennacchi, 1990; Gorton and Winton, 2000). Moreover, we will assume that there is a social cost of bank capital equal to ρ per unit, $\kappa \geq \rho > 0$.[6] We will focus on the case where funds used for deposit insurance carry a higher social cost than bank capital, $\lambda \geq \rho$. This seems the most plausible case to us, but the assumption can be relaxed at the cost of some additional case distinctions.

The regulator sets a capital requirement for the bank as a whole if it has a branch structure and for each of the units if it has a subsidiary structure. We denote by k_B the capital requirement for the

[3] Of course, in reality there are many other factors that affect banks' choice of legal structure, such as cost efficiency; proximity to the local environment and brand; the amount of "red tape" imposed by regulators and other public authorities; corporate taxes etc. We abstract from all these elements to focus on the role of limited liability and capital requirements.

[4] Our results would also go through if a fixed deposit insurance premium were introduced. The crucial assumption is that the premium cannot be adjusted to reflect the risk taken by the bank. Moreover, it does not matter whether the deposit insurance scheme is private or public, as long as there is a social cost of providing it.

[5] If we think of the cost of deposit insurance as the social loss from distortionary taxes, Ballard et al. (1985) provide empirical estimates of λ in the range $[0.17, 0.56]$.

[6] Note that the informational dilution cost of bank capital is a private cost as it represents a pure transfer from the existing to the new equity holders. However, the liquidity cost of bank capital is both a private and a social cost of bank capital. It is therefore natural to assume that $\kappa \geq \rho > 0$. We refer to Hellman et al. (2000) and Gorton and Winton (2000) for further discussion of this issue.

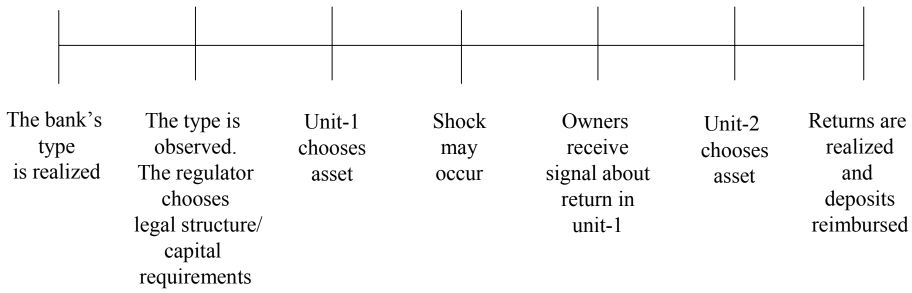

Figure 1: The timing of the game when the regulator observes the bank's type.

branch structure and by k_S the total capital requirement for the subsidiary structure. Finally, the regulator neither observes the order in which investment opportunities arise nor whether the bank is hit by a shock (until payoffs are realized). Therefore, capital requirements cannot be made contingent upon these events.

Information of the Regulator We consider two scenarios concerning the information of the regulator. In section 3 the regulator observes a bank's type and determines both capital requirements and legal structure. In section 4 the regulator does not observe the type. To make use of the banks' private information, the regulator might therefore announce the capital requirements for a branch and for a subsidiary structure, and let banks select their preferred legal structure.

2.3 The Timing of the Game

Figure 1 describes the timing of the game in section 3 where the regulator observes the bank's type. First, the bank's type is realized. The regulator then chooses the legal structure of the bank and the capital requirements. Next, the sequence of investment opportunities is realized, and the bank invests in unit-1. The exogenous shock may then hit unit-1. The bank observes the future return on the assets of unit-1, after which the investment in unit-2 is made. At the end of the game, all returns are realized and deposits are paid back.

3 Optimal Regulation

In this section we study the optimal regulation when the regulator observes the bank's risk type. We start by determining the capital requirements that secure prudent investment by banks with a branch and with a subsidiary structure. Afterwards, we compare the two legal structures in terms of welfare for banks of different types.

3.1 Capital Requirement for Banks with a Branch Structure

Consider the subgame where the bank has set up as a branch structure. The game is solved by backwards induction, and we start by looking at the investment in unit-2. There are three types of situations to consider, depending on the asset choice in unit-1 and on the realization of the shock. Suppose first that unit-1 has invested prudently and that no exogenous shock has occurred. The bank then invests prudently in unit-2 if and only if:

$$2\alpha + k_B - 2 \geq p(R + \alpha + k_B - 2) + (1-p)\max(0, \alpha + k_B - 2). \tag{1}$$

We denote by k_B^g the minimal capital requirement necessary to secure that condition (1) is satisfied,

$$k_B^g = \max\left(\frac{p(R+\alpha-2) - 2(\alpha-1)}{1-p}, 0\right). \tag{2}$$

Suppose instead that unit-1 gambled successfully so that the return in unit-1 will be R. Arguing as in the previous case, we obtain that the bank always invests prudently in unit-2.

Finally, consider the subgames where an exogenous shock has occurred and/or the bank gambled unsuccessfully in unit-1. Let k_B^b be the minimal capital requirement such that unit-2 invests prudently,

$$k_B^b = \frac{p(R-2) - (\alpha - 2)}{1-p}. \tag{3}$$

Assumption 1 *ii)* implies that $k_B^b > 1$. If $k_B = k_B^b$, the bank will therefore be able to pay back deposits and survive if unit-2 invests prudently.

We now go one stage back and look at the asset choice in unit-1. The minimal capital requirement k_B^0 that ensures prudent investment is given by:

$$k_B^0 = 2 - (\alpha - Rp)\frac{(2-p)}{(1-p)^2}. \tag{4}$$

To reduce the number of cases that we need to consider, but without loss of insight, it is assumed that k_B^0 is positive:

Assumption 2. $\dfrac{2(1-p)^2}{2-p} > \alpha - pR.$

Notice that $k_B^g < k_B^0 < k_B^b$. A bank with a branch structure that is faced with a capital requirement of k_B^0 will therefore gamble in unit-2 if and only if it is hit by an exogenous shock.

3.2 Capital Requirements for Banks with a Subsidiary Structure

Consider now the risk-taking incentive within a subsidiary structure. Each of the two units is subject to limited liability and faces a separate capital requirement. Therefore, the return in one unit is not affected by the return in the other unit.

Since the two units of the bank are symmetric, the regulator optimally sets symmetric capital requirements as well. Each of the units will invest prudently if and only if:

$$\alpha + k_S/2 - 1 \geq p(R + k_S/2 - 1).$$

Let k_S^0 be the minimal total capital requirement that ensures prudent investment,

$$k_S^0 = \frac{2p(R-1) - 2(\alpha - 1)}{1-p}. \tag{5}$$

Assumption 1 *ii)* secures that k_S^0 is strictly positive.

3.3 Comparison of the Capital Requirements

We are now ready to compare the branch and the subsidiary structure. First, we look at the decision of the bank when investing in unit-2. The following result follows from the analysis above.

Lemma 1 *The capital requirements that prevent gambling in unit-2 can be ranked as follows:* $k_B^g < k_S^0 < k_B^b$.

Proof. Follows directly from comparing (2), (3), and (5). ■

The intuition behind Lemma 1 is that a bank with a branch structure considers the net return in unit-1 like additional equity when investing in unit-2. Hence, if the net return in unit-1 is positive, the bank has little incentive to gamble and to put the return in unit-1 at risk. The capital requirement for banks with a branch structure can thus be set lower than for banks with a subsidiary structure, $k_B^g < k_S^0$. A negative net return on the other hand, provides a strong incentive to take risk within a branch structure, because the deposit insurer carries most of the gamble's downside. This is the problem of risk spillovers discussed in the introduction. Risk spillovers do not arise within a subsidiary structure, which explains why $k_S^0 < k_B^b$.

With respect to the asset choice in unit-1, we obtain the following result.

Lemma 2 *The total capital requirement needed to prevent gambling in unit-1 is lower for banks with a branch structure than for banks with a subsidiary structure,* $k_B^0 < k_S^0$.

Proof. Follows directly from comparing (4) and (5). ■

It is only within a branch structure that a failed gamble in unit-1 is a liability for unit-2. Therefore, as shown in Lemma 2, a bank with a branch structure is less inclined to take risk in unit-1, and a lower capital requirement is needed to ensure prudent investment.

Taken together, Lemma 1 and 2 illustrate the basic trade-off between the two legal structures. Banks with a branch structure are more prudent than banks with a subsidiary structure in normal times when net returns are positive. However, if problems arise in one of the units of a branch structure, it may trigger gambling by the other unit. The branch structure is at the same time more resilient and more fragile than the subsidiary structure.

3.4 Optimal Choice of Legal Structure

We now turn to the regulator's preferred combination of capital requirements and legal structure. The regulator maximizes welfare, which consists of the bank's profit plus payments to depositors minus the total cost of the deposit insurance scheme. Let $W_i(k_i, \theta)$ denote the expected welfare when the capital requirement is k_i and the type is θ. Subscript i indicates the legal structure, $i \in \{B(ranch), S(ubsidiary)\}$.

We obtain:

$$\begin{aligned} W_B(k_B, \theta) \quad = \quad & \theta(2\alpha + k_B - 2) + (1-\theta)p(R + k_B - 2) - \\ & (1-\theta)(1-p)(2-k_B)(1+\lambda) - (1+\rho)k_B \text{ for } k_B^b > k_B \geq k_B^0, \end{aligned} \tag{6}$$

since the social cost of bank capital is ρ per unit and the bank gambles in unit-2 if a shock occurs. With probability $1-p$ the gamble fails, and depositors are bailed out by the deposit insurance scheme. Similarly, we get:

$$W_B(k_B,\theta) = \theta(2\alpha + k_B - 2) + (1-\theta)(\alpha + k_B - 2) - (1+\rho)k_B \text{ for } k_B \geq k_B^b, \tag{7}$$

because the bank always invests prudently and never has to draw on the deposit insurance scheme.

Finally, the welfare if the bank has a subsidiary structure is:

$$\begin{aligned} W_S(k_S,\theta) &= \theta(\alpha + k_S/2 - 1) + (\alpha + k_S/2 - 1) - \\ &\quad (1-\theta)(1-k_S/2)(1+\lambda) - (1+\rho)(k_S) \text{ for } k_S \geq k_S^0. \end{aligned} \tag{8}$$

We make an additional assumption that allows us to focus on the minimal capital requirements derived above:

Assumption 3. $(1-\eta)Max(1/2, 1-p) \leq \dfrac{\rho}{\lambda} \leq (1-p)^2$.

In Appendix A it is shown that assumption 3 implies that the optimal total capital requirement is k_S^0 for banks with a subsidiary structure and either k_B^0 or k_B^b for banks with a branch structure. Assumption 3 reflects a situation where bank capital is costly but not excessively so. It is optimal to set the capital requirements sufficiently high to ensure prudent investment in unit-1. However, it is not optimal to increase capital requirements beyond that, unless it changes the risk-taking behavior of the bank. Notice also that Assumption 3 implies that $p \leq \eta$. That is, the endogenous risk when the bank gambles in unit-1 is assumed to be at least as high as the exogenous risk.

The next remark, which looks at the use of public funds, is helpful to interpret our later results.

Remark 1 *Suppose that the capital requirements for a bank with a branch and a subsidiary structure are k_B^0 and k_S^0, respectively. Then, conditional on the type, the expected use of public funds for the deposit insurance scheme is higher for the branch than for the subsidiary structure. If a bank with a branch structure is subject to a capital requirement of k_B^b, it will never be insolvent in equilibrium, and hence use no public funds.*

Proof. See Appendix B. ■

We now turn to the regulator's preferred combination of legal structure and capital requirements as a function of the bank's exogenous risk. By substituting (3) and (4) into (6) and (7), we obtain:

$$W_B(k_B^0,\theta) \geq W_B(k_B^b,\theta) \Leftrightarrow \theta \geq 1 - \frac{\rho}{(1-p)\left[(1-p)+(2-p)\lambda\right]} \equiv A. \tag{9}$$

From the comparison of $W_B(k_B^0,\theta)$ and $W_B(k_B^b,\theta)$, we obtain the following straightforward but important result:

Proposition 1 *For $\eta < A$ the optimal capital requirement for a bank with a branch structure is (weakly) increasing in the exogenous risk, whereas the capital requirement for a bank with a subsidiary structure is independent of the risk.*

Proof. Follows from the discussion above. ■

The result of Proposition 1 is due to the risk spillovers that arise within the branch structure. The problem of risk spillovers is greater the more likely the bank is to be hit by a shock. Therefore the capital requirement should be increasing in the exogenous risk, in order to prevent gambling and to reduce the cost of deposit insurance. No risk spillovers arise within the subsidiary structure, and the optimal capital requirement is independent of the bank's type.

It is important to notice that Proposition 1 applies both when the legal structure is chosen by the bank itself, as is typically the case today, and when it is chosen by the regulator. The result has immediate policy implications with respect to capital adequacy rules. The existing Basel capital rules do not take into account banks' liability structure, but our model suggests that they should. Specifically, Proposition 1 shows that capital requirements for banking groups with a branch structure should be more sensitive to the overall financial health of the banking group than for banking groups with a subsidiary structure. Within the new capital adequacy rules for credit institutions, Basel II, banks' legal structure could be taken into account in pillar 2, the supervisory review process. As emphasized by BIS (2004), the supervisory review process is supposed to include risk factors that are not fully taken into account when computing the minimum capital requirements in pillar 1.

Continuing with the analysis of the optimal choice of legal structure, the subsidiary structure dominates the branch structure when the following two conditions hold:

$$W_S(k_S^0,\theta) \geq W_B(k_B^0,\theta) \Leftrightarrow \theta \leq 1 - \frac{\rho p}{(1+\lambda)(1-p)^2} \equiv B, \tag{10}$$

$$W_S(k_S^0,\theta) \geq W_B(k_B^b,\theta) \Leftrightarrow \theta \geq 1 - \frac{\rho}{\lambda} \equiv C. \tag{11}$$

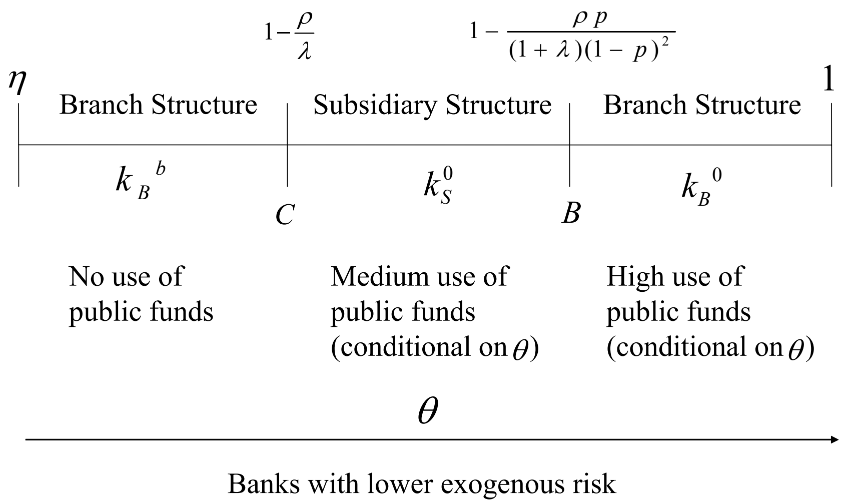

Figure 2: The optimal regulation for $\lambda/(1+\lambda) < (1-p)^2/p$.

The thresholds derived above compare in the following way:

$$B > A > C \Leftrightarrow \frac{\lambda}{1+\lambda} < \frac{(1-p)^2}{p}, \tag{12}$$

$$C > A > B \Leftrightarrow \frac{\lambda}{1+\lambda} > \frac{(1-p)^2}{p}. \tag{13}$$

Consider first the case where $B > A > C$. Figure 2 illustrates the welfare maximizing combination of legal structure and capital requirement as a function of the type θ.[7]

Bank capital imposes a cost on society with certainty, but reduces the cost of deposit insurance only if an exogenous shock occurs (remember that unit-1 always invests prudently because of Assumption 3). For this reason, the optimal regulation involves less use of private funds and more use of expensive public funds (conditional on θ), as the exogenous risk of the bank decreases. First, if the bank faces low exogenous risk ($\theta \geq B$), a branch structure and a capital requirement of k_B^0 is the optimal regulation. Since the probability of a negative shock is low, the regulator accepts that gambling may occur in unit-2 to reduce the capital requirement. For an intermediate risk type ($B > \theta > C$), the expected cost of gambling becomes too high. Instead, the regulator prefers a subsidiary structure with a total capital requirement of k_S^0. This is an intermediate solution both in terms of the amount of public and private funds used (see Lemma 1, Lemma 2, and Remark 1). Finally, a risky type ($C \geq \theta$) should set

[7] In the discussion we assume that $\eta < C$. If $\eta \geq C$ or $\eta \geq B$ not all the solutions illustrated in Figure 2 are relevant.

up as a branch structure with a capital requirement of k_B^b to prevent the use of public funds altogether.

Let us briefly consider the comparative statics of the model. The more expensive public funds are (relative to private funds), the higher the capital requirements should be in order to reduce the cost of deposit insurance. Therefore, the thresholds B and C are increasing (decreasing) in λ (ρ). The role of p, the likelihood that a gamble pays out, is more involved. An increase in p generally makes gambling more attractive for the banks, and capital requirements must be increased to ensure prudent investment. This unambiguously reduces welfare for the subsidiary structure and for the branch structure with $k_B = k_B^b$. The welfare is reduced by the same amount under the two solutions, which leaves the threshold C unchanged. For the branch structure with $k_B = k_B^0$ there is a countervailing effect. Since gambling occurs with probability $1 - \theta$ in equilibrium, a higher value of p implies that the gamble is more likely to be successful. This positive effect of an increase in p implies that the branch structure with a capital requirement of k_B^0 becomes more attractive (relative to the two other solutions), resulting in a decrease in A and B.

The other case where $C > A > B$ shows the same overall picture: the optimal regulation implies more use of public funds and less use of private funds as the exogenous risk decreases (again conditional on θ). The main difference to the previous case is that a subsidiary structure is never optimal. Instead, the regulator chooses a branch structure either with a capital requirement of k_B^0 (if $\theta \leq A$) or of k_B^b (if $\theta > A$). The intuition for the difference is twofold. First, the cost of public funds is relatively high compared to the case discussed before. This makes the subsidiary structure less attractive relative to the branch structure with a capital requirement of k_B^b, a solution that uses no public funds. Second, as p at the same time is relatively high compared to the previous case, the branch structure with a capital requirement of k_B^0 does well compared to the subsidiary structure, for the reasons explained above.

The following proposition summarizes the analysis in this section.

Proposition 2 ***(Optimal regulation)*** *The regulator decides that safe banks have to set up as a branch structure ($\theta \geq \max\{B, A\}$). The capital requirement is set such that there is no gambling in unit-1, but there is gambling in unit-2 if the bank is hit by an exogenous shock ($k_B = k_B^0$). Risky banks also have to set up as a branch structure ($\theta < \min\{A, C\}$). The capital requirement is so high that the bank never gambles and never becomes insolvent in equilibrium ($k_B = k_B^b$). Finally, if the cost of public funds and the probability of success when gambling are both low ($\lambda/(1+\lambda) < (1-p)^2/p$), intermediate risk banks have to set up as a subsidiary structure ($C \leq \theta < B$). The capital requirement is between those for risky and safe types and induces prudent investment ($k_S = k_S^0$).*

The general insight is that if the regulator observes the exogenous risk of a banking group, the regulator should optimally decide not only the capital requirement but also the legal structure. Indeed, the analysis in the next section shows that all banks prefer the branch structure with the low capital requirement (k_B^0) among the solutions that appear in Proposition 2. The banks can therefore not be expected to choose the welfare maximizing combination of capital requirement and legal structure themselves.

Before continuing to different extensions of the model, a couple of points deserve some discussion. We have assumed that if one unit fails within a subsidiary structure, the rest of the banking group can "walk away" at no cost. This assumption is extreme, and one could argue that reputational concerns should induce the other members of the group to try to bail it out. Even if reputation does matter, it is not clear that the longer-run reputational cost of letting the subsidiary fail is larger than the short-run cost of bailing it out.[8] The banking industry fiercely opposed US regulation in the late 1980s, which introduced some degree of cross liability between the subsidiaries of a bank holding company, which also suggests that the possibility of letting a subsidiary fail was considered a valuable option by the banks. We return to these issues in section 5.1 that discusses a source of strength policy.

Practitioners have argued that large banks should receive a capital requirement discount because of diversification benefits. Usually this refers to a statistical property: since large banks have a larger portfolio of investments, the return on their assets tends to have a lower variance. The argument follows that this makes them safer than smaller banks. Let us briefly investigate this argument within our framework. Large banks would here refer to the branch structure and small banks to the subsidiary structure. It is not obvious how to define diversification benefits in a model of endogenous investment choices, but one possibility is the following: suppose that $k_S = k_S^0$ so that small banks invest prudently. Let large banks face a capital requirement $k_B = \widetilde{k}_B$, which is chosen such that small and large banks are equally costly in terms of deposit insurance per unit of deposits. Thus $\widetilde{k}_B$ takes cross-subsidization within large banks into account and captures diversification benefits. Straightforward calculations show that $k_B^0 < \widetilde{k}_B < k_B^b$, see also Remark 1. The incentive effect analyzed in this paper therefore goes beyond diversification benefits. For safe banks, incentive considerations push towards lower capital requirements for branch structures (i.e. large banks) than what a pure diversification argument would suggest, whereas for risky banks it is precisely the other way around.

[8] For example, two banks decided in 2002 not to bail out their distressed Argentinean subsidiaries: The Canadian Bank of Nova Scotia with its subsidiary Quilmes, and the French Credit Agricole with its three banks, Banco Bisel, Banco Sugia, and Banco de Entre Rios (Dermine, 2002).

4 Screening of Banking Groups

Up to now we have assumed that the regulator could observe a banking group's exogenous risk. However, banks may through their day-to-day business acquire information about their exposure to risk that is not available in the same way to the regulator. In this section we therefore study the optimal regulation when the regulator does not observe the banks' types. All proofs are in Appendix B.

The optimal regulation depends on a bank's exogenous risk as shown in section 3. The regulator might therefore try to use the banks' private information about their type by offering a menu of choices to the banks. As a first step, let us show that the regulation derived in section 3 is not implementable in this situation. The profit function of a bank as a function of the capital requirement, the legal structure, and its type is given by:

$$\Pi_B(k_B,\theta) = \begin{cases} \theta(2\alpha + k_B - 2) + (1-\theta)p(R + k_B - 2) - (1+\kappa)k_B \text{ for } k_B^b > k_B \geq k_B^0, \\ \theta(2\alpha + k_B - 2) + (1-\theta)(\alpha + k_B - 2) - (1+\kappa)k_B \text{ for } k_B \geq k_B^b, \end{cases} \tag{14}$$

$$\Pi_S(k_S,\theta) = (1+\theta)(\alpha + k_S/2 - 1) - (1+\kappa)k_S \text{ for } k_S \geq k_S^0. \tag{15}$$

Proposition 2 shows that the optimal regulation involves three combinations of capital requirement and legal structure: (k_B^0, branch), (k_S^0, subsidiary), and (k_B^b, branch). We have:

$$\begin{aligned} \Pi_B(k_B^0,\theta) - \Pi_S(k_S^0,\theta) &= \rho\frac{p}{(1-p)^2}(\alpha - pR) > 0, \\ \Pi_S(k_S^0,\theta) - \Pi_B(k_B^b,\theta) &= (\rho + 1 - \theta)\frac{\alpha - pR}{1-p} > 0. \end{aligned}$$

Hence, faced with a menu that contains these three options, the banks would for all θ choose to set up as a branch structure subject to the low capital requirement, k_B^0. This shows that the optimal regulation derived in section 3 cannot be implemented when the regulator does not observe the banks' types.

4.1 Optimal Screening

We now turn to the issue of whether and how the regulator should screen the banks. This cannot achieve the outcome of Proposition 2, but it might still do better than imposing the same regulation on all banks. The banks always prefer the lowest possible capital requirement, given the legal structure.

It is thus without loss of generality to restrict attention to a menu with only one capital requirement for each structure.

We continue to assume that it is optimal to prevent the banks from gambling in unit 1, i.e. $k_S \geq k_S^0$ and $k_B \geq k_B^0$. We mainly focus on the case of $k_B^0 \leq k_B < k_B^b$, but show towards the end of the section that it is never optimal to set $k_B \geq k_B^b$.

Suppose that banks have the choice between a subsidiary structure with a total capital requirement of k_S and a branch structure with a capital requirement of k_B. Solving the equation $\Pi_B(k_B, \widehat{\theta}) = \Pi_S(k_S, \widehat{\theta})$ for $\widehat{\theta}$, we find:

$$\widehat{\theta}(k_B, k_S) = 1 - \frac{(k_S - k_B)\kappa}{(\alpha - 1) - p(R-2) + k_B(1-p) - k_S/2}. \tag{16}$$

We will say that there is *screening* when $\widehat{\theta}(k_B, k_S) \in (\eta, 1)$ so that not all types choose the same legal structure. Notice that if the capital requirement is independent of the legal structure (i.e. $k_S = k_B$), equation (16) implies that all types will set up as a subsidiary structure due to the benefit of double limited liability.

The following two lemmata characterize the screening mechanism.

Lemma 3 *Necessary conditions for screening are $k_S > k_B$ and*

$$\partial(\Pi_B(k_B, \theta) - \Pi_S(k_S, \theta))/\partial\theta > 0. \qquad \text{(Single Crossing)}$$

The single crossing condition in Lemma 3 ensures that types above $\widehat{\theta}(k_B, k_S)$ will set up as a branch structure whereas types below $\widehat{\theta}(k_B, k_S)$ will set up as a subsidiary structure.

In the following we derive the optimal capital requirements, assuming that the conditions of Lemma 3 are satisfied. Having done this, we then verify that these conditions hold for the solution found.

Lemma 4 *Suppose that the conditions of Lemma 3 are satisfied. Then the optimal capital requirement for the subsidiary structure is k_S^0.*

The intuition behind this result is that a high value of k_S must go together with a high value of k_B in order to induce risky types to choose the subsidiary structure. For this reason, Assumption 3 implies that it is optimal to set k_S as low as possible in order to minimize the total use of capital. We will from now on suppress k_S^0 in the notation, such that $W_S(\theta) \equiv W_S(k_S^0, \theta)$ and $\widehat{\theta}(k_B) \equiv \widehat{\theta}(k_B, k_S^0)$.

Calculating $k_B(\hat{\theta}) \equiv \widehat{\theta}^{-1}(k_B)$, we obtain:

$$k_B(\hat{\theta}) = k_B^0 + \frac{p(\alpha - pR)\kappa}{(1-p)^2((1-p)(1-\hat{\theta}) + \rho)}. \tag{17}$$

Here $k_B(\hat{\theta})$ is the capital requirement that induces all types higher (lower) than $\widehat{\theta}(k_B)$ to choose the branch structure (subsidiary structure). We have that $\partial k_B(\hat{\theta})/\partial\hat{\theta} > 0$ and $k_B(1) = k_S^0$. In a solution with screening, banks with a branch structure face a lower capital requirement than banks with a subsidiary structure.

Before continuing to the optimal choice of k_B, let us verify that the solution found is valid and induces screening.

Lemma 5 *Consider a screening threshold $\widehat{\theta}(k_B) \in (\eta, 1)$. The corresponding capital requirements $k_B(\hat{\theta})$ and k_S^0 satisfy the conditions of Lemma 3 and induce screening.*

The screening works, because double limited liability is more valuable to risky banks, which are more likely to be hit by a shock. Thus risky banks choose a subsidiary structure, whereas safe banks choose a branch structure in order to obtain a capital requirement discount.

The expected welfare as a function of k_B is given by the following expression:

$$W(k_B) \equiv \left[\int_{\eta}^{\hat{\theta}(k_B)} W_S(\tilde{\theta}) f(\tilde{\theta}) d\tilde{\theta} + \int_{\hat{\theta}(k_B)}^{1} W_B(k_B, \tilde{\theta}) f(\tilde{\theta}) d\tilde{\theta} \right], \tag{18}$$

where $k_B \in (k_B(\eta), k_B(1))$.

Using Leibniz' formula, the first order condition amounts to:

$$\frac{\partial W(k_B)}{\partial k_B} = \left[W_S(\hat{\theta}(k_B)) - W_B(k_B, \hat{\theta}(k_B)) \right] f(\hat{\theta}) \frac{\partial \hat{\theta}(k_B)}{\partial k_B} + \int_{\hat{\theta}(k_B)}^{1} \frac{\partial W_B(k_B, \tilde{\theta})}{\partial k_B} f(\tilde{\theta}) d\tilde{\theta} = 0. \tag{19}$$

It is not possible to determine the sign of the second order condition in general. To screen the banks in the optimal way, it is thus necessary to check the welfare for all solutions to (19). Corner solutions, which do not lead to screening, are discussed in section 4.2.

The two terms in (19) have a straightforward interpretation. The first term is the marginal benefit from inducing type $\hat{\theta}$ to set up as a subsidiary rather than as a branch structure. The second term is the infra-marginal cost of screening. It reflects the fact that if the regulator raises the capital requirement for the branch structure to induce type $\hat{\theta}$ to set up as a subsidiary structure, it has a cost since all types above $\hat{\theta}$ face a higher capital requirement. We note that since the second term in (19) is negative by Assumption 3, the first term is positive whenever (19) is satisfied. The welfare if the marginal type chooses the subsidiary structure is higher than if it chooses the branch structure.

Our results establish that it might be possible to screen the banks according to their type by choosing the capital requirements appropriately. This still leaves the question of whether screening is desirable in terms of welfare? There are here competing effects. Suppose that a solution to (19) exists. Then the following condition is fulfilled: $\partial(W_B(k_B,\theta) - W_S(k_S^0,\theta))/\partial\theta > 0$.[9] The banks therefore self-select in the right way from the point of view of welfare, safe banks choose the branch and riskier banks choose the subsidiary structure. There is however, a cost of screening. From (17) it follows:

$$k_B(\eta) = k_B^0 + \frac{p(\alpha - pR)}{(1-p)^2((1-p)(1-\eta)+\rho)} > k_B^0.$$

Screening the banks is costly in terms of bank capital, because the capital requirement for the branch structure has to be increased discretely from k_B^0 to $k_B(\eta)$ just to induce the riskiest type, $\theta = \eta$, to set up as a subsidiary structure. If the regulator also wants safer types than η to choose the subsidiary structure, the capital requirement has to be increased further as $\partial k_B(\hat{\theta})/\partial\hat{\theta} > 0$. Therefore, screening imposes a cost on the safest types, $\theta > \hat{\theta}$, that face a suboptimally high capital requirement. Assumption 3 implies that this is also socially costly, since the capital requirement is increased for these banks without affecting their risk-taking behavior.

In section 4.3 we consider a specific numerical example where it is possible to derive the optimal capital regulation explicitly. Not surprisingly, it shows that screening the banks can be optimal but is not necessarily so.

This concludes the analysis of screening for the case of $k_B^0 \leq k_B < k_B^b$. The next lemma shows that setting $k_B \geq k_B^b$ is never optimal.

Lemma 6 *It is never optimal to set $k_B \geq k_B^b$ and to screen the banks by imposing $k_S > k_B$.*

Screening is not optimal for $k_B \geq k_B^b$ as it requires $k_S > k_B$. The branch structure dominates the subsidiary structure then for two reasons. First, unlike the subsidiary structure, no public funds are used for deposit insurance. Second, less private funds are used for bank capital. For $k_B \geq k_B^b$ the regulator should thus require all banks to set up as a branch structure rather than to induce screening.

[9] In an equilibrium with screening we have that $W_B(k_B,1) > W_S(k_S^0,1)$ since $k_B < k_S$. Since $W_S(\hat{\theta}) > W_B(k_B,\hat{\theta})$ and $\partial(W_B(k_B,\theta) - W_S(k_S^0,\theta))/\partial\theta$ is constant in θ, we have that $\partial(W_B(k_B,\theta) - W_S(k_S^0,\theta))/\partial\theta > 0$ for all $\theta \in (\eta, 1)$.

The following proposition summarizes the analysis of screening.

Proposition 3 ***(Screening)*** *The candidate solutions to the regulator's problem that induce screening are characterized as follows: Banks with a subsidiary structure should face the minimal capital requirement that prevents gambling ($k_S = k_S^0$). The optimal capital requirement for banks with a branch structure, k_B^*, is a solution to (19). Banks with a branch structure should be offered a capital requirement discount compared to banks with a subsidiary structure, but the capital requirement is still higher than necessary to stop them from gambling in unit-1 ($k_B^0 < k_B^* < k_S^0$). In equilibrium safe types ($\theta \geq \widehat{\theta}(k_B^*)$) choose the branch and riskier types ($\theta < \widehat{\theta}(k_B^*)$) the subsidiary structure where $\widehat{\theta}(k_B^*)$ is given by equation (16).*

Within our model, the optimal capital requirement for a standalone bank is $k_S^0/2$. An attractive feature of the capital regulation described in Proposition 3 is that it can be implemented also in a situation where the regulator does not know which banking operations are part of a banking group. If a bank chooses to set up as a subsidiary structure, the two units are treated like standalone banks ($k_S = k_S^0$). It is only if the branch structure is chosen, thereby revealing the members of the group, that the bank receives a capital requirement discount. Therefore the regulation does not require the regulator to actively determine the members of banking groups.[10] This is particularly important in an international context where regulators often have great difficulties identifying banks with common ownership, so-called parallel-owned banks (BIS, 2003).

Our analysis might also shed some light on the surprising fact that cross-border banking within the European Union often takes place through subsidiaries, although the EU's single banking licence rule makes it much easier for multinational banks to expand through branches (Dermine, 2002).[11] One explanation could be that the existing Basel capital adequacy rules do not take the legal structure of banks into account. Taking all the other factors that affect banks' choice of legal structure to be equal (see also foodnote 3), our model suggests that in this situation banks should indeed prefer the subsidiary structure, due to double limited liability.

[10] It may, of course, be desirable to have this information for reasons outside of our model. The regulator might, for example, need this information to monitor the bank's dealings with other banks.

[11] The single banking licence rule allows any EU bank to expand within the EU as long as it operates through branches (Second Banking Co-ordination Directive, 1993). Banks that want to operate through a subsidiary need a local licence.

4.2 No Screening

Screening is costly, because banks that choose the branch structure face too high a capital requirement. For this reason, the regulator may optimally decide not to screen the banks; i.e. to impose the same capital requirement and legal structure on all banks. In this case the regulator has to compare the expected welfare resulting from different combinations of legal structure and capital requirement. Since the welfare functions are linear in θ, we can use the analysis in Section 3 to derive the optimal regulation without screening using the banks' expected type, $E(\theta)$, instead of θ.

Proposition 4 ***(No screening)*** *The regulator may optimally choose not to screen the banks. The optimal regulation is then as described in Proposition 2 with $E(\theta)$ replacing θ.*

The trade-offs that shape the optimal regulation in this situation have already been discussed in the previous section, the only difference being that the comparison of the candidate solutions is in terms of expectations.

4.3 Discussion

To illustrate the results obtained, we derive the optimal regulation for a specific example where the types are uniformly distributed on the interval $[0.68, 1]$. Figure 3 illustrates the capital requirements as a function of the cost of public funds, λ. There are a couple of points to notice from the figure. First, for low values of λ, k_B is set at k_B^0 and all banks choose the branch structure, a solution that uses few private but many public funds. Second, there is a discrete increase in k_B as λ becomes so high that the regulator starts to screen the banks to save on public funds. This increase represents the cost of screening discussed above.

In this analysis we have assumed that the cost of bank equity is independent of the legal structure chosen. This can be thought of as a situation where enough capital is raised ex-ante, i.e. before the type is realized, to satisfy the capital requirement for both legal structures. Alternatively, the owners of the bank have "deep pockets" such that additional bank capital is inside equity provided by the existing shareholders. A new issue arises if the owners have to raise capital to comply with the capital requirement after choosing the legal structure. The choice of legal structure then serves as a signal of the bank's type to the financial markets, and affects the cost of raising capital. The fact that choosing a subsidiary structure signals a high risk type introduces a "lemons problem": the safest types choosing the subsidiary structure pay a particularly high cost of capital, because they have a

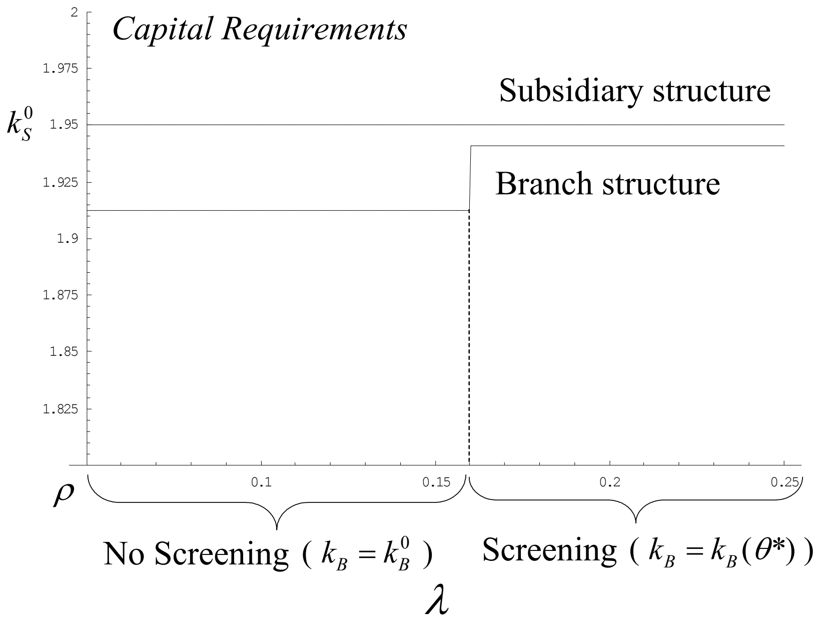

Figure 3: The capital requirement for the branch and for the subsidiary structure as a function of λ when $\theta \sim U\,[0.68, 1]$, $p = 0.6$, $R = 2.9$, $\alpha = 1.75$, $\kappa = 0.1$, and $\rho = 0.05$.

lower risk than the average bank choosing this legal structure. However, if these relatively safe types choose the branch structure instead of the subsidiary structure to reduce financing costs, the average type choosing the subsidiary structure becomes worse (i.e. of higher risk). This increases the cost of capital further, and can, in turn, make even riskier types prefer the branch structure, etc. This process could, in extreme cases, make the screening mechanism unravel. Although this is a concern, we argue that the problem is less severe than the above discussion might suggest. It is to interpret the model too literally to think of banks as being "born" with a type. Rather the type is realized over time as the bank builds up its business relations and specializes in different market segments. The initial capital to start the banking operation is therefore raised before the type is realized. Later, once the type is realized, the bank might have to raise additional capital to switch to the optimal legal structure. However, as it is maximally the difference between the capital requirement for the branch and the subsidiary structure that has to be raised, the adverse selection problem is much less severe.

5 Extensions

In the following we discuss two additional extensions to the basic setup of section 3, where the regulator observes the type, a source of strength policy, and a legal structure where one unit is a fully owned subsidiary of the other unit. To save on space, we have left out most of the formal proofs of the results, but details are available from the authors upon request.

5.1 A Source of Strength Policy

Below we relax the assumption that if one unit of a bank holding company fails, the other unit can just "walk away" without incurring any cost. Instead we allow for some degree of joint liability within the subsidiary structure, a so-called "source of strength policy" using the terminology of the Federal Reserve Banks (Gilbert, 1991). This captures the regulation of bank holding companies introduced in the end of the 1980s in the US. The Financial Institutions Reform, Recovery, and Enforcement Act of 1989 established a cross-guarantee provision that gave the FDIC the authority to charge-off any expected losses from a failing banking subsidiary to the capital of the non-failing subsidiaries within the holding company.[12] The intention of the law was to hold the shareholders of bank holding companies responsible for the losses of the subsidiaries beyond their equity investments.

We model a source of strength policy by assuming that if one subsidiary of the bank fails, the other subsidiary is liable for a fraction γ of the loss, $\gamma \in [0, 1]$. The subsidiary structure plus a source of strength policy therefore represents an intermediate case between the branch structure ($\gamma = 1$) and the subsidiary structure ($\gamma = 0$) analyzed before.

The analysis follows the method outlined in section 3, but requires more case distinctions as failure in unit-1 may or may not cause unit-2 to gamble, depending on γ. The following lemma summarizes the results concerning the capital requirements.

Lemma 7 *The welfare maximizing total capital requirement for the subsidiary structure when a source of strength policy is in place is one of the two following candidates:*
i) $k_S = k_S^0(\gamma)$*, which ensures prudent investment in unit-1. The bank invests prudently in unit-2 if and only if unit-1 is not hit by a shock. Here,* $k_S^0(\gamma)$ *is decreasing in* γ*,* $k_S^0(0) = k_S^0$*, and* $k_S^0(1) = k_B^0$*.*
ii) $k_S = k_S^b(\gamma)$*, which ensures prudent investment in both units in all subgames. Here,* $k_S^b(\gamma)$ *is increasing in* γ*,* $k_S^b(0) = k_S^0$*, and* $k_S^b(1) = k_B^b$*.*

[12] Until now the courts have upheld the cross-guarantee provision on two separate occasions; see Ashcraft (2004) for further details.

The capital requirements $k_S^0(\gamma)$ and $k_S^b(\gamma)$ reflect the trade-off identified in the baseline model: the more the units are liable for each other's deposits, the weaker the incentive to gamble in unit-1. However, at the same time the incentive to gamble in unit-2 is stronger if unit-1 is hit by a shock.

Let us compare the subsidiary structure plus a source of strength policy to the branch structure. First, suppose that $k_B = k_B^0$ and $k_S = k_S^0(\gamma)$. We will first look at the use of public funds. The subsidiary structure has a higher capital requirement ($k_S^0(\gamma) \geq k_B^0$) but a lower degree of joint liability ($\gamma \leq 1$). It can be shown that these two effects cancel each other exactly out. The branch and the subsidiary structure have the same expected use of public funds. Since the two structures also induce the same risk-taking behavior, the branch structure results in higher welfare because it requires banks to hold less capital.

Suppose now instead that $k_S = k_S^b(\gamma)$, which prevents gambling in equilibrium. We denote by $W_S^b(k_S^b(\gamma), \theta, \gamma)$ the welfare of the subsidiary structure in this case. Due to the essentially linear structure of our model, we find that $\partial W_S^b(k_S^b(\gamma), \theta, \gamma)/\partial\gamma$ takes on a constant sign. The optimal level of joint liability is therefore either full joint liability ($\gamma = 1$) or no joint liability ($\gamma = 0$). These results lead immediately to the following proposition.

Proposition 5 *The subsidiary structure with a source of strength policy is either dominated by the branch structure or by the subsidiary structure with no joint liability.*

This result might seem surprising, as a source of strength policy gives one degree of freedom more when designing the optimal regulation. The analysis shows that a higher joint liability always weakens the incentive to gamble in good times, but strengthens the incentive to gamble in bad times. In our framework this trade-off resolves itself in a monotone way, which explains why a subsidiary structure plus a source of strength policy is inferior to one of the two structures analyzed in section 3. Having stated this, it should be noted that we are arguing from the point of view of optimal regulation. In a second best world where regulation is suboptimal and banking groups tend, for example, to choose the subsidiary structure too often, a source of strength policy might well have positive welfare effects by making the branch and the subsidiary structure more alike.

5.2 A Bank with a Fully Owned Subsidiary

In this subsection we analyze a third possible legal structure where one unit is a fully owned subsidiary of the other unit. Since the two units no longer are symmetric, we change the notation slightly to avoid confusion. Assume therefore that unit-M(other) owns the other unit, unit-D(aughter). We denote the capital requirement of unit-i by k_i, $i = D, M$. The two units are equally likely to invest first, as in the basic model.

The liability within this structure is a mixture of the branch and the subsidiary structure. If unit-D goes bankrupt, unit-M can continue in operation as it would in a subsidiary structure. If instead unit-M goes bankrupt, the outcome resembles the branch structure. Since the ownership of unit-D is an asset of unit-M, the profits of unit-D are used to pay back the depositors of unit-M. This liability structure causes an asymmetric response to financial difficulties. Troubles in unit-M may trigger gambling in unit-D in an attempt to save the entire, bank but not the reverse.[13]

Below we outline the analysis of the legal structure with a fully owned subsidiary, and discuss the implications. Throughout the analysis we maintain the equivalent of Assumption 3, i.e. i) it is optimal to prevent gambling except possibly when a shock occurs, and ii) the use of bank capital is socially costly. For a given risk-taking behavior of the bank, the capital requirement should thus be minimized. Since the two units are asymmetric, it is important which one invests first. We will look separately at the capital requirements that induce prudent investment if unit-M invests first and if unit-D is the first one to invest. As the last step, we compare the legal structure with a fully owned subsidiary to the branch and to the subsidiary structure.

5.2.1 The Capital Requirements

Let us look at the case where unit-M has the first investment opportunity. The capital requirement is set such that unit-M invests prudently. If there is no shock, unit-M is thus solvent, independently of the return in unit-D. Hence the bank invests prudently in the subsidiary if and only if $k_D \geq k_S^0/2$. Suppose instead that unit-M is hit by a shock. Now the bank might gamble in unit-D to save unit-M. There is no gambling in unit-D if and only if:

$$p(R + k_D + k_M - 2) \geq Max\{0, \alpha + k_D + k_M - 2\},$$

which is equal to $k_D + k_M \geq k_B^b$. Notice that unit-D will bail out unit-M whenever possible. There is thus effectively joint liability, as in the branch structure.

Turning to the invest decision of unit-M, a failed gamble might force the bank to gamble in unit-D as well. Similar to the branch structure, the bank invests prudently in unit-M if and only if

[13] Remember that the regulator does not observe whether the bank is hit by a shock. Therefore, if the mother bank is in trouble it may influence the asset choice of the daughter bank without the knowledge of the regulator.

$k_D + k_M \geq k_B^0$.

The following lemma summarizes the analysis of this case and compares it to the one of the branch structure.

Lemma 8 *Consider the legal structure with a fully owned subsidiary and assume that unit-M invests first. Then, the following holds:*
i) When $k_D \geq k_S^0/2$ *and* $k_B^b > k_D + k_M \geq k_B^0$*, there is no gambling in unit-M. However, if unit-M is hit by a shock, unit-D gambles.*
ii) When $k_D \geq k_S^0/2$ *and* $k_D + k_M \geq k_B^b$*, there is no gambling in equilibrium.*
iii) Like the branch structure, there is full joint liability between the units.
iv) The branch structure can for a (weakly) lower total capital requirement induce the same risk-taking behavior as the structure with a fully owned subsidiary.

Let us also briefly look at the case where unit-D invests first. Similar to the subsidiary structure, unit-M here walks away from a negative return in unit-D. Like the branch structure however, a positive return in unit-D works like additional equity in unit-M, and reduces the incentive to gamble. In terms of capital requirements, this implies that $k_D + k_M \geq k_B^g$ ensures prudent investment in unit-M if there is no shock, and $k_M \geq k_S^0/2$ prevents gambling in unit-M altogether. We will only discuss the case where $k_M \geq k_S^0/2$. Here the investment decision in unit-M is independent of the outcome in unit-D. Therefore, the bank invests prudently in unit-D if and only if $k_D \geq k_S^0/2$. Notice also that there is no joint liability between the units.

Lemma 9 *Consider the structure with a fully owned subsidiary and assume that unit-D invests first. Then the following holds:*
i) When $k_D, k_M \geq k_S^0/2$*, the two units never gamble in equilibrium.*
ii) Like the subsidiary structure, there is no joint liability between the units.
iii) The subsidiary structure induces (for the same capital requirements) the same risk-taking behavior as the structure with a fully owned subsidiary.

5.2.2 Welfare Analysis

Using the above results, it is now possible to compare the structure with a fully owned subsidiary to the branch and the subsidiary structure. We assume in the following that for the type in question the branch structure with $k_B = k_B^0$ is the optimal regulation among the candidate solutions considered in Proposition 2. The other cases can be analyzed in a similar manner.

From the conditions of Lemma 8 and 9 plus the assumption that there should be no gambling if the bank is not hit by a shock, we have that $k_D, k_M \geq k_S^0/2$. The next proposition shows that for these capital requirements, the branch structure results in higher welfare than the structure with a fully owned subsidiary.

Lemma 10 *Suppose that $k_D, k_M \geq k_S^0/2$ and $W_B(k_B^0, \theta) \geq Max\{W_B(k_B^b, \theta), W_S(k_S^0, \theta)\}$. The branch structure with a capital requirement of k_B^0 then dominates the structure with a fully owned subsidiary in terms of welfare.*

Proof. Consider first the case $k_B^b > k_D + k_M \geq k_S^0$. The assumption that bank capital is costly implies that the optimal capital requirements are $k_D = k_M = k_S^0/2$. The welfare if unit-M invests first is then lower than $W_B(k_B^0, \theta)$. The reason is that the bank's risk-taking behavior is the same as for the branch structure with $k_B = k_B^0$ but the total capital requirement is higher. The welfare if unit-D invests first is the same as for the subsidiary structure, which again is lower than $W_B(k_B^0, \theta)$. We conclude that the branch structure with $k_B = k_B^0$ dominates the structure with a fully owned subsidiary in terms of expected welfare.

Consider now the case $k_D + k_M \geq k_B^b$. The optimal total capital requirement is the minimal one, $k_D + k_M = k_B^b$. Moreover, the optimal distribution of bank capital is $k_D = 1$ and $k_M = k_B^b - 1 = k_S^0$, because it avoids the use of public funds. It is easy to verify that the legal structure with a fully owned subsidiary for these capital requirements gives rise to the same expected welfare as the branch structure with $k_B = k_B^b$. Hence the branch structure with $k_B = k_B^0$ dominates the structure with a fully owned subsidiary. ■

The complete analysis of the structure with a fully owned subsidiary requires quite a number of different case distinctions, but the proof follows the method sketched above. Proposition 6 summarizes the main result of this analysis.

Proposition 6 *The structure with a fully-owned subsidiary is (weakly) dominated in terms of welfare by either the branch or by the subsidiary structure.*

Within our framework, we find therefore no reason for the regulator to impose the legal structure with a fully owned subsidiary if the two other structures are optimally regulated. The caveat mentioned in the discussion of Proposition 5 applies also here. The intuition for our results is that the risk-taking behavior induced by the structure with a fully owned subsidiary can be replicated either by the branch or by the subsidiary structure for a (weakly) lower total capital requirement. As bank capital is socially costly, this implies that the structure with a fully owned subsidiary is jointly dominated by the two other legal structures.

6 Concluding Remarks

In this paper we have studied regulation of banking groups. We have shown that in normal times banks with a branch structure are more prudent than banks with a subsidiary structure. In times of financial distress however, banks with a branch structure are more prone to gamble due to risk spillovers, and must be subject to higher capital requirements. The upshot is that capital requirements should be more sensitive to the financial health of the bank when the branch structure has been chosen.

We have analyzed capital regulation and the choice of legal structure both when the benevolent regulator has information about the banks' risk types and when this is private information to the banks. We argued that if the regulator observes the risk types, the regulator should determine both capital requirements and legal structure. Safe and risky banks should set up as a branch structure (subject to a low and a high capital requirement respectively) whereas it can be optimal that banks of an intermediate risk type set up as a subsidiary structure.

In circumstances where banks have private information about their risk, the regulator may choose to screen the banks such that risky banks choose the subsidiary structure and safe banks the branch structure. To induce safe banks to set up as a branch structure, they must receive a capital requirement discount compared to banks with a subsidiary structure. However, it is costly to screen the banks, because the capital requirement for banks with a branch structure must be set suboptimally high. For this reason, the optimal policy may be to impose the same legal structure and capital requirement on all banks.

We have considered two additional extensions of the model: a source of strength policy, which introduces some degree of joint liability within the subsidiary structure, and a third legal structure with a fully owned subsidiary. We show that neither of these alternatives improve upon the regulation that can be obtained with a branch structure and a subsidiary structure with no joint liability.

There is an emerging literature on the regulation of financial conglomerates (Boot and Schmeits, 2000; Freixas et al., 2005). Some of the issues studied in this paper appear also in this context, in particular risk spillovers. Presumably, the regulator can have great difficulties judging the risk of a financial conglomerate because of the different kinds of activities undertaken. It would therefore be interesting to explore in future work whether a screening mechanism similar to the one proposed here could be applied also in such a context.

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A Derivation of Assumption 3

First, we derive the condition which secures that the regulator sets the minimum capital requirements necessary to induce a certain behavior. We get:

$$\frac{\partial W_B(k_B,\theta)}{\partial k_B} \mid_{k_B \geq k_B^b} < 0,$$

$$\frac{\partial W_B(k_B,\theta)}{\partial k_B} \mid_{k_B \geq k_B^0} < 0 \Leftrightarrow \frac{\rho}{\lambda} > (1-p)(1-\theta), \tag{20}$$

$$\frac{\partial W_S(k_S,\theta)}{\partial k_S} \mid_{k_S \geq k_S^0} < 0 \Leftrightarrow \frac{\rho}{\lambda} > \frac{1}{2}(1-\theta), \tag{21}$$

We have that (20) and (21) are satisfied if $\frac{\rho}{\lambda} > (1-\theta)Max(1/2, 1-p)$.

Consider now the regulator's payoff from setting the capital requirements below k_B^0 and k_S^0. We have:

$$\frac{\partial W_B(k_B,\theta)}{\partial k_B}\mid_{k_B<k_B^0}>0 \Leftrightarrow \frac{\rho}{\lambda}<(1-p)(1-\theta p), \tag{22}$$

$$\frac{\partial W_S(k_S,\theta)}{\partial k_S}\mid_{k_S<k_S^0}>0 \Leftrightarrow \frac{\rho}{\lambda}<\frac{1}{2}((1-p)+(1-\theta p)). \tag{23}$$

Since $(1-p)(1-\theta p) < \frac{1}{2}((1-p)+(1-\theta p))/2$ we obtain that (22) and (23) are satisfied if $\frac{\rho}{\lambda} < (1-p)(1-\theta p)$. Suppose that this condition holds. Then the optimal capital requirements for $k_B < k_B^0$ and $k_S < k_S^0$ are $k_B^0 - \varepsilon$ and $k_S^0 - \varepsilon$ (ε small). Since $W_B(k_B^0,\theta) > W_B(k_B^0-\varepsilon,\theta)$ and $W_S(k_S^0,\theta) > W_S(k_S^0-\varepsilon,\theta)$, the regulator never sets capital requirements below k_B^0 and k_S^0.

Finally, $(1-\theta)Max(1/2, 1-p) \leq \frac{\rho}{\lambda} \leq (1-p)(1-\theta p)$ is fulfilled for all $\theta \in [\eta, 1]$ if and only if Assumption 3 is satisfied. ■

B Proof of Remark, Lemmata, and Propositions

B.1 Proof of Remark 1

First, compare the branch and the subsidiary structure with a capital requirement of k_B^0 and k_S^0, respectively. The expected use of public funds is $(1-\theta)(1-p)(2-k_B^0)$ for the branch structure and $(1-\theta)(1-k_S^0/2)$ for the subsidiary structure. We have that $(1-\theta)(1-p)(2-k_B^0)-(1-\theta)(1-k_S^0/2) = (1-\theta)(\alpha - pR) > 0$. The second part of the remark follows from $\alpha + k_B^b > 2$. ■

B.2 Proof of Lemma 3

From (16) it follows that we want to exclude screening for combinations of k_B and k_S such that $k_S < k_B$ and

$$\partial(\Pi_B(k_B,\theta) - \Pi_S(k_S,\theta))/\partial k_S < 0 \Leftrightarrow (\alpha-1) - p(R-2) + k_B(1-p) - k_S/2 < 0. \tag{24}$$

First, consider $p < 1/2$. We have that necessary conditions for (24) to be satisfied are $(\alpha-1) < p(R-2)$ and $k_S < 2(p(R-2)-(\alpha-1))/(1-2p)$. However, since $2(p(R-2)-(\alpha-1))/(1-2p) < k_S^0$, (24) is never satisfied in the range considered. Consider instead $p \geq 1/2$. A necessary condition for (24) to be satisfied is that $k_B > 2(\alpha-1-p(R-2))/(2p-1) > k_B^b$. Again this is outside the range considered, so (24) is not satisfied. ■

B.3 Proof of Lemma 4

For any marginal type, $\hat{\theta} \in [\eta, 1]$, there exists a pair $(\hat{k}_B, k_S^0)$ that satisfies (16). Consider any other pair $(\tilde{k}_B, \tilde{k}_S)$ that induces $\hat{\theta}$. Given the range considered we have that $\tilde{k}_S > k_S^0$. From (16) we obtain that $\tilde{k}_B > \hat{k}_B$. Assumption 3 then implies that the regulator prefers $(\hat{k}_B, k_S^0)$. ■

B.4 Proof of Lemma 5

Plugging $k_B(\hat{\theta})$ and k_S^0 into the single-crossing condition we obtain:

$$\frac{\partial(\Pi_B(k_B,\theta) - \Pi_S(k_S,\theta))}{\partial\theta}\Big|_{k_B=k_B(\hat{\theta}),k_S=k_S^0} = \frac{p(\alpha - pR)\kappa}{(1-p)((1-p)(1-\hat{\theta})+\rho)} > 0.$$

The single-crossing condition is thus satisfied. Whenever there is screening, $\widehat{\theta} \in (\eta, 1)$, the condition $k_S > k_B$ also holds. The solution found is thus valid and induces screening. ■

B.5 Proof of Lemma 6

Assume that $k_B \geq k_B^b$. As in Lemma 3, we have that screening requires $k_S > k_B$. Analogous to Lemma 4, the optimal capital requirement for the branch structure is k_B^b in order to reduce the use of private funds. Comparing the two structures, we have that $W_B(k_B^b, \theta) > W_S(k_S, \theta)$ for all θ since the branch structure involves less use of both public and private funds. Hence screening is not optimal. ■