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Feess, Eberhard and Wohlschlegel, Ansgar

Frankfurt School of Finance Management, Portsmouth Business School

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Eberhard Feess
Frankfurt School of Finance & Management

Ansgar Wohlschlegel
Portsmouth Business School

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Abstract

Tighter capital requirements and mandatory deferral of compensation are among the most prominently advocated regulatory measures to reduce excessive risk-taking in the banking industry. We analyze the interplay of the two instruments in an economy with two heterogenous banks that can fund uncorrelated projects with fully diversifiable risk or correlated projects with systemic risk. If both project types are in abundant supply, we find that full mandatory deferral of compensation is beneficial as it allows for weaker capital requirements, and hence for a larger banking sector, without increasing the incentives for risk-shifting. With competition for uncorrelated projects, however, deferred compensation may misallocate correlated projects to the bank which is inferior in managing risks. Our findings challenge the current tendency to impose stricter regulations on more sophisticated institutes.

1 Introduction

In the aftermath of the financial crisis, tighter capital requirements (e.g. Admati and Hellwig (2014)) and mandatory deferral of bankers' compensation (e.g. Bebchuk and Fried (2010)) are the two most prominent suggestions for mitigating the incentives for excessive risk-taking. After a one-year negotiation with its member states, the European Parliament eventually released its Capital Requirements Directive IV in April 2013 which increases capital requirements from 2% to 4.5% from Common Equity Tier 1 capital.

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Bankers' bonuses are capped to 100% of the fixum, but are allowed to rise to 200% if approved by shareholders. Depending on the circumstances and the overall percentage of variable pay, at least 40%-60% of variable payments need to be deferred by no less than three to five years.

In a similar vein, legal rules that will (partially) already be enforced in 2015 and that increase the tier 1 capital to risk weighted asset ratio from 4% to 6% were introduced in the US (see Board of Governors of the Federal Reserve System, July 2013). The new US legislation does not contain bonus caps, but discretionary bonus payments during any quarter are prohibited if the bank's eligible retained income, defined as the net income of the four preceding quarters is negative and if its capital conservation buffer in the beginning of the quarter was below 2.5%.[1] These buffer requirements, however, are mandatory only for those large institutions which are seen as critical to avoid globally relevant systemic risks.

In this paper, we contribute to the ongoing discussion on how the risk appetite of financial institutions can be reduced by analyzing the interplay of capital requirements and mandatory deferral of bankers' compensation. While most of the literature has focused on one of these two regulatory instruments, we are particularly interested in their potential complementarity or substitutability. We consider an economy with two heterogenous banks choosing between funding projects with only diversifiable risk (uncorrelated projects) and projects with systematic risk (correlated projects).[2] Uncorrelated projects are superior from the society's point of view, but banks may still prefer correlated projects as they benefit from limited liability, and because bankruptcy costs cannot be fully internalized. One of the two banks which we refer to as *good* bank is superior in managing correlated projects, and if correlated projects are funded at all, this should be done by the good bank.

Shareholders decide about the timing of their managers' compensation which can be either *early* or *deferred*. The early part of the compensation is paid out before the return of correlated projects is realized, while the deferred part can only be paid out if the bank is not bankrupt. A first result is that, whenever banks face a positive default risk, shareholders prefer early bonuses to deferred bonuses. The reason is that, with deferred compensation, managers are exposed to the default risk, and hence demand higher compensation in the non-bankruptcy case. This shows that shareholders have a vital interest in early compensation, so that our model focuses on the external agency

[1] Comparable rules are contained in the European CRD IV which entails five new capital buffers, and firms that do not meet the requirements are constrained in their discretionary distribution of earnings.

[2] As the risk of uncorrelated projects can be fully diversified, we also refer to them as *safe* projects. Accordingly, we refer to correlated projects also as *risky* projects.

between the society and shareholders rather than on the internal agency problem between shareholders and their managers.

The regulator has two instruments to regulate the banking sector, capital equity ratios, which determine the maximum number of projects banks can fund with their given equity, and the percentage of compensation that needs to be deferred. We distinguish between two settings, a setting where all projects are in abundant supply, and a setting where a scarcity of the socially preferable uncorrelated projects leads to competition between banks. In the simpler case with an abundant supply of both project types, there is no interdependency of the two banks' projects choices, and mandatory deferral of *all* compensation has then no downside. The reason is that, for any given capital requirement, the bank's incentive to fund correlated rather than uncorrelated projects is strictly decreasing in the percentage of deferred compensation: If the bank funds uncorrelated projects and hence faces no bankruptcy risk, then the bank value is independent of the percentage of deferred compensation, since the manager faces no default risk and hence demands the same salary with early and with deferred compensation. With default risk, however, the bank value decreases in deferred compensation due to the higher payment to the manager in the no-default case. As a consequence, the regulator can avoid risk-shifting[3] even with lower capital ratios, which increases social welfare. Our main result with an abundant supply of both project types is thus that mandatory deferral of compensation allows to increase the size of a risk-free banking sector.

A potential downside of mandatory deferral of compensation, however, emerges when safe projects are in limited supply. Consider a situation in which the regulator wants to keep just one bank risk-free, because the number of uncorrelated projects is limited, and since expected social costs from the potential default of just one bank are lower than social costs of implementing a very small banking sector. As the good bank has an advantage in managing correlated projects, this bank should be the one exposed to default risk. If the whole compensation needs to be deferred, however, then the good bank may prefer uncorrelated projects, and only correlated projects are left over for the bad bank. We refer to this case as *misallocation of projects*, since the correlated projects are funded by a bank with a comparative disadvantage. In these cases, the regulator may wish to allow for early compensation in order to increase the good bank's incentive for risky projects, so that the safe projects are left for the bad bank. This potential downside of mandatory deferral of compensation arises in our model only when competition of heterogenous banks for safe projects is taken into account.[4]

[3]We will use the term risk-shifting when banks fund correlated instead of uncorrelated projects.

[4]We have developed the basic idea that mandatory deferral of compensation may lead to a misallocation of risky projects between heterogenous banks already in an earlier working paper (Feess and

Note that the peril of a misallocation of risky projects in the economy would be reinforced when at least one of the two regulatory instruments is stricter for the good bank - the tighter the capital equity ratio and the higher the percentage of mandatory deferral of compensation, the lower is the incentive for risk-shifting. Thus, while our findings with an abundant supply of both project types call unambiguously for strict regulations, our setting with competition for uncorrelated projects challenges the current tendency to impose stricter regulations on large, globally operating banks.[5] While this is indeed likely to reduce large banks' risk appetite, it may come at the expense of transferring risky projects to smaller banks or even to financial institutions in the shadow banking sector which are likely to be less cautious in managing risky projects.[6]

Another issue from an applied perspective arising from our model concerns the fact that the bonus cap for bankers in the EU can be extended from 100% of the fixum to 200% if approved by shareholders. Such a regulation implies that regulators are more concerned about the internal rather than about the external agency problem, while our analysis suggests that shareholders themselves benefit from early compensation and risk-shifting. In a similar spirit, Goodhart claims that "one of the worst suggestions ever made...is to align the interests of (bank) managers with the interests of banks' shareholders" (Public Lecture at LSE, July 14, 2010).[7]

Our paper is related to the literature on deferred compensation as well as to the one on capital requirements. With respect to payment schemes, we restrict attention to the fundamental difference between early and deferred compensation, while other papers provide more detailed suggestions for regulating bankers' pay. These proposals include the timing of deferred compensation schemes (Bebchuk and Fried (2010)), tying CEO compensation to the CDS spread to account for the risk perceived by the market (Bolton, Mehran and Shapiro (2010)), and charging deposit insurance premiums depending on the compensation structure (Phelan and Clement (2010)).

In a similar vein as in our paper, Edmans and Liu (2011) argue that giving managers inside debt in form of pension funds or deferred compensation mitigates the risk-shifting problem. Their view corresponds to empirical evidence by Wei and Yermack (2010) who

Wohlschlegel (2012)), in which, however, we used a very different framework. For instance, we did not take into account banks' choice of portfolio size, and we did not analyze the relationship between optimal regulations of bank capital and bank managers' compensation in that working paper.

[5]In the US, only the eight largest banks are subject to Basel III-regulations, so that these banks face tighter capital equity ratios than smaller banks do.

[6]According to a release of the Board of Governors of the Federal Reserve System from July 2, 2013, the global shadow banking system has increased from about 28000 billion US$ in 2002 to about 70000 billion US$ in 2011.

[7]Quoted after Chaigneau (2013, p. 778).

find that the CDS spread is decreasing in the percentage of CEO remuneration paid in inside debt. Jarque and Prescott (2010) restrict attention to internal agency problems and show that the optimal percentage of deferred compensation from the shareholders' point of view depends crucially on the timing of the game.

In Inderst and Pfeil (2010), banks need to incentivize agents for screening the quality of loans which becomes private information (internal agency problem). Banks may provide too little incentives for screening due to an externality problem vis-à-vis the buyers of securities who benefit from higher loan quality (external agency problem). Deferred compensation has countervailing effects on the banks' interest in incentivizing loan screening. Bolton, Freixas and Shapiro (2010) show that, even though performance-based pay maximizes the expected value of the bank's equity, it is likely to induce excessive risk-taking from the debtholders' point of view. For mitigating these inefficiencies, they suggest tying bank managers' compensation not only to performance measures, but also to measures of default risk (see also Bebchuk and Spamann (2010); and Edmans and Liu (2011)). In Hakenes and Schnabel (2014), variable payments are beneficial since they induce effort of bank managers, but may also lead to risk-shifting. In case of potential public bail-outs, they find that a system of capped bonuses optimizes the trade-off between effort incentives and excessive risk-taking. We are not aware of any papers analyzing the impact of deferred compensation on the allocation of projects within a heterogenous banking sector.[8]

Similar to the analysis of mandatory deferral of compensation, the theoretical literature on the impact of capital requirements on risk-shifting finds countervailing effects (see the overviews in Bhattacharya et al. (1998) and Allen (2004)). Allen et al. (2011) develop a model to explain why banks often hold capital above the regulatory minimum requirements. Banks can improve the quality of loans by monitoring but face a moral hazard problem due to limited liability, and higher equity can be used as a commitment device for monitoring. Most recently, the highly influential book by Admati and Hellwig (2014) calls for far higher capital equity ratios and argues that the argument that higher capital equity ratios would ultimately reduce bank lending is flawed. Other current proposals go beyond tighter capital requirements and include mandatory default insurance (Kashyap et al. (2008)), reverse convertibles where debt is converted to equity in case the regulator assumes an increased default risk (Squam Lake Group (2009)), flexible capital requirements depending on the price of Credit Default Swaps for debt (Hart and Zingales

[8]Since we use a theoretical model to make our point, we do not go into the details of the empirical literature, which finds mixed evidence on compensation-induced risk-taking. While DeYoung et al. (2010), Suntheim (2010) and Cheng et al. (2010) find a connection between incentive pay and risk-taking, this is not supported in Fahlenbrach and Stulz (2011), for instance.

(2011)) and so-called "Equity Liability Carriers" which are supposed to guarantee that financial institutions with limited liability can meet their obligations (Admati and Pfleiderer (2010)). All of these suggestions aim at mitigating or even eliminating the limited liability effect, and hence the incentives of shareholders and banks' CEOs for risk-shifting.

A basic effect in our model is that the risk-shifting incentives for shareholders are increasing in the compensation of managers, the reason being that compensation counts only in the non-bankruptcy event. A vastly growing body of literature endogenizes the bank managers' salaries and then shows that fiercer competition for managerial talent leads to excessive risk-taking (Acharya et al. (2010), Thanassoulis (2012)). This effect is reinforced when the managers' talent is private information, as excessively high-powered incentive contracts are then offered to attract the best people (Bannier et al. (2013)).

Finally, our modelling of uncorrelated and correlated projects draws on Feess and Hege (2012) who also show that the incentives for risk-shifting are increasing in the number of projects banks are allowed to fund via capital requirements. While they focus on the distinction between internal and external rating, they do not consider managers' compensation schemes, and hence also not the impact of (mandatory) deferral of compensation.

The remainder of the paper is organized as follows: Section 2 presents the model. In section 3, we show that shareholders strictly prefer early compensation in case of positive default risk. Section 4 considers the scenario with an abundant supply of both project types. When extending the model to include competition for uncorrelated projects in section 5, we point out a potential drawback of deferred compensation. Section 6 considers exogenous restrictions on the regulator's choice set. We conclude in section 7.

2 The Model

Banks and project types. In our model, there are two banks, $i \in \{G, B\}$, each of which is run by a manager and owned by shareholders maximizing their expected profits. The two banks have identical equity endowments of E. There are two different kinds of projects banks can fund, and the choice between these project types determines their risk exposure. Costs of all projects are normalized to one. One type of projects contains only idiosyncratic risk that is fully diversifiable, and we call them uncorrelated projects. The other type of projects is exposed to systematic risk that cannot be diversified, and we refer to them as *correlated* projects.

Uncorrelated projects yield a gross return $X > 2$ with probability $k \geq \frac{1}{2}$, and zero return with probability $1 - k$. As these projects contain only fully diversifiable risk, the return of any measurable portfolio of n uncorrelated projects will be exactly knX.

We assume that the return of uncorrelated projects is independent of whether they are funded by the good or by the bad bank. Correlated projects have perfectly correlated gross returns, which are equal to X with probability $\theta_G < k$ when funded by the good bank and with probability $\theta_B \in \left(\frac{1}{X}, \theta_G\right)$ when funded by the bad bank, and zero in the complementary event. Due to the perfect correlation of their returns, either the entire portfolio of correlated projects fails or succeeds. Hence, bank i's gross return of a portfolio of n correlated projects will be nX with probability θ_i, and zero with probability $1 - \theta_i$.

Summing up, our assumptions have the following implications: First, the default risk of banks is exclusively driven by correlated projects, while the (certain) return of uncorrelated projects effectively bolsters a bank's equity, and hence reduces the bankruptcy risk. Second, the advantage of the good bank over the bad bank refers only to correlated projects. The assumption that both banks perform equally well for uncorrelated projects simplifies the analysis, but all we need is the reasonable feature that the good bank has a comparative advantage for correlated, and in this sense risky, projects. As a consequence, if correlated projects are funded at all, this should be done by the good bank. The latter point will become important in section 5 when we discuss potential advantages of allowing for (partially) early compensation.[9]

Bank Regulation. We assume that the regulator has two instruments to influence the portfolio size and its composition, capital requirements and mandatory deferral of the compensation paid to bank managers. For capital requirements, note first that, if the regulator was able to perfectly observe the banks' portfolios, it would be easy to implement the socially optimal choices by differentiating the capital equity ratios for correlated and uncorrelated projects appropriately. To avoid this trivial solution, we consider the more realistic case of asymmetric information in which the regulator cannot observe the projects chosen by banks. Thus, banks have the possibility to misreport correlated projects as uncorrelated ones, so that differentiating the capital equity ratios is meaningless. We denote the single capital equity ratio by b. The banks' portfolio size is thus restricted by $n \leq \frac{E}{b}$.[10]

[9]Note that our assumptions imply that correlated projects bear larger risk and have lower expected return. If uncorrelated projects had lower return, shareholders would *always* prefer correlated projects to benefit from the limited liability effect. Our assumptions are hence standard in models on banking regulation.

[10]Our assumption that the regulator does not differentiate the capital ratios between safe and risky projects also resembles a clear-cut tendency in the current regulation. The financial crisis has shown that regulators can hardly assess the riskiness of banks' assets, and that banks will always be one step ahead in their creativity of camouflaging the risk of their portfolios. As a consequence, regulators define ratios more and more with respect to the banks' market capitalization (Core Tier-1 capital in Basel III)

In addition to capital requirements, the regulator defines a minimum percentage λ of the manager's compensation which can be paid out only after the return of projects has been realized, and if the bank is solvent (deferred compensation). This means that we define deferred compensation as a legal system where compensation is junior to all other claims in case of liquidation.[11] Note that we do not consider the difference between variable and fixed payments, but focus exclusively on the timing of compensation which, in our view, is crucial for the incentives of shareholders to implement payment schemes which induce risk-shifting. The question we are most interested in is the interplay between capital equity ratios and deferred compensation, that is, the link between the socially optimal values of b and λ.

Social Costs of Default Risk. We capture the expected social costs from bank failure as generally as possible. Specifically, we define $B_i(n_i)$ as social cost when bank i with a portfolio of size n_i defaults with probability $1 - \theta_i$, and if it is the only bank with positive bankruptcy risk. If both banks face positive default risk, expected social costs are denoted by $B_{GB}(n_G, n_B)$. All structure that we impose is that, for every n, $B_G(n) < B_B(n) < B_{GB}(n, n)$, and that $B_G(n)$, $B_B(n)$ and $B_2(n) := B_{GB}(n, n)$ are convex in n. Given that the bad bank faces higher risk than the good bank for identical portfolios, this is a natural assumption. We then define the expected social welfare as the sum of expected net returns of projects funded by banks, less the expected social cost of default.

Compensation schemes for managers. Recall that each bank is run by a single manager who decides on the bank's portfolio. We assume that managers are risk neutral and demand an expected compensation of e to sign a contract in a bank. e can be interpreted as exit options (or opportunity costs) of bank managers. We assume that shareholders can observe their managers' project choices, so that there is no internal agency problem in our model. The reason is that the impact of early vs. deferred compensation on bank managers' incentives for risk-taking is well-known, so that our focus is on the impact of mandatory deferral of compensation on the *shareholders'* incentives to implement correlated projects. We thus restrict attention to the external agency problem caused by the fact that the regulator cannot observe the banks' portfolios.

Each bank's shareholders can suggest a compensation scheme to a manager as a take-it-or-leave-it-offer. As shareholders can observe the banks' portfolios, they can make payments contingent on those. Compensation contracts will thus specify *(i)* the actual

rather than by trying to make capital requirements dependent on the riskiness of the bank's assets.

[11]Otherwise, the distinction between early and deferred compensation would be meaningless in our model.

compensation to be paid to the manager, based on the manager's project choice, and *(ii)* the percentages $\alpha \geq \lambda$ of this compensation to be paid after the project return has been realized. We will refer to this part as deferred compensation, and to the part $1 - \alpha$ as early compensation. We assume $e < E$ as equity E would otherwise not be sufficient to compensate the manager for his exit option e with early payments only.

Competition for projects. We will consider two settings, one with an abundant supply of projects, and one where the number of uncorrelated projects is bounded to 1. In the first case, the only restriction on the banks' portfolios is the capital equity ratio b. This implies that the two banks' portfolios are independent from each other. In the second setting, the two banks may compete for uncorrelated projects. For the case where both banks prefer uncorrelated projects which are in limited supply, we simply *assume* that the good bank can attract these projects. This assumption could be endogenized by assuming that the good bank is also (marginally) superior in funding uncorrelated projects. Then, the good bank could always slightly undercut the bad bank's offer to project owners. However, this would require to explicitly model the game between project owners and banks, which would only complicate the analysis without yielding new insights.

Timing. The timing of the game is as follows:

1. The regulator announces b and λ
2. Shareholders offer contracts to managers.
3. Managers decide on acceptance and, if so, choose portfolios.
4. Nature determines the success or failure of correlated projects.
5. Contracts are enforced.

3 Optimal Compensation Contracts

When shareholders make take-it-or-leave-it contract offers to managers, they need to ensure that the manager's project choice coincides with their own profit maximizing choice (incentive compatibility), and that the manager accepts the contract (participation constraint). Furthermore, the regulatory constraint for the percentage α of deferred compensation needs to be observed, i.e. $\alpha \geq \lambda$.

As shareholders can observe their manager's project choice, an easy way to achieve incentive compatibility is to specify zero compensation whenever the manager's project choice differs from the portfolio fixed in the contract. The participation constraint then requires that the manager's expected compensation is at least as large as their opportunity cost. Specifying *actual* compensation to be equal to e, however, is only sufficient if the manager can be sure to receive the whole payment, that is, when all compensation is early or when there is no default risk. With positive failure risk and partly deferred compensation, the actual compensation needs to be above e in order to give the manager e in expectation.

The following Lemma shows that, whenever shareholders want the manager to fund a portfolio with positive default risk, he will defer as little of the manager's compensation as possible, $\alpha = \lambda$.

Lemma 1 *Suppose bank i wants to fund n_U^i uncorrelated and n_C^i correlated projects. Then:*

(i) If $E + (kX - 1)\, n_U^i - n_C^i < \frac{1-\lambda}{1-(1-\theta_i)\lambda} e$, then deferred compensation is as low as possible, $\alpha = \lambda$. The bank's expected value is

$$\pi_i \left(n_U^i, n_C^i\right) = \theta_i \left[E + (kX - 1)\, n_U^i + (X - 1)\, n_C^i\right] - \frac{\theta_i e}{1 - (1 - \theta_i)\lambda}. \tag{1}$$

(ii) If $E+(kX - 1)\, n_U^i - n_C^i \geq \frac{1-\lambda}{1-(1-\theta_i)\lambda} e$, then the bank's expected value is, independently of α, given by

$$\pi_i \left(n_U^i, n_C^i\right) = E + (kX - 1)\, n_U^i + (\theta_i X - 1)\, n_C^i - e. \tag{2}$$

Proof. All proofs are relegated to the Appendix. ■

In *Case (i)*, the number n_C^i of correlated projects is so large and the part of the compensation paid out early so small that the bank defaults if the correlated projects fail. Then, the shareholders maximize bank value by deferring only the legally binding part of the compensation: Early compensation protects the manager from the default risk, who hence weighs each Dollar of early compensation with one Dollar. The shareholders, by contrast, care about the payment only in the non-bankruptcy case. In the extreme case where the manager is paid in full up front, paying the manager an amount of e only imposes expected costs $\theta_i e$ on the bank. As the fraction λ the bank needs to defer increases, the manager must be compensated for the foregone salary in case of default. This is reflected by the bank's expected costs of compensating the manager, $\frac{\theta_i e}{1-(1-\theta_i)\lambda}$, which is strictly increasing in λ. Hence, shareholders set $\alpha = \lambda$.

By contrast, *case (ii)* shows that the timing of the compensation payment is irrelevant for banks that face no default risk: Then, paying the manager expected compensation

e imposes expected cost e on the bank irrespective of λ. In this sense, the expression $e - \frac{\theta_i e}{1-(1-\theta_i)\lambda} = \frac{(1-\theta_i)(1-\lambda)}{1-(1-\theta_i)\lambda} e$ may be interpreted as the expected amount of money a bank saves in manager compensation by switching from a safe to a risky portfolio. Since this expression is strictly decreasing in λ, the bank can save less and less in manager compensation by introducing default risk as the regulation of manager compensation gets stricter.

Over all, the lesson of Lemma 1 is that mandatory deferral of compensation reduces a bank's expected profit (1) if it is exposed to default risk due to the large number of correlated projects in its portfolio, but leaves profit (2) unchanged if the bank relies mainly on uncorrelated projects. In other words, mandatory deferral of compensation makes correlated projects less attractive and, thus, reduces banks' risk-taking incentives *ceteris paribus*.

In the following, we consider two settings: First, we assume that there is an abundance of both project types, which means that the two banks' shareholders' portfolio decisions are unlinked. In section 4, we proceed to competition for projects.

4 Abundant Supply of Projects

Equilibrium Project Choices. If projects are supplied in abundance, all that restricts banks' portfolios is capital-equity regulation. Capital requirements b imply

$$n = n_U + n_C \leq \frac{E}{b}, \tag{3}$$

that is, the maximum number of projects a bank can fund is $\frac{E}{b}$. Hence, bank i's problem is to choose n_U^i and n_C^i so as to maximize expected value given by (1) and (2) subject to (3).

Straightforwardly, the capital requirement is always binding: Adding a marginal uncorrelated project to a given portfolio increases the value of a solvent bank by $(kX - 1)$ and leaves a defaulting bank's value unchanged at zero, thus strictly increasing a bank's *expected* value.

Consider next the choice between correlated and uncorrelated projects. Without default risk, shareholders always prefer uncorrelated projects due to their higher expected return, $k > \theta_i$. With default risk, however, shareholders face a trade-off between the higher return of uncorrelated projects and the fact that, in case of bankruptcy, the bank does not have enough equity to cover its liabilities. This means that, whenever the bank funds risky projects at all, it is profitable to replace even more uncorrelated projects with correlated projects. This is the well-known risk shifting problem: If equity is wiped out anyway in the case of failure, then increasing the risk even further keeps shareholders' downside risk constant, while improving gains on the upper tail of the distribution. As a consequence, shareholders will strictly prefer either correlated or uncorrelated projects.

The choice between the two project types then depends on the capital equity ratio b and the percentage of compensation that needs to be deferred, λ. The tighter the capital requirement b is, the lower is the number of projects the bank can fund, and the lower hence the benefit from the limited liability effect. Similarly, the higher λ, the less capital can indirectly be protected from bankruptcy by transferring it to the manager. The following Proposition thus shows that shareholders prefer uncorrelated projects if and only if b and λ are sufficiently large, thereby confirming the intuition that the two regulatory instruments have comparable impacts on the incentives for excessive risk-taking.[12]

Proposition 1 *Suppose that both project types are in abundant supply. Then, depending on the capital equity ratio b and the minimum fraction λ of deferred compensation, bank i's portfolio is:*

$$\text{(i) } n_U^i = \frac{E}{b} \text{ and } n_C^i = 0, \quad \text{if } b \geq \hat{b}_i(\lambda) := \frac{E}{1-\theta_i} \frac{\theta_i(X-1)-(kX-1)}{E - \frac{1-\lambda}{1-(1-\theta_i)\lambda}e};$$

$$\text{(ii) } n_U^i = 0 \text{ and } n_C^i = \frac{E}{b}, \quad \text{otherwise.}$$

Proposition 1 shows the driving forces of banks' risk-taking incentives. The numerator of the threshold capital-equity ratio $\hat{b}_i(\lambda)$ is the difference between the bank's expected return from correlated projects when imposing the default risk on creditors, $\theta_i(X-1)$, and the bank's return from uncorrelated projects when default is avoided, $kX-1$. As this difference is larger for the good bank due to its advantage in funding correlated projects ($\theta_G > \theta_B$), one might expect that the good bank has higher risk-taking incentives, i.e. that $\hat{b}_B(\lambda) < \hat{b}_G(\lambda)$. While this is true for extreme regulatory choices where either none or all compensation needs to be deferred, the impact of θ_i on the reduction in expected compensation costs $\frac{1-\lambda}{1-(1-\theta_B)\lambda}e$ that is caused by incurring default risk creates a countervailing effect on risk-taking incentives which may dominate the direct effect that good banks are better at managing risky projects than bad banks.

Optimal Regulation. Recall that our measure of social welfare is just the sum of net returns of all projects, reduced by social cost of default. With the equilibrium project choices derived in Proposition 1, we get:[13]

[12]The impact of the capital requirement is the same as in Lemma 1 in Feess and Hege (2012). Our Proposition extends that Lemma to include mandatory deferral of compensation and combines both policy instruments.

[13]Superscript "A" expresses the setting where uncorrelated projects are in abundant supply.

$$SW^A(b) = \begin{cases} SW_i^A(b) := 2(kX-1)\frac{E}{b}, & \text{if } b \geq \max\{\hat{b}_G(\lambda), \hat{b}_B(\lambda); \\ SW_{ii}^A(b) := ((k+\theta_B)X-2)\frac{E}{b} - B_B\left(\frac{E}{b}\right), & \text{if } \hat{b}_G(\lambda) \leq b < \hat{b}_B(\lambda); \\ SW_{iii}^A(b) := ((k+\theta_G)X-2)\frac{E}{b} - B_G\left(\frac{E}{b}\right), & \text{if } \hat{b}_B(\lambda) \leq b < \hat{b}_G(\lambda); \\ SW_{iv}^A(b) := ((\theta_G+\theta_B)X-2)\frac{E}{b} - B_{GB}\left(\frac{E}{b}, \frac{E}{b}\right), & \text{if } b \geq \min\{\hat{b}_G(\lambda), \hat{b}_B(\lambda); \\ \end{cases} \tag{4}$$

The first line captures the case where both banks' shareholders prefer uncorrelated projects, so that there is no default risk. In the mixed cases in the two subsequent lines, either only the bad or the good bank funds correlated projects and faces default risk. Finally, both banks fund correlated projects in the fourth line.

For a *given* capital regulation b it is easy to check that $SW_i^A(b) > SW_{iii}^A(b) > SW_{ii}^A(b) > SW_{iv}^A(b)$ holds: Uncorrelated projects have higher return and are hence superior, and if one of the banks has an all-correlated portfolio, this should be the good bank. The least desirable option is that both banks have all-correlated portfolios. Whenever there is some default risk (cases (ii) - (iv)), banks impose two kinds of externalities: First, due to limited liability, they don't take into account their creditors' losses in the case where they default. Second, the additional social cost of default $B_i(.)$ are a negative externality. Hence, banks choose their privately optimal project portfolios characterized in Proposition 1 although all-uncorrelated portfolios are always socially optimal.

The analysis of the banks' portfolio choices in Proposition 1 has shown that, when the regulator wants to implement a risk-free banking sector, he needs to impose tight restrictions, so that the banking sector will be small. Thus, there is a trade-off between inducing banks to make more efficient project choices and permitting more projects to be carried out in the economy (recall that, neglecting bankruptcy costs, correlated projects also provide positive expected net return). The trade-off is illustrated in Figure 1, which displays social welfare for different numbers of projects that banks are permitted to fund. The linear function represents the case with uncorrelated projects ($SW_i^A(b)$) in which each additional project just adds its expected net return $kX - 1 > 0$ to social welfare. By contrast, the curve representing $SW_{iii}^A(b)$ is concave due to the social cost of default.

Figure 1 displays a situation where social welfare is higher when the regulator restricts the number of projects so that the banking sector is risk free (case i in equation (4)), $W/\hat{b}_G(\lambda)$, compared to a setting where the good bank switches to an all-correlated portfolio (case iii in equation (4)). In order to increase the number of projects for which the bank still prefers uncorrelated projects, it is then optimal to demand full deferral of compensation, $\lambda = 1$. In figure 1, this moves the threshold $W/\hat{b}_G(\lambda)$ to the right. Thus, whenever the regulator wants to keep the entire banking sctor risk free, $\lambda = 1$ is optimal.

If the capital requirements need to be very strict to avoid any risk of default (low threshold $W/\hat{b}_G(\lambda)$), however, the regulator may prefer the good bank to fund an all-correlated portfolio in order to increase the size of the banking sector. In this case, the optimal capital regulation b is driven by the trade-off between bank size and social cost of default rather than by the threshold implied by λ. Hence, any extent of mandatory deferral of compensation that this interior optimal b is consistent with can be part of optimal regulation. This case distinction is discussed in the following Proposition.

Before presenting the Proposition, it will prove useful to introduce some additional notation. Let, for all $j \in \{ii, iii, iv\}$,

$$b_j^o := \text{argmax} SW_j^A(b)$$

denote the unique peaks of each of the concave functions that the social welfare function is made up of. To exclude the uninteresting case, assume that it is never optimal for the regulator to induce both banks to fund all-correlated project portfolios:

Assumption 1 $\max_b SW_{iv}^A(b) < \max\{SW_i^A(\hat{b}_G(1)), SW_{iii}^A(\max\{b_{iii}^o, \hat{b}_B(1)\})\}$.

Then, the optimal mix of capital requirement and regulation of managerial compensation can be characterized as follows:

Proposition 2 *Suppose that both project types are in abundant supply and that Assumption 1 holds. Then:*

(a) If $SW_{iii}^A\left(\max\left\{\hat{b}_B(1), b_{iii}^o\right\}\right) < SW_i^A(\hat{b}_G(1))$*, then the unique optimal regulation is* $\lambda = 1$ *and* $b = \hat{b}_G(1)$*.*

(b) If $b_{iii}^o < \hat{b}_B(1)$ *and* $SW_i^A(\hat{b}_G(1)) \leq SW_{iii}^A(\hat{b}_B(1))$*, then the unique optimal regulation is* $\lambda = 1$ *and* $b = \hat{b}_B(1)$*.*

(c) Otherwise, the optimal regulation is $b = b_{iii}^o$ *and any* $\lambda \in \left\{\lambda : \hat{b}_B(\lambda) \leq b_{iii}^o\right\}$*.*

Proof. Follows immediately from above.

Proposition 2 implies that, with an abundant availability of the socially preferable uncorrelated projects, the economy will never end up in a situation in which the good bank funds uncorrelated, but the bad bank funds correlated projects. Such a misallocation of projects can never happen as long as the good bank, which is superior in managing correlated projects, has a higher incentive to choose these projects. Hence, the regulator just needs to decide whether he prefers a small banking sector without default risk or a larger, but risky banking sector. It is only in the first case that mandatory deferral of compensation is beneficial as it allows for a less tight capital requirement without inducing risk-shifting.

5 Competition for Uncorrelated Projects

Equilibrium Project Choices. We now turn to our second setting where the number of uncorrelated projects in the economy is restricted to 1. Recall that we have assumed that, when both banks compete for these projects, the good bank can attract them. To exclude uninteresting case distinctions, we introduce a lower and an upper bound for the capital requirement:

Assumption 2 $b \in (E, 2E)$

The lower bound for b ensures that the good bank is in the same situation as without competition for correlated projects, that is, the good bank's portfolio choice is still only restricted by $n_U^G \leq 1$, and the threshold $\hat{b}_G(\lambda)$ still applies. The upper bound means that, when the good bank prefers uncorrelated projects, the bad bank is restricted in its portfolio choice by the scarcity of uncorrelated projects. Otherwise, we would be back to the section on abundant supply of uncorrelated proejcts.

Given Assumption 2, Proposition 3 characterizes the banks' portfolio choices for given b and λ.

Proposition 3 *Suppose that only the correlated project is in abundant supply. Then, depending on the capital equity ratio b and the minimum fraction λ of deferred compensation, the two banks' portfolios are:*

$$\begin{array}{ll}
\textit{(i) } n_U^G = \frac{W}{b}, n_C^G = 0, n_U^B = 1 - \frac{E}{b} \textit{ and } n_C^B = 2\frac{E}{b} - 1, & \textit{if } b \geq \max\left\{\hat{b}_G(\lambda), \frac{E\left(1+\frac{k-\theta_B}{1-\theta_B}X\right)}{E-\frac{1-\lambda}{1-(1-\theta_B)\lambda}e+\frac{k-\theta_B}{1-\theta_B}X}\right\}; \\
\textit{(ii) } n_U^G = \frac{E}{b}, n_C^G = 0, n_U^B = 0 \textit{ and } n_C^B = \frac{E}{b}, & \textit{if } \hat{b}_G(\lambda) \leq b < \frac{E\left(1+\frac{k-\theta_B}{1-\theta_B}X\right)}{E-\frac{1-\lambda}{1-(1-\theta_B)\lambda}e+\frac{k-\theta_B}{1-\theta_B}X}; \\
\textit{(iii) } n_U^G = 0, n_C^G = \frac{E}{b}, n_U^B = \frac{E}{b} \textit{ and } n_C^B = 0, & \textit{if } \hat{b}_B(\lambda) \leq b < \hat{b}_G(\lambda); \\
\textit{(iv) } n_U^G = 0, n_C^G = \frac{E}{b}, n_U^B = 0 \textit{ and } n_C^B = \frac{E}{b}, & \textit{if } b < \min\left\{\hat{b}_B(\lambda), \hat{b}_G(\lambda)\right\}.
\end{array}$$

The first point to note is that, even when the bad bank is restricted in its portfolio choice, it will always fund as many projects as possible, that is, $n_B = \frac{E}{b}$. The first line in the Proposition then captures the case where all uncorrelated projects are funded, and where the bad bank fills up its portfolio with correlated projects. In the second line, the good bank funds only uncorrelated, and the bad bank only correlated projects. The third line displays the opposite case, whereas the banking sector consists only of correlated projects in the fourth line.

An interesting insight of Proposition 3 concerns the bad bank's risk-taking incentives which are higher than in the case where the supply of uncorrelated projects is abundant (to see this, compare the critical capital equity ratios which separate cases (i) and (ii) of

Proposition 3 with the threshold $\hat{b}_B$ from Proposition 1. The reason is that the bank value in case of an all-correlated portfolio is the same as before, whereas funding uncorrelated projects becomes less profitable when the portfolio must be filled up with projects with lower expected return. To see this, just recall that a bank can only prefer correlated projects if there is some default risk. Hence, even in cases in which only uncorrelated projects would be funded with abundant supply, $1 - \frac{E}{b}$ uncorrelated projects might be left over when their supply is limited.

Optimal Regulation. For the sake of readability, let us denote the threshold that separates cases (i) and (ii) in Proposition 3 by

$$\hat{b}_R(\lambda) := \frac{E\left(1 + \frac{k-\theta_B}{1-\theta_B}X\right)}{E - \frac{1-\lambda}{1-(1-\theta_B)\lambda}e + \frac{k-\theta_B}{1-\theta_B}X}.$$

Then, the equilibrium project choices derived in Proposition 3 imply the following social welfare function:[14]

$$SW^C(b) = \begin{cases} SW_i^C(b) := (k-\theta_B)X + 2(\theta_B X - 1)\frac{E}{b}, & \text{if } b \geq \max\{\hat{b}_G(\lambda), \hat{b}_R(\lambda); \\ SW_{ii}^C(b) := ((k+\theta_B)X - 2)\frac{E}{b} - B_B\left(\frac{E}{b}\right), & \text{if } \hat{b}_G(\lambda) \leq b < \hat{b}_R(\lambda); \\ SW_{iii}^C(b) := ((k+\theta_G)X - 2)\frac{E}{b} - B_G\left(\frac{E}{b}\right), & \text{if } \hat{b}_B(\lambda) \leq b < \hat{b}_G(\lambda); \\ SW_{iv}^C(b) := ((\theta_G+\theta_B)X - 2)\frac{E}{b} - B_{GB}\left(\frac{E}{b}, \frac{E}{b}\right), & \text{if } b \geq \min\{\hat{b}_G(\lambda), \hat{b}_B(\lambda); \\ \end{cases} \tag{5}$$

Just like in the case where uncorrelated projects are in abundant supply, we have the result that, for every b, $\min\{SW_{iii}^C(b), SW_i^C(b)\} > SW_{ii}^C(b) > SW_{iv}^C(b)$. However, whenever the limited supply of uncorrelated projects is binding, social welfare will be lower than with abundant supply of these projects for a given capital requirement due to the mere fact that some of the uncorrelated projects had to be replaced by less profitable correlated ones.

Furthermore, there are two potential inefficiencies arising from the scarcity of uncorrelated projects: First, if the regulator decides to keep the whole banking sector free from default risk, the limited supply of uncorrelated projects implies that the correlated projects are funded by the bad bank rather than by the good bank. Hence, the scarcity of correlated projects leads to a misallocation of projects between the two banks. As a consequence, provided the social default cost $B_G(.)$ is sufficiently small, it may be the case that, for some b, $SW_i^C(b) < SW_{iii}^C(b)$.

[14]Superscript "C" denotes the case with competition for uncorrelated projects..

The second inefficiency is caused by the possibility that the bad bank has higher risk-taking incentives than the good bank: Recall that, with abundant supply of uncorrelated projects, the regulator could avoid such a situation, in which the bad bank funds an all-correlated and the good bank an all-uncorrelated portfolio (Case (ii) of Proposition 3), simply by choosing extreme forms of regulations of managers' pay (i.e., $\lambda = 0$ or $\lambda = 1$). Due to the limited number of uncorrelated projects, the bad bank may now switch to a correlated portfolio even in cases where the good bank prefers the uncorrelated portfolio: While the good bank still receives a higher return from correlated projects than the bad bank, risk-free portfolios are now less attractive for the bad bank as they will include some less profitable correlated projects. Both cases just discussed have in common that correlated projects are misallocated to the bad bank, while the good bank, which would have been better at managing the risks associated with correlated projects, funds an all-uncorrelated portfolio.

In order to rule out some of the less relevant cases, let us assume that it is never efficient to allow the bad bank to fund an all-correlated portfolio, neither when the good bank funds an all-uncorrelated portfolio (Assumption 3a) nor when the good bank funds an all-correlated portfolio (Assumption 3b).[15] Note that the latter part of the assumption corresponds to Assumption 1 in the case of abundant supply of uncorrelated projects.

Assumption 3 *(a)* $\max_b SW_{ii}^C(b) < \max\{SW_i^C(\hat{b}_R(1)), SW_{iii}^C(\hat{b}_G(0))\}$.

(b) $\max_b SW_{iv}^C(b) < \max\{SW_i^C(\max\{\hat{b}_G(1), \hat{b}_R(1)\}), SW_{iii}^C(\hat{b}_B(1)), SW_{iii}^C(\hat{b}_G(0)), SW_{iii}^C(b_{iii}^o)\}$.

The optimal regulation can be characterized as follows:

Proposition 4 *Suppose that banks compete for uncorrelated projects and that Assumptions 2 and 3 hold. Then:*

(a) If $\max\{SW_{iii}^C(\hat{b}_B(1)), SW_{iii}^C(\hat{b}_G(0)), SW_{iii}^C(b_{iii}^o)\} < SW_i^C(\max\{\hat{b}_G(1), \hat{b}_R(1)\})$, *then the unique optimal regulation is* $\lambda^* = 1$ *and* $b^* = \max\{\hat{b}_G(1), \hat{b}_R(1)\}$.

(b) If $b_{iii}^o < \hat{b}_B(1)$ *and* $SW_i^C(\max\{\hat{b}_G(1), \hat{b}_R(1)\}) \leq SW_{iii}^C(\hat{b}_B(1))$, *then the unique optimal regulation is* $\lambda^* = 1$ *and* $b^* = \hat{b}_B(1)$.

[15] There are two reasons why we neglect the cases where it is optimal for the regulator that the bad bank funds an all-correlated portfolio. First, if it were optimal that both banks fund only correlated projects (the case excluded by Assumption 3b), then the optimal regulation is entirely trivial. Second, the potential misallocation of projects that we focus on, and which leads to a potential downside of mandatory deferral of compensation, is precisely the case in which the bad bank rather than the good bank funds correlated projects, so that the case in which this is optimal is uninteresting from the perspective of our paper.

(c) If $\hat{b}_G(1) < b^o_{iii}$ and $SW^C_i(\max\{\hat{b}_G(1), \hat{b}_R(1)\}) < SW^C_{iii}(\min\{b^o_{iii}, \hat{b}_G(0)\})$, then the optimal regulation is $b^* = \min\{b^o_{iii}, \hat{b}_G(0)\}$ and $\lambda^* \in \{\lambda : b^o_{iii} \leq \hat{b}_G(\lambda)\} \cup \{0\}$.

(d) Otherwise, the optimal regulation is $b^* = b^o_{iii}$ and any $\lambda^* \in \left\{\lambda : \hat{b}_B(\lambda) \leq b^o_{iii}\right\}$.

Parts (a), (b) and (d) correspond to the respective cases discussed in Proposition 2, but taking into account that the optimal regulation conditional on avoiding any default risk is now $\max\{\hat{b}_G(1), \hat{b}_R(1)\}$ instead of $\hat{b}_G(1)$. The main difference introduced by competition is discussed in Part (c), which is illustrated in Figure 2 for the case where $\hat{b}_R(1) \leq \hat{b}_G(1)$: If all compensation needs to be deferred ($\lambda = 1$) and $b = \hat{b}_G(1)$, then the bank can fund many projects without incurring any default risk, because the bank's equity is not reduced by payments to the manager. However, it would be more efficient to let the good bank incur default risk, but with less projects at stake due to $b^o_{iii} > \hat{b}_G(1)$. The only way of making the good bank fund less projects while still retaining its risk-taking incentives is to reduce the fraction λ of the manager's compensation that is required to be deferred. If even $b^o_{iii} > \hat{b}_G(0) \geq \hat{b}_R(0)$, then the uniquely optimal regulation will require $\lambda = 0$. Thus, the reason why early compensation may be superior is that it enhances the good bank's risk-taking incentives, which allows the bad bank to fund uncorrelated projects, and hence avoids the misallocation of projects between banks.

If, on the other hand, $\hat{b}_G(1) < \hat{b}_R(1)$, tougher regulation of the manager's compensation may reduce welfare due to the potential misallocation problem that the bad bank wants to fund an all-correlated portfolio: The shaded area in Figure 3 displays the set $[\hat{b}_G(0), \hat{b}_R(0))$ of capital requirements that induce case (ii) of Proposition 3 absent any requirement to defer compensation ($\lambda = 0$). Due to our Assumption 3, the regulator wants to avoid this case. The optimal capital requirement outside the shaded area is $\hat{b}_G(0)$, in which case the banking sector would be quite large, with the good bank being at risk of default. Introducing mandatory deferral of compensation will then move the shaded area to the right, which reduces social welfare for the capital requirement $b = \hat{b}_G(\lambda)$. At the same time the optimal default-risk free regulation $b = \hat{b}_R(\lambda)$ may still be less attractive. Hence, not requiring any deferral of compensation would be the strictly optimal regulation in this case.

The intuition for both of these sub-cases of part (c) of Proposition 4 is that whenever $b \geq \hat{b}_G(\lambda)$, the correlated projects funded in the economy are misallocated to the bad bank, which is why the regulator prefers a scenario in which the good bank funds an all-correlated portfolio. In order to limit the projects at stake when the good bank risks default, while still retaining the good bank's risk-taking incentives, it may be optimal for the regulator to reduce the fraction of compensation that is required to be deferred.

Let us briefly summarize the differences of the cases with an abundant and a limited supply of uncorrelated projects. In the first case, mandatory deferral of compensation is weakly dominant: if the regulator wants to keep the banking sector risk-free, then the number of projects he can implement via the capital requirement b is strictly increasing in λ. Otherwise, λ is not uniquely defined. With a limited number of uncorrelated projects, however, it may be better to accommodate risk-shifting by the good bank in order to enable the bad bank, which is inferior in funding correlated projects, to fund uncorrelated projects. When avoiding this misallocation, early compensation of managers may be beneficial as it enhances the good bank's incentive for risk-shifting without weakening the capital equity ratio, and hence without increasing the number of projects that are at risk of default.

6 Restricted Regulation

So far, we have assumed that the regulator is free in the choice of the policy parameters. In reality, there may be upper bounds both on the capital requirements b and the percentage of deferred compensation λ. These upper bounds may be constituted by lobbyism and the threat of banks to relocate to countries with less strict regulations, or driven by countervailing effects of high capital requirements or deferred compensation which are ignored in our model.[16] Thus, it is interesting to discuss the impacts of upper bounds on either λ or b on the restrcited optimal choice of the respective other policy parameter.

Upper bound on the percentage of deferred compensation. We start by considering the impact of a restriction of deferred compensation by assuming that there exists an upper bound $\lambda^{\max} < 1$. From Proposition 2, we know that, whenever the regulator wants to implement a risk-free banking sector, he will set $\lambda = 1$, since this allows for a larger banking sector without inducing risk-shifting by the good bank. The restriction $\lambda^{\max} < 1$ hence has two consequences for the regulator: First, when the regulator wants to avoid risk-shifting, he needs to tighten the capital equity ratio. This is an interesting implication of mandatory deferral of bonuses: As deferred bonuses reduce the banks' risk appetite, they enable the regulator to scale up the banking sector without inducing risk-shifting. Thus, the restriction on λ reduces the social welfare from a risk-free banking sector.

This leads to the second potential consequence: In case (c) of Proposition 2, in which the good bank is subject to default risk, social welfare is independent of λ. Thus, compared to a risk-free banking sector, a risky banking sector becomes more advantageous, so that the regulator's incentive to accommodate risk-shifting increases. Summing up,

[16] Recall the discussion of other potential drawbacks in the literature review.

exogenous restrictions on λ may either tighten the capital equity ratio b, thereby reducing the social welfare of a now smaller and risk-free banking sector, or may induce the regulator to implement a banking sector with default risk.

The aforementioned effects are also relevant in the case with competition for scarce uncorrelated projects. The difference between abundant and limited supply of uncorrelated projects is that it may be optimal for the regulator to reduce the part of the manager's compensation to be deferred in order to avoid misallocation of correlated projects. Of course, the case in which this is optimal will not be affected by the upper bound on λ. However, note that social welfare in this case is constant in the upper bound on λ, but social welfare of keeping the banking sector free from default risk is strictly increasing in that upper bound. Hence, as the upper bound on λ is becoming tighter, optimal regulation may shift from a risk-free banking sector with maximum possible mandatory deferral of compensation to a situation in which the good bank is at risk of default with little or no mandatory deferral of compensation, i.e. λ is well below the upper bound.

Upper bound on the capital requirement An upper bound on the capital equity ratio implies that bank sizes below E/b^{max} are no longer implementable. This may mean that the banking sector cannot be kept risk free any more. Hence, if an unrestricted regulator's optimal choice is to keep the banking sector risk free, an upper bound $b^{max} < \hat{b}_G(1)$ may render mandatory deferral of compensation, which would have been used to its maximum absent the upper bound on capital regulation, irrelevant or even undesirable: λ becomes irrelevant if the new restricted optimal regulation is in case (c) of Proposition 2 with abundant supply and in case (d) of Proposition 4 with limited supply of uncorrelated projects, while it becomes undesirable if there is competition for scarce uncorrelated projects and the new restricted optimal regulation is in case (c) of Proposition 4.

7 Conclusion

We analyze the interplay of capital requirements and mandatory deferral of bankers' compensation in a model where two heterogenous banks can fund uncorrelated (safe) and correlated (risky) projects. The banks' shareholders design the compensation schemes for managers, and as there is no asymmetric information between shareholders and managers in our model, shareholders ultimately decide about the banks' risk appetite. Regulators have two instruments for mitigating the shareholders' risk appetite, capital requirements which determine the number of projects that can be funded, and a percentage of mandatory deferral of compensation.

As prerequisites of our analysis, we show that shareholders strictly prefer early compensation to deferred compensation whenever there is positive default risk, that they prefer either an all-correlated or an all-uncorrelated portfolio to a mixed portfolio, and that all-correlated portfolios are funded if and only if capital equity ratios are below a specific threshold.[17] Based on these features of our model, we find that mandatory deferral of compensation has no downside if all projects are in abundant supply: The higher the percentage of deferred compensation, the lower is the shareholders' risk appetite, and the larger hence the number of projects a regulator can allow via capital requirements without inducing risk-shifting. This seems to be a first interesting result as it means that mandatory deferral of compensation increases the socially optimal size of the financial sector.

A potential drawback of mandatory deferral of compensation arises in our model when the two banks compete for uncorrelated (safe) projects. If these projects are limited, the regulator may want to allow for some risky projects, and these projects should then be funded by the good bank rather than by the bad bank. Then, the regulator needs to enhance the good bank's risk appetite, which can be done in two ways, either by reducing the capital requirement or by allowing for early compensation. As lower capital requirements inevitably increase the number of projects, and hence social costs in case of bankruptcy, early compensation may be welfare superior. Mandatory deferral of bonuses may hence backfire by leading to a misallocation of projects in the society.

From an applied point of view, our paper questions the current tendency to "minimize the burden on smaller, less complex financial institutions" (Board of Governors of the Federal Reserve System, July 2013, p.1), and to impose stricter regulations on more sophisticated institutes. Of course, we are aware of the fact that the systemic risk of bank failure is increasing in the size of the respective financial institutions, but larger banks may also be better in dealing with the correlation of projects. In any case, the current process based on the experience of the financial crisis clearly reverses the long lasting former tendency of the Basel framework which culminated in the distinction between the Standard Approach for a rating of risk-weighted assets and the Internal Ratings Based Approach which was pretty much in favor of large sophisticated banks. Our model provides arguments not to overshoot in the opposite direction.

[17]The latter two results have already been developed by Feess and Hege (2012) where our modelling of correlated and uncorrelated projects is basically taken from.

Appendix

A Proof of Lemma 1

Define $Z_i := E + (kX-1)\,n_U^i - n_C^i$ as bank i's value in the case where the correlated projects fail and in absence of any compensation for the manager. Depending on the manager's contractual compensation C_i and the share $\alpha_i \geq \lambda$ of that compensation to be deferred, there are the following cases:

Case (a): If $Z_i \geq C_i$, the bank can pay C_i to the manager in full even if the correlated projects fail. Hence, the manager's participation constraint is satisfied if $C_i = e$, and the bank's expected value is given by (2).

Case (b): If $(1-\alpha_i)C_i \leq Z_i < C_i$, the firm's value upon failure of the correlated projects is positive but insufficient to pay the deferred fraction $\alpha_i C_i$ of the manager's contractual compensation. Hence, the manager's participation constraint is binding if $(1-\alpha_i)C_i + \theta_i\alpha_i C_i + (1-\theta_i)[Z_i - (1-\alpha_i)C_i] = e$, which is equivalent to $C_i = \frac{e-(1-\theta_i)Z}{\theta_i}$. Again, the bank's resulting expected value is given by (2).

Case (c): If $Z_i < (1-\alpha_i)C_i$, then failure of the correlated projects wipes out the bank's entire cash, which means that the deferred fraction of the manager's compensation is paid out only if the correlated projects succeed. Hence, the manager's participation constraint is binding if $(1-\alpha_i)C_i + \theta_i\alpha_i C_i = e$, which is equivalent to $C_i = \frac{e}{1-(1-\theta_i)\alpha_i}$.

The bank's value is positive only if the correlated projects succeed, in which case the full contractual compensation C is paid out to the manager. Hence, the bank's expected value is

$$\begin{aligned}\pi_i(\alpha_i) &= \theta_i\left[E + (kX-1)\,n_U^i + (X-1)\,n_C^i - C\right] \\ &= \theta_i\left[E + (kX-1)\,n_U^i + (X-1)\,n_C^i\right] - \frac{\theta_i e}{1-(1-\theta_i)\alpha_i},\end{aligned}$$

which is strictly decreasing in α_i.

Summary: The bank's expected value in case (c) is larger than that in cases (a) and (b), which is given by (2), if and only if $\alpha_i < \frac{e-Z_i}{e-(1-\theta_i)Z_i}$. Hence, we can summarize the three cases concluding that the bank's problem is to choose α_i so as to maximize expected value

$$\pi_i(\alpha_i) = \begin{cases} \theta_i\left[E + (kX-1)\,n_U^i + (X-1)\,n_C^i\right] - \frac{\theta_i e}{1-(1-\theta_i)\alpha_i}, & \text{if } \alpha < \frac{e-Z_i}{e-(1-\theta_i)Z_i}; \\ E + (kX-1)\,n_U^i + (\theta_i X - 1)\,n_C^i - e, & \text{otherwise.} \end{cases}$$

subject to $\alpha \geq \lambda$. Noting that $\pi_i(\alpha_i)$ is continuous, it follows that $\alpha_i = \lambda$ is the unique optimum if $\lambda < \frac{e-Z_i}{e-(1-\theta_i)Z_i}$, which is equivalent to the condition $E + (kX-1)\,n_U^i - n_C^i < \frac{1-\lambda}{1-(1-\theta_i)\lambda}e$ for part (i) of the Lemma, and that the bank's expected value is independent of the choice of α_i otherwise. ■

B Proof of Proposition 1

Bank i's expected value when carrying out project plan (n_U^i, n_C^i) is

$$\pi_i\left(n_U^i, n_C^i\right) = \begin{cases} \theta_i\left[E + (kX-1)\, n_U^i + (X-1)\, n_C^i\right] - \frac{\theta_i e}{1-(1-\theta_i)\lambda}, & \text{if } E + (kX-1)\, n_U^i - n_C^i \\ & < \frac{1-\lambda}{1-(1-\theta_i)\lambda} e; \\ E + (kX-1)\, n_U^i + (\theta_i X - 1)\, n_C^i - e, & \text{otherwise,} \end{cases}$$

which is continuous, and increasing in n_U^i and n_C^i within both cases. Hence, $n_U^i + n_C^i = \frac{E}{b}$ in optimum. Substituting for $n_C^i = \frac{E}{b} - n_U^i$ yields

$$\pi_i\left(n_U^i\right) = \begin{cases} \theta_i\left[\frac{b+X-1}{b}E - (1-k)Xn_U^i\right] - \frac{\theta_i e}{1-(1-\theta_i)\lambda}, & \text{if } \frac{b-1}{b}E + kXn_U^i < \frac{1-\lambda}{1-(1-\theta_i)\lambda}e; \\ \frac{b+\theta_i X-1}{b}E + (k-\theta_i)\, Xn_U^i - e, & \text{otherwise,} \end{cases}$$

Clearly, $\pi_i(.)$ is decreasing in n_U^i in the upper case, which is relevant for low n_U^i, and increasing in the lower case (high n_U^i). Hence, the optimal choice of n_U^i is either zero or the maximum $\frac{E}{b}$. Substituting for these boundary solutions yields the result that $\pi_i(0) \leq \pi_i\left(\frac{E}{b}\right)$ if and only if $b \geq \frac{E\left(1-\frac{k-\theta_i}{1-\theta_i}X\right)}{E-\frac{1-\lambda}{1-(1-\theta_i)\lambda}e}$. ■

C Proof of Proposition 3

Recall that, depending on regulation of manager compensation λ, bank i's value when carrying out n_U^i uncorrelated and n_C^i correlated projects is given by Lemma 1. Furthermore, due to the competitive advantage that we have assumed that the good bank G has when acquiring uncorrelated projects, bank G's problem is the same as in Proposition 1 with the additional constraint $n_U^G \leq 1$ which, however, can never bind due to our assumption that $E < b$. Hence, bank G's choice is

$$\text{(i) } n_U^G = \frac{E}{b} \text{ and } n_C^G = 0, \quad \text{if } b \geq \hat{b}_G = \frac{E\left(1-\frac{k-\theta_G}{1-\theta_G}X\right)}{E-\frac{1-\lambda}{1-(1-\theta_G)\lambda}e};$$
$$\text{(ii) } n_U^G = 0 \text{ and } n_C^G = \frac{E}{b}, \quad \text{otherwise.}$$

Turning to the bad bank's project choice, note that the bad bank's problem of project choice is identical to that discussed in Proposition 1 if the good bank carries out only correlated projects which are in abundant supply anyway. Hence, if $b < \hat{b}_G$, then the bad bank will choose $n_U^B = \frac{E}{b}$ and $n_C^B = 0$ if $b \geq \hat{b}_B$, and $n_U^B = 0$ and $n_C^B = \frac{E}{b}$ otherwise, which proves Cases (iii) and (iv) of the Proposition.

It remains to analyze the case where $b \geq \hat{b}_G$, which means that the good bank chooses an all-uncorrelated portfolio so that there are only $1 - \frac{E}{b}$ uncorrelated projects left for the bad bank. As we have argued earlier that the capital-equity ratio b is always binding in optimum, this implies that, for every number of correlated projects n_C^B the bad bank chooses to carry out, the optimal number of uncorrelated projects is

$$n_U^B = \min\left\{\frac{E}{b} - n_C^B, 1 - \frac{E}{b}\right\}. \tag{6}$$

If

$$n_C^B < 2\frac{E}{b} - 1, \tag{7}$$

then (6) implies that $n_U^B = 1 - \frac{E}{b}$ and, therefore, that the bank's value is given by case (i) of Lemma 1 if and only if

$$n_C^B > E - \frac{1-\lambda}{1-(1-\theta_B)\lambda}e + (kX-1)\left(1 - \frac{E}{b}\right). \tag{8}$$

In the opposite case where (7) does not hold, (6) implies that $n_U^B = \frac{E}{b} - n_C^B$, so that the bank's value is given by case (i) of Lemma 1 if and only if $E - \frac{1-\lambda}{1-(1-\theta_B)\lambda}e + (kX - 1)\left(\frac{E}{b} - n_C^B\right) - n_C^B < 0$, which is equivalent to

$$n_C^B > \frac{E - \frac{1-\lambda}{1-(1-\theta_B)\lambda}e + (kX-1)\frac{E}{b}}{kX}. \tag{9}$$

For the sake of readability, define $\hat{e}_B := \frac{e}{1-(1-\theta_B)\lambda}$. Comparing the relevant thresholds for n_C^B given by the right-hand sides of (7), (8) and (9) yields that $2\frac{E}{b} - 1 < \frac{E-(1-\lambda)\hat{e}_B+(kX-1)\frac{E}{b}}{kX} < E - (1-\lambda)\hat{e}_B + (kX-1)\left(1 - \frac{E}{b}\right)$ if

$$b > \frac{E(1+kX)}{E - (1-\lambda)\hat{e}_B + kX}, \tag{10}$$

and $E - (1-\lambda)\hat{e}_B + (kX-1)\left(1 - \frac{E}{b}\right) \leq \frac{E-(1-\lambda)\hat{e}_B+(kX-1)\frac{E}{b}}{kX} \leq 2\frac{E}{b} - 1$ otherwise. Hence, we can distinguish the following cases when using Lemma 1 to derive bank B's value depending on its choice of correlated projects n_C^B, given that it chooses the optimal number of uncorrelated projects based on n_C^B:

Case A: $b > \frac{E(1+kX)}{E-(1-\lambda)\hat{e}_B+kX}$. Then bank B's value is

$$\Pi_B(n_C^B) = \begin{cases} E - e + (kX-1)\left(1 - \frac{E}{b}\right) + (\theta_B X - 1)n_C^B, & \text{if } n_C^B \leq 2\frac{E}{b} - 1; \\ E - e + (kX-1)\frac{E}{b} - (k-\theta_i)Xn_C^B, & \text{if } 2\frac{E}{b} - 1 < n_C^B \leq \frac{E-(1-\lambda)\hat{e}_B+(kX-1)\frac{E}{b}}{kX}; \\ \theta_i\left(E - \hat{e}_B + (kX-1)\frac{E}{b} + X(1-k)n_C^B\right), & \text{if } n_B^R > \frac{E-(1-\lambda)\hat{e}_B+(kX-1)\frac{E}{b}}{kX}. \end{cases}$$

This function is continuous and N-shaped: It is strictly increasing in n_C^B in the first case, strictly decreasing in the second case and strictly increasing again in the third case.

Comparing the two peaks at $n_C^B = 2\frac{E}{b} - 1$ and $n_C^B = \frac{E}{b}$ yields that the bank's optimal project choice in this case is $n_C^B = 2\frac{E}{b} - 1$ if and only if

$$b \geq \frac{E\left(1 + \frac{k-\theta_B}{1-\theta_B} X\right)}{E - (1-\lambda)\hat{e}_B + \frac{k-\theta_B}{1-\theta_B} X}. \tag{11}$$

Note that $\frac{1+\frac{k-\theta_B}{1-\theta_B}X}{E-(1-\lambda)\hat{e}_B+\frac{k-\theta_B}{1-\theta_B}X} = \frac{1+kX-\frac{\theta_B(1-k)}{1-\theta_B}X}{E-(1-\lambda)\hat{e}_B+kX-\frac{\theta_B(1-k)}{1-\theta_B}X} > \frac{1+kX}{E-(1-\lambda)\hat{e}_B+kX}$, which implies that the set of b in Case A for which the bad bank's optimal choice is $n_C^B = \frac{E}{b}$ is non-empty.

Case B: $b \leq \frac{E(1+kX)}{E-(1-\lambda)\hat{e}_B+kX}$. Then bank B's value is

$$\Pi_B(n_C^B) = \begin{cases} E - e + (kX-1)\left(1-\frac{E}{b}\right) & \\ \qquad +(\theta_B X - 1)n_C^B, & \text{if } n_C^B \leq E - (1-\lambda)\hat{e}_B + (kX-1)\left(1-\frac{E}{b}\right); \\ \theta_i\left(E - \hat{e}_B + (kX-1)\left(1-\frac{E}{b}\right)\right. & \text{if } E - (1-\lambda)\hat{e}_B + (kX-1)\left(1-\frac{E}{b}\right) < n_C^B \\ \qquad \left. +(X-1)n_C^B\right), & \qquad \leq 2\frac{E}{b} - 1; \\ \theta_i\left(E - \hat{e}_B + (kX-1)\frac{E}{b}\right. & \\ \qquad \left. +X(1-k)n_C^B\right), & \text{if } n_B^R > 2\frac{E}{b} - 1. \end{cases}$$

Again, the bank's value is continuous. However, it is now strictly increasing in n_C^B throughout, so that we can directly conclude $n_C^B = \frac{E}{b}$ in this case.

Summary: The conclusion of the analysis of Cases A and B above is that, assuming that the good bank chooses an all-uncorrelated portfolio, the bad bank's optimal project choice is $n_U^B = 1 - \frac{E}{b}$ and $n_C^B = 2\frac{E}{b} - 1$ if (11) holds, and $n_U^B = 0$ and $n_C^B = \frac{E}{b}$ otherwise. ■

D Proof of Proposition 4

Due to Assumption 2, the optimal regulation is either $\max\{\hat{b}_G(1), \hat{b}_R(1)\}$ or $\text{argmax}_{\hat{b}_G(0) \leq b \leq \hat{b}_B(1)} SW_{iii}^C(b)$, whichever yields the higher $SW^C(b)$. Note that

$$\text{argmax}_{\hat{b}_G(0) \leq b \leq \hat{b}_B(1)} SW_{iii}^C(b) \subset \{\hat{b}_G(0), b_{iii}^o, \hat{b}_B(1)\},$$

and it is equal to $\hat{b}_G(0)$ if $\hat{b}_G(0) < b_{iii}^o$, and equal to $\hat{b}_B(1)$ if $b_{iii}^o < \hat{b}_B(1)$. Hence, Part (a) follows immediately.

Parts (b)-(d) then deal with the three aforementioned cases in which $\text{argmax} SW^C(b) = \text{argmax}_{\hat{b}_G(0) \leq b \leq \hat{b}_B(1)} SW_{iii}^C(b)$ one by one, the conditions for each cases being (i) the condition for the respective maximum of $SW_{iii}^C(b)$ as just explained, and (ii) the condition that $SW_{iii}^C(b)$ at this local maximum is larger than the local maximum for $b \geq \max\{\hat{b}_G(1), \hat{b}_R(1)\}$. ■

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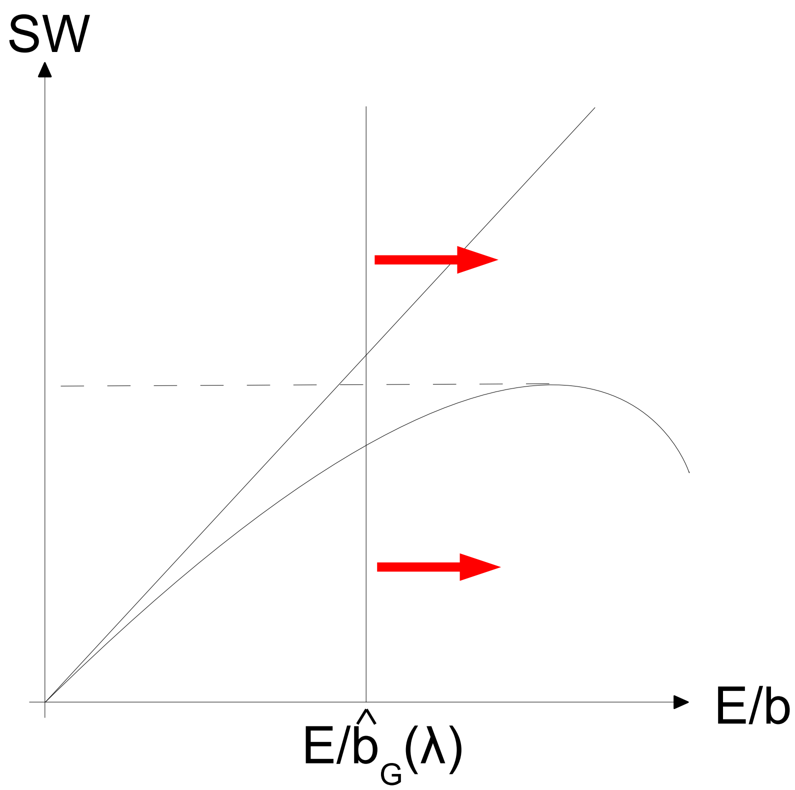

Figure 1: Abundant Supply of Projects: Maximum Mandatory Deferral of Compensation in a Risk-Free Banking Sector

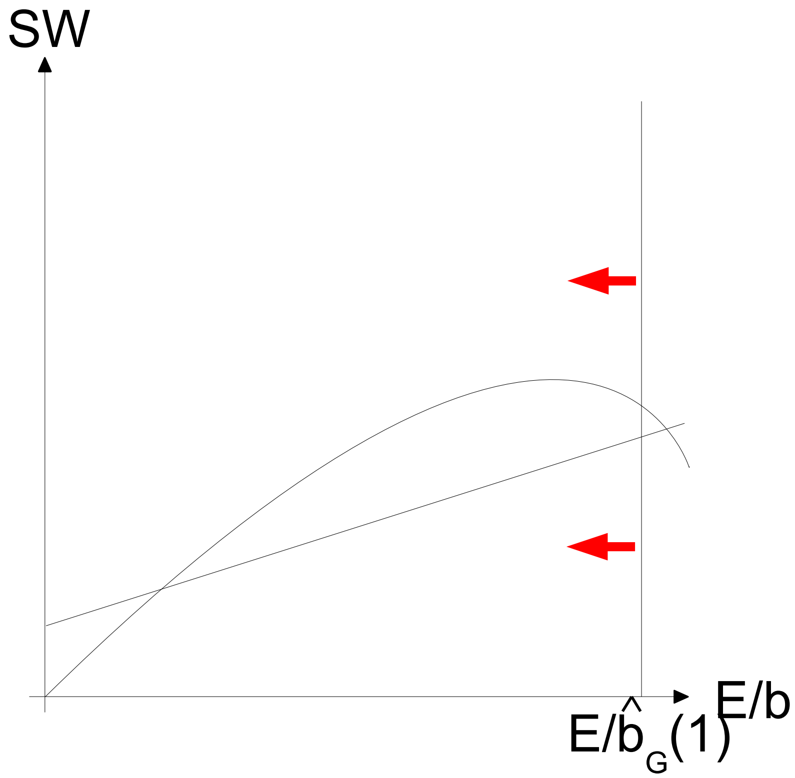

Figure 2: Competition for Uncorrelated Projects: Misallocation of Projects in a Risk-Free Banking Sector

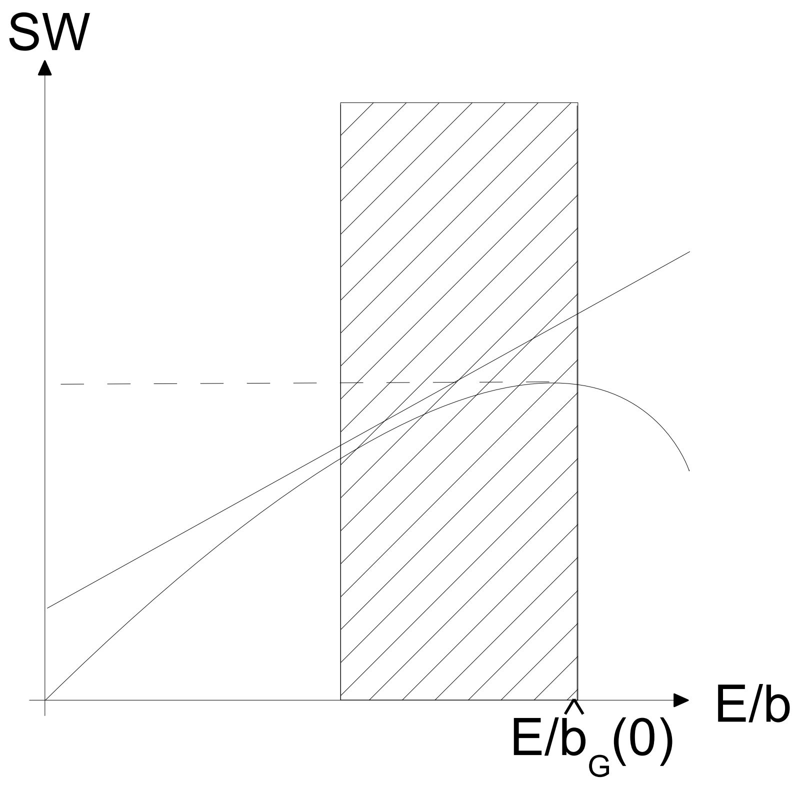

Figure 3: Competition for Uncorrelated Projects: Misallocation of Projects with Default Risk