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Abstract: This paper discusses the relationship between bank size and risk-taking under Pillar I of the New Basel Capital Accord. Using a model with imperfect competition and moral hazard, we find that small banks (and hence small borrowers) may profit from the introduction of an internal ratings based (IRB) approach if this approach is applied uniformly across banks. However, the banks' *right to choose* between the standardized and the IRB approaches unambiguously hurts small banks, and pushes them towards higher risk-taking due to fiercer competition. This may even lead to higher aggregate risk in the economy.

Keywords: Basel II, IRB approach, bank competition, capital requirements, SME financing.

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1 Introduction

Even before its implementation, the Basel II accord has come under fire by both academics and politicians. The critique by academics centers on the inability of the new accord to control aggregate risk because it neglects the endogeneity of risk and tends to have procyclical effects (see, e. g., Daníelsson, Embrechts, Goodhart, Keating, Muennich, Renault, and Shin (2001)). In contrast, politicians are more worried about the potential consequences of the new accord for the provision of credit, most notably to small- and medium-sized enterprises (SMEs). This even led to an amendment of the accord, which now has special provisions for loans to SMEs.

Our paper describes a novel channel through which the new capital regulation (Pillar I of the new Basel accord) may harm especially small banks—and hence their borrowers who tend to be small as well—, and thereby lead to an increase in aggregate risk. Interestingly, this result does not follow from the implementation of the internal ratings based (IRB) approach as such, but rather from the banks' *right to choose* between the standardized and the IRB approaches. In fact, in our model the introduction of an IRB approach can be beneficial to small banks, if it is applied uniformly to all banks and the fixed costs of implementation are small.

The problem arises from the implicit asymmetric treatment of small and large banks by the new regulation: The implementation of the IRB approach requires large initial investments in risk management technologies, which may deter small banks from choosing the IRB approach. In that case, only large banks profit from the reduction in capital requirements (and hence marginal costs) for safe loans in the IRB approach. This gives them a competitive advantage compared to small banks. In our model, this may lead to reduced market shares and higher risk-taking at the small banks due to fiercer competition in the market for deposits, and to an increase in aggregate risk in the economy. If small banks are specialized in extending loans to small firms, the shrinking market shares of small banks imply a cutback in the lending to these borrowers, especially to the more creditworthy ones among them.[1]

There exists by now a large literature on the new Basel Accord. Most empirical papers (too many to be reviewed here) deal with the question whether the new accord assigns the correct risk weights to different risk groups. We will abstract from this issue here by assuming that the risk weight functions are "correct." Several theoretical papers deal with the potentially adverse macroeconomic effects of Basel II, especially with its procyclicality and its neglect of the endogeneity of financial risk (see, e. g., Lowe (2002), Kashyap and Stein (2004), and Daníelsson, Shin, and Zigrand (2004)). Similar to those papers, we are interested in the implications of the new accord for the aggregate risk in the economy (but in a static setup). A paper

[1] It is now widely accepted that small banks have a competitive advantage in extending relationship loans based on soft information to opaque borrowers, whereas large banks have an advantage in granting loans based on hard information to transparent borrowers. See Berger and Udell (2002) and Stein (2002) for theoretical arguments, and Haynes, Ou, and Berney (1999), Berger, Miller, Petersen, Rajan, and Stein (2002), Carter and McNulty (2004), and Cole, Goldberg, and White (2004) for empirical evidence using U. S. data.

by Decamps, Rochet, and Roger (2004) is the only one to analyze the interactions between the three pillars of the new accord. In contrast, we focus on pillar I, the new capital regulation.

The papers most closely related to ours are the ones by Rime (2003) and Repullo and Suarez (2004) who analyze the implications of the co-existence of the standardized and the IRB approaches for banks' risk choices. Both papers argue that banks eligible for the IRB approach have a competitive advantage in the provision of low-risk loans (due to the lower capital requirement in the IRB approach), while the less sophisticated banks have a competitive advantage in the provision of high-risk loans (where the capital requirement is lower in the standardized approach). This situation leads to a sorting of borrowers in the sense that high risks tend to be financed by unsophisticated banks, and low risks by sophisticated banks.[2]

Our paper makes a different, and complementary, point by starting from a setup that differs from those of Rime and Repullo and Suarez in several important respects. First, there are no moral hazard effects in their models. Their results are entirely driven by the cost differentials from the two regulatory approaches. In our model, we emphasize moral hazard effects because we believe that one of the main purposes of capital requirements is the provision of incentives for prudent bank behavior. Second, the other two papers model bank competition in the loan market, and ignore competition on the liabilities side. In both models, it is crucial that borrowers are actually able to switch between banks. In contrast, we model competition on the liabilities side of banks' balance sheets, and ignore competition for loans by assuming that banks serve different clienteles in their loan business. The large empirical literature on relationship versus transactions loans, cited above, suggests that such an assumption is appropriate for the case relevant in our model, namely the competition between large and small banks. In a context similar to ours, Berger (2004) presents additional empirical evidence on this phenomenon. We assume, however, that large and small banks draw from a similar pool of deposits or other refinancing. Finally, we also consider the effects of regulation on *aggregate* risk-taking in the economy.

The purpose of our paper is not to model the effects of capital regulation as such. This has been done, for example, by Repullo (2004) in a more sophisticated way (see also Hellmann, Murdoch, and Stiglitz (2000)). Instead we employ a simple framework that yields reasonable predictions on the effects of capital regulation; then we analyze the effect of the coexistence of the standardized and the IRB approaches in this setup. Our model assumptions are similar to the ones by Repullo. However, there also are a number of differences: First, Repullo uses a dynamic framework to explicitly model franchise values. Second, deposits are fully insured in his model, but not in ours, such that deposit rates depend on the riskiness of investments in our model. Finally, Repullo focuses on symmetric equilibria whereas we also analyze asymmetric outcomes. It is reassuring that, in spite of the differences in modelling

[2] Repullo and Suarez (2004) add an interesting quantitative analysis where they simulate the effects of Basel II on loan rates and quantify the social costs of bank failures needed to justify the actual IRB capital requirements.

assumptions, our model yields similar predictions on the effects of flat and risk-based capital requirements as Repullo's model, at least for the symmetric cases.

Another paper related to ours is by Berger (2004) who empirically assesses the competitive effects caused by the preferential treatment of SME loans in the IRB approach. Our theoretical idea could also be applied to this more specific issue because it also implies a difference in capital requirements (and hence marginal costs) across different bank groups. Note, however, that our main interest is in the asymmetric treatment of banks due to the right to choose between the standardized and the IRB approaches, which may be quantitatively much more important than the "carve-out" on SME loans. Consistent with our assumption above, Berger concludes that the competitive effects in the loan market are likely to be small because large and small banks tend to make different kinds of SME loans. However, our analysis suggests that it may not be sufficient to consider competitive effects on the loan market to fully assess the implications of the special provisions for SME loans.

In the next section, we describe the features of the New Basel Capital Accord that are relevant for our theoretical model. Section 3 contains the setup of the model. In section 4, we analyze a banking sector where all banks are regulated according to the standardized approach. Section 5 turns to the IRB approach. We first show what happens when all banks are required to adopt the internal ratings based approach. Then we analyze the case where banks can choose between the standardized and the IRB approaches. Section 6 concludes.

2 The New Basel Capital Accord

Our analysis focuses on one particular—and arguably the most important—aspect of the New Basel Capital Accord: the enhancement of risk sensitivity of capital requirements for credit risk.[3] Instead of the broad risk categories defined in the 1988 Basel Accord, the new accord envisions that capital requirements should depend directly on the debtors' ratings, both external and internal. However, the information requirements are so high that only a subset of banks will be able to provide the necessary information in a reliable way. Therefore, the new accord offers banks the right to choose between a *Standardized Approach* and an *Internal Ratings Based (IRB) Approach*.[4] Within the IRB Approach, banks can opt for a Foundation or an Advanced IRB Approach, differing with respect to the extent that internal information is fed into the risk weight functions specified by the Accord.

As in the old accord, banks are required to have a capital ratio of at least 8 percent. The capital ratio is defined as the regulatory capital divided by risk-weighted assets.

[3]A detailed description of the new accord can be found in Basel Committee on Banking Supervision (2004).

[4]A similar right to choose already existed in the old Basel accord, namely in the treatment of market risk, where banks can choose between an internal models approach and a standardized method. Now this is extended to the treatment of credit risk.

The modifications in the new accord mostly affect the definitions of risk weights in the denominator of the capital ratio. In the model, we will not distinguish between regulatory capital and equity. Also, instead of defining risk weights, we will use the effective capital requirements implied by such weights. For example, a risk weight of 75 percent would translate into an effective capital requirement of 6 percent.

The *Standardized Approach* is very similar to the old Basel Accord. Assets are grouped into different supervisory categories, giving rise to different risk weights. In contrast to the old accord, the standardized approach recommends the use of external ratings, if they exist, and specifies different risk weights for different rating classes; in most other cases, the risk weight is 100 percent. For a large part of corporate loans, especially to SMEs, there hardly exist any external ratings in many countries, so the 100 percent weight applies to them (as it did in the old accord).[5] Similarly, there exist no external ratings for retail exposures; however, these loans are now subject to reduced risk weights of only 75 percent. In our model, we will assume that no external ratings are used in case of the standardized approach. This is similar to the simplified standardized approach (Basel Committee on Banking Supervision (2004, Annex 9)). Also, we will not distinguish between corporate and retail exposures. Hence, the minimum capital requirement is flat with regard to the riskiness of loans in our model. Because of the similarity of the standardized approach and the old regulation, we will treat them as identical.

In the *IRB Approach*, risk weights depend directly on external and internal assessments of asset risk. Banks estimate risk characteristics, such as the probability of default, on the basis of their internal data. These estimates then serve as inputs for the risk weight formulas specified by the Basel Committee. Retail exposures carry much smaller risk weights than corporate exposures. In our model, we define different capital requirements for different risk classes of assets, where the requirement for safe assets is below, and the one for risky assets is above the flat requirement in the standardized approach. This is in line with the objective of the Basel Committee to broadly maintain the aggregate level of minimum capital requirements (see Basel Committee on Banking Supervision (2004, paragraph 14)). It is not clear, however, whether this statement refers to the initial portfolio structure, or to the one after portfolio adjustments in reaction to the new accord.

Note that both approaches contain special provisions with respect to SME lending: First, loans to SMEs can under certain conditions be categorized as retail loans in both approaches, benefitting from smaller capital requirements. In addition, the IRB Approach allows for a firm-size adjustment for exposures to SMEs, which also reduces capital requirements.[6] Hence, SME lending is favored especially in the IRB approach, which reinforces the asymmetric treatment of large and small banks in the new accord (see Berger (2004) for an empirical analysis of this issue).

[5] An exception are the United States where many corporate borrowers are rated. However, the standardized approach is not going to be implemented in the U. S., but will be replaced with the rules from the old Basel accord.

[6] The illustration in the official documentation suggests that the firm-size adjustment reduces capital requirements by 20 to 25 percent.

Finally, the New Basel Accord contains a long list (51 paragraphs!) of minimum requirements that a bank has to fulfill to be eligible for the IRB Approach. Therefore, the introduction of the IRB Approach requires high fixed costs (e.g. for the installation of a sophisticated risk management system), which may deter smaller and less sophisticated banks from using the IRB Approach. In addition, the lack of sufficient historical data may make the use of the IRB Approach unfeasible for smaller banks. In both cases, small banks would not benefit from the decrease in capital requirements for relatively safe exposures. This paper analyzes how this asymmetric treatment of large and small banks affects banks' risk-taking and performance, as well as the aggregate risk in the economy. Note that our results do not hinge on the specific modelling details of the regulation. The main effect is driven by the combination of fixed costs and reduced marginal costs in the new regulation. Our specification is meant to model these features in the simplest way.[7]

3 Model Setup

Banks Consider an economy with $n+1$ chartered banks and no entry of new banks. The banks have limited liability and are risk neutral. They collect deposits and equity, and can invest these funds in one risky project. There are two types of projects that each bank can choose from. The "safe" project yields y_1 with probability p_1, and zero otherwise. The "risky" project returns y_2 with probability p_2, and zero otherwise. Assume that $p_1\,y_1 > p_2\,y_2$; hence, an investment in the safe project is efficient. Assume also that $y_2 > y_1$, so that there is scope for the typical risk-shifting problem à la Stiglitz and Weiss (1981).

There are two types of banks, large banks (L) and small banks (S). For simplicity, we assume that there is only one large bank. Introducing more than one large bank would weaken the competitive position of the large bank, but would leave the general structure of the model unchanged. The large bank competes with all small banks for deposits, whereas the small banks compete only with the large bank, but not with other small banks. This is to capture the idea that small banks operate in isolated local markets where they compete with large banks maintaining a branch at the same location, but not with small banks from other locations. Such a structure simplifies the calculations considerably, because one can analyze each local market separately.

There is imperfect competition in the deposit market. Specifically, the supply of deposits takes the following form,

$$d_L = D_L + n\,\sigma\,(r_L - r_S) \quad \text{and} \quad d_S = D_S/n + \sigma\,(r_S - r_L). \tag{1}$$

[7] The exact implementation of the new Basel Accord may differ across jurisdictions. In Europe and Japan, the new accord will probably be applied to all banks in their jurisdictions. In the United States, however, the largest banks will be required to switch to the Advanced IRB approach, whereas all other banks may remain in the old Basel I regulation or switch to the Advanced IRB approach. Even in such a situation, our main argument remains valid unless the largest banks would have preferred to stick to Basel I.

The deposit volume d_j supplied to a bank of type j depends on the *expected* (gross) returns for depositors, r_j, relative to the expected returns of the competitor bank. We implicitly assume that depositors are risk neutral and care about expected returns only. If, for example, depositors expect a bank to invest in the safe project, the relationship between the expected and the nominal rate is $r_j = p_1 \, r_j^{\text{nom}}$, or equivalently $r_j^{\text{nom}} = r_j / p_1$.

D_L and D_S/n can be thought of as the banks' clienteles. If two competing banks set identical deposit rates, their supplies of deposits are just their clienteles. The parameter σ measures depositors' interest rate sensitivity, and hence the intensity of competition in the deposit market. If σ is small, depositors are reluctant to switch banks even in the presence of relatively big interest rate differentials, and banks nearly enjoy monopolies with respect to their clienteles. If σ is large, depositors are very sensitive to interest rates, and the deposit market is rather competitive. Note that the aggregate supply of deposits is completely inelastic and equal to $D_L + D_S$. Deposit rates determine only how the aggregate supply is distributed among banks; they do not affect the aggregate supply. This means that any amount of deposits gained by one bank must be lost by another. Without loss of generality, we set $D_L + D_S = 1$, so that we can interpret d_L and d_S not only in absolute terms (deposit volumes), but also in relative terms (market shares). Furthermore, assume that $D_L > D_S$; the clientele of the large bank is larger than that of small banks.

The supply functions in (1) could be motivated by a model with spatial competition à la Hotelling (1929), with transportation costs that are inversely proportional to σ. Because the parameters for all small banks are identical, we do not have to distinguish between them (as long as they play pure strategies).[8]

In addition to deposits, banks can finance their lending activities through equity, k_j. Equity is provided by a single shareholder who demands an expected return of $r_k > p_1 \, y_1$. Equity finance is inefficient, but it may be used for regulatory purposes. Such an assumption has become standard in the literature (see e. g. Hellmann, Murdoch, and Stiglitz (2000) and Repullo (2004)). We assume that depositors cannot observe the amount of equity taken in by their bank, so that banks cannot use their equity as a signal for project quality.[9]

Capital Adequacy We analyze two different regulatory approaches.

1. The *standardized approach* does not distinguish between projects with different risk levels. A fraction of at least α of a bank's assets must be financed by equity.

[8] We ignore the depositors' participation constraints. If deposit rates are low, depositors may choose to stay at home (and save on transportation costs) rather than bring their money to the bank. We implicitly assume that depositors have to invest their money at a bank.

[9] If depositors could observe k_j, a bank would have an incentive to take enough equity to convince depositors that it will take the safe project. As a consequence, there would be no reason for banking regulation. Assuming that k_j is unobservable is a consistent way to leave some scope for regulation.

Figure 1: Time Structure

- Banks choose regulatory approaches and announce deposit rates, r_j.
- Banks first collect deposits, d_j, then equity, k_j. The depositors and the shareholder anticipate the project choices of banks.
- Banks choose projects and invest.
- Projects mature. If the projects are successful, banks repay debt and equity; otherwise, they default and repay nothing.

Hence, a bank's balance sheet must satisfy the regulatory constraint

$$k_j \geq \alpha\,(d_j + k_j),$$

where $d_j + k_j$ is the amount invested in risky assets.

2. The *internal ratings based (IRB) approach* distinguishes between different risk classes. The regulatory constraint is

$$k_j \geq \beta_1\,(d_j + k_j), \tag{2}$$

if the bank chooses the safe project, and

$$k_j \geq \beta_2\,(d_j + k_j), \tag{3}$$

if the bank chooses the risky project, where $\beta_2 > \alpha > \beta_1$. This specification implicitly assumes that the regulator can observe the riskiness of banks' assets, or at least that the regulator can set incentives for banks to truthfully report the level of their risk.[10] Finally, the IRB approach requires a sophisticated internal risk management, entailing a non-monetary fixed cost of C.

Figure 1 displays the time structure of the model. In the following, we will characterize the equilibria of the model under different types of capital regulation.

4 The Standardized Approach

In this section, we assume that all banks must adopt the standardized approach.

[10] At first sight, this assumption may seem unappealing. Why, then, does the regulator not simply prohibit banks from taking risky projects? The reason is that risky projects are not necessarily inefficient, and that banks are typically better than regulators in choosing the optimal risk-return ratio of their projects. Therefore, risky projects should not be banned completely.

4.1 Risk Choices of Banks

In this model, there is a simple decision rule concerning banks' project choices. A bank will choose the risky project if and only if expected returns on deposits exceed a critical deposit rate, r^{crit}. If a bank collects d units of deposits and k units of equity, it can invest $d+k$ in risky assets. The index j is omitted when there is no danger of confusion. If the bank offers an expected return of r, the bank's nominal debt amounts to $d\,r/p_1$, given that depositors anticipate the bank to take the safe project. Since equity cannot be used as a signal, regulatory constraints will always bind, $\alpha = k/(d+k)$ and $1-\alpha = d/(d+k)$.

If depositors anticipate the bank to choose the safe project and the shareholder obtains a fraction δ_1 of profits, the expected profits of the bank are, net of repayments to the debt and equity holders,

$$\Pi^1 = (1-\delta_1)\, p_1\, (y_1\, (d+k) - r\, d/p_1), \tag{4}$$

given that the bank chooses the safe project as anticipated by their depositors. If, however, depositors anticipate the bank to choose the safe project and the bank opts for the risky project, expected profits are

$$\Pi^2 = (1-\delta_1)\, p_2\, (y_2\, (d+k) - r\, d/p_1).$$

The critical expected return that equalizes Π^1 and Π^2 is

$$r^{\text{crit}} = \frac{d+k}{d}\, p_1\, \frac{p_1\, y_1 - p_2\, y_2}{p_1 - p_2} = \frac{p_1}{p_1 - p_2}\, \frac{p_1\, y_1 - p_2\, y_2}{1-\alpha}. \tag{5}$$

If the shareholder anticipates that the bank takes the safe project, the expected payment to him amounts to

$$k\, r_k = \delta_1\, (p_1\, y_1\, (d+k) - r\, d),$$

yielding an expected return of r_k, if the bank indeed chooses the safe project. Solving for δ_1 and substituting into (4), we get

$$\Pi^1 = (d+k)\, p_1\, y_1 - r\, d - k\, r_k.$$

Considering further that $k = d\,\alpha/(1-\alpha)$ implies

$$\Pi^1 = d\left(\frac{p_1\, y_1 - \alpha\, r_k}{1-\alpha} - r\right).$$

Following the same procedure for the case of the risky project and combining the two profit functions, we get expected profits of

$$\Pi = d\left(\frac{p_i\, y_i - \alpha\, r_k}{1-\alpha} - r\right), \tag{6}$$

with $i = 1$ (safe project) for $r \le r^{\text{crit}}$ and $i = 2$ (risky project) for $r > r^{\text{crit}}$.

Capital adequacy has two effects on the profitability of banks. First, for a given project choice, it deteriorates profitability, because the bank is forced to refinance itself through expensive equity. In general, part (but not necessarily all) of this cost is going to be shifted to depositors in the form of reduced deposit rates. Second, a higher α increases the critical deposit rate r^{crit}. If this induces a single bank to take the efficient project where it otherwise would have chosen the inefficient one, profitability is enhanced. In that case, the capital regulation is beneficial for the bank because it allows the bank to commit to the safe project and thus avoid higher refinancing costs.

4.2 Reaction Functions of Banks

We start with the analysis of a single bank (without loss of generality, the large bank) in a specific local market. If competition is weak and deposit rates are low, moral hazard is not a problem, and the large bank will choose the safe project. We will establish constraints on σ afterwards. Substituting (1) into (6) yields

$$\Pi_L^1 = \big(D_L + n\,\sigma\,(r_L - r_S)\big)\left(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r_L\right).$$

The first order condition implies

$$r_L = \frac{1}{2}\left(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} + r_S - \frac{D_L}{n\,\sigma}\right). \tag{7}$$

The bank's expected profits are then

$$\Pi_L^1 = \frac{n\,\sigma}{4}\left(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r_S + \frac{D_L}{n\,\sigma}\right)^2,$$

and its market share is

$$d_L = \frac{n\,\sigma}{2}\,\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} + \frac{D_L - n\,\sigma\,r_S}{2}.$$

When the competitor's rate r_S rises, the bank reacts by also offering higher rates (see (7)). At some point r_S^{kink}, it reaches the critical rate with $r_L = r^{\text{crit}}$,

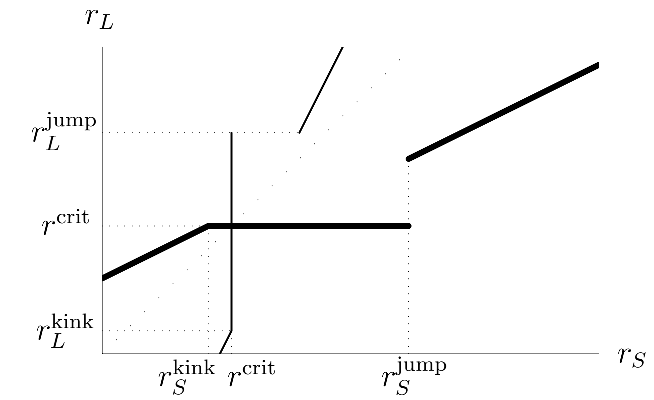
$$r_S^{\text{kink}} = 2\,r^{\text{crit}} + \frac{D_L}{n\,\sigma} - \frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha}.$$

When r_S rises further, the bank does not immediately offer higher deposit rates, but it continues to offer r^{crit} (hence the kinks in figure 2). Otherwise, depositors would anticipate that the bank will choose the risky project and demand a higher default premium. The bank's market share is now simply $d_L = D_L + n\,\sigma\,(r^{\text{crit}} - r_S)$.

However, at some point r_S^{jump}, market rates are so high that the bank prefers to raise its rate, thereby admitting that it will take the risky project, but "regaining" some volume. After this point, the bank sets a deposit rate of

$$r_L = \frac{1}{2}\left(\frac{p_2\,y_2 - \alpha\,r_k}{1-\alpha} + r_S - \frac{D_L}{n\,\sigma}\right).$$

Figure 2: Reaction Functions



Here and in the following figures, parameters are $y_1 = 2$, $p_1 = 2/3$, $y_2 = 3.5$, $p_2 = 1/3$, $\alpha = 1/10$, $r_k = 3/2$, $D_L = 3$, $D_S = 2$, and $\sigma = 3/4$. The thick curve is the reaction function of the large bank, the thin curve is that of small banks.

The nominal rate is then r_L/p_2. The regime switch occurs when expected profits of the bank are equal in both regimes,

$$\big(D_L + n\,\sigma\,(r^{\text{crit}} - r_S)\big)\left(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r^{\text{crit}}\right) = \frac{n\,\sigma}{4}\left(\frac{p_2\,y_2 - \alpha\,r_k}{1-\alpha} - r_S + \frac{D_L}{n\,\sigma}\right)^2.$$

At the critical r_S^{jump}, the deposit volume of the bank must jump up: An infinitesimal increase in the deposit rate leads to a strictly positive deterioration in refinancing conditions, hence the benefit must also be strictly positive. This can only be achieved by a jump of expected deposit rates.

Summing up, the large bank's reaction function is

$$r_L = \begin{cases} \frac{1}{2}\Big(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} + r_S - \frac{D_L}{n\,\sigma}\Big) & : \quad r_S \le r_S^{\text{kink}}, \\ r^{\text{crit}} & : \quad r_S^{\text{kink}} < r_S \le r_S^{\text{jump}}, \\ \frac{1}{2}\Big(\frac{p_2\,y_2 - \alpha\,r_k}{1-\alpha} + r_S - \frac{D_L}{n\,\sigma}\Big) & : \quad r_S^{\text{jump}} < r_S. \end{cases}$$

The reaction functions of small banks have an analogous form. Figure 2 depicts the reaction functions of both bank types for a numerical example.

4.3 Equilibrium

The equilibrium lies at the intersection of the reaction functions. Given the geometric structure of those functions, there is at least one equilibrium. However, as is also clear from the picture, the intersection may not be unique. For example, all banks may take the safe project (with deposit rates below the jump) in one equilibrium, whereas they may all take the risky project (with deposit rates above the jump) in another equilibrium. In such cases, we pick the Pareto-superior equilibrium with the lower deposit rates.

Banks' behavior can be characterized by a number of regimes, differing with respect to the banks' risk-taking and deposit rate policies. It depends on the intensity of competition in which regime the banks find themselves. In our discussion, we start from a regime with low competition (small σ) and then consider what happens if σ is increased. Figure 3 illustrates the effects of competition on banks' deposit rates, volumes, profits, and on welfare. We first discuss banks' deposit rates and risk-taking, before turning to banks' profits and to welfare.

Regime 1: All banks below the kink When both types of banks are below the kink, moral hazard is not a problem, and all banks choose the safe project. Equilibrium deposit rates are

$$r_L = \frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - \frac{D_L}{n\,\sigma} + \frac{D_L - D_S}{3\,n\,\sigma}, \tag{8}$$

$$r_S = \frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - \frac{D_S}{n\,\sigma} - \frac{D_L - D_S}{3\,n\,\sigma}. \tag{9}$$

As equilibrium deposit volumes, we obtain

$$d_L = D_L - \frac{D_L - D_S}{3},$$
$$d_S = D_S + \frac{D_L - D_S}{3\,n},$$

hence volumes do not depend on competition σ. Expected profits are

$$\Pi_L = \frac{1}{9\,n\,\sigma}\big(2\,D_L + D_S\big)^2 \quad \text{and} \quad \Pi_S = \frac{1}{9\,n\,\sigma}\big(2\,D_S + D_L\big)^2.$$

In equilibrium, small banks set deposit rates more aggressively than large banks ($r_S > r_L$) in order to attract market share. When competition increases (σ rises), both types of banks increase their deposit rates.

Regime 2: Small banks above the kink At some point the small banks, offering the higher rate, are going to reach the critical rate r^{crit}. They know that if they raised deposit rates further, depositors would anticipate that the bank chooses the inefficient project and demand an additional default premium. Therefore, small banks optimally leave their rates unchanged, foregoing some market share. This weakens competition for the large bank, who now sets a lower rate than it would in the absence of the moral hazard problem. However, as long as its deposit rate is below r^{crit}, the large bank increases its deposit rate as σ rises, albeit less strongly than before. Formally, deposit rates are given by

$$r_L = \frac{1}{2}\Big(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} + r^{\text{crit}} - \frac{D_L}{n\,\sigma}\Big),$$
$$r_S = r^{\text{crit}},$$

and market shares by

$$d_L = \frac{D_L}{2} + \frac{n\,\sigma}{2}\left(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r^{\text{crit}}\right),$$
$$d_S = \frac{D_L + 2\,D_S}{2\,n} - \frac{\sigma}{2}\left(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r^{\text{crit}}\right).$$

Now the large bank grows with increasing competition, the small banks shrink.

Regime 3: All banks above the kink At some point, large banks also reach the critical rate r^{crit}.[11] In this case, both types of banks offer the same expected rate

$$r_L = r_S = r^{\text{crit}}.$$

The nominal rate is also identical because all banks take the safe project. Hence no bank can attract any customers from another bank, and deposit volumes are simply equal to the respective clienteles,

$$d_L = D_L \qquad \text{and} \qquad d_S = D_S.$$

Regime 4: Small banks above the jump At some point, it becomes profitable for small banks to raise deposit rates and opt for the risky project. Depositors at these banks now anticipate the risky project. Therefore, nominal rates must jump up to include the higher default premium. However, the small banks raise deposit rates even further to gain market shares. The large bank sticks to the lower deposit rate, thereby accepting a sharp decrease in its market share. So equilibrium rates are

$$r_L = r^{\text{crit}},$$
$$r_S = \frac{1}{2}\Big(\frac{p_2\,y_2 - \alpha\,r_k}{1-\alpha} + r^{\text{crit}} - \frac{D_S}{n\,\sigma}\Big), \tag{10}$$

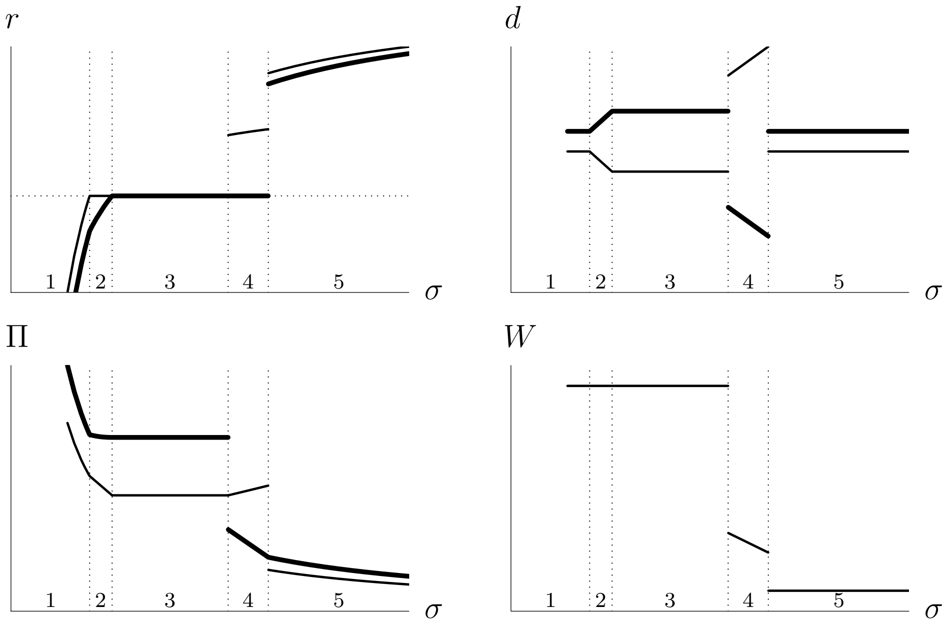
yielding the deposit volumes

$$d_L = \frac{2\,D_L + D_S}{2} - \frac{n\,\sigma}{2}\left(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r^{\text{crit}}\right),$$
$$d_S = \frac{D_S}{2\,n} + \frac{\sigma}{2}\left(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r^{\text{crit}}\right).$$

The increase in small banks' deposit rates may be so large that the large bank also finds it beneficial to raise its rate. In this case, regime 3 may directly be followed by regime 5 (see figure 4 for an illustration).

[11] If small and large banks are sufficiently asymmetric ($D_L \gg D_S$), or if the moral hazard problem is small ($p_1\,y_1 \approx p_2\,y_2$), it may happen that the small banks reach r^{jump} before the large bank reaches r^{crit}. This would give rise to an additional regime. We do not explicitly treat this regime in the paper because it does not provide any additional insights, but just makes the discussion more cumbersome.

Figure 3: Equilibrium Deposit Rates, Volumes, Profits, and Welfare



Thick lines denote the large bank, thin lines the small banks. For deposits and profits, *aggregate* amounts for the group of small banks are plotted. Numbers on the abscissa indicate regimes.

Regime 5: All banks above the jump Finally, even the large bank finds it profitable to raise deposit rates sharply and signal that it will take the risky project. From this point on, all banks take the risky project. The small banks react by raising deposit rates as well, but not as sharply as the large bank. Therefore, the small banks will lose some of the market share they had gained before. However, the small banks' rate continues to exceed the rate at the large bank.

Similar to (8) and (9), we obtain

$$r_L = \frac{p_2\, y_2 - \alpha\, r_k}{1-\alpha} - \frac{D_L}{n\,\sigma} + \frac{D_L - D_S}{3\,n\,\sigma},$$
$$r_S = \frac{p_2\, y_2 - \alpha\, r_k}{1-\alpha} - \frac{D_S}{n\,\sigma} - \frac{D_L - D_S}{3\,n\,\sigma}.$$

The expressions for deposit volumes and expected profits are the same as in regime 1 (but profits are much lower in this case due to higher competition and, hence, higher deposit rates).

We now discuss how banks' profits are affected by the different regimes (see the bottom left panel of figure 3). In general, increasing competition decreases profits. The reason is that banks have to offer higher interest rates to prevent their depositors from switching to another bank. Thereby they exert a negative externality on their competitors. In our model, this externality is very strong because of the inelastic aggregate supply of deposits; the qualitative result would still hold if the supply of deposits was elastic (but not perfectly).

However, in some regimes, the moral hazard problem prevents some banks from raising rates, which implies a drop in their market shares and profits if the competitor bank continues to raise rates. For example, in regime 4, large banks are prevented from offering higher rates, whereas small banks raise rates in response to higher competition. Even though this reduces small banks' margins, it may boost their profits due to the gains in market shares. Hence, in regime 4, small banks may actually *profit* from an increase in competition (see figure 3 for an example of this phenomenon). In this case, the large bank's deposit rate is a suboptimal response to the rate of the competitor bank, and the bank's profits decrease not only in absolute terms, but also relatively to the small bank. If both large and small banks are unwilling to raise rates (regime 3), an increase in σ leaves volumes, rates and profits unaffected.

Finally, we want to analyze the effects of competition on welfare (see the bottom right panel of figure 3). In our model, welfare consists of only two components: the proceeds from the project, and the opportunity costs from (inefficient) equity finance. The opportunity costs of depositors do not have to be taken into account because they are constant, given that the aggregate deposit volume is constant.[12] Interest payments are welfare-neutral. Hence, the welfare function is

$$\begin{aligned} W &= \sum_j \left[(p_j\, y_j)\, d_j - (r_k - p_j\, y_j)\, k_j\right] \\ &= \sum_j d_j\, \frac{p_j\, y_j - \alpha\, r_k}{1-\alpha}. \end{aligned}$$

The aggregate opportunity costs from equity finance (i. e. $r_k\,\alpha/(1-\alpha)$, since $D_L + D_S = 1$) do not depend on σ. Hence, welfare is affected through the banks' project choices alone. Welfare is highest (and constant) in regimes 1 to 3 when all banks choose the safe project, and lowest (and constant) in regime 5 when all banks choose the risky project. In regime 4, the banks choosing the risky project expand, such that welfare decreases in this regime. Welfare jumps discretely between the regimes 3 and 4, and 4 and 5, respectively, because at that point, one type of banks switches its entire portfolio from the safe to the risky project. Overall, welfare decreases in competition in our model. Hence, our model yields predictions similar to the literature on the trade-off between banking stability and competition.

4.4 The Impact of Capital Regulation

So far, we have been holding capital regulation constant. Now we ask how the banks respond to a tightening in capital adequacy. We first consider what happens *within* the regimes described in the preceding section. Then we discuss regime switches triggered by the tightened regulation.

[12]The assumption of a constant aggregate deposit volume facilitates the welfare analysis substantially. However, it also limits the generality of our welfare implications as will be discussed in the conclusion.

In regimes 1 and 5, tightened capital adequacy leaves deposit volumes and profits unaffected, but leads to the same decrease in deposit rates at small and large banks,

$$\frac{\partial r_L}{\partial \alpha} = \frac{\partial r_S}{\partial \alpha} = -\frac{r_k - p_1\, y_1}{(1-\alpha)^2} < 0.$$

This implies that the increase in the costs of equity finance is shifted entirely to the depositors in this regime, whereas the banks' profits are not affected by the regulation.

If only the small banks are above the kink (regime 2), tightened capital adequacy implies higher rates and volumes for the small banks,

$$\frac{\partial r_S}{\partial \alpha} = \frac{\partial r^{\text{crit}}}{\partial \alpha} = \frac{p_1}{p_1 - p_2}\,\frac{p_1\, y_1 - p_2\, y_2}{(1-\alpha)^2} > 0 \quad \text{and}$$
$$\frac{\partial d_S}{\partial \alpha} = \sigma\,\frac{p_1\,(r_k - p_2\, y_2) + p_2\,(r_k - p_1\, y_1)}{2\,(p_1 - p_2)(1-\alpha)^2} > 0.$$

The reason is that an increase in α raises r^{crit}, thereby relaxing the constraints on the small banks. By raising rates to the new r^{crit}, the small banks can attract more deposits and may increase their profits. Given the inelastic aggregate supply of deposits, the large bank must shrink. The effect on the large bank's deposit rate is ambiguous. On the one hand, the rate increase by the small banks induces the large bank to raise its rate as well. On the other hand, the investment becomes less profitable due to higher equity costs, which reduces competition for deposits and induces the large bank to decrease its rate. In any case, the large bank's profits may fall.

When both types of banks are above the kink, but below the jump (regime 3), a tightened regulation raises deposit rates for both types of banks,

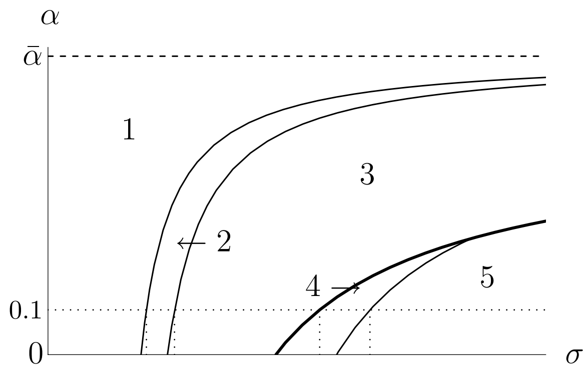
$$\frac{\partial r_L}{\partial \alpha} = \frac{\partial r_S}{\partial \alpha} = \frac{\partial r^{\text{crit}}}{\partial \alpha} > 0.$$

As before, the rise in the critical rate relaxes the constraints on banks. However, in this case the relaxation is not beneficial to the banks because they cannot attract any deposits from their competitors. Volumes remain unchanged, and profits of both types of banks decrease. The constancy of deposit volumes is a result of our assumption that deposit volumes are constant at the aggregate level. If we relaxed this assumption, volumes would increase in the presence of tightened regulation.[13] This result is interesting because it implies that a tightening of regulation may have an *expansionary* effect on the banking sector. The reason is that higher capital adequacy attenuates the moral hazard problem.

When markets are so competitive that small banks prefer to take the risky projects (regime 4), the effects of tightened capital regulation are the same as in regime 2, with reversed roles. The large bank will expand at the expense of small banks; the large bank will gain, the small banks will lose.

[13]However, profits may decrease even in the presence of an elastic aggregate supply of deposits.

Figure 4: Regimes for Varying α and σ, Standardized Approach



The numbers mark the areas of the different regimes as described in the text. The dotted horizontal line refers to $\alpha = 0.1$, the example used in the previous figures. The dashed line marks $\bar{\alpha} = p_1\, p_2\, (y_2 - y_1)/(p_1 - p_2)/r_k$ (here $\bar{\alpha} = 2/3$), above which only regime 1 exists.

The preceding discussion suggests that a tightening of capital requirements may lead to an expansion of one type of bank in certain cases. Of particular interest is regime 2, where small banks may expand in the face of tightened regulation. If one assumes that small banks are specialized in financing small and medium enterprises (SMEs), this result implies that the financing of SMEs is not necessarily choked by capital adequacy. In fact, the opposite may be true.

Note that in our model, a tightening of capital regulation always reduces welfare in the absence of regime switches. The reason is that higher capital adequacy increases the inefficiencies arising from equity finance, while leaving the aggregate level of deposits unchanged. If the aggregate supply of deposits were very elastic, welfare increases would be conceivable even without regime switches.

Within our model, welfare increases can only be obtained if the tightening of capital regulation induces a regime switch, rendering banks less likely to take the risky projects. Figure 4 illustrates this effect for a numerical example: Starting from a regime where one or both types of banks opt for the risky project (regimes 4 or 5), an increase in α eventually leads to a switch into a regime where both types of banks opt for the safe project (holding competition σ constant). The following proposition formalizes this result.[14]

Proposition 1 (Standardized Approach) *Higher capital requirements increase the critical levels of competition σ_S^{crit} and σ_L^{crit}, above which small and large banks choose the risky project, i. e. $\partial\sigma_S^{\text{crit}}/\partial\alpha > 0$ and $\partial\sigma_L^{\text{crit}}/\partial\alpha > 0$.*

Graphically, the proposition implies that the border between the area where all banks choose the safe project (regimes 1, 2, and 3) and the remaining area (regimes 4

[14] The proofs of propositions and remarks are found in the Appendix.

and 5), and the border between regimes 4 and 5 are strictly increasing (see figure 4). In fact, it is easy to show that the same is true for all other borders.

The proposition implies that higher capital requirements reduce the range of σ, for which at least one type of bank opts for the risky project (regimes 4 and 5). According to the following remark, this statement can be generalized to any other parameter of our model.

Remark 1 *Higher capital requirements weakly reduce the set of parameters for which at least one type of banks chooses the risky project.*

Hence, for *any* parameter of our model, the range of regimes 4 and 5 shrinks in reaction to an increase in α. The generality of this result is remarkable.

We can conclude that, in our model, the capital regulation always decreases welfare *within* regimes. However, tightened regulation may increase welfare because it may induce banks to switch from the risky to the safe project. The stricter the regulation, the more competitive markets must be to induce banks to take risky projects. If the net effect of higher inefficiencies from equity finance and lower risk-taking on welfare is positive, one may say that the capital regulation achieves its goal.

5 The IRB Approach

So far, we have discussed an economy in which all banks use the standardized approach. Now we turn to the IRB approach. We first consider what happens if all banks must adopt the IRB approach (Section 5.1). Then we analyze the implications of banks' right to choose between the two approaches, as envisioned by the new Basel accord (Section 5.2).

5.1 Compulsory IRB Approach

In this section, we assume that the IRB approach according to (2) and (3) is compulsory for all banks. What are the implications of switching from the standardized to the IRB approach? Clearly, the answer depends on whether the regulation has become stricter or looser. We assumed above that banks need less capital if they choose the safe project, compared to the standardized approach, and more capital if they choose the risky project, i. e. $\beta_1 < \alpha < \beta_2$. Note that our qualitative results are independent of how much β_1 lies below and β_2 above α.

Using the same procedure as in section 4.1, we derive the critical rate $\dot{r}^{\text{crit}}$. For distinction, we put a dot on variables that refer to the compulsory IRB approach. Here the assumption of a single shareholder becomes crucial. It implies that the equity investor can infer the bank's project choice from the amount of equity that the bank raises. Let Π^1 again denote the expected profits of a bank that chooses the safe project as anticipated by the depositors, and Π^2 the profits of a bank that deviates by taking the risky project. We then get

$$\begin{aligned} \Pi^1 &= (1-\delta_1)\,p_1\,(y_1\,(d+k_1) - r\,d/p_1) - C \quad \text{with} \\ k_1 &= \delta_1\,p_1\,(y_1\,(d+k_1) - r\,d/p_1)/r_k \end{aligned}$$

if the bank takes the safe project, and

$$\begin{aligned} \Pi^2 &= (1-\delta_2)\,p_2\,(y_2\,(d+k_2) - r\,d/p_1) - C \quad \text{with} \\ k_2 &= \delta_2\,p_2\,(y_2\,(d+k_2) - r\,d/p_1)/r_k \end{aligned}$$

if the bank deviates, yielding

$$\begin{aligned} \Pi^1 &= d\left(\frac{p_1\,y_1 - \beta_1\,r_k}{1-\beta_1} - r\right) - C, \quad \text{and} \\ \Pi^2 &= d\left(\frac{p_2\,y_2 - \beta_2\,r_k}{1-\beta_2} - \frac{p_2}{p_1}\,r\right) - C. \end{aligned}$$

The critical deposit rate is then

$$\dot{r}^{\text{crit}} = \frac{p_1}{p_1 - p_2}\left(\frac{p_1\,y_1 - r_k}{1-\beta_1} - \frac{p_2\,y_2 - r_k}{1-\beta_2}\right).$$

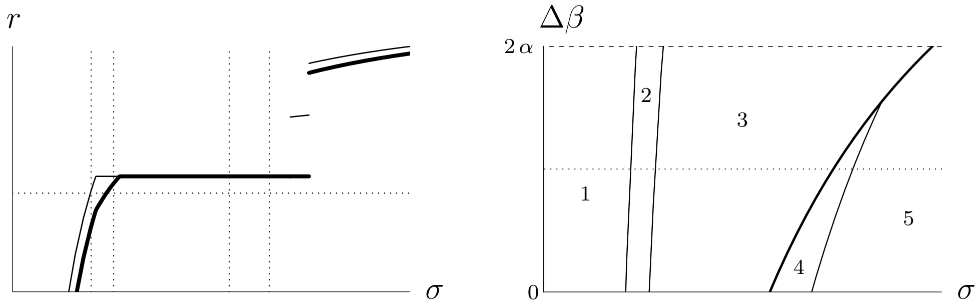
One can check that for $\beta_1 = \beta_2 = \alpha$, the critical rate is the same as in the standardized approach (see (5)). Comparative statics are $\partial\dot{r}^{\text{crit}}/\partial\beta_1 < 0$ and $\partial\dot{r}^{\text{crit}}/\partial\beta_2 > 0$. Raising β_1, while holding β_2 constant, lowers the relative costs of risk-shifting; raising β_2, while holding β_1 constant, increases them. Given our assumptions on β_1 and β_2, $\dot{r}^{\text{crit}}$ is strictly larger than r^{crit}.[15] In contrast to the standardized approach, the critical rate also depends on the cost of equity r_k, with $\partial\dot{r}^{\text{crit}}/\partial r_k > 0$. Higher costs of capital make risk-shifting less attractive. Fixed costs C are, of course, irrelevant for the marginal analysis and for risk-shifting.

The introduction of the IRB approach has two effects: First, it decreases the capital requirements for safe projects and increases them for risky projects. The effects are similar to the ones from a loosened or tightened capital regulation in the standardized approach. Second, it raises the critical rate. The qualitative properties of banks' reaction functions are just as under the standardized approach (see figure 2). As a result, we again have five regimes, depending on whether banks are below or above the kinks and the jumps of their reaction functions.

We start again by describing the behavior of banks within regimes, before discussing regime switches. If both types of banks are below the kink (regime 1), they will

[15] The fact that $\dot{r}^{\text{crit}}$ lies above (and possibly well above) r^{crit} is critical for the model when we introduce the right to choose between different regulatory approaches. If, for example, banks' deposit rates are constrained by r^{crit} (as in regime 3), they have an incentive to implement the IRB approach in order to overcome this constraint and raise rates, but not farther than $\dot{r}^{\text{crit}}$.

Figure 5: Equilibrium Deposit Rates and Regime Switches, IRB Approach



In the left panel, the thick line denotes the large bank, the thin line the small banks. Dotted vertical lines mark the regime switches in the *standardized* approach; the dotted horizontal line is the critical rate in the standardized approach. The right panel plots the critical σ's of the regime switches for varying $\Delta\beta = \beta_2 - \beta_1$. Here, we assume that β_1 and β_2 lie symmetrically around α. The dotted line refers to the parameter constellation of the left panel. The dashed line marks the maximal differentiation $\Delta\beta = 2\,\alpha$.

offer higher deposit rates. Lower capital requirements make the investment more profitable, hence the competition for deposits becomes more severe. The opposite is true when all banks are above the jump (regime 5). Here, because both types of bank take the risky project, capital adequacy is tightened, and deposit rates drop.

In regime 2, all banks raise their rates. Small banks raise their rates because the increase in the critical rate (from r^{crit} to $\dot{r}^{\text{crit}}$) relaxes the constraints on their deposit rate policies. The large bank also raises its rate, first, because the small banks raise their rates, and second, because investing becomes more profitable. However, the increase of the large bank is less pronounced than that of the small banks. This allows the small banks to "recapture" some market share from the large bank. Remarkably, this may even lead to increased profits at the small banks, implying that small banks may benefit from a transition from the standardized to the compulsory IRB approach. In contrast, the large bank shrinks, and its profits are always decreased compared to the standardized approach. These results are interesting because they appear to contradict the conventional wisdom that small borrowers are bound to suffer from the IRB approach. We see that small banks may actually gain relative to large banks from implementing the IRB approach. If we believe that small banks serve primarily small borrowers, our results suggest that the IRB approach may actually have an expansionary effect on SME borrowing.

In regime 3, all banks raise rates after the transition to the IRB approach because of the increase in the critical rate. This results in lower profits for both bank types. Finally, in regime 4, the large bank raises its rate because of the increase in the critical rate. The reaction of small banks is ambiguous. On the one hand, they want to raise rates in reaction to the large bank's rate increase. On the other hand, they want to cut rates because they are subject to a stricter capital requirement, β_2, rendering investment less attractive.

As before, we are interested most in whether the transition from the standardized to the IRB approach can deter banks from choosing the risky project. Figure 5 presents a numerical example. The left panel shows equilibrium deposit rates in the IRB approach for different levels of competition. For comparison, it also shows the levels of competition at which regime switches occurred in the standardized approach. Apparently, all regime switches move towards more competition. In the right panel, the critical σ's of the regime switches are plotted for varying $\Delta\beta = \beta_2 - \beta_1$, measuring the degree of differentiation by the IRB approach. The thick curve denotes the critical σ, above which at least one bank type chooses the risky project. The curve increases monotonically. Similarly, the border between regimes 4 and 5 increases monotonically. Hence, the more the IRB approach differentiates among risks, the more competitive markets must be to induce banks to choose the risky project. The following proposition states that these results are true for any parameter constellation. As before, the other borders increase as well. The proofs are analogous.

Proposition 2 (Compulsory IRB Approach) *A transition from the standardized to a compulsory IRB approach increases the critical levels of competition σ_S^{crit} and σ_L^{crit}, above which small and large banks choose the risky project, i. e. $\partial\sigma_S^{\text{crit}}/\partial\Delta\beta > 0$ and $\partial\sigma_L^{\text{crit}}/\partial\Delta\beta > 0$.*

Because switching to the risky project is more costly than under the standardized approach, both types will start to raise the rates (and signal that they will take the risky project) at a more competitive stage. Similar to the statement in remark 1, the transition from the standardized to a compulsory IRB approach weakly reduces the set of (any) parameters for which at least one type of bank takes the risky project.

Let us discuss the effects of the transition on welfare. Within the regimes, welfare is increased relative to the standardized approach if banks choose the safe project (regimes 1 to 3) because capital requirements are reduced. The opposite is true when both banks take the risky project (regime 5). In regime 4, the effect is ambiguous because capital requirements increase for one bank, but decrease for the other. In addition, welfare is increased relative to the standardized approach because the IRB approach is better at deterring banks from choosing the risky project than the standardized approach. However, banks have to incur fixed costs C under the IRB approach, which reduces welfare. In fact, these fixed costs may be so high that some banks are driven out of business. In our model, this would actually increase welfare, as long as the large bank stays in business.[16]

If the regulation is designed in a way that induces all bank types to opt for the safe project, and if fixed costs are not too high, the IRB approach is superior to the standardized approach in terms of welfare because it economizes on capital. Hence, we can conclude that the compulsory transition from the standardized to the IRB approach achieves its goal as long as the fixed costs C are not too high.

[16] The reason for this result is that there are no deadweight losses from monopolization, because the aggregate level of deposits is constant.

5.2 The Right to Choose

In the preceding section, we assumed that all banks have to adopt the IRB approach. However, the new Basel accord does not make such a prescription. Instead it allows banks to *choose* between the standardized and the IRB approaches. We will see that this right to choose fundamentally changes our assessment of the regulation.

Banks will opt for the IRB approach if this increases their profits, given the regulatory approaches and deposit rates of their competitor banks. If fixed costs C are so high that neither small nor large banks choose the IRB approach, we are back in the case of section 4. The regulatory amendment is then irrelevant. If fixed costs C are so low that all bank types opt for the IRB approach, we are back in the case of section 5.1. The interesting case is the intermediate situation where switching to the IRB approach is profitable only for the large bank.[17]

Since small banks stick to the standardized approach, their capital requirement is α. For the large bank, the requirement is reduced to β_1 because the large bank never chooses the risky project. If it did, regulation would become stricter because of the IRB approach; hence the investment C could not be profitable. As a result, competition must be relatively low. Furthermore, the IRB approach will allow the large bank to offer higher deposit rates. If the large bank has not yet reached the critical deposit rate, it will raise rates because the investment becomes more profitable. If it *has* reached the critical rate, it will raise rates because the critical rate rises. In both cases, competition for small banks increases.

Let us consider first what happens within the regimes. We put double dots on parameters that refer to the optional IRB approach. Note that regime 5 does not need to be considered here because it would imply that the large bank takes the risky project, rendering the choice of the IRB approach unprofitable.

In regime 1, equilibrium deposit rates are

$$\ddot{r}_L = r_L + \frac{2\,(\alpha-\beta_1)\,(r_k - p_1\,y_1)}{3\,(1-\alpha)\,(1-\beta_1)},$$
$$\ddot{r}_S = r_S + \frac{(\alpha-\beta_1)\,(r_k - p_1\,y_1)}{3\,(1-\alpha)\,(1-\beta_1)},$$

yielding deposit volumes of

$$\ddot{d}_L = d_L + \frac{n\,\sigma}{3}\,\frac{(\alpha-\beta_1)\,(r_k - p_1\,y_1)}{3\,(1-\alpha)\,(1-\beta_1)},$$

[17] The set of possible parameter settings is not empty: If C were negligible, all banks would (individually) benefit from switching to the IRB approach, except for the case in which they would take the risky project even after a switch to IRB. Now because of the assumed structure of competition, if we set $\sigma \sim 1/n$, the large bank's profits are independent of n, whereas the small banks' profits are inversely proportional to n. Therefore, for each C (and other parameters of the model), we must only choose n large enough to render the IRB approach unprofitable for small banks. Only for very high competition (large σ), *no* bank takes the IRB approach even for vanishing C. Because of immense competition, all banks will take risky projects anyway, so they would hurt themselves by opting for the IRB.

$$\ddot{d}_S = d_S - \frac{\sigma}{3} \frac{(\alpha - \beta_1)(r_k - p_1 y_1)}{3(1-\alpha)(1-\beta_1)}.$$

Hence in regime 1, deposit rates of all banks rise. The large bank raises its rate because investment becomes more profitable, and the small banks raise their rates in reaction to the large bank. However, the rate increase of the large bank is much larger, such that the large bank increases its market share at the expense of the small banks. The large bank's profits increase, those of the small banks decrease.

In regime 2, small banks have reached the critical rate. Because r^{crit} is independent of competition, we have $r_S = r^{\text{crit}}$, as defined in (5). The switch to the IRB approach induces the large bank to increase its deposit rate. Because the rates of small banks are constrained, small banks shrink, and the large bank grows. Profits of small banks decrease, whereas those of the large bank increase.

In regime 3, deposit rates were $r_S = r_L = r^{\text{crit}}$ (as defined in (5)) when both types of banks were using the standardized approach. Now r_L goes up to $\dot{r}^{\text{crit}}$. As a consequence, the large bank gains market share, whereas small banks loose market share. Again the profits of the small banks decrease, whereas those of the large bank increase.

In regime 4, the large bank's deposit rate rises to $\dot{r}^{\text{crit}}$. The rates of the small banks are as in (10), replacing r^{crit} by $\dot{r}^{\text{crit}}$. Hence, deposit rates of all banks rise. However, the large bank's rate rises more strongly, increasing the large bank's market share. As before, the profits of the large bank go up, those of small banks drop.

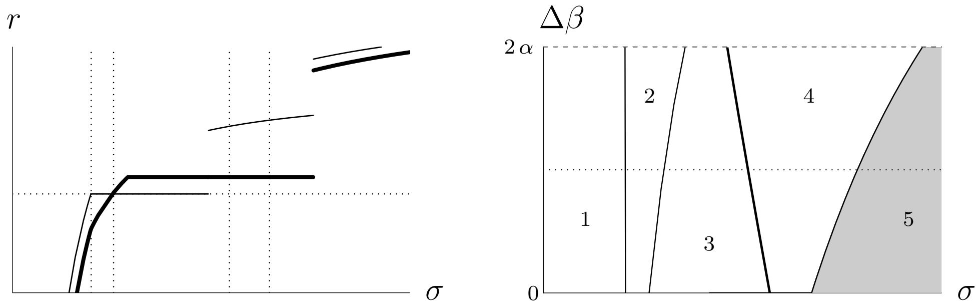
The discussion shows that, within each regime, a switch of the large bank from the standardized to the IRB approach reduces the small banks' volumes and profits. In contrast, the large bank benefits in all regimes from the right to choose between regulatory approaches.

So far, we have only considered changes *within* the regimes. Additionally, a regime change may occur when the large bank switches to the IRB approach. This is particularly problematic if small banks now switch to the risky project, i. e. the regime switches from 3 to 4. Such a regime switch would increase aggregate risk in the economy, and market rates would jump up.[18] The following proposition shows that the transition to an optional IRB approach may indeed lead to a switch from a regime without risk-taking (regimes 1, 2, or 3) to one with risk-taking (regime 4).

Proposition 3 (Optional IRB Approach) *Given that only the large bank switches to the IRB approach, a transition from the standardized to an optional IRB approach decreases the critical level of competition σ_S^{crit}, above which small banks choose the risky project, i. e. $\partial\sigma_S^{\text{crit}}/\partial\Delta\beta < 0$.*

[18] It is not possible that the regime switches to 5, i. e. that the large bank also takes the risky project in reaction to the jump in deposit rates. Banks choose the regulatory approach and the deposit rates at the same time. If the large bank sets rates above the critical rate (and hence plans to take the risky project), it cannot be profit-maximizing to implement the IRB approach.

Figure 6: Equilibrium Deposit Rates and Regime Switches, Right to Choose



Curves are as in figure 5. The important difference is that the thick line in the right panel *falls* monotonically if banks are allowed to choose between the approaches. The area of regime 5 is plotted in gray because it cannot occur here: if the large bank chose the risky project, it would not have adopted the IRB approach in the first place.

Hence, rather than deterring banks from risk-taking, the optional IRB approach may lead to *higher* risk-taking of small banks. The reason is that, under the optional IRB approach, only the large bank benefits from lower capital requirements, and hence marginal costs. This induces the large bank to expand and increase deposit rates, putting the small banks under competitive pressure. In reaction, the small banks raise deposit rates to regain part of their customer base, and take the risky project. This also translates into an increase in aggregate risk in the economy, given that the large bank always chooses the safe project.

The proposition is illustrated in figure 6. The left panel displays equilibrium deposit rates if there is a right to choose between the two approaches. We see that the border between regimes 3 and 4 actually moves towards *lower* competition, compared to the standardized approach, implying that risk-taking is increased by the regulation. At the former border between regimes 3 and 4, the small banks now strictly prefer to increase rates. The same result can be found in the right panel. In contrast to figure 5, the curve separating the regimes with and without risk-taking *falls* monotonically. Hence, if banks are allowed to choose between the two approaches and if only the large bank switches to the IRB approach, a more pronounced IRB approach enlarges the set of parameters σ for which (small) banks take excessive risks. Again, an analogous version of remark 1 applies.

Even in the case of a switch to regime 4, the small banks are bound to suffer. For the purpose of illustration, consider the case where the banks are just at the border between regimes 3 and 4 before the introduction of the optional IRB approach. Now an infinitesimal increase in $\Delta\beta$ has two effects: First, it induces the small banks to increase deposit rates discretely, which leaves their profits unchanged at the margin. Second, it increases the large bank's deposit rate, which unambiguously hurts the small banks. Therefore, the small banks will lose profits even in the case of regime switches.

Interestingly, even the large bank may suffer in the case of a regime switch. This result may be surprising at first sight, given that the large bank should exercise the option for the IRB approach only if it is beneficial. However, in choosing the approach, the large bank takes the small banks' interest rates as given. Hence, the possible transition from regime 3 to regime 4 is not entering the large bank's considerations. Starting again from the border between regimes 3 and 4, an infinitesimal increase in $\Delta\beta$ has two effects: first, the large bank raises its rate by an infinitesimal amount due to the increase in the critical rate; second, the small banks raise their rates discretely because they want to gain market share. An increased market share of the small banks implies that the profits of the large bank decrease. Hence, the large bank's profits may actually fall after the transition from the standardized to the optional IRB approach.

Apart from the case just described, the large bank will always benefit from a transition from the standardized to the optional IRB approach. This yields a political economy rationale for why certain interest groups may lobby the regulatory authorities towards a highly sophisticated IRB approach. The more sophisticated the approach, the higher the fixed costs, and the more likely it is that smaller banks will not be willing to adopt the new approach. The potential benefits from the IRB approach for large banks are largest when only a small number of banks switches to the new approach. The small banks, whose interests are less well organized, suffer from the introduction of the IRB approach *because* its use is only optional. However, given the degree of sophistication of the IRB approach, an adoption by all banks is impossible in the absence of subsidization.

In summary, we have shown that the introduction of an optional IRB approach may induce the small banks to take higher risks, which translates into an increase in aggregate risk, compared to the standardized approach. Therefore, the regulation does not achieve its goal of deterring banks from risk-taking. It appears that the advantages of the IRB approach are destroyed by the right to choose.

6 Conclusion

Our paper has presented a novel channel through which the New Basel Capital Accord may harm small banks and lead to an increase in aggregate risk in the economy. We started from the observation that the new accord implicitly treats small and large banks in an asymmetric way: Due to the high fixed costs from implementation, it is very likely that only large banks opt for the IRB approach. In that case, small banks cannot benefit from the lower capital requirements for safe loans. This distorts competition to the benefit of the larger banks whose capital requirements, and hence marginal costs, are reduced when adopting the IRB approach. Large banks are induced to increase deposit rates to attract more deposits and exploit the higher profitability of investments. Fiercer competition for deposits forces small banks to raise their deposit rates as well, to recapture some of their market shares. At this higher rate, small banks may prefer a risky investment strategy over a safe one. Starting from a situation where all banks choose a safe investment strategy, this implies an increase in aggregate risk. Hence, the new accord may actually *destabilize* the banking system, contrary to the regulators' intention.

Note that our results do not follow from the introduction of the IRB approach as such, but rather from the implicit asymmetric treatment of banks if they are given the right to choose between the standardized and the IRB approaches. If the IRB approach is applied uniformly across banks, banking stability is improved as intended. Small banks may even profit from the introduction of the IRB approach relative to the old Basel accord.

Our model relies on three important ingredients to obtain these results: the existence of moral hazard problems regarding the banks' risk choices, imperfect competition among banks, and equity that is more expensive than other sources of refinancing. In contrast, the exact market structure is not crucial for our results. For example, one may consider a banking system with *several* large banks competing with each other. As long as they are larger than the small banks, there will still be a range of fixed costs C so that only large banks implement the IRB approach. Marginal costs of lending decrease for large banks, and small banks suffer because of the fiercer competition, making a switch to riskier projects likely. Similarly, one could allow for competition among the small banks. This would complicate the analysis because all banks would have to be analyzed simultaneously. But it would still be true that the decrease in marginal costs at the large bank would increase competition for deposits at the small banks and would push them towards higher risk-taking. Furthermore, we have modelled competition among banks as price competition à la Hotelling (1929). Different types of competition, such as competition in capacities à la Cournot, would not alter our results, as long as the banks suffer from the lower marginal costs of their competitors.

Another simplifying assumption is that aggregate deposits are perfectly inelastic. Generally, one would think that the aggregate supply of deposits depends on deposit rates. Again our main results remain valid under this alternative assumption. In particular, the qualitative results regarding the risk-taking of banks are not affected. However, the effects of competition and regulation on profits and welfare would be slightly different because increases in deposit rates could lead to an aggregate increase in deposits. This would weaken the negative externality from interest rate increases on the competitor banks. Also the volume expansion would tend to increase welfare, especially if the aggregate deposit supply was very elastic. All this would leave our qualitative results unchanged. A more serious drawback of the assumption is that it yields somewhat awkward welfare implications regarding the optimal number of banks in the economy. It implies that there are no deadweight losses from a monopoly, such that, in the presence of fixed costs, a monopoly would actually be optimal. Of course, we do not want to draw such a policy conclusion from our model.

Let us now discuss the assumptions that may be more critical for our results. We assumed that banks' risk choices are dichotomous, i. e. banks can only choose between two projects. Therefore, an increase in risk by the small banks always translates into an increase in aggregate risk because the large banks' risk-taking cannot change to the better. The overall effect on aggregate risk would be more complicated if we allowed for continuous risk choices. Then the implementation of the IRB approach may induce the large banks to take smaller risks than before, exerting a countervailing effect on aggregate risk-taking. In such a model, there will still be parameter constellations for which aggregate risk-taking increases, but the opposite may also be true. However, this caveat does not dilute the basic message of our paper. The finding that the new capital regulation may under certain parameter constellations lead to the opposite of what is intended is in any case alarming.

Another critical assumption concerns the modelling of bank competition. We assumed that banks compete only in the deposit market, but not in the loan market. Boyd and De Nicoló (2005) have shown that, in a model with loan market competition, the risk-taking behavior of banks depends on whether the banks or their borrowers are subject to the risk-shifting problem. In the latter case, our results on risk-taking may actually be reversed. Hence our results are robust to the introduction of loan market competition only if banks face, in Boyd and De Nicoló's words, a portfolio problem and not an optimal contracting problem.

Moreover, the prompt effects of changes in capital regulation on risk-taking are due to the binding capital requirements in our model. In practice, banks tend to hold more than the required capital. If these additional capital buffers remain constant after the change in the capital regulation, the analysis is unchanged. However, as has been argued by Jokivuolle and Peura (2001), the IRB approach tends to induce a higher volatility of capital requirements, which may induce banks to increase their buffers after switching to the IRB approach. In that case, the general benefits from the IRB approach would be smaller, and so would the competitive distortions. But it is also conceivable that the capital buffers decrease since the banks have more control over how much capital they actually need. Then the effects from our model may even be reinforced.

In reality, banks may react in a number of ways to the new regulation that are not captured by our model. One possibility is bank mergers. The new regulation clearly sets incentives for bank mergers, especially between small banks or between large and small banks. In our model, the merged banks would take the safe project and economize on capital, which would constitute a welfare improvement. Outside of our model, there are a number of additional considerations that make this perspective less desirable. Most importantly, the merged banks may become "too big to fail," which would raise new incentive problems (see Hakenes and Schnabel (2004) for a recent theoretical treatment). Moreover, mergers may reduce competition. So far, empirical work on the U. S. has not been able to find any indications that acquisition activity will increase significantly after the introduction of Basel II (see Hannan and Pilloff (2004)).

Alternatively, the small banks may react to the new regulation by cooperating with other banks in their risk management (e. g. by establishing joint rating systems) to save on fixed costs. Similarly, the small banks may delegate their risk management to a third party; however, this may give rise to new incentive problems. In both cases, small banks could operate independently, but still benefit from economies of scale. In the context of our model, this would constitute a clear welfare improvement, and it would avoid many of the disadvantages of bank mergers. However, such solutions will only be possible if the regulators are willing to accept or even promote data pooling initiatives, which would allow smaller banks to overcome the problem of lacking historical data. Furthermore, legal restrictions (stemming, for example, from bank secrecy laws) may prevent banks from exchanging sensitive information about their customers with other banks or intermediaries.

Our results have important implications for the provision of loans to SMEs after the implementation of the new accord. If we believe that small firms are more likely to borrow from small banks, our model predicts not only a decrease in bank lending to SMEs, but also a shift from SMEs with safer projects to those with riskier ones. Hence, the SMEs with the most efficient projects are bound to loose the most. This effect may be mitigated by the preferential treatment of loans to SMEs in the IRB approach, which may induce some of the safer SMEs to switch to larger banks. However, the large banks may not be prepared to extend loans based primarily on soft information (see Stein (2002) for a theoretical treatment, and Berger (2004) for empirical evidence). In addition, the unequal treatment of small and large banks may be of concern for equity reasons.

In principle, the adverse effects of the new Basel accord described in this paper can be mitigated in three ways: first, by lowering the fixed costs of implementation for the IRB approach; second, by subsidizing the small banks to adopt the IRB approach; and third, by enabling smaller banks to exploit the existing economies of scale through cooperation or the use of intermediaries. A lowering of fixed costs may be difficult to obtain without changing the accord, and without compromising the reliability of the banks' rating systems. A subsidization through public funds is unlikely to occur. However, the lower capital requirements for good projects under the IRB approach may be seen as an implicit subsidy to induce banks to adopt the approach. But we suspect that this subsidy may not be sufficient to make a switch profitable for smaller banks. Therefore, the third solution seems to be easiest to implement. It only requires to lay the legal foundations for the pooling and exchange of internal bank data. It remains to be seen whether such a proposal will be able to gain political support. We argued above that the new accord may itself be seen as a manifestation of regulatory capture by the large banks who appear to be the overall winners of the new regulation. They may not want to give up their privileges easily.

A Appendix

Proof of Proposition 1: We consider the border between regions $1 \cup 2 \cup 3$ and $4 \cup 5$ (the proof for the border between regimes 4 and 5 proceeds analogously). At the border, $\sigma = \sigma_S^{\text{crit}}$ is such that small banks are just indifferent between the safe project (and the critical rate r^{crit}) and the risky project (and a rate *above* r^{crit}). The large bank's interest rate is r^{crit} in both cases. Expected profits of small banks are

$$\begin{aligned}
\Pi_S^{\text{Reg. 3}} &= \Big(\frac{D_S}{n} + \sigma\,(r^{\text{crit}} - r^{\text{crit}})\Big)\Big(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r^{\text{crit}}\Big) \\
&= \frac{D_S}{n}\Big(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r^{\text{crit}}\Big), \\
\Pi_S^{\text{Reg. 4}} &= \Big(\frac{D_S}{n} + \sigma\,(r_S - r^{\text{crit}})\Big)\Big(\frac{p_1\,y_1 - \alpha\,r_k}{1-\alpha} - r^{\text{crit}}\Big) \\
&= \frac{1}{4\,\sigma}\left(\frac{D_S}{n} + \sigma\left[\frac{p_2\,y_2 - \alpha\,r_k}{1-\alpha} - r^{\text{crit}}\right]\right)^2.
\end{aligned}$$

The function $\sigma_S^{\text{crit}}(\alpha)$ is defined by $\Pi_S^{\text{Reg. 3}} = \Pi_S^{\text{Reg. 4}}$. Solving for σ, we get

$$\begin{aligned}
\sigma_S^{\text{crit}} &= \frac{(p_1 - p_2)\,(1-\alpha)\,D_S/n}{\big(\sqrt{A} - \sqrt{B}\big)^2} \quad \text{with} \\
A &= (p_1 - p_2)\,(p_1\,y_1 - p_2\,y_2) \quad \text{and} \\
B &= p_1\,p_2\,(y_2 - y_1) - (p_1 - p_2)\,\alpha\,r_k.
\end{aligned}$$

Clearly, σ_S^{crit} is always nonnegative, and it goes to infinity if $A = B$, hence if

$$\alpha = \alpha_\infty := \frac{p_1^2\,y_1 - 2\,p_1\,p_2\,y_2 + p_2^2\,y_2}{(p_2 - p_1)\,r_k}.$$

For larger α, the algebraical solution is economically meaningless. This can be seen from figure 4, where the thick curve is the inverse of σ_S^{crit} as a function of α. As $\alpha \to \alpha_\infty$, the curve goes to infinity. If the thick curve reappeared in the plot from the right, the curve would have to cross the borders between regimes 1, 2 and 3, which does not make sense economically.

Hence the proof is complete if we can show that the slope of σ_S^{crit} does not change its sign between zero and the pole. One can show that the derivative of σ_S^{crit} with regard to α is never equal to zero. Consequently, σ_S^{crit} rises monotonously in α, until it reaches the pole at α_∞. ■

Proof of Remark 1: Proposition 1 refers only to the parameter σ. The remark implies that a similar statement applies to all other parameters. Only for $\sigma \leq \sigma_S^{\text{crit}}$, all banks take the safe project. Therefore, the monotonic increase in $\sigma_S^{\text{crit}}(\alpha)$ means that the set of σ's where all banks take the safe project grows for rising α, given the other parameters. More formally, let $\mathbf{P}$ summarize all exogenous parameters except σ and α, and let $\mathcal{S}$ denote the set of parameters where all banks take the safe project in equilibrium. Then, proposition 1 implies that

$$(\alpha_1, \mathbf{P}, \sigma) \in \mathcal{S} \implies (\alpha_2, \mathbf{P}, \sigma) \in \mathcal{S} \quad \text{for } \alpha_2 > \alpha_1.$$

This statement is symmetric with respect to all exogenous parameters. Therefore, one can state more generally that an increase in α weakly reduces the set of (all) parameters for which at least one type of banks chooses the risky project. An analogous argument holds for the following propositions 2 and 3. ■

Proof of Proposition 2: An increase in $\Delta\beta$ can be due to either a decrease in β_1 or an increase in β_2, or both. Hence, to show that $\mathrm{d}\sigma_S^{\mathrm{crit}}/\mathrm{d}\Delta\beta > 0$, it is sufficient to show that $\mathrm{d}\sigma_S^{\mathrm{crit}}/\mathrm{d}\beta_1 < 0$ and $\mathrm{d}\sigma_S^{\mathrm{crit}}/\mathrm{d}\beta_2 > 0$. We present the proof for $\mathrm{d}\sigma_S^{\mathrm{crit}}/\mathrm{d}\beta_2 > 0$, that for $\mathrm{d}\sigma_S^{\mathrm{crit}}/\mathrm{d}\beta_1 < 0$ is analogous.

The switch between regimes 3 and 4 is again defined by the indifference of small banks between safe and risky projects (the proof for the borders between regimes 4 and 5 proceeds analogously), hence

$$\Pi_S^{\mathrm{Reg.\,3}} = \frac{D_S}{n}\left(\frac{p_1\,y_1 - \beta_1\,r_k}{1-\beta_1} - \dot{r}^{\mathrm{crit}}\right) - C \stackrel{!}{=}$$
$$\Pi_S^{\mathrm{Reg.\,4}} = \frac{1}{4\,\sigma_S^{\mathrm{crit}}}\left(\frac{D_S}{n} + \sigma_S^{\mathrm{crit}}\left(\frac{p_2\,y_2 - \beta_2\,r_k}{1-\beta_2} - \dot{r}^{\mathrm{crit}}\right)\right)^2 - C.$$

This equality defines an implicit relation $\sigma_S^{\mathrm{crit}}(\beta_2)$. Because σ_S^{crit} depends also on $\dot{r}^{\mathrm{crit}}$, which in turn depends on β_2, one can write

$$\frac{\mathrm{d}\sigma_S^{\mathrm{crit}}}{\mathrm{d}\beta_2} = \frac{\partial\sigma_S^{\mathrm{crit}}}{\partial\beta_2} + \frac{\partial\sigma_S^{\mathrm{crit}}}{\partial\dot{r}^{\mathrm{crit}}}\,\frac{\partial\dot{r}^{\mathrm{crit}}}{\partial\beta_2}.$$

As stated in the main text, $\partial\dot{r}^{\mathrm{crit}}/\partial\beta_2 > 0$. Therefore, it remains to show that $\partial\sigma_S^{\mathrm{crit}}/\partial\beta_2 > 0$ (a rise in β_2 leads to a rise in σ_S^{crit} if $\dot{r}^{\mathrm{crit}}$ is held constant) and $\partial\sigma_S^{\mathrm{crit}}/\partial\dot{r}^{\mathrm{crit}} > 0$ (a rise in $\dot{r}^{\mathrm{crit}}$ leads to a rise in σ_S^{crit} if β_2 is kept constant).

We first show that $\partial\sigma_S^{\mathrm{crit}}/\partial\beta_2 > 0$, treating $\dot{r}^{\mathrm{crit}}$ as a constant. The implicit function theorem yields

$$\frac{\partial\sigma_S^{\mathrm{crit}}}{\partial\beta_2} = -\frac{\partial\Pi_S^{\mathrm{Reg.\,3}}/\partial\beta_2 - \partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\beta_2}{\partial\Pi_S^{\mathrm{Reg.\,3}}/\partial\sigma_S^{\mathrm{crit}} - \partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\sigma_S^{\mathrm{crit}}} = -\frac{\partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\beta_2}{\partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\sigma_S^{\mathrm{crit}}}.$$

$\Pi_S^{\mathrm{Reg.\,4}}$ decreases in β_2 because $\Pi_S^{\mathrm{Reg.\,4}}$ rises in $\Phi := \frac{p_2\,y_2 - \beta_2\,r_k}{1-\beta_2} - \dot{r}^{\mathrm{crit}}$, which in turn decreases in β_2 (because $r_k > p_2\,y_2$). Furthermore, $\Pi_S^{\mathrm{Reg.\,4}}$ increases in σ_S^{crit} (because it increases in σ, for constant $\dot{r}^{\mathrm{crit}}$). Otherwise, it could not have been optimal for the small banks to choose $\dot{r}^{\mathrm{crit}}$ for σ below σ_S^{crit}. This proves that $\partial\sigma_S^{\mathrm{crit}}/\partial\beta_2 > 0$.

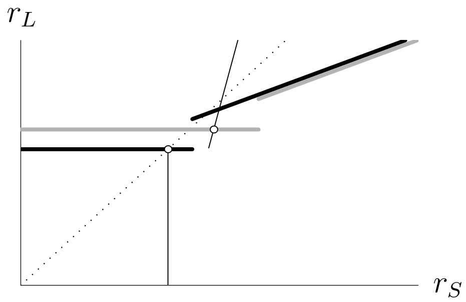
Now we show that $\partial\sigma_S^{\mathrm{crit}}/\partial\dot{r}^{\mathrm{crit}} > 0$. Using again the implicit function theorem,

$$\frac{\partial\sigma_S^{\mathrm{crit}}}{\partial\dot{r}^{\mathrm{crit}}} = -\frac{\partial\Pi_S^{\mathrm{Reg.\,3}}/\partial\dot{r}^{\mathrm{crit}} - \partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\dot{r}^{\mathrm{crit}}}{\partial\Pi_S^{\mathrm{Reg.\,3}}/\partial\sigma_S^{\mathrm{crit}} - \partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\sigma_S^{\mathrm{crit}}} = \frac{\partial\Pi_S^{\mathrm{Reg.\,3}}/\partial\dot{r}^{\mathrm{crit}} - \partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\dot{r}^{\mathrm{crit}}}{\partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\sigma_S^{\mathrm{crit}}}.$$

$\partial\Pi_S^{\mathrm{Reg.\,3}}/\partial\dot{r}^{\mathrm{crit}} = -D_S/n$ and $\partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\dot{r}^{\mathrm{crit}} = -(D_S/n + \Phi\,\sigma_S^{\mathrm{crit}})/2$ with Φ as defined above, hence $\partial\Pi_S^{\mathrm{Reg.\,3}}/\partial\dot{r}^{\mathrm{crit}} - \partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\dot{r}^{\mathrm{crit}} = -(D_S/n - \Phi\,\sigma_S^{\mathrm{crit}})/2$. Furthermore,

$$\partial\Pi_S^{\mathrm{Reg.\,4}}/\partial\sigma_S^{\mathrm{crit}} = \frac{\Phi}{2\,\sigma_S^{\mathrm{crit}}}\left(\frac{D_S}{n} + \Phi\,\sigma_S^{\mathrm{crit}}\right) - \frac{1}{4\,\sigma_S^{\mathrm{crit}\,2}}\left(\frac{D_S}{n} + \Phi\,\sigma_S^{\mathrm{crit}}\right)^2.$$

Figure 7: Reaction Functions Near the Critical α



Thin lines are reaction functions by small banks, thick lines those of large banks. Black lines denote the standardized approach, gray lines the IRB approach. Here, parameters are such that the kinks occur for negative deposit rates.

This term is equal to zero for $\Phi = \frac{D_S}{n\,\sigma_S^{\text{crit}}}$ (the other zero is for negative Φ). For smaller Φ, the term is negative, for larger Φ, it is positive. For smaller Φ, the term $\partial \Pi_S^{\text{Reg. 3}} / \partial \dot{r}^{\text{crit}} - \partial \Pi_S^{\text{Reg. 4}} / \partial \dot{r}^{\text{crit}}$ from above is also negative, and vice versa. As a result, numerator and denominator of $\partial \sigma_S^{\text{crit}} / \partial \dot{r}^{\text{crit}}$ always have the same signs. This proves that $\partial \sigma_S^{\text{crit}} / \partial \dot{r}^{\text{crit}} > 0$, and completes the proof of the proposition. ■

Proof of Proposition 3: For the proof, we build on the intuition delivered by figure 7. Black curves denote the reaction functions of small and large banks under the old regulatory framework, i. e. all banks use the standardized approach. Assume that α is such that the equilibrium is close to the border between regimes 3 and 4. In other words, in equilibrium, small banks are individually indifferent between the critical deposit rate r^{crit} and a higher rate (which would signal the risky project). We want to argue that an increase in $\Delta\beta$ then leads to a switch to regime 4. In figure 7, the equilibrium is given by the white dot to the left. Here, indeed, the equilibrium r_L is low enough to ensure that small banks offer r^{crit} and take the safe project. Also the large bank offers r^{crit}. However, it has some "reserves": Even if small banks raised deposit rates, the large bank would not react by raising rates, too (in the figure, the reaction function of the large bank "overlaps" the critical point).

We assumed that a switch to the IRB approach is profitable only for the large bank. As a result, the large bank implements the IRB approach, and the critical deposit rate for the large bank goes up from r^{crit} to $\dot{r}^{\text{crit}}$. The large bank raises deposit rates. Consequently, small banks now prefer offering a higher deposit rate (and signalling the risky project). Before the introduction of the IRB approach, all banks took the safe project, now all small banks take the risky project. Aggregate volume remains unchanged, hence aggregate risk in the economy has gone up.

There are two reasons why small banks may be indifferent between r^{crit} and a higher rate, but the situation may still be different from that in figure 7. First, small and large banks may be so asymmetric that, at the indifference point of small banks, the large bank offers a rate below r^{crit} (regime 2). Taking the derivative of (7) with respect to α, one proves that for given r_S, deposit rates of the large bank rise if regulation for large banks softens. As before, this induces the small banks to raise rates and pick the risky project.

Second, banks may be so symmetric, and the IRB approach so close to the standardized approach ($\beta_1 \approx \alpha \approx \beta_2$), that the introduction of the IRB approach at the large bank and the ensuing upward-jump of market rates would also induce the large bank to take the risky project. This, as already discussed, leads to a contradiction, because large banks would not have implemented the IRB approach in the first place. ■

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05-15	Hartmut Esser	Affektuelles Handeln: Emotionen und das Modell der Frame-Selektion
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