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Model Risk – an Agency Theoretic Approach*

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Abstract

In the recent financial crisis, risk management tools have been proven inadequate. Model risk, a key component of bank risk, has shown its negative impact. It seems that risk models did not cover the included risks comprehensively and were not kept up-to-date by banks, and also rating agencies. Consequently, in the aftermath of the crisis banks must adjust their models to reduce model risk. We discuss if banks undertake enough effort to improve their risk models. Furthermore, the paper deals with the optimal organizational structure of this improvement process. We take a close look at risk models of banks and discuss if banks generally invest enough effort to improve their risk models. The question of risk model innovation is analyzed from a managerial as well as from a welfare perspective in the context of a principal agent model – where the bank has to incentivize an agent to perform innovative improvement in the risk model technology.

Keywords: Banking crises, model risk, incentives, compensation, regulation.

JEL-Codes: G01, G21, L22.

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1 Introduction

The recent financial crisis has raised a host of questions concerning the quantitative models used by financial market participants: Why did rating systems and risk models of banks not warn against failing projects, especially in the real estate market? Have these systems not been good enough? Which role are organizational structures playing? It seems that the risk models did not cover all risks and were not kept up-to-date by banks.

Model risk typically is analyzed from an empirical or statistical perspective. However, to improve a risk model — and simultaneously reduce model risk —, two components are necessary: the institutional component and the technical component; the latter implies to have technical precedents, e.g. statistics or IT. In order to reduce model risk, choosing right incentives is essential. Therefore, the present paper focuses on the institutional component represented by the organizational and financial structures of firms that influence the incentives for innovation. Offering right incentives may enable an improvement of risk model accuracy.

Our paper contributes a further aspect to the understanding why existing risk models could not prevent the financial crisis. We discuss if banks undertake enough effort to improve their risk models. Furthermore, the paper deals with the optimal organizational structure: under which conditions is it preferable to engage an external agent for the task of risk model innovation compared to the situation where an internal employee works on the improvement? Finally, the question of risk model improvement is analyzed from a managerial as well as from a welfare perspective. In the context of a principal agent model, a bank has to incentivize an agent to perform innovations in the risk model technology.

Risk management strategies are based on the assumption of a certain risk model. To determine the future ability of a firm to repay credit, the bank's credit department will use a risk model which incorporates any relevant information it has available to assign the applicant to a certain risk class. However, the risk models are rarely reliable in representing the reality. It is possible that on the basis of a risk model credit-worthy firms are rejected and loan seeking firms that are not worth a credit are accepted. For this reason, the bank strives for the best achievable risk model.

Model risk has received little attention in the extant theoretical literature, but several empirical studies exist (e.g. Derman (1996), Alexander (2005)). In an article

by Rebonato (2003), model risk is defined as the risk “of occurrence of a significant difference between the mark-to-model value of a complex and/or illiquid instrument, and the price at which the same instrument is revealed to have traded in the market”. In a broader sense, model risk can be seen as the risk of losing money because of a failing model. Sibbertsen, Stahl, and Luedtke (2008) define model risk as every risk induced by application, choice, specification and estimation of a statistical model.

We apply a principal agent setting, where a bank owner has to incentivize its employee, i. e. the loan officer, to decide about credit approval of loan seeking projects in the bank owner’s interest. We show that the bank owner offers a wage that is reduced to the minimum possible amount and consists of two components: one administration fee and one bonus payment. As a result, the loan officer’s wage depends not only on the quality of the market and the costs for a credit check but also on the quality of the applied risk model.

In the next step, we add to the analysis a further agency problem resulting from the effort undertaken to make improvements of the risk model. This effort is private information of the agent as the bank owner may notice a modification of the risk model but is not able to recognize if this modification is a change for the better.

We regard both types of possible judgment errors of risk models: rejection of credit-worthy firms, which we call type-I-error or alpha-error, and the acceptance of firms unworthy of credits, called type-II-error or beta-error. As it is most important for banks to reduce their default rates – which are resulting from the beta-error, we predominantly concentrate on this failure. However, implications and interpretation of the analysis can be seen as general results.

By undertaking innovations, the bank is then able to reduce alpha- or beta-error. In this setting, the bank owner may outsource the work on the innovation process to an external agent, e. g. a risk manager or consultant. We examine here the three different possibilities of the bank: (i) to abandon a possible improvement or process, (ii) to incentivize the internal employee, e. g. the loan officer, to do an innovation or (iii) to engage the external consultant in order to improve the bank’s internal risk model.

We show that the decision about internal or external contracting for the innovation is depending on several factors, as market quality, effort costs and the extent of the

innovation. With lower market quality, e. g. a low share of good projects, the probability for an internal agent to perform the innovation is rising. With high market quality, the bank owner decides to delegate the innovation process to an external agent. If the innovation planned by the bank's owner is of a smaller extent, he prefers to engage the external consultant. The decision in favor of the external consultant will also be taken in the case of high effort costs required for the innovation.

Our results are intuitive if we imagine situations in which it is more difficult to implement an innovation. This is the case with subtleties as a very high market quality or a very small extent of innovation. High effort costs also make the improvement of a risk model more difficult. Due to the different incentives for credit check and innovation, in these cases, the principal benefits from the possibility of diversification and engages one agent for each task. This is a realistic results as we also observe that consultants are typically retained for special and difficult tasks in reality.

In some cases, for example when market quality or effort costs are very high, it may even be optimal for the bank owner to have no improvement process at all. Incentives, and therefore wages for internal or external agent, would be too costly for the bank. In our welfare analysis, we also find conditions under which an innovation would not be profitable. However, in a comparison of the welfare analysis and the bank decision, it can be seen that innovation happens too rarely. Externalities keep banks from investing in innovation at certain levels of market and risk model quality. We therefore can conclude that standards for risk models and for the improvement of risk models are necessary in the economy in order to reduce model risk whenever a reduction is welfare optimal.

The remainder of the paper is organized as follows. After a discussion of the related literature, Section 2 introduces our theoretical model. The next chapters deal with the extension of the basic model. Section 3 discusses the reduction of the beta-error of the risk model, starting with the structure of the innovation (in 3.1), then a discussion about conditions for the different regimes (in 3.2), and finally a welfare analysis with specific examples for the decision of the bank (in 3.3). Section 4 concludes. Proofs are in the appendix.

Literature. Our paper relates to many strands of the economic literature. In addition to the empirical literature about model risk that is already mentioned above

(for example Rebonato (2003), Derman (1996), Alexander (2005) and Sibbertsen, Stahl, and Luedtke (2008)), theoretical literature exists. The articles that are most closely related to our model are dealing with type-I- or type-II-error.

In his famous article, Broecker (1990) discusses imperfect credit check tests and relates this to the competition between banks. A similar subject is analyzed in the paper of Hauswald and Marquez (2003). The authors show how better information in credit screening decreases interest rates and the returns from screening. In a further article, Hauswald and Marquez (2006) are interested again in the interaction of information acquisition and banking competition. They find that investment in information acquisition is falling as competition increases.

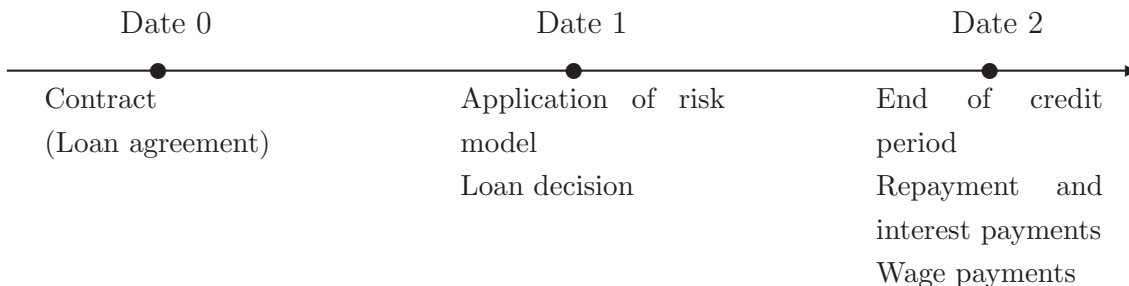
In addition, there is a theoretical literature on innovation. Hellmann and Thiele (2011) discuss innovation as an unplanned activity. In the context of different industries (no banking), interactions between planned and unplanned activities are considered and the conditions are discussed under which agents decide to pursue innovative and unplanned work. The authors find that it helps to reduce incentives for planned activities if desired innovations are very firm specific. A further article in the literature about innovation is from Manso (2011) who also looks at incentive problems for managers to innovate in a long-term structure. Aghion and Tirole (1994) discuss organizational questions regarding innovations made by R&D departments.

2 The Basic Model

Consider a principal agent problem where a loan officer (agent) decides about credit approval of loans by means of a risk model in the interest of the bank owner (principal). In our model, there is one representative firm seeking a loan. If the firm receives the loan, its project may either succeed or fail. For simplicity, we suppose that this happens with probability 1. Accordingly, there are two types of firms: a firm may either be good with success probability $p_{success} = 1$ or bad with success probability $p_{success} = 0$. All agents are risk neutral and maximize their profits.

The decision process of the bank is conducted by the loan officer. He uses the risk model as basis for his decision about approval or rejection by running a credit check on the loan seeking firm. This task costs effort costs c per credit check. As the

Figure 1: Time Structure



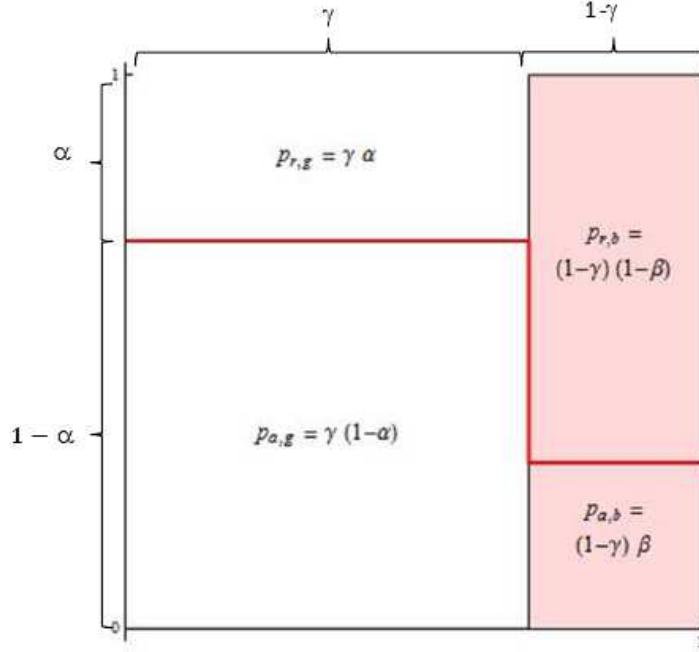
bank owner is not able to recognize directly if the loan officer is working on the credit decision as contracted, he needs to incentivize his employee by a certain wage structure.

The time structure of the model can be seen in Figure 1: at time 0, bank owner and loan officer conclude a contract. At time 1, the loan officer decides about lending on the basis of the risk model. At date 2, the credit period is over. The bank owner receives repayment of the credit and interest payments, the loan officer receives his wage.

With probability γ , a loan seeking firm is a good firm and creditworthy. With probability $1 - \gamma$, a firm will not be able to repay the loan amount. Thus, γ represents the quality of the market. The risk model is now used as an instrument to decide between firms that are worthy of credit or not. However, no such risk model is able to distinguish perfectly between the two classes of firms. It may recommend to reject a good firm (alpha- or type-I-error) or to accept a bad firm (beta- or type-II-error). This risk model is illustrated in Figure 2. Loans are accepted with probability $p_a = \gamma(1 - \alpha) + (1 - \gamma)\beta$ (area below the red line in the graph) and rejected with probability $p_r = \gamma\alpha + (1 - \gamma)(1 - \beta)$ (area above the red line) by the risk model or rather the loan officer who works with it.

If the firm, i. e. its project, is accepted by the bank, the bank has to pay the loan amount I to the firm at time 1. At the end of the credit period, the bank receives repayment of I and interest rate r from the firm. Probabilities $p_{r,g}$ (rejected, but good firm) and $p_{a,b}$ (accepted, but bad firm) mark alpha- and beta-error.

Figure 2: Structure of the Model



To incentivize the loan officer to work, the bank owner compensates him by paying a wage. The loan officer has the possibilities to work properly and to use the risk model or simply to shirk by rejecting or accepting all credit requests. In order to avoid the two shirking possibilities, the bank has to pay a wage that consists of two components. In our model, the loan officer receives an administration fee a for every rejected project (i. e. with probability p_r) and a bonus fee b for creditworthy and accepted loans (i. e. with probability $p_{a,g} = \gamma (1 - \alpha)$). This payment structure is used for example in banks where a bonus is paid at the end of the year depending of the outcome of projects. If less accepted loans default the bonus for the loan officer will be higher.

The expected profit of the bank owner consists of the repayment and interest rate of loans he receives and is reduced by the loan amounts granted to firms and by the wage he has to pay to the loan officer. This is

$$E\Pi B = p_{a,g} (1 + r) I - p_a I - (p_r a + p_{a,g} b). \quad (1)$$

The loan officer receives his wage and has credit check costs, thus his expected profit

is

$$E\Pi L = p_r a + p_{a,g} b - c. \quad (2)$$

The bank owner now calculates the optimal values for the wage parameters a and b in order to incentivize the loan officer to work. The loan officer is not shirking if his utility equates at least to the amount he can get if he just accepts every project or no project at all. Incentive Constraints are then:

$$E\Pi L \geq a \quad (3)$$

$$E\Pi L \geq \gamma b \quad (4)$$

The bank owner is willing to pay only the minimum necessary to fulfill incentive constraints. Therefore, both constraints are binding which leads to the following Lemma:

Lemma 1 *Optimal wage for the loan officer is determined by the parameters*

$$a = \frac{c}{(1 - \alpha - \beta)(1 - \gamma)} \text{ and} \quad (5)$$

$$b = \frac{c}{(1 - \alpha - \beta)\gamma(1 - \gamma)}. \quad (6)$$

The proof of Lemma 1 is in the appendix.

By inserting wage parameters (5) and (6) in profit functions (1) and (2), equilibrium profits can be calculated. Expected profits of the bank owner and the loan officer are

$$E\Pi B^{BasicModel} = [r(1 - \alpha)\gamma + (1 - \gamma)\beta]I - c - \frac{c}{(1 - \gamma)(1 - \alpha - \beta)} \text{ and}$$

$$E\Pi L^{BasicModel} = \frac{c}{(1 - \alpha - \beta)(1 - \gamma)}.$$

Evidently, the wage of the loan officer must depend on costs c , as the bank owner has to compensate his employee for his effort, respectively costs. The higher the costs, the higher is the wage. The quality of the risk model as well as the quality of the market also have a positive influence on the loan officer's wage.

3 Innovations of Risk Model: The Reduction of the Beta-Error

3.1 Structure of the Innovation

In order to improve the risk model, the bank owner may want to have an innovation process to improve alpha- and beta-error. In this chapter, we concentrate on the latter which is more relevant in recessions. The beta-error is responsible for losses in the bank whereas the alpha-error allows to raise profits. If there are high default rates in the bank, it is absolute priority to reduce them. In our analysis of the beta-error-reduction, we assume for simplicity that $\alpha = 0$.

The risk model improvement is a further agency problem, as the bank owner cannot directly observe the innovation process. In order to get the costly innovation done, he has to incentivize his employees. The bank owner may observe a modification of the risk model. However, as he is not working on a daily basis with the risk model, he can not directly notice if the modification is indeed a change for the better.

We assume that the bank owner has two possibilities to get the innovation done: he can engage either an internal employee, i. e. the loan officer, or an external innovator, i. e. a risk manager or consultant. In a managerial examination, we analyse whether the bank will innovate with the loan officer, with an external consultant or not at all.

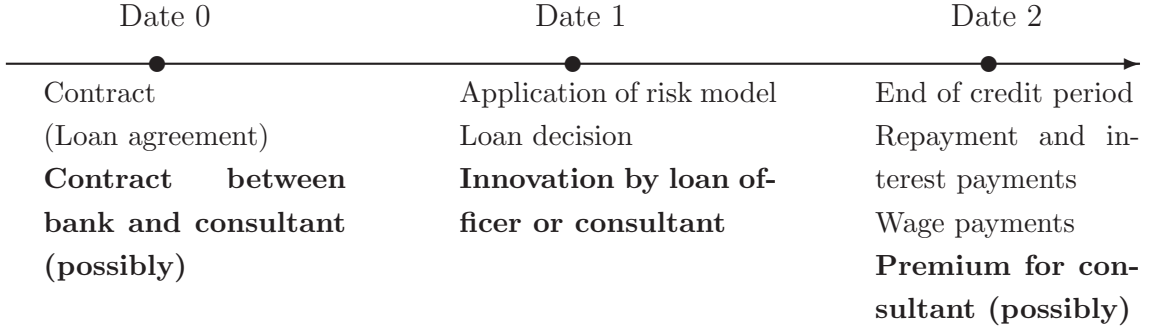
As can be seen in Figure 3, the time structure remains similar and is extended by a possible mandate for an external consultant.

The improvement of the beta-error reduces β by the multiplier ψ , with $0 < \psi < 1$. Therefore, a high ψ stands for a small extent of innovation and vice versa. Each innovation or improvement process costs some one-time effort costs e independent of the person who innovates.

After the innovation is done and with the assumption $\alpha = 0$, probabilities in the risk model (labeled as p^β) are changed to

$$\begin{aligned} p_{r,b}^\beta &= (1 - \gamma) (1 - \psi \beta) \\ p_{a,b}^\beta &= (1 - \gamma) \psi \beta \end{aligned}$$

Figure 3: Time Structure with Innovation (Beta-Error)



$$p_r^\beta = p_{r,g} + p_{r,b}^{\beta I} = 0 + (1 - \gamma) (1 - \psi \beta)$$

$$p_a^\beta = p_{a,g} + p_{a,b}^{\beta I} = \gamma + (1 - \gamma) \psi \beta.$$

Innovation by the loan officer. If the innovation is done by the loan officer, the structures of the bank owner's profit and the loan officer's wage are similar as before. The bank owner has to anticipate the possible improvement of the beta-error and the effort costs of the loan officer when incentivizing the agents.

The changes result in new profits for bank and loan officer. Probabilities are adjusted to the new models and the loan officer has to take additional effort costs e for the innovation into account.

$$E\Pi L^\beta = p_r^\beta a + p_{a,g} b - c - e \tag{7}$$

$$E\Pi B^\beta = p_{a,g} (1 + r) I - p_a I - (p_r^\beta a + p_{a,g} b). \tag{8}$$

In order to put new incentive constraints, all possible actions of the loan officer have to be considered: the loan officer can (a) exert effort for credit check and innovation, (b) exert effort for credit check but not for innovation, (c) do the innovation but shirk regarding the credit check or (d) omit the credit check as well as the innovation. In omitting the credit check, the loan officer can either simply accept all loan requests or reject all credit applications.

It can easily be seen that (c) never is optimal for the loan officer as (c) is dominated by (d). It makes no sense for the loan officer to costly improve the risk model if

he will not apply it and shirk in the next step. The incentive constraints need to ensure that (a) is preferred over (b) and (d). As (d) can be split in (d1) (acceptance of all loans) and in (d2) (rejection of all loans), there are three constraints:

$$E\Pi L^\beta \geq E\Pi L \quad (9)$$

$$E\Pi L^\beta \geq a \quad (10)$$

$$E\Pi L^\beta \geq \gamma b \quad (11)$$

With two wage variables (a and b), only two constraints simultaneously bind. Therefore, we end in two possible contracts between loan officer and bank. The proof of the following Lemma is in the appendix.

Lemma 2 *If $e \leq \frac{\beta(1-\psi)c}{1-\beta}$, contract 1 is used and wage parameters are*

$$a = \frac{c+e}{(1-\psi)\beta(1-\gamma)} \text{ and} \quad (12)$$

$$b = \frac{c+e}{(1-\psi)\beta\gamma(1-\gamma)}. \quad (13)$$

If $e \geq \frac{\beta(1-\psi)c}{1-\beta}$, contract 2 is used and wage parameters are

$$a = \frac{e}{(1-\psi)\beta(1-\gamma)} \text{ and} \quad (14)$$

$$b = \frac{c(\beta(1-\psi)(1-\gamma) + e(\gamma + \beta(1-\gamma)))}{(1-\psi)\beta\gamma(1-\gamma)}. \quad (15)$$

As in Section (2), we are able to calculate profit functions by using the results for the wage parameters in equilibrium. The profits are labeled with $i1$ respectively $i2$ as the beta-error is performed by the internal agent under contract 1 or 2.

If $e \leq \frac{\beta(1-\psi)c}{1-\beta}$ (contract 1), profits of the bank owner and the loan officer are

$$E\Pi B^{\beta,i1} = (r\gamma - (1-\gamma)\psi\beta)I - e - c - \frac{c+e}{(1-\gamma)(1-\psi)\beta}$$

$$E\Pi L^{\beta,i1} = \frac{c+e}{(1-\gamma)(1-\psi)\beta}.$$

If $e \geq \frac{\beta(1-\psi)c}{1-\beta}$ (contract 2), profits of the bank owner and the loan officer are

$$E\Pi B^{\beta,i2} = (r\gamma - (1-\gamma)\psi\beta)I - e - c - \frac{e}{(1-\gamma)(1-\psi)\beta}$$

$$E\Pi L^{\beta,i2} = \frac{e}{(1-\gamma)(1-\psi)\beta}.$$

It can be seen that the profit of the bank with both contracts differ only in the last term which is equivalent to the respective profit of the loan officer. What the bank owner earns from disbursed loans remains the same with both contracts. However, the wage he has to pay is different because of different incentives he has to account for. In both cases, the loan officer's wage is depending on effort costs and extent of the innovation, the quality of the market and the risk model. Also in both cases, the loan officer invests credit check costs. However, these costs do not appear directly in the wage of contract 2, as innovation costs e are above a certain level.

Innovation by the external consultant. If the innovation is done by the external consultant, the structures of the bank owner's profit and the loan officer's wage are similar as before. The loan officer is incentivized to use the improved risk model instead of shirking and the bank owner now has to pay a premium to the consultant.

After the bank owner engaged the consultant, he will adjust the wage of the loan officer to the new situation of the improved risk model. If the wage would not be adjusted, the bank owner would waive some additional profit, he otherwise could get for himself. The loan officer must be incentivized only to do the credit check, not the innovation. The wage therefore is similar to the one of the basic model as in Lemma 1, adjusted to the new situation of an improved risk model. Loan parameters from (5) and (6) are changed to

$$a = \frac{c}{(1-\psi\beta)(1-\gamma)} \quad \text{and} \quad (16)$$

$$b = \frac{c}{(1-\psi\beta)\gamma(1-\gamma)}. \quad (17)$$

by inserting $\alpha = 0$ and using the new risk model.

The external consultant is compensated by a premium that increases with the reduction of the beta-error. Hence, he receives a premium A for all rejected projects. With this compensation, the external consultant should be incentivized to exert effort for the innovation. His incentive constraint is the following:

$$p_r^\beta A - e \geq p_r A \quad (18)$$

If the consultant shirks, the loan officer has wrong incentives as he is able to recognize that he is working with a not improved risk model. Consequently, the loan officer will shirk and reject all loans. Hence, the bank owner only pays the premium to the external consultant if at least one loan is assigned. This guarantees incentives for both agents.

As the bank owner is only willing to pay the lowest possible amount to the external consultant, the above condition (18) is binding, which results in the premium

$$A = \frac{e}{\beta(1-\psi)(1-\gamma)}. \quad (19)$$

With these wage components, expected profits of bank owner, loan officer and external consultant are

$$\begin{aligned} E\Pi B^{\beta,e} &= [r\gamma - (1-\gamma)\psi\beta]I - e - c - \frac{1-\beta}{(1-\psi)\beta}e - \frac{c}{(1-\gamma)(1-\psi\beta)} \\ E\Pi L^{\beta,e} &= \frac{c}{(1-\gamma)(1-\psi\beta)} \\ E\Pi C^{\beta,e} &= \frac{1-\beta}{(1-\psi)\beta}e. \end{aligned}$$

As in $E\Pi B^{\beta,i1}$ and $E\Pi B^{\beta,i2}$, the bank owner again earns the same amount from allowed credits. This amount is reduced by the last four terms as he has to compensate loan officer and external consultant for credit check costs c and effort e for the innovation.

3.2 Discussion of Factors Influencing the Innovation Decision

So far, two different possibilities to perform the innovation are defined. The bank owner may assign the improvement process either internally to the loan officer or externally to a consultant. The bank owner maximizes his income, and therefore he chooses the option that leads to the highest profit.

Hence, the innovation decision of the bank is depending on different factors of the risk model and the market.

Proposition 1 *If γ is above a certain level, the bank owner engages the external consultant to perform the innovation. Otherwise, the loan officer will do the improvement of the beta-error.*

With contract 1 ($e \leq \frac{\beta(1-\psi)c}{1-\beta}$), $E\Pi B^{\beta,e} > E\Pi B^{\beta,i1}$, if and only if

$$\gamma > \frac{1 - 2\beta + \beta^2\psi}{(1 - \psi\beta)(1 - \beta)}. \quad (20)$$

With contract 2 ($e \geq \frac{\beta(1-\psi)c}{1-\beta}$), $E\Pi B^{\beta,e} > E\Pi B^{\beta,i2}$, if and only if

$$\gamma > \frac{\beta[(1-\psi)c - (1-\psi\beta)e]}{(1 - \psi\beta)(1 - \beta)e}. \quad (21)$$

A high γ means a high market quality. Many good projects are available which can be taken as a sign for a boom situation in the economy. In this case, the bank owner earns higher profits, if he does not need to incentivize the loan officer for both – credit check and innovation, but is able to differentiate between the two tasks. Obviously, the bank owner will decide for the alternative that promises higher profits.

The wage of the loan officer is composed of the bonus b and the administration fee a . In case of a high γ , the bonus is responsible for a high share of the total wage, and it is more difficult to incentivize the loan officer to do an additional effort for the innovation as the incentive for the improvement of the beta-error will be achieved mainly by the administration fee.

It can also be seen that the wage of the loan officer (in all cases, i.e. $E\Pi L^{\beta,i1}$, $E\Pi L^{\beta,i2}$ and $E\Pi L^{\beta,e}$) is increasing with γ whereas the consultant's profit ($E\Pi C^{\beta,e}$) is independent of γ . The marginal increase of the loan officer's wage is higher in the case of the innovation by the loan officer than in the case of the innovation by the consultant. Thus, at a certain level, it is more favorable to engage the external consultant as it becomes more expensive to incentivize the loan officer.

Proposition 2 *If ψ is below a certain level, the bank owner engages the external consultant to perform the innovation. Otherwise, the loan officer will do the improvement of the beta-error.*

With contract 1 ($e \leq \frac{\beta(1-\psi)c}{1-\beta}$), $E\Pi B^{\beta,e} > E\Pi B^{\beta,i1}$, if and only if

$$\psi < \frac{\beta - (1 - \beta)(1 - \gamma)}{\beta[1 - (1 - \beta)(1 - \gamma)]}. \quad (22)$$

If the bank owner wants to have a small effect of the innovation - that means he orders a low improvement of the risk model (high level of ψ), he prefers to engage the loan officer. With a small reduction of the beta-error, it is easier to incentivize the loan officer as the loan officer benefits from a better risk model himself in reaching better results of the also recompensated credit check. Only for a high extent of the innovation, it is better for the bank owner to differentiate between the two tasks of innovation and credit check. With contract 2, the decision dependent on ψ is not unambiguous.

3.3 Decision of the Bank and Welfare Analysis

Depending on the different parameters responsible for market quality, risk model quality, credit check costs and effort, the bank may decide to not innovate at all. Hence, the bank owner not only compares the two different possibilities for innovation but also takes into account to have no improvement of the risk model. We are able to find examples of parameters for each possible decision of the bank owner: no improvement (as in the basic model, labeled as BM), innovation by internal loan officer (i) and innovation by the external consultant (e). After a general welfare analysis, this chapter shows the concrete decision of the bank and the respective welfare optimal decision for specific parameter constellations of the risk model.

In a welfare analysis, we now answer the question if the decision of the bank is pareto optimal for the economy. To analyze the welfare implications, we define welfare as the sum of the rents of the bank owner, loan officer, external consultant and in addition the rents of all projects that are accepted for loans. Let us assume that good projects have a return of Y and consequently, that the rent of borrowers consists of $Y - (1 + r) I$. Only borrowers who are successful in their projects (i.e. borrowers with probability $p_{a,g}$) receive the return and are able to pay interest rates. Other borrowers earn 0 and their loans default or they did not receive any loan. Thus, welfare is

$$W = E\Pi B + E\Pi L + E\Pi C + p_{a,g} [Y - (1 + r) I]. \quad (23)$$

By inserting the profit equations from above, we find two different results for welfare: one of the basic model without an innovation and one of the model with improvement of the beta-error. Obviously, there is no difference in the welfare whether loan

officer or external consultant are contracted to do the innovation. This leads only to different allocations of rents, the sum of rents remains the same though. Thus, we focus on these two cases: without innovation (W^{BM}) and with innovation (W^β). Results for welfare functions are

$$W^{BM} = \gamma(Y - I) - \beta(1 - \gamma)I - c \text{ and} \quad (24)$$

$$W^\beta = \gamma(Y - I) - \psi\beta(1 - \gamma)I - c - e. \quad (25)$$

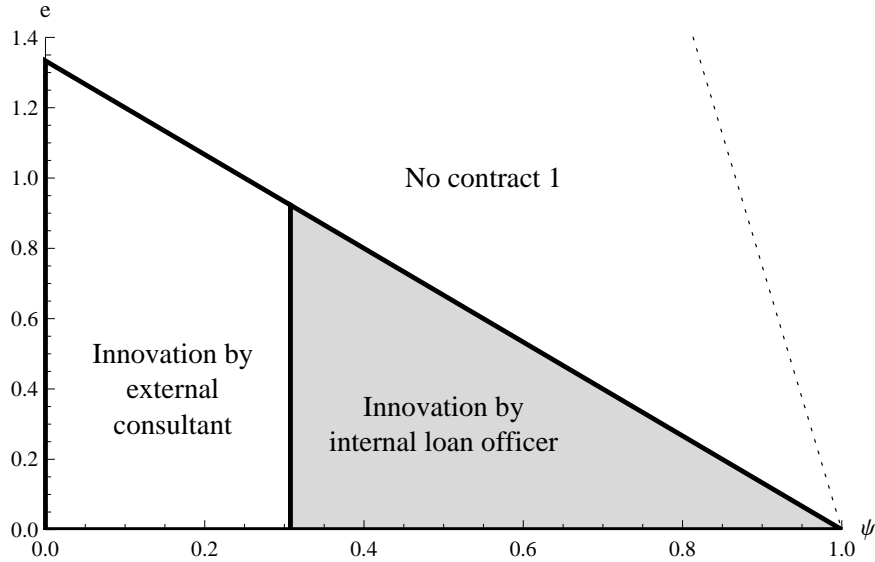
It can be seen that it is better from a welfare point of view not to exert effort for the innovation if $e > (1 - \psi)\beta(1 - \gamma)I$. Intuitively, the bank should refrain from improving the risk model if effort costs for this task are very high. The same decision should be taken if the market quality γ is very high, as incentivizing loan officer or external consultant will become more expensive. If the risk model has already a high quality, i.e. β is low, the costs for a further improvement of the risk model will be expensive and the probability for a welfare optimal reduction of the beta-error is decreasing.

Examples. Will the bank always incentivize agents for an improvement of the risk model if it is welfare optimal? And will the bank omit the innovation whenever $W^{BM} > W^\beta$? To answer these questions, the profits of the bank under the different possibilities have to be compared.

Figure 4 shows the different regimes under contract 1, that means $e \leq \frac{\beta(1-\psi)c}{1-\beta}$, for parameters $\gamma = 3/4$, $\beta = 1/4$, $c = 4$, $r = 7/8$ and $I = 60$. On the upper right side of the graph (above the black diagonal), the condition for contract 1 is not fulfilled and therefore this part is not relevant for the analysis. The dotted black line shows the border between welfare optimal innovation and welfare optimal status quo. To the left of the dotted line, it is always welfare optimal to exert effort for an improvement of the risk model.

With the given parameter constellation, the bank owner always decides for the innovation. If the planned innovation is small (high ψ), it is profitable for the bank owner to incentivize the loan officer. For a higher extent of improvement, the incentivizing wage for the internal loan officer would be too high, so it is better to differentiate between innovation and credit check by incentivizing two agents for the two tasks. However, all decisions under these parameters are welfare optimal.

Figure 4: Decision of the Bank under Contract 1



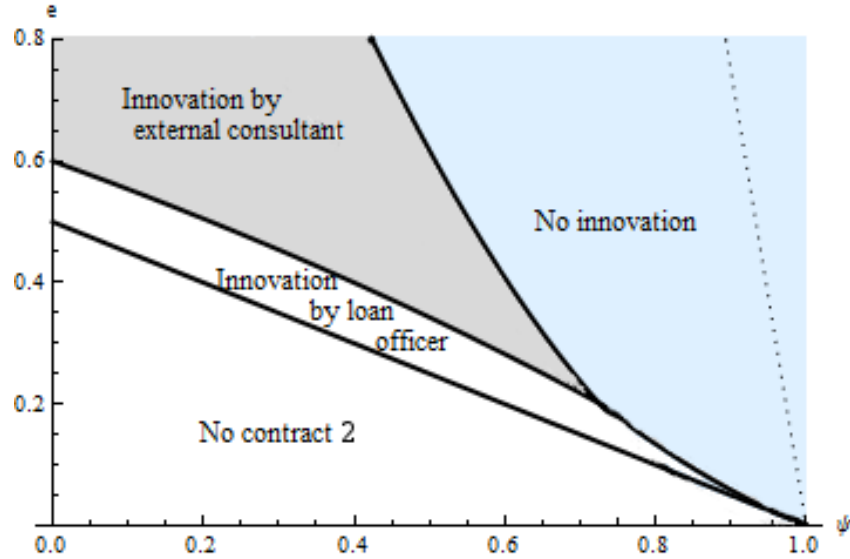
In Figure 5, the decisions of the bank under parameters $\gamma = 1/2$, $\beta = 1/4$, $c = 3/2$, $r = 7/8$ and $I = 60$ can be seen. In the lower left corner, conditions for contract 2 are not fulfilled, the other part shows the relevant regimes.

If effort costs are not too high, the bank owner will assign the task of innovation to the internal loan officer. With increasing effort costs it is better for the bank owner to entrust the external consultant with the improvement of the risk model. In addition, we can see that the higher the effort costs the higher is also the probability for the bank owner to decide for no innovation at all (depending also on ψ). This is very intuitive as high effort costs make it expensive for the bank owner to remunerate an agent for the innovation task.

Considering the x-Axis, it can be seen that, with a lower level of ψ , the external consultant will perform the innovation. In contrast, with a higher level of ψ , the risk model remains in its original condition. Therefore, a planned innovation will only be realized, if it is of a larger extent.

On the upper right side, we see a large area in which the bank decides for no innovation. However, only in a small part of it – the part on the right of the dotted line, it is also welfare optimal to do so. Because of externalities, the bank who bears the costs of asymmetric information chooses a policy that is not optimal for

Figure 5: Decision of the Bank under Contract 2



the economy. Hence, we find that under certain conditions, the bank does not put enough effort in the improvement of risk models. A possible measure to solve this problem would be regulation concerning risk models such as regulatory standards that must be kept or periodic controls.

4 Conclusion

This paper proposes a framework to study the relation between organizational structures and model risk. We have constructed a microeconomic model of a bank in which incentives for innovation play a crucial role. The bank uses a risk model as credit test that is assumed to be imperfect. As no accidental innovation exists, the bank owner has to incentivize an agent to improve the inaccurate risk model. If it is too difficult or expensive to incentivize an internal agent, the bank owner also has the possibility to engage an external consultant for the innovation. He will make use of this possibility if there are many good projects available, effort costs for the innovation are high or if the planned innovation is of a smaller extent. In short, the external agent is preferred from the bank owner in extreme cases.

The paper provides also a reason in ongoing discussions about consultancy and

its high costs. It argues that outsourcing tasks may be reasonable. In some cases that are discussed in this article, the bank owner benefits from the chance to differentiate between incentives for diverse tasks. Also from a welfare perspective, we find that under certain conditions external agents should be preferred over an internal solution.

However, in special cases, we find that banks undertake too less effort to incentivize internal or external service workers for an improvement of the bank's risk model. This is a clear argument for regulation. Regulatory standards for risk models could drive banks to innovate even under conditions that would not lead banks to decide for innovations by their own.

A Proofs

Proof of Lemma 1. Incentive constraints (3) and (4) are binding and can be rewritten as

$$\begin{aligned} (1 - \beta)a - c + (1 - \alpha)\gamma b - (1 - \alpha - \beta)\gamma a - c &= a \text{ and} \\ (1 - \beta)a - c + (1 - \alpha)\gamma b - (1 - \alpha - \beta)\gamma a - c &= \gamma b. \end{aligned}$$

Solving these two equations for a and b leads to the result of Lemma 1, i.e. the wage parameters of (5) and (6). ■

Proof of Lemma 2. For contract 1: If incentive constraints (10) and (11) are binding, the constraint (9) is fulfilled if and only if $e \leq \frac{\beta(1-\psi)c}{1-\beta}$. Parameters a and b can be calculated by solving (10) and (11) for a and b .

Incentive constraints (10) and (11) can be rewritten as:

$$\begin{aligned} (1 - \gamma)(1 - \psi\beta)a + \gamma b - c - e &\geq a \text{ and} \\ (1 - \gamma)(1 - \psi\beta)a + \gamma b - c - e &\geq \gamma b. \end{aligned}$$

If those constraints are binding, they can be solved for

$$a = \frac{c + e}{(1 - \psi\beta)(1 - \gamma)} \text{ and}$$

$$b = \frac{c + e}{(1 - \psi \beta) \gamma (1 - \gamma)}.$$

which are equations (12) and (13) from Lemma 2. If we now insert (12) and (13) in the incentive condition (9), this condition can be simplified to

$$e \leq \frac{\beta (1 - \psi) c}{1 - \beta}.$$

For contract 2: If incentive constraints (9) and (10) are binding, the constraint (11) is fulfilled if and only if $e \geq \frac{\beta (1 - \psi) c}{1 - \beta}$. Parameters a and b can be calculated by solving (9) and (10) for a and b .

Incentive constraints (9) and (10) can be rewritten as:

$$\begin{aligned} (1 - \gamma) (1 - \psi \beta) a + \gamma b - c - e &\geq (1 - \gamma) (1 - \beta) a + \gamma b - c \text{ and} \\ (1 - \gamma) (1 - \psi \beta) a + \gamma b - c - e &\geq a. \end{aligned}$$

If those constraints are binding, they can be solved for

$$\begin{aligned} a &= \frac{e}{(1 - \psi) \beta (1 - \gamma)} \text{ and} \\ b &= \frac{c (\beta (1 - \psi) (1 - \gamma) + e (\gamma + \beta (1 - \gamma)))}{(1 - \psi) \beta \gamma (1 - \gamma)}. \end{aligned}$$

which are equations (14) and (15) from Lemma 2. If we now insert (14) and (15) in the incentive condition (11), this condition can be simplified to

$$e \geq \frac{\beta (1 - \psi) c}{1 - \beta}.$$

A third possible contract does not exist as binding incentive constraints (9) and (11) do not have a solution for a and b . ■

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