Devices to screen borrowers' privately known default risk

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Motivation and Summary of Main Results

Lenders who consider to borrow to small and medium enterprises (SMEs) or consumers face substantial informational problems. Even if these borrowers are observationally identical for their lenders, as a matter of fact, they have some private information about their default risk. Thus, lenders who, ceteris paribus, merely offer a flat rate of interest to observationally identical borrowers, in effect pool borrowers with different default risks.

In case of perfect competition these lenders make zero expected profits. For this reason the flat rate of interest adjusts to the average risk of the pool. As a result, with the pooling interest rate low-risk borrowers pay a higher than their fair risk-adjusted interest rate. This has consequences for their welfare. On the one hand, because of the higher loan costs they raise a smaller loan than under symmetric information. On the other hand, it drives those low-risk borrowers out whose expected return from an investment of the loan is too low to afford the pooling interest rate. Both, underinvestment and adverse selection impose informational costs on low-risk borrowers.

Thus, the lenders are interested in a loan policy which reduces these informational costs for the low-risk borrowers. For that purpose, they offer a menu of loan contracts which is designed such that borrowers truthfully reveal their privately known riskiness by choosing their optimal loan contract. This raises the research question which contractual instruments are eligible to screen borrowers' private information about their default risk.

The thesis is subdivided into three chapters. Chapters 1 and 3 are done solely on my own. In Chapter 2 I have developed research idea and model on my own, but it is written down jointly with professor Philipp C. Wichardt. Although these chapters are individual papers and can be read independently, they are related to each other. Chapter 1 explains why there is credit rationing in competitive loan markets with imperfect information. As credit rationing causes informational costs, chapters 2 and 3 introduce cheaper devices to screen borrowers' privately known riskiness.

Chapter 1 theoretically shows why lenders ration loan size and loan applicants to screen borrowers' riskiness in a competitive spot loan market with imperfect information. In contrast to the existing literature, it explains why rationing of loan applicants exists and why it co-exists with rationing of loan size.

To answer these questions, it considers a competitive spot loan market with imperfect information about the technological characteristics of its loan applicants' investment projects which differ with respect to riskiness and return. If riskier technologies yield a higher return, rationing works as a screening instrument which is more costly for high-risk than for low-risk loan applicants. Then, although rationing of low-risk loan applicants imposes opportunity costs on them this makes them better off. Divisibility of investment technologies enables banks to use loan size as a further screening device. Then, banks favor to ration loan size instead of loan applicants. Only if the difference of the marginal return between the investment technologies is sufficiently small relative to the difference in their riskiness, solely rationing of loan size becomes too expensive and banks additionally ration loan applicants.

The results of this chapter suggest that future empirical research should pay more attention to the borrowers' privately known investment technology. Knowing the characteristic investment technologies would facilitate a better understanding why rationing occurs in loan markets with imperfect information. Furthermore, it is left to test empirically if observationally identical, but unobservably less risky borrowers are rather rationed. And, if less risky loan applicants are only rationed if rationing of their loan size becomes too expensive.

Chapter 2 theoretically examines how lenders can reduce costs to screen borrowers' riskiness by a commitment to grant a loan in the future and including a material adverse change (MAC) clause while a spot loan market co-exists. This contributes to the literature as it explains why the MAC clause under loan commitments is so ubiquitous although lenders do not invoke it very often.

In addition to the co-existing spot loan market in chapter 1, lenders now sell a commitment against a fee to grant a loan in the future at predetermined contractual terms agreed upon today. In the event of a takedown of the loan under the commitment, the low-risk borrowers repay the loan with a higher probability than the high-risk borrowers. Lenders take advantage of that and use the commitment fee to subsidize the interest rate.

However, the usage of a commitment as a screening device is limited as empirical evidence shows that high-risk borrowers have a higher takedown probability under a commitment than low-risk borrowers. Lenders counter that by including a material adverse change (MAC) clause in the commitment contract. This clause allows them to deny a loan legally if, in their opinion, a material adverse change in the borrowers' financial condition has occurred. With the MAC clause lenders decrease the takedown probability of the high-risk borrowers such that the low-risk borrowers benefit more from the subsidy of the interest rate. Thus, the MAC clause makes the loan commitment more effective as a screening device.

It is left for future research to test empirically that the inclusion of the MAC clause in the loan commitment contract attracts less risky borrowers and increases loan size even though there is still some credit rationing.

Chapter 3 empirically tests how borrowers' impatience can be used to screen their private information about default risk. With borrowers' impatience, it identifies a new screening device that has not been broadly analyzed in the literature yet.

To show this, it analyzes consumer loans on the German online lending platform smava.de between March 2007 and May 2012. Besides the fact that Smava provides information about the borrowers' repayment behavior, its unique lending process has further advantages. First, I can observe the same information about the loan application like the lenders on the platform. This enables me to distinguish between the effect of observable and unobservable risk on interest rate. Results show that both, observationally riskier and observationally identical, but riskier borrowers pay a higher interest rate. Second, starting with the day when a loan application is posted on smava, investors have a maximum of 14 days to supply the requested amount. As soon as loan supply equals requested loan size, the loan is granted. Impatient borrowers can make a use of this feature and offer a higher rate to obtain their loan significantly faster and with a higher probability. Third, smava provides an instant loan service which proposes an interest rate which is sufficiently high so that the applicant gets his loan financed within a few minutes or hours. Very impatient borrowers who choose an instant loan are on average riskier.

These empirical results leave several questions open for future research.

To mitigate asymmetric information, it is advantageous to disentangle the different types of impatience and to understand how they are related to default risk. This would have broad implications for policy and welfare. While credit rating agencies can use this knowledge to improve the evaluation of the loan applicants' riskiness, lenders can offer a menu of contracts which differ such that patience of loan applicants reveals their privately known default risk.

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Chapter 1

On the Existence of Credit Rationing and Screening with Loan Size in Competitive Markets with Imperfect Information

Abstract Although credit rationing has been a stylized fact since the ground-breaking papers by Stiglitz and Weiss (1981, hereinafter S-W) and Besanko and Thakor (1987a, hereinafter B-T), Arnold and Riley (2009) note that credit rationing is unlikely in the S-W model, and Clemenz (1993) shows that it does not exist in the B-T model. In this chapter, I explain why credit rationing, more specifically rationing of loan applicants, does exist in a competitive market with imperfect information, and occurs only for low-risk loan applicants. In cases of indivisible investment technologies, low-risk applicants are rationed. In cases of divisible investment technologies, rationing of loan size is restricted to rationing of loan applicants. In the event that the difference in the marginal return between the investment technologies is sufficiently small relative to the difference in their riskiness, rationing of loan size alone yields high opportunity costs; in addition, low-risk loan applicants are rationed in this case.

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1.1 Introduction

In their pioneering paper, Stiglitz and Weiss (1981, hereinafter S-W) state that credit rationing exists in markets with borrowers who privately know the riskiness of their investment technology. In fact, by credit rationing, S-W mean rationing of loan applicants; that is, in the equilibrium, some loan applicants are rejected while other observationally identical loan applicants are accepted. While S-W established the foundation for the literature on adverse selection and credit rationing in financial markets, Arnold and Riley (2009, hereinafter A-R) cast some doubt on S-W's globally hump-shaped expected bank profit as a function of loan rate. They show that this expected profit function cannot have the hump shape suggested by S-W.

A-R recall from S-W that, although all investment technologies have the same mean return, they differ with respect to their riskiness. This implies that riskier investment projects have a higher return than less risky projects if they are successful. From these investment technologies follows that a bank that merely offers a flat rate of interest to observationally identical borrowers effectively pools borrowers with differing levels of riskiness. Raising this flat loan rate simply drives the less risky applicants out of the loan; there is no 'hump'. Based on this observation, A-R show that any equilibrium with rationing must have at least two loan rates, with credit rationing for the lower loan rate and no rationing for the higher loan rate. However, running a numerical analysis, A-R conclude that credit rationing is unlikely.

Besanko and Thakor (1987a, hereinafter B-T) provide another explanation for credit rationing in a market under perfect competition. In their model, the loan applicants' privately known investment technology differs only in riskiness, but not with respect to return. In the B-T equilibrium, low-risk applicants are rationed if they cannot provide sufficiently high collateral. However, Clemenz (1993) points out that the situation described by B-T does not constitute a Nash-equilibrium. Clemenz shows that another profitable loan contract exists for low-risk loan applicants without credit rationing, but at a higher loan rate.

Credit rationing implies opportunity costs for the rejected low-risk loan applicants. To reduce these informational costs, banks use loan size to screen borrowers' riskiness. However, Milde and Riley (1988), Schmidt-Mohr (1997, hereinafter S-M) and Bester (1985) show that loan size must be rationed, thus incurring opportunity costs for the borrowers, as loan size rationing means that, for the given loan rate, they obtain a smaller loan size than desired.

Empirical evidence confirms that rationing exists for both loan applicants (Cole 1998, Blackwell and Winters 1997) and loan size (Petersen and Rajan 1994, 1995). Besanko and Thakor (1987b) consider these two types of rationing to be co-existing screening devices but cannot explain why rationing occurs. This raises the research question of why credit rationing exists, specifically rationing of observationally identical loan applicants. Further, why does loan size rationing exist, and why does it co-exist with rationing of observationally identical loan applicants?

In this chapter, I show that credit rationing is more costly for high-risk than for low-risk loan applicants. Thus, rationing works as a screening instrument that makes low-risk loan applicants better of although it imposes opportunity costs on them. Divisibility of investment technologies enables banks to use loan size as a further screening device. When possible, banks prefer to ration loan size rather than loan applicants. Only if the difference in the marginal return between the investment technologies is sufficiently small relative to the difference in their riskiness, rationing of loan size alone becomes too expensive and, as a result, banks ration loan applicants as well.

The remainder of this chapter is organized as follows: Section 2 analyzes the competitive loan market Nash-equilibrium for indivisible and divisible investment technologies, and Section 3 concludes the chapter.

1.2 The Analysis

1.2.1 The General Set-Up

The risk-neutral entrepreneur E_i considers raising a loan in a competitive market to invest it in a project. Before $t = 1$, E_i privately observes the technology of his investment project, which has either a low (L) or a high risk (H), in the sense of its success probability, such that $p^L > p^H$. The risk-neutral bank knows only that L occurs with probability α and that H

occurs with probability $1-\alpha$. At $t=1$, there are three stages. In the first stage, the bank offers a menu of loan contracts. In the second stage, E_i either applies for one of these loan contracts or chooses his outside option, with payoff 0. In the third stage, it is realized whether or not the bank will grant E_i the loan. If E_i does not obtain a loan, he chooses his outside option.[1] If E_i obtains the loan, he invests it in his project. In this case, at $t=2$, the project return of his investment is realized. The return depends on investment technology. With success probability p^i, its return is R^i; with probability $1-p^i$, it is zero. The timing of events is summarized in Figure 1.1.

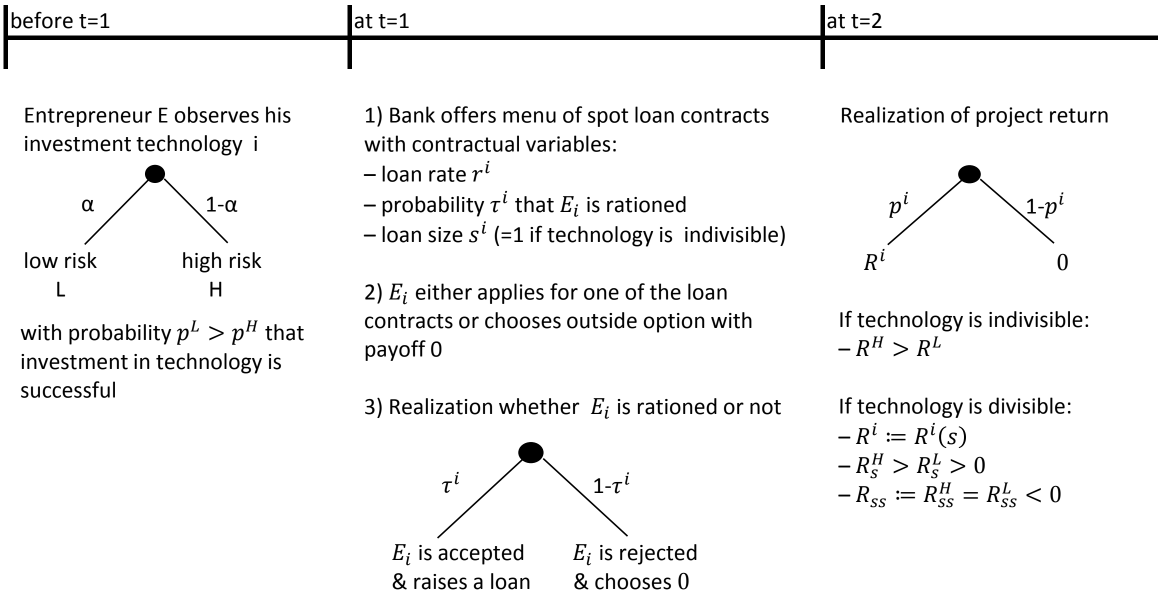

Figure 1.1: Timeline of events.

1.2.2 Indivisible Investment Technology

Consider an entrepreneur E_i who has the opportunity to invest in a project with an indivisible technology. The riskier technology has a higher return (i.e., $R^H > R^L$). To finance that project, E_i needs to borrow a loan of size one. The bank offers E_i a loan contract comprising loan rate r, the

[1] Stiglitz and Weiss (1981), Arnold and Riley (2009) and Clemenz (1993) note that rejected loan applicants may choose the contract with the higher loan rate. However, including this possibility in my model does not have any effect on the design of L's contract. Thus, for simplicity, I assume that a rejected loan applicant chooses his outside option.

probability τ that he is rationed, and a loan size equal to one. At $t = 1$, the bank's expected profit from a loan with contractual variables (τ, r) to E_i is given by

$$\Pi^{Bank}\left(\tau, r; p^i\right) := \tau\left(p^i r - \rho\right) \tag{1.1}$$

where ρ denotes the gross deposit rate, which represents the bank's costs of funds. If E_i applies for loan contract (τ, r), his expected profit function is given by

$$\Pi^i(\tau, r) := \tau p^i\left(R^i - r\right). \tag{1.2}$$

In a Nash-equilibrium, every bank takes offers of competing banks as given and independent of its own actions. A loan contract does not exist outside the Nash-equilibrium with which the bank, if offered, will make a positive profit. Thus, a competitive bank makes zero expected profits with borrower E_i:

$$\Pi^{Bank}\left(\tau^i, r^i; p^i\right) = 0. \tag{1.3}$$

As the bank cannot observe E_i's type, it can only separate L and H by an incentive compatible loan policy $(\tau, r) := \left(\tau^i, r^i\right)^i$, with $i = L, H$, which satisfies

$$\Pi^L\left(\tau^L, r^L\right) \geq \Pi^L\left(\tau^H, r^H\right) \tag{1.4}$$

$$\Pi^H\left(\tau^H, r^H\right) \geq \Pi^H\left(\tau^L, r^L\right) \tag{1.5}$$

Naturally, E_i prefers the contract that maximizes his expected profit function. He chooses to apply for his optimal loan contract if

$$\Pi^i(\tau, r) := \tau p^i\left(R^I - r\right) \geq 0. \tag{1.6}$$

From this follow Propositions 1 and 2.

Proposition 1 (Equilibrium) ***In a competitive loan market with asymmetric information about divisible investment technologies, a Nash-equilibrium exists only if the share of*** L ***is sufficiently small; that is,***

$$\alpha < \hat{\alpha}_{Indiv} := 1 - \rho^{-1} p^H\left(p^L R^L - p^H R^H\right)\left(p^L - p^H\right)^{-1}.$$

Then, in the Nash-equilibrium, the bank's optimal loan policy (r^*, τ^*)***, with loan rate*** r ***and probability*** τ ***that*** E_i ***is rationed, is separating and given***

by

$$r^{H*} = \rho/p^i,\ \tau^{H*} = 1$$
$$r^{L*} = \rho/p^i,\ \tau^{L*} = \left(R^H - \rho/p^H\right)\left(R^L - \rho/p^L\right)^{-1} < 1.$$

Proposition 2 (Welfare) ***In a competitive loan market with asymmetric information about indivisible investment technologies,*** H ***always obtains his first-best loan contract, while*** L ***does not and is rationed; that is,*** $\tau^{L*} < 1$***.***

The intuition of Proposition 2 is as follows. To evaluate welfare, consider the Nash-equilibrium under full information as a benchmark. It is straightforward to show that

$$r^{i*}_{FB} = \rho/p^i \tag{1.7}$$
$$\tau^{i*}_{FB} = 1. \tag{1.8}$$

Then, interest rate r^{i*}_{FB} **covers loan costs, and** E_i **is not rationed. To understand why the Nash-equilibrium under asymmetric information is not first-best, consider the slope of** E_i**'s iso-profit curve, which is described by the total differential of** (1.2) **with respect to** r **and** τ

$$\frac{dr}{d\tau}|_{\Pi^i=const.} = \frac{R^i - r}{\tau} > 0. \tag{1.9}$$

As $R^H > R^L$**,** H **always has a steeper iso-profit curve than** L**. That means that** H **is always willing to pay a higher** r **than** L **to be marginally less rationed. See Figure 1.2 for an illustration of credit rationing.**[2]

Consider a competitive bank that offers contract P **with a flat rate of interest** $\hat{r}^{Pool}$ **such that it makes zero profit. This contract pools** L **and** H**. As** L **has a lower success probability than the average of the pool, he has to pay a higher interest rate,** $\hat{r}^{Pool} > r^{L*}_{FB}$**.** L **always prefers a lower iso-profit curve, as, for a given** τ**, a smaller** r **increases his expected profit. Thus, in a competitive loan market, another bank can attract** L **with contract** A**, which has a lower loan rate of** $r^{L*} = r^{L*}_{FB}$**, although this means that** L **is**

[2] (1.9) satisfies the single-crossing property and has a maximum as $d^2r/d\tau^2|_{\Pi^i=const.} = -\left(R^i - r\right)/\tau^2 < 0$.

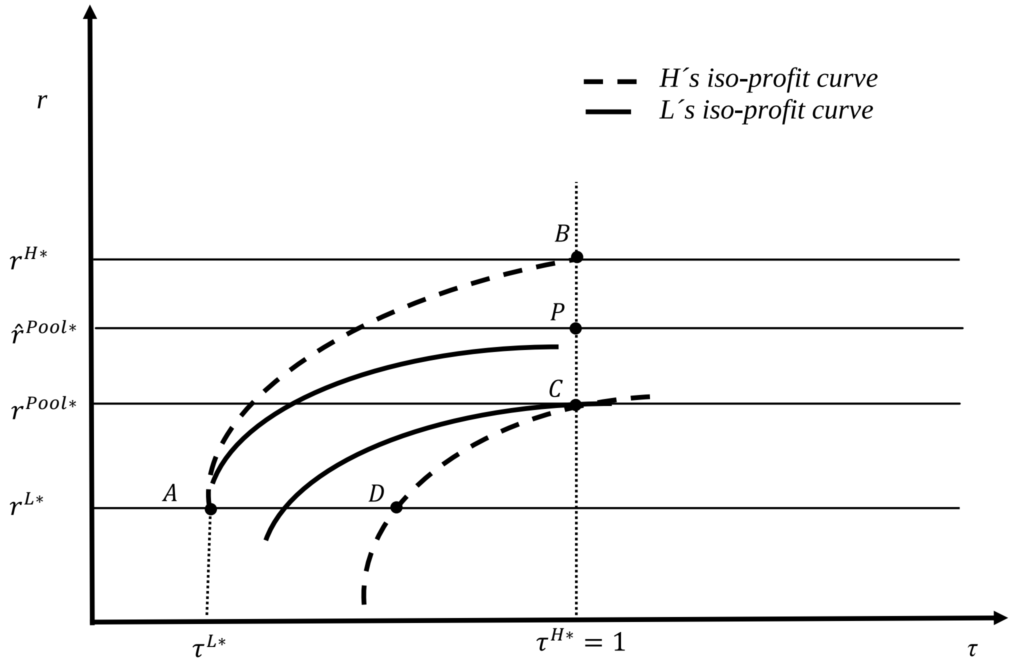

Figure 1.2: The Nash-equilibrium in a competitive loan market with asymmetric information about indivisible investment technologies. If the pooling loan rate r^{Pool} is sufficiently large, L prefers contract A to pooling contract P. In this case, a Nash-equilibrium does exist and is separating. H chooses contract B, and L chooses contract A, which rations him (i.e., $\tau^{L*} < 1$). If r^{Pool} is small enough that L prefers C to A, a Nash-equilibrium does not exist.

rationed (i.e. $\tau^{L*} < 0$). In contrast to L, H is willing to pay a higher r to avoid being rationed and chooses his first-best contract B.

This separating equilibrium is not a Nash-equilibrium, if $\alpha > \hat{\alpha}_{Indiv}$. In this case, r^{Pool*} is sufficiently low that L prefers pooling contract C to A. C is not a contract in the Nash-equilibrium, as another bank can attract L with contract D. In this case, the bank makes negative profits with contract C and thus no longer offers it. H also chooses D, so the bank also makes negative profits with D. Thus, a Nash-equilibrium exists only if $\alpha < \hat{\alpha}_{Indiv}$.

I will now review A-R and Clemenz to show why credit rationing is unlikely in the S-W model and impossible in the B-T model but does exist in the Nash-equilibrium of my model.

S-W and A-R consider a loan market which is characterized by asymmetric information about investment technologies, which all have the same mean return μ but differ with respect to their riskiness in the sense of mean

preserving spreads. Their argument for credit rationing relies on a bank whose expected profit as a function of loan demand is hump-shaped. A-R show that this function can never be globally (cf. S-W's Figure 4, p. 397), but only locally (cf. A-R's Figure 1, p. 2015) hump-shaped. Thus, the bank offers at least two equilibrium loan rates (cf. A-R's Figure 2, p. 2016 and S-W's Figure 5, p. 398). The lower loan rate entails an excess demand for loans (i.e., rationing of loan applicants). To satisfy the rejected applicants, the bank offers a second contract at higher than the Walrasian loan rate. Analyzing this credit rationing equilibrium numerically, A-R conclude that such a rationing equilibrium is unlikely. However, A-R and S-W only consider pooling contracts; in so doing, they rule out loan policies that reveal the borrowers' riskiness.

To examine whether, in the Nash-equilibrium, there is a loan policy that reveals the borrowers' riskiness truthfully, I simplify S-W and A-R's model and consider a high-risk (H) and a low-risk (L) investment technology. Following A-R's notation, E_i's random gross return is $\tilde{R}^i = \mu + \tilde{z}^i$. The random $\tilde{z}^i$ has a zero mean, but a distribution with support $[-\lambda^i, \lambda^i]$, where $z^H > z^L$. Moreover, A-R assume $\tilde{R}^i > 0$, which implies $\tilde{z}^i \leq \mu$. The assumption of a second-order stochastic dominance means that L's and H's distribution of returns $F_i(z)$ differ such that

$$\int_l^u F_H(z)\,dz \geq \int_l^u F_L(z)\,dz, \tag{1.10}$$

where $u > l$. In contrast to A-R, I also include the probability τ that E_i is rationed in his expected profit function, which is given by[3]

$$\Pi^i(r,\tau) = \tau\left[\mu + \int_{-\lambda^i}^{-(\mu-r)} F_i(z)\,dz - r\right]. \tag{1.11}$$

From above results E_i's isoprofit curve, which is given by the total differentiation of (1.11) with respect to r and τ:

$$\frac{dr}{d\tau}\Big|_{\Pi^i=const.} = \frac{\mu + \int_{-\lambda^i}^{-(\mu-r)} F_i(z)\,dz - r}{\tau\left(1 - F_i\left(-\left(\mu - r\right)\right)\right)} > 0. \tag{1.12}$$

[3] This payoff function corresponds to equation (1) in Arnold and Riley (2009, p. 2013). Their notation is adapted to the notation used in the present chapter.

$$\frac{d^2r}{d\tau^2}|_{\Pi^i=const.} = -\frac{\mu + \int_{-\lambda^i}^{-(\mu-r)} F_i(z)\,dz - r}{\tau^2\left(1 - F_i\left(-(\mu - r)\right)\right)} < 0. \tag{1.13}$$

As (1.11) **and** $F_H(z) \geq F_L(z)$, $\forall z$, H **always has a steeper iso-profit curve than** L. **This corresponds to the properties of** E_i**'s iso-profit curve** (1.9) **in my model. Thus, an equilibrium that constitutes a Nash-equilibrium can never be pooling. Instead, the Nash-equilibrium, if it exists, is always separating. Thus, credit rationing of** L **is likely in the S-W model.**

Clemenz (1993) shows that B-T's credit rationing equilibrium does not constitute a Nash-equilibrium. B-T's investment technologies differ with respect to their riskiness only, not with respect to their return in the event of a successful project such that, in my notation, $R := R^H = R^L$. **Then, including collateral as a screening instrument,** L **has a steeper iso-profit curve in the** (r, τ)**-space than** H. **Clemenz shows that a bank can deviate from B-T's rationing equilibrium and make positive profits by offering a loan contract with no rationing at a higher loan rate. Without collateral, there is also no credit rationing in the B-T model. To understand this, consider** E_i**'s iso-profit curve**

$$\frac{dr}{d\tau}|_{\Pi^i=const.} = \frac{R - r}{\tau} > 0. \tag{1.14}$$

Thus, L**'s and** H**'s iso-profit curve does not differ, which makes screening with credit rationing impossible.**

1.2.3 Divisible Investment Technology

Now, consider an entrepreneur E_i **who has the opportunity to invest a loan in a divisible technology. The riskier technology entails an invertible higher marginal return for all** s, $R_s^H > R_s^L > 0$, **but at a decreasing rate; that is,** $R_{ss} := R_{ss}^H = R_{ss}^L < 0$.[4] **At** $t = 1$, **the bank's expected profit from a loan to** E_i **- with the contractual variables loan rate** r, **size** s **and probability** τ **that** E_i **is rationed - is given by**

$$\Pi^{Bank}(r, \tau, s) = \tau\left(p^i r - \rho\right) s. \tag{1.15}$$

[4]S-M and Bester also include loan size as a contractual variable, but they do not consider the possibility of the rationing of loan applicants. While Bester's assumption B corresponds to my investment technology, S-M's technological characteristics are a special case of my model. S-M's investment projects always have the same mean return; i.e., $p^L R^L(s) = p^H R^H(s)$ for all s.

If E_i chooses this loan contract, his expected profit function is given by

$$\Pi^i (r, \tau, s) = \tau p^i \left(R^i (s) - rs \right). \tag{1.16}$$

In a Nash-equilibrium, a competitive bank does not make negative expected profits with any contract. Outside the equilibrium, there is no contract with which the bank, if offered, will make a positive profit. Thus, the bank's loan policy $(r, \tau, s) := (r^i, \tau^i, s^i)^i$ maximizes $\Pi^i (r, \tau, s)$, subject to

$$\Pi^L \left(r^L, \tau^L, s^L \right) \geq \Pi^L \left(r^H, \tau^H, s^H \right) \tag{1.17}$$

$$\Pi^H \left(r^H, \tau^H, s^H \right) \geq \Pi^H \left(r^L, \tau^L, s^L \right) \tag{1.18}$$

$$\Pi^i \left(r^i, \tau^i, s^i \right) \geq 0. \tag{1.19}$$

$$\Pi^{Bank} \left(r^i, \tau^i, s^i \right) = 0. \tag{1.20}$$

$$0 \leq \tau^i \leq 1 \tag{1.21}$$

where $i = L, H$. Note that (1.17) and (1.18) are the incentive-compatible constraints, (1.19) is E_i's participation constraint that guarantees that E_i raises a loan, (1.20) is the bank's zero expected profit condition, and (1.21) is the feasibility constraint for the rationing of E_i.

From this follow Propositions 3 and 4.

Proposition 3 (Equilibrium) ***In a competitive loan market with asymmetric information about divisible investment technologies, a Nash-equilibrium exists only if the share of L is sufficiently small; that is,***

$$\alpha < \hat{\alpha}_{Div} := \Pi^L \left(r^{L*}, \tau^{L*}, s^{L*} \right) = \Pi^{L,Pool} \left(r^{Pool*}, s^{Pool*} \right)$$

with $r^{Pool*} = \rho \left(\hat{\alpha}_{Div} p^L + (1 - \hat{\alpha}_{Div}) p^H \right)^{-1}$. This Nash-equilibrium is not first-best if the difference between H's and L'S marginal return (i.e., $\Delta R_s := R_s^H - R_s^L$) is sufficiently small relative to the difference in their riskiness ($\Delta p := p^L - p^H$). In this case, the bank's optimal loan policy (r^*, τ^*, s^*), which comprises gross loan rate r, loan size s and probability τ that E_i is

rationed, is separating such that** H**'s respectively** L**'s loan contract is

$$
\begin{aligned}
r^{H*} =&\rho/p^H,\ \tau^{H*} = 1,\ s^{H*} := p^H\left(R_s^H\left(s^{H*}\right) - \rho/p^H\right) = 0\\
r^{L*} =&\rho/p^L\\
\tau^{L*} =&\begin{cases} 1 & \textbf{\textit{if}}\ \frac{\epsilon_{\Pi^L_{L*}(\bar{\tau}^L=1),s^L}}{\epsilon_{\epsilon_{\Pi^H_{L*}(\bar{\tau}^L=1),s^L}}} \geq 1\\ \frac{R^H\left(s^{H*}\right)-r^{H*}s^{H*}}{R^H\left(s^{L*}\right)-r^{L*}s^{L*}} < 1 & \textbf{\textit{otherwise}} \end{cases}\\
s^{L*} :=&\begin{cases} R_s^L\left(s^{L*}\right) - \left(R_s^H\left(s^{L*}\right) - R_s^L\left(s^{L*}\right)\right)\frac{p^H}{p^L-p^H} = r^{L*} & \textbf{\textit{if}}\ \frac{\epsilon_{\Pi^L_{L*}(\bar{\tau}^L=1),s^L}}{\epsilon_{\Pi^H_{L*}(\bar{\tau}^L=1),s^L}} \geq 1\\ \frac{\partial\Pi^L_{L*}/\Pi^L_{L*}}{\partial s^L/s^{L*}} = \frac{\partial\Pi^H_{L*}/\Pi^H_{L*}}{\partial s^L/s^{L*}} & \textbf{\textit{otherwise}}. \end{cases}
\end{aligned}
$$

where** $\Pi^i_{L*}\left(\bar{\tau}^L = 1\right) := \Pi^i\left(r^{L*}, \bar{\tau}^L = 1, s^{L*}\right)$ **denotes** E_i**'s expected profit if he chooses the loan contract designed for** L**, assuming that the bank does not ration him (i.e.,** $\bar{\tau}^L = 1$**) and** $\epsilon_{\Pi^i_{L*}(\bar{\tau}^L=1),s^L} := \frac{\partial\Pi^i_{L*}\left(\bar{\tau}^L=1\right)/\Pi^i_{L*}\left(\bar{\tau}^L=1\right)}{\partial s^L/s^{L*}}$**. There is a unique interior solution for** s^{i*}**.

Proposition 4 (Welfare) ***In a competitive loan market with asymmetric information about divisible investment technologies,** H **always obtains his first-best contract, whereas** L **does not if the difference between** H**'s and** L**'s marginal return (i.e.,** $\Delta R_s := R_s^H - R_s^L$**) is sufficiently small relative to the difference in their probability of success (**$\Delta p := p^L - p^H$**).***

To evaluate welfare, consider the equilibrium under full information as a benchmark. In this scenario, the bank knows E_i's type and, in the Nash-equilibrium, the optimal loan policy maximizes E_i's expected profit subject to (1.20). It is a straightforward process to verify that the Nash-equilibrium under symmetric information is

$$r^{i*}_{FB} =\rho/p^i \tag{1.22}$$

$$\tau^{i*}_{FB} =1 \tag{1.23}$$

$$s^{i*}_{FB} :=R^i_s\left(s^{i*}_{FB}\right) = \rho/p^i \tag{1.24}$$

Under full information, interest rate r^{i*}_{FB} covers loan costs, E_i is not rationed (i.e., $\tau^{i*}_{FB} = 1$), and size s^{i*}_{FB} equates E_i's marginal return in the event of a project success and the bank's marginal lending costs.

The intuition of Proposition 3 is as follows. Consider the slope of E_i' s iso-profit curve which is the total differential of his expected profit function

(1.16) **with respect to** r **and** s**:**

$$\frac{dr}{ds}|_{\Pi^i=const.} = \frac{R_s^i - r}{s} \tag{1.25}$$

As $R_s^H > R_s^L$**,** $\forall s > 0$**,** H **is always willing to pay a higher** r **for a marginal increase of** s**; that is,** H **always has a steeper iso-profit curve than** L**.**[5] **See Figure 1.3 for an illustration.**

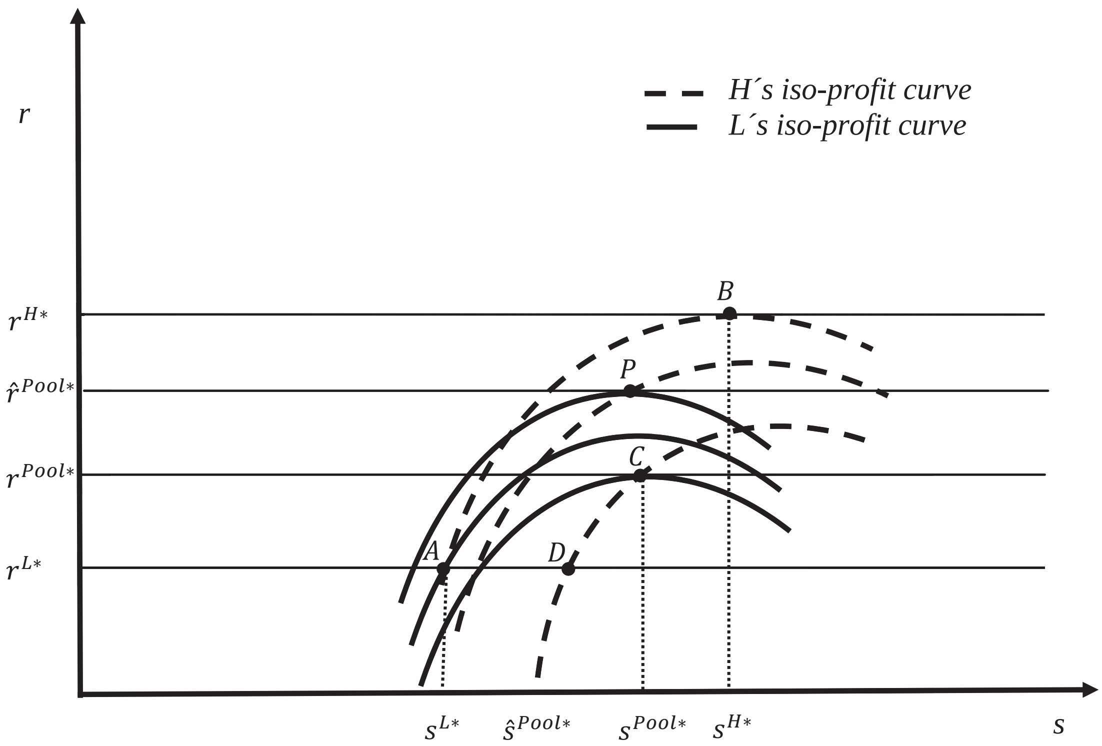

Figure 1.3: Nash-equilibrium in a competitive loan market with asymmetric information about indivisible investment technologies. The equilibrium is separating if H chooses contract B and L chooses contract A. If pooling interest rate r^{Pool} is sufficiently small, L and H will prefer pooling contract C in order to get on a lower iso-profit curve. In this case, deviation contract D attracts L. However, as this makes C unprofitable, H also chooses D, which, in turn, also becomes unprofitable. Thus, the bank offers no contracts, and a Nash-equilibrium does not exist.

Again, a competitive bank offers a menu of contracts A **and** B**, which satisfy the incentive compatibility constraints** (1.17) **and** (1.18) **as well as the bank's zero expected profit condition** (1.20)**.** B **has a higher loan rate**

[5](1.25) satisfies the single-crossing property and has a maximum as $d^2r/ds^2|_{\Pi^i=const.} = \left(R_{ss}^i s - \left(R_s^i - r\right)\right)/s^2 < 0$ as $R_s^i > 0$ and $R_{ss} < 0$, $\forall s > 0$.

and a larger loan size than A. L has no incentive to choose B, as $r^{H*} > r^{L*}$, although s^{H*} is too large for him. Thus, L's incentive compatibility constraint (1.17) is not binding, and H always obtains his first-best contract.

However, H's incentive compatibility constraint (1.18) is binding if H is willing to accept A's smaller-than-optimal loan size $s^{L*} < s^{H*}$ in order to pay A's lower $r^{L*} < r^{H*}$. This applies if the difference between H's and L's first-best loan size (i.e., $\Delta s^*_{FB} := s^{H*}_{FB} - s^{L*}_{FB}$) is sufficiently small relative to the difference in their first-best loan rate ($\Delta r^*_{FB} := r^{H*}_{FB} - r^{L*}_{FB}$). Δr^*_{FB} increases with the difference in the probability of success $\Delta p := p^L - p^H$, while Δs^*_{FB} increases with the difference in the marginal return of H and L (i.e., $\Delta R_s := R^H_s - R^L_s$). Thus, H chooses L's first-best contract if ΔR_s is sufficiently small relative to ΔR_s. To prevent this, under asymmetric information, contract A rations L's loan size in order to deter H. Loan size $s^{L*} < s^{L*}_{FB}$ is rationed because, in the Nash-equilibrium, for a given r^{L*}, L would like to raise a larger loan. This imposes opportunity costs on L, which increase with rationing of loan size. As soon as these costs are sufficiently high, specifically when

$$\epsilon_{\Pi^L_{L*}(\bar{\tau}^L=1),s^L} > \epsilon_{\epsilon_{\Pi^H_{L*}(\bar{\tau}^L=1),s^L}}, \tag{1.26}$$

in addition to loan size rationing, the bank rations L.

Such a Nash-equilibrium only exists if the pooling interest rate r^{Pool*} is sufficiently high. In this case, pooling contract P does not constitute a contract in the Nash-equilibrium. The reason is that another bank can attract exclusively L with contract A which has a lower interest rate $r^{L*} = r^{L*}_{FB}$ and a smaller loan size s^{L*} than P.

Otherwise, a Nash-equilibrium does not exist. In this case, r^{Pool*} is sufficiently low, such that L prefers pooling contract C to A. However, C does not constitute a Nash-equilibrium, as another bank can attract exclusively L with deviation contract D. Now, only H chooses C. Because the bank then makes negative profits with C, it chooses to stop offering it. Thus, H also chooses D. As a result, the bank also makes negative profits with D and then offers no loan contracts in a Nash-equilibrium. As r^{Pool*} decreases with α, a Nash-equilibrium does not exist for a sufficiently high $\alpha \geq \hat{\alpha}_{Div}$.

1.3 Concluding Remarks

Although A-R note that credit rationing is unlikely in the S-W model and Clemenz shows that it does not exist in the B-T model, this chapter shows that there is an appropriate framework for credit rationing. I analyze investment projects with technological characteristics similar to those in A-R's and S-W's model, but different from those in B-T's respectively Clemenz' model. In contrast to A-R and S-W, I consider loan policies that are incentive-compatible in the sense that they truthfully reveal the borrowers' privately known riskiness.

In the case of indivisible projects, rationing occurs if a riskier investment technology yields a higher return. In the case of divisible projects, rationing occurs only iff the marginal return on investment is sufficiently similar for both technologies relative to the difference in their riskiness. While high-risk borrowers always obtain their first-best contract, rationing occurs for low-risk borrowers. If the investment technology is divisible, the bank rations loan size. Only in the event that the rationing of loan size alone becomes too expensive does the bank also ration loan applicants.

These results suggest that future empirical research should pay more attention to borrowers' privately known investment technologies. Knowing the characteristics of these technologies would facilitate a better understanding of why rationing occurs in loan markets with imperfect information. Furthermore, it is left to future research to test empirically whether observationally identical but unobservably less risky borrowers are rationed more than their riskier counterparts.

1.4 Appendix

Proof of Proposition 1. Consider a competitive loan market with asymmetric information about indivisible investment technologies. In a competitive loan market, the bank makes zero profits in the Nash equilibrium. Thus, equation (1.1) can be solved for

$$r^{i*} = \rho / p^i. \tag{1.27}$$

Recall from (1.7) that E_i then pays his first best loan rate, i.e. $r^{i*} = r^{i*}_{FB}$. As $p^L > p^H$, L has a lower first best loan rate than H, i.e. $r^{L*}_{FB} < r^{H*}_{FB}$ and L has no incentive to choose H's first best loan contract. Thus, I can drop L's incentive compatible constraint (1.4) and set $\tau^{H*} = 1$. However, H has an incentive to choose L's first best loan contract. An incentive compatible loan policy must satisfy H's incentive compatible constraint (1.5), which is written out

$$p^H \left(R^H - \rho/p^H\right) \geq \tau^L p^H \left(R^H - \rho/p^L\right). \tag{1.28}$$

Solve equation (1.28) for τ^L:

$$\tau^{L*} \leq \frac{R^H - \rho/p^H}{R^H - \rho/p^L}. \tag{1.29}$$

It is straightforward to see that τ^{L*} is always smaller than one as $p^L > p^H$.

Figure 1.2 illustrates that a Nash-equilibrium does only exist if L prefers separating loan contract A to pooling contract P

$$\Pi^L \left(\tau^{L*}, r^{L*}\right) > \Pi^L \left(\tau^{Pool*}, r^{Pool*}\right). \tag{1.30}$$

Recall that the bank does only ration to deter H. As P pools H and L rationing does not occur, i.e. $\tau^{Pool*} = 1$. Written out, inequality (1.30) is

$$\tau^{L*} p^L \left(R^L - r^{L*}\right) \geq p^L \left(R^L - r^{Pool*}\right). \tag{1.31}$$

Set (1.29), (1.27) and $r^{Pool*} = \alpha\rho/p^L + (1-\alpha)\rho/p^H$ in (1.31) to get

$$\left(p^H R^H - \rho\right)\left(p^L R^L - \rho\right)^{-1} p^L \left(R^L - \rho/p^L\right) \geq p^L \left(R^L - \left(\alpha\rho/p^L + (1-\alpha)\rho/p^H\right)\right). \tag{1.32}$$

Then, solve (1.32) for α

$$\alpha < \hat{\alpha}_{Indiv} := 1 - \rho^{-1} p^H \left(p^L R^L - p^H R^H\right)\left(p^L - p^H\right)^{-1}. \tag{1.33}$$

■

Proof of Proposition 2. To evaluate welfare of E_i under asymmetric information, compare it to the full information Nash-equilibrium. H does always obtain the first best contract. While L is not rationed under full information, he is rationed under asymmetric information. To understand the effect of rationing on L's welfare, differentiate L's expected profit with respect to τ^L:

$$\partial\Pi^L/\partial\tau^L = p^L\left(R^L(s) - rs\right) > 0. \tag{1.34}$$

Thus, rationing of L decreases his expected profit, which is why he does not obtain his first best contract under asymmetric information. ■

Proof of Proposition 3. Consider a competitive loan market with asymmetric information about divisible investment technologies. In this market, a bank with expected profit function $\pi^{Bank}(r, \tau, s; p^i)$ offers a menu of loan contracts $(r, \tau, s) := (r^i, \tau^i, s^i)^i$ to E_i with contractual variables loan rate r, probability τ that E_i is rationed and size s. E_i's expected profit function from this loan contract is $\pi^i(r, \tau, s)$. He chooses his optimal loan contract or outside option 0.

This proof is organized as follows. First, I show that L's incentive compatible constraint (1.17) is never binding. Second, I show for which divisible investment technologies H's incentive compatibility constraint (1.18) is not binding. Third, given that investment technologies are such that (1.18) is binding, I formulate the Lagrangian. I differentiate this Lagrangian with respect to contractual variables r, τ, s and Lagrange multipliers to determine the menu of loan contracts in the Nash-equilibrium. Finally, I show under which conditions a Nash-equilibrium does exist.

Proof that L's incentive compatibility constraint is never binding. To proof this, analyze L's incentive compatibility constraint (1.17) under full information. Written out, and reduced by p^L on both sides of the inequality, (1.17) is

$$R^L\left(s_{FB}^{L*}\right) - r_{FB}^{L*}s_{FB}^{L*} > R^L\left(s_{FB}^{H*}\right) - r_{FB}^{H*}s_{FB}^{H*}. \tag{1.35}$$

As $p^L > p^H$, L pays a lower loan rate than H, i.e. $r_{FB}^{L*} > r_{FB}^{H*}$. As s_{FB}^{L*} is a unique interior solution, L does not profit from another loan size. Concluding, L has no incentive to choose H's first best loan contract.

Proof for which investment technologies H's incentive compatibility constraint is not binding. To proof this, analyze H's incentive compatibility constraint (1.18) under full information. Writing out (1.18) and reducing it

by p^H on both sides of the inequality results in

$$R^H\left(s_{FB}^{L*}\right) - r_{FB}^{L*} s_{FB}^{L*} > R^H\left(s_{FB}^{H*}\right) - r_{FB}^{H*} s_{FB}^{H*}. \tag{1.36}$$

Transform (1.36) **to**

$$R^H\left(s_{FB}^{H*}\right) - R^H\left(s_{FB}^{L*}\right) < \left(r_{FB}^{H*} s_{FB}^{H*} - r_{FB}^{L*} s_{FB}^{L*}\right). \tag{1.37}$$

As R_s^i is invertible, $R_s^i\left(s_{FB}^{i*}\right) = \rho/p^i$ can be transformed to $s_{FB}^{i*} = R_s^{i^{-1}}\left(\rho/p^i\right)$. Thus, the first best s_{FB}^{i*} depends on R_s^i and p^i, i.e. $s_{FB}^{i*}\left(R_s^i, p^i\right)$ and I can rewrite (1.37) **as**

$$\begin{aligned} &R^H\left(s_{FB}^{H*}\left(R_s^H, p^H\right)\right) - R^H\left(s_{FB}^{L*}\left(R_s^L, p^L\right)\right) < \\ &\quad \left(p^L s_{FB}^{H*}\left(R_s^H, p^H\right) - p^H s_{FB}^{L*}\left(R_s^L, p^L\right)\right) \frac{\rho}{p^H p^L}. \end{aligned} \tag{1.38}$$

In equation (1.37) **I can see that H incurs opportunity costs from L's smaller loan as $s_{FB}^{H*} > s_{FB}^{L*}$, but benefits from L's lower loan rate, $r_{FB}^{H*} > r_{FB}^{L*}$. Now, regard equation** (1.38)**. As for a higher $R_s^{i^{-1}}(x)$, $\forall x$, s^{H*} becomes larger, $\Delta s_{FB}^* := s_{FB}^{H*} - s_{FB}^{L*}$ increases with $\Delta R_s := R_s^H - R_s^L$. As $r_{FB}^{i*} = \rho/p^i$, $\Delta r := r_{FB}^{H*} - r_{FB}^{L*}$ increases with $\Delta p := p^L - p^H$. Concluding, H's incentive compatibility constraint** (1.18) **is only binding if ΔR_s is sufficiently small relative to Δp.**

Lagrangian and FOC. **As L's incentive compatibility constraint** (1.17) **is never binding, it can be dropped. Then, H does always obtain his first best contract $\left(r^{H*}, \tau^{H*}, s^{H*}\right)$, so that $\Pi_{H*}^H := \Pi^H\left(r^{H*}, \tau^{H*}, s^{H*}\right)$. In the following, suppose that ΔR_s is sufficiently small relative to Δp such that H's incentive compatibility constraint** (1.18) **is binding. Then, L's loan contract is chosen such that it maximizes his expected profit subject to** (1.18)**. In brief, the Lagrangian is**

$$\begin{aligned} &L\left(r^L, \tau^L, s^L; \lambda_I, \lambda_B\right) = \\ &\Pi^L\left(r^L, \tau^L, s^L\right) + \lambda_I\left[\Pi_{H*}^H - \Pi^H\left(r^L, \tau^L, s^L\right)\right] + \lambda_B \Pi^{Bank}\left(r^L, \tau^L, s^L; p^L\right) \end{aligned} \tag{1.39}$$

and written out

$$L\left(r^{L},\tau^{L},s^{L};\lambda_{I},\lambda_{B}\right)=\tau^{L}p^{L}\left(R^{L}\left(s^{L}\right)-r^{L}s^{L}\right)$$
$$+\lambda_{I}\left[\Pi_{H*}^{H}-\tau^{L}p^{H}\left(R^{H}\left(s^{L}\right)-r^{L}s^{L}\right)\right]$$
$$+\lambda_{B}\tau^{L}\left(p^{L}r^{L}-\rho\right)s^{L}. \tag{1.40}$$

To determine the bank's optimal contract, at first, calculate the first order conditions of (1.40) **with respect to contractual variables** $\left(r^{L},\tau^{L},s^{L}\right)$ **and Lagrange multipliers** λ_I **and** λ_B[6]

$$\partial L/\partial r^{L}=\tau^{L}s^{L}\left(-p^{L}+\lambda_{I}p^{H}+\lambda_{B}p^{L}\right)=0 \tag{1.41}$$

$$\partial L/\partial s^{L}=\tau^{L}\left[p^{L}\left(R_{s}^{L}-r^{L}\right)-\lambda_{I}p^{H}\left(R_{s}^{H}-r^{L}\right)+\lambda_{B}\left(p^{L}r^{L}-\rho\right)\right]=0 \tag{1.42}$$

$$\partial L/\partial\tau^{L}=p^{L}\left(R^{L}-r^{L}s^{L}\right)-\lambda_{I}p^{H}\left(R^{H}-r^{L}s^{L}\right)+\lambda_{B}\left(p^{L}r^{L}-\rho\right)s^{L}=0 \tag{1.43}$$

$$\partial L/\partial\lambda_{I}=\Pi_{H*}^{H}-\tau^{L}p^{H}\left(R^{H}-r^{L}s^{L}\right)=0 \tag{1.44}$$

$$\partial L/\partial\lambda_{B}=\tau^{L}\left(p^{L}r^{L}-\rho\right)s^{L}=0. \tag{1.45}$$

Then, solve first order condition

- (1.41) **for** λ_I

$$\lambda_{I}=\frac{p^{L}}{p^{H}}\left(1-\lambda_{B}\right); \tag{1.46}$$

- (1.42) **for** λ_B

$$\lambda_{B}=1-\frac{p^{H}}{p^{L}}\lambda_{I}. \tag{1.47}$$

As (1.46) **and** (1.47) **only contain** λ_I **and** λ_B**, I can determine the Lagrange multipliers by setting**

- (1.46) **into** (1.47) **and solve for** λ_B^*

$$\lambda_{B}^{*}=\frac{R_{s}^{H}-R_{s}^{L}}{R_{s}^{H}-r^{L}}=1-\frac{R_{s}^{L}-r^{L}}{R_{s}^{H}-r^{L}}; \tag{1.48}$$

- λ_B^* **into** (1.46) **and solve for** λ_I^*

$$\lambda_{I}^{*}=\frac{p^{L}\left(R_{s}^{L}-r^{L}\right)}{p^{H}\left(R_{s}^{H}-r^{L}\right)}. \tag{1.49}$$

[6]For brevity, I denote $R^{L}:=R^{L}\left(s\right)$ for $i=L,H$.

Menu of loan contracts in the equilibrium. **In the equilibrium, the bank offers the menu of loan contracts** $\left(r^{L*}, \tau^{L*}, s^*\right)$. **Because of perfect competion, the bank solves** (1.41) **for** r^{L*} **and makes zero profits**

$$r^{L*} = \rho / p^L. \tag{1.50}$$

Then, to determine the optimal contract, the bank first checks whether to ration L **or not. Based on the initial situation that there is no rationing, i.e.** $\hat{\tau}^L = 1$, **the bank does not ration** L **if rationing of loan size, i.e. a decrease of** s^L, **yields lower opportunity costs for** L **than rationing of loan applicants, i.e. a decrease of** τ^L. **Then,** L **benefits more from a marginal increase of** τ^L **than of** s^L**:**

$$\begin{aligned} p^L\left(R_s^L - r^L\right) - \lambda_I^* p^H\left(R_s^H - r^L\right) \geq \\ p^L\left(R^L - r^L s^L\right) - \lambda_I^* p^H\left(R^H - r^L s^L\right). \end{aligned} \tag{1.51}$$

Set (1.49) **and** (1.50) **into** (1.51)

$$\begin{aligned} p^L\left(R_s^L - \rho/p^L\right) - \frac{p^L\left(R_s^L - \rho/p^L\right)}{p^H\left(R_s^H - \rho/p^L\right)} p^H\left(R_s^H - \rho/p^L\right) \geq \\ p^L\left(R^L - s^L\rho/p^L\right) - \frac{p^L\left(R_s^L - \rho/p^L\right)}{p^H\left(R_s^H - \rho/p^L\right)} p^H\left(R^H - s^L\rho/p^L\right) \end{aligned} \tag{1.52}$$

It is straightforward to see that left side of equation (1.52) **is zero. Transform** (1.52) **to get**

$$\frac{p^H\left(R_s^H - \rho/p^L\right)}{p^H\left(R^H - s^L\rho/p^L\right)} \leq \frac{p^L\left(R_s^L - \rho/p^L\right)}{p^L\left(R^L - s^L\rho/p^L\right)} \tag{1.53}$$

If condition (1.53) **holds, in the equilibrium,** L **is not rationed, i.e.** $\tau^{L*} = 1$. **Then, the bank sets** λ_B^* **and** λ_I^* **into** (1.42) **and chooses** s^* **such that**

$$R_s^L\left(s^{L*}\right) - \frac{\rho}{p^L} = \left(R_s^H\left(s^{L*}\right) - R_s^L\left(s^{L*}\right)\right)\frac{p^H}{p^L - p^H}. \tag{1.54}$$

There is an interior solution for L**'s optimal loan size** s^*. **First, regard the left side of equation** (1.54). L**'s marginal return** R_s^L **decreases with** s **as** $R_{ss}^L < 0$. **Thus, the left side of equation** (1.54) **decreases with** s. **Second, regard the right side of equation** (1.54). **As** $R_{B,ss} \geq R_{G,ss}$, **term** $R_{B,s} - R_{G,s}$

is non-decreasing with investment size. Thus, s^* can be chosen to equate the left and the right side of (1.54).

If condition (1.53) does not hold, the bank sets

- **(1.49) and (1.48) into (1.43) to get**

$$\frac{p^H\left(R_s^H\left(s^{L*}\right)-\rho/p^L\right)}{p^H\left(R^H\left(s^{L*}\right)-s^{L*}\rho/p^L\right)} \leq \frac{p^L\left(R_s^L\left(s^{L*}\right)-\rho/p^L\right)}{p^L\left(R^L\left(s^{L*}\right)-s^{L*}\rho/p^L\right)} \tag{1.55}$$

- **(1.49) and (1.48) into (1.44) to get**

$$\tau^{L*} = \frac{\Pi_{H*}^H}{p^H\left(R^H - s^{L*}\rho/p^L\right)} \tag{1.56}$$

Conditions for existence of Nash-equilibrium. **From Figure 1.3, I know that a Nash-equilibrium does only exist if L prefers the separating to the pooling contract, i.e. $\Pi^L\left(r^{L*}, s^{L*}\right) > \Pi^{L,Pool}\left(r^{Pool*}, s^{Pool*}\right)$. The bank's expected profit function is**

$$\Pi^{Bank,Pool}(r,s) := \left(p^{Pool}r - \rho\right)s. \tag{1.57}$$

Under a perfect competition, the bank makes zero profits. It chooses loan rate r^{Pool*} such that $\Pi^{Bank,Pool}(r,s) = 0$. Trivial transformations result in $r^{Pool*} = \rho\left(\alpha p^L + (1-\alpha)p^H\right)^{-1}$. Thus, a higher fraction of L, α, decreases r^{Pool*}. A lower r^{Pool*} again increases L's profit from the pooling loan contract $\Pi^{L,Pool}\left(r^{Pool*}, s^{Pool*}\right)$. Thus, L chooses the separating loan contract if $\alpha < \hat{\alpha}_{Div}$ where

$$\hat{\alpha}_{Div} := \Pi^L\left(r^{L*}, s^{L*}\right) = \Pi^{L,Pool}\left(r^{Pool*}, s^{Pool*}\right) \tag{1.58}$$

with

$$r^{Pool*} = \rho\left(\hat{\alpha}_{Div}p^L + \left(1-\hat{\alpha}_{Div}\right)p^H\right)^{-1}. \tag{1.59}$$

■

Proof of Proposition 4. **To analyze welfare of E_i in a competitive loan market Nash-equilibrium, I compare his loan contract $\left(r^{i*}, \tau^{i*}, s^{i*}\right)$ to his first best contract $\left(r_{FB}^{i*}, \tau_{FB}^{i*}, s_{FB}^{i*}\right)$. While it is straightforward to see that $r^{H*} = r_{FB}^{H*}$ and that $\tau^{i*} < 1$ decreases welfare, I need to prove that $s^{L*} < s_{FB}^{L*}$. For that compare (1.54) and (1.24). They only differ in their right side.**

While the right side of (1.24) is zero, the right side of (1.54) is bigger than zero. Thus, $s^{L*} < s^{L*}_{FB}$. ∎

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Chapter 2

Why the MAC Clause Is so Ubiquitous in Bank Loan Commitments Although It Is Hardly Ever Invoked

Abstract Many loan commitment contracts contain a material adverse change clause which allows banks to renege or step back from their commitment based on rather subjective claims regarding the borrowers' prospective financial situation. While this sounds like an attractive option for banks, empirical evidence shows that, despite its frequent appearance in contracts, the clause is rarely invoked (cf. Sufi, 2009; Ivashina and Scharfstein, 2010). In the present paper, we argue that this is due to the fact that, in combination with appropriate pricing on the spot loan market, the clause is essentially an effective means to screen the borrowers' riskiness. In particular, it renders loan commitment contracts comparably more expensive for high-risk borrowers, thereby directing them to the spot loan market. Low-risk borrowers, in turn, are still attracted to loan commitment contracts as for them the implicit extra cost is lower. Thus, there is no need for banks to step back from earlier promises. Moreover, we show that the presence of the clause increases welfare as it decreases credit rationing for low-risk entrepreneurs and reduces total loan costs.

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2.1 Introduction

In addition to spot loans, bank loan commitments are an important instrument for corporate liquidity management which contributes to over 80 percent of commercial and industrial loans (Duca and Van Hoose, 1990). Loosely speaking, by selling such a commitment, banks promise to grant a loan to the respective entrepreneur in the future based on contractual terms agreed upon today. However, such loan commitments imply a considerable risk for banks as entrepreneurs tend to intensify their usage in periods of economic distress (Agarwal et al., 2006) or if they have higher financial distress likelihoods (Sufi, 2009); and both situations imply an increased probability of default.

As a natural consequence of this risk, banks have developed various ways to protect themselves against future losses. For example, they often condition their commitment on the development of some variable not falling below / rising above a predefined threshold.[1] Doing so, they try to avoid having to grant a loan if there is a significant deterioration of the borrowers' financial condition. An obvious problem of such covenants, however, is that they are always backwards oriented as the respective financial variables are derived from past performance. In practice, banks therefore usually renegotiate as soon as they *anticipate* a future covenant violation.[2]

In order to put these renegotiations and, more generally, potential withdrawals from the commitment on safer grounds, banks can (and do) include a material adverse change (MAC) clause in the loan commitment contract (Sufi, 2009; and Berger and Udell, 1995). This clause allows them to deny loans under the commitment if "*in the opinion of the Bank*, any material adverse change in the Borrower's financial condition from that reflected in its annual report for its fiscal year ending December 31,__, or in the Borrowers business operations or prospects" has occurred (Ergungor, 2001, p.2/3, providing a typical MAC clause; emphasis as in original). Thus, the MAC clause is only legally effective if banks receive new information indicating a credible threat that the borrowers' financial condition will

[1] Demiroglu and James (2010) examine such financial covenant variables and the determinants of their thresholds in bank loans.

[2] Roberts and Sufi (2009) find that only around 20% of renegotiations in their sample are based on actual covenant violations.

deteriorate after the loan commitment has been sold.

An apparent drawback of the MAC clause, of course, is its subjective phrasing. As argued by Boot, Greenbaum and Thakor (1993), this offers banks an opportunity, for example, to deny loans when the banks themselves are at a low resource state. It is therefore less surprising that an invocation of the MAC clause often leads to litigation (Ivashina and Scharfstein, 2010). What is more surprising, though, is that the empirical evidence shows that banks rarely invoke the MAC clause (Sufi, 2009 and Ivashina and Scharfstein, 2010).

This raises two questions. Namely, why is the MAC clause so ubiquitous although banks do not rely on it very often? Eventually, the product sold, i.e. the loan commitment contract, would supposedly be more attractive without it – a fact that might be exploited to generate further revenues. And, more generally, why should borrowers buy a commitment that can be broken for rather subjective reasons, potentially resulting in long legal disputes, in periods of distress when they would need it most?

In the present paper, we try to answer exactly these questions. In particular, we argue that, in the presence of an additional spot market, including the MAC clause into loan commitment contracts is an effective means to screen the borrowers' riskiness so that the actual invocation of the clause is essentially an off equilibrium path event. In a nutshell, the argument is that, using the MAC clause, banks can increase the price of a loan commitment in a way that affects high-risk entrepreneurs more strongly than low-risk entrepreneurs. Thus, if appropriately combined with other screening instruments such as credit rationing, low-risk borrowers obtain more loans under loan commitments than on the spot market while high-risk entrepreneurs raise larger loans on the co-existing spot market and pay a higher rate than low-risk entrepreneurs under the commitment.

While the present discussion is purely theoretical, there are of course various related empirical studies on loan commitments and credit rationing which by and large support the present argument. For example, the finding that there is credit rationing on the spot loan market is empirically confirmed by Petersen and Rajan (1994), Cole (1998) or Blackwell and Winters (1997) – although Thakor (2005) provides a theoretical argument to the contrary. Moreover, the prediction that under loan commitments with the MAC clause there be less credit rationing than on the spot market is empirically supported by Berger and Udell (1992).[3] And, last but not least, the finding that borrowers who rely on loan commitments bear less risk than borrowers who raise a spot loan is compatible with earlier theoretical results by Duan and Yoon (1993) and Thakor (1989); in addition, both Avery and Berger (1991) and Qi and Shockley (1995) provide empirical evidence for this prediction.

Finally, the present analysis suggests the new testable empirical prediction that the introduction of the MAC clause into loan commitment contracts attracts less risky borrowers and increases loan size even though there is still some credit rationing. While it is beyond the scope of this paper to establish the empirical correctness of these predictions, we are optimistic that this will be possible in future research.

The rest of the paper is organized as follows. In Section 2, we present the technical analysis: the general set-up (Section 2.2.1), the spot loan equilibrium (Section 2.2.2), the loan commitment without and with an MAC clause (Section 2.2.3). Section 3 concludes. All formal proofs are gathered in the Appendix.

2.2 The Analysis

The subsequent discussion is subdivided into three parts. After a description of the general set-up in Section 2.2.1, Section 2.2.2 analyzes a situation with only a spot loan market and shows that only high-risk borrowers obtain their first best contract but low-risk borrowers do not. Section 2.2.3, then, introduces an additional loan commitment market and explains why these commitments attract only low-risk borrowers. Moreover, it argues how adding MAC helps to further separate low-risk borrowers from high-risk ones and that, by doing so, the MAC clause has positive welfare effects.

2.2.1 The General Set-Up

Consider the following situation: There are two agents, an entrepreneur, E, and a bank. At $t = 0$, E considers to invest in a risky project. The

[3]Note that other papers predict that there is over-lending (Duan and Yoon, 1993; and Thakor, 2005) or optimal lending (Thakor, 1989) under commitments.

investment has to be made in the future, namely at $t = 1$, and is realized at $t = 2$. The return of the project, R, depends on three factors: the investment size, I, an agent specific state of the world at $t = 1$, θ, which can either be good ($\theta = G$) or bad ($\theta = B$), and the type of E, which can be either high risk (H) or low risk (L) and which is indexed by i, i.e. $i \in \{H, L\}$. Thus, we have $R := R^i(I, \theta)$ with I being a variable of choice to be made at $t = 1$ and i and θ being random variables determined by Nature prior to $t = 0$ (i) and between $t = 0$ and $t = 1$ (θ). Moreover, by assumption, θ is observable to both agents at $t = 1$ and we have $\theta = G$ with probability β and $\theta = B$ with probability $1 - \beta$. By contrast, the type i of E is private information of the entrepreneur and we have $i = L$ with probability α and $i = H$ with probability $1 - \alpha$; slightly abusing notation, we simply write H instead of E_H and L instead of E_L in the sequel.

Regarding the actual return of the project at $t = 2$, we assume the following dependencies for $i \in \{L, H\}$:

- **The state of the world, θ, affects the return only if $\theta = B$ and the project is successful. In that case the project's return R is reduced by a fixed amount D. Otherwise, there is no effect of θ on R.**

- **The project is successful with type-dependent probability p^i, $i \in \{H, L\}$; $p^L > p^H$. If it is successful, we assume that for all $I > 0$ and $\theta \in \{G, B\}$:**

$$R_I^H(I, \theta) := \frac{\partial R^H(I, \theta)}{\partial I} > \frac{\partial R^L(I, \theta)}{\partial I} =: R_I^L(I, \theta) > 0$$

  and, using the same simplification of notation, $0 > R_{II}^H(I, \theta) \geq R_{II}^L(I, \theta)$. Moreover, for the sake of argument, we assume that the revenue R^i always exceeds D (the fixed additional cost if $\theta = B$) if the project is successful.

- **In case the project fails, we assume that $R^i = 0$ for $i \in \{L, H\}$.**

Finally, in addition to the project, we assume that E_i always has the chance to opt for a deterministic outside option at $t = 1$ which generates a value of O at $t = 1$.

In this situation, E_i has to decide at $t = 0$ how to finance the project at $t = 1$ conditional on the realization of θ. Here, we assume that E_i, in addition to his cash flow, C, can either choose to buy a loan commitment

at $t = 0$, which he may or may not use at $t = 1$ depending on θ, or to raise a spot loan at $t = 1$ if his expected return from the project is positive. The timing of events is summarized in Figure 2.1.

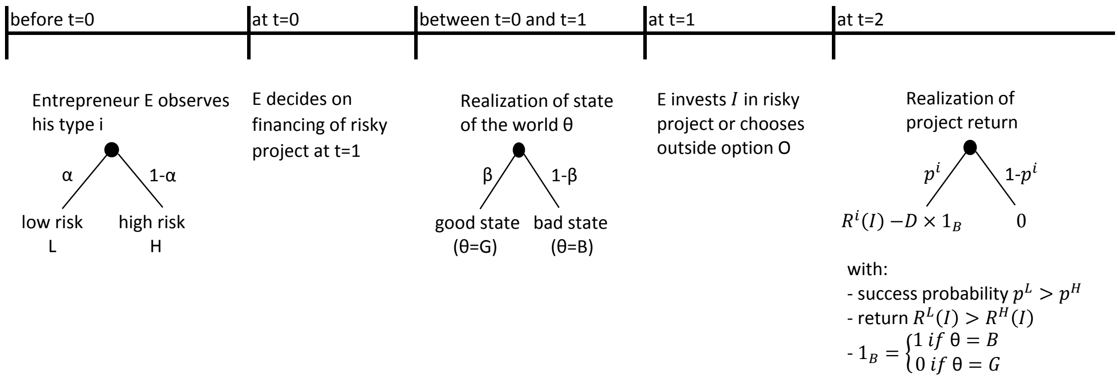

Figure 2.1: **Time-line of events.**

2.2.2 The Spot Loan Market

To begin with, we analyze the situation in which only a spot loan market exists. Consider the entrepreneur E_i who considers at $t = 0$ to raise a spot loan at $t = 1$. At $t = 1$, the bank offers E_i a menu of spot loan contracts comprised of a gross loan rate r and a loan size s.

Regarding the loan-contracts offered by the bank, it is important to note that the bank's expected profit from any spot loan does not depend on θ but is only a function of contractual variables $\{r, s\}$, evaluated at $t = 1$. The reason for this is that the realization of θ has no effect on E_i's repayments to the bank.[4] Thus, the bank's expected payoff, conditional on E_i's type, is given by

$$\Pi^{Bank}_{Spot}(r, s) := \rho^{-1}\left(p^i r - \rho\right) s. \tag{2.1}$$

Here, we assume that the bank finances the loan at deposit rate ρ.

Turning to E_i, he either accepts the bank's spot loan contract offer $\{r, s\}$ or chooses his outside option. If E_i raises a spot loan with contractual variables $\{r, s\}$, his (expected) profit function, evaluated at $t = 1$, is given

[4]Recall that in case the project fails, the loan is lost anyway and that, by assumption, R always covers the loan if the project is successful.

by

$$\Pi^i_{Spot}(r,s) := p^i \rho^{-1} \left(R^i(I,\theta) - rs\right) \tag{2.2}$$

where E_i invests $I = C + s$ in the project at $t = 1$.

In a competitive Nash equilibrium, the bank's profit must equal zero. Moreover, the bank knows each type's project characteristics, but cannot observe E_i's type. Thus, the bank's spot loan policy $(r_{Spot}, s_{Spot}) := \left(r^i_{Spot}, s^i_{Spot}\right)^i$ maximizes $\Pi^i(r_{Spot}, s_{Spot})$ subject to

$$\Pi^L\left(r^L_{Spot}, s^L_{Spot}\right) \geq \Pi^L\left(r^H_{Spot}, s^H_{Spot}\right) \tag{2.3}$$

$$\Pi^H\left(r^H_{Spot}, s^H_{Spot}\right) \geq \Pi^H\left(r^L_{Spot}, s^L_{Spot}\right) \tag{2.4}$$

$$\Pi^i\left(r^i_{Spot}, s^i_{Spot}\right) \geq O. \tag{2.5}$$

$$\Pi^{Bank}\left(r^i_{Spot}, s^i_{Spot}\right) = 0. \tag{2.6}$$

with $i = L, H$. Note that (2.3) and (2.4) are the incentive compatibility constraints; (2.5) is E_i's participation constraint which guarantees that E_i raises a loan; and (2.6) reflects the competitive markets assumption which ensures the bank's expected profit is zero.

Given $\left(r^*_{Spot}, s^*_{Spot}\right)$, E_i then either raises his optimal spot loan or chooses outside option O. Note that E_i's choice does not only depend on his type, but also on the realization of state θ. Here we assume that, if $\theta = G$, both H and L want to invest in the project and, hence, want to raise a spot loan at $t = 1$. However, if $\theta = B$, E_i's return in case of a success reduces by D if he invests in the project – and this is independent of his type. In order to make the problem interesting, we assume that in this situation only H raises a spot loan while L chooses his outside option O.[5]

The resulting equilibrium in a pure spot loan market is described in Proposition 5; implications for welfare are stated in Proposition 6; derivations are provided in the appendix.

Proposition 5 (Equilibrium) ***In a pure spot loan market, there only exists a Nash-equilibrium in which banks offer a spot loan if the share of L is sufficiently small ($\alpha < \hat{\alpha}_{Spot}$). The bank's optimal spot loan policy in this case, comprised of gross loan rate r^*_{Spot} and loan size s^*_{Spot}, is separating***

[5] This assumption is in accordance with empirical findings (Sufi, 2009) suggesting that borrowers intensify their investments if they are more likely to get into financial distress.

and implicitly determined by

$$r_{Spot}^{i*} = \rho/p^i \tag{2.7}$$

$$s_{Spot}^{H*} := R_s^H\left(s_{Spot}^{H*}\right) = r_{Spot}^{H*} \tag{2.8}$$

$$s_{Spot}^{L*} := R_s^L\left(s_{Spot}^{L*}\right) - \left(R_s^H\left(s_{Spot}^{L*}\right) - R_s^L\left(s_{Spot}^{L*}\right)\right) p^H \left(p^L - p^H\right)^{-1} = r_{Spot}^{L*} \tag{2.9}$$

with $i = L, H$***. Equation*** (2.7) ***states that*** $r_{Spot}^{H*} > r_{Spot}^{L*}$***, equations*** (2.8) ***and*** (2.9) ***implicitly define a unique interior solution for*** s_{Spot} ***such that*** $s_{Spot}^{H*} > s_{Spot}^{L*}$***. Moreover,*** H ***chooses*** $\left(r_{Spot}^{H*}, s_{Spot}^{H*}\right)$***, independent of the realization of*** θ***, and L chooses*** $\left(r_{Spot}^{L*}, s_{Spot}^{L*}\right)$ ***if*** $\theta = G$***, but outside option*** O ***if*** $\theta = B$***.***

Proposition 6 (Welfare) ***In the pure spot loan market equilibrium, independent of the realization of*** θ***, both*** H ***and*** L ***receive their first best loan rate*** r_{FB}^{i*}***. However, only*** H ***obtains his first best loan size*** s_{FB}^{H*}***, while*** L***'s loan size*** s_{Spot}^{L*} ***is rationed.***

Note that the result is the typical one for situations with asymmetric information: while the "bad" type, H, obtains his first best, the "good" type, L, has to pay the price for separating from the bad – here in terms of an inefficient loan size. As the returns to investment are higher for H, loan size rationing of L ensures that, despite the difference in interest payments, H does not opt for the cheaper loan.[6]

2.2.3 Adding a Loan Commitment Market

In the previous part, we have shown that in a pure spot loan market, L does not obtain the first best contract as his loan size must be rationed in order to avoid pooling of L and H. In the sequel, we investigate whether the introduction of a loan commitment market, in addition to the coexisting spot loan market, can increase welfare.

Loan Commitment without MAC Clause

For loan commitments, the situation is as follows: At $t = 0$, the bank sells a commitment against the payment of a fee F to grant a loan at $t = 1$ to

[6] That credit rationing is possible if the return to investment increases with its riskiness has, for example, also been observed by Bester (1985).

the contractual terms (r, s) agreed upon at $t = 0$. Then, E_i decides whether to buy the commitment or not. In order to pay the commitment fee, E_i uses his cash flow C which we assume to equal F^* in equilibrium.[7] E_i has the option to take down the commitment at $t = 1$, but is not obliged to do that. Apart from a takedown, E_i also has the option to raise a spot loan or to choose his outside option O at $t = 1$. At $t = 2$, in the event of an investment in the project, returns are realized.

Whether E_i will take down the commitment at $t = 1$ or not depends on the realization of θ. While both types take down the commitment if $\theta = G$, we again assumet that only H does so if $\theta = B$. Thus, at $t = 0$ the banks' expected payoff, conditional on E_i's type is given by

$$\pi_{Com}^{Bank} = F + \gamma^i \rho^{-1} s \left(p^i r - \rho\right) \tag{2.10}$$

where γ^i denotes E_i's takedown probability.

If E_i buys a loan commitment with contractual variables (F, r, s), his (expected) profit function, evaluated at $t = 0$, is given by

$$\pi_{Com}^{i}(F, r, s) = \gamma^i \rho^{-1} p^i \left(R^i(I; \theta) - rs\right) + \left(1 - \gamma^i\right) O - F \tag{2.11}$$

with $I = s$ and $i = L, H$.

In order to solve the resulting optimization problem, consider first the spot loan market and recall that H already obtains his first best contract in this market, whereas L's loan size is rationed. Thus, the only agent who might profit from the additional loan commitment market is L. In a competitive loan commitment market the bank's policy $\{F, r, s\}$ therefore maximizes $\pi_{Com}^{L}(F, r, s)$ subject to

$$\pi_{Com}^{L}(F, r, s) \geq \pi_{Spot}^{L}\left(r_{Spot}^{H*}, s_{Spot}^{H*}\right) \tag{2.12}$$

$$\pi_{Spot}^{H}\left(r_{Spot}^{H*}, s_{Spot}^{H*}\right) \geq \pi_{Com}^{H}(F, r, s). \tag{2.13}$$

$$\pi_{Com}^{Bank}(F, r, s) = 0 \tag{2.14}$$

$$r \geq 1 \tag{2.15}$$

[7] The assumption $F^* = C$ is not crucial, but facilitates the technicalities as we can abstract from how F is financed.

where (2.12) is L's participation constraint; (2.13) is the incentive compatibility constraint which ensures that H does not choose the loan commitment; (2.14) is the bank's zero expected profit condition; and (2.15) is the condition guaranteeing non-negative net loan rates.

The resulting equilibrium is described in Proposition 7, the existence of the equilibrium in Corollary 1 and the effect of the introduction of the loan commitment without an MAC on welfare in Proposition 8. Again, all derivations are deferred to the appendix.

Proposition 7 (Equilibrium) ***In a situation with both, a competitive spot loan market and a competitive loan commitment market (without MAC clause), there only is a Nash-equilibrium in which positive loan commitments are offered if the share of*** L ***is sufficiently small, i.e.*** $\alpha < \hat{\alpha}_{Com}$ ***(otherwise, there is only a pure spot loan market Nash-equilibrium). For*** $\beta p^L - p^H$ ***sufficiently large,*** H ***chooses a spot loan at*** $t = 1$ ***and does so independent of the realization of*** θ***;*** L ***in turn buys a loan commitment at*** $t = 0$ ***with contractual variables – fee*** F^*_{Com}***, rate*** r^*_{Com} ***and size*** s^*_{Com} ***– implicitly defined by:***

$$s^*_{Com} := R^L_I\left(s^*_{Com}\right) - \left(R^H_I\left(s^*_{Com}\right) - R^L_I\left(s^*_{Com}\right)\right)\frac{\beta p^H}{\beta p^L - p^H} = \frac{\rho}{p^L} \tag{2.16}$$

$$F^*_{Com} = \left[p^H\left(R^H\left(s^*_{Com}\right) - \frac{\rho s^*_{Com}}{p^L}\right) - \pi^H_{Spot}\right]\frac{\rho^{-1}\beta p^L}{\beta p^L - p^H} \tag{2.17}$$

$$r^*_{Com} = \frac{\pi^H_{Spot} - p^H\left(R^H\left(s^*_{Com}\right) - r^{H*}_{Spot}s^*_{Com}\right) - (1-\beta)\, r^{H*}_{Spot}s^*_{Com}}{\left(\beta p^L - p^H\right)s^*_{Com}}. \tag{2.18}$$

Equation (2.16) ***implicitly defines a unique interior solution for*** s_{Com}***. Moreover,*** L ***takes down the loan commitment only if*** $\theta = G$***; if*** $\theta = B$***,*** L ***chooses outside option*** O***.***

Corollary 1 (Existence of separating Nash equilibrium) ***Adding a loan commitment market increases the range of low-risk borrowers for which there is a separating Nash equilibrium, i.e.*** $\hat{\alpha}_{Com} > \hat{\alpha}_{Spot}$***.***

Proposition 8 (Welfare) ***Combining the spot loan market with a loan commitment market increases the effectiveness of the bank's screening so that*** L***'s welfare is improved while the welfare of*** H ***remains unchanged.***

In particular, H ***still obtains his first best loan on the spot loan market, while*** L ***now obtains a larger loan*** $s^*_{Com} > s^*_{Spot}$ ***than on the spot loan market.***

Intuitively, the point to note is that, on the loan commitment market, banks at $t = 0$ **charge a fee,** F**, which they can later use to subsidize the repayment of the loan via a reduction in** r**. As borrowers differ in their probability of success for a given investment, this can be used to offer contracts consisting of a fee** F**, a loan size** s **and an interest rate** r **which only just keep** H **on the spot loan market but still provide an improvement for** L**; see Figure 2.2 for an illustration. In particular, low-risk borrowers are willing to accept slightly higher increases in** F **for a given reduction in** r **as their probability of success (and, hence, later repayments) is higher.**

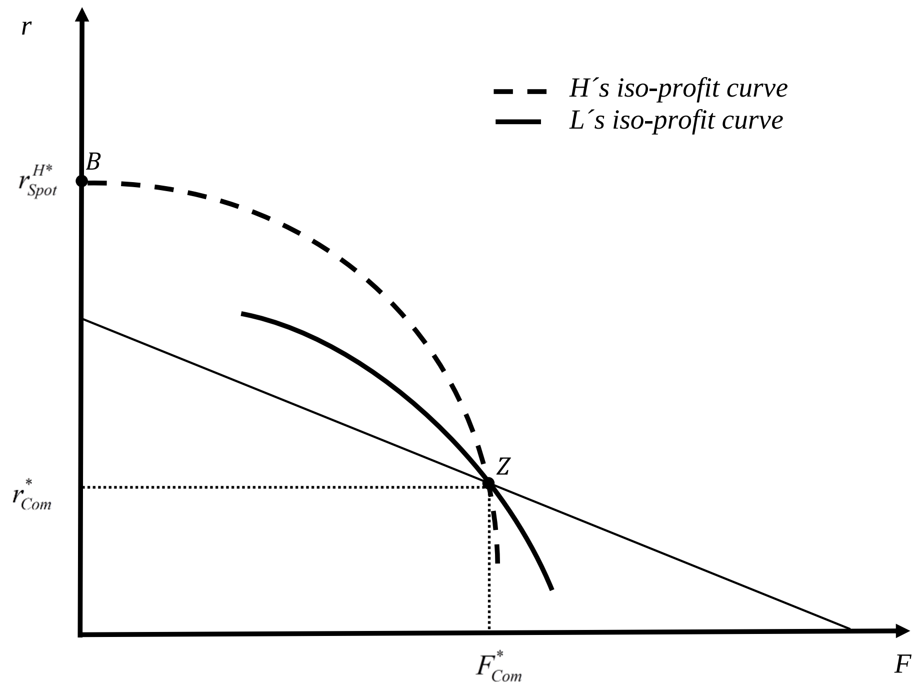

Figure 2.2: Iso-profit curves for L and H type borrowers for spot loan and loan commitment market (without MAC clause). H's iso-profit curve intersects with the bank's zero profit line at Z so that, in equilibrium, H chooses spot loan contract B and L chooses loan commitment contract Z.

However, even with the additional loan commitment market there still is a rationing of the loan size for L **and, of course, also the initially payable**

fee F induces costs. As the agent specific state of the world itself offers a further possibility to differentiate between types, there still room left for further improvements in the situation of L – assuming the market for loans to be competitive. As we argue next, introducing the MAC clause utilizes just this possibility.

Loan Commitment with MAC Clause

In the previous discussion, we have shown that H always raises a loan on the spot loan market, while L is drawn to the co-existing loan commitment market. However, although adding the loan commitment market improves the situation for L, it still induces considerable screening costs. However, as we will argue in the following, adding the MAC clause offers a way for banks to screen the borrowers' riskiness in a way that is less costly – in expected terms – for L. More specifically, with the MAC clause, the bank is legally able to deny a loan if, in the opinion of the bank, a material adverse change (MAC) in the borrower's financial condition has occurred (cf. Ergungor, 2001).[8] As this in itself has a stronger deterrent effect on high-risk borrowers than on low-risk ones, it allows banks to offer loan commitment contracts which otherwise are more attractive in terms of loan size and interest rate. As we will see, again assuming competitive markets, this leads to a further improvement in the welfare of L.

In terms of our model, the bank can infer the borrower's financial condition from his type specific state of the world θ which is determined prior to $t = 1$. In particular, we assume that, if θ indicates a material adverse change in the borrower's financial condition ($\theta = B$), the bank invokes the MAC clause and simply denies the loan to E at $t = 1$. Thus, at $t = 0$, the invocation of the MAC clause is probabilistic and given by $\mu(\theta)$ where $\mu(G) = 0$ and $\mu(B)$ reflects the share share of H-type borrowers who buying a loan commitment at $t = 0$. Accordingly, the bank's profit function evaluated at $t = 0$ is given by

$$\pi_{MAC}^{Bank}\left(\mu\left(\theta\right), F, r, s\right) = F + \rho^{-1}\left(1 - \mu\left(\theta\right)\right)\gamma^{i} s\left(p^{i} r - \rho\right). \tag{2.19}$$

[8]The invocation of the MAC clause can only become operative if there is a credible threat that the borrower's financial condition will deteriorate sufficiently. Commonly, the MAC clause may refer to material adverse changes (i) in the market, (ii) in the financial conditions of the borrower or (iii) in the national or international financial, economic or political conditions (Worthington, 2003).

As E can only take down the commitment if the bank has not invoked the MAC clause, his expected profit function, evaluated at $t = 0$, is given by

$$\pi^i_{MAC}\left(\mu\left(\theta\right), F, r, s\right) = \rho^{-1}\left(1-\mu\left(\theta\right)\right)\gamma^i p^i \left(R^i\left(I\right) - rs\right) + \rho^{-1}\mu\left(\theta\right)\gamma^i O^i - F \quad (2.20)$$

with $i = H, L$ and $O^H = \pi^H_{Spot,H}$ for H and $O^L = O$ for L.

Putting things together, the resulting equilibrium under a loan commitment with an MAC clause is described in Proposition 9, existence of a separating equilibrium is discussed in Corollary 2 and the effect of the introduction of the MAC clause on welfare is stated in Proposition 10. Derivations once again are deferred to the appendix.

Proposition 9 (Equilibrium) ***In a situation with both, a competitive spot loan market and a competitive loan commitment market (with MAC clause), there is a separating Nash equilibrium if the share of L-type borrowers is sufficiently small, i.e. $\alpha < \hat{\alpha}_{MAC}$. In such an equilibrium, H chooses a spot loan at $t = 1$ independent of the realization of θ, and L buys a loan commitment including an MAC clause at $t = 0$ where the contractual variables – fee F^*_{MAC}, rate r^*_{MAC} and size s^*_{MAC} – are implicitly determined by:***

$$s^*_{MAC} := R^L_I\left(s^*_{MAC}\right) - \left[R^H_I\left(s^*_{MAC}\right) - R^L_I\left(s^*_{MAC}\right)\right]\frac{\beta p^H}{p^L - p^H} = \frac{\rho}{p^L} \quad (2.21)$$

$$F^*_{MAC} = \left[p^H\left(R^H\left(s^*_{MAC}\right) - \frac{\rho s^*_{MAC}}{p^L}\right) - \pi^H_{Spot,G}\right]\frac{\rho^{-1}\beta p^L}{p^L - p^H} \quad (2.22)$$

$$r^*_{MAC} = \frac{\pi^H_{Spot,G} - p^H\left(R^H - r^{H*}_{Spot}s^*_{MAC}\right)}{\left(p^L - p^H\right)s^*_{MAC}} \quad (2.23)$$

$$\mu^*\left(\theta = B\right) = 1 \quad \& \quad \mu^*\left(\theta = G\right) = 0 \quad (2.24)$$

Equation* (2.21) *implicitly defines a unique interior solution for s_{MAC}. Moreover, L takes down the loan commitment at $t = 1$ only if $\theta = G$, while he chooses outside option O if $\theta = B$; thus, in equilibrium, the MAC clause is never invoked.

Corollary 2 (Existence of separating Nash equilibrium) ***Under a loan commitment that includes an MAC clause there is a separating Nash equilibrium for a higher share of L than under a loan commitment without an MAC clause or in a pure spot market, i.e.*** $\hat{\alpha}_{MAC} > \hat{\alpha}_{Com} > \hat{\alpha}_{Spot}$.

Proposition 10 (Welfare) ***In a situation with both, a competitive spot loan market and a competitive loan commitment market (with MAC clause) H's welfare does not change but L's welfare increases. In particular, H still obtains his first best loan on the spot market, while L now obtains a larger loan $s^*_{MAC} > s^*_{Com}$ than in the case where loan commitment contract have no MAC clause.***

Intuitively, the above argument is rather straightforward. As the bank knows E_i's expected profit function (2.20) the bank can infer that: (a) if $\theta = G$, both L and H take down the commitment, (b) if $\theta = B$, only H, whose return to investment is higher than L's, would take down the commitment. As the bank only wants to attract L with the commitment, it will always invoke the MAC clause if $\theta = B$ – which only affects H. Accordingly, introducing the MAC clause renders buying the loan commitment less profitable for H as it decreases his expected profit at $t = 0$.

As a consequence of this, H requires a larger subsidy of r as a compensation for a marginal increase of F than under a commitment without an MAC clause, i.e. the iso-profit curve of H becomes steeper. And this makes the usage of F to subsidize r more efficient as a screening instrument; see Figure 2.3. Eventually, H still chooses his first best spot loan contract B while L gets on a lower iso-profit curve implying that his expected profit increases. In particular, the higher efficiency of the subsidy of r via F enables the bank to reduce the usage of loan size rationing until it has the same screening costs. Thus, by the inclusion of the MAC clause L obtains larger loan size $s^*_{MAC} > s^*_{Com}$ which increases his welfare.

To wit, while including a material adverse change clause into loan commitment contracts appears to be a very unattractive feature from the perspective of the borrowers, it is actually turned out to be to their benefit rather than to the benefit of the bank.

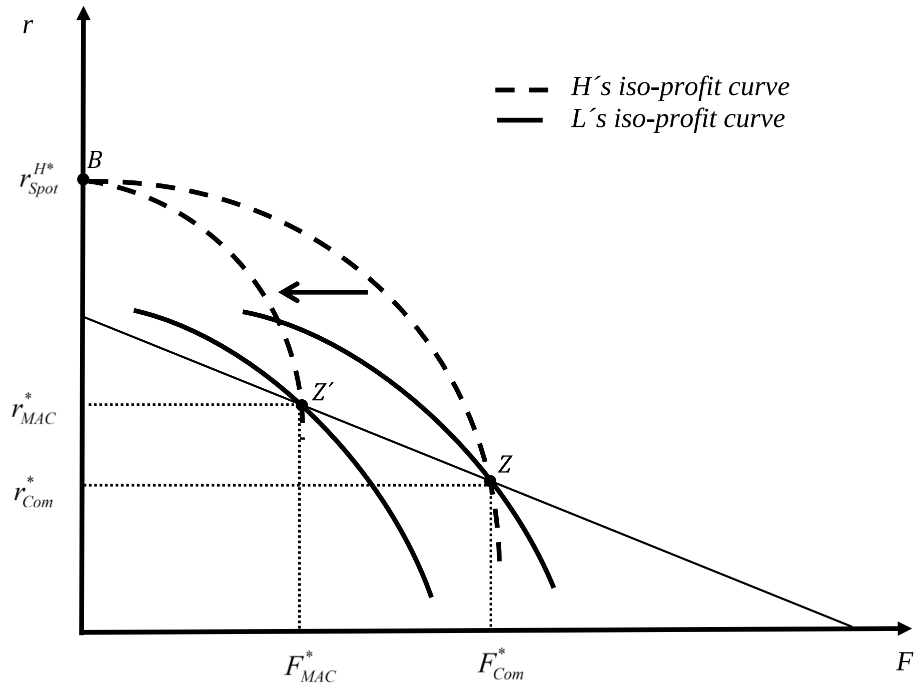

Figure 2.3: Illustration of change in iso-profit curves for H and L once loan commitments include an MAC clause. H's iso-profit curve becomes steeper. Thus, while H still chooses B, L now chooses loan commitment contract Z' and thereby reaches a lower iso-profit curve.

2.3 Concluding Remarks

In the present paper, we have provided an argument for why the inclusion of a MAC clause into loan commitment contracts is actually rather in the interest of the borrowers, whose credit conditions are improved in equilibrium, than of the banks, whose profits are reduced (assuming competitive markets). In particular, the MAC clause offers a non-monetary means to reduce the attractiveness of loan commitment contracts comparably for high-risk borrowers relative to low risk ones. Thus, as we have argued, high-risk borrowers in equilibrium are directed to the spot loan market while only low-risk borrowers still buy loan commitment contracts. And, as in equilibrium there is no need for banks to step back from earlier promises, there is no need for banks to invoke the clause, this provides an explanation for the empirical evidence which shows that, despite its frequent appearance in contracts, the MAC clause is rarely invoked (cf. Sufi, 2009; Ivashina and Scharfstein, 2010). Moreover, we have shown that the

presence of the clause increases welfare as it decreases credit rationing for low-risk entrepreneurs and reduces total loan costs.

2.4 Appendix

Proof of Proposition 1. Consider a spot loan market. In this market, a bank offers a menu of spot loan contracts $(r_{Spot}, s_{Spot}) := \left(r^i_{Spot}, s^i_{Spot}\right)^i$ with $i = H, L$ to E_i with contractual variables rate and size respectively. Then, E_i chooses his optimal loan contract.

The proof is organized as follows. First, we formulating the Lagrangian and solve for contractual variables to determine the menu of spot loan contracts in the equilibrium. Then, we show that L never has incentive to choose H's spot contract and analyze under which conditions L's spot loan contract is not first best. Finally, we show under which conditions a separating Nash equilibrium exists.

Lagrangian and FOC. The bank's expected profit function is $\pi^{Bank}_{Spot}\left(r_{Spot}, s_{Spot}; p^i\right)$, E_i's expected profit function is $\pi^i_{Spot}\left(r_{Spot}, s_{Spot}\right)$. We assume that L never has an incentive to choose H's spot loan contract, later we show that this assumption always applies. Then, H always obtains his first best contract and L's loan contract is chosen such that it maximizes his expected profit subject to that H does not have an incentive to choose it. In brief, the Lagrangian is[9]

$$L\left(r^L, s^L; \lambda_I, \lambda_B\right) = \pi^L_{Spot}\left(r^L, s^L\right) + \lambda_I\left[\pi^H_{Spot}\left(r^H, s^H\right) - \pi^H_{Spot}\left(r^L, s^L\right)\right] + \lambda_B \pi^{Bank}_{Spot}\left(r^L, s^L; p^L\right) \quad (2.25)$$

and written out

$$\begin{aligned} L\left(r^L, s^L; \lambda_I, \lambda_B\right) &= \rho^{-1} p^L\left(R^L\left(I^L\right) - r^L s^L\right) \\ &+\lambda_I\left\{\rho^{-1} p^H\left(R^H\left(C + s^H\right) - r^H s^H\right) - \left[\rho^{-1} p^H\left(R^H\left(I^L\right) - r^L s^L\right)\right]\right\} \\ &+\lambda_B\left\{\rho^{-1}\left(p^L r^L - \rho\right) s^L\right\} \end{aligned} \quad (2.26)$$

[9]For brevity, we denote $r^i := r^i_{Spot}$ and size $s^i := s^i_{Spot}$.

with $I^L = C + s^L$. To determine the bank's optimal contract, at first, calculate the first order conditions of (2.26) with respect to contractual variables (r, s) and Lagrange multipliers λ_I and λ_B[10]

$$\partial L/\partial r^L = \rho^{-1} s^L \left(-p^L + \lambda_I p^H + \lambda_B p^L\right) = 0 \tag{2.27}$$

$$\partial L/\partial s^L = \rho^{-1} p^L \left(R_I^L - r^L\right) - \lambda_I \rho^{-1} p^H \left(R_I^H - r^L\right) + \lambda_B \rho^{-1} \left(p^L r^L - \rho\right) = 0 \tag{2.28}$$

$$\partial L/\partial \lambda_I = \rho^{-1} p^H \left(R^H - r^H s^H\right) - \rho^{-1} p^H \left(R^H - r^L s^L\right) = 0 \tag{2.29}$$

$$\partial L/\partial \lambda_B = \rho^{-1} \left(p^L r^L - \rho\right) s^L = 0. \tag{2.30}$$

Then, solve first order condition

- (2.27) **for** λ_I

$$\lambda_I = \frac{p^L}{p^H} \left(1 - \lambda_B\right); \tag{2.31}$$

- (2.28) **for** λ_B

$$\lambda_B = 1 - \frac{p^H}{p^L} \lambda_I. \tag{2.32}$$

As (2.31) **and** (2.32) **only contain λ_I and λ_B, we can determine the Lagrange multipliers by setting**

- (2.31) **into** (2.32) **and solve for** λ_B^*

$$\lambda_B^* = \frac{R_I^H - R_I^L}{R_I^H - \frac{\rho}{p^L}} = 1 - \frac{R_I^L - \frac{\rho}{p^L}}{R_I^H - \frac{\rho}{p^L}}; \tag{2.33}$$

- λ_B^* **into** (2.31) **and solve for** λ_I^*

$$\lambda_I^* = \frac{p^L \left(R_I^L - \frac{\rho}{p^L}\right)}{p^H \left(R_I^H - \frac{\rho}{p^L}\right)}. \tag{2.34}$$

Menu of spot loan contracts in the equilibrium. **In the equilibrium, the bank offers the menu of spot loan contracts $\left(r_{Spot}^*, s_{Spot}^*\right)$. To determine the optimal contract, the bank**

[10] For brevity, we denote $R^L := R^L(s)$ for $i = L, H$.

- **sets λ_B^* and λ_I^* into (2.28) and chooses s_{Spot}^* such that**

$$R_I^L\left(s_{Spot}^{L*}\right) - \frac{\rho}{p^L} = \left(R_I^H\left(s_{Spot}^{L*}\right) - R_I^L\left(s_{Spot}^{L*}\right)\right)\frac{p^H}{p^L - p^H}. \tag{2.35}$$

  There is an interior solution for L's optimal loan size s_{Spot}^*. First, regard the left side of equation (2.35). L's marginal return R_I^L decreases with s as $R_{II}^L < 0$. Thus, the left side of equation (2.35) decreases with s. Second, regard the right side of equation (2.35). As $R_{B,II} \geq R_{G,II}$, term $R_{B,I} - R_{G,I}$ is non-decreasing with investment size. Thus, s_{Spot}^* can be chosen to equate the left and the right side of (2.35).

- **Then, it solves (2.27) for r_{Spot}^{L*}**

$$r_{Spot}^* = \frac{\rho}{p^L}. \tag{2.36}$$

Proof that L's incentive compatibility constraint is never binding. **To prove this, we analyze L's incentive compatibility constraint (2.3) under full information. Written out, and reduced by p^L on both sides of the inequality, (2.3) is**

$$R^L\left(s_{FB}^{L*}\right) - r_{FB}^{L*}s_{FB}^{L*} > R^L\left(s_{FB}^{H*}\right) - r_{FB}^{H*}s_{FB}^{H*}. \tag{2.37}$$

As $p^L > p^H$, L pays a lower loan rate than H, i.e. $r_{FB}^{L*} > r_{FB}^{H*}$. As s_{FB}^{L*} is a unique interior solution, L does not profit from another loan size. Thus, L has no incentive to choose H's first best loan contract.

Proof for which investment technologies H's incentive compatibility constraint is binding. **To prove this, analyze H's incentive compatibility constraint (2.4) under full information. Writing out (2.4) and reducing it by p^H on both sides of the inequality results in**

$$R^H\left(s_{FB}^{L*}\right) - r_{FB}^{L*}s_{FB}^{L*} > R^H\left(s_{FB}^{H*}\right) - r_{FB}^{H*}s_{FB}^{H*}. \tag{2.38}$$

Transform (2.38) to

$$R^H\left(s_{FB}^{H*}\right) - R^H\left(s_{FB}^{L*}\right) < \left(r_{FB}^{H*}s_{FB}^{H*} - r_{FB}^{L*}s_{FB}^{L*}\right). \tag{2.39}$$

As R_s^i is invertible, $R_s^i\left(s_{FB}^{i*}\right)=\rho/p^i$ can be transformed to $s_{FB}^{i*}=R_s^{i\,-1}\left(\rho/p^i\right)$. Thus, the first best s_{FB}^{i*} depends on R_s^i and p^i, i.e. $s_{FB}^{i*}\left(R_s^i,p^i\right)$ and we can rewrite (2.39) as

$$\begin{aligned}&R^H\left(s_{FB}^{H*}\left(R_s^H,p^H\right)\right)-R^H\left(s_{FB}^{L*}\left(R_s^L,p^L\right)\right)<\\&\left(p^Ls_{FB}^{H*}\left(R_s^H,p^H\right)-p^Hs_{FB}^{L*}\left(R_s^L,p^L\right)\right)\frac{\rho}{p^Hp^L}.\end{aligned}\tag{2.40}$$

In equation (2.39), we can see that H incurs opportunity costs from L's smaller loan as $\Delta s_{FB}^*:=s_{FB}^{H*}>s_{FB}^{L*}$, but benefits from L's lower loan rate, $\Delta r_{FB}^*:=r_{FB}^{H*}>r_{FB}^{L*}$. Thus, H does only have an incentive to choose L's first best contract if Δr_{FB}^* is sufficiently small relative to Δs_{FB}^*.

To understand for which investment technologies this occurs, consider equation (2.40). For a given x, s_{FB}^{i*} becomes larger with $R_s^i\left(x\right)$. This implies that Δs_{FB}^* increases with $\Delta R_s:=R_s^H\left(x\right)-R_s^L\left(x\right)$, $\forall x$. As $r_{FB}^{i*}=\rho/p^i$, r_{FB}^{i*} becomes smaller with p^i. Thus, Δr_{FB}^* increases with $\Delta p:=p^L-p^H$. Hence, H's incentive compatibility constraint (2.4) is only binding if ΔR_s is sufficiently small relative to Δp.

Conditions for existence of a separating Nash equilibrium. **From Figure 2.4, we can see that in a separating spot loan market a Nash equilibrium only exists if L prefers the separating to the pooling contract, i.e. $\Pi_{Spot}^L\left(r_{Spot}^{L*},s_{Spot}^{L*}\right)>\Pi_{Spot}^{L,Pool}\left(r_{Spot}^{Pool*},s_{Spot}^{Pool*}\right)$. As the loan rate of the pooling spot loan contract is $r_{Spot}^{Pool*}=\rho\left(\alpha p^L+\left(1-\alpha\right)p^H\right)^{-1}$ a higher fraction of L, α, decreases r_{Spot}^{Pool*}. A lower r_{Spot}^{Pool*} again increases L's profit from the pooling spot loan contract $\Pi_{Spot}^{L,Pool}\left(r_{Spot}^{Pool*},s_{Spot}^{Pool*}\right)$. Thus, L chooses the separating spot loan contract if $\alpha<\hat{\alpha}_{Spot}$ where**

$$\hat{\alpha}_{Spot}:=\Pi_{Spot}^L\left(r_{Spot}^{L*},s_{Spot}^{L*}\right)=\Pi_{Spot}^{L,Pool}\left(r_{Spot}^{Pool*},s_{Spot}^{Pool*}\right)\tag{2.41}$$

with

$$r_{Spot}^{Pool*}=\rho\left(\hat{\alpha}_{Com}p^L+\left(1-\hat{\alpha}_{Com}\right)p^H\right)^{-1}.\tag{2.42}$$

■

Proof of Proposition 2. **To analyze the welfare of E_i in a pure spot loan market equilibrium, we compare his spot loan contract $\left(r_{Spot}^{i*},s_{Spot}^{i*}\right)$ to his first best contract $\left(r_{FB}^{i*},s_{FB}^{i*}\right)$.**

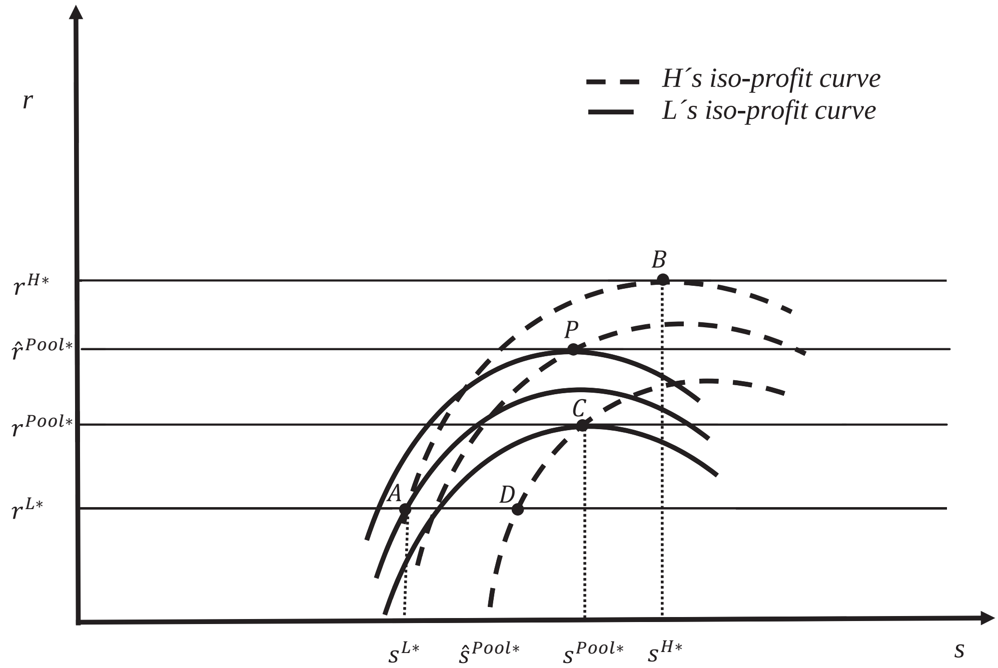

Figure 2.4: Spot loan market equilibrium. The equilibrium is separating if H chooses contract B and L contract A.

In the first best equilibrium, information is symmetric such that the bank also knows E_i's type. From this, we derive E_i's first best spot loan contract $\{r_{FB}^{i*}, s_{FB}^{i*}\}$

$$r_{FB}^{i*} = \rho/p^i \tag{2.43}$$

$$s_{FB}^{i*} := R_I^i\left(s_{FB}^{i*}\right) = r_{FB}^{i*}. \tag{2.44}$$

E_i's first best loan rate r_{FB}^{i*} entails zero profits for the bank, where H pays a higher loan rate than L as he has a higher default risk. E_i's first best loan size s_{FB}^{i*} equates marginal return R_I^i and r_{FB}^{i*}. Thus, for a given r, H prefers a larger s than L as $R_I^H > R_I^L$.

While it is straightforward to see that $r_{Spot}^{H*} = r_{FB}^{H*}$, we need to prove that $s_{Spot}^{L*} < s_{FB}^{L*}$. For that compare (2.35) and (2.44). They only differ in their right side. While the right side of (2.44) is zero, the right side of (2.35) is bigger than zero. Thus, $s_{Spot}^{L*} < s_{FB}^{L*}$.

■

Proof of Proposition 3. In addition to the co-existing spot loan market,

a bank now offers a loan commitment contract without an MAC clause with contractual variables fee F, rate r and size s. (F,r,s) does not affect H's expected profit from his optimal spot loan contract at $t=0$ so that we can write $\pi^H_{Spot} := \pi^H_{Spot}\left(r^{H*}_{Spot}, s^{H*}_{Spot}\right)$. Moreover, $\pi^i_{Com}(F,r,s)$ denotes E_i's expected profit function at $t=0$ if he buys a commitment.

The rest of this proof is organized as follows. To begin with, we formulate the Lagrangian and then solve for contractual variables to determine the loan commitment contract without the MAC clause in the equilibrium.

Lagrangian and FOC. **In brief, the Lagrangian is**

$$L(F,r,s;\lambda_I,\lambda_B) = \pi^L_{Com}(F,r,s) + \lambda_I\left[\pi^H_{Spot} - \pi^H_{Com}(F,r,s)\right] + \lambda_B \pi^{Bank}_{Com}\left(F,r,s;p^L\right) \tag{2.45}$$

and written out

$$\begin{aligned} L(F,r,s;\lambda_I,\lambda_B) = {} & \rho^{-1}\beta p^L\left(R^L(C-F+s)-rs\right)+(1-\beta)w-F \\ & +\lambda_I\left\{\pi^H_{Spot}-\left[\rho^{-1}p^H\left(R^H(C-F+s)-rs\right)-F\right]\right\} \\ & +\lambda_B\left\{\rho^{-1}\beta\left(p^Lr-\rho\right)s+F\right\}. \end{aligned} \tag{2.46}$$

To determine the bank's optimal contract, at first, calculate the first order conditions of (2.46) with respect to contractual variables (F,r,s) and Lagrange multipliers λ_I and λ_B[11]

$$\partial L/\partial F = -\left(1+\rho^{-1}\beta p^L R^L_I\right)+\lambda_I\left(1+\rho^{-1}p^H R^H_I\right)+\lambda_B = 0 \tag{2.47}$$

$$\partial L/\partial r = \rho^{-1}s\left(-\beta p^L+\lambda_I p^H+\lambda_B\beta p^L\right) = 0 \tag{2.48}$$

$$\partial L/\partial s = \rho^{-1}\beta p^L\left(R^L_I - r\right)-\lambda_I\rho^{-1}p^H\left(R^H_I-r\right)+\lambda_B\rho^{-1}\beta\left(p^Lr-\rho\right) = 0 \tag{2.49}$$

$$\partial L/\partial \lambda_I = \pi^H_{Spot}-\rho^{-1}p^H\left(R^H-rs\right)+F = 0 \tag{2.50}$$

$$\partial L/\partial \lambda_B = \rho^{-1}\beta\left(p^Lr-\rho\right)s+F = 0. \tag{2.51}$$

Then, solve first order condition

[11] For brevity, we denote $R^i := R^i(s)$ for $i=L,H$.

- (2.48) **for** λ_I

$$\lambda_I = \frac{\beta p^L}{p^H}\left(1-\lambda_B\right); \tag{2.52}$$

- (2.49) **for** λ_B

$$\lambda_B = 1 - \frac{p^H}{p^L}\lambda_I; \tag{2.53}$$

- (2.50) **for** F

$$F = \rho^{-1} p^H \left(R^H - rs\right) - \pi^H_{Spot}; \tag{2.54}$$

- (2.51) **for** r

$$r = \frac{\rho}{p^L} - \frac{\rho F}{p^L \beta s} = \frac{\rho}{p^L}\left(1 - \frac{F}{\beta s}\right). \tag{2.55}$$

As (2.52) **and** (2.53) **only contain** λ_I **and** λ_B**, we can determine the Lagrange multipliers by setting**

- (2.52) **into** (2.53) **and solve for** λ^*_B

$$\lambda^*_B = \frac{R^H_I - R^L_I}{R^H_I - \frac{\rho}{p^L}} = 1 - \frac{R^L_I - \frac{\rho}{p^L}}{R^H_I - \frac{\rho}{p^L}}; \tag{2.56}$$

- λ^*_B **into** (2.52) **and solve for** λ^*_I

$$\lambda^*_I = \frac{\beta p^L \left(R^L_I - \frac{\rho}{p^L}\right)}{p^H \left(R^H_I - \frac{\rho}{p^L}\right)}. \tag{2.57}$$

Loan commitment contract without MAC clause in the equilibrium. **In equilibrium, the bank offers loan commitment contract** $(F^*_{Com}, r^*_{Com}, s^*_{Com})$**. To determine the optimal contract, the bank sets**

- λ^*_B **and** λ^*_I **into** (2.47) **and chooses** s^*_{Com} **such that**

$$R^L_I\left(s^*_{Com}\right) - \frac{\rho}{p^L} = \left(R^H_I\left(s^*_{Com}\right) - R^L_I\left(s^*_{Com}\right)\right)\frac{\beta p^H}{\beta p^L - p^H}; \tag{2.58}$$

- s^*_{Com} **and** (2.54) **into** (2.55) **and solves for** r^*_{Com}

$$r^*_{Com} = \frac{\rho \pi^H_{Spot} - p^H\left(R^H - r^{H*}_{Spot}\beta s^*_{Com}\right)}{\left(\beta p^L - p^H\right) s^*_{Com}}; \tag{2.59}$$

- s^*_{Com} and r^*_{Com} into (2.54) and solves for F^*_{Com}

$$F^*_{Com} = \left[p^H \left(R^H - \frac{\rho s^*_{Com}}{p^L} \right) - \rho \pi^H_{Spot} \right] \frac{\rho^{-1} \beta p^L}{\beta p^L - p^H} \tag{2.60}$$

so that $F^*_{Com} > 0$ as $p^H \left(R^H (I^*) - \left(p^L\right)^{-1} \rho s^*_{Com} \right) > \pi^H_{Spot}$.

■

Proof of Corollary 1. In Proposition 1, we show that in a pure spot loan market a Cournot Nash equilibrium does only exist if $\alpha < \hat{\alpha}_{Spot}$. Now, in addition L can choose a loan commitment without an MAC clause. In Proposition 3, we show that L has a higher expected profit with this loan commitment, $\Pi^L_{Com}(r^*_{Com}, s^*_{Com}) > \Pi^L_{Spot}\left(r^{L*}_{Spot}, s^{L*}_{Spot}\right)$, which is why L prefers the loan commitment to a spot loan. Now, a separating Nash equilibrium only exists if L prefers the loan commitment contract to the pooling spot loan contract, i.e. $\Pi^L_{Com}\left(r^{L*}_{Com}, s^{L*}_{Com}\right) > \Pi^{L,Pool}_{Spot}\left(r^{Pool*}_{Spot}, s^{Pool*}_{Spot}\right)$. Thus, L's profit from a pooling spot loan contract must be higher than in a pure spot loan market. As α increases $\Pi^{L,Pool}_{Spot}\left(r^{Pool*}_{Spot}, s^{Pool*}_{Spot}\right)$, we have $\hat{\alpha}_{Com} > \hat{\alpha}_{Spot}$ where

$$\hat{\alpha}_{Com} := \Pi^L_{Com}\left(r^{L*}_{Com}, s^{L*}_{Com}\right) = \Pi^{L,Pool}_{Spot}\left(r^{Pool*}_{Spot}, s^{Pool*}_{Spot}\right) \tag{2.61}$$

with

$$r^{Pool*}_{Spot} = \rho \left(\hat{\alpha}_{Com} p^L + (1 - \hat{\alpha}_{Com}) p^H \right)^{-1}. \tag{2.62}$$

■

Proof of Proposition 4. In a co-existing spot loan and loan commitment market equilibrium, H still chooses his first best spot loan contract. Thus, adding a loan commitment to the spot loan market does not change his welfare. However, H now chooses the loan commitment instead of a spot loan. To analyze its effect on L's welfare, we compare his loan commitment contract (r^*_{Com}, s^*_{Com}) to his spot loan contract $\left(r^*_{Spot}, s^*_{Spot}\right)$ in equilibrium.

Proof that $s^*_{Com} > s^{L*}_{Spot}$. Suppose that $s^*_{Com} > s^{L*}_{Spot}$. Compare the right sides of (2.58) and (2.35). The right side of (2.35) is bigger than the right side of (2.58) as

$$\begin{aligned}\left(R_I^H\left(s^*_{Com}\right)-R_I^L\left(s^*_{Com}\right)\right)\frac{p^H}{p^L-p^H} &> \left(R_I^H\left(s^*_{Com}\right)-R_I^L\left(s^*_{Com}\right)\right)\frac{\beta p^H}{\beta p^L-p^H}\\ \frac{p^H}{p^L-p^H} &> \frac{\beta p^H}{\beta p^L-p^H}\\ \beta p^L-p^H &> \beta p^L-\beta p^H\\ \beta &> 0.\end{aligned} \tag{2.63}$$

Thus, $s^*_{Com} > s^{L*}_{Spot}$.

Proof that $r^*_{Com} < r^*_{Spot}$. Suppose that $r^*_{Com} < r^*_{Spot}$. Transform this inequality to $\pi^H_{Spot} - p^H\left(R^H - \rho s^*/p^L\right) - (1-\beta)\rho s^*\left(1-p^H\right)/p^H < 0$. As the bank does not completely screen the types[12] with s, π^H_{Spot} is smaller than $p^H\left(R^H\left(I^*\right) - \left(p^L\right)^{-1}\rho s^*\right)$. As the third term is also negative, $r^*_{Com} < r^*_{Spot}$.

■

Proof of Proposition 5. Knowing E_i's expected profit function (2.20), the bank can infer who will take down the commitment conditional on θ. If $\theta = G$, both L and H take down the commitment. If $\theta = B$, a material adverse change decreases the expected profit of E_i's investment by D. Then, only H, who has a higher expected return than L, would want to take down the commitment. As the bank only wants to attract L with the commitment, it does only invoke the MAC clause if L does not take down the commitment. Thus, the bank does not invoke the MAC clause if $\theta = G$, i.e. $\mu(\theta = G) = 0$, and invokes the MAC clause if $\theta = B$, i.e. $\mu(\theta = B) = 1$. Then, H chooses his first best spot loan as it were the case under the commitment without the MAC clause.

The rest of this proof is organized as follows. To begin with, we formulate the Lagrangian and then solve for contractual variables to determine the loan commitment contract with the MAC clause in the equilibrium.

[12]If the bank screened with s, then $F = 0$ and $r^*_{Com} = r^*_{Spot}$. Then, there wouldn't be a loan commitment.

Lagrangian and FOC. **The inclusion of the MAC changes H's expected profit function under the commitment to**

$$\pi^{H}_{MAC}(F,r,s)=\rho^{-1}\beta p^{H}\left(R^{H}(C-F+s)-rs\right)+(1-\beta)\,\pi^{H}_{Spot}-F. \tag{2.64}$$

Under a perfect competition the bank offers a loan commitment contract such that it makes zero profits. This maximizes L's expected profit under the commitment with an MAC clause subject to that H chooses his first best spot loan contract. In brief, the Lagrangian is

$$L(F,r,s;\lambda_I,\lambda_B)= \\ \pi^{L}_{MAC}(F,r,s)+\lambda_I\left[\pi^{H}_{Spot}-\pi^{H}_{MAC}(F,r,s)\right]+\lambda_B\pi^{Bank}_{MAC}\left(F,r,s;p^{L}\right) \tag{2.65}$$

and written out

$$\begin{aligned} L(F,r,s;\lambda_I,\lambda_B)&=\rho^{-1}\beta p^{L}\left(R^{L}(C-F+s)-rs\right)+(1-\beta)\,w-F\\ +\lambda_I&\left\{\pi^{H}_{Spot}-\left[\beta\rho^{-1}p^{H}\left(R^{H}(C-F+s)-rs\right)+(1-\beta)\,\pi^{H}_{Spot}-F\right]\right\}\\ &+\lambda_B\left\{\rho^{-1}\beta\left(p^{L}r-\rho\right)s+F\right\}. \end{aligned} \tag{2.66}$$

To determine the bank's optimal contract, at first, calculate the first order conditions of (2.66) **with respect to contractual variables** (F,r,s) **and Lagrange multipliers λ_I and λ_B**[13]

$$\partial L/\partial F=-\left(1+\rho^{-1}\beta p^{L}R^{L}_{I}\right)+\lambda_I\left(1+\rho^{-1}\beta p^{H}R^{H}_{I}\right)+\lambda_B=0 \tag{2.67}$$

$$\partial L/\partial r=\rho^{-1}\beta s\left(-p^{L}+\lambda_I p^{H}+\lambda_B p^{L}\right)=0 \tag{2.68}$$

$$\partial L/\partial s=\rho^{-1}\beta\left[p^{L}\left(R^{L}_{I}-r\right)-\lambda_I p^{H}\left(R^{H}_{I}-r\right)+\lambda_B\left(p^{L}r-\rho\right)\right]=0 \tag{2.69}$$

$$\partial L/\partial\lambda_I=\beta\pi^{H}_{Spot,G}-\beta\rho^{-1}p^{H}\left(R^{H}-rs\right)+F=0 \tag{2.70}$$

$$\partial L/\partial\lambda_B=\rho^{-1}\beta\left(p^{L}r-\rho\right)s+F=0. \tag{2.71}$$

Then, solve first order condition

- (2.68) **for λ_I**

$$\lambda_I=\frac{p^{L}}{p^{H}}(1-\lambda_B); \tag{2.72}$$

[13] For brevity, we denote $R^{i}:=R^{i}(s)$ for $i=L,H$.

- (2.69) **for** λ_B

$$\lambda_B = 1 - \frac{p^H}{p^L}\lambda_I; \tag{2.73}$$

- (2.70) **for** F

$$F = \rho^{-1}\beta p^H \left(R^H - rs\right) - \rho^{-1}\beta \pi^H_{Spot,G}; \tag{2.74}$$

- (2.71) **for** r

$$r = \frac{\rho}{p^L} - \frac{\rho F}{p^L \beta s} = \frac{\rho}{p^L}\left(1 - \frac{F}{\beta s}\right). \tag{2.75}$$

As (2.72) **and** (2.73) **only contain** λ_I **and** λ_B**, we can determine the Lagrange multipliers by setting**

- (2.72) **into** (2.73) **and solve for** λ_B^*

$$\lambda_B^* = \frac{R_I^H - R_I^L}{R_I^H - \frac{\rho}{p^L}}; \tag{2.76}$$

- (2.76) **into** (2.72) **and solve for** λ_I^*

$$\lambda_I^* = \frac{p^L\left(R_I^L - \frac{\rho}{p^L}\right)}{p^H\left(R_I^H - \frac{\rho}{p^L}\right)}. \tag{2.77}$$

Loan commitment contract with MAC clause in the equilibrium. In equilibrium, the bank offers loan commitment contract $(F^*_{MAC}, r^*_{MAC}, s^*_{MAC})$**. To determine the optimal contract, the bank sets**

- λ_B^* **and** λ_I^* **into** (2.58) **and chooses** s^*_{MAC} **such that**[14]

$$R_I^L\left(s^*_{MAC}\right) - \frac{\rho}{p^L} = \left[R_I^H\left(s^*_{MAC}\right) - R_I^L\left(s^*_{MAC}\right)\right]\frac{\beta p^H}{p^L - p^H}; \tag{2.78}$$

- s^*_{MAC} **and** (2.74) **into** (2.75) **and solves for** r^*_{MAC}

$$r^*_{MAC} = \frac{\pi^H_{Spot,G} - p^H\left(R^H - \frac{\rho}{p^H}s^*_{MAC}\right)}{\left(p^L - p^H\right)s^*_{MAC}}; \tag{2.79}$$

[14]The reasons for an interior solution are the same as in (2.58).

- s^*_{MAC} **and** r^*_{MAC} **into** (2.74) **and solves for** F^*_{MAC}

$$F^*_{MAC} = \left[\rho^{-1}\beta p^H \left(R^H - \frac{\rho s^*_{MAC}}{p^L}\right) - \rho^{-1}\beta\pi^H_{Spot,G}\right]\frac{p^L}{p^L - p^H}. \tag{2.80}$$

■

Proof of Corollary 2. **The proof of Corollary 2 works the same way like the proof of Corollary 1. In Corollary 1, we show that on a co-existing spot loan and loan commitment market without an MAC clause a Cournot Nash equilibrium does only exist if** $\alpha < \hat{\alpha}_{Com}$. **Now, in addition,** L **can choose a loan commitment with an MAC clause. In Proposition 5, we show that** $\Pi^L_{MAC}(r^*_{MAC}, s^*_{MAC}) > \Pi^L_{Com}(r^*_{Com}, s^*_{Com})$, **which is why** L **prefers the loan commitment with an MAC clause to a loan commitment without an MAC clause. Now, a separating Nash equilibrium only exists if** L **prefers the loan commitment contract with an MAC clause to the pooling spot loan contract, i.e.** $\Pi^L_{MAC}\left(r^{L*}_{MAC}, s^{L*}_{MAC}\right) > \Pi^{L,Pool}_{Spot}\left(r^{Pool*}_{Spot}, s^{Pool*}_{Spot}\right)$. **As** α **increases** $\Pi^{L,Pool}_{Spot}\left(r^{Pool*}_{Spot}, s^{Pool*}_{Spot}\right)$, **we have** $\hat{\alpha}_{MAC} > \hat{\alpha}_{Com}$ **where**

$$\hat{\alpha}_{MAC} := \Pi^L_{MAC}\left(r^{L*}_{MAC}, s^{L*}_{MAC}\right) = \Pi^{L,Pool}_{Spot}\left(r^{Pool*}_{Spot}, s^{Pool*}_{Spot}\right) \tag{2.81}$$

with

$$r^{Pool*}_{Spot} = \rho\left(\hat{\alpha}_{Com}p^L + (1-\hat{\alpha}_{Com})\,p^H\right)^{-1}. \tag{2.82}$$

■

Proof of Proposition 6. **In a co-existing spot loan and loan commitment with MAC clause market,** H **still chooses his first best spot loan contract. To analyze its effect on** L**'s welfare, we compare his loan commitment contract with an MAC clause** $(r^*_{MAC}, s^*_{MAC}, F^*_{MAC})$ **to his loan commitment contract without an MAC clause** $(r^*_{Com}, s^*_{Com}, F^*_{Com})$ **in the equilibrium.**

As shown in Proposition 5, using the commitment fee to subsidize the interest rate becomes more effective as a screening device. This decreases total screening costs as then a bank which includes an MAC clause in the loan commitment contract can adjust size s **as shown in the following.**

Proof that $s^*_{MAC} > s^*_{Com}$. **Compare** (2.78) **and** (2.58). **They only differ in** β **on the right side of equation** (2.78). **As** $\beta < 1$, **the right side of equation**

(2.58) is bigger than the right side of (2.78), so that $s^*_{MAC} > s^*_{Com}$. ■

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Chapter 3

Does Borrowers' Impatience Disclose their Hidden Information about Default Risk?

Abstract

This chapter provides new evidence on borrowers' hidden information about their riskiness and its link to their impatience. To do so, I analyze consumer loans on the German platform Smava, which has a unique peer-to-peer lending process. Observationally identical but unobservably riskier borrowers offer investors a higher interest rate. This helps them to obtain their loan faster and with a higher probability. Very impatient borrowers who use Smava's instant loan service pay a higher interest rate and have a higher default risk than less impatient borrowers. These findings suggest that borrowers' impatience can be used to screen their riskiness.

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3.1 Introduction

Lenders use contractual variables to reveal their borrowers' privately known riskiness. In recent decades, the literature has identified several screening devices, including loan size (Milde and Riley, 1987), co-signers (Besanko and Thakor, 1987) and collateral (Bester, 1985a). However, the costs incurred by using these devices indicate a need for cheaper instruments.[1]

Among the potential devices to screen borrowers' riskiness, one that has been mainly ignored in the literature thus far is the borrowers' patience. Experimentally soliciting impatient borrowers, Meier and Sprenger (2012) find that these borrowers default more often than more patient ones. However, the authors do not investigate a loan policy designed to screen borrowers' riskiness via their impatience. This raises the question of whether borrowers signal hidden information about their default risk through their impatience.

To answer this question, I analyze the German peer-to-peer platform smava.de, which has a unique lending design. On the platform, loan applicants post a contract offer including their requested loan size and the interest rate they are willing to pay. Based on this offer, investors decide whether and how much to invest in this loan. As soon as the loan application's aggregated supply equals the requested loan size, or after 14 days, applicants obtain their requested loan. Thus, impatient loan applicants can offer a higher interest rate to induce investors to supply their desired loan faster. Further, very impatient loan applicants can make use of Smava's instant loan service. Through this service, Smava proposes an interest rate that is high enough for the applicant to have his loan financed within a few minutes or hours.[2]

This chapter is related to empirical literature on the role of hidden information for loan contract choice. Hidden information is difficult to identify, especially on credit markets (Chiappori and Salanie 2000). To put this into practice, Ausubel (1999) and Agarwal et al. (2010) use market experiments that show that borrowers who accept inferior offers are more likely to default. However, in their analysis, it remains unclear whether

[1]For example, because borrowers do not obtain their desired loan size (Bester, 1985b) or the transfer of collateral incurs a value loss (Chan and Kanatas, 1985).

[2]This information was provided by Smava at the author's requestSmava.

interest rate variation causes hidden action or hidden information about default risk drives interest rate.[3] To disentangle hidden information and hidden action, Karlan and Zinman (2009) develop a new market field experiment methodology. Using this method, they show that a variation in interest rate not only is caused by hidden information but also contributes to hidden action.

With respect to identification of hidden information and hidden action, this chapter is most closely related to Adams et al. (2009). For identification purposes, Adams et al. assume that, conditional on observable information, hidden action depends on size but not directly on interest rate. However, this contradicts Karlan and Zinman's (2009) insights showing that variation in interest rate does also cause hidden action. Thus, my identification assumption is that, conditional on observable information, hidden action only depends on the repayment amount to the extent it increases the default risk via size. From this reasoning, it follows that, if an increase of repayment amount via interest rate residual yields a higher default risk than the same increase of the repayment amount via size, this occurs due to hidden information about default risk.

Another challenge in the literature is to determine whether information is observable or unobservable for investors. Most data sets do not include information collected by loan agents who personally meet loan applicants. On Smava, loan applicants act anonymously from the perspective of investors, who can only observe information provided on the platform. Because I can access the same information as the investors, it is likely that any variation in the interest rate that cannot be explained by observable information exclusively incorporates information that is hidden to investors.

Indeed, the empirical results of this chapter clearly indicate that borrowers' impatience is a key driver for their contract choice and their default risk. A higher repayment amount via size has a weaker effect on default risk than a higher repayment amount via loan rate, conditional on observable information. This strongly suggests that residual loan rate incorporates some hidden information that cannot be explained by hidden action. Highly impatient borrowers who choose Smava's instant loan op-

[3] Ausubel (1999) only notes that it is unlikely for a small variation in interest rate to cause a significant change in default risk.

tion pay a higher interest rate and default more often than less impatient borrowers. Moreover, observationally identical but riskier borrowers pay a markup on the interest rate conditional on observable information. As a result, they are more likely to obtain their loans and get them significantly faster. This suggests that impatience always plays an important role. Lenders' observable information affects contract design, as borrowers with an observably higher default risk pay a higher interest rate.

This chapter is organized as follows. Section 2 explains Smava's lending process. Section 3 identifies hidden information about default risk. Section 4 analyzes why borrowers signal hidden information about default risk. Section 5 identifies an alternative source of hidden information about default risk. Finally, Section 6 concludes the chapter.

3.2 Description of Smava lending process and variables

The observation sample in this study includes all listings posted on Smava, Germany's peer-to-peer online lending platform, between March 2007 and May 2012. A peer is a private person who is either a borrower or a lender; lending is considered peer-to-peer as a lender directly gives a loan to a borrower. Smava acts only as an intermediary that sets up the lending rules for the peers.

A private person who wants to be a peer on Smava must first verify his or her identity via the postident procedure of the German postal service provider Deutsche Post. Through this identification, Smava collects and verifies information about this private person, including socio-economic variables (name, gender, birthdate, and state of residence in Germany) and risk variables (Schufa rating and KDF indicator). The Schufa rating, which indicates the probability that a private person will default, ranges between A (lowest risk) and M (highest risk).[4] The KDF indicator reflects the private person's financial burden from the loan. To determine this, Smava calculates the KDF ratio[5] and assigns it to a category between 1

[4]The Schufa is a German national credit bureau.

[5]The KDF ratio is calculated in three steps. In the first step, Smava determines monthly payments on all outstanding consumer debts, including loans taken or requested on Smava. In the second step,

KDF indicator	1	2	3	4	5
KDF ratio	0 to 20 %	20 to 40 %	40 to 60 %	60 to 80 %	80 to 100 %

Table 3.1: **KDF indicator.**

(lowest financial burden) and 4 (highest financial burden), as shown in table 3.1.[6] In addition, the private person provides his or her employment status, which is not verified by Smava.[7]

Smava permits a private person to become a peer only if he or she is at least 18 years old and has a German residence. A peer may be only either a borrower or an investor, but not both. A peer who wants to apply for a loan must have a monthly income of at least EUR 1,000, a KDF ratio not exceeding 67 percent, and a Schufa rating indicating a risk no higher than H.

A private person who becomes a peer does not reveal his or her identity to other market participants. For identification purposes, peers operate under a unique username.[8] After the verification process, Smava continuously updates information about the peer.

In the observation sample, 5,902 peers applied for a loan. A peer who applies for a loan posts a contract offer on the platform comprising the

Smava determines the private person's personal monthly disposable income. It treats mortgage payments as expenditures and subtracts them from the disposable income. Household savings are not taken into account. Income from other household members can be optionally included who then are liable, too. In the third step, Smava divides the private person's personal monthly disposable income by his monthly payments on all outstanding consumer debts.

[6]As Smava only publishes the KDF indicator, it provides only a rough estimate of the private person's personal financial burden. On the platform, the actual income and savings are not observable. Furthermore, nothing is known about the income and wealth of other household members or whether other household members are included in the calculation of the monthly disposable income or not.

[7]In addition, the private person can voluntarily provide information about his or her education and family status and may upload a picture. As individuals only sporadically choose to provide this information, however, I have not included it in the analysis. Moreover, I define consumer loans as those raised by blue-collar employees, white-collar employees, public officers or pensioners and investment loans as those raised by businessmen, freelancers or managing partners. After establishing these definitions, I split the sample and compared consumer to investment loans. As these two loan types seem to have a different effect on rate and default risk, and as investment loans were introduced later to the Smava lending platform and thus still constitute a small number of observations, I focus on consumer loans in this study.

[8]Since October 2010, a peer can also comprise two private persons, whereby the second person is the partnerwho must live in the same household. They are both liable but are treated as one peer. Thus, all information is aggregated, with the exception of the age and gender of the partner, which are suppressed.

requested loan amount, the interest rate, and the desired term of the loan.[9] The loan applicant also chooses the purpose of the loan from a list of 17 options. In addition, he may voluntarily choose to describe the purpose of the loan.

After the listing is posted, investors can review this loan application and evaluate the information provided on Smava's website. In addition, investors take macroeconomic conditions into account. As it is not possible for me to observe what types of external information investors consider, for the purpose of this study I use the average interest rate charged by banks on the consumer loan market in the month of the loan[10] and time fixed effects as a proxy for these conditions.

Based on observable information, each investor can decide whether he wants to contribute to the loan application. If an investor decides to supply a loan, he must place a bid of at least EUR 250 but may not exceed the requested loan amount.[11] Due to risk diversification considerations, most investors provide only a small fraction of the amount requested in the application; thus, most loans are financed by many investors together. The application is closed after 14 days or as soon as the aggregated supply equals the requested loan amount. Thus, investors cannot underbid offers from other investors by offering money at a lower interest rate. In contrast, a loan applicant can raise the offered interest rate during the bid period. In this case, all lenders obtain the final rate, which can be higher than the starting rate.

If at least 25 percent of the requested loan amount is supplied, investors are committed by Smava to grant the loan. This occurred for 5,312 applications in the observation sample. If the loan applicant accepts this loan grant, the loan business is legally valid. In total, 4,945 loans were financed. After loans are financed, Smava charges the borrower and lenders a fee. Within my observation period, Smava changed its fee policy several times, as shown in Table 3.2.

As the exact date of the change of the fee structure is known and changes on average every year, I only control for fee fixed effects rather than year-

[9]The requested loan amount is a multiple of EUR 500 and ranges between EUR 500 and EUR 50,000. The interest rate is a multiple of 0.1 percentage points. The term is either 36 or 60 months.

[10]This information is available from the Deutsche Bundesbank.

[11]The bid must be a multiple of EUR 250; the maximum possible bid is EUR 25,000.

	Fee for borrower		Fee for lender
	36 months	60 months	
March 2007 to February 2009	1 % * size	1 % * size	0 €
February 2009 to May 2010	max (2 % * size, 40 €)	max (2,5 % * size, 40 €)	4 € per bid
June 2010 to May 2012	max (2,5 % * size, 40 €)	max (3,5 % * size, 60 €)	1,35 % * bid size

Table 3.2: **Smava's fee policy.**

fixed effects when estimating or controlling for interest rate. After the loan is paid out, the borrower is required to repay installments in monthly annuities.[12] A borrower who wants to repay his loan early is permitted to do so but must compensate his lenders for missed interest payments. Smava records and publishes which installments are repaid on time, repaid early, or not repaid.[13] Table 3.2 defines the variables.

3.3 Identification of hidden information about default risk

3.3.1 Empirical strategy

The first goal of this study is to test whether borrowers signal that they have some hidden information about default risk. Even if investors use all available information to evaluate a loan applicant's riskiness, they cannot access as much information as the loan applicant can. Thus, a loan applicant may have some private information about default risk that is hidden from investors. In this case, the applicant's default risk is higher or lower as known to the applicant than as evaluated by investors. This private information about default risk may have an impact on the applicant's contract offer; if so, investors can use the contract offer as a signal to infer hidden information about the applicant's default risk. However, in trying to identify this hidden information, they face two main obstacles,

[12]As Smava only permits annuity loans, the amount of the monthly installments is the same each month.

[13]A credit is declared as defaulted when the monthly payment is 60 days late.

Table 3.3: **Variable definitions**

Contractual characteristics	
Interest rate	Final nominal annual interest rate
IRR	Internal rate of return
Size (€1,000s)	Actual size of the loan
Term (60 months=1)	Dummy variable that takes a value of one if duration of the loan is 60 months and zero if duration is 36 months
Demand (€1,000s)	Requested loan amount
Supply (€1,000s)	Aggregate supply
Instant loan	Dummy variable that takes a value of one if the loan is granted until the 4th, 120th or 1,000th bid minute and zero otherwise
Interest rate raised	Dummy variable that takes a value of one if loan applicant has raised interest rate during bid period
Final - start rate	Final minus starting nominal annual interest rate
Risk characteristics	
Schufa rating	8 dummy variables A (lowest risk) to H (highest risk)
KDF indicator	4 dummy variables 1 (the lowest) to 4 (the highest financial burden)
Socio-economic characteristics	
Age	Age of loan applicant at application date
Gender (male=1)	Dummy variable that takes a value of one if male and zero if female
Job fixed effects	3 dummy variables that indicate whether loan applicant is blue/white-collar employee, public officer or pensioner
Residence fixed effects	16 dummy variables that indicate state of the loan applicant's residence in Germany
Loan-specific information	
Membership, ln	Logarithm of thetime between date of becoming a peer and application date
Description, ln	Logarithm of the number of characters in the description provided with the loan application
Purpose fixed effects	17 dummy variables that indicate purpose of loan
Macroeconomic conditions	
Bank's interest rate	average interest rate charged by banks on the consumer loan market in the month of the loan
Fee fixed effects	3 dummy variables that indicate Smava's fee policy at the loan application date

as illustrated in Figure 3.1.

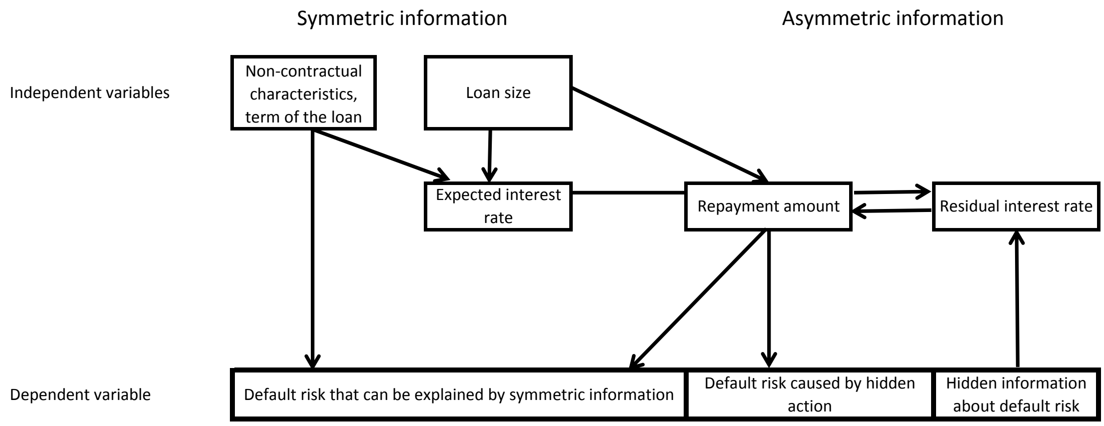

Figure 3.1: Empirical strategy to identify hidden information about default risk.

Default risk can be driven by either symmetric information, which is observable to both lenders and borrowers, or asymmetric information, which is observable to borrowers but not to lenders.

In the first step of my empirical strategy, I disentangle the effects of symmetric from asymmetric information on interest rate. To identify the effects of symmetric information on interest rate, I assume that symmetric information has a causal effect on interest rate, but not vice versa. I explain the interest rate conditional on symmetric information comprising of non-contractual characteristics, term of the loan and size. Based on the expected interest rate, I calculate the residual interest rate that cannot be explained by symmetric information.

In the second step, I identify whether asymmetric information can be traced to hidden information or to hidden action. Ausubel (1999), Agarwal et al. (2010) and Adams et al. (2009) assume that only size, and not residual interest rate, affects hidden action. However, this assumption contradicts Karlan and Zinman's (2009) empirical evidence that residual interest rate does cause hidden action. Thus, my identification assumption is that, controlling for observable information, hidden action depends on the repayment amount. The reasoning behind this assumption is that a larger repayment amount increases the borrowers' private costs to repay the loan as a function of effort. As the borrowers' action is hidden from their lenders, these higher costs give the borrowers an incentive to reduce their effort. Loan size and residual interest rate affect hidden action insofar

as they influence the repayment amount. If an increase in the repayment amount via interest rate residual yields a higher default risk than the same increase in the repayment amount via size, I assume that this additional risk is caused by hidden information.

To identify hidden action, I also control for the KDF indicator to capture the effect of a higher repayment amount. This indicator is determined by the KDF ratio, as shown in table 3.1. While the ratio increases with the repayment amount, the KDF indicator only varies as a result of a sufficiently large change in the KDF ratio. Thus, the KDF ratio is an imperfect measure of the effect of repayment amount on hidden action.[14]

Directly controlling for repayment amount causes multicollinearity problems with the interest rate residual. By definition, a higher residual interest rate increases the repayment amount. For this reason, I control for loan size instead of repayment amount. Estimation results show that the effect of the repayment amount on default risk via size is relatively small compared to the effect of the repayment amount on default risk via residual interest rate. Thus, a higher default risk due to a higher residual interest rate cannot be justified only by the repayment amount.[15]

A potential concern with my analysis is that interest rate incorporates information about default risk that is only observable to investors, but not by the present researcher. In this case, observationally identical borrowers have a different default risk for their lenders. This matters insofar as lenders presumably charge a higher interest rate if this additional information indicates relatively higher riskiness. Figure 3.2 illustrates that, on Smava, borrowers with a worse Schufa rating pay a higher interest rate. As I cannot explain this higher interest rate by risk characteristics that are observable to me, it translates to a higher residual interest rate. In extreme cases, this fact indicates that variation in the residual interest rate is due only to investors' additional information about their borrowers' default risk.

It is improbable that this concern will arise, as loan applicants on Smava act anonymously and investors only have access to the same information

[14]Other observable characteristics are not influenced by a loan. While it is natural to assume that a loan request does not change socio- or macroeconomic characteristics, German law forbids the inclusion of the anticipated effect of a loan request on default risk in the Schufa rating.

[15]In a robustness check using total repayment amount instead of loan size, residual rate still had a significantly positive and important effect on default.

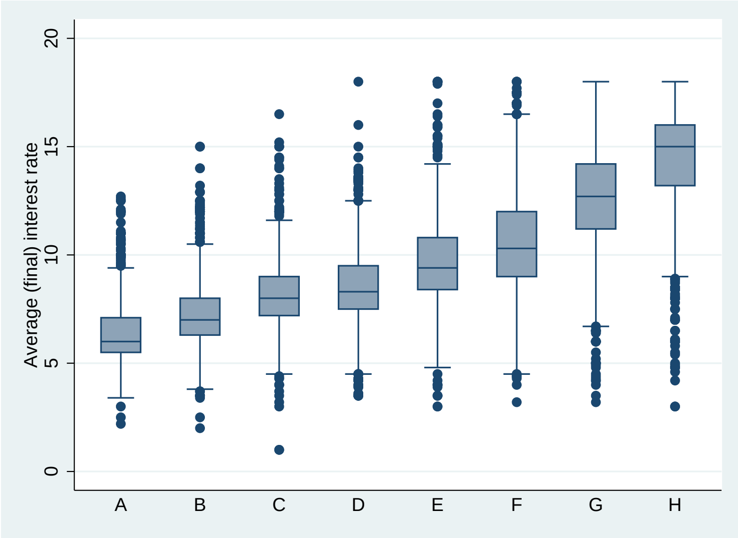

Figure 3.2: Average interest rate conditional on Schufa rating.

that I am able to observe in conducting this research. [16] Moreover, as investors are private households, I expect that they evaluate available information less professional than I do, indicating that my results actually underestimate the true effects.[17]

Note that my identification assumption implies loan size increases default risk not only because of hidden action but also because of hidden information. The fact that borrowers have some hidden information about default risk can also induce them to request a larger loan (Bester 1985b, Adams et al. 2009). A loan applicant who privately knows that he has a higher default risk than observed by investors may both request a higher loan size and be willing to pay a higher interest rate (Bester, 1985b). This implies that loan size may incorporate not only hidden action but also some hidden information, as shown in figure 3.1.[18] As size pools hidden action and some hidden information, using its effect via repayment amount

[16] Using my empirical strategy, samples including bank loans are less eligible than my observation sample as loan officers may collect some private information about their borrowers' riskiness that researchers are usually unable to observe.

[17] For example, I show that lenders misinterpret the KDF indicator and thus supply a larger loan if it indicates a higher risk. Moreover, investors may observe risk-relevant information that is not available on the platform, such as macroeconomic conditions. To account for this, I use as a proxy the average consumer loan interest rate that banks charge on the consumer loan market, as well as time-fixed effects.

[18] Adams et al. (2009) use variation of down payments to identify the effect of hidden information about default risk on loan size.

as a proxy for hidden action underestimates the true effect of hidden information on default risk.

3.3.2 Identification of hidden information

I first identify the effects of symmetric information on the rate for any loan i. To do so, I specify an OLS model to regress interest rate r_i on X_i, which denotes non-contractual information and term of the loan, and on loan size s_i:

$$r_i = \beta X_i + \gamma f(s_i) + \tilde{r}_i \tag{3.1}$$

where $\tilde{r}_i$ is the error term, and $\gamma f(s_i) \equiv \gamma_1 s_i + \gamma_2 s_i^2$. For my baseline estimation, I use the (final) loan interest rate.

A potential concern with using interest rate is that Smava has a non-linear fee structure and changes its fee policy over time (see figure 3.2), resulting in two effects: 1) there is no linear relationship between interest rate and the internal rate of return, and 2) a borrower and his lenders have a different internal rate of return, which is non-linearly related. To account for this, I run two additional regressions with both the borrower's and the lenders' average internal rate of return.[19] The monthly annuity of loan application i at the end of every loan month is therefore

$$annuity_i = s_i \frac{r_i^{month}\left(1 + r_i^{month}\right)^{T_i}}{\left(1 + r_i^{month}\right)^{T_i} - 1} \tag{3.2}$$

where T denotes the term of the loan and $r^{month} = r/12$.[20] The borrower's internal rate of return $IRR_i^{borrower}$ equates

$$s_i - F_i^{borrower} = -annuity_i \sum_{t=1}^{T_i} \left(1 + IRR_i^{borrower}\right)^{-t} \tag{3.3}$$

and his lenders' internal rate of return $IRR_i^{lenders}$ equates

$$-\left(s_i + F_i^{lenders}\right) = annuity_i \sum_{t=1}^{T_i} \left(1 + IRR_i^{lenders}\right)^{-t} \tag{3.4}$$

[19] To prevent biases caused by different average bid sizes between loans, I use the average number of bidders in the sample to calculate the lenders' fee.

[20] Smava divides the annual loan interest rate by 12 to calculate the annuity.

where F denotes the fee, which differs between a borrower and his lenders. Because of this fee, a borrower actually obtains $s_i - F_i^{borrower}$, whereas his lenders invest $s_i + F_i^{lenders}$. During the term of the loan, the borrower repays his annuities to his lenders at the end of every month.

Table 3.4 shows how observable information affects the interest rate, the internal rate of return for a borrower and the internal rate of return for investors, respectively.[21] Not surprisingly, borrowers with an observationally higher risk pay a significantly higher interest rate. In the first instance, the requested interest rate decreases with age, while rate increase with age squared. On average, male borrowers pay less than female borrowers. The banks' monthly average consumer loan interest rate has a significantly positive effect on interest rate, whereas contractual characteristics and loan-specific information do not have a significant impact on interest rate.

To identify hidden information about default risk, I calculate residual rate, with the assumption that residual rate incorporates not only the borrower's private information about default risk θ but also some randomness:

$$\tilde{r}_i = \theta_i + \tilde{u}_i \tag{3.5}$$

Next, I rescale $\tilde{r}_i$ by the generated regressor $\hat{r}_i$. The rescaled $\tilde{r}_i$ still underlies the same uncertainty as r_i[22]. Thus, using residual rate as a regressand yields consistent estimations with a valid interference.

3.3.3 Hidden information and default risk

Next, I test whether the residual interest rate incorporates some hidden information about default risk. However, in the observation sample, only 895 of 5,026 loans could have come to the end of their loan term. As it allows me to work with the full sample, I estimate default risk using Cox's (1972) proportional hazard model. This accounts for the default pattern of the loan over time and with it for right-censored observations.

[21] I report the squared loan size, as I will show in the next section that loan size non-linearly increases default risk.

[22] Wooldridge (2002, p. 115) discusses only estimators (in my case $\hat{r}_i$) as generated regressors. As this approach ignores sampling variation, some uncertainty must be added to guarantee a valid inference.

Table 3.4: **Identification of the effect of observable information on interest rate.** OLS regression with the dependent variable interest rate in column 1, internal rate of return for borrower in column 2, and internal rate of return for lenders in column 3. As internal rate of return already includes fees, changes in Smava's fee policy are captured as dummies in column 1 but not in columns 2 and 3.

	(1)		(2)		(3)	
	Interest rate		IRR borrower		IRR lenders	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Contractual characteristics						
Size (€1,000s)	0.009	(0.009)	-0.009	(0.011)	0.011	(0.010)
Size squared(€1,000s)	-0.000	(0.000)	0.000	(0.000)	-0.000	(0.000)
Term (60 months=1)	0.009	(0.052)	-0.376***	(0.059)	0.234***	(0.057)
Risk characteristics						
Schufa rating						
B	0.778***	(0.069)	0.849***	(0.079)	0.817***	(0.076)
C	1.653***	(0.082)	1.825***	(0.094)	1.749***	(0.091)
D	2.159***	(0.083)	2.358***	(0.095)	2.281***	(0.091)
E	3.184***	(0.083)	3.531***	(0.095)	3.409***	(0.092)
F	4.029***	(0.083)	4.463***	(0.095)	4.325***	(0.091)
G	6.073***	(0.079)	6.801***	(0.090)	6.598***	(0.087)
H	7.810***	(0.091)	8.851***	(0.104)	8.575***	(0.100)
KDF indicator						
2	0.178*	(0.078)	0.168	(0.089)	0.187*	(0.085)
3	0.367***	(0.075)	0.384***	(0.086)	0.393***	(0.083)
4	0.701***	(0.080)	0.763***	(0.092)	0.774***	(0.088)
Socio-economic characteristics						
Age	-0.049***	(0.010)	-0.052***	(0.012)	-0.052***	(0.011)
Age squared	0.001***	(0.000)	0.001***	(0.000)	0.001***	(0.000)
Gender (male=1)	-0.126**	(0.047)	-0.146**	(0.054)	-0.149**	(0.052)
Job fixed effects	Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes	
Loan-specific information						
Membership, ln	-0.005	(0.017)	-0.001	(0.020)	0.005	(0.019)
Description, ln	0.000	(0.013)	0.008	(0.015)	-0.008	(0.015)
Purpose fixed effects	Yes		Yes		Yes	
Macroeconomic conditions						
Banks' interest rate	0.696***	(0.199)	1.969***	(0.161)	1.416***	(0.155)
Month fixed effects	Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes	
Fee fixed effects	Yes		No		No	
Constant	1.893	(1.397)	-3.872***	(1.078)	-0.718	(1.035)
R sq	0.797		0.775		0.807	
Adj. R squ	0.794		0.772		0.805	
F-test	269.915		243.752		296.467	
p value	0.000		0.000		0.000	
Observations	5026		5026		5026	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

The probability that a loan i defaults at t, given that it has not defaulted before t, is

$$h(t \mid X_i, s_i, \tilde{r}_i) = h_0(t) \exp(\beta X_i + \gamma s_i + \delta f(\tilde{r}_i)) \tag{3.6}$$

where $h(t \mid X_i, s_i, \tilde{r}_i)$ denotes the proportional hazard rate, t the number of months the loan is running, $h_0(t)$ the baseline hazard, X_i the observable information for lenders, s_i the loan size, $\tilde{r}_i$ the residual rate and $\delta f(\tilde{r}_i) \equiv \delta_1 \tilde{r}_i + \delta_2 \tilde{r}_i^2$. The main assumption of this model is that the baseline hazard $h_0(t)$ depends only on t. This implies that X, s and $\tilde{r}$ only shift the proportional hazard rate, but do not change the default pattern over time.

Figure 3.3 shows the time pattern of the hazard rate for a loan with a Schufa rating of A (lower line), E (middle line) and H (upper line). Borrowers with a lower-risk Schufa rating (with a lower line) have a lower

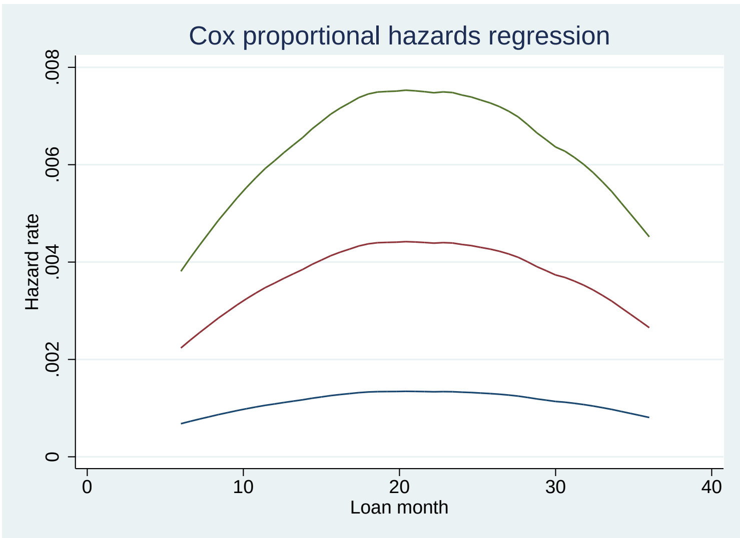

Figure 3.3: Hazard rate conditional on Schufa rating of A (lower line), E (middle line) and H (upper line).

hazard rate for every loan month. The hazard rate increases non-linearly with the loan month, reaches its maximum at around loan month 21, and then decreases again.

As it is difficult to interpret the hazard rate intuitively, in addition, I calculate the probability that loan i with term T will be fully repaid:

$$S_i(T) = exp\left\{-\int_0^T h(t \mid X_i, s_i, \tilde{r}_i)\, dt\right\}. \tag{3.7}$$

Figure 3.4 shows this repayment probability as a function of the term of the loan, conditional on its Schufa rating - A (upper line), E (middle line) and H (lower line). Repayment probability decreases with the term of the loan, and borrowers with a lower-risk Schufa rating (higher line) have a higher repayment probability. To interpret figure 3.4, suppose, for example, that the term of the loan is 36 months. For this loan, a borrower with a Schufa rating of A has a repayment probability of more than 95 percent, which drops to less than 90 percent for a rating of E and only around 80 percent for a rating of H. This shows that there is a considerable variation of default risk conditional on the borrower's Schufa rating.

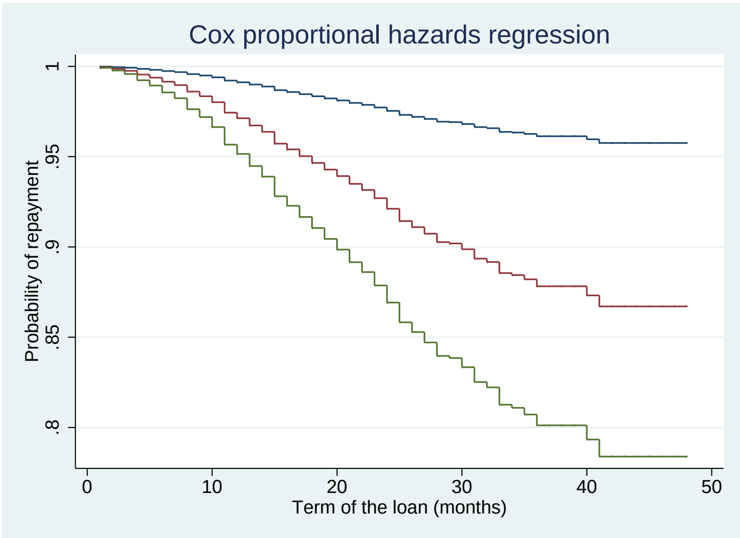

Figure 3.4: Probability of repayment of the loan conditional on Schufa rating of A (upper line), E (middle line) and H (lower line).

Using a proportional hazard rate estimation, I suppose that the baseline hazard solely depends on t. This constant relative hazard assumption is reasonable if the log-log probability of the repayment, as a function of the loan month conditional on the Schufa rating, shows a parallel pattern. As an example, see figure 3.5. It compares such a function with Schufa rating D to loans with another Schufa rating and finds this parallel pattern. Running the same test with the other Schufa ratings shows similar results.

Table 3.5 shows the results of a proportional hazard rate estimation.[23]

[23]Loans repaid early are treated as being repaid until the last observation period.

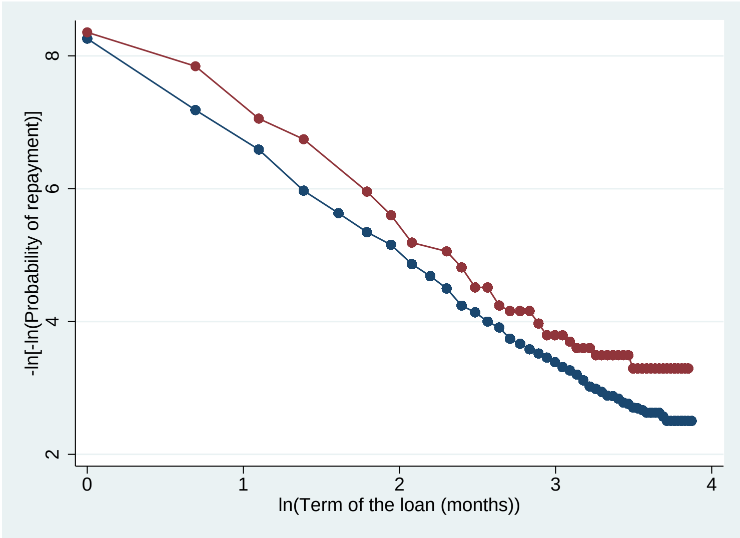

Figure 3.5: Survival rate function of Schufa rating D (upper line) is nearly parallel to survival rate function of the other Schufa ratings (lower line).

In column 1, I control for residual interest rate; in column 2, for internal rate of return for a borrower; and in column 3, for internal rate of return for investors.[24] To make coefficients interpretable, table 3.5 displays the coefficients in exponentiated form, which is denoted as hazard ratio. Interest rate residual has a significant, non-linear, but mainly positive effect on hazard ratio. A one percent higher residual interest rate increases the hazard ratio by 26.5 percent, while its square decreases the hazard ratio by 0.5 percent. Controlling for internal rate of return in columns 2 and 3 improves the significance level to the 0.1 percent level. Meanwhile, a one percent higher residual internal rate of return increases the hazard ratio by 27.1 for borrowers and 21.1 percent for lenders, while its square decreases the hazard ratio by 0.8 and 0.5 percent, respectively.

Although I focus on interest rate residual, the effect of other contractual characteristics is similarly interesting. For all columns, I find that a €1,000 larger loan causes a 4.3 to 4.4 percent higher hazard ratio, while its square causes a 0.1 percent lower hazard ratio. If KDF indicates that the loan imposes a higher financial burden on the borrower, the default risk is significantly higher. If the Schufa rating is worse, the default risk tends to

[24] I only include fee dummies if I control for interest rate, as the internal rate of return already includes fees.

Table 3.5: **Hidden information and default risk.** Cox proportional hazard regression with dependent variable hazard ratio (exponentiated hazard rate). Column 1 controls for residual interest rate as well as for fee dummies, column 2 controls for residual internal rate of return for a borrower and column 3 controls for residual internal rate of return for lenders.

	(1) Hazard ratio exp(Coef.)	Std. err.	(2) Hazard ratio exp(Coef.)	Std. err.	(3) Hazard ratio exp(Coef.)	Std. err.
Contractual characteristics						
Residual interest rate	1.265**	(0.092)				
Residual interest rate squared	0.995*	(0.003)				
Residual IRR borrower			1.271***	(0.058)		
Residual IRR borrower squared			0.992***	(0.002)		
Residual IRR lenders					1.212***	(0.062)
Residual IRR lenders squared					0.995*	(0.002)
Size (€1,000s)	1.044***	(0.007)	1.043***	(0.007)	1.044***	(0.007)
Size squared(€1,000s)	0.999***	(0.000)	0.999***	(0.000)	0.999***	(0.000)
Term (60 months=1)	1.131***	(0.037)	1.145***	(0.037)	1.147***	(0.037)
Risk characteristics						
Schufa rating						
B	1.446***	(0.083)	1.447***	(0.083)	1.447***	(0.083)
C	1.756***	(0.109)	1.758***	(0.109)	1.754***	(0.109)
D	1.286***	(0.089)	1.295***	(0.089)	1.289***	(0.089)
E	3.491***	(0.195)	3.531***	(0.198)	3.494***	(0.196)
F	2.637***	(0.152)	2.641***	(0.152)	2.632***	(0.151)
G	3.689***	(0.201)	3.656***	(0.199)	3.635***	(0.198)
H	6.089***	(0.342)	6.092***	(0.343)	6.030***	(0.339)
KDF indicator						
2	1.976***	(0.143)	1.985***	(0.143)	1.987***	(0.143)
3	2.726***	(0.189)	2.760***	(0.191)	2.753***	(0.191)
4	3.272***	(0.227)	3.305***	(0.229)	3.298***	(0.229)
Socio-economic characteristics						
Age	0.931***	(0.005)	0.931***	(0.005)	0.931***	(0.005)
Age squared	1.001***	(0.000)	1.001***	(0.000)	1.001***	(0.000)
Gender (male=1)	0.919**	(0.026)	0.919**	(0.026)	0.921**	(0.026)
Job fixed effects	Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes	
Loan-specific information						
Membership, ln	1.091***	(0.012)	1.093***	(0.012)	1.091***	(0.012)
Description, ln	0.904***	(0.009)	0.910***	(0.009)	0.910***	(0.009)
Purpose fixed effects	Yes		Yes		Yes	
Macroeconomic conditions						
Banks' interest rate	2.218***	(0.242)	1.679***	(0.142)	1.653***	(0.139)
Month fixed effects	Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes	
Fee fixed effects	Yes		No		No	
Pseudo R sq	0.037		0.037		0.037	
AIC	143451.040		143476.630		143469.962	
BIC	144171.422		144177.542		144170.874	
p value	0.000		0.000		0.000	
Observations	124853		124853		124853	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

be higher.[25] A longer term of the loan significantly increases default risk.

Socio-economic characteristics also play a small role for default risk. When a borrower is one year older, the hazard ratio is expected to decrease by 6.9 percent, while squared age increases it by 0.1 percent. Gender is still significant at the 1 percent level; males have a 7.9 to 8.1 percent lower hazard risk than females.

A potential concern for large samples is that, although regressors are significant at a low confidence level, they do not contribute to the relative quality of the regression. Thus, including such a significant regressor may increase the likelihood but overfit the model. Thus, although the residual interest rate is significant, it may be relatively unimportant for the default risk. One way to address this concern is to discuss the size of the exponentiated coefficient. The estimation results suggest that an increase in the residual interest has a strong impact on the hazard rate. To understand this, regard column 3. On average, the hazard ratio increases by 71.86 percent per riskier Schufa class; this percentage changes by 43.92 percent when regarding only classes A to G.[26] This change is relatively small compared to the impact of the internal rate of return for investors. A one percent higher residual internal rate of return increases the hazard ratio by 21.2 percent, while its square only decreases the ratio by 0.5 percent.

Another potential concern is that a higher residual interest rate may only be due to hidden action. Specifically, a higher interest rate increases the repayment amount, which may affect hidden action and thus default risk. To understand why this is improbable, consider column 1 of table 3.5, which shows that a one percent higher interest rate, on average, increases hazard ratio by 26.5 percent, while its square decreases it by 0.5 percent. To understand what a higher interest rate means for the repayment amount, consider a loan with the average loan size of €6,259.14 and the average interest rate of 9.53 percent. In this case, a one percent higher interest rate increases the repayment amount by €62.59. The repayment amount would increase to the same extent if I increased the size by €57.14.[27] According to column 1 of table 3.5, an increase of the re-

[25]These results are robust and do not change when same regressions are run without residual interest rate or loan size.

[26]The average increase of the hazard ratio for the seven Schufa classes A to H is $(6.030-1)100\%/7 = 71.86\%$, while for the six Schufa classes A to G it is $(3.635-1)100\%/6 = 43.92\%$.

[27]9.53%×€57.14+€57.14=€62.59

payment amount via size increases the hazard ratio by 0.25 percent, while increasing via the square of the size only increases the hazard ratio by 0.006 percent.[28] This means that the effect of the repayment amount on the hazard ratio is remarkably small. Thus, for the most part, the significant positive link between residual interest rate and default risk cannot be explained by hidden action.

In table 3.5, I suggest that residual rate is non-linearly related to hazard ratio. However, a simple interpretation of the exponentiated coefficients does not aid in deciding whether a linear or a non-linear effect of interest rate on hazard rate implies a better goodness of fit. To address this concern, I use the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). To the term $-2ln\,(L)$, AIC adds the penalty term $2p$ and BIC adds the penalty term $ln\,(N)\,p$, where L is the maximized log-likelihood, which uses p parameters. BIC differs from AIC in that it additionally accounts for sample size N. For both criteria, a lower value indicates a better fit of the model.[29]

Tables 3.6, 3.7 and 3.8 show the estimation results controlling for residual interest rate, residual internal rate of return for a borrower and residual internal rate of return for investors respectively. Each table contains three columns. The first column does not control for rate, the second includes rate linearly, and the third includes rate non-linearly by additionally including its square.

Both information criteria suggest that residual interest rate, residual internal rate of return for a borrower and residual internal rate of return for investors are important determinants of the hazard rate. For the best goodness of fit, the AIC suggests to control for rate and its square in table 3.6, while the BIC suggests to control for internal rate of return non-linearly in table 3.7 and for interest rate linearly in tables 3.6 and 3.8.[30]

[28]As I only regard the small interval of €1,000, I suppose that the percentage increase of hazard ratio is linear with the size. This results in an increase of 4.4%×€57.14/€1,000=0.25% and for its square 0.1%×€57.14/€1,000=0.006%.

[29]In determining whether rate is important, the absolute value of the information criterion does not play a role. A high absolute value results from a large number of parameters. While a reduction in the number of parameters may improve the goodness of fit, it does not change the importance of residual rate as a regressor of hazard rate.

[30]Another concern may be that residual interest rate may underlie uncertainty, in the sense of that the error term follows a normal distribution, although the Cox proportional hazard rate estimation supposes a lognormal distribution. To address this concern, I ran several robustness checks using bootstrapping with residuals randomly drawn from the sample according to a log-normal distribution.

3.4 Why borrowers signal hidden information about default risk

3.4.1 Empirical strategy

The main result found in the previous section is that observationally identical borrowers signal their privately known default risk via interest rate that cannot be explained by symmetric information. That means that from the perspective of lenders, unobservably riskier borrowers pay a higher interest rate despite the fact that doing so implies higher costs for the borrowers. This raises the question of why borrowers signal their hidden information about default risk in this way.

To answer this question, it may be informative to consider Smava's unique lending design. After the loan application is posted, the bid period starts. This period can last up to 14 days, but it is closed earlier when investors fully supply the requested loan amount. Thus, loan applicants may offer a higher interest rate to induce investors to provide the loan faster or with a higher probability.

3.4.2 Probability of obtaining the requested amount

To analyze how a higher interest rate affects the probability of obtaining the requested loan amount, I include loan applications that are not financed. Consider a loan application i with X_i, which denotes symmetric information except loan size, and a request of size D_i. Based on the OLS estimation of interest rate in the previous section, the loan applicant is expected to offer a rate of interest

$$\hat{r}_i = \hat{\beta} X_i + \hat{\gamma} f\left(D_i\right) \tag{3.8}$$

The results do not change.

Table 3.6: **Hidden information and default risk - robustness check with residual interest rate.** Cox proportional hazard regression with dependent variable hazard ratio, which is the exponentiated hazard rate. As a robustness check, column 1 controls for residual interest rate, column 2 controls for residual interest rate, column 3 controls for residual interest rate and its square. A lower AIC or BIC indicates a better fit of the model. Changes in Smava's fee policy are captured by dummies in all columns.

	(1)		(2)		(3)	
	Hazard ratio		Hazard ratio		Hazard ratio	
	exp(Coef.)	Std. err.	exp(Coef.)	Std. err.	exp(Coef.)	Std. err.
Contractual characteristics						
Residual interest rate			1.096***	(0.008)	1.265**	(0.092)
Residual interest rate squared					0.995*	(0.003)
Size (€1,000s)	1.048***	(0.007)	1.044***	(0.007)	1.044***	(0.007)
Size squared(€1,000s)	0.999***	(0.000)	0.999***	(0.000)	0.999***	(0.000)
Term (60 months=1)	1.187***	(0.039)	1.131***	(0.037)	1.131***	(0.037)
Risk characteristics						
Schufa rating						
B	1.457***	(0.083)	1.446***	(0.083)	1.446***	(0.083)
C	1.778***	(0.110)	1.755***	(0.109)	1.756***	(0.109)
D	1.306***	(0.090)	1.283***	(0.088)	1.286***	(0.089)
E	3.573***	(0.199)	3.466***	(0.194)	3.491***	(0.195)
F	2.668***	(0.153)	2.631***	(0.151)	2.637***	(0.152)
G	3.607***	(0.196)	3.679***	(0.200)	3.689***	(0.201)
H	5.809***	(0.324)	6.035***	(0.338)	6.089***	(0.342)
KDF indicator						
2	1.975***	(0.143)	1.979***	(0.143)	1.976***	(0.143)
3	2.758***	(0.191)	2.724***	(0.189)	2.726***	(0.189)
4	3.325***	(0.231)	3.267***	(0.227)	3.272***	(0.227)
Socio-economic characteristics						
Age	0.931***	(0.005)	0.931***	(0.005)	0.931***	(0.005)
Age squared	1.001***	(0.000)	1.001***	(0.000)	1.001***	(0.000)
Gender (male=1)	0.921**	(0.026)	0.922**	(0.026)	0.919**	(0.026)
Job fixed effects	Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes	
Loan-specific information						
Membership, ln	1.094***	(0.012)	1.090***	(0.012)	1.091***	(0.012)
Description, ln	0.907***	(0.009)	0.903***	(0.009)	0.904***	(0.009)
Purpose fixed effects	Yes		Yes		Yes	
Macroeconomic conditions						
Banks' interest rate	2.278***	(0.249)	2.217***	(0.242)	2.218***	(0.242)
Month fixed effects	Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes	
Fee fixed effects	Yes		Yes		Yes	
Pseudo R sq	0.036		0.037		0.037	
AIC	143594.800		143453.120		143451.040	
BIC	144295.712		144163.767		144171.422	
p value	0.000		0.000		0.000	
Observations	124853		124853		124853	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

Table 3.7: **Hidden information and default risk - robustness check with residual internal rate of return for borrower.** Cox proportional hazard regression with dependent variable hazard ratio, which is the exponentiated hazard rate. As a robustness check, column 1 does not control for residual internal rate of return for a borrower, column 2 controls for residual internal rate of return for a borrower, column 3 controls for residual internal rate of return for a borrower and its square. A lower AIC or BIC indicates a better fit of the model.

	(1)		(2)		(3)	
	Hazard ratio		Hazard ratio		Hazard ratio	
	exp(Coef.)	Std. err.	exp(Coef.)	Std. err.	exp(Coef.)	Std. err.
Contractual characteristics						
Residual IRR borrower			1.075***	(0.007)	1.271***	(0.058)
Residual IRR borrower squared					0.992***	(0.002)
Size (€1,000s)	1.048***	(0.007)	1.044***	(0.007)	1.043***	(0.007)
Size squared(€1,000s)	0.999***	(0.000)	0.999***	(0.000)	0.999***	(0.000)
Term (60 months=1)	1.199***	(0.039)	1.147***	(0.037)	1.145***	(0.037)
Risk characteristics						
Schufa rating						
B	1.454***	(0.083)	1.447***	(0.083)	1.447***	(0.083)
C	1.773***	(0.110)	1.754***	(0.109)	1.758***	(0.109)
D	1.307***	(0.090)	1.290***	(0.089)	1.295***	(0.089)
E	3.575***	(0.199)	3.481***	(0.195)	3.531***	(0.198)
F	2.660***	(0.152)	2.626***	(0.151)	2.641***	(0.152)
G	3.577***	(0.194)	3.627***	(0.197)	3.656***	(0.199)
H	5.776***	(0.322)	5.972***	(0.335)	6.092***	(0.343)
KDF indicator						
2	1.988***	(0.143)	1.991***	(0.144)	1.985***	(0.143)
3	2.782***	(0.193)	2.756***	(0.191)	2.760***	(0.191)
4	3.351***	(0.232)	3.298***	(0.229)	3.305***	(0.229)
Socio-economic characteristics						
Age	0.930***	(0.005)	0.931***	(0.005)	0.931***	(0.005)
Age squared	1.001***	(0.000)	1.001***	(0.000)	1.001***	(0.000)
Gender (male=1)	0.923**	(0.026)	0.925**	(0.026)	0.919**	(0.026)
Job fixed effects	Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes	
Loan-specific information						
Membership, ln	1.095***	(0.012)	1.091***	(0.012)	1.093***	(0.012)
Description, ln	0.911***	(0.009)	0.910***	(0.009)	0.910***	(0.009)
Purpose fixed effects	Yes		Yes		Yes	
Macroeconomic conditions						
Banks' interest rate	1.725***	(0.146)	1.691***	(0.143)	1.679***	(0.142)
Month fixed effects	Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes	
Pseudo R sq	0.036		0.037		0.037	
AIC	143606.783		143489.369		143476.630	
BIC	144288.225		144180.546		144177.542	
p value	0.000		0.000		0.000	
Observations	124853		124853		124853	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

Table 3.8: **Hidden information and default risk - robustness check with residual internal rate of return for investors.** Cox proportional hazard regression with dependent variable hazard ratio, which is the exponentiated hazard rate. As a robustness check, column 1 does not control for residual internal rate of return for lenders, column 2 controls for residual internal rate of return for lenders, column 3 controls for residual internal rate of return for lenders and its square. A lower AIC or BIC indicates a better fit of the model.

	(1)		(2)		(3)	
	Hazard ratio		Hazard ratio		Hazard ratio	
	exp(Coef.)	Std. err.	exp(Coef.)	Std. err.	exp(Coef.)	Std. err.
Contractual characteristics						
Residual IRR lenders			1.083***	(0.007)	1.212***	(0.062)
Residual IRR lenders squared					0.995*	(0.002)
Size (€1,000s)	1.048***	(0.007)	1.044***	(0.007)	1.044***	(0.007)
Size squared(€1,000s)	0.999***	(0.000)	0.999***	(0.000)	0.999***	(0.000)
Term (60 months=1)	1.199***	(0.039)	1.148***	(0.037)	1.147***	(0.037)
Risk characteristics						
Schufa rating						
B	1.454***	(0.083)	1.446***	(0.083)	1.447***	(0.083)
C	1.773***	(0.110)	1.751***	(0.109)	1.754***	(0.109)
D	1.307***	(0.090)	1.285***	(0.088)	1.289***	(0.089)
E	3.575***	(0.199)	3.463***	(0.194)	3.494***	(0.196)
F	2.660***	(0.152)	2.622***	(0.151)	2.632***	(0.151)
G	3.577***	(0.194)	3.620***	(0.197)	3.635***	(0.198)
H	5.776***	(0.322)	5.964***	(0.334)	6.030***	(0.339)
KDF indicator						
2	1.988***	(0.143)	1.991***	(0.144)	1.987***	(0.143)
3	2.782***	(0.193)	2.750***	(0.190)	2.753***	(0.191)
4	3.351***	(0.232)	3.293***	(0.228)	3.298***	(0.229)
Socio-economic characteristics						
Age	0.930***	(0.005)	0.931***	(0.005)	0.931***	(0.005)
Age squared	1.001***	(0.000)	1.001***	(0.000)	1.001***	(0.000)
Gender (male=1)	0.923**	(0.026)	0.924**	(0.026)	0.921**	(0.026)
Job fixed effects	Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes	
Loan-specific information						
Membership, ln	1.095***	(0.012)	1.090***	(0.012)	1.091***	(0.012)
Description, ln	0.911***	(0.009)	0.910***	(0.009)	0.910***	(0.009)
Purpose fixed effects	Yes		Yes		Yes	
Macroeconomic conditions						
Banks' interest rate	1.725***	(0.146)	1.657***	(0.140)	1.653***	(0.139)
Month fixed effects	Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes	
Pseudo R sq	0.036		0.037		0.037	
AIC	143606.783		143473.076		143469.962	
BIC	144288.225		144164.253		144170.874	
p value	0.000		0.000		0.000	
Observations	124853		124853		124853	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

where $\hat{\beta}$ and $\hat{\gamma}$ denote the coefficients from estimation (3.1), and $\hat{\gamma} f(D_i) \equiv \hat{\gamma}_1 D_i + \hat{\gamma}_2 D_i^2$.[31] However, I observe that the actual interest rate of loan application i is r_i; that is, it deviates by $\tilde{r}_i$ from $\hat{r}_i$. According to the results of the previous section, a higher $\tilde{r}_i$ incorporates some of borrowers' hidden information about a higher default risk.

One potential benefit of a higher residual interest rate may be that it increases investors' willingness to supply a higher S_i. To test this, I specify the Tobit model

$$S_i = \begin{cases} S_i^* = \beta X_i + \delta f(\tilde{r}_i) + \varepsilon_i & if\ S_i^* < D_i \\ D_i & if\ S_i^* \geq D_i \end{cases} \tag{3.9}$$

As I can only observe supply S_i^* if $S_i^* < D_i$. If $S_i^* \geq D_i$, I observe only D_i; thus, I only know that investors are willing to supply at least as much as loan applicants demand.

Table 3.9 shows the estimation results. Columns 1 and 2 include all loan applications, while columns 3 and 4 include only those loans that are financed. Also, columns 1 and 3 control for interest rate, while columns 2 and 4 control for the internal rate of return for investors.

For all columns, a higher interest rate residual induces investors to supply significantly more. For example, in column 1, a one-percent higher interest rate residual increases supply by €1,109. The positive effect of the interest rate residual is weaker if we regard only those loans that are financed. In column 3, a one-percent higher interest rate residual only increases supply by €418.

For financed loans, the Schufa rating does not influence supply. Regarding loan applications, investors supply significantly less for Schufa classes F to H. Interestingly, investors are willing to supply more if the KDF indicates a higher risk. Also, a higher loan term significantly decreases supply in columns 1 and 2 but has no effect in columns 3 and 4. Socio-economic and loan-specific information does not have a significant impact on supply.

The results in table 3.9 show that the loan applicant can only estimate S_i under uncertainty. Thus, the previous results suggest that a higher $\tilde{r}_i$

[31] Note that here $\hat{\gamma}_1$ and $\hat{\gamma}_2$ are multiplied by D_i and not by S_i. Thus, during the bid period, I suppose that $S_i = D_i$. While this applies for most observations in my sample, it also helps me to understand how D_i affects the speed and probability of obtaining a loan.

Table 3.9: **Hidden information and supply.** Tobit regression with the dependent variable loan supply. As supply can only be observed if it is smaller than $Demand_i$ and larger than zero, the model has a lower limit of zero and an upper limit of $Demand_i$, which can vary with every loan application i. Columns 1 and 2 contain all loan applications, while columns 3 and 4 contain only loans that are financed. Columns 1 and 3 control for residual interest rate, while column 2 controls for internal rate of return for investors based on requested loan amount, and column 4 controls for internal rate of return for investors based on loan size. Changes in Smava's fee policy are captured as dummies in columns 1 and 3, but not in columns 2 and 4, as the internal rate of return for lenders already includes fees.

	(1)		(2)		(3)		(4)	
	Supply		Supply		Supply		Supply	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Contractual characteristics								
Residual interest rate	1.109***	(0.058)			0.418***	(0.106)		
Residual IRR investors			1.001***	(0.052)				
Residual IRR lenders							0.385***	(0.095)
Term (60 months=1)	-2.138***	(0.283)	-2.605***	(0.285)	0.050	(0.500)	0.132	(0.496)
Risk characteristics								
Schufa rating								
B	-0.560	(0.416)	-0.494	(0.413)	-1.374	(0.727)	-1.432*	(0.729)
C	-0.357	(0.492)	-0.230	(0.489)	-1.241	(0.830)	-1.330	(0.832)
D	-0.446	(0.477)	-0.352	(0.473)	1.029	(0.975)	0.934	(0.976)
E	-0.568	(0.478)	-0.437	(0.474)	-0.376	(0.901)	-0.362	(0.905)
F	-1.833***	(0.434)	-1.625***	(0.430)	-1.922*	(0.784)	-1.987*	(0.786)
G	-1.872***	(0.412)	-1.597***	(0.409)	-1.264	(0.785)	-1.318	(0.788)
H	-1.556***	(0.457)	-1.164*	(0.456)	-1.487	(0.839)	-1.539	(0.841)
KDF indicator								
2	1.920***	(0.296)	1.878***	(0.294)	1.176	(0.611)	1.197	(0.611)
3	3.675***	(0.310)	3.648***	(0.308)	2.009***	(0.609)	2.053***	(0.609)
4	4.659***	(0.353)	4.603***	(0.350)	2.106***	(0.635)	2.178***	(0.633)
Socio-economic characteristics								
Age	-0.102	(0.053)	-0.099	(0.053)	-0.034	(0.101)	-0.038	(0.101)
Age squared	0.001	(0.001)	0.001	(0.001)	0.000	(0.001)	0.000	(0.001)
Gender (male=1)	-0.419	(0.258)	-0.369	(0.256)	0.313	(0.441)	0.299	(0.443)
Job fixed effects	Yes		Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes		Yes	
Loan-specific information								
Membership, ln	-0.152	(0.103)	-0.151	(0.102)	-0.257	(0.177)	-0.233	(0.177)
Description, ln	-0.154	(0.084)	-0.135	(0.083)	-0.012	(0.158)	-0.040	(0.155)
Purpose fixed effects	Yes		Yes		Yes		Yes	
Macroeconomic conditions								
Banks' interest rate	-5.193***	(0.929)	-4.645***	(0.799)	-3.177	(1.643)	-3.758*	(1.464)
Month fixed effects	Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes	
Fee fixed effects	Yes		No		Yes		No	
Constant	24.214***	(6.382)	19.307***	(5.127)	16.839	(11.002)	25.369**	(9.112)
lnsigma constant	1.340***	(0.025)	1.335***	(0.025)	1.325***	(0.037)	1.330***	(0.037)
p value	0.000		0.000		0.000		0.000	
Observations	5983		5983		5026		5026	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

increases the probability that loan application i's requested amount will be financed. Moreover, the requested amount also affects this probability. I test this hypothesis by specifying the Probit model

$$Prob\,(S_i \geq D_i | X_i, D_i, \tilde{r}_i) = \Phi\,(\beta X_i + \delta f\,(\tilde{r}_i) + \gamma D_i + \varepsilon_i) \qquad (3.10)$$

where D is the loan size demanded in application i. If the loan applicant accepts the granted loan, the loan business comes into effect, which occurs with probability $Prob\,(accepted | S_i \geq D_i)$.

Table 3.10 shows the estimation results. In columns 1 and 2, I estimate the probability that the requested amount will be fully granted, and in columns 3 and 4 I estimate the probability that the loan will be fully financed.

In all columns of table 3.10, estimation results are similar. Residual rate has a positive impact on the probability that the loan will be financed, while its square has a negative effect. For example, in column 3, a one-percent increase of the residual interest rate significantly increases the probability that the loan will be fully financed - specifically, by 22.2 percent - whereas its square only decreases the probability by 0.8 percent. Not surprisingly, a €1,000 larger demand decreases the probability of obtaining the requested amount by one percent and decreases the probability that the loan will be financed by 1.2 percent. A longer loan term decreases the probability of obtaining a loan by between 4.9 and 7.5 percent. However, this effect is small relative to that of the residual rate.

In all columns, loan applicants whose Schufa rating is F or riskier have a significantly lower probability of obtaining a loan. This is in contrast to the counterintuitive result that loan applicants with a riskier KDF indication actually have a higher probability of obtaining a loan.[32]

A potential concern is that demand is correlated with other observable characteristics. As a robustness check, I ran the same regressions as in table 3.10 and dropped the regressor *Demand*. The significance and signs of the coefficients remained constant.

[32] Barasinska and Schäfer's (2010) analysis of Smava finds the same result.

Table 3.10: **Hidden information and probability of obtaining requested amount.** Probit regression with the dependent variables probability that the requested loan amount will be fully granted (in columns 1 and 2) and probability that the requested amount will be fully financed (in columns 3 and 4). All columns contain all loan applications. Columns 1 and 3 control for residual interest rate and its square, while columns 2 and 4 control for internal rate of return for investors based on the requested loan amount and its square. Changes in Smava's fee policy are captured as dummies in columns 1 and 3, but not in columns 2 and 4, as internal rate of return for lenders already includes fees.

	(1)		(2)		(3)		(4)	
	Pr(granted)		Pr(granted)		Pr(financed)		Pr(financed)	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Contractual characteristics								
Residual interest rate	0.152***	(0.014)			0.222***	(0.020)		
Residual interest rate squared	-0.005***	(0.001)			-0.008***	(0.001)		
Residual IRR investors			0.123***	(0.011)			0.157***	(0.015)
Residual IRR investors squared			-0.003***	(0.000)			-0.005***	(0.001)
Demand (€1.000s)	-0.010***	(0.001)	-0.010***	(0.001)	-0.012***	(0.001)	-0.012***	(0.001)
Term (60 months=1)	-0.058***	(0.009)	-0.075***	(0.009)	-0.049***	(0.011)	-0.069***	(0.011)
Risk characteristics								
Schufa rating								
B	-0.034**	(0.012)	-0.033**	(0.012)	-0.027	(0.015)	-0.026	(0.015)
C	-0.028	(0.015)	-0.023	(0.015)	-0.032	(0.018)	-0.028	(0.018)
D	-0.040**	(0.014)	-0.036*	(0.014)	-0.046**	(0.018)	-0.045*	(0.018)
E	-0.031*	(0.015)	-0.025	(0.015)	-0.041*	(0.018)	-0.038*	(0.018)
F	-0.073***	(0.013)	-0.065***	(0.013)	-0.094***	(0.017)	-0.090***	(0.017)
G	-0.070***	(0.013)	-0.062***	(0.013)	-0.086***	(0.016)	-0.083***	(0.016)
H	-0.060***	(0.015)	-0.048**	(0.015)	-0.098***	(0.018)	-0.095***	(0.018)
KDF indicator								
2	0.066***	(0.010)	0.064***	(0.010)	0.119***	(0.013)	0.118***	(0.013)
3	0.113***	(0.010)	0.112***	(0.010)	0.173***	(0.013)	0.174***	(0.013)
4	0.140***	(0.011)	0.139***	(0.011)	0.202***	(0.014)	0.204***	(0.014)
Socio-economic characteristics								
Age	-0.002	(0.002)	-0.002	(0.002)	-0.001	(0.002)	-0.001	(0.002)
Age squared	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)	0.000	(0.000)
Gender (male=1)	-0.014	(0.008)	-0.012	(0.008)	-0.008	(0.010)	-0.007	(0.010)
Job fixed effects	Yes		Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes		Yes	
Loan-specific information								
Membership, ln	-0.007*	(0.003)	-0.007*	(0.003)	-0.003	(0.004)	-0.004	(0.004)
Description, ln	-0.002	(0.003)	-0.000	(0.002)	0.001	(0.003)	0.003	(0.003)
Purpose fixed effects	Yes		Yes		Yes		Yes	
Macroeconomic conditions								
Banks' interest rate	-0.221***	(0.029)	-0.203***	(0.024)	-0.224***	(0.038)	-0.130***	(0.028)
Month fixed effects	Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes	
Fee fixed effects	Yes		No		Yes		No	
Observations	5983		5983		5983		5983	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

3.4.3 Time until the loan is financed

In the previous subsection, I showed that a higher residual interest rate significantly increases investors' willingness to supply. This subsection will first analyze whether a higher residual interest rate also helps loan applicants to obtain their loan faster and then will examine whether impatient loan applicants default more often.

Bid time until requested loan amount is supplied

To examine the speed with which a loan applicant obtains a loan, I regard the bid time from the posting of loan application i to its closing. To estimate bid time b_i, I specify the Tobit model

$$b_i = \begin{cases} 0 & if\, b_i \leq 1 \\ b_i^* = \beta X_i + \delta f\left(\tilde{r_i}\right) + \varepsilon_i & if\, 1 < b_i < 20.160 \\ 20.160 & if\, b_i \geq 20.160. \end{cases} \tag{3.11}$$

I cannot observe the bid time if the loan is supplied in the first minute, as in this case investors could theoretically have preferred to supply even faster. I also cannot observe the bid time if the loan application is closed after 14 days and demand still exceeds supply (i.e., $S_i < D_i$). In this case, more time would be required for the demand to be satisfied. Thus, I can only observe the bid time if $S_i = D_i$ occurs between the first and the 20,160th minute.[33]

Table 3.11 shows estimation results. Columns 1 and 2 include all observations, while columns 3 and 4 only include financed loans. Bid time significantly decreases with interest rate, but this effect is non-linear, as it weakens with a higher interest rate. For example, in column 3, a one percentage point higher residual interest rate significantly decreases bid time on average by 88 minutes and increases its square by 3 minutes. A 60-month loan term increases bid time in column 1 by 42, in column 2 by 50, and in columns 3 and 4 by 24 minutes, compared to a 36-month term. Moreover, in columns 1 and 2, a risky Schufa rating (F to H) significantly extends the bid time; on the other hand, surprisingly, bid time decreases with a KDF indicating a higher risk.

[33] 14 days times 24 hours/day times 60 minutes/hour = 20,160 minutes.

Table 3.11: **Hidden information and bid time.** Tobit regression with lower limit of one and upper limit of 20,160 as the dependent variable bid time (minutes) is censored. Columns 1 and 2 contain all loan applications, while columns 3 and 4 contain only financed loans. Columns 1 and 3 control for residual interest rate as well as for fee dummies, column 2 controls for internal rate of return for investors based on requested loan amount, and column 4 controls for internal rate of return for investors based on loan size.

	(1)		(2)		(3)		(4)	
	Bid time		Bid time		Bid time		Bid time	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Residual interest rate	-55.777***	(3.974)			-87.767***	(7.873)		
Residual interest rate squared	1.541***	(0.165)			3.026***	(0.299)		
Residual IRR investors(lenders)			-53.387***	(3.531)			-59.185***	(5.601)
Residual IRR inv.(lend.) squ.			1.420***	(0.137)			2.264***	(0.242)
Term (60 months=1)	42.333***	(3.024)	50.053***	(3.012)	24.839***	(2.807)	23.558***	(2.784)
Risk characteristics								
Schufa rating								
B	0.841	(4.319)	0.269	(4.321)	-1.207	(3.858)	-1.091	(3.869)
C	-5.091	(5.166)	-6.569	(5.167)	-6.467	(4.613)	-6.244	(4.626)
D	1.784	(5.127)	0.124	(5.130)	-3.929	(4.631)	-3.871	(4.644)
E	0.915	(5.131)	-2.070	(5.139)	-4.203	(4.666)	-4.135	(4.681)
F	21.337***	(5.026)	17.704***	(5.033)	12.530**	(4.620)	12.393**	(4.636)
G	21.032***	(4.772)	17.561***	(4.774)	9.283*	(4.428)	9.371*	(4.444)
H	14.023**	(5.414)	8.861	(5.420)	-0.148	(5.102)	0.360	(5.124)
KDF indicator								
2	-27.423***	(4.246)	-27.251***	(4.247)	7.270	(4.344)	6.731	(4.355)
3	-37.636***	(4.098)	-37.853***	(4.096)	8.204	(4.200)	7.510	(4.209)
4	-49.071***	(4.448)	-49.645***	(4.441)	5.157	(4.478)	4.413	(4.486)
Socio-economic characteristics								
Age	1.398*	(0.626)	1.412*	(0.626)	0.546	(0.582)	0.622	(0.583)
Age squared	-0.009	(0.007)	-0.009	(0.007)	-0.002	(0.006)	-0.003	(0.006)
Gender (male=1)	7.144*	(2.908)	6.819*	(2.909)	3.228	(2.653)	3.019	(2.661)
Job fixed effects	Yes		Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes		Yes	
Loan-specific information								
Membership, ln	1.541	(1.086)	1.510	(1.085)	0.271	(0.970)	0.250	(0.970)
Description, ln	5.040***	(0.829)	4.634***	(0.821)	4.251***	(0.754)	4.508***	(0.749)
Purpose fixed effects	Yes		Yes		Yes		Yes	
Macroeconomic conditions								
Banks' interest rate	107.903***	(11.946)	110.794***	(8.485)	67.934***	(11.184)	92.465***	(7.929)
Month fixed effects	Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes	
Fee fixed effects	Yes		No		Yes		No	
Constant	-113.788	(87.770)	-75.543	(61.304)	318.676***	(94.769)	-101.011	(61.764)
sigma constant	98.184***	(0.898)	98.253***	(0.898)	82.463***	(0.822)	82.719***	(0.825)
Pseudo R sq	0.037		0.036		0.019		0.018	
p value	0.000		0.000		0.000		0.000	
Observations	5983		5983		5026		5026	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

A potential concern of the estimation results in table 3.11 is that a larger demand increases bid time. To address this concern, I could simply control for *Demand*. However, if observable characteristics indicate a lower risk, investors may be willing to supply more. If observationally less risky loan applicants anticipate this, they may, on average, demand more. In turn, investors may supply loans faster even though demand is greater. To prevent this problem, I focus on investors' bid speed instead of bid time. As a proxy for bid speed, I use the average bid size per minute, denoted by $B_i \equiv D_i/b_i$. To estimate B_i, I specify the Tobit model

$$B_i = \begin{cases} 0 & if\ B_i \leq 0 \\ B_i^* = \beta X_i + \delta f\left(\tilde{r}_i\right) + \varepsilon_i & if\ 0 < B_i < D_i \\ D_i & if\ B_i \geq D_i. \end{cases} \tag{3.12}$$

I cannot observe B_i if investors do not supply anything during the 14-day bid period (i.e. if $B_i = 0$). If, in contrast, a loan request is granted immediately in the first minute, this results in $B_i = D_i$; in this case, I cannot observe whether investors would have preferred to supply more. Thus, I can only observe B^* if $0 < B_i < D_i$.

Table 3.12 shows estimation results. Columns 1 and 2 include all observations, while columns 3 and 4 include only financed loans. In the first two columns, residual interest rate non-linearly increases bid size per minute, while in the last two columns it has only a linear effect.[34] For example, in column 1, a one percentage point higher residual interest rate increases the bid size per minute by €2.631, but its square only decreases the bid size by €80 per minute. In column 3, a one percentage point higher residual interest rate increases the bid size per minute by €180 per minute. In fact, in all columns, riskier Schufa classes have a significantly negative impact on bid speed. In contrast, investors have a higher bid speed if KDF indicates a higher risk as well as if the term of the loan is longer.

[34] I ran robustness checks controlling for residual interest rate linearly and non-linearly and compared the AIC and the BIC. The regressions with the lowest values are shown in table 3.12.

Table 3.12: **Hidden information and bid speed.** Tobit regression with lower limit zero and variable upper limit demand D_i as the dependent variable bid speed (bid size per minute) is censored. D_i can vary for every loan application i. Columns 1 and 2 contain all loan applications, while columns 3 and 4 contain only financed loans. Columns 1 and 3 control for residual interest rate as well as for fee dummies, column 2 controls for internal rate of return for investors based on requested loan amount, and column 4 controls for internal rate of return for investors based on loan size.

	(1)		(2)		(3)		(4)	
	Size/min		Size/min		Size/min		Size/min	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Contractual characteristics								
Residual interest rate	2.631***	(0.306)			0.180***	(0.052)		
Residual interest rate squared	-0.080***	(0.012)						
Residual IRR investors			1.972***	(0.247)				
Residual IRR investors squared			-0.051***	(0.009)				
Residual IRR lenders							0.149**	(0.047)
Term (60 months=1)	1.852***	(0.176)	1.534***	(0.176)	2.558***	(0.185)	2.592***	(0.183)
Risk characteristics								
Schufa rating								
B	-0.884***	(0.247)	-0.863***	(0.246)	-0.776**	(0.251)	-0.775**	(0.251)
C	-0.972***	(0.295)	-0.930**	(0.295)	-1.108***	(0.300)	-1.111***	(0.300)
D	-1.399***	(0.295)	-1.345***	(0.294)	-1.355***	(0.303)	-1.345***	(0.302)
E	-1.404***	(0.297)	-1.313***	(0.297)	-1.438***	(0.306)	-1.438***	(0.306)
F	-1.757***	(0.289)	-1.645***	(0.289)	-1.606***	(0.302)	-1.598***	(0.302)
G	-2.042***	(0.274)	-1.946***	(0.273)	-1.811***	(0.286)	-1.815***	(0.286)
H	-2.900***	(0.312)	-2.776***	(0.311)	-2.865***	(0.326)	-2.872***	(0.326)
KDF indicator								
2	1.919***	(0.247)	1.928***	(0.246)	1.207***	(0.286)	1.220***	(0.285)
3	3.027***	(0.238)	3.041***	(0.237)	1.927***	(0.275)	1.940***	(0.275)
4	2.988***	(0.256)	3.010***	(0.255)	1.577***	(0.292)	1.587***	(0.292)
Socio-economic characteristics								
Age	-0.039	(0.036)	-0.039	(0.036)	-0.002	(0.038)	-0.004	(0.038)
Age squared	0.001	(0.000)	0.001	(0.000)	0.000	(0.000)	0.000	(0.000)
Gender (male=1)	0.082	(0.167)	0.101	(0.167)	0.248	(0.173)	0.253	(0.173)
Job fixed effects	Yes		Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes		Yes	
Loan-specific information								
Membership, ln	-0.390***	(0.062)	-0.393***	(0.062)	-0.412***	(0.063)	-0.412***	(0.063)
Description, ln	-0.016	(0.048)	-0.004	(0.047)	0.053	(0.049)	0.050	(0.049)
Purpose fixed effects	Yes		Yes		Yes		Yes	
Macroeconomic conditions								
Banks' interest rate	-1.289	(0.676)	-1.454**	(0.483)	0.535	(0.715)	-0.216	(0.511)
Month fixed effects	Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes	
Fee fixed effects	Yes		No		Yes		No	
Constant	-7.625	(5.166)	-5.433	(3.634)	-1.950	(5.052)	3.296	(3.432)
lnsigma constant	1.667***	(0.010)	1.665***	(0.010)	1.625***	(0.011)	1.625***	(0.011)
p value	0.000		0.000		0.000		0.000	
Observations	5983		5983		5026		5026	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

Instant loan

In the previous subsection, I showed that a higher interest rate induces investors to provide a loan faster or with a higher probability. However, a loan applicant may not offer a higher interest rate for that purpose; instead, he may have other reasons which I cannot observe. If this is the case, then impatience may not be the reason that observationally identical but unobservably riskier borrowers are willing to pay a higher interest rate.

To address this potential concern, I examine Smava's instant loan service as an applicant must access it before posting his loan request. This service helps impatient applicants to obtain their loan within a few minutes or hours. In practice, Smava proposes a sufficiently high interest rate through this service to enable a loan applicant to get his loan financed instantly. Thus, by choosing the proposed interest rate for an instant loan, a loan applicant unambiguously pays a higher interest rate because he is impatient.

However, I cannot observe whether a peer has used the instant loan service before posting his current loan application, as Smava does not publish this information. Hence, I use a proxy to indicate an instant loan; following Smava's definition of an 'instant' loan as a loan financed within a few minutes or hours, I specify a loan as instant if its bid time does not exceed a certain number of minutes. As a robustness check, I vary this number of minutes.

Table 3.13 shows the results of the estimation of the hazard rate using the Cox proportional hazard rate model. In columns 1, 2 and 3, I define a loan as instant if its bid time does not exceed 4, 120 or 1,000 minutes respectively. In column 4, I control for the bid time nonlinearly as a proxy for the expected bid time, in order to analyze its effect on default risk.

Columns 1 to 3 show that borrowers who choose an instant loan have significantly higher default risk. In column 1, borrowers who raise an instant loan have a 78.2 percent higher hazard risk than borrowers who raise loans more slowly. If the bid time exceeds four minutes, the probability that some of the loans I define as 'instant' are in actuality *not* instant increases. In these cases, borrowers obtain their loans quickly because they offer a higher interest rate for other purposes or simply due to luck, rather than because they have used Smava's instant loan service or wanted to have the loan financed instantly. Results in columns 2 and 3 indicate that borrowers who wait longer for their loans default significantly less often. While in column 2 borrowers with an instant loan have a 47.7 percent higher risk than other borrowers, this percentage decreases to 42.2 percent in column 3. However, a shorter bid time does not always mean a higher default risk; column 4 shows a non-linear relationship between bid time and default risk.

Although the dummy for an instant loan has a strong impact on default risk, a higher residual interest rate still has a significant non-linear impact on default risk. For example, in column 1, a one percent higher residual interest rate increases the hazard ratio by 20 percent, but its square only decreases the ratio by 0.6 percent. This result is remarkable, as a higher interest rate could also capture the effect of the dummy that indicates an instant loan. This could make my indicator for an instant loan insignificant and works against me. The fact that the residual interest rate still has a significant and positive effect indicates a strong link between impatience and default risk which cannot be justified merely by the effect of a higher residual interest rate.

In a robustness check, I control for residual interest rate instead of for residual internal rate of return for investors. In this case, residual interest rate has a significant effect on default risk but does not have a non-linear effect.

3.5 Disclosure of information through starting interest rate

The main result of this chapter is that observationally identical but unobservably riskier applicants pay a higher interest rate because they are more impatient to obtain a loan. Up to this point, I have only analyzed the role of the final interest rate that is paid in the event of a legally valid loan business. However, this is not the only information about interest rate contained in my sample.

With the initial posting of the loan application, applicants offer a starting interest rate. During the bid period, they have the opportunity to raise this starting rate. If they do so, their final interest rate will higher

Table 3.13: **Instant loans and default risk.** Cox proportional hazard regression with dependent variable hazard ratio, which is the exponentiated hazard rate. Columns 1, 2 and 3 include a dummy for all loans that are granted until the 4th, 120th and 1,000th bid minute, respectively. Column 4 controls for bid time and its square in days.

	(1)		(2)		(3)		(4)	
	Hazard ratio		Hazard ratio		Hazard ratio		Hazard ratio	
	exp(Coef.)	Std. err.	exp(Coef.)	Std. err.	exp(Coef.)	Std. err.	exp(Coef.)	Std. err.
Contractual characteristics								
Residual IRR borrower	1.200***	(0.054)	1.186***	(0.054)	1.187***	(0.054)	1.199***	(0.055)
Residual IRR borrower squared	0.994**	(0.002)	0.995*	(0.002)	0.995*	(0.002)	0.995*	(0.002)
Instant loan (=1 if $\leq$ 4th min)	1.782***	(0.069)						
Instant loan (=1 if $\leq$ 120th min)			1.477***	(0.050)				
Instant loan (=1 if $\leq$ 1000th min)					1.422***	(0.045)		
Bid time (days)							0.912***	(0.011)
Bid time (days) squared							1.005***	(0.001)
Size (€1,000s)	1.063***	(0.008)	1.064***	(0.008)	1.064***	(0.008)	1.065***	(0.008)
Size squared(€1,000s)	0.999***	(0.000)	0.998***	(0.000)	0.998***	(0.000)	0.998***	(0.000)
Term (60 months=1)	1.173***	(0.038)	1.174***	(0.038)	1.170***	(0.038)	1.161***	(0.038)
Risk characteristics								
Schufa rating								
B	1.430***	(0.082)	1.424***	(0.082)	1.449***	(0.083)	1.474***	(0.085)
C	1.756***	(0.109)	1.721***	(0.107)	1.755***	(0.109)	1.782***	(0.110)
D	1.289***	(0.089)	1.282***	(0.088)	1.292***	(0.089)	1.283***	(0.088)
E	3.493***	(0.195)	3.479***	(0.195)	3.496***	(0.196)	3.536***	(0.198)
F	2.679***	(0.154)	2.692***	(0.155)	2.738***	(0.157)	2.717***	(0.156)
G	3.714***	(0.202)	3.717***	(0.202)	3.739***	(0.204)	3.724***	(0.203)
H	6.194***	(0.348)	6.230***	(0.350)	6.343***	(0.357)	6.427***	(0.363)
KDF indicator								
2	1.973***	(0.142)	1.955***	(0.141)	1.977***	(0.142)	2.025***	(0.146)
3	2.766***	(0.192)	2.747***	(0.190)	2.758***	(0.191)	2.811***	(0.195)
4	3.304***	(0.229)	3.281***	(0.228)	3.288***	(0.228)	3.352***	(0.232)
Socio-economic characteristics								
Age	0.931***	(0.005)	0.929***	(0.005)	0.930***	(0.005)	0.931***	(0.005)
Age squared	1.001***	(0.000)	1.001***	(0.000)	1.001***	(0.000)	1.001***	(0.000)
Gender (male=1)	0.930*	(0.027)	0.931*	(0.027)	0.925**	(0.026)	0.927**	(0.026)
Job fixed effects	Yes		Yes		Yes		Yes	
Residence fixed effects	Yes		Yes		Yes		Yes	
Loan-specific information								
Membership, ln	1.107***	(0.012)	1.109***	(0.012)	1.104***	(0.012)	1.099***	(0.012)
Description, ln	0.927***	(0.009)	0.922***	(0.009)	0.920***	(0.009)	0.920***	(0.009)
Purpose fixed effects	Yes		Yes		Yes		Yes	
Macroeconomic conditions								
Banks' interest rate	2.274***	(0.199)	2.180***	(0.191)	2.081***	(0.180)	2.012***	(0.173)
Month fixed effects	Yes		Yes		Yes		Yes	
Year fixed effects	Yes		Yes		Yes		Yes	
Pseudo R sq	0.038		0.038		0.038		0.038	
AIC	143266.124		143345.851		143355.320		143369.800	
BIC	143976.771		144056.499		144065.967		144090.182	
p value	0.000		0.000		0.000		0.000	
Observations	124853		124853		124853		124853	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

than their starting interest rate. Previous results suggest that the starting interest rate contains some private information about default risk for two reasons. First, less risky but observationally identical applicants are more sensitive to the interest rate and may be more likely to prefer to start with a lower interest rate. Second, more patient applicants are willing to wait longer in exchange for a lower interest rate. Both of these reasons give them an incentive to start with a lower interest rate than the final rate.

To test this, I run a Cox proportional hazard rate estimation, as shown in table 3.14. In column 1, I additionally include a dummy that is equal to one if the starting interest rate is lower than the final interest rate and is equal to zero otherwise; in column 2, I control for the difference between final and starting interest rate.

The starting interest rate is a significant signal for a loan applicant's privately known default risk. In particular, with a starting interest rate smaller than the final interest rate is an important signal, as it decreases the hazard ratio by 20.4%. Conversely, a final interest rate one percentage point higher than the starting interest rate significantly decreases the hazard ratio by 3.4%.

3.6 Concluding Remarks

This chapter uses data from the unique German online lending platform Smava to develop a new empirical strategy to identify hidden information about default risk. It shows that borrowers signal hidden information about their default risk as a result of their impatience. Observationally identical but unobservably riskier borrowers offer a significantly higher residual interest rate, which induces investors to supply more and thus to grant the loan faster and with a higher probability. On average, very impatient borrowers who use Smava's instant loan service to obtain a loan within a few minutes or hours are riskier than less impatient other borrowers.

These insights contribute to a better understanding of which contractual instruments are effective in screening borrowers' privately known riskiness. Nonetheless, this study leaves several questions open for future research. Although it describes how impatience helps to screen borrowers' riskiness,

Table 3.14: **Starting interest rate and default risk.** Cox proportional hazard regression with dependent variable hazard ratio, which is the exponentiated hazard rate. Column 1 includes a dummy that is equal to one if the starting interest rate is lower than the final interest rate and is equal to zero otherwise; column 2 includes the difference between final and starting interest rate.

	(1) Hazard ratio exp(Coef.)	Std. err.	(2) Hazard ratio exp(Coef.)	Std. err.
Contractual characteristics				
Residual IRR borrower	1.247***	(0.057)	1.263***	(0.057)
Residual IRR borrower squared	0.993**	(0.002)	0.993***	(0.002)
Interest rate raised	0.796***	(0.025)		
Final - start rate			0.966***	(0.009)
Size (€1,000s)	1.050***	(0.007)	1.046***	(0.007)
Size squared(€1,000s)	0.999***	(0.000)	0.999***	(0.000)
Term (60 months=1)	1.150***	(0.037)	1.141***	(0.037)
Risk characteristics				
Schufa rating				
B	1.455***	(0.083)	1.446***	(0.083)
C	1.778***	(0.110)	1.769***	(0.110)
D	1.309***	(0.090)	1.301***	(0.090)
E	3.540***	(0.198)	3.548***	(0.199)
F	2.655***	(0.153)	2.651***	(0.152)
G	3.705***	(0.202)	3.678***	(0.200)
H	6.244***	(0.352)	6.234***	(0.352)
KDF indicator				
2	1.985***	(0.143)	1.983***	(0.143)
3	2.754***	(0.191)	2.754***	(0.191)
4	3.309***	(0.230)	3.288***	(0.228)
Socio-economic characteristics				
Age	0.930***	(0.005)	0.931***	(0.005)
Age squared	1.001***	(0.000)	1.001***	(0.000)
Gender (male=1)	0.913**	(0.026)	0.913**	(0.026)
Job fixed effects	Yes		Yes	
Residence fixed effects	Yes		Yes	
Loan-specific information				
Membership, ln	1.099***	(0.012)	1.093***	(0.012)
Description, ln	0.915***	(0.009)	0.911***	(0.009)
Purpose fixed effects	Yes		Yes	
Macroeconomic conditions				
Banks' interest rate	1.770***	(0.150)	1.675***	(0.141)
Month fixed effects	Yes		Yes	
Year fixed effects	Yes		Yes	
Pseudo R sq	0.037		0.037	
p value	0.000		0.000	
Observations	124853		124853	

Notes: *, ** and *** denote significance on the 5%, 1% and 0.1% levels respectively.

it does not disentangle different types of impatience (e.g. the speed or the probability of obtaining the loan). Moreover, it identifies borrowers' impatience solely via their contract choice. This raises the question of how to identify impatience that is related to default risk. This could be especially important for credit rating agencies as it helps them to mitigate asymmetric information.

3.7 References

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