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The banking firm: the role of signaling with collaterals

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Dresden Discussion Paper Series in Economics

The Banking Firm:
The Role of Signaling with Collaterals

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Dresden Discussion Paper in Economics No. 04/08

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The Banking Firm: The Role of Signaling with Collaterals

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Abstract:

In this paper we challenge basic results of signaling models. In our banking model each project of a borrower is described by a continuous density of outcomes. Different density functions are classified according to second stochastisch dominance. Combining these features we find that in a banking model collateral is no longer in a position to signal the degree of riskiness of the borrower to the lender. In most cases the equilibrium is a pooling equilibrium.

JEL-Classification: D8, G20

Keywords: Signaling, collateral, perfect Bayesian equilibrium

1 Introduction

An important goal of economic theory is to understand what allocation mechanisms, or institutions, are best suited to minimize the economic losses generated by private information. Asymmetric information are a typical problems in the asset and liability management of banking firms.[1] When will a market mechanism suffice to allocate resources efficiently? As it turned out, the market implements efficient outcomes only under very stringent conditions. The basic problem is that borrowers have an incentive to economize with their private information. To overcome this problem a collateral offered by a borrower is often viewed as a credible signal of the riskiness of the project. Signaling with collateral seems to be an efficient procedure of information transmission. This paper challenges this view. We argue that under regular conditions there is no way to convey private information by the collateral amount offered by a borrower and hence there is no way to derive a separating equilibirum. In general, our model is characterized either by a pooling equilibrium or no equilibrium at all.

For the most part, a bank‘s lending decision takes place in an asymmetric information environment. Typically, the bank is the information outsider and the borrower is the information insider. In order to overcome the information gap, signaling activities do help to convey information to the bank. Because of his insider status the borrower knows the probability distribution of his projects cash flow with certainty. The bank does not know these details. All the bank knows by assumption is that the borrowers project quality is either a low risk or a high risk. A signaling process is bound to identify the members of different classes. The existing literature is able to proof that a financial contract using collateral as a signal is able to overcome the asymmetric information problem and separate the borrowers.[2] In contrast to this position, we are going to demonstrate that there is no way for collaterals to convey valuable information from the information insider to the outsider.

In our paper, we challenge this result. According to our reasoning collateral is not in a position to overcome the informational asymmetry. The reason is that we are no longer arguing in a world with only two outcomes. In the papers mentioned above there are only two outcomes existing. Based on this assumption the authors are in a position to show that signaling matters.

[1]See, for example, Broecker (1990), Wong (1992), (1998), Eckwert and Zilcha (2003), Broll and Eckwert (2006).

[2]See Bester (1987), Besanko and Thakor (1987), Chan and Kanatas (1985), Milde and Riley (1988). For an overview, see, Freixas and Rochet (1997).

In contrast, we are going to analyse the problem in a world with a continuum of outcomes.

This paper proceeds as follows. Section 2 describes the standard model and the role of collateral in credit markets with asymmetric information. The perfect Bayesian equilibrium is developed in section 3. In section 4 we demonstrate the impossibility of a separating equilibrium with collateral. Section 5 contains concluding remarks.

2 The model

In this section we are going to discuss the basic structure of a signaling contract. For example, the collateral offered by a borrower can be considered as a signal of the unobservable degree of riskiness of the entrepreneur's project. As confirmed in banking models the unobservable quality is revealed by an observable action. A perfectly revealing signal enables the information outsider to infer on the a priori knowledge of the information insider.

Bank credit analysts have typically referred to collateral as an important factor to predict a borrowers default probability. In order to overcome the basic informational asymmetry the logic of a signaling contract can be explained as follows. A borrower with a high risk project has a great aversion to putting up collateral because he knows about the great probability of loosing it. Exploiting this property, the banker can offer the borrower two alternative contracts: a secured loan and a unsecured loan. In a signaling contract, each amount of collateral is linked to one and only one loan rate or repayment obligation. If the combination of collateral and loan rate is properly designed the borrower has an incentive to choose exactly the contract that is intended for his type of riskiness. This process is called self selecting or truth revealing.

There are different instruments available to set up a signaling contract, i.e. loan size, collateral, maturity, covenants. Mostly, the existing literature is able to proof and confirm the separating solution. The purpose of our paper is to prove that this result is true only under very restrictive assumptions.

The following assumptions about the lender-borrower relationship are considered in our model. There are two risk neutral decision makers, a bank B and an entreprenuer, E, i.e. the borrower. The bank is an information outsider and the borrower is the information insider. Two different classes of borrowers exist: borrowers of class z_1 have a low risk project; borrowers of class z_2 have a high risk project. The bank knows this but is unable to tell who is who. From past experience the the proportions of the risk classes are know; class z_1 occurs with $\lambda\%$ and class z_2 occurs with $(1-\lambda)\%$ and $0 < \lambda < 1$.

The cash flow of type z_i is a nonnegative random variable x with a density $f(x; z_i)$ and cumulative distribution function $F(x; z_i)$ for $i = 1, 2$. The expected values $\overline{x}$ are identical. For both types the maximum cash flow is S with $0 < S < \infty$. In addition, we assume $f(x; z_i) > 0$ for all $x \in [0, S]$ and $f(x, z_i) = 0$ for all $x \notin [0, S], i = 1, 2$.

The riskiness of both types is defined as follows: type z_1 exhibits second order stochastic dominance (SSD) over type z_2: $\int_0^t F(x, z_1)dx \leq \int_0^t F(x, z_2)dx$ for all $t \in [0, S]$. Both types exhibit an identical initial project outlay l which is exogenously given, assuming $l < \overline{x}$. The signaling contract is characterized by the collateral c and repayment obligation L with with $c \leq \hat{l}$, where $\hat{l}$ is any pre-specified number $0 < \hat{l} < l$.

The operating cash flows of the project are assigned to the bank and to the borrower contingent on the different states of the world. The borrower is in a position to repay the predetermined obligation or, alternatively, he/she is not able to do so. The sources of the repayment are the projects cash flow on the one hand and the liquidation cash flow of the collateral c on the other hand, that is $x + c$. If the cash flow is sufficiently large to permit the repayment, the borrower will do so. Thus, the bank receives the full amount of the predetermined repayment. The residual amount goes to the borrower. If the project's cash flow is not sufficient, the bank takes all available cash flows leaving the borrower with a loss of his collateral.

Indicating the banks and the borrower's cash flow by u_B and u_E, respectively, and the definition of $\hat{x} = L - c$, we find:

$$u_B = \begin{cases} L - l & \text{if} \quad x \geq \hat{x}, \\ x + c - l & \text{if} \quad x < \hat{x}. \end{cases}$$

$$u_E = \begin{cases} l + x - L & \text{if} \quad x \geq \hat{x}, \\ l - c & \text{if} \quad x < \hat{x}. \end{cases}$$

From cash flows we obtain the expected net cash flow of the bank, R, and the borrower, P, respectively:

$$R(c,L;z_i) = \int_0^{\hat{x}} (x+c) f(x;z_i)dx + \int_{\hat{x}}^{S} L f(x;z_i)dx - l$$

$$P(c,L;z_i) = \int_0^{\hat{x}} (-c) f(x;z_i)dx + \int_{\hat{x}}^{S} (x-L) f(x;z_i)dx + l$$

The expected cash flows $R(c,L;z_i)$ and $P(c,L;z_i)$ sum up to the expected value of the projects operating cash flows: $\int_0^S x f(x;z_i)dx = \overline{x}$.

3 The perfect Bayesian equilibrium

The equilibrium concept employed is the perfect Bayesian equilibrium (PBE). A PBE is a tupel $(c^*, L^*, ^*)$ with $c^* = (c_1^*, c_2^*)$. The collateral amounts accepted by borrowers of both risk classes are denoted by c_1^* and c_2^*, respectively. The term * indicates the banks beliefs on the borrower risk class. Depending on the amounts c_1^* and c_2^*, the bank is in a position to revise its beliefs (c). In other words, $(c) \in [0,1]$ is the probability as seen by the bank that the borrower is a z_1 type (low risk) and $(1-(c))$ is the proability of a z_2 type (high risk).

Now we discuss in detail the signaling contract. The bank designs signaling contracts by combining alternative repayment obligations L with alternative amounts of collateral $c \leq \hat{l}$. The lender can offer a menu of loan contracts based on the bank's beliefs (c) contingent on the class z_i. Therefore the expected net payoff of the bank is given by

$$(c)R(x,L;z_1) + (1-(c))R(c,L;z_2).$$

We define the expected gross payoff of a type z_i borrower by

$$R^g(c,L;z_i) = R(c,L;z_i) + l.$$

Assuming a competitive banking industry the banks expected profit is driven down to zero. Hence the contract $\{c, L\}$ satisfies the zeroprofit condition

$$(c)R^g(c,L;z_1) + (1-(c))R^g(c,L;z_2) - l = 0.$$

In order to derive the properties of the signaling contract we calculate the marginal rate of substitution (MRS) between L and c. The MRS is the absolute value of the slope of the indifference curves in the (c,L)-diagram.

It will be shown below that the indifference curve of a prespecified class z_i is strictly decreasing and strictly convex. The relevant interval is $[0,\hat{l}]$ with $0<\hat{l}<l$. The graph $c\rightarrow L_i(c)$ is identical to the indifference curve of the type i borrower given the level $\overline{x}$. The function $L_i(c)$ is defined by $R(c,L_i(c);z_i)=0$. As $F(\cdot;z_1)$ is dominating $F(\cdot;z_2)$ in the sense of SSD, we find $L_1(c)\leq L_2(c)$ for all $c\in[0,\hat{l}]$. Next we claim

Proposition 1 *The slope of the indifference curve of a borrower of type i is given by $-p(c,L;z_i)/(1-p(c,L;z_i))=\int_0^{\hat{x}} f(x;z_i)dx$ with $p(c,L;z_i)$ denoting the probability of the project z_i financed with a bank loan whose underlying contract.*

Proof The indifference curve of type i borrower at level α is given by $(c,L):P(c,L;z_i)=\alpha$. For $F(c,L;z_i)=P(c,L;z_i)-\alpha$, the $\alpha-$curve is implicitly defined by $F(c,L;z_i)=0$. Let F_1 and F_2 denote the partial derivative of F with respect to c and L, respectively. We get the following expression for the slope of the α-curve

$$\frac{dL}{dc}|_{E,i,\alpha}=-\frac{F_1(c,L(c);z_i)}{F_2(c,L(c);z_i)}.$$

Note that $F(c,L;z_i)=l+\int_0^{\hat{x}}(-c)f(x,z_i)dx-\int_S^{\hat{x}} xf(x;z_i)dx+L\int_S^{\hat{x}} f(x;z_i)dx-\alpha$, we find $F_1(c,L;z_i)=-\int_0^{\hat{x}} f(x;z_i)dx$ and $F_2(c,L;z_i)=-\int_{\hat{x}}^S f(x;z_i)dx=-[1-\int_0^{\hat{x}} f(x;z_i)dx]$. The claim follows.

From the discussion we obtain the following

Corollary *The indifference curves of borrowers are strictly monotonously decreasing.*

Proposition 2 *The indifference curves of borrowers are strictly convex in $[0,\hat{l}]$.*

Proof We obtain

$$\frac{d^2L}{dc^2}|E,i=\frac{f(\hat{x};z_i)[1-\int_0^{\hat{x}} f(x;z_i)dx]+f(\hat{x};z_i)\int_0^{\hat{x}}(f(x;z_i)dx}{[1-\int_0^{\hat{x}} f(x;z_i)dx]^2}>0.$$

Proposition 3 *Since $F(\cdot;z_2)$ is a mean preserving spread of $F(\cdot;z_1)$, hence $L_1(c)\leq L_2(c)$ holds for all $c\in[0,\hat{l}]$.*

Proof Assume the contrary to the claim that there is a $c \in [0, \hat{l}]$ with $L_1(c) > L_2(c)$. Then, there is a number $\varepsilon > 0$ such that $L_2(c) = L_1(c) - \varepsilon$. Using $\hat{x}_i = L_i(c) - c$ and noticing that $\int_0^{\hat{x}_i} x f(x; z_i)dx = \hat{x}_i F(\hat{x}_i; z_i) - \int_0^{\hat{x}_i} F(x; z_i)dx$, we obtain, for $i = 1, 2$

$$\begin{aligned} l &= \int_0^{\hat{x}_i} (x + c) f(x; z_i)dx + L_i(c) \int_{\hat{x}_i}^{S} f(x; z_i)dx \\ &= \int_0^{\hat{x}_i} x f(x; z_i)dx + c \int_0^{\hat{x}_i} f(x; z_i)dx + L_i(c)[1 - \int_o^{\hat{x}_i} f(x; z_i)dx] \\ &= \hat{x}_i F(\hat{x}_i; z_i) - \int_0^{\hat{x}_i} F(x; z_i)dx + cF(\hat{x}_i : z_i) + L_i(c)(1 - F(\hat{x}; z_i)) \\ &= L_i(c) - \int_0^{\hat{x}_i} F(x; z_i)dx. \end{aligned}$$

Thus, we wind up with $L_2(c) = l + \int_0^{L_2(c)-c} F(x; z_2)dx = l + \int_0^{L_1(c)-\varepsilon-c} F(x; z_2)dx = l + \int_0^{L_1(c)-c} F(x; z_2)dx - \int_{L_1(c)-\varepsilon-c}^{L_1(c)-c} F(x; z_2)dx > l + \int_0^{L_1(c)-c} F(x; z_1)dx - \varepsilon = L_1(c) - \varepsilon$. The inequality is valid according to SSD. Note that $L_i(0) < S$ implies $L_i(c) < S$ for all $c \in [0, \hat{l}]$. Thus, we get $L_1(c) - \varepsilon < L_2(c)$. However this is in contradiction to $L_1(c) - \varepsilon = L_2(c)$ for c chosen above there exists no c with $L_1(c) > L_2(c)$. Therefore, $L_1(c) \leq L_2(c)$ is valid for all $c \geq 0$.

Finally, $\int_0^{\hat{x}} x f(x; z_i)dx = \hat{x} F(\hat{x}; z_i) - \int_0^{\hat{x}} F(x; z_i)dx$ remains to be shown. Note that the antiderivative of $x f(x; z_i)$ is given by $H(x; z_i) = xF(x; z_i) - \int_0^{\hat{x}} [\int_0^y f(u; z_i)du]dy$. We obtain

$$\begin{aligned} \frac{d}{dx} H(x; z_i) &= F(x; z_i) + x \frac{d}{dx} F(x; z_i) - \int_0^x f(u; z_i)du \\ &= \int_0^x f(u; z_i)du + x \frac{d}{dx} \int_0^x f(u; z_i)du - \int_0^x f(u; z_i)du \\ &= x f(x; z_i). \end{aligned}$$

The claim has been proven.

4 Properties of the solutions

In this section we are going to discuss two different cases in order to prove our findings. (A) $L_1(c) < L_2(c)$ for all $c \in [0, \hat{l}]$ and (B) $L_1(c) = L_2(c)$ for all $c \in [0, \hat{l}]$.

(A) There is a separating perfect Bayesian equilibrium (PBE) $(\hat{\sigma}, \hat{\mu})$ with $\hat{\sigma} = ((\hat{c}_1, \hat{c}_2), \hat{L}(\cdot))$ and $\hat{c}_1, \hat{c}_2 \in [0, \hat{l}]$, $\hat{c}_1 \neq \hat{c}_2$. As a result, there is an incentive

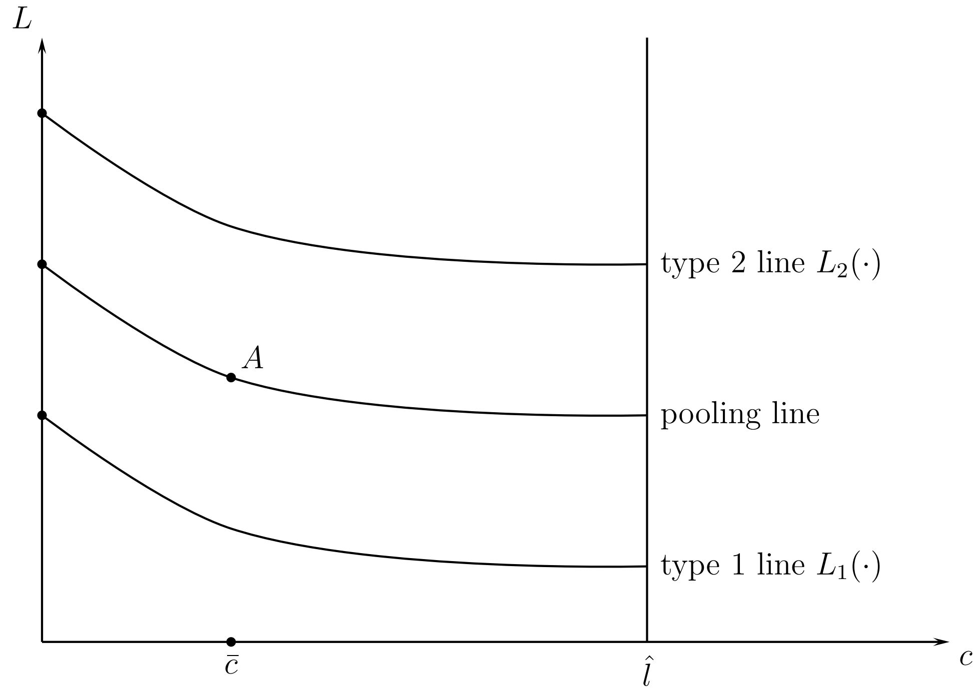

Figure 1: Preference maps of borrowers

for the type z_2 borrower to choose the contract characterized by $\hat{c}_1$ instead of $\hat{c}_2$. Given this choice the type z_2 borrower is in a position to improve his situation by achieving a higher indifference curve.

However, in $(\tilde{\sigma}, \tilde{\mu})$ with $\tilde{\sigma} = ((\tilde{c}_1, \tilde{c}_2), \tilde{L}(\cdot))$, with $\tilde{c}_1 = \tilde{c}_2 = \tilde{c} =\in [0, \hat{l}]$ we find a pooling PBE if $\tilde{L}(\cdot)$ is chosen in such a way that its graph is located above the indifference curve of type z_1 borrower and type z_2 borrower through the point $(\tilde{c}, \tilde{L}(\tilde{c}))$, illustrated by point A in Figure 1. $\tilde{L}$ is chosen in such a way that its graph is strictly above both indifference curves, apart from the point $(\tilde{c}, \tilde{L}(\tilde{c}))$.

The value $\tilde{L}(\tilde{c})$ is given by $\tilde{L} = L_\lambda(c)$ with L_λ being defined by the zero profit condition $\lambda R^g(c, L_\lambda(c); z_1) + (1-\lambda)R^g(c, L_\lambda(c); z_2) - l = 0, c \in [0, \hat{l}]$. The mapping $c \rightarrow L_\lambda(c)$, $c \in [0, \hat{l}]$ is called the pooling line. Note that the beliefs of the bank, $\tilde{\mu}(\cdot)$, are generated according to the zeroprofit condition in correspondence with $\tilde{L}(\cdot)$. This particular choice of $\tilde{L}$ is possible, if and only if the type z_1 borrower's indifference curve through the point $(\tilde{c}, \tilde{L}(\tilde{c}))$, illustrated by A in Figure 1, does not intersect the graph of $c \rightarrow L_2(c)$, i.e. type 2 line in the Figure 1, which is the type z_2 borrower's indifference curve with index $\bar{x}$. Due to zeroprofit condition $L_1(c) < \tilde{L}(c) \leq L_2(c)$ is satisfied for all $c \in [0, \hat{l}]$.

Such a situation is given if the low risk project is characterized by the smaller default probability of all loan contracts $\{c, L\}$ with the exclusion of the full cover contract $\{l, L\}$, i.e., if $p(c, L; z_1) < p(c, L; z_2)$ holds for all contracts with $0 \leq c < l$ and $l \leq L < S$. For $\tilde{L}(\tilde{c})$ with $\tilde{c} = \hat{l}$ the zero profit condition, $\lambda R^g(\tilde{c}, \tilde{L}(\tilde{c}); z_1) + (1-\lambda) R^g(\tilde{c}, \tilde{L}(\tilde{c}); z_2) - l = 0$, is satisfied. The resulting pair $(\tilde{c}, \tilde{L}(\tilde{c})) = (\hat{l}, \tilde{L}(\hat{l}))$ constitutes a pooling equilibrium. The reason is that the indifference of type z_1 borrower through $(\hat{l}, \tilde{L}(\hat{l}))$ does not intersect the graph of $c \rightarrow L_2(c)$, i.e., type 2 line in Figure 1. To this end, consider the indifference curve of type z_1 and type z_2 through $(\hat{l}, \tilde{L}(\hat{l}))$. Note that type z_1's MRS, i.e. $p(\hat{l}, \tilde{L}(\hat{l}); z_1))/1 - p(\hat{l}, \tilde{L}(\hat{l}); z_1)$, at that point is smaller than type z_2's MRS, i.e. $p(\hat{l}, \tilde{L}(\hat{l}); z_2))/1 - p(\hat{l}, \tilde{L}(\hat{l}); z_2)$, due to the assumption on the default probabilities. Note that type z_1's indifference curve through $(\hat{l}, \tilde{L}(\hat{l}))$ is strictly below type z_2's indifference curve through that point regarding the interval $[0, \hat{l}]$, apart from the point $(\hat{l}, \tilde{L}(\hat{l}))$ of course, again due to the assumption on the default probabilities. This prevents an intersection from taking place.

(B) Now we consider another case which is characterized by the existence of a $c \in [0, \hat{l}]$ with $L_1(c) = L_2(c)$. This is indeed an irrelevant special case. However, there is a separating equilibrium. Suppose there is a $\bar{c} \in [0, \hat{l}]$ with $L_1(c) = L_2(c)$. As a result, we find that $(\bar{\sigma}, \bar{\mu})$ with $\bar{\sigma} = ((\bar{c}_1, \bar{c}_2), \bar{L}(\cdot))$ is a separating PBE if $\bar{c}_1 = \bar{c}$ with $\bar{c}_2 \neq \bar{c}$, and $\bar{L}(c) = L_2(c)$ holds for all $c \in [0, \hat{l}]$. In addition, the beliefs are given by $\bar{\mu}(\bar{c}) = 1$ and $\bar{\mu}(c) = 0$ for all $c \in [0, \hat{l}]$ with $c \neq \bar{c}$. Note that the beliefs $\bar{\mu}$ are consistent with the choice $\bar{L}(\cdot)$ according to zeroprofit condition.

Three additional comments are in order.

(i) In case B any $\bar{c} \in [0, \hat{l}]$ with $L_1(\bar{c}) = L_2(\bar{c})$ constitutes a perfect pooling equilibrium as well. Given $\breve{c}_1 = \breve{c}_2 = \bar{c}$ and $\breve{L}(c) = L_2(c)$ for all $c \in [0, \hat{l}]$, we find that $(\breve{\sigma}, \breve{\mu})$ with $\breve{\sigma} = ((\breve{c}_1, \breve{c}_2), L(\cdot))$ is a PBE. The precondition for this result is that the formation of beliefs is based on $\breve{\mu}(\bar{c}) = \lambda$ and $\breve{\mu}(c) = 0$ for all $c \in [0, \hat{l}]$ with $c \neq \bar{c}$.

(ii) In B any pooling equilibrium is based on $\bar{c} \in [0, \hat{l}]$ with $L_1(c) = L_2(c)$. Suppose a perfect pooling equilibrium $(\breve{\sigma}, \breve{\mu})$ with $\breve{\sigma} = ((\breve{c}_1, \breve{c}_2), \breve{L}(\cdot))$ and $L_1(\breve{c}) < L_2(\breve{c})$ for $\breve{c}_1, \breve{c}_2 = \breve{c}$ with $\breve{c} \in [0, \hat{l}]$. $\breve{L}(\breve{c})$ is given by $\lambda R^g(\breve{c}, \breve{L}(\breve{c}); z_1) + (1-\lambda) R^g(\breve{c}, \breve{L}(\breve{c}); z_2) = l$. In this situation there is an incentive for type z_i borrowers to unilaterally deviate from the original contract by choosing a collateral $\bar{c} \in [0, \hat{l}]$ with $L_1(\bar{c}) = L_2(\bar{c})$ because there is a possibility to be better off. Note that $\breve{L}(\bar{c}) = L_1(\bar{c}) = L_2(\bar{c})$ and $L_1(\breve{c}) < \breve{L}(\breve{c}) < \breve{L}_2(\breve{c})$.

(iii) If there is a separating equilibrium, the type z_i borrower can achieve an expected payoff $\bar{x}$. The same payoff holds in case B for all perfect pooling equilibria. As a consequence, all equilibria in B are characterized by identical payoffs.

We summerize our findings in an impossibility

Theorem *Given a continuum of outcomes of the borrowers risky investment and projects are classified by second order stochastic dominance. Then collaterals are no longer devices for screening heterogenous borrowers.*

The *proof* follows from the above discussion.

5 Concluding remarks

In this paper we challenge basic results of signaling models in the credit market. In banking literature collateral is considered a very powerful instrument to convey valuable information from the borrower to the bank. As a result the bank is in a position to sort and classify its borrowers according to the degree of riskiness. A perequisite for this result is the introduction of some very strong and simplify assumptions. The most important assumption is a world with only two possible outcomes to the random cash flow.

In our model each risky project is described by a continous density of outcomes. Moreover, density functions are classified according to the concept of second order stochastic dominance. Combining these two features we find that collateral is no longer in a position to signal the unoberservable degree of riskness to the information outsider, i.e. the bank. As a result, a signaling contract is not able to sort and classify the borrowers. Under regular conditions there is hardly a way to derive a separating equilibrium in our model. In most cases the equilibrium is a pooling equilibrium. Alternatively, an equilibrium does not exist.

If there is no possibility to convey valuable information, the credit market is characterized by adverse selection and quantity rationing. Credit rationing will occure again. According to our analysis, there is no reason to be very optimistic with respect to the application of signaling concepts to banking issues. Generally speaking, many frictions and imperfections will continue to dominate the features of financial markets.

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