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DEALING WITH ADVERSE SELECTION ON FINANCIAL MARKETS

Abstract. *In the present paper we develop a model of financial contracting with adverse selection, the starting point being the work of Freixas and Laffont. We analyze the model of lending and borrowing within the standard framework of an agency problem: the Agent, the borrower, is endowed with private information about its productivity parameter which is unknown to the Principal, the lender. After having derived the optimal contracts in symmetric information, we present the case where the Agent can be of one of two types and we derive the features of the optimal loan agreements. Next we propose an extension to the standard model, allowing the Principal to use an auditing technology in order to screen the Agent's type.*
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1. Introduction

The adverse selection problem arises almost naturally on financial markets. Many times, the investors (financial institutions, banks) have less information about the investments projects and their future returns than the borrowers. This situation is somehow similar with the classical example of buying second hand cars - "the Akerlof's problem of lemons": the creditor (investor) has the same position as the used car's buyer who does not know the true valuation of the car. In this case, the quality of the project is unknown to the lender. Due to this informational asymmetry, inefficiency arises when dealing with investment funds, such that some good quality projects are not financed. Usually, this kind of situations is known as "credit rationing problem" and was first discussed by Jaffee and Modigliani (1969) and Jaffee and Russell (1976). In their paper, Stiglitz and Weiss (1981) developed a model of credit rationing in which they have highlighted the role of interest rates as screening devices for distinguishing between good and bad risks and also as an incentive mechanism developed in order to change the borrowers' behavior. . While theoretical work on asymmetric information and financial contracting is huge (Bester (1985), De Meza and Webb (1987), Freixas and Rochet (1990, 1999), Harris and Raviv (1992)), empirical research in this area is still in an early stage of development; recent papers belong to Chiappori and Salanie (2004), Garmaise and Moskowitz (2004), Karlan and Zinman (2009), Garmaise and Natividad (2010).

The present paper directs attention toward an issue of credit rationing by the bankers and the risk sharing arrangement between a bank and its potential customers. The benefit of a contractual relationship between a borrower and a bank is not only emerging from trading, but also from the effective arrangement concerning the amounts traded and the prices involved. The most important issue is that, by means of such contracts, the bank and its clients can share the risks associated with an uncertain future return, this problem being somewhat similar to the problem of private information in insurance contracts, in which the less risk averse party, the insurer, agrees for a fee to bear some of the risks to which the other party, the insuree, would otherwise be exposed.

The rest of the paper is organized as follows. In Section 2 the model is set up. The first best contracts are briefly derived in Section 3. In Section 4 we assume the presence of informational asymmetry between lenders and borrowers and we determine the optimal loan contracts. Section 5 presents an extension to the standard model of adverse selection, considering the case where the Principal uses an auditing technology to screen the Agent's types. We there characterize the nature of the optimal contractual arrangements. The last part of the paper adds some concluding comments.

2. The Model

We consider a financial contracting relationship between a lender and a borrower, analyzed in a basic Principal-Agent framework first proposed by Freixas and Laffont (1990) and later developed by Laffont and Martimort (2002). The Principal is the lender (a financial institution) intending to provide a loan to a borrower (the Agent). The loan has the size K. From the Principal's point of view, the cost of the capital is given by RK, where R is the risk free interest rate in the financial market. We could consider the risk free rate as the return generated by any other opportunity to invest the money without risk in the economy.

The Principal's profit function can be written as:

$$V = t - RK$$

The Agent invests the loan received from the Principal and gets a revenue $\theta f(K)$, where the parameter θ represents a productivity shock. The production function $f(K)$ describes the output produced using K units of capital. We assume that the production function satisfy the usual conditions $f'(\cdot) > 0,\ f''(\cdot) < 0$. On the other hand, the Agent repays a sum t (the cost of the borrowed capital) to the Principal. We can then write the Agent's objective function as:

$$U = \theta f(K) - t$$

The productivity parameter θ is the Agent's private information and can take only two distinct values $\theta \in \{\underline{\theta}, \overline{\theta}\}$, with $\underline{\theta} < \overline{\theta}$. The probability that θ has the value $\underline{\theta}$ is known by both the Principal and the Agent and it is denoted by $1-\nu$.

In terms of economic contract modeled by the agency theory, the contractual variables are t and K. As in the standard problem of adverse selection, the Principal has all the bargaining power and makes a "take it or leave it" contractual offer to the Agent.

3. Optimal contracts in symmetric information

We begin our analysis looking at the situation in which there is no asymmetry of information between the contractual participants. If the Principal knows perfectly what type of Agent he faces, the optimal contract he could offer is given by the following optimization problem:

$$\begin{aligned}
&\max_{K,t} \{t - RK\} \\
&s.t. \\
&\theta f(K) - t \geq 0 \\
&t \geq 0, K \geq 0
\end{aligned}$$

We denote by λ the Lagrange multiplier of the participation constraint. The Lagrange function is now written as:

$$L(t, K, \lambda) = t - RK + \lambda\left[\theta f(K) - t\right]$$

The necessary and sufficient conditions, assuming an interior solution ($K^* > 0, t^* > 0$) are:

$$\frac{\partial L}{\partial t} = 0 \text{ or } 1 - \lambda = 0$$

$$\frac{\partial L}{\partial K} = 0 \text{ or } -R + \lambda \theta f(K) = 0 \text{ or } \theta f'(K) = R$$

The second condition corresponds to the standard efficiency condition: the marginal productivity of the capital equals the risk free rate of return.

The first condition shows that $\lambda^* = 1$, meaning that at optimum, the participation constraint is binding.

The features of the first best solution are the following:

- If the Agent has the type $\underline{\theta}$, the optimal contract $\left(\underline{t}^*, \underline{K}^*\right)$ satisfies:

$$\underline{t}^* = \underline{\theta} f\left(\underline{K}^*\right) \text{ and } \underline{\theta} f'\left(\underline{K}^*\right) = R$$

- If the Agent has the type $\bar{\theta}$, the optimal contract $\left(\bar{t}^*, \bar{K}^*\right)$ satisfies:

$$\bar{t}^* = \bar{\theta} f\left(\bar{K}^*\right) \text{ and } \bar{\theta} f'\left(\bar{K}^*\right) = R$$

Before going further, we should make some *comments.*

1. Using $\underline{\theta} < \bar{\theta}$, we have $\frac{R}{\underline{\theta}} > \frac{R}{\bar{\theta}}$ and so $f'\left(\underline{K}^*\right) > f'\left(\bar{K}^*\right)$. By the concavity of the production function $f(K)$, its first derivative $f'(K)$ is strictly decreasing; we simply get:

$$\underline{K}^* < \bar{K}^*$$

2. From the previous result, it also follows that:

$$\underline{t}^* < \bar{t}^*$$

4. Optimal contracts in the situation of asymmetric information

More realistic is the situation when the information regarding the productivity parameter is unknown by the Principal. He only knows the probability $1-\nu$ that the Agent's type is $\underline{\theta}$. In this case, the Principal's optimal decision consists in offering a menu of incentive feasible contracts $\left\{\left(\underline{t}, \underline{K}\right), \left(\bar{t}, \bar{K}\right)\right\}$ - one contract for each type of Agent – such that the expected profit is maximized.

The standard adverse selection problem to be solved is:

$$\max_{(\underline{t},\underline{K}),(\bar{t},\bar{K})} \left\{ \nu\left(\bar{t} - R\bar{K}\right) + (1-\nu)\left(\underline{t} - R\underline{K}\right) \right\}$$
$$s.t.$$
$$\left(PC_{\underline{\theta}}\right): \quad \underline{\theta} f\left(\underline{K}\right) - \underline{t} \geq 0$$
$$\left(PC_{\bar{\theta}}\right): \quad \bar{\theta} f\left(\bar{K}\right) - \bar{t} \geq 0$$
$$\left(ICC_{\underline{\theta}}\right): \underline{\theta} f\left(\underline{K}\right) - \underline{t} \geq \underline{\theta} f\left(\bar{K}\right) - \bar{t}$$
$$\left(ICC_{\bar{\theta}}\right): \bar{\theta} f\left(\bar{K}\right) - \bar{t} \geq \bar{\theta} f\left(\underline{K}\right) - \underline{t}$$
$$\underline{t}, \underline{K}, \bar{t}, \bar{K} \geq 0$$

Some comments

1. As in the standard framework, the right hand side of each participation constraint represents the reservation utility level. We use the zero reservation utility as the outside utility level of each type of agent, without loss of generality.

2. In what it follows, we use a change of variables. The new working variables are the informational rents. Hence, let $\underline{U} = \underline{\theta} f\left(\underline{K}\right) - \underline{t}$ and $\bar{U} = \bar{\theta} f\left(\bar{K}\right) - \bar{t}$ be the informational rent for each type of Agent.

With this change of variables, the participation constraints simple become sign constraints:

$\underline{U} \geq 0$ and $\bar{U} \geq 0$

The incentive compatibility constraints are now:

$$\underline{U} \geq \bar{U} - \Delta\theta f\left(\bar{K}\right)$$

and:

$$\bar{U} \geq \underline{U} + \Delta\theta f\left(\underline{K}\right)$$

with $\Delta\theta = \bar{\theta} - \underline{\theta}$.

We look now at the form of the Principal's problem:

$$\max_{(\underline{U},\underline{K}),(\bar{U},\bar{K})}\left\{\nu\left(\bar{\theta} f\left(\bar{K}\right)-\bar{U}-R\bar{K}\right)+(1-\nu)\left(\underline{\theta} f\left(\underline{K}\right)-\underline{U}-R\underline{K}\right)\right\}$$
$$s.t.$$
$$\left(PC_{\underline{\theta}}\right):\ \ \underline{U}\geq 0$$
$$\left(PC_{\bar{\theta}}\right):\ \ \bar{U}\geq 0$$
$$\left(ICC_{\underline{\theta}}\right):\underline{U}\geq\bar{U}-\Delta\theta f\left(\bar{K}\right)$$
$$\left(ICC_{\bar{\theta}}\right):\bar{U}\geq\underline{U}+\Delta\theta f\left(\underline{K}\right)$$
$$\underline{t},\underline{U},\bar{t},\bar{U}\geq 0$$

We simplify the analysis of deriving the optimal solution by first finding the relevant binding constraints. We can reduce the problem dimensionality: intuition suggests that the most efficient type want to lie upward and claims he is less efficient. Therefore, we can ignore, for the moment, the participation constraint of the type $\bar{\theta}$ (this constraint is implied by other two constraints) and the incentive compatibility constraint of the type $\underline{\theta}$. We are left with two remaining constrains, $\left(PC_{\underline{\theta}}\right)$ and $\left(ICC_{\bar{\theta}}\right)$. It is easy to check that these two remaining constraints are binding at the optimum.

So, at the optimum we must have:

$$\underline{U}=0 \ \text{ and } \ \bar{U}=\underline{U}+\Delta\theta f\left(\underline{K}\right)$$

Next, using the expressions of the informational rents, we can rewrite the objective function to be maximized:

$$\max_{\underline{K},\bar{K}}\left\{\nu\left[\bar{\theta} f\left(\bar{K}\right)-\Delta\theta f\left(\underline{K}\right)-R\bar{K}\right]+(1-\nu)\left[\underline{\theta} f\left(\underline{K}\right)-R\underline{K}\right]\right\}$$

The necessary conditions are the following:

$$\frac{\partial(\cdot)}{\partial\bar{K}}=0 \text{ or } \nu\left[\bar{\theta} f'\left(\bar{K}\right)-R\right]=0 \text{ or } \bar{\theta} f'\left(\bar{K}\right)=R \tag{1}$$

$$\frac{\partial(\cdot)}{\partial\underline{K}}=0 \text{ or } -\nu\Delta\theta f'\left(\underline{K}\right)+(1-\nu)\left[\underline{\theta} f'\left(\underline{K}\right)-R\right]=0 \tag{2}$$

Looking at the condition (1), it follows that:

$$\bar{\theta} f'\left(\bar{K}\right)=R$$

Hence, we obtained the same efficiency condition as in the case of symmetric information (see the previous section):

$$\bar{K}^{SB} = \bar{K}^{*}$$

where $\bar{K}^{SB}$ represents the second best solution assigned to the Agent with type $\bar{\theta}$.

In the presence of private information, there is no distortion for the loan borrowed by the efficient type with respect to the first best level.

The first order condition (2) reduces to:

$$\left(\underline{\theta} - \frac{\nu}{1-\nu}\Delta\theta\right) f'\left(\underline{K}^{SB}\right) = R$$

Using $\underline{\theta} f'\left(\underline{K}^{SB}\right) > R = \underline{\theta} f'\left(\underline{K}^{*}\right)$, we get:

$$\underline{K}^{SB} < \underline{K}^{*}$$

Given the above inequality, there is a downward distortion for the loan borrowed by the inefficient type of Agent. This distortion is directly dependent on the spread of uncertainty on the Agent's private information (the productivity parameter).

Concluding, we can compare the solutions we got in two different situations, i.e., the first best and the second best solution. It is worth to note that the gap between the optimal second best levels of capital becomes larger:

$$\underline{K}^{SB} < \underline{K}^{*} < \bar{K}^{*} = \bar{K}^{SB}$$

If we return to the optimal second best levels of informational rents, the binding participation constraint is $\left(PC_{\underline{\theta}}\right)$, such that the Agent with low productivity parameter gets no informational rent:

$$\underline{U}^{SB} = 0$$

The Agent with high productivity level gets a strictly positive informational rent given by:

$$\bar{U}^{SB} = \Delta\theta f\left(\underline{K}^{SB}\right)$$

The above expression shows that the greater the gap between adverse selection parameters is, the larger the informational rent is. Also, the rent is directly depending on the second best level of capital borrowed by the efficient type of Agent. In fact, the result expresses the well known important trade-off between efficiency and rent extraction which arises under asymmetric information: the Principal must give up a positive informational rent to the most efficient Agent in order to increase the second best loan associated with the least efficient type of Agent.

Returning to the original variables, now we can express the optimal levels of repayments made by the Agent to the Principal. The expressions of the informational rents yield to:

$$\underline{t}^{SB} = \underline{\theta} f\left(\underline{K}^{SB}\right)$$

and:

$$\bar{t}^{SB} = \bar{\theta} f\left(\bar{K}^{SB}\right) - \Delta\theta f\left(\underline{K}^{SB}\right)$$

or

$$\bar{t}^{SB} = \bar{\theta} f\left(\bar{K}^{*}\right) - \Delta\theta f\left(\underline{K}^{SB}\right)$$

The second best levels of transfers satisfy the following inequalities:

$$\underline{t}^{SB} = \underline{\theta} f\left(\underline{K}^{SB}\right) < \underline{\theta} f\left(\underline{K}^{*}\right) = \underline{t}^{*}$$

and:

$$\bar{t}^{SB} = \bar{\theta} f\left(\bar{K}^{*}\right) - \Delta\theta f\left(\underline{K}^{SB}\right) < \bar{\theta} f\left(\bar{K}^{*}\right) = \bar{t}^{*}$$

The above relations are simply consequences of the presence of private information within the contractual relationship.

5. Extending the Model: Auditing Mechanisms

The previous section has shown that the Principal's fundamental concern is to minimize the conflict between the lack of information and the costly informational rent he must give up to the better informed Agent. Technically this objective could be achieved by relaxing the incentive compatibility constraint of the efficient type; in this manner, the efficient Agent would be less often tented to mimic the inefficient type.

The Principal can improve the rent extraction and efficiency trade-off terms by using some screening tools. A way of solving this problem consists in using an auditing technology that might detect the false message sent by the Agent about his type. If it is the case of a lie, the Agent is punished and has to pay some penalties. Also, the auditing technology gives to the Principal, at some cost, the possibility to verify the state of nature signaled by the Agent. But, this technology being costly, it cannot be systematically used by the Principal.

Next we keep the same informational structure as in the previous sections, but we now suppose that the Principal owns an auditing technology by means he can observe the real type of the Agent with probability *p*. The Principal incurs a cost $c(p)$, with $c'(p) > 0, c''(p) > 0$. For technical reasons, we assume that the Inada conditions are satisfied, meaning $c'(0) = 0$ and $c'(1) = \infty$.

An incentive mechanism can now be viewed as the set of: a loan size $K\left(\tilde{\theta}\right)$, a transfer (Principal's repayment) $t\left(\tilde{\theta}\right)$, a probability of audit $p\left(\tilde{\theta}\right)$ and a penalty $P\left(\theta,\tilde{\theta}\right)$ paid by the Agent if his announce is $\tilde{\theta}$ when his true type is θ. We denote by $\underline{P} = P\left(\underline{\theta},\bar{\theta}\right)$ and $\bar{P} = P\left(\bar{\theta},\underline{\theta}\right)$ the respective punishments.

According to the Revelation Principle, the optimal menu of contracts is written as:

$$\left\{\left(\underline{U},\underline{K},\underline{p},\underline{P}\right),\left(\bar{U},\bar{K},\bar{p},\bar{P}\right)\right\}$$

While the participation constraints remain the same as in the standard problem, it is not the case for the incentive compatibility constraints. The presence of positive penalties relaxes those compatibility constraints, which now become:

$$\underline{U} = \underline{\theta} f\left(\underline{K}\right) - \underline{t} \geq \underline{\theta} f\left(\bar{K}\right) - \bar{t} - \bar{p}\underline{P}$$

and

$$\bar{U} = \bar{\theta} f\left(\bar{K}\right) - \bar{t} \geq \bar{\theta} f\left(\underline{K}\right) - \underline{t} - \underline{p}\bar{P}$$

Next we consider the penalties. The literature discusses two types of punishments.

The first type corresponds to exogenous punishments, meaning that the penalty cannot be greater than an exogenous threshold, *l*. So, we have:

$\bar{P} \leq l$ and $\underline{P} \leq l$ respective.

The second approach uses endogenous penalties, i.e., the maximal amount of the Agent's assets that could be sized in the case of false announcement:

$\underline{P} \leq \underline{\theta} f\left(\bar{K}\right) - \bar{t}$ and $\bar{P} \leq \bar{\theta} f\left(\underline{K}\right) - \underline{t}$ respective.

In what follows, we will consider the first approach. The Principal's problem to be solved is the following:

$$\max_{(\underline{U},\underline{K}),(\bar{U},\bar{K})}\left\{\nu\left(\bar{\theta} f\left(\bar{K}\right)-\bar{U}-R\bar{K}-c\left(\bar{p}\right)\right)+\left(1-\nu\right)\left(\underline{\theta} f\left(\underline{K}\right)-\underline{U}-R\underline{K}-c\left(\underline{p}\right)\right)\right\}$$

$$\begin{aligned}
&s.t.\\
&\left(PC_{\underline{\theta}}\right):\ \ \underline{U}\geq 0\\
&\left(PC_{\bar{\theta}}\right):\ \ \bar{U}\geq 0\\
&\left(ICC_{\underline{\theta}}\right):\underline{U}\geq\bar{U}-\Delta\theta f\left(\bar{K}\right)-\bar{p}\underline{P}\\
&\left(ICC_{\bar{\theta}}\right):\bar{U}\geq\underline{U}+\Delta\theta f\left(\underline{K}\right)-\underline{p}\bar{P}\\
&\left(penC\right):\bar{P}\leq l,\ \underline{P}\leq l\\
&\underline{t},\underline{U},\bar{t},\bar{U}\geq 0
\end{aligned}$$

It is worth to make some preliminary remarks before solving the above problem.

The possibility of an audit and the use of penalties do not affect the structure of the problem's binding and nonbinding constraints. The binding constraints are again the least efficient type's participation constraint and the compatibility constraint of the efficient type.

Then, is it almost obvious that there is no need to audit claiming that he is efficient, because the incentive compatibility constraint of the least efficient type is already slack. More, the auditing tool is costly for the Principal. Hence, it is necessarily that we have $\bar{p}=0$ at the optimum.

Third, from the two penalty constraints, only one is binding:

$$\bar{P}\leq l$$

By rising the penalty as much as possible in case of detecting a false announcement coming from the efficient type, the Principal might reduce the right hand side of the incentive constraint assigned to this type, meaning it becomes easier satisfied.

Having in mind all these remarks, we get:

$$\underline{U}=0\,,\ \bar{U}=\Delta\theta f\left(\underline{K}\right)-\underline{p}\bar{P}$$

and also $\bar{p}=0$, $\bar{P}=l$.

Using the above results, the optimization problem is significantly reduced and transformed into a simple optimization problem without constraints:

$$\max_{\underline{K},\bar{K},\underline{p}}\left\{\nu\left[\bar{\theta} f\left(\bar{K}\right)-\Delta\theta f\left(\underline{K}\right)-R\bar{K}-\underline{p}l\right]+\left(1-\nu\right)\left[\underline{\theta} f\left(\underline{K}\right)-R\underline{K}-c\left(\underline{p}\right)\right]\right\}$$

The first order conditions are also sufficient conditions, the objective's program being concave:

$$\frac{\partial(\cdot)}{\partial \bar{K}}=0 \text{ or } \nu\left[\bar{\theta} f'\left(\bar{K}\right)-R\right]=0 \tag{3}$$

$$\frac{\partial(\cdot)}{\partial \underline{K}}=0 \text{ or } -\nu\Delta\theta f'\left(\underline{K}\right)+(1-\nu)\left[\underline{\theta} f'\left(\underline{K}\right)-R\right]=0 \tag{4}$$

$$\frac{\partial(\cdot)}{\partial \underline{p}}=0 \text{ or } -\nu l+(1-\nu)c'\left(\underline{p}\right)=0 \text{ or } c'\left(\underline{p}\right)=\frac{\nu l}{1-\nu} \tag{5}$$

The condition (3) yields to:

$$\bar{\theta} f'\left(\bar{K}\right)=R$$

But $\bar{\theta} f'\left(\bar{K}\right)=R=\bar{\theta} f'\left(\bar{K}^{*}\right)$, such that the optimal contract assigned to the efficient type consists in a size loan that is not distorted with respect to the first best. Therefore, we have:

$$\bar{K}^{SBP}=\bar{K}^{*}.$$

From (4) it follows that:

$$f'\left(\underline{K}\right)\left(\underline{\theta}-\frac{\nu}{1-\nu}\Delta\theta\right)=R=\underline{\theta} f'\left(\underline{K}^{*}\right)$$

Also we have that:

$$f'\left(\underline{K}\right)\underline{\theta}= f'\left(\underline{K}\right)\frac{\nu}{1-\nu}\Delta\theta+R>R=\underline{\theta} f'\left(\underline{K}^{*}\right)$$

Using the properties of the production function we can conclude that:

$$\underline{K}^{SBP}<\underline{K}^{*}$$

In the case of penalties, the optimal contract entails a downward distortion of the loan size assigned to the inefficient Agent.

The optimal probability of audit is positive only for the efficient type and it is given by (5).

We conclude this section by summarizing the main features of the solution. Allowing penalties and with audit, the menu of optimal contract is characterized by the following:

i) Only the efficient type of Agent is audited and the probability of audit is given by:

$$c'\left(\underline{p}^{SBP}\right)=\frac{\nu l}{1-\nu}$$

ii) The punishments for the inefficient type of Agent are maximal:

$$\bar{P}^{SBP}=l$$

iii) The optimal size loan is not distorted with respect to the first best, for the efficient type:

$$\bar{K}^{SBP}=\bar{K}^{*}$$

iv) There is a downward distortion of the loan size assigned to the inefficient Agent:

$$\underline{K}^{SBP}<\underline{K}^{*}$$

v) The Agent with the lowest productivity gets no informational rent, while the Agent with the highest productivity gets positive informational rent:

$$\underline{U}^{SBP}=0\,,\ \bar{U}^{SBP}=\Delta\theta f\left(\underline{K}^{SBP}\right)-\underline{p}l$$

6. Conclusions

The model considered here is a static one and only one shot contracts are analyzed. The model assumed that there were no pre-existing contractual relations or long term contracting between the lender and the borrower. But despite these limitations, the paper have proposed an economic way of reducing the lack of information of the lender and the informational asymmetry using a costly auditing technology. We showed that the Principal can improve the rent extraction and efficiency trade-off terms by means of some screening tools. The auditing technology might detect the false message sent by the Agent about his type. If it is the case of a lie, the Agent is punished and he has to pay some penalties. Also, the auditing technology gives to the Principal, at some cost, the possibility to verify the state of nature signaled by the Agent. The final part of the paper characterized the features of the second best contracts when penalties were allowed.

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