Size, Risk and Efficiency

Tianxi Wang*

University of Essex

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Abstract

The paper examines the signaling role of bank finance and based on it, relates bank sizes to the asset risks and efficiency. It predicts that across banks of an economy, the bigger the bank, the lower the default risk of its assets, but across economies, the bigger the banking sector, the higher the default risks; and that so long as risk shifting problems are contained, the banking sector is not too big. Furthermore, the paper suggests that a universal payment cap upon the banking sector improve social efficiency. Lastly, it sheds new lights on the economies of financial intermediation.

Key Words: Signaling Role of Bank Finance; the Sizes of Banks; Asset Risks; Social Efficiency; Payment Cap; Financial Intermediation

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*Email: wangt@essex.ac.uk. Correspondence: Economics, University of Essex, Colchester, CO4 3SQ, UK. Fax: +44 (0) 1206 872724.

1 Introduction

Do the sizes of banks affect their asset risks? The answer seems to be no. It is well known that only the ratio of equity matters, and the asset size does not, for the incentive of risk shifting, hence for the asset risk (see e.g. Jensen and Meckling 1976), *given the bank's quality of screening projects.* However, there is evidence that the size matters for *the screening quality.* Ross (forthcoming) documents that loans from the three US dominant banks (J.P. Morgan Chase, Bank of American, and Citigroup) induce the borrowers' stock prices to jump higher and are issued at lower interest rates and "less likely to be protected by a borrowing base", and the stock price jump is larger when the borrower is opaque[1], altogether suggesting "the dominant banks provide a higher level of certification"; and Hao (2003) systematically documents an inverse correlation between bank size and loan yield spread.[2] The paper explores a logic line that connects bank size to screening quality through the incentive of investing in screening expertise.

Part of this investment is in IT infrastructures. But the more important part is spent in obtaining key human capital, with high salaries and bonuses; for example, over 2005-2010 period, the average ratio of compensation and benefits to the overall non-interest expenses, for Goldman Sachs is 65%, and for Morgan Stanley is 64%.[3] Actually, the high payments in the banking sector have stirred extensive public anger, but are obstinately defended by banks for fear of losing key human capital. *From the point of view of social efficiency*, do banks overpay their staff? The paper shed lights on this question by examining whether banks over-spend in screening expertise.

The paper is built on two pillars. One is the signaling role of bank finance. Empirical studies well document that the announcement of commercial bank loans induces significant stock price movements.[4] However, the signaling role is not confined to commercial bank

[1]Similarly, Maskara and Mullineaux (forthcoming) document that the positive stock price responses to loan issuance are confined to small firms, which are arguably opaque.

[2]Note that these effects or features of the individual loans cannot be explained by the argument of diversification, to which the literature usually resorts when addressing the efficiency of bank size; see, for example, McAllister and McManus (1993) and Berger and Mester (1997).

[3]Calculated from the annual reports of the two banks published on their websites. In fact, Coleman et. al. (2002) use this ratio to proxy banks' monitoring ability.

[4]See James (1989), Mikkelson and Partch (1988), Lummer and McConnell (1989), Best and Zhang (1993), and Billett et. al. (1995), Maskara and Mullineaux (forthcoming), and Ross (forthcoming).

loans. For example, Goldman Sachs' recent purchase of \$375 million of Facebook shares sends Facebook's value to \$50 billion, which is unusually high considering currently its annual revenue is \$2 billion and net profit \$472 million.[5] To capture this signaling role of bank finance, the paper assumes that laymen do not observe the qualities of entrepreneurs' projects and to invest in the projects, they rely on the screening service of bankers who observe project quality to some precision.

To provide screening service, bankers need to commit their own capital, which is the other pillar of the paper. Bankers could, like rating agents, do it by simply announcing their evaluations of the projects before laymen. However, the paper assumes that this way of cheap talk is not working; laymen would ask "if you, a banker, thinks the projects good, why not put your own capital?" Indeed, if a banker is observed to have invested *enough of* her own capital in a project, then she must truly think it good. Therefore, for signaling purpose, entrepreneurs need certain amount of bankers' capital, although it is more expensive than laymen's capital.

In fact, the entrepreneurs of evaluated-good projects demand only the minimum amount of bankers' capital that can just signal the quality of their projects, and finance the shortfall with cheap laymen's capital. Such demands by entrepreneurs pin down the price of bankers' capital through market clearing, *given the screening qualities of bankers.*

Ex ante bankers have incentives of investing to improve the screening quality, measured by the precision to which they evaluate projects. The more precise are their evaluations, the more likely *evaluated good* projects are *actually good*; and hence the entrepreneurs are more willing to demand their capital for signaling purpose and the higher the return rates charged. In two dimensions the amounts of bankers' capital affect their investment incentives, and hence their screening qualities. One, for an individual banker, the more capital under her control, the more the profit is raised with an increase in the return rate and the bigger the incentive of improving her evaluation precision so as to charge a higher rate. The other is a general equilibrium effect: The larger the aggregate stock of bankers' capital, the lower the rate it earns, which reduces *all* bankers' incentives. If each and every banker's capital increases by one unit, the two effects are in conflict. In net, the

[5] See "Facebook move lucrative for Goldman" and "Facebook", on *Financial Times,* the 4th and 9th of Jan. respectively.

latter effect dominates and the screening quality goes down.

The following empirical predictions thus ensue. Across banks within a given economy, which are subject to the former effect only, the bigger the bank, the higher the screening quality and hence the smaller the default risk of its assets. But across economies, the bigger the banking sector relative to the GDP, the bigger the default risks of its assets.

The paper further finds that the equilibrium screening quality is higher than the second best choice, that is, bankers over-invest in screening expertise, which is mainly spent in paying for human capital. In this sense, the payments in the banking sector are indeed too high. A universal payment cap might improve social efficiency.

Lastly, the paper examines the leverage of bankers, namely, their borrowing from laymen. Leverage enlarges the capital under bankers' control and consequently diminishes the equilibrium quality of screening. However, even with bankers levered at the maximum ratio compatible with the risk shifting problem (namely the problem that bankers would invest in evaluated bad projects if they had borrowed too much), the equilibrium screening quality is still too high. Therefore, the banking sector is not too big so far as the risk shifting problem is contained.

The paper's first contribution is that it models the signaling role of bank finance and based on it, relates banks' sizes to their asset risks and efficiency. It fits in the literature that examines in general equilibrium banks' provision of services which help firms with certain information friction; see Williamson (1987), Besanko and Kanatas (1993), Holmstrom and Tirole (1997), Cantillo (2005), Morrison and White (2005), and Allen et. al. (forthcoming). All these papers, including the present one, can be classified along three lines. First, the service is ex ante monitoring helping with moral hazards, in Besanko and Kanatas (1993), Holmstrom and Tirole (1997), Morrison and White (2005), and Allen et. al. (forthcoming), is ex post monitoring or restructuring in Williamson (1987) and Cantillo (2005), helping with costly state verification à la Townsend (1979), and is screening in the present paper, helping with unobservability of project quality. Second, Besanko and Kanatas (1993), Holmstrom and Tirole (1997), and the present paper feature the complementarity between bank finance and direct finance, whereas the two sources of finance are mutually exclusive in Williamson (1987), Cantillo (2005), and Allen et. al. (forthcoming), while Morrison and White (2005) do not examine explicitly the sector of entrepreneurs. Third, the banks' equity capital is exogenous and scarce in Holmstrom and Tirole (1997), Morrison and White (2005), and the present paper, abundant in Besanko and Kanatas (1993), and endogenous in Cantillo (2005) and Allen et. al. (forthcoming), while unaddressed in Williamson (1987).

The paper also contributes to the literature that examines from the first principles the economies of financial intermediation. The literature consists of two sets of research, one starting with Diamond (1984), underlining real services banks provide, the other starting with Diamond and Dybvig (1983), underlining the sharing of liquidity risks; and for a survey, see Gorton and Winton (2003). In the paper, financial intermediation naturally arises, because on the asset side bankers earn the rate of the informed capital, while on the liability side they borrow at the rate of the uninformed (laymen's) capital, and the former rate is higher. And financial intermediation places more capital under bankers' control and thereby improves ex ante efficiency by decreasing the equilibrium screening quality, which is too high.

The over-invest result of the paper is in the line of Anott et. al. (1992), Fostel and Geanakoplos (2008), Lorenzoni (2008), Hombert (2009), and Korinek (2010); for a survey see Wagner (2010). In this literature, externality arises because decentralized agents take no account of the feeding of market price (or return rate) into borrowing constraint or incentive compatibility constraint. Similarly, bankers of the present paper over-invest in screening expertise, because they take no account of the effect that the increase in one banker's screening quality marginally raises the equilibrium profit to entrepreneurs, which damps the incentives of all the other bankers.

The rest of the paper is organized as follows. Section 2 examines the signaling role of bank finance in a competitive economy, given bankers' screening qualities. Section 3 examines bankers' choices of screening quality. Section 4 considers the leverage of bankers. Section 5 concludes. Appendix A examines the model of Section 2 for the case of a continuum of types. Appendix B contains some proofs.

2 Signaling through Bank Finance in a Competitive Economy

2.1 The Model

There are two dates with no discount, today for contracting and financing, tomorrow for repayment and consumption.

The economy consists of three sectors of identical agents: entrepreneurs, bankers, and laymen, all risk neutral and protected by limited liability. Entrepreneurs have projects but no capital. Bankers and laymen have capital. Entrepreneurs are of measure 1×1, and bankers of measure 1; for example, if measure 1 means 1,000, then there are one million entrepreneurs and one thousand bankers. Thus, each banker serves a continuum of measure 1 of entrepreneurs in equilibrium and can resort to the Law of Large Numbers. The measure of laymen does not matter.

The project of an entrepreneur requires investment of $\$B$, and returns $\$Z$ if it succeeds and nothing if it fails. Projects, and accordingly entrepreneurs, are of two types, high or low; the assumption of two types is for simplicity and the analysis for the case of a continuum of types, which is mathematically more elegant, is to be found in Appendix A. High projects succeed with probability $\overline{q}$ and low ones with probability $\underline{q}$.

$$1 > \overline{q} > \underline{q} > 0.$$

The proportion of high types is $\overline{n}$, that of low types $\underline{n} = 1 - \overline{n}$. High projects have a positive net present value (NPV) and on average projects have a negative NPV. That is,

$$\overline{q}Z > B \geq (\overline{n}\overline{q} + \underline{n}\underline{q})Z.$$

Let $\overline{V} \equiv \overline{q}Z - B$ be the NPV of a high type and $\underline{V} \equiv \underline{q}Z - B$ be the NPV of a low type. The assumption is therefore

$$\overline{V} > 0 \geq \overline{n}\overline{V} + \underline{n}\,\underline{V}. \tag{1}$$

Each banker has $K > 0$ units of capital. A unit is the sum total of a continuum of measure 1 of dollars; that is, out of 1 unit of capital, \$1 can be invested in each of a measure 1 continuum of projects; if measure 1 means 1,000, as was in the above example, 1 unit means 1,000 dollars. The bankers' capital is scarce:

$$K < \overline{V}\overline{n}\frac{\underline{q}}{\overline{q}-\underline{q}}. \tag{2}$$

Each layman has a small amount of capital, but in aggregation their capital is abundant.

If not invested in entrepreneurs' projects, capital is invested in a risk free asset with gross return rate 1. As laymen have abundant capital and are risk neutral, they are satisfied with expected return rate 1.

Laymen only know the prior distribution of the types, but bankers have the expertise to evaluate them. In this section, we assume bankers perfectly observe the types. The only significance of the assumption is that the precision of banks' evaluations is given, the choice of which is to be examined in the next section; if bankers observe noisy signals of the types, then just redefine the signals as the types and all the analysis carries on.

Given the knowledge difference between bankers and laymen, the capital provided by bankers is called *the informed capital,* that provided by laymen *the uninformed capital.*

To focus on the sector of bankers, we assume that an entrepreneur does not know his type before being evaluated by a banker, but after that he knows the evaluation.

Signalling Through Bank Finance

As bankers' capital is scarce, entrepreneurs mainly depend on laymen's capital to finance their projects. Laymen do not have the expertise of evaluating the projects' qualities, and on average the projects are of a negative NPV. Therefore, laymen will not finance any projects unless they are convinced that the projects are evaluated high by some bankers. How to credibly communicate the high evaluations to laymen, thus channeling their capital into the productive sector, is the key concern of the paper.

A banker could simply announce her evaluation of a project to laymen. However, this way of cheap talk cannot work, because the economy is essentially static and reputation mechanisms are assumed away.[6] More formally, consider an entrepreneur-banker contract

[6] In fact, even under repeated interactions, reputational mechanisms will *not* work if $\overline{q}$ is small enough, that is, if the observed signal, success or failure, is very noisy about the true quality; see the literature on reputation under imperfect monitoring, e.g. Abreu et. al. (1986) and Abreu et. al. (1988), in particular Banerji and Wang (2011).

in which the entrepreneur pays some fee T in case of success to the banker for her evaluation. Such a contract cannot signal a high type, because the banker always wants to sign it with a low type and get his project financed, by which she expects to earn additionally $\underline{q}T$. On the other hand, if a banker invests enough of her own capital in a project, she must think it good. Put differently, word of mouth is worthless, because it is infinitely supplied, whereas real capital does not lie, because it is scarce and thus subject to serious opportunity costs.

For signaling purpose, therefore, an entrepreneur-banker contract must involve the investment of the banker's capital. Specifically, it stipulates the amount of her capital to be invested and the amount of return to be repaid when the project succeeds (on its failure, by limited liability, no one gets anything). The ratio of the latter amount over the former one gives *the book rate of return,* that is, the gross rate of return that is read from the contract.

After an entrepreneur secures a financial contract from a banker, he goes to the market for laymen's capital. He shows before them the contract, trying to convince them that his project is of high type. If they are convinced, they accept book rate $1/\overline{q}$, namely, for \$1 given up today they get back $\$1/\overline{q}$ tomorrow if the project succeeds, which gives expected return rate 1. Certainly, the projects in which no bankers are willing to invest are of quality below the prior average and hence are not be financed by laymen.

Timing of Events and Definition of Equilibrium

The timing of today's events is as below, which starts with stage 2 for the purpose of leaving stage 1 to be filled in the next section.

2: Each banker posts R, the expected return rate she is to charge for her capital.

3: Each entrepreneur goes to one banker and is evaluated by her, with the evaluation observed by both sides.

4: The entrepreneur submits his demand for her capital. If she accepts it, she signs a contract with him which specifies the amount of her capital to be invested and the book rate of return.

5: Entrepreneurs, showing the contracts with the bankers if available, go to the market for laymen's capital.

6. A project is started if the entrepreneur has got $\$B$ altogether.

The concept of equilibrium used is general equilibrium. Remember R denotes the expect return rate of the informed capital and let I denote the demand of the informed capital by high type entrepreneurs and L denote that by low types. For a variable x, let $\widehat{x}$ denote its value in equilibrium.

Definition 1 *The profile of* $\left(\widehat{R};\widehat{I},\widehat{L}\right)$ *forms an equilibrium if*

(i): given the price of the informed capital $\widehat{R}$*, a high type entrepreneur demands* $\$\widehat{I}$ *of the informed capital and a low type* $\$\widehat{L}$*;*

(ii): given the demands of the two types of entrepreneurs as above, $\widehat{R}$ *clears the market for the informed capital.*

We finish setting up the model so far, and proceed to analyzing it.

2.2 The Characterization of the Equilibrium

There is a unique equilibrium in which high types are sorted out by the amount of the informed capital invested, that is, $\widehat{I} \neq \widehat{L}$, whereby all the socially efficient projects are financed and the first best allocation is implemented. Below we first characterize this separating equilibrium and then demonstrate its uniqueness.

Start with condition (ii), which is simpler. If low types are sorted out, they cannot be financed. Hence in the separating equilibrium, they want nothing of the informed capital, namely,

$$\widehat{L} = 0.$$

Each high type entrepreneur demands $\$\widehat{I}$ of the informed capital. Therefore, the aggregate demand for the informed capital is $\overline{n}\widehat{I}$ units. On the other hand, the aggregate supply is K units. The market clearing commands

$$\overline{n}\widehat{I} = K. \tag{3}$$

Move on to condition (i). Here is the key point: Given the rate charged by a banker, R, a high enough demand of her capital, I, sorts out a high type. Consider what a low type gets by mimicking, namely, by also demanding $\$I$ of the banker's capital. The banker knows of the low quality of his project, and therefore asks him to repay $\$\frac{RI}{\underline{q}}$ in case of success, in order to get the same expected rate of return, R, for the $\$I$ of her capital as she would get from a high type. By mimicking, the low type convinces laymen that his project is of high type, and thus has them finance the shortfall, $\$(B-I)$, at book rate $\frac{1}{\overline{q}}$, which gives rise to overall repayment $\$\frac{B-I}{\overline{q}}$. Therefore, by mimicking, the low type obtains, in case of success, $Z - \frac{RI}{\underline{q}} - \frac{B-I}{\overline{q}}$. Mimicking is unprofitable for him if

$$Z - \frac{RI}{\underline{q}} - \frac{B-I}{\overline{q}} \leq 0 \Leftrightarrow I \geq \frac{\overline{V}}{R\frac{\overline{q}}{\underline{q}} - 1}. \tag{4}$$

By this argument, demanding at expected rate R no less than $\$\frac{\overline{V}}{R\frac{\overline{q}}{\underline{q}}-1}$ of the banker's capital signals high types. However, the expected rate is not readable in the contracts with the bank; what is read there is the book rate of return, F (which is paid only in the case of success), and the scale of the banker's investment, I. In this separating equilibrium $R = \overline{q}F$. Substitute $\overline{q}F$ for R in (4). High types are thus signaled out by the contracts that read that the banker invests at book rate F no less than $\$\frac{\overline{V}}{F\frac{\overline{q}^2}{\underline{q}}-1}$ of her capital.

Remark: Given R, the banker charges book rate $R/\overline{q}$ for high types and $R/\underline{q}$ for low types. The latter is higher than the former. It seems that out of this difference in the book rate alone can high types be signaled. However, the assumption is that besides the contract shown before laymen, an entrepreneur could have other contracts with the banker; it is too costly to check *all* the contracts he signed with her. Thus, if laymen could be convinced of high types with the investment of $I' < \frac{\overline{V}}{R\frac{\overline{q}}{\underline{q}}-1}$ (the critical level in 4) dollars of the banker's capital at book rate $R/\overline{q}$, a low type would profitably mimic by signing two contracts with the banker, in one, to be shown before laymen, the banker agrees to invest $\$I'$ at book rate $R/\overline{q}$, as she would do to a high type, in the other the low type agrees to pay her additionally $I'(R/\underline{q} - R/\overline{q})$ in case of success; doing so he gets in case of success $Z - I'R/\overline{q} - I'(R/\underline{q} - R/\overline{q}) - (B - I')/\overline{q} > 0$ if $I' < \frac{\overline{V}}{R\frac{\overline{q}}{\underline{q}}-1}$. Therefore, the book rate read from the contract shown before laymen alone is not enough to signal a high type.

Back to the demand decisions of high types. If they want to signal their type, they have to demand no less than $\$\frac{\overline{V}}{R\frac{\overline{q}}{\underline{q}}-1}$ of the banker's capital. As will be shown soon, $R > 1$; the informed capital, as being assumed scarce by (2), is more expensive than the uninformed capital. Therefore, high types only demand the minimum of the amounts by which they can signal the quality of their projects. By (4), this minimal amount is

$$I(R) = \frac{\overline{V}}{R\frac{\overline{q}}{\underline{q}} - 1}. \tag{5}$$

Note that $I'(R) < 0$; that is, the more expensive the informed capital, the less of it is needed for signaling purpose.

By demanding \$$I(R)$ of the banker's capital, high types signal their type and get the shortfall of the investment need, $B - I(R)$, financed by laymen at book rate $1/\overline{q}$. In case of success, they get

$$Z - \frac{RI(R)}{\overline{q}} - \frac{B - I(R)}{\overline{q}} = \frac{\overline{V}R}{\overline{q}} \frac{\frac{\overline{q}}{\underline{q}} - 1}{R\frac{\overline{q}}{\underline{q}} - 1} > 0. \tag{6}$$

On the other hand, if they demand less than \$$I(R)$ of the banker's capital, by the argument leading to (4), they will be mixed with low types, not be financed, and get 0 value. Therefore, their optimal demand of her capital is $I(R)$, given by (5), when the banker charges rate R.

The profit in case of success, given by (6), times $\overline{q}$, the probability of success, gives the expected profit of high types at given rate R, which is thus $\overline{V}R(\frac{\overline{q}}{\underline{q}} - 1)/(R\frac{\overline{q}}{\underline{q}} - 1)$. This expected profit of high types times $\overline{n}$, the probability of being among high types, gives the *ex ante* expected profit of the entrepreneurs who come to a banker charging rate R, which is thus

$$\Pi(R) = \overline{n}\overline{V}\frac{R(\frac{\overline{q}}{\underline{q}} - 1)}{R\frac{\overline{q}}{\underline{q}} - 1}. \tag{7}$$

Note that this profit decreases with R. Therefore, in equilibrium all the bankers charge the same price, $\widehat{R}$, for their capital. And note that even if R goes to infinity, this profit does not go to 0, that is, bankers cannot take away all the surplus even if the market on their side is very short. The reason is to be found in equation (5), by which the demand of the informed capital decreases with its price and the repayment to the banker, IR, is upper bounded by $\overline{V}\underline{q}/\overline{q} < \overline{V}$.

Substitute $R = \widehat{R}$ into (5), and the equilibrium demand of the informed capital by a high type is then

$$\widehat{I} = \frac{\overline{V}}{\widehat{R}\frac{\overline{q}}{\underline{q}} - 1}.$$

Combine it with (3) to solve for $\widehat{I}$ and $\widehat{R}$. Then the equilibrium in which all the high types are sorted out and financed is:

$$\widehat{R} = \frac{q}{\overline{q}}(\frac{\overline{n}\overline{V}}{K}+1); \quad (8)$$

$$\widehat{I} = \frac{K}{\overline{n}}; \quad (9)$$

$$\widehat{L} = 0.$$

Assumption (2) ensures that the informed capital is indeed more expensive than the uninformed, that is $\widehat{R} > 1$, and insufficient to finance all the high type projects (i.e. $\widehat{I} < B$).

Except the equilibrium expounded above, there are no other equilibria. First, in any equilibrium, given bankers observe the qualities of projects and have positive units of capital, they will finance a positive measure of high type projects in equilibrium. Second, since bankers invests in equilibrium path, laymen cannot ignore what this investment means to a project's quality: It must be somewhat good. That is, the equilibrium must feature signaling through bank finance. Third, by the argument leading to (4), the more the bank finance obtained, the better the quality signaled. And lastly, in the equilibrium path, it cannot occur that a positive measure of low types are mixed with high types by demanding the same amount of bank finance. Suppose on the contrary the mix occurred. Then laymen would demand book rate $\frac{1}{q'}$ with $q' < \overline{q}$ to finance the entrepreneurs. It follows that any financed entrepreneur would want to demand $\$\epsilon$ more of the informed capital to signal that he is 100% of high type. By doing so his costs of obtaining the informed capital would increase by $\$\epsilon \cdot R$, but he would obtain the uninformed capital at book rate $\frac{1}{\overline{q}}$, instead of $\frac{1}{q'}$, and hence save $\$(B - I - \epsilon) \cdot (\frac{1}{q'} - \frac{1}{\overline{q}})$ in case of success, which dominates $\$\epsilon \cdot R$.

Therefore, there is a unique competitive equilibrium, in which however scarce the informed capital is, it always suffices to sort out all the high type projects and thereby to implement the first best allocation. Key to this result is competition or the general equilibrium effect: The scarcer the informed capital, the higher is its price (by 8), and then the less of it is needed to signal out a high type (by 5).

In this equilibrium, the rate of the informed capital, $\widehat{R}$, decreases with K, the aggregate supply of the capital; and the ex ante profit of entrepreneurs, $\widehat{\Pi}$, is to be found by substituting R of (7) with $\widehat{R}$ given by (8), that is,

$$\widehat{\Pi} = \frac{\overline{q} - \underline{q}}{\overline{q}}(\overline{n}\overline{V} + K). \tag{10}$$

It increases with K. And the aggregate accounting profit of bankers (gross of the opportunity costs of their capital) is $K\widehat{R} = \frac{\underline{q}}{\overline{q}}(\overline{n}\overline{V} + K)$. This formula and (10) together suggest that in aggregation the surplus on the table is the sum of the social value of all the high type projects, $\overline{n}\overline{V}$, plus the capital contributed by bankers, K; and of this surplus proportion $(\overline{q} - \underline{q})/\overline{q}$ goes to the entrepreneur sector and proportion $\underline{q}/\overline{q}$ to the banker sector. The former proportion increases with the dispersion of project quality, measured by $\overline{q}/\underline{q}$, and the latter decreases with it. Finally, the aggregate economic profit of bankers is to be found by extracting the opportunity costs of their capital, K, out of the accounting profit given above, which gives $\frac{\underline{q}}{\overline{q}}\overline{n}\overline{V} - \frac{\overline{q}-\underline{q}}{\overline{q}}K$, decreasing with K. This decreasing is due to the general equilibrium effect that the price of the informed capital, $\widehat{R}$, decreases with its aggregate supply, as is shown by (8). However, for an individual banker, who takes $\widehat{R}$ as given, her profit is $K(\widehat{R} - 1)$ and increases linearly with the stock of her capital.

To summarize:

Proposition 1 *Suppose the quality of screening service of bankers is sunk. There is a unique competitive equilibrium in which:*

(i) high type projects are sorted out by obtaining (no less than) \$$\overline{V}/(R\frac{\overline{q}}{\underline{q}} - 1)$ of bank finance at rate R, with the shortfall financed by laymen.

(ii) however scarce is bankers' capital, all the socially efficient projects are financed and the first best allocation is implemented;

(iii) the price of bankers' capital decreases with its aggregate supply, K;

(iv) the profit of the real sector, namely the sector of entrepreneurs, increases with K, while the economic profit of the banking sector decreases with it;

(v) the profit of the real sector increases with the dispersion of project quality, while the profit of the banking sector decreases with it.

The validity of all these five claims for the case of a continuum of types is confirmed in Appendix A, where claim (i) becomes that the larger the amount of bank finance obtained, the higher the quality signaled and the lower the book rate of the deal; and the "dispersion" in claim (v) is ranked according to the second order stochastic dominance.

By Proposition 1, given the quality of screening service, the size of bankers' capital does not matter for efficiency, though it matters for distribution. Next section adds stage 1 on which the quality is chosen by bankers through investment, and finds that the size then matters for efficiency.

3 Size, Investment in Screening, and Efficiency

3.1 The Investment in Screening Expertise

In this section, the screening quality of a banker is not given, but depends on how much she invests in it. If she invests $C(p)$, then her screening service is to be of quality p, measured by the precision of her evaluations: For each project evaluated, she independently receives a signal $\widetilde{s} = g(\text{ood})$ or $b(\text{ad})$ according to:

$$\Pr(\widetilde{s} = b|\widetilde{q} = \underline{q}) = p; \Pr(\widetilde{s} = g|\widetilde{q} = \underline{q}) = 1 - p; \Pr(\widetilde{s} = g|\widetilde{q} = \overline{q}) = 1. \tag{11}$$

Across the projects she screens, the signals come independent.

The probability of success of a project that is *evaluated good* to precision p, denoted by $q_g(p)$, is thus $\frac{\overline{n}\overline{q}+\underline{n}(1-p)\underline{q}}{\overline{n}+\underline{n}(1-p)}$;[7] the probability of success of an *evaluated bad* project, denoted by $q_b(p)$, is $\underline{q}$; and the *proportion* of evaluated good projects, $n_g(p)$, is $\overline{n} + \underline{n}(1-p)$ by the law of large numbers. Then, let $V_g(p) \equiv q_g(p)Z - B$, namely the NPV of a evaluated good project; let $S(p) \equiv n_g(p)V_g(p)$, namely the ex ante social surplus of a project if it is financed only when being evaluated good; and let $a(p) \equiv \frac{q_g(p)}{q_b(p)}$, namely the quality dispersion between evaluated good and bad projects.

Actually, the particular way of modelling the precision, such as (11), does not matter. The paper's analysis below only requires the following four properties:

P1. $q_g'(p) > 0$, that is, the more precise the evaluations, the higher the probability in which *evaluated* good projects succeed, because the more likely they are *actually* good.

[7] As entrepreneurs do not know their types before coming to bankers, the proportion of high types among all the entrepreneurs coming to any banker is $\overline{n}$, the same as the proportion for the population.

P2. $a'(p) > 0$, that is, the more precise the evaluations, the bigger the difference in quality between evaluated good and bad projects.

P3. $a(p) > 1$, that is, this difference is always positive.

P4. $S'(p) > 0$ and $S''(p) \leq 0$, that is, the marginal social benefit of more precise evaluations is positive but decreasing.

So long as evaluation gives binary signals, any reasonable way of modelling the precision should satisfy these four properties, which delineates the generality of the paper's analysis.

Cost function $C(\cdot)$ is convex over interval $[0, 1]$ and satisfies $C''(\cdot) > 0, C(0) = C'(0) = 0$, and $C'(1) = \infty$. Note that the $C(p)$ is the cost of obtaining screening expertise of certain quality, not the marginal cost of evaluating an entrepreneur, which is assumed away for simplicity. Introducing a constant positive marginal cost would not qualitatively change anything. What we essentially assume is that the cost of *obtaining* certain quality of screening expertise depends on the quality, but not much on the extent to which the expertise is used.[8]

Moreover, to simplify the exposition, we assume $C(p)$ is laid not out of the banker' capital stock, but out of the investment revenue. That is, having made the investment of $C(p)$, she still has K units of capital in hand. If, instead, $C(p)$ were extracted out of K, none of the papers' results would qualitatively change.

The screening qualities of bankers, when having been sunk, are publicly observed to all the agents. The assumption buys the benefit that there is only one dimension of asymmetric information between laymen and bankers, which is concerned with the evaluations. The alternative assumption that p is private information is to be discussed in Subsection 3.6.

As was in Section 2, an entrepreneur does not know his type before being evaluated by a banker, and afterwards he knows the evaluation; an entrepreneur gets financed by laymen

[8] We would interpret the investment is mainly spent in taking in financial geniuses (whom bankers recognize but laymen do not). Then $C(p)$ represents those parts of their payments that are not in piece rate, or closely related to performance in general; casual observations suggest that such non-performance-related parts take a large bulk of the payments. For example, in year 2009, Morgan Stanley's earning per basic share is -\$0.77, but it still uses 61.6% of net revenues for compensation and benefits (see its 2009 annual report).

only if they are convinced that his project is evaluated good to *a high enough precision*; and bankers can credibly convey their good evaluations only by investing enough of their own capital.

3.2 Timing of Events and Definition of Equilibrium

With the ex ante stage of investing in screening quality added, the timing is hence as follows.

1. Each banker invests to obtain quality p, which is publicly observed hereafter.

2: Each banker posts R, the expected return rate she is to charge for her capital.

3: Each entrepreneur goes to one banker and is evaluated by her, with the evaluation observed by both sides.

4: The entrepreneur submits his demand of her capital. If she accepts it, she signs a financial contract with him.

5: Entrepreneurs, showing the contracts with the bankers if available, go to the market for laymen's capital.

6. A project is started if the entrepreneur has got $\$B$ altogether.

The concept of equilibrium used in this section is Subgame Perfect Nash Equilibrium, defined as follows. Let bankers be indexed by real numbers $j \in [0,1]$; so are their strategies. And remember that for a variable x, "$\widehat{x}$" denotes its value in equilibrium.

Definition 2 *A profile of* $\left(\widehat{p}_j, \widehat{R}_j, \widehat{\Pi}, \widehat{I}_j, \widehat{L}_j\right)$ *forms an equilibrium if*

(i): at stage 1, given all the other bankers obtain qualities $\{\widehat{p}_m\}_{m \neq j}$*, it is optimal for banker* j *to obtain quality* $\widehat{p}_j$*;*

(ii): given that bankers have obtained qualities $\{\widehat{p}_j\}_{j \in [0,1]}$*, and that the all the other bankers charge rates of return* $\{\widehat{R}_m\}_{m \neq j}$*, it is optimal for bank* j *to charge rate* $\widehat{R}_j$*;*

(iii): given bankers have obtained $\{\widehat{p}_j\}_{j \in [0,1]}$ *and charged* $\{\widehat{R}_j\}_{j \in [0,1]}$*, entrepreneurs go to those bankers whose deals give them the highest expected profit,* $\widehat{\Pi}$;

(iv): among the entrepreneur customers of banker j*, those evaluated good demand* $\$\widehat{I}_j$ *of her capital and those evaluated bad* $\$\widehat{L_j}$*;*

(v): The total demand of any banker's capital equals K*, her capital stock.*

The definition looks complex. However, it degenerates into a general equilibrium, we are going to show, which, if existing, is symmetric and unique in generic: All the bankers choose the same $\widehat{p}$ and $\widehat{R}$, and the entrepreneurs randomly go to any bankers and demand $\$\widehat{I}$ when evaluated good and 0 when evaluated bad. Before passing on to the detailed analysis, one remark which will greatly facilitate it shall be made.

When all (but 0 measure) bankers have obtained the same quality and evaluated good projects are to be financed, the circumstance from stage 2 onward is isomorphic to that studied in Section 2, by redefining the signal observed as the type, or more specifically, by mapping good evaluation to high type, bad evaluation to low type, q_g to $\overline{q}$, q_b to $\underline{q}$, and n_g to $\overline{n}$. Therefore, the results there can be directly applied here in the present section with proper mappings. For example, by arguments isomorphic to those leading to (4) and (5), among the entrepreneurs who come to a banker offering deal (p, R), those evaluated good need at least $\$\frac{V_g}{R\frac{q_g}{q_b}-1}$ of the banker's capital to signal the good evaluations of them (see 4) and they actually demand this minimum amount (see 5). In general, we have:

(MapB): As for the results of the last section that are concerned with an individual banker, like (4), (5) and (7), they can be applied here by substituting high type there with good evaluation here, low type with bad evaluation, $\overline{n}$ with n_g, $\overline{q}$ with q_g, $\underline{q}$ with q_b, and $\overline{V}$ with V_g.

(MapE): As for the results there concerned with equilibrium, like (8) and (10), they can be applied here by substituting high type with good evaluation, low type with bad evaluation, $\overline{n}$ with $\widehat{n_g}$, $\overline{q}$ with $\widehat{q_g}$, $\underline{q}$ with $\widehat{q_b}$, and $\overline{V}$ with $\widehat{V_g}$.

3.3 The Symmetry, Existence and Uniqueness of Equilibrium

The Symmetry of Equilibrium

To prove the symmetry of the equilibrium, it suffices to show that in equilibrium, all bankers obtain the same quality $\widehat{p}$. If they offer the same quality of screening service, then they will charge the same rate $\widehat{R}$ for their capital, which will induce symmetric behavior of entrepreneurs.

To find a banker's quality choice, we figure out her profit associated with any given quality. The profit depends on the rate she charges for her capital, which in turn depends on the competition between bankers. It seems that in Nash equilibrium one banker has to deal with the strategies of the continuum of all the others. It turns out, however, only one variable concerns her, the equilibrium profit of entrepreneurs, $\widehat{\Pi}$.

Suppose a banker obtains quality p and charges rate R. The ex ante profit of the entrepreneurs coming to her, $\Pi(R,p)$, is to be found by applying (MapB) to (7) and thus equals

$$n_g V_g \cdot \frac{R(\frac{q_g}{q_b}-1)}{R\frac{q_g}{q_b}-1}.$$

Use notations $S(p) = n_g(p)V_g(p)$ and $a(p) = \frac{q_g(p)}{q_b(p)}$. Then,

$$\Pi(R,p) = S\frac{(a-1)R}{aR-1}. \tag{12}$$

The banker can attract entrepreneurs to her, if and only if what they expect to get from her, $\Pi(R,p)$, equals what they expect to get from some other bankers, $\widehat{\Pi}$ (namely their equilibrium profit); that is,

$$S\frac{(a-1)R}{aR-1} = \widehat{\Pi}.$$

It follows that the rate she charges, R, as a function of p and $\widehat{\Pi}$, is

$$R(p;\widehat{\Pi}) = \frac{\widehat{\Pi}}{a(p)\widehat{\Pi}-(a(p)-1)S(p)}. \tag{13}$$

Note, however, that the banker can always choose not to compete for entrepreneurs and invest her capital in the risk free asset with gross return rate 1. Hence, the gross return rate of her capital, after having obtained quality p, is $\max\{R,1)$, while the opportunity cost rate of her capital is 1. Therefore, by obtaining quality p, her economic profit is

$$K\cdot(\max\{R(p;\widehat{\Pi}),1\}-1)-C(p).$$

Substitute (13) and we find the banker's choice of quality, p, solves

Problem ($\widehat{\Pi}$): $\max_{0\le p\le 1} K\cdot(\max\{\frac{\widehat{\Pi}}{a(p)\widehat{\Pi}-(a(p)-1)S(p)},1\}-1)-C(p).$

In generic the problem has a *unique* solution (for exceptions see footnote 9 below). *Let it denoted by* $\rho(\widehat{\Pi};K)$.

The banker's choice of quality, therefore, is $\rho(\widehat{\Pi};K)$, the same as all the others, since across them all K and $\widehat{\Pi}$ are the same. The same choice of quality, as was argued, establishes the symmetry of equilibrium. Thus,

Lemma 1 *Equilibrium, if existing, is symmetric in generic.*

Move on to examine the conditions under which equilibrium exists and those under which it does not, and to show that when it exists, it is unique.

The Existence and Uniqueness of Equilibrium

The analysis so far suggests that equilibrium could be defined in a manner of general equilibrium, where $\widehat{\Pi}$ summarizes the market conditions for bankers and plays the role of the price, while the decisions are to choose quality, $\widehat{p}$, as below:

Definition 3 *A profile of* $(\widehat{p}, \widehat{\Pi})$ *forms an equilibrium, if:*

(i) given entrepreneurs expect to get $\widehat{\Pi}$*, bankers find it optimal to obtain quality* $\widehat{p}$*.*

(ii) given all bankers have obtained quality $\widehat{p}$*, entrepreneurs expect to get* $\widehat{\Pi}$*.*

As for condition (i), the analysis above shows that all bankers solve Problem $(\widehat{\Pi})$ and choose

$$\widehat{p} = \rho(\widehat{\Pi}; K). \tag{14}$$

As for condition (ii), the equilibrium profit of entrepreneurs depends on whether the evaluated good projects deserve to be financed or not. By assumption (1), if there is not any signaling of high types, then on average projects are of a negative social value, and thus no projects are to be financed, by which entrepreneurs get 0. So is the case when the quality of screening service of bankers is so low that the social value of the evaluated good projects is negative, namely, $V_g(p) < 0$. Thus, $\widehat{\Pi} = 0$ for $\widehat{p} \leq \underline{p}$, where $\underline{p}$ is defined by

$$V_g(\underline{p}) = 0.$$

That is, $\underline{p}$ is the critical level of quality beyond which the screening service of bankers generates a positive social value.

If $\widehat{p} > \underline{p}$, evaluated good projects are of a positive social value and are to be financed. Apply (MapE) to (10) of Section 2, and we find the equilibrium profit of entrepreneurs is

$$\widehat{\Pi} = \frac{\widehat{q}_g - \widehat{q}_b}{\widehat{q}_g}(\widehat{n}_g \widehat{V}_g + K), \tag{15}$$

equal to $\frac{a(\widehat{p})-1}{a(\widehat{p})}(S(\widehat{p})+K)$, as $S(p)=n_g V_g$ and $a(p)=\frac{q_g(p)}{q_b(p)}$.

Overall, condition (ii) of Definition 3 is summarized by

$$\widehat{\Pi}=\left\{\begin{array}{c} 0, \text{ if } \widehat{p}\leq \underline{p} \\ \frac{a(\widehat{p})-1}{a(\widehat{p})}(S(\widehat{p})+K), \text{ if } \widehat{p}>\underline{p} \end{array}\right\}. \tag{16}$$

Lemma 2 *Equilibrium exists if and only if simultaneous equations (14) and (16) have a solution for* $(\widehat{p},\widehat{\Pi})$.

Let us illustrate the two equations in the $\widehat{p}-\widehat{\Pi}$ plane, the latter first. Note that both $a(\cdot)$ and $S(\cdot)$ are increasing functions (by P2 and P4), and hence so is $\frac{a(\cdot)-1}{a(\cdot)}(S(\cdot)+K)$; when $\widehat{p}=1$, it arrives at the highest value, $\frac{\overline{q}-\underline{q}}{\overline{q}}(\overline{n}\overline{V}+K)$. So (16) is illustrated as follows.

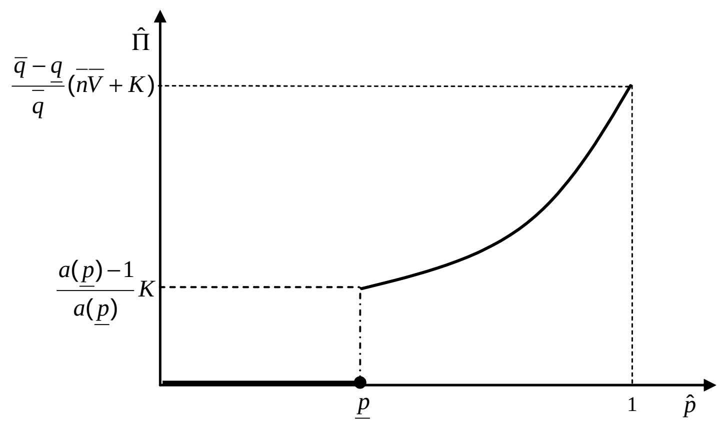

Figure 1: Equation (16)

Now consider equation (14) which summarizes condition (i). $\rho(\widehat{\Pi};K)$ is the solution of Problem $(\widehat{\Pi})$ above, that is,

$$\rho(\widehat{\Pi};K)=\arg\max_{0\leq p\leq 1} K\cdot(\max\{\frac{\widehat{\Pi}}{a(p)\widehat{\Pi}-(a(p)-1)S(p)},1\}-1)-C(p).$$

First, note that a banker invests in screening expertise only if she expects to obtain thereafter a rate $R>1$, otherwise she does not want to incur the investment cost at all. Therefore, the solution to Problem $(\widehat{\Pi})$ is either $p=0$ by which the banker gets 0, or it is the solution of the following problem by which she gets its value, $\Theta(\widehat{\Pi};K)$:

$$\Theta(\widehat{\Pi};K)\equiv\max_{0\leq p\leq 1} K\cdot(\frac{\widehat{\Pi}}{a(p)\widehat{\Pi}-(a(p)-1)S(p)}-1)-C(p). \tag{17}$$

Then,

Lemma 3 *$\rho(\widehat{\Pi};K) > 0$ and is the solution of problem (17) if $\Theta(\widehat{\Pi};K) > 0$ and $\rho(\widehat{\Pi};K) = 0$ if $\Theta(\widehat{\Pi};K) < 0$.*

Second, if the denominator in the objective function $a(p)\widehat{\Pi} - (a(p)-1)S(p) = 0$ for some $p' \in [\underline{p}, 1)$, then $\Theta(\widehat{\Pi};K) = \infty$. Mathematically, this is obvious if $\widehat{\Pi} > 0$. In economic terms, if $\widehat{\Pi} = \frac{a(p')-1}{a(p')}S(p')$ for some $p' \in [\underline{p}, 1)$, then a banker can *both* charge $R = \infty$ *and* attract all the entrepreneurs by giving them more than $\widehat{\Pi}$. On her deal (p, R), the entrepreneurs coming to her expect to obtain, by (12), $\Pi(R,p) = \frac{(a(p)-1)R}{a(p)R-1}S(p)$, which increases with p, decreases with R, and is thus always bigger than $\frac{a(p)-1}{a(p)}S(p)$, the limit value at $R = \infty$. Therefore, if she offers $p = p' + \epsilon < 1$ and $R = \infty$, the entrepreneurs coming to her get more than $\widehat{\Pi}$: $\Pi(\infty, p'+\epsilon) = \frac{a(p)-1}{a(p)}S(p)|_{p=p'+\epsilon} > \frac{a(p')-1}{a(p')}S(p') = \widehat{\Pi}$, as $\frac{a(\cdot)-1}{a(\cdot)}S(\cdot)$ is increasing.

By the argument above, if $\widehat{\Pi} < \frac{a(1)-1}{a(1)}S(1) = \frac{\bar{q}-q}{\bar{q}}\overline{n}\overline{V}$, then bankers get an infinitely large profit, which is not the case in equilibrium. Thus we are not bothered with the case. On the other hand, by (16), $\widehat{\Pi}$ is not beyond $\frac{\bar{q}-q}{\bar{q}}(\overline{n}\overline{V} + K)$. Therefore, we are concerned with $\widehat{\Pi} \in [\frac{\bar{q}-q}{\bar{q}}\overline{n}\overline{V}, \frac{\bar{q}-q}{\bar{q}}(\overline{n}\overline{V} + K)]$.

Third, $\Theta(\widehat{\Pi};K)$ decreases with $\widehat{\Pi}$ over $\widehat{\Pi} \geq \frac{\bar{q}-q}{\bar{q}}\overline{n}\overline{V}$. Mathematically, the objective of problem (17) decreases with $\widehat{\Pi}$ for any p if $\widehat{\Pi} \geq \max_p \frac{a(p)-1}{a(p)}S(p) = \frac{\bar{q}-q}{\bar{q}}\overline{n}\overline{V}$, and hence so is the the problem's value. Economically, the social value of a project is divided between the entrepreneur and the banker; the bigger the profit to the former, the smaller the surplus to the latter. This decreasing of Θ with $\widehat{\Pi}$ implies:

Lemma 4 *For $\widehat{\Pi} \in (\frac{\bar{q}-q}{\bar{q}}\overline{n}\overline{V}, \frac{\bar{q}-q}{\bar{q}}(\overline{n}\overline{V} + K))$, $\Theta(\widehat{\Pi};K) > 0$ if $\Theta(\frac{\bar{q}-q}{\bar{q}}(\overline{n}\overline{V} + K);K) \geq 0$ and $\Theta(\widehat{\Pi};K) < 0$ if $\Theta(\frac{\bar{q}-q}{\bar{q}}\overline{n}\overline{V};K) \leq 0$.*

By the lemma, if $\Theta(\frac{\bar{q}-q}{\bar{q}}\overline{n}\overline{V};K) < 0$,[9] then $\Theta(\widehat{\Pi};K) < 0$ for all $\widehat{\Pi} \geq \frac{\bar{q}-q}{\bar{q}}\overline{n}\overline{V}$, which, by Lemma 3, implies that $\rho(\widehat{\Pi};K) = 0$, namely no bankers invest in screening expertise.

[9] If $\Theta(\Pi^m;K) = 0$ for some $\Pi^m \in [\frac{\bar{q}-q}{\bar{q}}\overline{n}\overline{V}, \frac{\bar{q}-q}{\bar{q}}(\overline{n}\overline{V} + K))$, then there might be a mixed equilibrium where only a fraction α of bankers invest in screening expertise. In the equilibrium $\widehat{\Pi} = \Pi^m$ and the quality choice of the investing bankers, $\widehat{p}$, solves (17) for this $\widehat{\Pi}$. To find α, note that with the aggregate informed capital being αK instead of K, the equilibrium profit of entrepreneurs, $\widehat{\Pi}$, by (15), is $\frac{a(\widehat{p})-1}{a(\widehat{p})}(S(\widehat{p}) + \alpha K)$; and hence, $\frac{a(\widehat{p})-1}{a(\widehat{p})}(S(\widehat{p}) + \alpha K) = \Pi^m$. If the α so found is between 0 and 1, the mixed equilibrium described above exists.

However, by (16), if $\widehat{p} = 0$, then $\widehat{\Pi} = 0$, which, we saw in the second note, cannot be the case in equilibrium. Therefore,

Proposition 2 *If* $\Theta(\frac{\overline{q}-q}{\overline{q}}\overline{n}\overline{V}; K) < 0$, *then equilibrium does not exists.*

Consider then the case under which $\Theta(\frac{\overline{q}-q}{\overline{q}}(\overline{n}\overline{V} + K); K) \geq 0$, where, we are going to show, the equilibrium uniquely exists. In this case, by lemma 4 $\rho(\widehat{\Pi}; K) > 0$ for $\widehat{\Pi} \in [\frac{\overline{q}-q}{\overline{q}}\overline{n}\overline{V}, \frac{\overline{q}-q}{\overline{q}}(\overline{n}\overline{V} + K))$ and by Lemmas 3, $\rho(\widehat{\Pi}; K)$ solves problem (17).

For $\widehat{\Pi} > \frac{\overline{q}-q}{\overline{q}}\overline{n}\overline{V} = \frac{a(1)-1}{a(1)}S(1)$, if p approaches 1, the the objective function of the problem goes to $-\infty$, because cost $C(p)$ goes to infinite, but the profit goes to a finite number. Therefore, the solution of the problem, $\rho(\widehat{\Pi}; K)$, is internal and satisfies the first order condition:

$$K\widehat{\Pi}\frac{(a(p) - 1)S'(p) - a'(p)(\widehat{\Pi} - S(p))}{[a(p)\widehat{\Pi} - (a(p) - 1)S(p)]^2} = C'(p). \tag{18}$$

The left hand side (LHS), which represents the marginal profit of higher screening quality to a banker, decrease with $\widehat{\Pi}$. Hence, so does the quality choice:

Lemma 5 $\frac{d\rho(\widehat{\Pi};K)}{d\widehat{\Pi}} < 0$.

Proof. See Appendix B. ■

The lemma drives the main propositions of the paper. It arises because a banker's incentive of improving screening quality decreases with the equilibrium profit to entrepreneurs, $\widehat{\Pi}$. Intuitively, from each and every entrepreneur coming to her, she gets the surplus of the social value of his project, $S(p)$, minus the profit she has to surrender him, $\widehat{\Pi}$. Let $N(p, \widehat{\Pi})$ denote the number (or measure) of the entrepreneurs she screens. Then her profit with quality p is $N(p, \widehat{\Pi})(S(p) - \widehat{\Pi})$. Hence the marginal profit is $N_p'(p, \widehat{\Pi})(S(p) - \widehat{\Pi}) + N(p, \widehat{\Pi})S'(p)$, namely both from the expansion of scale ($N_p' > 0$; see below) and from the widening of profit margin. Both benefits are reduced by a higher $\widehat{\Pi}$: For the former, it diminishes the profit margin ($(S(p) - \widehat{\Pi})'_{\widehat{\Pi}} = -1$) and thus reduces the benefit from the scale expansion; for the latter, it shrinks the scale, as $N_{\widehat{\Pi}}' < 0$, and thus reduces the benefit from the margin widening. To see $N_p' > 0$ and $N_{\widehat{\Pi}}' < 0$, note that $N = \frac{K}{\widetilde{I}(p,\widehat{\Pi}))}$, where $\widetilde{I}$ is the expected demand of her capital by an entrepreneur, and

$\widetilde{I}'_p < 0$ and $\widetilde{I}'_{\widehat{\Pi}} > 0$, both driven by the fact, suggested by (5), that the higher the rate charged, the less of bankers' capital is needed for signaling: $\widetilde{I}'_p < 0$ because the higher the screening quality, the higher the rate can be charged; and $\widetilde{I}'_{\widehat{\Pi}} > 0$ because in order to surrender the entrepreneurs more profit, the rate has to be lowered.[10]

For $\widehat{\Pi} = \frac{\overline{q}-\underline{q}}{\overline{q}}\overline{n}\overline{V}$, the solution of (17) $\rho(K, \frac{\overline{q}-\underline{q}}{\overline{q}}\overline{n}\overline{V}) = 1$ if $C'(p) = o(\frac{1}{(1-p)^2})$ for $p \approx 1$[11], because at $\widehat{\Pi} = \frac{\overline{q}-\underline{q}}{\overline{q}}\overline{n}\overline{V}$, for $p \approx 1$, the marginal profit (the LHS of 18) is in the order of $\frac{1}{(1-p)^2}$ and therefore dominates the marginal cost, $C'(p)$, if $C'(p) = o(\frac{1}{(1-p)^2})$.[12]

All in all, if $\Theta(K, \frac{\overline{q}-\underline{q}}{\overline{q}}(\overline{n}\overline{V} + K)) \geq 0$ and $C'(p) = o(\frac{1}{(1-p)^2})$ for $p \approx 1$, $\rho(\widehat{\Pi}; K)$ decrease from 1 to $\rho(K, \frac{\overline{q}-\underline{q}}{\overline{q}}(\overline{n}\overline{V} + K)) \geq 0$ with $\widehat{\Pi}$ rolling over $[\frac{\overline{q}-\underline{q}}{\overline{q}}\overline{n}\overline{V}, \frac{\overline{q}-\underline{q}}{\overline{q}}(\overline{n}\overline{V} + K)]$, the range that we are concerned with. The graph of $\widehat{p} = \rho(\widehat{\Pi}; K)$, which summarizes condition (i), is thus illustrated as follows:

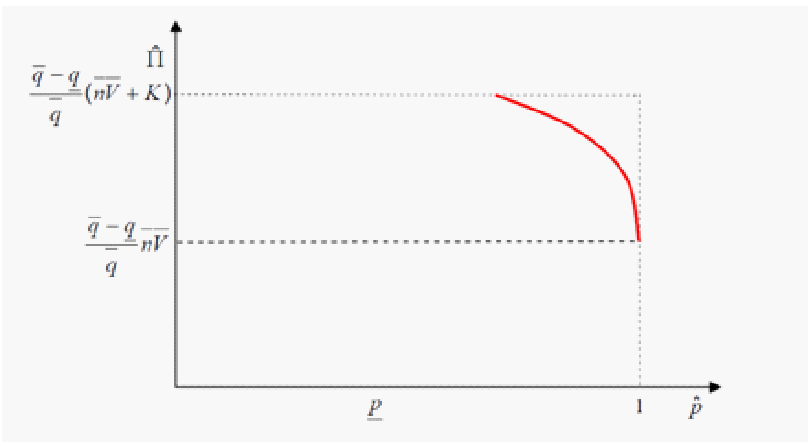

Figure 2: Equation (14) if $\Theta(K, \frac{\overline{q}-\underline{q}}{\overline{q}}(\overline{n}\overline{V} + K)) \geq 0$ and $C'(p)|_{p\approx 1} = o(\frac{1}{(1-p)^2})$

Put together the two equations, namely the two figures above:

[10]Strictly, apply (MapB) to (5) and an evaluated-good entrepreneur demands $\frac{V_g}{Ra-1}$, which times n_g, the probability of getting an good evaluation, gives rise to $\widetilde{I} = \frac{S}{Ra-1}$. Substitute (13) for R and $\widetilde{I} = \frac{a(p)}{a(p)-1}\widehat{\Pi} - (a(p)-1)S(p)$. Thus $\widetilde{I}'_p < 0$ and $\widetilde{I}'_{\widehat{\Pi}} > 0$ by P2 through P4.

[11]Notation $x = o(y)$ for $p \approx 1$ means that $\lim_{p\to 1} \frac{x}{y} = 0$.

[12]On the other hand, if $C'(p)$ is in the order strictly higher that $\frac{1}{(1-p)^2}$, the solution is internal and determined by the first order condition, (18).

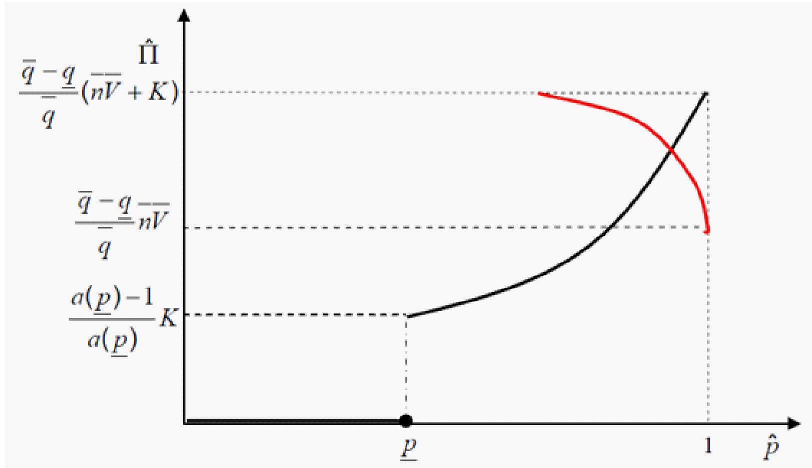

Figure 3: The Existence and Uniqueness of Equilibrium if $\Theta(K, \frac{\bar{q}-\underline{q}}{\bar{q}}(\overline{n}\overline{V}+K)) \geq 0$ and $C'(p)|_{p\approx 1} = o(\frac{1}{(1-p)^2})$

We find equations (14) and (16) has a unique solution. By Lemma 2, the equilibrium exists and is unique.

To summarize:

Proposition 3 *If* $\Theta(\frac{\bar{q}-\underline{q}}{\bar{q}}(\overline{n}\overline{V}+K); K) \geq 0$, *where* $\Theta(\widehat{\Pi}; K)$ *is defined in (17), and* $C'(p) = o(\frac{1}{(1-p)^2})$ *for* $p \approx 1$, *then equilibrium exists and is unique.*

In economic terms, banker face two constraints, the incentive compatibility constraint (IC), and the individual rationality constraint (IR). The IC is summarized by the first order condition (18). And the IR is that bankers get more by investing in screening expertise than by not investing at all and being uninformed. Both conditions that $\Theta(K, \frac{\bar{q}-\underline{q}}{\bar{q}}(\overline{n}\overline{V}+K)) \geq 0$ and that $C'(p) = o(\frac{1}{(1-p)^2})$ require cost function $C(\cdot)$ does not increase too fast so that the IR can be met. However, note that no bankers investing is *not* in equilibrium, because then $\widehat{\Pi} = 0$ and as we noted following Lemma 3, a banker gets an infinitely large profit by providing screening service of quality a little higher than $\underline{p}$.

The next subsection characterizes the unique symmetric equilibrium, when it exists.

3.4 The Characterization of the Equilibrium

If the equilibrium exists, then the equilibrium quality of screening, $\widehat{p}$, satisfies the first order condition (18) and $\widehat{\Pi} > 0$. By (16), $\widehat{\Pi} = \frac{a(\widehat{p})-1}{a(\widehat{p})}(S(\widehat{p}) + K)$. Substituting it into (18), we find $\widehat{p}$ satisfy:

$$\frac{1}{a(\widehat{p})}(\frac{S(\widehat{p})}{K} + 1)(S'(\widehat{p}) + \frac{a'(\widehat{p})}{a(\widehat{p})}(\frac{S(\widehat{p})}{a(\widehat{p}) - 1} - K)) = C'(\widehat{p}) \tag{19}$$

It implicitly defines $\widehat{p}$ as a function of K.

The LHS term measures the equilibrium incentive of investing in screening expertise. It decreases with K (as $S(\widehat{p}) > 0$ and $a'(\cdot) > 0$), which suggests that the equilibrium quality $\widehat{p}$ decreases with K.

Lemma 6 $\frac{d\widehat{p}}{dK} < 0$*, that is, the equilibrium quality of screening decreases with* K*.*

Proof. See Appendix B. ■

The lemma together with $q_g'(p) > 0$ (by P1) implies that $\frac{d(1-q_g(\widehat{p}))}{dK} > 0$, that is, the default probability of the projects invested by bankers (namely the evaluated good projects), $1- q_g(\widehat{p})$, increases with K. Note that K denotes both the individual stock and aggregate stock of bankers' capital. Hence, an increase by one unit of K means that each and every banker increases her capital stock by one unit. From Lemma 7, therefore, it follows:

Proposition 4 *Suppose the quality of screening service of bankers depends on costly investments. If each and every banker's capital increases by one unit, then in equilibrium the quality of screening service goes down and the default risks of all the bankers' assets go up.*

To intuitively understand this comparative static result, note that an increase by one unit in each and every banker's capital generates two effects upon the equilibrium incentive of improving screening quality.

One is *the partial equilibrium effect*: The more capital a banker controls, the more extra profit she earns from an increment in the interest rate, *given the market conditions* *which is summarized by* $\widehat{\Pi}$, and hence the bigger the incentive of improving screening quality so as to charge a higher rate. This effect is captured by the first order condition (18): Given $\widehat{\Pi}$, the LHS term, which represents the incentive, is in proportion to K.

The other is *the general equilibrium effect*: The bigger the aggregate stock of the informed capital (K), the higher the equilibrium profit to entrepreneurs ($\widehat{\Pi}$) (by 16); and then the worse the market conditions to bankers, and the smaller is their incentives of investing in screening expertise, as is captured by Lemma 5 and the discussion thereafter.

The two effects are thus in conflict. In net, Lemma 6 asserts, the latter dominates and hence the equilibrium screening quality decreases with the size of the banking sector.

The proposition suggests that across economies, the bigger the banking sector relative to the GDP (which can be proxied by $\overline{n}\overline{V}$), the bigger the default risks of the sector's assets.

On the other hand, within a given economy, where the market conditions (namely $\widehat{\Pi}$) are fixed and the same to all the banks and hence only the partial equilibrium effect presents itself, a bank's incentive of improving screening quality is in proportion to the capital stock under its control. Therefore, the bigger the bank, the higher the quality of its screening service and the smaller the default risk of its assets. Furthermore, by (13), the expected rate charged, R, increases with the screening quality, p. It follows that the bigger the bank, the higher the *expected* rate charged. But note that the book rate, $\frac{R}{q_g}$, might decreases with p, because q_g increases with p also. To summarize,

Empirical Prediction A: Across banks within a given economy, the bigger the bank, the higher the screening quality; and hence the smaller the default risk of its assets and the higher the expected rate charged (but not necessarily the higher the book rate).

Empirical Prediction B: Across economies, however, the bigger the banking sector (relative to the GDP), the bigger the default risks of its assets.

3.5 The Efficiency of the Equilibrium

By Proposition 1, there are no concerns of ex post efficiency: After the screening quality is sunk, all the socially efficient projects are financed. As for ex ante efficiency, the equilibrium quality, characterized by (19), is to be compared with the choice of the social planner, under certain circumstances.

The first best arrangement is that only one banker invests in screening expertise and then uses it to evaluate all the projects, of measure 1×1. This arrangement, however, does respect the friction that certain *verifiable* amount of the banker's capital is needed to communicate each and every good evaluation, as it allocates each entrepreneur almost \$0 of the banker's capital.[13]

To respect the friction, we move on to the second best arrangement in which the social planner allocates to each banker the same number of entrepreneurs as she serves in the equilibrium, namely, a continuum of measure 1, and chooses screening quality for her. If the quality chosen is p, then the screening service generates social value $S(p)$ out of the continuum of measure 1 of projects, while the social cost of obtaining the quality is $C(p)$. The social planner's problem is therefore[14]

$$\max_{0 \leq p \leq 1} S(p) - C(p).$$

The second best choice of quality, denoted by p^*, thus satisfies the following first order condition:

$$S'(p^*) = C'(p^*). \tag{20}$$

To compare p^* with the equilibrium quality, $\widehat{p}$, rewrite equation (19) that characterizes it. In the equilibrium all bankers choose the same quality $\widehat{p}$. The equilibrium return rate of bankers' capital, by (13), is $\widehat{R} = R(\widehat{p}, \widehat{\Pi}) = \frac{\widehat{\Pi}}{a(\widehat{p})\widehat{\Pi} - (a(\widehat{p})-1)S(\widehat{p})}$. Substitute $\widehat{\Pi} = \frac{a(\widehat{p})-1}{a(\widehat{p})}(S(\widehat{p}) + K)$ (by 16), then

$$\widehat{R} = \frac{1}{a(\widehat{p})}(\frac{S(\widehat{p})}{K} + 1). \tag{21}$$

(This equation could also be derived by applying (MapE) to (8) which gives the equilibrium return rate in Section 2.) From this equation, it follows that $S(\widehat{p}) = (a(\widehat{p})\widehat{R} - 1)K$.

[13] Use the example of measure 1 equivalent to 1,000, mentioned at the beginning of Section 2. The banker has several thousands of dollars of capital, but there are one million entrepreneurs. Therefore, each entrepreneur is allocated with such a small amount of the banker's capital that the investment of it is unverifiable to laymen and hence unfitting for the signaling role.

[14] Note that when the equilibrium exists, the value of this problem is positive, that is, the IR constraint of the social planner is always satisfied, because in the equilibrium, the value to each banker is positive, while she only gets part of the social value, the rest got by the entrepreneurs.

Substitute it for $S(\widehat{p})$ in (19), and $\widehat{p}$ is then characterized by

$$\widehat{R}(S'(\widehat{p}) + \frac{a'(\widehat{p})K}{a(\widehat{p})-1}(\widehat{R}-1)) = C'(\widehat{p}). \tag{22}$$

Now it is easy to compare p^* with $\widehat{p}$. When equilibrium exists, $\widehat{R} > 1$; otherwise, there would be not profitable for bankers to invest in screening expertise and hence $\widehat{\Pi} = 0$, which, as was noted following Lemma 3, could not be the case in equilibrium. And $\frac{a'(\widehat{p})}{a(\widehat{p})-1} > 0$ (by P2 and P3). Hence, the LHS of (22) is always bigger than that of (20). The following is thus suggested.

Proposition 5 $\widehat{p} > p^*$, *namely, bankers overinvest in screening expertise.*

Proof. Let $\eta \equiv \frac{a'(\widehat{p})K}{a(\widehat{p})-1} > 0$ be a constant and $p(x)$ be the function implicitly defined by $U(x,p) \equiv x(S'(p) + \eta(x-1)) - C'(p) = 0$ for $x \geq 1$. Then, $p(1) = p^*$ and $p(\widehat{R}) = \widehat{p}$. The proposition is equivalent to $p'(x) > 0$. By implicit function theorem, $p'(x) = -\frac{U'_x}{U'_p}$. Obviously $U'_x > 0$. And $U'_p = xS'' - C'' \leq -C'' < 0$, where "$\leq$" is because $S'' \leq 0$ (by P4). ■

For an intuition of the proposition, let us go back to the discussion following Lemma 5. There we shew that to each banker, improved screening quality brings two benefits, one from the expansion of scale, the other from the widening of profit margin, $S(p) - \widehat{\Pi}$. As $(S(p) - \widehat{\Pi})' = S'(p)$, the latter is exactly the same as the benefit it brings to the social planer. However, to the social planner, the former benefit is not accrued: For her, the scale, namely the number of entrepreneurs allocated to each banker, is fixed. Therefore, it is the benefit of seizing more entrepreneurs through higher-quality screening service that drives bankers to overinvest in screening expertise.

Put differently, in the competition for entrepreneurs bankers fail to take into account a negative externality, that the increase in one banker's screening quality marginally raises the equilibrium profit to entrepreneurs, $\widehat{\Pi}$, which damps all the other bankers' incentives of improving screening quality (by the discussion following Lemma 5). With $\widehat{\Pi}$ playing the role of price, the externality is in the spirit of fire sale externality: The fire sale by one agent marginally damps the asset price, and thus tightens all the others' financial constraints.

Essential to the proposition is the feature that bankers' capital is mainly used for signaling purpose and the investments of the projects are mainly funded by laymen's capital. Should the sector of laymen not be there, an entrepreneur's demand of the banker's capital would be fixed at $\$B$, the investment need, and hence the banker would serve a measure $\frac{K}{B}$ continuum of entrepreneurs, whatever her screening quality. Thus, improved screening quality would bring to her no benefit of seizing more entrepreneurs, nor would the overinvestment result arise.

3.6 The Unobservability of Screening Quality

Above we assume every banker's screening quality is publicly observed. This assumption is made because it reasonably captures real life, and because the alternative assumption, that the quality is private information of the banker, entails serious theoretical difficulties.

For several reasons, it is reasonable to believe that a bank's screening quality is public information in real life. First, this quality could be recovered from the data of its balance sheet, particularly the default rate of the loans it made to the real sectors. Second, it is reflected in the reputation of the bank, particularly their reputation of hunting good deals. Third, if the spending in screening expertise consists mainly in hiring talented people, the movement of top bankers is often exposed by the media.

If the quality is assumed private information of the banker, the major difficulty is that the equilibrium will be very sensitive to off equilibrium assumptions. Suppose a banker thinks all the other bankers obtain quality $\widehat{p}$. For it to be the equilibrium quality, the banker must get more from obtaining the same quality, $\widehat{p}$, than from obtaining an off-equilibrium quality. The off-equilibrium profit, however, is very sensitive to what is assumed on how the banker invests her residual capital if she could not find enough evaluated good projects from the entrepreneurs coming to her in equilibrium.[15] Two

[15] If p is private information, in and off the equilibrium path, the banker screens a measure 1 continuum of entrepreneurs, of whom $n_g(p)$ are evaluated good, each demanding $\$I(\widehat{p}^e)$, such that $n_g(\widehat{p})I(\widehat{p}) = K$. Note the demand only depends on $\widehat{p}^e$, laymen's rational expectation of $\widehat{p}$ (all this is to convince them) and hence does not change with the actual screening quality of the banker. Therefore, if $n_g(p) < n_g(\widehat{p})$, the overall demand of her capital by all the evaluated good entrepreneurs, $n_g(p)I(\widehat{p})$, is smaller than K and she needs to consider how to invest the residual $K - n_g(p)I(\widehat{p})$ units of her capital. By contrast, if p is publicly observed, as we studied, in the subgame where $n_g(p) < n_g(\widehat{p})$, there will be measure α

possibilities have been explored. One is that the banker could lower the book rate a little, by which she attracts more entrepreneurs than is supposed in equilibrium (a continuum of measure 1); the other is that she has to invest the residual capital in the risk free asset. The two assumptions lead to opposite results.[16]

Another difficulty in connection with the assumption of the quality being private information is that however a banker invests her residual capital, if she obtains an off-equilibrium quality, her asset will be different from that of all the other bankers (who obtain the equilibrium quality). Then what stops laymen (and entrepreneurs) inferring from this difference her actual quality? If they do, the quality will, in effect, become observable to laymen and entrepreneurs, as was assumed.

So far, bankers do not borrow from laymen and all the capital they invest are their own; they are hence not susceptible to risk shifting problems. This enables us to focus on the ex ante investment in screening expertise. The next section extends the model to examine the leverage of bankers, namely, their borrowing from laymen, by which they do financial intermediation. The purpose is to see how the ex ante and ex post problems interact and what is the efficiency of financial intermediation in this setting.

For this exercise, the issue of correlation between the projects needs to be clarified. The analysis hitherto does not depend on whether the risks of the projects are independent, thus diversifiable, or not. The issue becomes important when we consider the leverage of bankers. A banker finances a continuum of projects and issues debt contracts to laymen.[17] If the projects are independent, the risks on her asset side will be diversified away, the debt contract will be risk free, and no risk shifting problems will arise. On the contrary, if they are subject to a common, undiversifiable risk, her assets will be risky and risk shifting will be a concern. Hence, for the purpose of the exercise, the latter is assumed.

Specifically, there are three possible states of the world, $\{\phi, b, g\}$, with probability $1-\overline{q}, \overline{q}-\underline{q}$, and $\underline{q}$. In state ϕ, no projects succeed; in state b, only high type projects

continuum of entrepreneurs coming to the banker such that $\alpha n_g(p)I(p) = K$, that is, the overall demand of her capital equals K.

[16] The detailed analysis could be obtained upon request.

[17] In the paper, bankers are assumed not to issue outside equities to laymen, possibly due to some friction of costly state verification in the manner of Townsend (1979), Diamond (1984), and Gale and Hellwig (1985).

succeed and low types fail; and in state g, all the projects succeed. So a high type project succeeds in both state b and g, thus with probability $\overline{q}$, and a low type succeeds in state g only, thus with probability $\underline{q}$.

4 Extension: The Leverage of Bankers and the Efficiency of Financial Intermediation

Financial intermediation arises naturally in the economy. On becoming informed, bankers earn a return rate above 1, the rate of the informed capital, on the asset side, while they repay return rate 1, the rate of the uninformed capital, to laymen on the liability side. The rate gap gives the profit margin of doing financial intermediation. In fact, individual bankers take this profit margin as given, and so long as it is positive, they want to borrow as much as possible. If this borrowing were unconstrained, it would expand the informed capital so much that the profit margin eventually disappears. As a result, bankers would have no incentive to become informed, by which the banking sector altogether would collapse. This prospect, fortunately, does not realize, because borrowing is constrained by the risk shifting problem, explained below.

The Risk Shifting Problem and Leverage Ratio

Consider a banker who first borrows D units capital from laymen at book rate f (namely, the total face value of the debt is Df), then obtains quality p, and finally charges expected return rate R. The risk shifting problem occurs at the stage of financing entrepreneurs. When the level of debt, D, is too high, as Jensen and Meckling (1976) for the first time show, the banker could invest in evaluated bad projects at a lower expected return rate but a higher book rate than would be obtained by investing in evaluated good projects.

The expected return rate of investing in the evaluated good projects, which succeed with probability q_g, is R. Hence the book rate of the investment is $F = \frac{R}{q_g}$. Let F' be the book rate the banker obtains by investing in an evaluated bad project, which succeeds with probability q_b. The book rate is to be negotiated between her and the entrepreneur and lies somewhere between F and $\frac{q_g F}{q_b}$: On the one hand, the banker does not accept any

$F' < F$; on the other hand, at $F' = \frac{q_g F}{q_b}$, by the argument leading to (4), the entrepreneur gets nothing from mimicking. Let the bargaining power of the banker be $1 - \alpha$ and that of the entrepreneur be α. Then,

$$F' = ((1-\alpha)\frac{q_g}{q_b} + \alpha)F. \tag{23}$$

Suppose the banker invests M out of $K + D$ units of capital under her control (K of her own and D borrowed) in evaluated bad projects and $K + D - M$ in evaluated good ones. The prospect is then as follows.

In state ϕ, no projects succeed and no one gets anything.

In state b, high type projects succeed, but low type projects fail. Out of all the evaluated good projects, the proportion of high types is $\Pr(\widetilde{q} = \overline{q} | \widetilde{s} = g) = \frac{\overline{n}}{n_g}$ where, with (11), $n_g = \overline{n} + \underline{n}(1-p)$ is the probability of obtaining a good evaluation, while the proportion out of the evaluated bad projects is $\Pr(\widetilde{q} = \overline{q} | \widetilde{s} = b) = 0$.[18] When a high type (which is always evaluated good) succeeds, it returns to the banker \$$F$ for each dollar invested. Hence, in state b, by the law of large numbers proportion $\frac{\overline{n}}{n_g}$ of the investment in the evaluated good projects succeeds, while none of the investment in the evaluated bad projects does, which altogether gives her revenue $(K + D - M) \cdot \frac{\overline{n}}{n_g} \cdot F + M \cdot 0 \cdot F'$. And her liability is Df. Her profit is then:

$$\max\{(K + D - M)\frac{\overline{n}}{n_g}F - Df, 0\}$$

In state g, all her projects succeed. A dollar invested in an evaluated good project returns \$$F$ and a dollar invested in an evaluated bad one returns \$$F'$. Hence the banker's profit is

$$(K + D - M)F + MF' - Df$$

Altogether, her expected profit, by investing M units capital in the evaluated bad projects, is $\Theta(M) = (\overline{q} - \underline{q}) \max\{(K+D-M)\frac{\overline{n}}{n_g}F - Df, 0\} + \underline{q}((K+D-M)F + MF' - Df)$. She chooses M to maximize this profit.

If M is small enough such that $(K + D - M)\frac{\overline{n}}{n_g}F - Df \geq 0$, then debt holders are not exploited and the banker optimally chooses $M = 0$. Mathematically, $\Theta(M) =$

[18] In this section we explicitly use (11) to illustrate the analysis. However, for any binary evaluation technology that satisfies properties P1 through P4 laid out in Subsection 3.1, the same condition (24) would be derived and the whole analysis would carry on.

$(K+D)q_gF - M(q_gF - \underline{q}F') - D \cdot \overline{q}f$ and is maximized at $M = 0$, because $q_gF > \underline{q}F'$ by (23).

Otherwise if $(K + D - M)\frac{\overline{n}}{n_g}F - Df < 0$, then debt holders are exploited and the banker's optimal choose is $M = K + D$. Mathematically, $\Theta(M) = \underline{q}((K+D)F + M(F' - F) - Df)$ and is maximized at $M = K + D$ because $F' > F$ by (23).

Therefore, $\Theta(M)$ is maximized either at $M = 0$ or $M = K + D$. To prevent the banker from investing in the evaluated bad projects, it commands $\Theta(0) \geq \Theta(K + D)$, or equivalently, $(K + D) \cdot q_gF - D \cdot \overline{q}f \geq (K + D)\underline{q}F' - D\underline{q}f$. Substitute (23) for F' and remember $q_b = \underline{q}$ with (11). The risk shifting problem commands the following upper bound on the leverage ratio of bankers.

$$\frac{D}{K} \leq \frac{\alpha(q_g - q_b)F}{(\overline{q} - \underline{q})f - \alpha(q_g - q_b)F}(p^e) \equiv L(p^e), \tag{24}$$

where q_g, q_b, and F are functions of p^e, laymen's expectation of the quality that the banker is going to choose, because borrowing is assumed to occur before the investment in screening expertise is made.[19]

The argument above shows also that, so long as bankers do not invest in any evaluated bad projects, their debt is fully repaid in both states g and b, thus with probability $\overline{q}$. Laymen are satisfied with expected return rate 1, that is, $\overline{q}f = 1$. Hence:

$$f = \frac{1}{\overline{q}}. \tag{25}$$

The Charaterization of Equilibrium with Leverage When It Exists

As was seen at the beginning of the section, each banker wants to borrow as much as possible, so long as $R = q_gF > 1$, namely, as there is a positive rate gap, which is the case when equilibrium exists. Therefore, each banker borrows to the upper bound with $D = K \cdot L(p^e)$ and the stock of capital under her control becomes

$$K + D = K(1 + L). \tag{26}$$

[19]If borrowing occured after the investment (but before the charging of rate), then D would be a function of p (namely $D = KL(p)$) in the banker's problem of choosing the quality (see 27). The results would be qualitatively the same, though the analysis would be more complex. The detailed analysis could be obtained upon request.

By the discussion above, if the constraint for risk shifting, (24), is honored, a banker invests in good projects only and gets economic profit $(K+D)\cdot q_g F - D\cdot \overline{q}f - K$. The expected rate charged, $R = q_g F$, as was in Section 3, gives the entrepreneurs coming to her the equilibrium profit $\widehat{\Pi}$, which implies $R = \frac{\widehat{\Pi}}{a(p)\widehat{\Pi}-(a(p)-1)S(p)}$ (by 13). Suppose the equilibrium exists, namely, bankers invest in screening expertise. Then, their problem of choosing quality p is

$$\max_p (K+D)\cdot \frac{\widehat{\Pi}}{a(p)\widehat{\Pi}-(a(p)-1)S(p)} - D\cdot \overline{q}f - K - C(p). \tag{27}$$

The optimal quality satisfies the same first order condition as (18), except capital stock under her control is now $K+D$ instead of K then, that is,

$$(K+D)\widehat{\Pi}\frac{(a(p)-1)S'(p)-a'(p)(\widehat{\Pi}-S(p))}{[a(p)\widehat{\Pi}-(a(p)-1)S(p)]^2} = C'(p). \tag{28}$$

Given $\widehat{\Pi}$, namely, within an given economy, the bigger the banker's asset (i.e. $K+D$), the bigger the marginal profit of higher screening quality, represented on the LHS of (28), and the higher the quality chosen (i.e. p), which confirms Empirical Prediction A above. Furthermore, note that $L = \frac{\alpha(q_g-q_b)F}{(\overline{q}-\underline{q})f-\alpha(q_g-q_b)F}$ increases with $\alpha(q_g-q_b)$, which in turn increases with p^e. And in equilibrium $p^e = p$. Therefore, we have the following empirical prediction:

Empirical Prediction C: The bigger the bank, the higher the leverage ratio.

This link between the size and leverage is empirically documented by Liang and Rhoades (1991), McAllistera and McManus (1993), Akhavein et al. (1997), Demsetz and Strahan (1997), and Berger (1998).

Having examined the quality choice of individual bankers, we move to determine the equilibrium profit to entrepreneurs, $\widehat{\Pi}$, which summarizes the market conditions. As each and every banker borrows D, the aggregate stock of capital under bankers' control is now $K+D$ instead of K. Substitute $K+D$ for K in (16) (and conditional on the existence of equilibrium), the equilibrium profit of entrepreneurs is

$$\widehat{\Pi} = \frac{a(\widehat{p})-1}{a(\widehat{p})}(S(\widehat{p})+K+D). \tag{29}$$

Here $\widehat{p}$ is the equilibrium screening quality.

Note that both in (28) and in (29), the borrowed capital D plays the same role as the equity capital K. Thus, the ex ante investment in screening expertise depends only on the asset sizes of bankers, not on the composition of their liabilities.

Put (28) and (29) together. The same characterization of equilibrium quality as (19) is derived, except that the capital stock is $K + D$ now instead of K then:

$$\frac{1}{a(\widehat{p})}(\frac{S(\widehat{p})}{K+D}+1)(S'(\widehat{p})+\frac{a'(\widehat{p})}{a(\widehat{p})}(\frac{S(\widehat{p})}{a(\widehat{p})-1}-K-D))=C'(\widehat{p}) \quad (30)$$

To complete the characterization of the equilibrium, move on to find the equilibrium leverage ratio. By rational expectation, $p^e = \widehat{p}$. And $\widehat{F} = \frac{\widehat{R}}{\widehat{q}_g}$. The equilibrium return rate of the informed capital, $\widehat{R}$, by (21) (again with K replaced with $K + D$) is:

$$\widehat{R} = \frac{1}{a(\widehat{p})}(\frac{S(\widehat{p})}{K+D}+1)$$

This together with (24), (25), (26), and $p^e = \widehat{p}$, gives the following leverage ratio in equilibrium:

$$L = \frac{\alpha(\widehat{a}-1)(\frac{\widehat{S}}{K}+1)}{\frac{\overline{q}-q}{\overline{q}}\widehat{a}^2-\alpha(\widehat{a}-1)} \quad (31)$$

Note that the dominator is always positive: $\frac{\overline{q}-q}{\overline{q}}\widehat{a}^2 - \alpha(\widehat{a}-1) > \frac{\overline{q}-q}{\overline{q}}\widehat{a}^2 - (\widehat{a}-1) = (1-\frac{1}{a(1)})\widehat{a}^2 - (\widehat{a}-1) = \widehat{a}[\frac{a(1)-1}{a(1)}\widehat{a} - \frac{\widehat{a}-1}{\widehat{a}}] > \frac{a(1)-1}{a(1)} - \frac{\widehat{a}-1}{\widehat{a}} > 0$ because $\{\frac{a(\cdot)-1}{a(\cdot)}\}' > 0$.

Altogether, the equilibrium (D, L, p) is characterized by simultaneous equations of (26), (30), and (31). Denote by $\widehat{p}^L$ the equilibrium quality with leverage. Compare $\widehat{p}^L$ with $\widehat{p}$ (the equilibrium quality without leverage) and p^* (the second best choice examined in Subsection 3.5) below.

On the one hand, $\widehat{p}^L < \widehat{p}$: Leverage expands the stock of the informed capital, which, by Lemma 6, lowers the equilibrium quality. Mathematically, equation (30), which determines $\widehat{p}^L$, can be derived from (19), which determines $\widehat{p}$, by substituting $K + D$ for K; $K + D > K$; and hence by Lemma 6, $\widehat{p}^L < \widehat{p}$.

On the other hand, $\widehat{p}^L > p^*$ still, that is, bankers still over-invest. The result holds, as we saw in Subsection 3.5, so long as $\widehat{R} > 1$, which is true if the equilibrium exists, otherwise no bankers have incentives of investing in screening expertise at all, which cannot occur in equilibrium. The social planner, therefore, wants to push down the equilibrium quality as much as possible, and hence picks the maximum leverage ratio commanded by the risk shifting problem. That is, the planner chooses the equilibrium leverage ratio. To sum up:

Proposition 6 *By placing more capital under bankers' control, leverage lowers down the equilibrium quality of screening and thereby improves the ex ante efficiency. The social planner picks the equilibrium leverage ratio, as is stated in (31).*

The proposition suggests that so far as the ex post risk shifting problem is contained, then bankers are not overleveraged. Therefore, capital adequacy regulation should target ex post risk shifting rather than ex ante overinvestment in screening expertise. In the paper, no such regulation is called up, because it assumes laymen are perfectly rational and there are no government provided insurance for bankers' liabilities.[20] If either is not true, capital adequacy regulation might be needed to protect laymen (who are usually small depositors), according to Dewatripont and Tirole (1994), or to protect tax-payers.

5 Conclusion

The paper examines the signaling role of bank finance and based on it the effects of banks' asset sizes on their asset risks and on social efficiency. It is built on the interaction between their human capital of providing screening service and their physical capital: On the one hand, to provide the service, banks need to commit their physical capital; on the other hand, the more capital under their control, the higher profit they earn by providing higher quality screening service, by which the asset size is related to the quality choice. The paper finds competition plays different roles after and before banks invest in screening expertise. Ex post, competition drives the social best allocation: However scarce the capital of the banking sector, competition drives the price of its capital at such a level where all the socially efficient projects are sorted out and financed. However, ex ante, competition for entrepreneurs through higher quality screening service drives banks to over-spend in screening expertise. If the spending consists mainly in taking in financial geniuses, then this over-spending result suggests that the banking sector over-pays its staff and thereby sucks in too much and too good human talent. A payment cap universally imposed on the banking sector could curb the over-spending and improve social efficiency.

[20] A justification for the insurance could be found in Diamond and Dybvig (1983), and Gorton and Pinnachhi (1990).

Appendix

A: Signaling through Bank Finance: The Case of a Continuum of Types

This appendix is used to show that all the claims (i) to (v) of Proposition 1, with proper adjustment of the statements, hold true for the case of a continuum of types.

Suppose here and now that the probability of success of projects atomlessly distributes over $[0, 1]$ with p.d.f being $g(\cdot)$ and c.d.f being $G(\cdot)$; and in all the other respects the setting is the same as that presented in Section 2, especially, bankers perfectly observe an entrepreneur's type, namely, his probability of success, q, and entrepreneurs demand certain quantity of the informed capital, denoted by I, to signal their types. We are going to show that in equilibrium all the socially efficient projects are separately sorted out.

An equilibrium consists of a profile of $(q(I), R)$, such that (a): if laymen believe that an entrepreneur who demands I are of quality (namely success probability) $q(I)$, then this belief is rationalized, namely, indeed the entrepreneurs of type q finds it optimal to demand I such that $q(I) = q$; and (b): Given such demands by entrepreneurs, R clears the market for the informed capital.

Let $\underline{q} = \frac{B}{Z}$. That is, a project of type q is socially efficient, if and only if $q > \underline{q}$. The assumption of the scarcity of the informed capital now takes the form

$$K < \int_{\underline{q}}^{1} B \cdot g(q)dq = B(1 - G(\underline{q})). \tag{A1}$$

That is, the informed capital alone is not enough to finance all the efficient projects, and to finance them, therefore, laymen's capital is necessary.

Lemma A1: In equilibrium, the demand of the informed capital by type q entrepreneurs is $I(q) = \begin{cases} B(1 - (\underline{q}/q)^{\frac{1}{R-1}}), \text{ if } q \geq \underline{q} \\ 0, \text{ if } q < \underline{q} \end{cases}$, that is, $q(I) = \underline{q}(\frac{B}{B-I})^{R-1}$ for $I > 0$ and $q \leq \underline{q}$ (namely, inefficient) for $I = 0$; and R is the unique root of

$$K = \int_{\underline{q}}^{1} B[1 - (\underline{q}/q)^{\frac{1}{R-1}}] \cdot g(q)dq \equiv \lambda(R). \tag{A2}$$

And $R > 1$ under Assumption (A1).

Proof: Given laymen's belief, $q(I)$, and the return rate of the informed capital, R, if an entrepreneur of type $q > \underline{q}$ comes to a banker and demands $\$I$ of her capital, the banker, as knowing his type, will charge book rate $\frac{R}{q}$ for the loan to him, so its face value is $\$\frac{RI}{q}$; and with this amount of the informed capital, laymen believe he is of type $q(I)$ and accept book rate $\frac{1}{q(I)}$ for financing the shortfall $\$B-I$. Hence, a type q entrepreneur's decision problem of choosing the amount of the informed capital is

$$\max_{I\geq 0} Z - \frac{RI}{q} - \frac{B-I}{q(I)}.$$

We am going to check soon that given equilibrium belief $q(I)$, the objective is concave of I. Hence the solution satisfies the first order condition:

$$-\frac{R}{q} + \frac{1}{q(I)} + \frac{(B-I)q'(I)}{q(I)^2} = 0. \tag{A3}$$

The rational expectation of laymen commands

$$q(I) = q.$$

Substitute it into (A3), and find $q(I)$ satisfies the following differential equation:

$$\frac{q'(I)}{q} = \frac{R-1}{B-I}.$$

For the equilibrium, the initial condition is

$$I(\underline{q}) = 0.$$

In together,

$$q(I) = \underline{q}(\frac{B}{B-I})^{R-1}. \tag{A4}$$

Check further two things with this belief function.

First, with this function and $R > 1$, the entrepreneur's objective function above is indeed concave: Its concavity is the same as that of $-\frac{B-I}{\underline{q}(\frac{B}{B-I})^{R-1}}$, so the same as that of $-(B-I)^R$, which is concave with respect to I for $R > 1$.

Second, with this function $q(I)$, for any $q < \underline{q}$, a type q entrepreneur's optimal choice is $I = 0$, namely,

$$Z - \frac{RI}{q} - \frac{B-I}{q(I)} \leq 0 \text{ for any } I \geq 0 \text{ if } q < \underline{q}. \tag{A5}$$

Substitute (A4) into it, the inequality is equivalent to $Z - \frac{RI}{q} - \frac{(B-I)^R}{qB^{R-1}} \leq 0 \Leftrightarrow$

$$\underline{q}Z \leq \frac{\underline{q}RI}{q} + \frac{(B-I)^R}{B^{R-1}} \tag{A6}$$

The RHS term's derivative with respect to I equals $R(\underline{q}/q - (\frac{B-I}{B})^{R-1}) \geq 0$, since $R > 1$ and $\underline{q}/q > 1 \geq (\frac{B-I}{B})^{R-1}$ for any $I \geq 0$ if $q < \underline{q}$. The RHS of (A6), therefore, is minimized at $I = 0$ with value B. Hence (A5) is implied by $\underline{q}Z \leq B$, which holds true with equality by the definition of $\underline{q}$.

Therefore, given $R > 1$, the demand of the informed capital is

$$I(q) = \left\{ \begin{array}{c} B(1 - (\underline{q}/q)^{\frac{1}{R-1}}), \text{ if } q \geq \underline{q} \\ 0, \text{ if } q < \underline{q} \end{array} \right\}.$$

Given this demand function, the aggregate demand of the informed capital is

$$\int_{\underline{q}}^{1} B(1 - (\underline{q}/q)^{\frac{1}{R-1}}) \cdot g(q)dq \equiv \lambda(R)$$

And the aggregate supply is K. Thus, the market clearing commands: $K = \lambda(R)$, which is (A2). Note that $\lambda' = \frac{-1}{(R-1)^2}\int_{\underline{q}}^{1} B(\underline{q}/q)^{\frac{1}{R-1}} \log q/\underline{q} \cdot g(q)dq < 0$, as $\log q/\underline{q} > 0$ for $q > \underline{q}$. Hence R is uniquely determined by (A2) and λ is maximized at $R = 1$ with value $\int_{\underline{q}}^{1} B \cdot g(q)dq$. Therefore, if $K < \int_{\underline{q}}^{1} B \cdot g(q)dq$, then $R > 1$.

Q.E.D.

By the lemma, all the efficient projects are sorted out by a proper amount of bank finance, however scarce it is. Actually, $q'(I) > 0$, that is, the larger the amount of bank finance obtained, the higher the quality signaled, and the lower the book rate ($\frac{R}{q}$). So are claims (i) and (ii) of Proposition 1 proved.

As for claim (iii): It is equivalent to $\frac{dR}{dK} < 0$. By (A2) and the implicit function theorem, $\frac{dR}{dK} = \frac{1}{\lambda'(R)} < 0$, since $\lambda'(R) < 0$ as was shown above.

As for claim (iv): It is sufficient to show that the aggregate economic profit of the banking sector decreases with K, namely, $\frac{dK(R-1)}{dK} < 0$, which is equivalent to $\frac{dK(R-1)}{dR} > 0$, with $K = \lambda(R)$. As was calculated, $\lambda' = \frac{-1}{(R-1)^2}\int_{\underline{q}}^{1} B(\underline{q}/q)^{\frac{1}{R-1}} \log q/\underline{q} \cdot g(q)dq$. Then, $\frac{dK(R-1)}{dR} = \frac{d\lambda(R)(R-1)}{dR} = \lambda(R) + (R-1) \cdot \lambda'(R) = \int_{\underline{q}}^{1} B(1 - (\underline{q}/q)^{\frac{1}{R-1}}) \cdot g(q)dq - (R-1) \cdot \frac{1}{(R-1)^2}\int_{\underline{q}}^{1} B(\underline{q}/q)^{\frac{1}{R-1}} \log q/\underline{q} \cdot g(q)dq = B\int_{\underline{q}}^{1}\{1 - (\underline{q}/q)^{\frac{1}{R-1}}(1 + \frac{1}{R-1}\log q/\underline{q})\} \cdot g(q)dq$, which is positive if $1 - (\underline{q}/q)^{\frac{1}{R-1}}(1 + \frac{1}{R-1}\log q/\underline{q}) > 0$ for any $q/\underline{q} > 1$, or equivalently, if $1 > (\underline{q}/q)^{\frac{1}{R-1}}(1 + \frac{1}{R-1}\log q/\underline{q}) \Leftrightarrow (q/\underline{q})^{\frac{1}{R-1}} > 1 + \frac{1}{R-1}\log q/\underline{q} \Leftrightarrow (q/\underline{q})^{\frac{1}{R-1}} > 1 + \log(q/\underline{q})^{\frac{1}{R-1}}|_{\text{Let } x=(q/\underline{q})^{\frac{1}{R-1}}>1} \Leftrightarrow x > 1 + \log x$ for $x > 1 \Leftrightarrow x - \log x > 1$ for $x > 1$; the last inequality is true, because $f(x) = x - \log x$ has derivative $f' = 1 - \frac{1}{x} > 0$ for $x > 1$ and hence $f(x) > f(1) = 1$ for $x > 1$.

As for claim (v): We find that the dispersion of project quality, for the case of a continuum of types, should be ranked according to the second order stochastic dominance. Note that the whole social value of all the efficient projects is divided between the banking sector and the real sector. When one gets more, the other must get less. The former gets $K(R-1)$, with R determined by K through (A2): $K = \int_{\underline{q}}^{1} B(1 - (\underline{q}/q)^{\frac{1}{R-1}}) \cdot g(q)dq \equiv \lambda(R; g)$. To make the dependence of R on distribution g explicit, denote the solution by $R(g)$. Then,

Lemma A2: For two distributions g and g', if $\lambda(R; g') > \lambda(R; g)$ for any $R > 1$, then $R(g') > R(g)$.

Proof: By the condition, $\lambda(R(g); g') > \lambda(R(g); g)$, the latter equal to K by definition, and so does $\lambda(R(g'); g')$. Hence, $\lambda(R(g); g') > \lambda(R(g'); g')$, which implies $R(g) < R(g')$, because given g', $\frac{d\lambda(R;g')}{dR} < 0$.

Q.E.D.

Seek conditions for $\lambda(R; g') > \lambda(R; g)$. Note that $B(1 - (\underline{q}/q)^{\frac{1}{R-1}})$ is increasing and concave function of q for $R > 1$: Its first order derivative is $B\frac{1}{R-1}\underline{q}^{\frac{1}{R-1}}q^{\frac{-1}{R-1}-1} > 0$ and the second order derivative is $-B\frac{1}{R-1}(\frac{1}{R-1}+1)\underline{q}^{\frac{1}{R-1}}q^{\frac{-1}{R-1}-2} < 0$. Hence, if distribution g' second-order stochastically dominates distribution g over $[\underline{q}, 1]$, then $\int_{\underline{q}}^{1} B(1-(\underline{q}/q)^{\frac{1}{R-1}}) \cdot g'(q)dq > \int_{\underline{q}}^{1} B(1-(\underline{q}/q)^{\frac{1}{R-1}}) \cdot g(q)dq$ (see page 197 of Mas-Collen, Winston and Green 1995), that is $\lambda(R; g') > \lambda(R; g)$ for any $R > 1$, which, by Lemma A2, implies $R(g') > R(g)$. Therefore, the banker sector gets more from distribution g' than from distribution g if g' is less dispersed than g according to the second order stochastic dominance.

To summarize,

Proposition A: For the case of a continuum of types, all the claims of Proposition 1 keep holding true, as detailed below.

(i): The qualities of all the socially efficient projects are separately signaled out by the investment of a proper amount of the informed capital. The bigger the amount, the higher the project's quality (q) signaled and the lower the book rate of the deal ($\frac{R}{q}$).

(ii): However scarce is bankers' capital, all the socially efficient projects are financed and the first best result implemented.

(iii): The return rate of bankers' capital decreases with its aggregate stock, K.

(iv): The total profit of the real sector increases with K, while that of the banking sector decreases with it.

(v): If the quality distribution of the socially efficient projects becomes more dispersed according to the second order stochastic dominance, the real sector gets more and the banking sector gets less.

B: The Proofs

For Lemma 5:

Proof. Denote the left hand side term of (18) by $Y(p, \widehat{\Pi})$. Then, by implicit function theorem, $\frac{d\rho(\widehat{\Pi};K)}{d\widehat{\Pi}} = \frac{\partial Y}{\partial \widehat{\Pi}} \cdot [-(\frac{\partial Y}{\partial p} - C'')]^{-1}$. By the second order condition of the maximization problem (17), $\frac{\partial Y}{\partial p} - C'' < 0$ at $p = \rho(\widehat{\Pi}; K) \equiv \widetilde{p}$. Therefore, to prove the lemma, it suffices to show $\frac{\partial Y}{\partial \widehat{\Pi}} < 0$. Note that $\frac{Y}{K} = \frac{(a(\widetilde{p})-1)S'(\widetilde{p})\widehat{\Pi}}{[a(\widetilde{p})\widehat{\Pi}-(a(\widetilde{p})-1)S(\widetilde{p})]^2} + a'(\widetilde{p}) \cdot \frac{(S-\widehat{\Pi})\widehat{\Pi}}{[a\widehat{\Pi}-(a-1)S]^2}$; both terms are to be shown decreasing with $\widehat{\Pi}$. For the former, $(a(\widetilde{p}) - 1)S'(\widetilde{p}) > 0$ and $\frac{\widehat{\Pi}}{[a(\widetilde{p})\widehat{\Pi}-(a(\widetilde{p})-1)S(\widetilde{p})]^2}$ decreases with $\widehat{\Pi}$ for $\widehat{\Pi} > \frac{a(1)-1}{a(1)}S(1) > \frac{(a(\widetilde{p})-1)}{a(\widetilde{p})}S(\widetilde{p})$. For the latter, $a'(\widetilde{p}) > 0$ and $\{\frac{(S-\widehat{\Pi})\widehat{\Pi}}{[a\widehat{\Pi}-(a-1)S]^2}\}'_{\widehat{\Pi}} < 0 \Leftrightarrow \{(S - \widehat{\Pi})\widehat{\Pi}\}'[a\widehat{\Pi} - (a-1)S]^2 < (S - \widehat{\Pi})\widehat{\Pi}\{[a\widehat{\Pi} - (a-1)S]^2\}' \Leftrightarrow (S - 2\widehat{\Pi})[a\widehat{\Pi} - (a-1)S] < 2a(S - \widehat{\Pi})\widehat{\Pi}$. Note that $\Theta > 0$ only if $S > \widehat{\Pi}$, namely if bankers get positive surplus $S - \widehat{\Pi}$ from each and every project screened. Therefore, the last inequality of the chain holds true if $S - 2\widehat{\Pi} < 0$. If $S - 2\widehat{\Pi} > 0$, the left hand side of the last inequality is smaller than $(S - 2\widehat{\Pi})a\widehat{\Pi}$, which is in turn smaller than $a(S - \widehat{\Pi})\widehat{\Pi}$, less than the right hand side. ■

For Lemma 6:

Proof. Denote the left hand side term of (19) by $X(p, K)$. Then, by implicit function theorem, $\frac{d\widehat{p}}{dK} = \frac{\partial X}{\partial K} \cdot [-(\frac{\partial X}{\partial p} - C'')]^{-1}$. It has been noted that $\frac{\partial X}{\partial K} < 0$. To prove the lemma, it suffices to prove $\frac{\partial X}{\partial p} - C'' < 0$, for which we refer back to the proof of Lemma 5 above. Let $g(p, K) \equiv \frac{a(p)-1}{a(p)}(S(p) + K)$, that is, $\widehat{\Pi} = g(\widehat{p}, K)$. Then, $X(p, K) = Y(p, g(p, K))$, where $Y(p, \widehat{\Pi})$ was used to denoted the left hand side of (18) in the proof of Lemma 5. Therefore, $\frac{\partial X}{\partial p} = \frac{\partial Y}{\partial p} + \frac{\partial Y}{\partial \widehat{\Pi}}\frac{\partial g}{\partial p} < \frac{\partial Y}{\partial p}$, because $\frac{\partial Y}{\partial \widehat{\Pi}} < 0$ as was shown in the proof of Lemma 5 and $\frac{\partial g}{\partial p} > 0$. It follows that $\frac{\partial X}{\partial p} - C'' < \frac{\partial Y}{\partial p} - C'' < 0$, where the last inequality was shown in the proof of Lemma 5. ■

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