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Benchmarking and Comparing Entrepreneurs with Incomplete Information

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Abstract

This paper studies how the creation of benchmarks and rankings can be used to provide information in financial markets. Although an investor cannot precisely estimate the future returns of an entrepreneur's projects, the investor can mitigate the incomplete information problem by comparing different entrepreneurs and financing only the very best ones. Incomplete information can be eliminated with certainty if the number of compared projects is sufficiently large. Because the possibility to make benchmarks and comparisons favours centralised information gathering, it creates a novel rationale for the establishment of a financial intermediary.

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1. Introduction

Asymmetric information has long been recognised as a key problem in financial markets (Stiglitz & Weiss, 1981; de Meza & Webb, 1987). There are several means by which outside investors can mitigate the adverse effects of asymmetric information: ex ante monitoring (Broecker, 1990), interim and ex post monitoring (Holmström & Tirole, 1997; Diamond, 1984), collateral requirements (Bester, 1985) and long-term lending relationships (von Thadden, 1995).[1] It is widely felt that the need for such things in the credit markets can explain the existence of financial intermediaries. The analysis is extended in this paper, which explores how making benchmarks and comparisons of potential investment projects can help to mitigate - even eliminate - the asymmetric information problem in financial markets, and how this benefit of benchmarking is conducive to centralised financial intermediation.

To conduct ex ante monitoring properly, outside investors ought to gather comprehensive information on each entrepreneur or firm applying for funding and on their projects. For example, the skills and experience of the entrepreneur or firm's management, the quality of the business plan, the tangible and intangible assets, the market potential of the products, and the cost efficiency should all be examined in detail. Based on this information, investors can evaluate the expected returns of the proposed project and provide finance at appropriate (risk-based) pricing. It is, however, not easy to assess expected returns precisely or to price risks correctly. In particular, in new markets where investors have little, or no, prior experience and entrepreneurs' assets are intangible, it is virtually impossible to make precise evaluations. In more familiar sectors, finance for new entrepreneurs with no track record is difficult to price. Even if entrepreneurs or firms seeking outside finance are well known to the investors, changes in the economic environment may hamper the rating of applicants and hence their funding.

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[1] Freixas & Rochet (1997) and Gorton & Winton (2003) provide thorough surveys of this literature.

In this paper we argue that investors can overcome the difficulties in ex ante monitoring by making benchmarks and comparisons. Although incomplete information problems in funding entrepreneurs and their projects relate to individual characteristics, learning from other entrepreneurs' projects can help to uncover the true distribution of project characteristics in the economy. As a result, investors can compare and rank the projects and choose the very best. These projects will succeed with above-average probability. Hence by making benchmarks and comparisons, investors gather valuable information and thereby boost their investment yields. Moreover, if an investor compares sufficiently many entrepreneurs, the incomplete information problem will be eliminated with certainty.

As an example, consider 10 *de novo* entrepreneurs from the same narrow high-tech sector. Such entrepreneurs typically have fresh prototype products, their primary assets consist of human capital and intellectual property rights, and they lack funds for the investments required to commercialise the prototypes. Any outside investor will certainly find it a demanding task to assess the value of a prototype, its expected sales revenues, marketing strategy and ability of entrepreneurs, and so on. However, if the investor would contact each of the 10 firms and investigate their prototypes, intellectual property portfolios, and entrepreneurial talent and then compare these, she may discover crucial differences between entrepreneurs' business plans. The investor can rank the entrepreneurs and finance only the best ones. As a result, the investor can be quite confident that the best entrepreneurs' products and plans are of sufficiently high quality that the entrepreneurs will be able to repay the funding.

To benefit from the creation of benchmarks and rankings, however, an outside investor needs to evaluate numerous entrepreneurs, even if she can finance only one. With multiple investors operating in isolation, each entrepreneur is evaluated and compared several times. This duplicates the costs of information gathering. Wasteful duplication could be avoided if the investors joined together to establish a financial intermediary, which would evaluate each loan applicant,

compare and rank them, and finance only the best ones. Each applicant is evaluated only once, and inefficient duplication is eliminated. Consequently, the possibility to make benchmarks and comparisons creates a novel rationale for centralised financial intermediation and delegated information gathering. In this respect our paper is related to the literature on the role of information provision in explaining financial intermediaries. Beyond the seminal contribution by Leland and Pyle (1977), our argument is closely related those of Diamond (1984), Ramakrishnan & Thakor (1984), and Boyd & Prescott (1986). As in these papers, a major advantage of forming a financial intermediary in our model is to reduce monitoring costs. Another advantage is information production in the sprit of Ramakrishnan & Thakor (1984) and Boyd & Prescott (1986). Finally, our intermediary engages in asset transformation as in Diamond (1984) and Boyd & Prescott (1986). Our work thus adds to the long string of literature that extends the basic insights on financial intermediaries as delegated monitors and information gatherers into various dimensions (see, e.g. Krasa & Villamil, 1992, Winton, 1995, Cerasi & Daltung, 2000, Hellwig, 2000, and Niinimäki, 2001).

Although the intermediary emerging from our analysis is bank-like and we treat entrepreneurs seeking outside finance as loan applicants, most of the analysis deals with a single investor and needs not specify the form of the financial contract. Moreover, the benefits of benchmarking are most evident in the finance of new ideas in new markets, where debt contracts are less predominant. Our paper therefore touches the literature on entities that finance innovation such as private equity and venture capitalists (for an authoritative survey of venture capital finance, see Gompers & Lerner, 2004). In particular, our study sheds light on the question of why and how venture capitalists benchmark their projects as in Bergemann & Hege (2002). In contrast to Bergemann & Hege (2002), which emphasises the value of benchmarking and staggered project

finance in alleviating moral hazard, project comparison in our model provides benchmarks that mitigate the hidden information problem.[2]

Another connection with the works of Bergeman & Hege (1998, 2002) is that making benchmarks and comparisons can be seen as a special form of costly learning or experimentation in financial markets.[3] Although benchmarks and comparisons provide information, they are costly to make, since an investor must monitor numerous entrepreneurs to gather information. Thus the investor has to weigh the opportunity cost of monitoring yet one entrepreneur against the future informational benefits, as in the theory of experimentation. The key difference versus the learning and experimentation literature is that information derived from making benchmarks and comparisons exploits the differences between entrepreneurs and does not require observations on the same entrepreneur over time. Indeed, in our model no additional information is gained by observing the same entrepreneur more than once.

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[2] For benchmarking, see also Siems & Barr (1998), Balk (2003) and Courty & Marschke (2004).

[3] For experimentation and costly learning during long-term lending relationships, see Sharpe (1990) and von Thadden (2004). In these papers, borrower types are unobservable. A bank learns the borrower types by lending to borrowers and by monitoring them during the lending relationships. As a result, the bank has information advantage regarding its existing borrowers against outside banks. In some cases, banks optimally share borrower specific information among themselves (Pagano & Jappelli, 1993). In practice, learning by lending is strongly utilized in credit scoring programs (see Thomas, 2000; Berger & Frame & Miller, 2005, and Blochlinger & Leippold, 2006). Using a statistical program, a bank compares the information of a loan applicant to the credit performance of former borrowers with similar profiles. A credit scoring program awards points for each factor that helps predict who is likely to pay back a loan. A total number of points – a credit score – helps evaluate how creditworthy a loan applicant is. Hence, credit scoring programs offer an important instrument to handle information within banks. Since the quality of the credit scoring system is increasing in the number of former borrowers, the programs may generate information-releted economics of scale in banking. Additionally, established banks with credit scoring programs may have information advantage against de novo banks. Benchmarks and comparisons complete information that can be obtained using credit scoring.

Since the problem of asymmetric information and alternative suggestions to eliminate it play important roles in the theory of finance, we have mostly considered our analysis from this point of view: a loan applicant knows the type of his project, but the type is unobservable to investors. Alternatively, in our framework it is possible to assume that neither the loan applicant nor the investors know the quality of the project. Each entrepreneur will always search finance for his project since the project incurs no costs to him. Whether or not the loan applicant knows the quality of his project, he will always search for finance and the investors aim to evaluate the project quality.[4]

The paper is organised as follows. In sections 2-3 we develop the main ideas and present the costs and benefits of comparing using a simple model with one investor and at most two entrepreneurs. In section 4 we consider a more general environment where the number of potential entrepreneurs can increase without bound. In section 5 we allow for multiple investors and show how comparing can explain the existence of financial intermediaries. Section 6 concludes.

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[4] We will thank anonymous referees who highlighted the point "it is possible to assume that neither the loan applicant nor the investors know the quality of the project" to us.

2. The economy

2.1 Financial market participants

In the basic model there are, $N \in Z^+$, risk-neutral entrepreneurs (= loan applicants) and one risk-neutral investor. In section 5 we allow for multiple investors. The entrepreneurs lack funds, but each has a project that requires a fixed start-up investment of unit size. The funding can be obtained from the investor (she), who has a unit of capital but no project of her own. The project of an entrepreneur (he) is good with probability g and bad with probability $1-g$. Project quality is unobservable to outsiders and, without risk of confusion, we refer to good and bad entrepreneurs. A good project yields a transferable income Y with certainty, and a bad project only generates a non-transferable private benefit B to the entrepreneur.

We assume that *contacting* an entrepreneur is costly. This cost, denoted by c, includes, e.g., the costs of waiting or searching for an entrepreneur, evaluating and monitoring his project, making the funding decision, and writing the funding contract or informing of the rejection of funding application. The cost occurs when the investor contacts and monitors an entrepreneur, and it cannot be avoided. A contact provides an informative signal about the entrepreneur's type, which will be specified in the next subsection.[5]

Since there is only one investor we assume that the investor has full bargaining power. Besides simplifying the analysis, the assumption is convenient when we look more closely at the benefits of centralised financial intermediation with multiple investors in section 5, since the

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[5] Although we believe that unavoidable contacting and monitoring costs are empirically relevant, the assumption is essentially a short-cut. We could have regarded c as a signal extraction expense and assumed that it can be avoided but only at the cost of not receiving the signal. This would have complicated the analysis by adding one layer to the decision problem of the investor.

assumption implies that investors have no incentive to form a financial intermediary to gain market power. The assumption also means that the form of financial contract is indeterminate: the investor can seize the entire output of a good project, *Y*, by driving the entrepreneur to the zero profit level. It is assumed that $Y - r - c > 0$ where $r \geq 1$ denotes the economy's risk-free interest rate (investor's opportunity cost). Hence a good project has a positive net present value. In contrast, a bad entrepreneur is assumed to have a project with negative net present value, i.e., $B - r < 0$.[6]

2.2 Signals

Upon contacting an entrepreneur, the investor receives a signal on the entrepreneur's type. Each signal is informative in itself but, more importantly, they can be used as a benchmark with which subsequent signals will be compared. The signal can originate from any information reflecting profitability of the entrepreneur's project. For brevity, we assume the signal can take only three values: s_1, s_2, and s_3 where $s_1 > s_2 > s_3$. Besides entrepreneur's type, the value of a signal depends on the state of the world:

- With probability h, the state of the world is *high*, in which case a good entrepreneur's signal is invariably s_1 and a bad entrepreneur's signal is invariably s_2.

- With probability 1-*h*, the state of the world is *low*, in which case a good entrepreneur's signal is invariably s_2 and a bad entrepreneur's signal s_3.

Then, on average, the value of a signal is larger in a high state of the world than in a low state of the world. For simplicity, we do not allow the state of the world to affect the project return but only the

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[6] Strictly speaking we do not need the assumption that *B*<*r*, but it is more appropriate to label entrepreneurs bad if their projects have negative net present value.

value of the signal. Because the investor cannot receive the signal s_3 from a good entrepreneur and the signal s_1 from a bad entrepreneur, the signals s_1 and s_3 are perfectly informative in that they fully reveal both the state of the world and type of loan applicant. Signal s_1 tells the investor that the state of the world is high and the entrepreneur is good. Similarly, signal s_3 says that the state of the world is low and the entrepreneur is bad. After observing either s_1 or s_3, the investor operates under perfect information.

Signal s_2 is more interesting. It indicates a bad entrepreneur in a high state of the world or a good one in a low state. Although the investor can use the signal s_2 to update her prior beliefs about the state of the world and entrepreneur's type, incomplete information remains after observing such a signal. After observing s_2 from the first loan applicant, the investor must accept or reject the application without knowing the entrepreneur's type, or she can use the first signal as a benchmark and gather more information by contacting another entrepreneur and comparing him with the benchmark. If the second signal is s_1, the comparison of s_1 with the benchmark s_2 reveals that the state of the world is necessarily high and that the first entrepreneur is bad and the second is good. If the second signal is s_3, the investor learns that the state of the world is low, the first entrepreneur is good and the second is bad.

If the investor receives s_2 from the second applicant, we still have incomplete information. However, even in this case, seeking a second loan applicant and comparing with the benchmark yields useful information, since the investor can update her beliefs about the state of the world and entrepreneur's type. Thus, although the investor still must make a lending decision under incomplete information, she is better informed.

Note that it is optimal to contact the loan applicants sequentially since this ensures that each contact provides some useful information and no costs of contacting are wasted. Since contacting a new loan applicant is costly, the investor encounters an optimal stopping problem each

time she receives the signal s_2. We nonetheless assume for brevity that the contacts take place fast enough so that the state of the world remains unchanged and that previous contacts can be recalled. As a result, if the first signal is s_2 but the second is s_3, the investor optimally returns to the first entrepreneur and grants him a loan.

In sum, the signalling technology is simple: there are only three signals and they are informative. Two of the signals are actually very informative: good and bad signals perfectly reveal the borrower type. Despite this simple signalling technology, it is more informative to compare several entrepreneurs than just to observe the same entrepreneur over time, since the signals can vary according to the state of the world. Subsection 3.4 cites examples where signals depend on the state of the world.

2.3 The timing of events

The investor's decision problem has two stages. In the first stage, the investor who may have contacted some entrepreneurs previously faces three options. First, she can exit the credit market without lending to anyone. Second, she can grant a loan to any of entrepreneurs she has contacted previously. Finally, she can pool the previous signals with her prior to form a benchmark and invest c to acquire more information by comparing a new loan applicant with the benchmark. In the second stage, the investor will collect her payoffs from exit or lending decisions.. In case the investor decides to contact a new entrepreneur, she will receive a signal on the entrepreneur's type and updates her belief about the entrepreneur's type and the state of the world. In this case the investor again faces the aforementioned three options.

3. Benchmarking and comparing with two loan applicants

In this section, we first consider a loan market with perfect information. We then further develop

concepts in the context of a simple example where there is only one loan applicant in the economy.

Finally, we introduce a second loan applicant to demonstrate the value of benchmarking..

3.1 Perfect information

Under perfect information the investor can separate good from bad firms and grant a loan to a good

one. We assume that under perfect information, lending is profitable to the investor, i.e.,

$$g(Y-r)-c>0. \qquad (1)$$

As explained, g in (1) is the probability of contacting a good entrepreneur. In such case the investor

can reap the entire output of the project, Y; r denotes the opportunity cost of invested capital and c

the cost of a contact. Suppose first that the economy has only one entrepreneur, who is contacted by

the investor. With probability $g,$ the investor learns that the entrepreneur represents a good type.

The investor finances the project and makes profit $Y-r-c$, since a good project always succeeds.

With probability 1-$g,$ the entrepreneur proves to be bad. The investor does not lend to him. In

contrast, the investor invests his endowment at the risk-free interest rate of the economy and bears

the cost of contacting. Thus, the investor's returns are $-c$. In sum, with probability g the investor

makes profits $Y-r-c$ and with probability 1-g she loses $-c$. The expected returns of the investor

amount to $g(Y-r)-c>0$, which is positive owing to (1).

Suppose now that the investor can contact numerous entrepreneurs until a good

entrepreneur appears. The expected value of the each contact is $g(Y-r)-c>0$ to her. If the

economy has n entrepreneurs, the investor's expected profits amount to $[g(Y-r)-c]+$

$(1-g)[g(Y-r)-c]+ \quad + (1-g)^2[g(Y-r)-c]+ .....$, which is equal to

$$[1-(1-g)^n]\frac{g(Y-r)-c}{g} \quad .$$

This is always positive when (1) is satisfied.

3.2 Incomplete information with one loan applicant

If the economy consists of just one entrepreneur, the investor has to decide first whether to incur c

and contact the entrepreneur and then whether to grant a loan to the entrepreneur given her updated

belief about the entrepreneur's type. With probability hg, the signal is s_1. With this signal, the

investor knows that the entrepreneur is good and she grants him a loan. With probability $(1-h)(1-g)$

the signal is s_3 and the investor knows that the entrepreneur is bad and she does not grant a loan.

With probability $h(1-g)+(1-h)g$ the signal is s_2 and the investor can update her belief about

entrepreneur's type, but incomplete information remains. In such a case, the investor may or may

not grant a loan in the presence of uncertainty about the type of entrepreneur. Thus the value of a

loan to the investor with one entrepreneur in the economy is given by

$$V_{N=1} = \max\{hg(Y-r)+[h(1-g)+(1-h)g]v_R(s_2)-c,0\} \tag{2}$$

where subscript $N=1$ of V is the number of entrepreneurs in the economy and

$$v_R(s_2) = \max\{p(g|s_2)Y-r,0\} \tag{3}$$

is the value of a loan under uncertainty, given the signal s_2. In (3)

$$p(g|s_2) = \frac{(1-h)g}{h(1-g)+(1-h)g} \tag{4}$$

is the conditional probability that signal s_2 indicates a good entrepreneur. As (3) shows, $v_R(s_2)$ is positive since the investor finances a project only if its expected NPV is positive. Note that the positive value of $v_R(s_2)$ has nothing to do with limited liability, which plays no role in this context since the investor uses only her own funds. Similarly, the value of a loan given by (2) is positive since the investor contacts the entrepreneur only if it is profitable. From (1) and (2) it is clear that incomplete information reduces the value of the lending opportunity: with perfect information the investor never needs to risk of losing her capital (r) whereas with incompelete information the investor takes such risk when the first signal is s_2 and $v_R(s_2)$ is strictly positive.

3.3 Incomplete information with two loan applicants

With two entrepreneurs, the investor must first decide whether to contact either of the entrepreneurs. If she contacts one of them, she has to decide whether to grant a loan to him or use him as a benchmark. By creating the benchmark the investor can contact a second entrepreneur and compare him with the benchmark. Then the investor must decide whether to grant a loan to either or neither of the two entrepreneurs. Since the investor has only one unit of capital, he can not finance

both projects even when both of them are good.[7] If the first signal is either s_1 or s_3, the investor's decision problem is straightforward so we first characterise them.

The first signal is s_1. If the signal from the first entrepreneur is s_1, the investor knows that he is good. Since the investor has only one unit of capital, there is no need to contact the second entrepreneur, and the investor grants a loan to the first entrepreneur, which yields $Y - r$ with certainty.

The first signal is s_3. If the signal received upon contacting the first entrepreneur is s_3, the entrepreneur is bad with certainty. If the second contact also yields s_3, the investor does not lend. If the second signal is s_2, the investor can eliminate the incomplete information problem by comparing signals. Because the first signal, s_3, reveals that the state of the world is low, the second entrepreneur with s_2 must be a worthy borrower. Since the probability that the second entrepreneur emits s_2 is g, the value of a loan when s_3 is the first signal is given by $v(s_3) = \max\{g(Y - r) - c, 0\}$. As $g(Y - r) - c > 0$ by (1), we obtain

$$v(s_3) = g(Y - r) - c > 0. \tag{5}$$

Note that the value of a loan stems entirely from the possibility of comparing the entrepreneurs.

The first signal is s_2. In this case the investor's problem is more complicated. If the second signal is also s_2, the investor cannot be sure about the entrepreneurs' type and can only update her beliefs. The value of a loan under uncertainty when both signals are s_2 is given by

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[7] By assuming that an investor has only a unit of capital in this section, we will emphasise that the investor's sole reason to contact numerous entrepreneurs is to gather more information. As a result, it is possible to explore optimal stopping in information gathering. The analysis is extended in section 5, where the economy has numerous investors and entrepreneurs. All good projects are then financed. Thus, there is no credit rationing.

$$v_R(s_2, s_2) = \max\{p(g|s_2, s_2)Y - r, 0\} \tag{6}$$

where, analogously to (4),

$$p(g|s_2, s_2) = \frac{(1-h)g^2}{h(1-g)^2 + (1-h)g^2} \tag{7}$$

is the conditional probability that signal s_2 indicates a good entrepreneur after two observations. Again, $v_R(s_2, s_2)$ is positive since the investor finances a project only if its NPV is positive.

If the signal received from the second entrepreneur is s_1, the investor knows that she is dealing with a good entrepreneur and grants a loan. If the second contact yields s_3, the investor knows that the state is low, the entrepreneur is bad and the first entrepreneur is good. The investor thus grants a loan to the first entrepreneur. When the first signal is s_2, the value of a loan can be written as

$$v(s_2) = \max\{v_R(s_2), t_2(Y - r) + (1 - t_2)v_R(s_2, s_2) - c, 0\}. \tag{8}$$

where $t_2 = p(h|s_2)g + [1 - p(h|s_2)](1 - g)$ is the probability that incomplete information can be eliminated by using the second signal. Here

$$p(h|s_2) = \frac{h(1-g)}{h(1-g) + (1-h)g} = 1 - p(g|s_2) \tag{9}$$

is the conditional probability that the state is high when the investor observes signal s_2. As it stands, (8) shows the three choices faced by the investor after observing s_2 from the first contact. First, if $p(g|s_2)Y - r < 0$ implying $v_R(s_2) = 0$, and if $t_2(Y - r) + (1 - t_2)v_R(s_2, s_2) - c < 0$, the investor does not lend at all and $v(s_2)=0$. That is, the investor can achieve zero returns by omitting lending.[8] Otherwise, the maximisation problem on the right-hand side of (8) reflects the investor's choice of whether to contact the second entrepreneur. If the investor decides to grant a loan under uncertainty after contacting only one entrepreneur, her expected payoff is given by $v_R(s_2)$. From (8) we observe that the investor contacts the second entrepreneur if

$$t_2(Y - r) + (1 - t_2)v_R(s_2, s_2) \ge c + v_R(s_2). \tag{10}$$

In Appendix A we prove that the investor's optimal lending strategy after observing s_2 satisfies the following conditions:

Proposition 1. *Suppose that the first loan applicant's type is unknown (signal s_2). Then,*

i) if the contacting cost (c) is sufficiently low, the investor contacts a second loan applicant and compares him with the first one,

ii) if c is sufficiently high and if either the prior probability that a loan applicant has a good project (g) is sufficiently high or if the prior probability of a high state (h) is sufficiently low to render the net present value of a loan under uncertainty positive ($v_R(s_2) > 0$), the investor grants a loan to the first applicant.

iii) if c is sufficiently high and if either g is sufficiently low or h sufficiently high to render $v_R(s_2) \le 0$, the investor does not lend at all.

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[8] The investor can achieve zero returns, since the sunk costs of the first contact are not included in $v(s_2)$ and $v(s_3)$. The sunk costs appear in (11).

The LHS of (10) shows the benefits of benchmarking: with positive probability (t_2) the second contact will probably eliminate the asymmetric information problem and, even if it does not, the investor can gather more information by comparing entrepreneurs and updating her beliefs. The cost of benchmarking is on the RHS of (10). Besides the cost of contacting, the opportunity cost of benchmarking stems from the possibility to grant a loan under uncertainty about the type of the first entrepreneur. For the case $g>1/2$, it is easy to see why part i) of Proposition 1 must be true, since then $Y - r > v_R(s_2, s_2) \geq v_R(s_2)$, i.e., the payoff from benchmarking clearly exceeds the value of the loan under uncertainty. But it turns out that the same conclusion holds even for $g<1/2$, so the benefits exceed the cost of benchmarking when the cost of contacting is sufficiently low.

In the first case in Table 1 we give a numeric example where the investor optimally creates a benchmark and compares entrepreneurs after receiving s_2 from the first contact. The parameter values of interest are $g=0.25$, $h=0.5$, and $c=0.1$.[9] If the first signal is s_2, the probability that the signal indicates a good entrepreneur is relatively low (0.25) and a loan under uncertainty is unprofitable. Instead, the investor uses s_2 as a benchmark and contacts a second entrepreneur. This will eliminate incomplete information with probability 0.375. Although a loan remains unprofitable if incomplete information is not eliminated, a low cost of contacting ($c = 0.1$) makes benchmarking and contacting the second entrepreneur optimal.

As part ii) suggests, the investor may prefer to grant a loan under uncertainty about the type of the first entrepreneur over using him as a benchmark if the cost of contacting is sufficiently high. The strategy may also be optimal with moderate or even with low contacting cost if the first entrepreneur, given signal s_2, is good with sufficiently high probability, that is, when g is close to one or h is close to zero. In such circumstances, incomplete information causes a minor nuisance and the expected benefits of benchmarking do not cover the cost of contacting.

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[9] In all numerical examples we hold Y at 2 and r at 1 and vary g, h, and c.

A numerical example in which granting a loan under uncertainty about the type of the first entrepreneur is optimal can be found in Case 2 of Table 1. Here $g=0.75$, $h=0.25$, and $c=0.5$. Because the priors of a good entrepreneur and a low state are high (both 0.75), the first entrepreneur with s_2 is good with a high probability ($p(g|s_2) = 0.9$). Together with relatively costly contacting ($c=0.5$) this makes contacting a second entrepreneur unprofitable.

Part iii) of Proposition 1 can also be seen from (10). The investor prefers not to lend at all after signal s_2 if the expected return on a loan under uncertainty is not positive and the cost of contacting is sufficiently high to render a search for a second entrepreneur unprofitable. This possibility is illustrated by Case 3 of Table 1, with $g=0.75$, $h=10/11$, and $c=0.65$. Note that it is profitable to contact a first entrepreneur but not a second one: The probability that incomplete information will be eliminated by contacting the first entrepreneur is fairly high ($hg+(1-h)(1-g)\approx0.7$). However, if incomplete information remains, the probability that the problem will be eliminated by seeking a second entrepreneur is somewhat lower (below 0.64).

The value of a loan. We have above determined the conditional value of a loan for the three possible values of the first signal. The initial value of a loan – the investor's expected return before she has contacted either loan applicant – is then given by

$$V_{N=2} = hg\,(Y - r) + \left[h(1 - g) + (1 - h)g\right]v(s_2) + (1 - h)(1 - g)\,v(s_3) - c \quad . \tag{11}$$

In (11) $v(s_2)$ and $v(s_3)$ are given by (8) and (5), and they give the values of a loan to the investor when the first signals are s_2 and s_3. The value of a loan after the investor receives signal s_1 from the first entrepreneur is simply *Y-r*. These values of loans are weighted by the appropriate probabilities: with probability hg the signal of the first entrepreneur is s_1, with probability $\left[h(1 - g) + (1 - h)g\right]$ the signal is s_2, and with probability $(1-h)(1-g)$ it is s_3.

That the investor's optimal strategy under incomplete information can involve benchmarking can be seen from (11). After contacting the first entrepreneur, the investor can gather more information by using the first signal as a benchmark, seeking a second entrepreneur and comparing him with the benchmark. If the signal from the first entrepreneur is 'better' than the signal of the second, the first proves to be worthy of finance and vice versa. If the received signals are identical, the investor can update her prior beliefs on the state of the world and types of entrepreneurs, but the incomplete information problem remains. The investor will create a benchmark and search for a second entrepreneur if the benefits outweigh the opportunity costs of doing so. If the cost of contacting is sufficiently large, the investor may want to grant a loan to the first entrepreneur without benchmarking and comparing, although there is higher risk of credit loss than for a loan under uncertainty after contacting the second entrepreneur. Alternatively, the investor will not grant a loan at all. If $V_{N=2} \geq 0$ the loan market opens up. This occurs if c is not too high. If $V_{N=2} \geq 0$, (1) also holds, but not necessarily vice versa.

We summarise the benefits of benchmarking based on the above analysis as follows:

Proposition 2. *By using the first entrepreneur as a benchmark and comparing the second entrepreneur with him, the investor can gather more information and raise the expected return on her loan. If the signals received from the entrepreneurs differ, incomplete information is eliminated, and the investor can grant the loan to the good entrepreneur. Even if both signals are the same (s_2) and incomplete information obtains, the investor can update prior beliefs on types of entrepreneurs.*

We give an example of the last point – the benefits of benchmarking and comparing when both signals are s_2 and the problem of incomplete information remains - in Case 4 of Table 1. The parameter values are $g=0.25$, $h=0.2$, and $c=0.1$. Now monitoring is cheap and the investor contacts the second entrepreneur even if lending to the first entrepreneur appeared to be profitable

($p(g|s_2)Y - r \approx 0.14$). Yet, the investor is no longer willing to grant a loan after receiving s_2 also

from the second entrepreneur ($p(g|s_2, s_2)Y - r \approx \ddot{} - 0.38$). In other words, since both the state of the

world is likely to be low and average entrepreneur is likely to be bad, the investor interprets the first

s_2 as indicating a good type with a relatively high probability ($p(g|s_2) \approx 0.57$). Upon observing a

second s_2, however, the investor begins to put more weight on the possibility that the state is high

and, consequently, on the possibility that an entrepreneur with s_2 represents a bad type

($p(g|s_2, s_2) \approx 0.31$).

In spite of all the benefits of using the first entrepreneur as a benchmark, the investor's

lending decision is still less efficient than under perfect information. From (1) and (11), we see that

four inefficiencies remain: i) The first entrepreneur is good, but his type is unobservable to the

investor because of signal s_2. The investor may waste resources by searching for a second

entrepreneur or she may inefficiently exit the credit markets; ii) The investor encounters two good

entrepreneurs, but the entrepreneurs' types remain unobservable. If $p(g|s_2, s_2)Y < r$, the investor

makes a mistake and denies a loan; iii) The investor contacts a bad entrepreneur who signals s_2 and

who inefficiently receives a loan, if c is sufficiently high and $p_2(g|s_2)Y > r$ (part ii) of Proposition

1); iv)The investor contacts two bad entrepreneurs with s_2, and she grants a loan if

$p_2(g|s_2, s_2)Y > r$.

Table 1. Four numerical examples with *N*=2, *Y*=2,and *r*=1.

	CASE 1	CASE 2	CASE 3	CASE 4
	$g=1/4;h=1/2;c=1/10$	$g=3/4;h=1/4;c=1/2$	$g=3/4;h=10/11;c=65/100$	$g=1/4;h=1/5;c=1/10$
$p(g\|s_2)$	0.25	0.9	0.23077	0.57143
$v_R(s_2)$	0	0.8	0	0.14286
$v(s_s)$	0.15	0.25	0.1	0.15
$p(g\|s_2,s_2)$	0.1	0.96429	0.47368	0.30769
$v_R(s_2,s_2)$	0	0.92857	0	0
t_2	0.375	0.3	0.63462	0.53571
$v(s_2)$	0.275	0.8	0	0.43571
$V_{N=2}$	0.21875	0.23438	0.03409	0.1925

3.4 Discussion

The model with one investor, two entrepreneurs, and three signals is admittedly limited. In the subsequent sections we will allow for multiple entrepreneurs and financiers. While the extension of the model to arbitrary number of signals is beyond the scope of this paper, it is clear that the basic insight about the value of making benchmarks and comparisons would not change in so far the signal space is finite.[10]

To gain intuition for the upcoming results and illustrate the value of benchmarking, we illustrate few examples.

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[10] Increasing the number of intermediate signals that do not perfectly reveal the borrower type would make the information asymmetry friction costlier to resolve but would not otherwise affect the results. If there were uncountable measure of signals, having access to many borrowers would not eliminate the information asymmetry. However, even in that case benchmarking and comparing would be valuable.

- Variation of signals across sectors: Financial ratios reveal valuable information to investors, but a part of this information is sector-specific. What is regarded as a good ratio of asset turnover, administration costs, gross profit or solvency will vary across industries. Thus, even when the financial ratios of a sector are fixed in time, the critical values of financial ratios differ across sectors. Hence, if an investor who has no previous experience in the sector evaluates a firm, the firm's financial ratios do not reveal its true financial condition to the investor. To evaluate the firm properly, the investor must compare the financial ratios of the firm with the financial ratios of the other firms in the very same sector. Only after studying sufficiently many firms, will the investor understand the correct meaning of financial ratios in the sector.

- Variation of signals over time: The investor may have previous experience in the sector, but the signal value fluctuates over time, making the information value of a single signal modest. For instance, a good firm might earn handsome profits if the industry is booming or moderate profits if the industry is in recession, whereas a bad firm might earn moderate profits during a boom or fail in a recession. Hence, whether moderate profit indicates a good or a bad firm would depend on the stage of the industry cycle. Without comparing, the investor might make a wrong decision by granting a loan to a bad firm with moderate profits.

- Variation of signals across regions: Production costs and market potential differ from one region to another. The same wage cost per employee, for example, may indicate a good, efficient firm in Area A, or a bad, inefficient firm in Area B. To be able to evaluate the

competitiveness of a firm in its local region, the investor needs to compare the firm's characteristics with its local competitors.

- Variation of signals in research and development: The progress of research and development is stochastic almost by definition. At first glance, the prototype of an entrepreneur may seem to be promising. However, careful comparison with the other entrepreneurs' prototypes or products in the sector may reveal that the prototype is lagging. Financing the first entrepreneur is likely to be a mistake since its product will hardly be commercially viable.

- Variation of signals according to the industry dynamics. Multiple equilibria are pervasive in network industries. A network firm's profit may be negative, but contrasting the firm with other firms in the industry may reveal that the firms are engaged in fierce competition for dominance where all firms are making losses, and that the firm is leading the competition for a dominant position in the market. Once in the dominant position, the firm will be able to raise its price and make substantial profits. Denying the firm finance would probably be a mistake.

- The profitability of a firm varies with the industry equilibria. Efficient firms may, for example, earn supernormal profits if the firms in an industry collude and moderate profits if they compete. Less efficient firms may earn moderate profits if the industry is in collusion or zero profits if there is competition. Moderate profits may signal an efficient firm if the firms compete or an inefficient firm in case of collusion.

- Technological cycles change the meanings of signals. The propensity to patent changes over time depending on the legal and technological environment. For example, it is known that

innovations can come in waves: after a breakthrough invention it is easier to make follow up innovations. A successful innovative firm may possess dozens of patents after a breakthrough, having had only a handful before. A less innovative firm, having struggled to obtain one patent before the breakthrough, may easily obtain a handful of patents after the breakthrough. For an outsider, it is hard to know whether a handful of patents indicates an innovative or an unsuccessful firm.

4. Benchmarking and comparing with N loan applicants

So far we have assumed that the investor can contact at most two firms. Although a complete characterization of a more general case with an arbitrary number of entrepreneurs is beyond the scope of this study, in this section we briefly confirm that the insights gained from the two entrepreneur case apply for a larger pool of loan applicants.

We first note that incomplete information can be eliminated with certainty when the number of contacted entrepreneurs approaches infinity. Recall that incomplete information obtains only if the investor receives signal s_2. Consequently, when the number of compared entrepreneurs grows, incomplete information still obtains after n contacts only with probability $(1-h)g^n + h(1-g)^n$. With probability $1-h$ the state is low and with probability g^n the investor has contacted only good entrepreneurs. With probabilities h and $(1-g)^n$ the state is high and the investor has compared only bad entrepreneurs. Because probabilities g^n and $(1-g)^n$ are decreasing in n, the probability that incomplete information obtains approaches zero, when $n \rightarrow \infty$.

Even if the investor has not received two different signals over the first n contacts, comparing can in practice render the deficiency of information insignificant. To see this, consider

contacting the nth entrepreneur that yields, like all previous n-1 contacts, signal s_2. The probability

that the entrepreneur is good is $p(g|S_{2,n}) = \dfrac{(1-h)g^n}{(1-h)g^n + h(1-g)^n}$ or

$$p(g|S_{2,n}) = \frac{1}{1 + \dfrac{h}{1-h}\,(\dfrac{1}{g}-1)^n}. \tag{12}$$

where $S_{2,n} = [s_{2,1}, s_{2,2}, ..., s_{2,n}]$ is the vector of signals s_2 received from n entrepreneurs. From (12) it

is evident that if $g < \frac{1}{2}$, the probability that signal s_2 indicates a good entrepreneur is decreasing

in n. Similarly, if $g > \frac{1}{2}$, the probability that entrepreneurs with s_2 are good is increasing in n. In

the limit when n approaches infinity, incomplete informational is removed with certainty: If

$g < \frac{1}{2}$, $\lim\limits_{n->\infty} p(g|S_{g,n}) = 0$, and if $g > \frac{1}{2}$, $\lim\limits_{n->\infty} p(g|S_{g,n}) = 1$.

The above discussion dismisses the costs of contacting. If the investor contacts n

entrepreneurs, the total cost of contacting amounts to nc.. To investigate the investor's optimal

choice of how much to invest in information gathering, taking into account the costs, we write the

initial value of a loan analogously to (11) as

$$V_N = hg\,(Y-r) + [h(1-g)+(1-h)g]v_N(s_2) + (1-h)(1-g)\,v_N(s_3) - c\;, \tag{13}$$

where subscript N denotes the total number of entrepreneurs. The first term in the right-hand side of

(13) captures the possibility that the first signal is s_1, prompting the investor grant a loan

immediately. The second and third term arise from the cases where the first signal is s_2 or s_3.

The first signal is s_3. As discussed in the previous section, if the first signal is s_3, the

investor knows that the entrepreneur is bad with certainty. This can be used as a benchmark so that

if the second entrepreneur releases s_2, the investor can eliminate incomplete information by comparing signals. If the second signal is also s_3, the investor does not lend and may or may not continue contacting. Thus the value of a loan when there are *N* potential entrepreneurs and when the first signal is s_3 can be written as

$$v_N(s_3) = \max\{g\,(Y-r) - c + (1-g)v(s_3, s_3), 0\},\tag{14}$$

where $v(s_3, s_3)$ is the value of a loan after two observations of s_3. Note that $v(s_3, s_3)$ cannot be negative, as the investor can always decide not to grant a loan at all. Since also $g\,(Y-r) - c > 0$ by (1), the investor continues comparing if the first signal is s_3. Because the investor's problem is stationary, we can easily solve (14) recursively. This yields

$$v_N(s_3) = \left[g\,(Y-r) - c\right]\left[\frac{1-(1-g)^{N-1}}{g}\right].\tag{15}$$

In words, if the first signal is s_3, the investor continues contacting and comparing the entrepreneurs until she encounters signal s_2. The value of the loan is increasing in the total number of entrepreneurs in the economy, since it becomes increasingly likely that the investor will find a good entrepreneur and can grant a loan.

The first signal is s_2. As in section 3, if the first signal is s_2, and the second signal is different (either s_1 or s_3), incomplete information is eliminated and the investor can make an optimal lending decision. However, if the second signal is also s_2, the investor can update her priors. Subsequently, the investor can grant a loan to either of the entrepreneurs releasing signal s_2, she can decide to exit the credit market without lending, or she can proceed to compare a third loan

applicant. If she takes the last option, she will be in a similar but not identical position as after the second contact: either the incomplete information is eliminated or she can update her beliefs.

In general, after the investor has encountered n-1 entrepreneurs who have emitted s_2, the value of a loan can be written as

$$v(S_{2,n-1}) = \max\{v_R(S_{2,n-1}), t_n(Y-r) + (1-t_n)v(S_{2,n}) - c\} \tag{16}$$

where $v_R(S_{2,n-1}) = \max\{p(g|S_{2,n-1})Y - r, 0\}$ is the value of a loan under uncertainty after n-1 s_2 signals and where $t_n = p(h|S_{2,n-1})g + [1 - p(h|S_{2,n-1})](1-g)$ is the probability that incomplete information will be eliminated by the nth contact. Here $p(h|S_{2,n-1}) = \dfrac{h(1-g)^{n-1}}{h(1-g)^{n-1} + (1-h)g^{n-1}} = 1 - p(g|S_{2,n-1})$ is the conditional probability that the state is high when all n-1 previous signals are s_2.

The value of the loan (16) could be solved backwards, beginning with the termination payoff $v_R(S_{2,N}) = \max\{p(g|S_{2.N})Y - r, 0\}$. Because the problem is non-stationary, however, solving (16) completely is a messy exercise and does not yield substantial insights. Nonetheless, a few general results can be obtained from (16). The first of them is proved in Appendix B.

Proposition 3. *If the net present value of a loan under uncertainty is negative ($v_R(s_2) \leq 0$) and the prior probability that a loan applicant has a good project is less than one half ($g < \frac{1}{2}$), the investor continues to contact and compare new loan applicants until the problem of incomplete information is eliminated.*

To understand Proposition 3, recall from (12) that $p(g|S_{2,n})$ is decreasing in n when $g < \frac{1}{2}$. Thus, if granting a loan to the first entrepreneur signalling s_2 is unprofitable ($p(g|s_2)Y < r$), it will remain unprofitable for all subsequent entrepreneurs with s_2. It also turns out that an exit, yielding zero payoff, is not optimal if $g < \frac{1}{2}$. In the case of $g < \frac{1}{2}$ the probability that a new contact eliminates incomplete information exceeds g and, thus the expected return from each new contact exceeds $g(Y-r)-c > 0$ (recall (1)). The investor thus compares entrepreneurs until incomplete information is eliminated. Under the parameter values of Case 1 of Table 1, the investor operates as predicted by Proposition 3.

If $g > \frac{1}{2}$, the investor's behaviour is different. In such circumstance the optimal number of comparisons is always finite, as verified by the following proposition.

Proposition 4. *If $g > \frac{1}{2}$, the investor stops comparing new loan applicants even if incomplete information remains.*

We give a heuristic argument here (the formal proof is in Appendix C). On the one hand, $p(g|S_{2,n})$ is increasing in n by (12), if $g > \frac{1}{2}$. The probability approaches unity when n is large enough, and the expected return from a loan under uncertainty, $p(g|S_{2,n})Y - r$, approaches $Y - r$. On the other hand, the expected return from contacting a new loan applicant is always lower than $Y - r - c$. Thus, when n is large enough, the investor prefers granting a loan under uncertainty to contacting and comparing a new loan applicant, and the number of compared loan applicants is finite.

An implication of Proposition 4 is that it can be optimal to grant a loan already to the first entrepreneur even if uncertainty about his type remains, as in the two-entrepreneur economy of section 3.3. It is easy to see that such a lending strategy is optimal if the first loan applicant is good

with a sufficiently high probability or if the contacting is sufficiently costly. For example, this investment strategy is optimal under the parameter values of Case 2 in Table 1.

5. Multiple investors and financial intermediation

Sections 3 and 4 show how making benchmarks and comparisons is beneficial even if there is only one investor in the credit market. If there are multiple investors, however, an arrangement wherein each investor separately collects information has many shortcomings: If an investor contacts one loan applicant and receives s_2, the investor operates under incomplete information. The investor can gather more information by using the first signal as a benchmark and comparing signals from subsequent loan applicants with it. But this is costly. Each investor needs to contact several loan applicants even if each investor has only a unit of capital and she can grant only one loan. Each loan applicant is then contacted several times although each time the monitoring provides the very same information. Moreover, an investor cannot be sure ex ante that comparing several entrepreneurs will eliminate incomplete information. In this section we show how investors can overcome these shortcomings by establishing a coalition, financial intermediary as in Boyd & Prescott (1986) and Diamond (1984).

For brevity, we focus on the case where there are equally many entrepreneurs and investors. Suppose that an investor establishes a financial intermediary, invests her endowment in it as equity capital. The other investors deposit their savings in the intermediary, which promises to pay fixed interest r_D on deposits. The owner of the intermediary then operates as a banker contacting loan applicants and monitoring them on the behalf of the other investors. When each investor invests her endowment in the bank and when the banker monitors each loan applicant of the economy, each loan applicant is monitored once and only once.

As the financial intermediary grows, it becomes increasingly likely that the banker contacts two different types of loan applicants, which eliminates incomplete information. Even if all its loan applicants are similar, the banker becomes increasingly confident about the true state of the world and types of its loan applicants. In the limit, when the financial intermediary is sufficiently large, the incomplete information will be eliminated with certainty (Proposition 3), and the number of monitored loan applicants is equal to the units of the funds invested. To put it differently, a sufficiently large financial intermediary achieves the very same optimal solution that is achieved under perfect information. A conclusion follows:

Proposition 5. *If the investors join together and establish a financial intermediary, each loan applicant is contacted only once and the duplication of information provision cost is avoided. When the intermediary is sufficiently large, incomplete information will be removed with certainty.*

This result resembles that of Diamond (1984). In both models, a financial intermediary is bank-like and eliminates the duplication of information provision, thereby cutting the costs of lending. Nonetheless, the models differ in some important aspects: In Diamond (1984), centralised information provision is profitable, since a single investor can finance only a small fraction of a project. Thus many investors are needed to finance the whole project. If each investor monitored the project, the cost of monitoring would be duplicated. The duplication can be eliminated by establishing a financial intermediary, which monitors the project only once. On the contrary, in our model, centralised information provision is profitable even if a single investor finances the whole project. Although a single investor finances only one project, she should contact numerous loan applicants to gather information. With multiple investors, the same loan applicants would be contacted by several investors and the cost of contacting would be duplicated. Useless duplication can be avoided by establishing a centralised intermediary, which contacts each loan applicant only

once. In our case centralisation also removes incomplete information whereas in Diamond (1984) centralisation yields no informational advantages beyond economising the monitoring costs.

Pushing the argument for centralised financial intermediation to the limit, we can also determine the deposit rate in the credit market. Let Π denote the total profit of the intermediary. If the intermediary has N investors (as well as loan applicants), $\frac{1}{N}\Pi$ is the profit share of a single investor.

Remark. *A sufficiently large intermediary can pay to an investor-member a fixed return, of*

$$r_D \equiv \lim_{N \to \infty} \frac{1}{N}\Pi = gY + (1-g)r - c.$$

The result follows from the law of large numbers and it utilises the idea of Diamond (1984). We can also interpret r_D as the deposit interest rate for the credit market. At the beginning of period, each investor deposits her unit in the intermediary, which invests a share g of the funds in good projects and puts the rest in the outside option. At the end of the period, the loans yield a net return of $N(gY - c)$ and the outside option yields $N(1-g)r$. The intermediary can then pay a return of r_D per deposit unit and the banker also obtains return r_D on his investment. From the assumed market structure, it follows that investors gain the full project surplus, whereas entrepreneurs earn zero profit.

Note that, in equilibrium, there is no incentive problem between the banker and the depositors. Suppose that the banker misbehaves and contacts only a fraction α of the loan applicants. In this way she can not only save the costs of contacting $(1-\alpha)cN$ but also invest a fraction $(1-\alpha)N$ of the intermediary's funds in the outside option. The intermediary's net revenue – the banker's income - is at most (when the banker has contacted sufficiently many loan applicants to be able to interpret the signals correctly)

$$\pi_B = Max \left\{ \alpha N\left[gY + (1-g)r\right] + (1-\alpha)Nr - (N-1)r_D, 0 \right\} \qquad (17)$$

Since the intermediary is very large, the realised fractions of different asset types are fixed owing to the law of large numbers. In (17) $\alpha g N Y$ represents lending returns from the contacted loan applicants who proved to be good. The rest of the contacted loan applicants proved to be bad and a fraction $\alpha(1-g)Nr$ of the funds were allocated in the outside option. The funds saved from $(1-\alpha)N$ loan applicants that were not contacted yield $(1-\alpha)Nr$ when invested in the outside option. Finally, $(N-1)r_D$ denotes payments on deposits. After some manipulation using the definition of r_D given by the Remark, (17) can be rewritten as

$$Max \left\{ r_D + \alpha Nc - N(1-\alpha)\left[g(Y-r) - c\right], 0 \right\} \qquad (18)$$

The banker incurs the opportunity cost of the equity capital invested in the financial intermediary, r_D, and the (non-monetary) costs of contacting, αNc, which implies that the bank's revenue should be at least $r_D + \alpha Nc$ to cover the banker's costs. Since $-N(1-\alpha)\left[g(Y-r) - c\right]$ is negative in (18) (recall (1)), the banker can obtain $r_D + \alpha Nc$ only if $\alpha = 1$. That is, the banker optimally contacts and monitors all entrepreneurs. Just as in Diamond (1984) the incentive problem between the bank and its depositors is eliminated thanks to the law of the large numbers. Furthermore, the banker's income is subordinated to payments on deposits.

Finally, note that investors have no incentive to form an intermediary to gain market power, since by assumption they can extract all the surplus from entrepreneurs. The tendency towards centralised financial intermediation arises solely from economics of scale in comparing.

6. Conclusion

In this paper we study benchmarking and comparing as a source of information in financial markets. Making benchmarks and comparing others with it amount to a simple instrument of learning. It has many features common with other forms of learning such as learning by doing, experimentation and imitation. The other forms of learning, however, require many observations on the same entrepreneur over time whereas comparing exploits the differences between entrepreneurs. We show how incomplete information can be reduced by making benchmarks and comparisons. By comparing sufficiently many entrepreneurs, an investor can separate good from bad loan applicants.

If every investor invests in information gathering, it will be inefficient, since loan applicants are compared several times with zero information gain. To prevent the useless duplication of comparing, the investors optimally join together and establish a financial intermediary, which contacts each loan applicant only once. If the intermediary can grow without bound, the problem of incomplete information can be eliminated with certainty without further investment in information acquisition. This provides a novel rationale for centralised financial intermediation.

An implication of our model is that financial institutions such as banks can become dominant financiers of an industry by exploiting scale economies in comparing. Once a bank has gathered information about firms in the industry by comparing them, it is difficult for new financial institutions to enter the market for finance of the industry. The entrants should start the process of comparing from the beginning whereas the incumbents know the firms and the signals. Thus, even if the incumbents and entrants observe the same information, the incumbents may have an information advantage since they are able to interpret the information correctly. Only in new industries, will old and new financiers compete on equal footing. In such circumstances the efficient

use of benchmarks and comparisons can be the crucial determinant of financial institutions' successes and failures.

Indeed, although we have emphasised the role of comparing in credit markets and that the intermediary arising from our analysis is bank-like, comparing is perhaps even more relevant for business angels, venture capitalists and other entities that focus on financing new high-tech industries. As carefully documented by Gompers and Lerner (2004), such private equity financiers frequently encounter ideas for businesses in areas where there is little available information. The lack of track records for applicants or business area does not lead to the collapse of markets for innovation finance, since financiers seek many applications from the same narrow area. In comparing applications, it becomes evident that funding should be denied to some business ideas. The most promising projects receive the first stage financing. After a new round of comparing, only the most successful firm can obtain second stage financing. The next logical step is to endogenise the form of financial contract so as to enable assessment of the relative benefits of benchmarking and comparing in private equity and debt finance.

Another interesting issue would be to introduce some tradeoffs to counter the tendency towards bigger financial intermediaries predicted by our model. For example, investors should be allowed to go beyond benchmarking and comparing and use other strategies to mitigate information asymmetry such as estimation of cash flows. That and many other intriguing issues are left for future work.

Appendix A: Proof of Proposition 1

Proof of part i): In the proof we use the following observation frequently

$$h(1-g) + (1-h)g - g(1-g) = (1-h)g^2 + h(1-g)^2. \tag{A.1}$$

Given (3), (6), and (10), it is profitable to contact the second applicant if

$$t_2(Y-r) + (1-t_2)Max\{p(g|s_2,s_2)Y - r, 0\} \geq Max\{p(g|s_2)Y - r, 0\} + c \tag{A.2}$$

The inequality is satisfied if $p(g|s_2)\,Y \le r$ for sufficiently low c. Hence, we focus on the case where $p(g|s_2)\,Y > r$. There are two possibilities, depending on whether $p(g|s_2,s_2)\,Y - r$ is positive or negative. Using (9), we rewrite $t_2 = p(h|s_2)g + [1 - p(h|s_2)](1-g)$ as

$t_2 = \dfrac{g(1-g)}{h(1-g)+(1-h)g}$. As a result, if $p(g|s_2,s_2)\,Y < r$, (A.2) simplifies to

$$\frac{g(1-g)}{h(1-g)+(1-h)g}(Y-r) \ge \frac{(1-h)g}{h(1-g)+(1-h)g}Y - r + c \text{ or, using (A.1), to}$$

$$r\left[(1-h)g^2 + h(1-g)^2\right] + gY(h-g) \ge [h(1-g)+(1-h)g]c. \tag{A.3}$$

Adding and subtracting $Y(1-h)g^2$ in the LHS of (A.3) yields

$$r\left[(1-h)g^2 + h(1-g)^2\right] - Y(1-h)g^2 + Ygh(1-g) \ge [h(1-g)+(1-h)g]c. \tag{A.4}$$

Since $p(g|s_2,s_2)\,Y < r$ implies $(1-h)g^2 Y < \left[(1-h)g^2 + h(1-g)^2\right]r$, the LHS of (A.4) is positive. Hence, (A.4) holds if c is sufficiently low.

Now assume $p(g|s_2,s_2)\,Y > r$. Equation (A.2) simplifies to

$$Y\left[t_2 - p(g|s_2) + (1-t_2)p(g|s_2,s_2)\right] \ge c. \tag{A.5}$$

Since $1-t_2 = \dfrac{(1-h)g^2 + h(1-g)^2}{h(1-g)+(1-h)g}$ by (A.1), (A.5) can be further simplified to

$$\frac{(1-g)gh}{h(1-g)+(1-h)g} \ge \frac{c}{Y}, \tag{A.6}$$

which is true if c is sufficiently low.

Proof of part ii): From (A.2) we see that a necessary condition for the optimality of a loan under uncertainty about the first entrepreneur's type is $p(g|s_2)\,Y - r > 0$. When $p(g|s_2)\,Y - r > 0$, (A.2) implies that the loan under uncertainty is optimal if

$$p(g|s_2)Y - r \ge t_2(Y-r) + (1-t_2)Max\{p(g|s_2,s_2)Y - r, 0\} - c \tag{A.7}$$

Because the RHS of (A.7) is smaller than $Y - r - c$, a sufficient condition for optimality of the loan under uncertainty is that the LHS of (A.7) exceed $Y - r - c$. As a result, a sufficient condition for part ii) of Proposition 1 to hold is

$$c \geq \left(1 - p(g|s_2)\right)Y \ . \tag{A.8}$$

Condition (A.8) holds if c or $p(g|s_2)$ is sufficiently large. The latter occurs when g is close to one or h is close to zero (see (9)).

Proof of part iii): If $p(g|s_2)\, Y - r\ < 0$, the investor does not grant a loan to the first entrepreneur. Thus, if c is so high that (A.2) is violated, the investor does not grant a loan.

QED

Appendix B: Proof of Proposition 3

The proof consists of three steps.

Step 1: We show that $t_{n+1} < t_n$ for all n. Rewrite t_n as

$$t_n \ = \ \frac{h\, A^{n-1} g + (1-h)(1-g)}{hA^{n-1} + (1-h)}, \tag{B.1}$$

where $A = \frac{1}{g} - 1$. Without loss of generality, we assume that n is continuous. Differentiating (B.1) gives:

$$\frac{dt_n}{d\,n} = \frac{1}{\left[hA^{n-1} + (1-h)\right]^2}\ \left\{hg\,(hA^{n-1} + 1 - h)A^{n-1}\ln A - \left[hA^{n-1}g + (1-h)(1-g)h\right]A^{n-1}\ln A\right\}$$

$$= \frac{hA^{n-1}\ln A}{\left[hA^{n-1} + (1-h)\right]^2}\ \left[g\,(hA^{n-1} + 1 - h) - (hA^{n-1}g + (1-h)(1-g)\right] \tag{B.2}$$

$$= \frac{hA^{n-1}\,(1-h)(2g - 1)\ln A}{\left[hA^{n-1} + (1-h)\right]^2} < 0.$$

Step 2: We next verify that $\lim\limits_{n \to \infty} t_n = g$. Using (B.1), it is easy to show that

$$\lim_{n\to\infty} t_n = \lim_{n\to\infty} \frac{h\,g + \dfrac{(1-h)(1-g)}{A^{n-1}}}{h + \dfrac{1-h}{A^{n-1}}} = \frac{hg}{h} = g. \tag{B.3}$$

Step 3: Since we assume that $p(g|s_2)Y < r$ and since $p(g|S_{2,n})$ is decreasing in n (recall (12)), $p(g|S_{2,n})Y < r$ for all n. Given $p(g|S_{2,n})Y < r$, the value of a loan under uncertainty is zero for all n, i.e., $v_R(S_{2,n-1}) = 0$. Thus, (16) can be concisely written as

$$v(S_{2,n-1}) = \max\{0, t_n(Y-r) + (1-t_n)v(S_{2,n}) - c\}. \tag{B.4}$$

If $v(S_{2,n})$ is positive for all n, the investor will contact and compare loan applicants until she receives either s_1 or s_3. The RHS of (B.4) is strictly positive since $t_n > g$ (steps 1 and 2) and $g(Y-r) - c > 0$ by (1). Hence, after contacting the first loan applicant, the investor optimally seeks the second loan applicant and compares him with the first one, and continues the process until incomplete information is eliminated. *QED*

Appendix C: Proof of Proposition 4

If $g > \frac{1}{2}$, $p(g|S_{2,n})$ is increasing in n and approaches 1 and when $n \to \infty$ (see (12)). Thus, there exists a $\underline{p} < 1$, such that $\underline{p}Y - r = Y - r - c > 0$, where the last inequality follows from (1). Let k denote the smallest number of contacted loan applicants that satisfies $p(g|S_{2,k}) \geq \underline{p}$.

Equation (16) implies that the investor contacts a new loan applicant if

$$v_R(S_{2,n-1}) \leq t_n(Y-r) + (1-t_n)v(S_{2,n}) - c \tag{C.1}$$

where $v_R(S_{2,n-1}) = \max\{p(g|S_{2,n-1})Y - r, 0\}$ and

$v(S_{2,n}) = \max\{v_b(S_{2,n}), t_{n+1}(Y-r) + (1-t_{n+1})v(S_{2,n+1}) - c\}$. When $n - 1 \geq k$, (C.1) can be written as

$$p(g|S_{2,n-1})Y - r \leq t_n(Y-r) + (1-t_n)(p(g|S_{2,n})Y - r) - c \tag{C.2}$$

because $\quad p(g|S_{2.n})Y - r > p(g|S_{2.n-1})Y - r \geq Y - r - c > t_{n+1}(Y - r) + (1 - t_{n+1})v(S_{2,n+1}) - c$. Subtracting

$Y - r - c$ from both sides of (C.2) yields

$$p(g|S_{2.n-1})Y - r - (Y - r - c) \leq -Y(1 - p(g|S_{2.n}))(1 - t_n). \tag{C.3}$$

In (C.3) the LHS is positive since $n - 1 \geq k$, and the RHS is negative. As a result, the inequality is not satisfied, and it is not optimal to go on comparing. Thus, the optimal number of compared entrepreneurs is finite.

QED

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