A smoke screen theory of financial intermediation*

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Abstract

This paper explores the role of diversification and size in protecting information. We present a simple two period credit market with a sophisticated lender faced with competitors who free ride on his screening activity. Absent commitment problems, the lender funds one borrower and exerts optimal evaluation. When borrowers cannot commit to a long term relationship, the free riding problem is responsible for too little evaluation. We show how this problem can be mitigated by simultaneously financing several borrowers. This effect provides a rationale for intermediaries as an 'information garbling' device.

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1. Introduction

Most professional lenders provide valuable services by evaluating applicants and sorting profitable borrowers from non-profitable ones. In the process, their financing decisions naturally convey information to other investors. When borrowers have a limited commitment ability, this 'information spillover' is conducive to suboptimal evaluation as the initial lender (correctly) anticipates that competitors will use his financing decision to poach good borrowers *ex post*. This paper concerns how lenders—and particularly financial intermediaries—can protect their information in response to this basic problem.

From a general perspective, this screening situation is an instance of production of socially valuable information by private agents. Two pervasive problems undermine this type of activity [28]. The *appropriability problem*—illustrated above—arises when the individual cannot prevent others from using the information without buying it, leading to a standard free riding phenomenon. The *reliability problem* arises on the contrary when an individual cannot credibly pass the information to others, with the consequence that opportunities to sell the information are limited. In both situations, information production is limited because the producer cannot extract the full value of information.

Intermediaries—and other institutions—may have been tailored as a response to those and analogous informational frictions [24]. Specifically, Ramakrishnan and Thakor [40] and Allen [3], amongst others, have shown that financial intermediaries can mitigate the reliability problem by lowering the cost of signaling.[1] In contrast, we model financial intermediation as a solution to the appropriability problem. Precisely, we show how diversification (and size) arises as a strategy to reducing the leakage of information from the producer to free riders, thereby raising the share of the value of information that is appropriable. This size advantage provides a rationale for the emergence of intermediaries as 'informational rent protectors'. Further, we show that this effect may appear even for limited size.

While the impact of the free riding problem on the behavior of informed traders

[1] The idea originates in Leland and Pyle [35]. See also [19, 12, 44].

has been extensively analyzed—following the early contributions by Grossman and Stiglitz [25] and Kyle [34]—the question of how an informed *lender* may protect his information has received comparatively little attention. (Recent exceptions are Anand and Galetovic [4] and Bernhardt and Krasa [6], discussed below). In effect, it is commonly assumed in the literature on relationship lending that lenders' (e.g., banks') information about their clients is proprietary (see [11]). Although such an assumption has proven to be a useful shortcut in many applications, we believe it is worthwhile to investigate to what extent this aspect can be explained by the lender's strategy to protect his information. This paper proposes such an investigation.

The starting point of our analysis is a two period credit market with no *ex ante* information asymmetries. Instead, the major inefficiency is the type of commitment problem pointed out by Mayer [37] and Hellwig [26]. Precisely, the situation is that of a sophisticated lender (hereafter, 'the lender') with the ability to evaluate a limited number of candidate borrowers—one in the model under study. The information produced generates value over two periods, and efficiency requires that the specialist extracts some share of the future value of information. Absent commitment problems, the lender would offer finance to one borrower and exert the optimal level of screening. We analyze the case where borrowers cannot commit to stay with the initial lender, and the lender faces interim competition from outside investors who use his initial financing decision as a signal on borrowers' quality. When the lender finances one borrower, we show that the appropriability problem results in too little evaluation. We then show that one solution is for the lender to raise external funds and finance more borrowers than he can evaluate—a form of diversified intermediation. The intuition runs as follows. By financing a larger portfolio of borrowers (two in our model) the lender introduces 'noise' in his credit decision and can more easily conceal information about individual borrowers. This increases the share of the value of information that he can appropriate, which in turn raises his *ex ante* incentives to screen. When the efficiency loss stemming from financing unscreened borrowers is not too large, overall surplus in the credit market is higher.

Although our contribution is purely theoretical, we believe that our mechanism has relevance for real world intermediaries such as banks or venture capital firms.[2] A large empirical literature pioneered by James [31] and surveyed in James and Smith [32] documents that banks' credit decisions convey information to outside investors, suggesting that free riding might be a concern. Likewise, Anand and Galetovic [4] report anecdotal evidence of free riding on evaluation in the venture capital community. In section 6 we relate the model to the empirical question of efficient size among banks and VC firms. In particular we show that even though the efficient size is chosen, the cross sectional implications are consistent with a *negative* relationship between size and profitability. This suggests a reason why scale economies in financial institutions are difficult to document [29].

The rest of the paper is organized as follows. Section 2 discusses related literature. In section 3 the environment is laid out and the social value of information is computed. The equilibria with individual finance and diversified intermediation are solved in section 4 and section 5. Section 6 provides some discussion. An appendix contains some proofs.

2. Related literature

Our analysis is related to three strands of research.

First, this work naturally relates to the literature on relationship banking.[3] As mentioned above, one contribution of the paper is to account for the proprietary aspect of the lender's information—a primitive of most models in that literature. This aspect of banks' information is regarded as a key element in firms' funding choice, either as a negative [41, 39] or a positive determinant [45, 7].[4] We provide a rationale for this assumption as we show that a lender financing a large portfolio of projects can more easily protect his information. Besides, we offer an explanation for the informational lock-in of borrowers that does not hinge on the initial lender receiving private informa-

[2] To the extent that small banks and organizations rely more heavily on "soft", subjective information, and large ones more on "hard", publicly available information [42, 5], our argument should be more relevant for the former than for the latter.

[3] See [21], [10] and [24] for surveys.

[4] That confidentiality has value in its own right was suggested by Campbell [14].

tion over the relationship [38], but on the lender's strategy to protect his information. Our explanation is consistent with existing evidence on the impact of credit decision announcements on a firm's share price (see section 6).

Secondly, our paper provides a novel argument for diversification within intermediaries in a world of risk neutrality. In our paper a larger portfolio diminishes the informational leakage about individual borrowers. In the delegated monitor model of Diamond [19], perfect diversification reduces delegation costs because in the limit the intermediary's liabilities become independent of the intermediary's private information. While Diamond analyzes a setup with *ex post* monitoring in which appropriability is not an issue, we consider *ex ante* screening when appropriability is a concern. Moreover, our explanation does not require intermediaries to be arbitrarily large or perfectly diversified. Delegated monitoring is further analyzed in [44, 33, 27]. More related to our work is the paper by Cerasi and Daltung [15]. They introduce diseconomies of scale in monitoring and show that despite this some diversification raises the bank's incentives to monitor. Like them, we have some notion of diseconomies of scale (in screening) and we show that limited diversification can be beneficial. Their paper focus on the structure (debt financed) and optimal size of banks. Less than perfect diversification is also considered in Krasa and Villamil [33] and Bond [9]. None of the above papers consider the appropriability problem.

Finally, this paper adds to the literature on information production in credit markets. Chan et al. [16] analyze the interplay between the reusability of information about borrowers and lenders' incentives to engage in screening activities. The appropriability problem and related issues are considered in the context of credit-worthiness tests in Broecker [13] and Gehrig [23]. The main focus of those paper is the effect of increased competition on the equilibrium on the credit market. The papers that are most related to ours are Anand and Galetovic [4] and Bernhardt and Krasa [6]. Anand and Galetovic [4] argue that the competitive structure of the market endogenously adapts in response to the free riding problem. Precisely, they show that an oligopoly of long-lived intermediaries can credibly commit not to free ride on rivals' screening activities. Bernhardt and Krasa [6] show how the possibility of outside funding affects the contracting terms when an informed financier has more information than the entrepreneur. Our work is complementary to these papers, as we investigate a distinct solution to the same basic problem. Anand and Galetovic analyze a market structure response; Bernhardt and Krasa consider a contractual response. In some sense, we analyze an organizational response.

3. The environment

3.1. Agents and technology

We consider a two period economy populated by entrepreneurs (borrowers) and investors. All agents are risk neutral and act to maximize $\mathrm{E}_{t=0}[c_1 + c_2]$. The riskless rate of interest is normalized to 0.

Borrowers. There are 2 cashless identical borrowers, labeled $j = A, B$. Each borrower can be of either high ($\theta = H$) or low ($\theta = L$) type. The probability λ that a given borrower is of type H is common knowledge. A borrower has access to two successive projects, each one requiring an initial investment of $I_t = 1$. In a given period, we will refer to the project owned by a type θ ($\theta = H, L$) borrower as a type θ project. In the first period, a project succeeds with probability p^θ in which case it generates a cash flow $\pi_1 > 1$ or fails and yields 0. A type H project is better in the sense of first order stochastic dominance: $p^H > p^L$. To simplify the algebra, it will be assumed that $p^L = 0$.[5] In the second period, the project of a type L borrower always fail, while that of a type H borrower generate a cash flow $\pi_2 > 1$ with certainty. For the ease of exposition, we invoke the following restrictions on parameters, the interpretation of which will be given momentarily:

$$\lambda p^H \pi_1 > 1, \tag{A1}$$

$$\lambda \left(1 - p^H\right)(\pi_2 - 1) < 1 - \lambda. \tag{A2}$$

To focus on the interplay between the production of information and the creation of informational asymmetries, we assume that borrowers do not know their type.[6]

[5] What matters for the analysis is that a (first period) type L project be socially inefficient. All the results go through as soon as $p^L \pi_1 < 1$.

[6] This is a simplifying assumption, given that borrowers have no collateral available. For arguments

Investors. There are two types of potential investors. First, there is a large number of investors with sufficient individual endowment to finance one project per period ($e_t = 1$). Secondly, there is one sophisticated lender—named S—with a similar endowment but with the ability to screen one borrower at date 1. More precisely, say because screening takes time, the sophisticated lender is unable to screen two projects at the same time. To put it differently, screening exhibits decreasing return to scale. Another interpretation of this specification is that S has expertise in evaluating A or B, with private information about which of the two he is able to evaluate. Instead, outsiders think he is able to screen A or B with equal probabilities. This assumption captures the idea that there is some prior (but imperfect) knowledge so as the lender' specialization.

Screening is costly and yields a perfectly informative signal about the borrower's type. The type is then revealed to S and to the borrower. However, the act of screening is not publicly observable, and is therefore non contractible. We let c denote S's screening cost (in utility terms). Most of the analysis will be conducted under the assumption that there is only one sophisticated lender. In section 5.5.3, we consider the case of two lenders, with heterogenous screening costs, c and C ($c < C$).

3.2. Value of information.

Throughout the paper, we use the expression 'value of information' to refer to the social value of screening. This value is computed by comparison with the allocation of credit without screening.

If a borrower's type is unknown, the first period project is funded, according to assumption (A1). In period 2, refinancing is contingent on the first period outcome. As all type L project fail, a success in period 1 signals that the borrower is of type H, so that his second period project is funded. A borrower whose first period project failed is of type H with probability

$$\lambda' \equiv \Pr[H|\text{failure}] = \frac{\lambda\left(1-p^H\right)}{\lambda\left(1-p^H\right)+1-\lambda}. \tag{1}$$

as to why informed lenders may be better at evaluating projects than entrepreneurs, see [22, 6, 30].

Now, (A2) can be rearranged to yield $\lambda' \pi_2 < 1$ implying that the second period project of such a borrower has negative NPV, and is not financed.

Knowledge of the type allows to reject low type projects in period 1 and to avoid rejecting high type projects in period 2. The social value of information can therefore decomposed as the sum $v_1 + v_2$ of first period and second period values, with

$$v_1 = 1 - \lambda, \tag{2}$$

$$v_2 = \lambda \left(1 - p^H\right) (\pi_2 - 1) . \tag{3}$$

It will be assumed that screening is socially optimal but that the short term value of information does not cover the screening cost:

$$v_1 + v_2 > c > v_{1.} \tag{A3}$$

3.3. Contractual restrictions.

We exclude long term contracts between a lender and a borrower in the following sense. At time 1, the borrower cannot pledge his second project cash-flows, nor can the lender commit to the terms of future financing. This market imperfection, which we take as exogenous, might arise for several reasons such as the existence of a "fresh-start" legal rule, or the inalienability of human capital.[7] One may also think of the entrepreneur's projects as non contractible "ideas".

We view this as a stark way to capture the more general assumption that contractual possibilities are not sufficient to solve the problem of the appropriability of information. In conjunction with assumption (A3), this induces the problem of the appropriability of the information produced by a the lender because the short term value of information, v_1, is not sufficient to induce screening.[8]

[7] Consider the following situation. The investor contracts with a firm, but the firm's prospects depend on the ability of some key employees. While long term contracts between the investor and the firm are feasible, employees can leave the firm at the interim stage and set up their own business or be hired by another firm in the same industry.

[8] It is straightforward to extend the analysis to the case where a positive fraction b of future cash flows are pledgeable at date 1, as long as $b > 1$.

3.4. Timing of events.

Given S's advantage in evaluating projects, assuming either Bertrand competition for borrowers (where all investors post an interest rate) or take-it-or-leave it offers to borrowers by S both result in the lender extracting all the short term surplus from trade. To ease the exposition, we adopt the latter.

At *date 0,* the lender offers an interest rate R for period 1 financing (to one or both borrowers). If he receives an offer from S, a borrower can either accept it or seek finance at competitive terms from unsophisticated investors. If his offer is accepted, S may evaluate one project, and reject negative NPV projects. First period investment are made.

Date 1. The payoffs of first period projects are realized and publicly observed. Payment R is made in case of success. The (potentially informed) lender and borrowers bargain for period 2 contract according to a generalized Nash solution.

At *date 2,* payoff of second period projects are realized and shared according to the agreement reached at date 1.

The following two sections solve for the equilibrium on the credit market under two distinct cases. In section 4, we investigate the case where S does not raise additional endowments and approaches one borrower. In section 5, we characterize the equilibrium when he raises enough funds to finance A and B—we refer to this latter case as diversified intermediation.

4. Equilibrium with one borrower

This section solves for the equilibrium when the specialist does not raise additional funds and makes an offer to one borrower. This provides a benchmark case, and will be useful in introducing the way we solve for the equilibrium.

As a general notation, let $s\,(\in[0,1])$ be the sophisticated lender's mixed screening strategy (viz, s denotes the probability of screening). Given that screening is not publicly observable, market expectations as to the screening strategy will be part of the equilibrium. We let $s^a\,(R)$ denote this anticipated strategy—which in general can be a function of R as contracts offer are public.

Note that unsophisticated lenders would require a payment $R^0 = \frac{1}{\lambda p^H}$ to finance a first period project. As S can extract all the surplus from a borrower, it is then obvious that $R \geq R^0$. Indeed, this is necessary for the specialist to create value:

Lemma 1. *If $R < R^0$ then S does not screen and does not provide finance.*

Proof. The proof is by contradiction. If $\lambda p^H R < 1$ then it is not rational to fund a project without knowing its type. Financing a project therefore perfectly reveals a type H, driving to 0 the share of the long term profit that the initial lender is able to obtain. By (A3), $s = 0$, and no project is financed. □

We proceed in two steps. First, we analyse in section 4.1 the informational rent that the initial investor is able to extract in period 2, taking as given expectations $s^a(R)$. Second, in section 4.2 we study the optimal screening strategy and characterize the equilibrium.

4.1. Rent extraction in period 2

In the second period, the rent that the informed lender is able to extract on positive NPV projects depends on his competitors' information. Let $\rho(p)$ denote this rent, with p the probability assessed by outside investors that the borrower is of type H. Formally $p \equiv \Pr[H|\mathcal{I}]$, with $\mathcal{I}$ the public information at date $t = 1$.

To fix ideas, we assume that the informed lender and the borrower bargain over the rent associated with their bilateral relationship. We use a generalized Nash bargaining solution.[9] The borrower's outside option is the surplus he gets if financed by another investor, while the lender's outside option is simply 0 (riskless rate). The bilateral rent is given by $\left(\pi_2 - 1 - \left(\pi_2 - \frac{1}{p}\right)\right) = \frac{1}{p} - 1$ when the borrower can get financed outside the relationship (at the rate $\frac{1}{p}$) and $\pi_2 - 1$ otherwise. The lender can seek finance outside the relationship only if $p\pi_2 > 1$. Further assuming that threat points equate

[9] But see footnote 10.

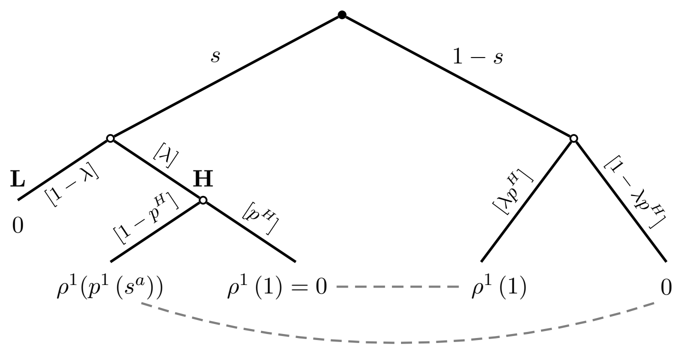

Figure 1: Second period gains for a specialist with mixed strategy s. Dashed lines represent the information set of outside investors.

outside options and that S has all the bargaining power one gets:[10]

$$\rho(p) = \min\left\{\frac{1}{p} - 1, \pi_2 - 1\right\}. \tag{4}$$

As prescribed by intuition, the informational rent increases with the investor's informational advantage, measured by $\left(1 - \frac{1}{p}\right)$.

Figure 1 represents the lender's possible information about the borrower's type, and the relevant profit. The lender cannot extract any profit in period 2 if the first project succeeds as this publicly signals a high type (thus $p = 1$ in that case, implying $\rho(1) = 0$). The rent that can be extracted on a high type borrower who experienced a failure is a function of outsiders' expectations as to the screening strategy. For an anticipated strategy s^a, we let $p^1(s^a)$ be the probability (of a type H) assessed by an outside investor after observing that the borrower was financed and that the first project failed. Using Bayes' rule this can be computed as

$$p^1(s^a) = \frac{s^a\lambda(1-p_H)}{s^a\lambda(1-p_H) + (1-s^a)(1-\lambda p_H)} \cdot 1 + \frac{(1-s^a)(1-\lambda p_H)}{s^a\lambda(1-p_H) + (1-s^a)(1-\lambda p_H)} \cdot \lambda'.$$

Rearranging and using expression (1), $p^1(s^a)$ can be expressed using the prior proba-

[10]Alternatively, we could assume a first price sealed auction between the informed specialist and uniformed competitors, as in Rajan [39] or von Thadden [43]. Our assumptions are such that proposition 3 in Rajan [39] applies, yielding expression (4) as the expected gain of the informed lender.

bility corrected from first period failure λ':

$$p^1(s^a) = \frac{s^a\lambda'}{s^a\lambda' + 1 - s^a} \cdot 1 + \frac{1 - s^a}{s^a\lambda' + 1 - s^a} \cdot \lambda'. \tag{5}$$

One convenient way to look at Eq. (5) is as the weighted average of the information possessed by an informed investor and by an uninformed one. To see this denote by $\mathcal{I}^S \in \{h, \varnothing\}$ the information possessed by the sophisticated lender.[11] Then outsiders's assessment of the type can be computed as

$$p^1(s^a) = \Pr[H|h] \cdot \Pr[h|y,f] + \Pr[H|\varnothing, f] \cdot \Pr[\varnothing|y,f]. \tag{6}$$

where "y" stands for stage 1 financing ("yes") and "f" for stage 1 failure. Now, the probability of the specialist having superior information about the project's type is (conditional on stage 1 financing):

$$\Pr[h|y,f] = \frac{s^a \Pr[H|f]}{s^a \Pr[H|f] + 1 - s^a}. \tag{7}$$

Plugging (7) in (6) yields formula (5). Expression (5) features the leakage of the specialist's private information to outside investors. This is apparent from the fact that $p^1(s^a) > \lambda'$ as soon as $s^a > 0$: observing the financing of a borrower has informational content. In the case of an anticipated pure strategy $s^a = 1$, there is complete revelation of the initial lender's information, as $p^1(1) = 1$.

4.2. Equilibrium characterization

We focus on equilibria where agents' expectations are correct. An equilibrium is therefore a first period payment R, a screening strategy $s^*(R)$ and a funding policy for the lender, and market expectations $s^a(R)$ such that the lender's action satisfy sequential rationality given $s^a(R)$, and investors' expectations satisfy $s^a(R) = s^*(R)$.

We first solve for S's screening strategy for given expectations $s^a(R)$. In a second step, the equilibrium strategy and expectations are jointly determined.

[11] With the straightforward notation that $\mathcal{I}^S = h$ when S knows the borrower to be of the H type and $\mathcal{I}^S = \varnothing$ when he does not have superior information. As no recognized L-project gets financed, the case $\mathcal{I}^S = l$ can be pruned.

Consider first the lender's expected gain. As $R \geq R^0$, S rejects a borrower when he knows he is of type L, and provide first period finance otherwise. The expected gain as a function of the screening strategy s writes

$$\Pi(s,R) \equiv s\left[\lambda\left(p^H R - 1 + \left(1-p^H\right)\rho\left(p^1\left(s^a\left(R\right)\right)\right)\right) - c\right] + (1-s)\left[\lambda p^H R - 1\right], \quad (8)$$

with $\rho\left(p^1\left(s^a\left(R\right)\right)\right)$ the rent extracted in the second period on a type H borrower whose period 1 project failed. From the linearity of profit (8) it follows that the optimal screening decision is given by the "knife-edge" strategy:

$$s^*(R) = \begin{cases} 0 & \lambda\left(1-p^H\right)\rho\left(p^1\left(s^a\left(R\right)\right)\right) + (1-\lambda) < c \\ [0,1] \text{ when} & \text{———————} = c \\ 1 & \text{———————} > c \end{cases} \quad (9)$$

Using (9) it is easy to solve for the equilibrium. As a first result, one can show that the assumption that the net present value of information is positive but that the short term value falls short of the initial cost implies that there must be some screening in equilibrium ($s^* > 0$) but that optimal screening cannot be attained ($s^* < 1$).

Proposition 1. *There is no equilibrium in pure strategies.*

Proof. Consider first the candidate equilibrium $s^* = 1$. Using (9), it must hold that $\lambda\left(1-p^H\right)\rho\left(p^1(1)\right) + (1-\lambda) > c$. Noting that $\rho\left(p^1(1)\right) = \rho(1) = 0$, this is equivalent to $v_1 > c$ which is ruled out by the right hand side of (A3). Consider next the symmetric case $s^* = 0$. By (9), it must hold that $\lambda\left(1-p^H\right)\rho(\lambda') + (1-\lambda) < c$. But (4) implies $\rho(\lambda') = \pi_2 - 1$ so that $\lambda\left(1-p^H\right)(\pi_2 - 1) + (1-\lambda) < c$, which is ruled out by the left hand side of (A3). □

The intuition for this result is as follows. If outside investors anticipate no screening, the credit granting decision is considered as uninformative. Then the specialist would have an incentive to exert screening as his private information would not be revealed to the market. Conversely, if outside investors anticipate perfect screening then the credit decision would perfectly reveal the outcome of the specialist's screening. Anticipating that outside investors would free ride on his screening activity, the specialist would have no incentives to screen. As a consequence, there must be mixed screening in equilibrium.

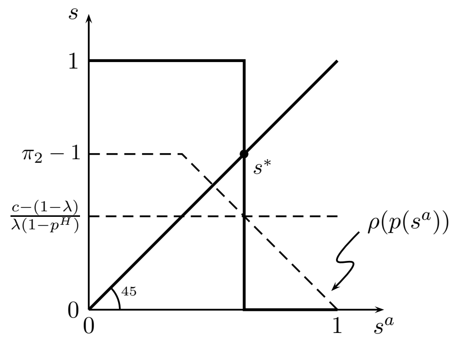

Figure 2: Equilibrium screening ($s^* = s^a$)

Now, in an equilibrium in mixed strategy S must be indifferent between screening and not screening, given market expectations:

$$\lambda\left(1 - p^H\right)\rho\left(p^1\left(s^a\left(R\right)\right)\right) + \left(1 - \lambda\right) = c \tag{10}$$

This characterizes the expectations $s^a(R)$. Eq (10) simply states that in equilibrium the resulting rent must be such that the private value of information equates the screening cost. (The reasoning is illustrated in figure 2).

One consequence of equation (10) is that in equilibrium expectations as to the screening intensity $s^a(R)$ are not affected by the first period payment, R. Accordingly, from now on we write the market expectation as s^a.

To fully characterize the equilibrium, we simply need to consider the borrower's participation constraint. If he rejects the lender's offer, he can get short term finance at the fair rate R^0, yielding the expected utility

$$\bar{U} \equiv \lambda p_H\left(\pi_1 - R^0\right) + \lambda p_H\left(\pi_2 - 1\right), \tag{11}$$

whereas accepting the lender's offer yields

$$U\left(R, s^a\right) = \lambda p_H\left(\pi_1 - R\right) + \lambda p_H\left(\pi_2 - 1\right) + s^a\lambda\left(1 - p_H\right)\left(\pi_2 - 1 - \rho\left(p^1\left(s^a\right)\right)\right). \tag{12}$$

Hence, the borrower accepts the lender's offer whenever $U\left(R, s^a\right) \geq \bar{U}$, or equivalently

$$s^a\lambda\left(1 - p_H\right)\left(\pi_2 - 1 - \rho\left(p^1\left(s^a\right)\right)\right) \geq \lambda p_H R - 1. \tag{13}$$

Note that the short term payment cannot exceed the project's profits ($R \leq \pi_1$). Now, using (9) and the fact that $\rho\left(p^1\left(s^a\right)\right)$ decreases with s^a yields the following characterization:

Proposition 2. *The equilibrium is unique and is characterized by a mixed strategy* $0 < s_1^* < 1$ *such that*

$$\lambda\left(1-p^H\right)\rho\left(p^1\left(s_1^*\right)\right)+(1-\lambda)=c. \tag{14}$$

The equilibrium payment R_1^* *is the maximum payment consistent with* $R \leq \pi_1$ *and the borrower's participation constraint (13).*

Proof. The first part is obvious. The second part comes from the observation that $\Pi\left(s_1^*, R\right)=\lambda p^H R-1$, and that the borrower's participation constraint is satisfied for $R=R^0$. □

Using expression (4) and equation (14), straightforward computations yield the following corollary of proposition 2 (proof in the appendix):

Corollary 3. *The equilibrium level of screening for a specialist financing one borrower is given by*

$$s_1^*=2-\frac{c}{1-\lambda}. \tag{15}$$

The result in proposition 2 can be interpreted as follows. For information production to take place in equilibrium, the sophisticated lender's decision in period 1 must not be fully revealing. In equilibrium, mixed screening provides a partial solution to the tradeoff between the production and the revelation of information by introducing noise in (the informational content of) the financing decision. This mirrors, in our screening context, the logic underlying Grossman and Stiglitz's paradox, and how it can be partially resolved by non fully revealing prices [25, 34].

Note that—to ease exposition—we have assumed that the sophisticated lender, S, extracts all the short term surplus from trade. As the equilibrium level of screening is independent of the lender's profit, this simplification is inconsequential for the analysis of the efficiency of the credit market.

5. Equilibrium with two borrowers

This section shows that the sophisticated lender can retain more of his informational advantage by forming a financial intermediary and increasing the number of borrowers in his portfolio. Specifically, we show that by attracting simultaneously A and B, S can (partially) conceal his information, and thereby have more incentives to screen at date 0. The formation of an intermediary means that S collects the endowment of some other investor and act as a 'delegated screener'.

Given that S cannot screen both borrowers, we let s denotes the probability that he screens one of them, and s^a the associated expectations by outside investors. Importantly, outside investors cannot distinguish borrowers and hold identical belief about which one is (potentially) evaluated.

5.1. Leakage of information

We first analyze the leakage of information and show that diversification results in more private information to be retained *for a given level of market expectations*. Again, $R \geq R^0$ must hold in equilibrium, so that an unscreened project is financed in the first period.

Conditional on the screening strategy, we now have three cases for the lender's (private) information about borrowers:

- with probability $1 - s$, he does not have any information about any borrower's type, in which case he finances both of them borrowers in the first period.
- with probability $s\lambda$, he learns that the (screened) borrower is a type H borrower, and finances both borrowers.
- with probability $s(1 - \lambda)$, he learns that the (screened) borrower is a type L. In that case, the screened borrower is denied credit and only one borrower is financed in the first period.

As before, no rent is extracted on borrowers whose first project succeeds. Note that rejection of one borrower in the first period then reveals that he is a low type and that the specialist has no information as to the other's type. We are left with the cases where S funds both borrowers. Under the maintained assumption that first period profits are observable the leakage of information—for a failed project—when outside investors anticipate a screening strategy s^a depends on whether one or two project failed. Let $p^2_{ff}(s^a)$ be the assessment on a failed project when both failed, and $p^2_{sf}(s^a)$ the assessment when the second project succeeded. Taking into account the relevant probabilities and conditioning on first period failure, we get (see A.2 for computations):

$$p^2_{ff}(s^a) = \frac{s^a\lambda'}{s^a\lambda' + 1 - s^a}\frac{1+\lambda'}{2} + \frac{1-s^a}{s^a\lambda' + 1 - s^a}\lambda', \tag{16}$$

$$= \lambda' + \frac{s^a\lambda'}{s^a\lambda' + 1 - s^a} \cdot \frac{1-\lambda'}{2}. \tag{17}$$

and

$$p^2_{sf}(s^a) = \frac{s^a\lambda'}{s^a\lambda' + s^a + 2(1-s^a)}1 + \frac{s^a + 2(1-s^a)}{s^a\lambda' + s^a + 2(1-s^a)}\lambda', \tag{18}$$

$$= \lambda' + \frac{s^a(1-\lambda')}{s^a\lambda' + 2 - s^a}\lambda'. \tag{19}$$

Expressions (17) and (19) show that S's initial credit decision does reveal some information to the market as both probabilities are greater than the unconditional probability, λ'. However for given market expectations there is less leakage of information than in the case of the individual investor. Formally, the comparison of (17), (19) and (5) shows that[12]

$$\lambda' < p^2_{sf}(s^a) < p^2_{ff}(s^a) < p^1(s^a) \leq 1 \qquad \forall s^a > 0. \tag{20}$$

In particular note that $p^2_{ff}(1) < 1 = p^1(1)$, so that a lender screening with probability one still retains private information as to the borrower's type (contrary to the case with one borrower).

5.2. Equilibrium screening

We now proceed to the equilibrium characterization. Without loss in generality, we consider contracts that specify a first period payment R on any (funded) project

[12] See section A.2 in the Appendix.

that succeeds. Furthermore, we first assume that S pays the riskless rate $r = 0$ on the additional endowment collected, and verify that this is indeed the case in equilibrium.

Consider first the lender's screening strategy, taking market beliefs as given. What matters for S's decision is the information inferred by the market from his financing decision, viz. p_{sf}^2 and p_{ff}^2. Specifically, S chooses his screening strategy so as to maximize $\Pi_2(s, R) - sc$, where

$$\begin{aligned}\Pi_2(s,R) &\equiv (1-s)\left[2\left(\lambda p_h R - 1\right)\right] + s\left(1-\lambda\right)\left[\lambda p_h R - 1\right] \\ &\quad + s\lambda\left[p_h R - 1 + \lambda p_h R - 1 + (1-p_H)\left(\lambda p_h \rho\left(p_{sf}^2\right) + (1-\lambda p_H)\,\rho\left(p_{ff}^2\right)\right)\right].\end{aligned}$$

The above expression can be simplified as

$$\Pi_2(s,R) = s(1-\lambda) + s\lambda(1-p_H)\left(\lambda p_h \rho\left(p_{sf}^2\right) + (1-\lambda p_H)\,\rho\left(p_{ff}^2\right)\right). \tag{21}$$

The analysis of the equilibrium is analogous to that in section 4 with the exception of the substitution of the expected rent $\left[\lambda p_h \rho\left(p_{sf}^2\right) + (1-\lambda p_H)\,\rho\left(p_{ff}^2\right)\right]$ for $\rho\left(p^1\right)$. The same argument can be applied to show that there must be some evaluation in equilibrium. However, there are now cases where the equilibrium screening strategy is $s^* = 1$ if the extracted rent is sufficient. Specifically, $s^* = 1$ if the following condition holds:

$$1-\lambda+\lambda(1-p_H)\left(\lambda p_h \rho\left(p_{sf}^2(1)\right) + (1-\lambda p_H)\,\rho\left(p_{ff}^2(1)\right)\right) > c. \tag{22}$$

Using (17) and (19) the above condition can be rewritten as

$$1-\lambda+\lambda(1-p_H)\left(\lambda p_h \frac{2}{1+\lambda'} + \frac{1}{2}(1-\lambda p_H)\frac{\lambda'+1}{\lambda'} - 1\right) > c. \tag{23}$$

We therefore have the following characterization for the equilibrium screening strategy:

Proposition 4. *There exists a unique equilibrium with (i)* $s_2^* = 1$ *if condition (23) holds, and (ii)* $0 < s_2^* < 1$ *otherwise, with*

$$\lambda\left(1-p^H\right)\left(\lambda p_h \rho\left(p_{sf}^2\left(s_2^*\right)\right) + (1-\lambda p_H)\,\rho\left(p_{ff}^2\left(s_2^*\right)\right)\right) + (1-\lambda) = c \tag{24}$$

Proof. Follows from the monotonicity of $p_2^{sf}(.)$ and $p_{ff}^2(.)$. □

The intuition behind this result is as follows. The left hand side of (22) is the maximum private value of screening for the specialist. Now, the lender's optimal screening strategy is still given by the first order condition (9) with the obvious substitution for $\rho\left(p^1\left(s^a\right)\right)$. By a reasoning similar to that of section 4.2 one has $0 < s_2^* < 1$ in so far as condition (23) does not hold.

As diversification entails less leakage of information, the equilibrium screening strategy is characterized by more screening:

Proposition 5. *In equilibrium, it holds that $s_2^* > s_1^*$.*

Proof. Assume the contrary. From propositions 2 and 4, s_1^* and s_2^* satisfy

$$\lambda p_h \rho\left(p_{sf}^2\left(s_2^*\right)\right) + \left(1 - \lambda p_H\right)\rho\left(p_{ff}^2\left(s_2^*\right)\right) = \rho\left(p^1\left(s_1^*\right)\right). \tag{25}$$

From $s_2^* \leq s_1^*$ and the monotonicity of $p_{sf}^2(.)$ and $p_{ff}^2(.)$, we have $p_{sf}^2\left(s_2^*\right) \leq p_{sf}^2\left(s_1^*\right)$ and $p_{ff}^2\left(s_2^*\right) \leq p_{ff}^2\left(s_1^*\right)$, so that (25) implies

$$\lambda p_h \rho\left(p_{sf}^2\left(s_1^*\right)\right) + \left(1 - \lambda p_H\right)\rho\left(p_{ff}^2\left(s_1^*\right)\right) = \rho\left(p^1\left(s_1^*\right)\right). \tag{26}$$

Now, $p_{sf}^2\left(s_1^*\right) < p_{ff}^2\left(s_1^*\right) < p^1\left(s_1^*\right)$ from (20) and $s_1^* < 1$. As $\rho(.)$ is decreasing, (26) cannot hold. □

This result has a simple intuition. A larger portfolio allows the lender to commit to screen more because outside investors are unsure about which borrower is being screened.

Note that as in the previous case the level of screening (and the surplus created in the credit market) does not depend on the first period payment offered by S. In equilibrium, the first period payment R_2^* is the maximum payment compatible with limited liability ($R \leq \pi_1$) and the borrowers' participation constraints. Given that any individual borrower have a probability $\frac{1}{2}s_2^*$ of being screened, a borrower's participation constraint writes

$$\frac{1}{2}s_2^*\lambda\left(1 - p_H\right)\left(\pi_2 - 1 - \left(\lambda p_h \rho\left(p_2^{sf}\left(s_2^*\right)\right) + \left(1 - \lambda p_H\right)\rho\left(p_{ff}^2\left(s_2^*\right)\right)\right)\right) \geq \lambda p_H R - 1. \tag{27}$$

This participation constraint is strictly satisfied for $R = R^0$, implying that in equilibrium $\pi_1 \geq R_2^* > R^0$.

To conclude, we need to check that S can obtain additional funds at no cost from an unsophisticated investor to finance two projects. This easily follows from the fact that the equilibrium payment is at least $R^0 = \frac{1}{\lambda p_H}$ and that the probability that a (first period) project financed by S succeeds with probability strictly higher than the unconditional probability λp_H. Indeed, this implies that there is a $\rho^* < R^0$ such that offering a payment ρ^* if one (first period) project gives the outside investor zero expected first period rate of return. Consequently, there is no additional cost due to intermediation.

5.3. When is intermediation best

Proposition (5) asserts that diversification raises the specialist' s incentives to screen one borrower because he can retain more informational rent. In terms of the surplus generated in the credit market, the increase in screening intensity yields a gain

$$(s_2^* - s_1^*)\,(v_1 + v_2 - c) > 0. \tag{28}$$

Thus, when there are no cost associated with S financing an *unscreened* borrower, financing both A and B is optimal. When the sophisticated lender does extracts all this surplus—that is, when π_1 is large enough—his profit is also higher with two borrowers.

More generally, that S finances an unscreened borrower may carry some cost. For instance, S might face higher cost of resources than unsophisticated investors—reflecting 'intermediation costs', or higher 'organizational costs' for a sophisticated lender. Letting $k > 0$ denote this additional cost, we have the straightforward result:

Proposition 6. *A larger portfolio is optimal if*

$$(s_2^* - s_1^*)\,(v_1 + v_2 - c) > k. \tag{29}$$

Alternatively, there may be other investors with the ability to screen the additional borrower. To get some insights into this, consider that there are two sophisticated lenders: S, with a screening cost c, and T, with a screening cost $C > c$. We maintain the assumption that $v_1 < c < C < v_1 + v_2$. We show that even if S does not screen the "second" borrower, it may be optimal to have S financing both borrowers.

For the ease of exposition, we introduce the following notations for the (gross) social surpluses for a screened and an unscreened project, respectively:

$$U_e = \lambda \left(p^H \pi_1 - 1 + \omega\right), \tag{30}$$

$$U_{ne} = \lambda p^H \left(\pi_1 + \omega\right) - 1. \tag{31}$$

Naturally, one has $U_e - U_{ne} = v_1 + v_2$. Consider first the case in which each lender finances one borrower. From section 4 we know that the specialists' screening intensities depend on their respective costs. The expected surplus is

$$\left[s^1(c)\left(U_e - c\right) + \left(1 - s^1(c)\right) U_{ne}\right] + \left[s^1(C)\left(U_e - C\right) + \left(1 - s^1(C)\right) U_{ne}\right], \tag{32}$$

whereas if S finances both borrowers the expected surplus is given by

$$\left[s^2(c)\left(U_e - c\right) + \left(1 - s^2(c)\right) U_{ne}\right] + U_{ne}. \tag{33}$$

Comparing (32) and (33) yields the following condition for intermediation to be best:

$$\left[s^2(c) - s^1(c)\right]\left(v_1 + v_2 - c\right) > s^1(C)\left[v_1 + v_2 - C\right] \tag{34}$$

The left hand side of (34) is the gain in S's screening intensity on the "first" borrower resulting from the dissimulation effect of diversification. The right hand side is the loss associated with not screening the "second" borrower.

Proposition 7. *Fix λ, p_H, π_1, π_2, and c. Then there exists a (unique) threshold $C^* > c$ such that intermediation is best for $C > C^*$, and specialized finance is best for $C^* > C > c$.*

Proof. Follows from the monotonicity of the R.H.S. of (34) and the cases $C = c$ and $C \to v_1 + v_2$. □

Proposition 7 shows that even if S is not the best screener for the second borrower, the gain in screening one borrower may more than offset the cost. Regarding comparative statics, one noteworthy consequence of proposition 7 is that a decrease in information costs may have a non-monotonic impact on intermediation. A decrease in the competitor's screening cost C unambiguously leads to a decrease in intermediation. However, a decrease in c may lead to either more intermediation (when c is high) or less intermediation (as $c \to v_1$).

6. Discussion

We now relate our theoretical model to the discussion on the informational content of financing decisions (section 6.1) and that on the optimal size of financial institutions (section 6.2).

6.1. Informational Content of Financing Decisions

In this section, we discuss the timing of the flow of information from the information producer to the market, and we argue that it is consistent with the empirical literature on the impact of credit announcement decision on a firm's share price.

In our framework, the informational content of an initial credit granting is naturally defined as the difference between the probability of a borrower being of a high type conditional on obtaining a credit and the unconditional probability. The former for the case of an information producer with one or two projects, respectively, is easily computed as

$$\Pr[H|\text{loan}] = \frac{s_1^*\lambda}{s_1^*\lambda + 1 - s_1^*} \cdot 1 + \frac{1 - s_1^*}{s_1^*\lambda + 1 - s_1^*} \cdot \lambda, \tag{35}$$

and

$$\Pr[H|\text{loan}] = s_2^*\lambda \cdot \frac{1+\lambda}{2} + (1 - s_2^*\lambda) \cdot \lambda. \tag{36}$$

The informational content of a loan renewal decision is analogously defined as the change in the market assessment of a type H induced by refinancing. Obviously we have for both cases

$$\lambda = \Pr[H] < \Pr[H|\text{loan}] < \Pr[H|\text{loan renewal}] = 1, \tag{37}$$

which asserts that in equilibrium the information produced by S is revealed progressively to the market.

To be precise, eq. (37) implies that initial funding and refunding are both informative. This pattern is consistent with the evidence of a positive impact of bank loans agreement—as opposed to other types of loans— on a borrower's equity price, as first documented on US data by James [31]. Lummer and McConnel [36] find that only loan renewals have a statistically significant impact. Further studies have qualified this sharp contrast, showing that both new loans and renewed loans are interpreted as good news by the stock market (see for instance [2] on Canadian data).[13] Billet et al. [8] provide evidence that the market reaction is positively related to the lender's quality, as measured by Moody's rating. The model is consistent with this finding, if we interpret a "better" lender as one with a lower cost of screening, c. A decrease in c raises the equilibrium level of screening, $s_1^*(.)$ or $s_2^*(.)$, and (from eq. (35) and (36)) the overall informativeness of a funding decision.

We are not the first to provide a theoretical model consistent with these broad empirical finding (see for instance [20]). However, the interpretation we offer is quite different from existing ones. Indeed, the finding that loan renewals convey information to outside investors is generally interpreted as evidence that the initial lender obtains proprietary information over the course of the relationship [39, 38]. We show that this need not be the case. In our model, in contrast, this is a consequence of the lender's strategy to maintain his information private.

6.2. Optimal Size of Sophisticated Lenders

We now discuss some of the model's implications about the optimal size of sophisticated lenders (e.g., banks or VC funds), in terms of the number of projects financed. Our focus on size—as opposed to other measures of diversification—is motivated by the following considerations. Firstly, the concept of diversification is typically difficult to measure.[14] Secondly, diversification strategies obtained by sectoral or geographical expansion might be driven by different motives. Finally, and more importantly, our mechanism hinges on the fact that the informed lender has the expertise to evaluate any individual project in his portfolio, suggesting that projects should have similar characteristics based on publicly available information.[15]

Regarding the determinants of size, we expect our rationale to be more relevant when (i) the extent of outside competition is more important and, (ii) in the early life

[13] For a comprehensive survey of that strand of literature, see [32].

[14] For a discussion of this issue in the context of banking, see Acharya et al. [1].

[15] This rules out, for instance, the case of a banking institution entering a new industry of which it has little previous knowledge.

of the funded firms, when arguably the cost of screening are concentrated but the value not fully realized. We find some supportive evidence in Cumming [17], who studies factors affecting portfolio size—measured by the number of entrepreneurial firms—among a sample of Canadian venture capital funds. In line with (ii), he finds that VCs that specialize in early stage firms hold larger portfolio on average. He also finds that syndication is associated with smaller portfolios. To the extent that syndication lowers competition among partners, this is consistent with (i).

To conclude this section, we wish to emphasize some cross-sectional implications of the model. Precisely, we argue that the model is not inconsistent with a negative relationship between size and profitability. This observation is partly motivated by the empirical literature on efficiency in banking institutions and the fact that most studies fail to find evidence of increasing returns to scale in banking (see Hugues et al. [29] for a discussion). For the sake of the argument, assume a sample of informed lenders with heterogenous (and unobserved) screening costs c. Further assume that c takes only two values, c^H and c^L, with $v_1 + v_2 > c^H > v_1 > c^L$. Now, type c^L lenders will fund only one project and will have a higher profitability per project financed than type c^H lenders. *Decreasing* returns to scale might therefore appear when regressing profitability on size, even though size is optimally chosen in the model.

7. Concluding remarks

This paper has presented a model of a financial intermediary as an institution designed to protect informational rents. While the exact mechanism we have outlined is of interest, the broader message of the paper is that information producers in credit markets might find it necessary to develop strategies to retain private information. We believe that this insight could be used to analyze other ways to protect informational rents. For instance, legal systems—*via* e.g. accounting standards—could be thought of as legal protection of informational rents (in a way analogous to patent policy for innovation). A potential application would be to explain the empirical link between the stringency of disclosure requirements by firms and the orientation—bank-based or market-based—of the financial system [18].

A. Appendix

A.1. Proof of corrolary 3.

Given proposition 1, we know that $\rho\left(p^1\left(s_1^*\right)\right) = \frac{1}{p^1\left(s_1^*\right)} - 1$. Rearranging (5), one gets

$$p^1\left(s_1^*\right) = \lambda' \frac{1}{s\lambda' + 1 - s},$$

and

$$\rho\left(p^1\left(s_1^*\right)\right) = \frac{1}{p^1\left(s_1^*\right)} - 1 = \frac{1-\lambda'}{\lambda'}\left(1 - s_1^*\right). \tag{38}$$

Now, plugging (38) into (14), using (1) and solving for s_1^* yields formula (15).

A.2. A few computations

This section provides some computations for $p^1(.)$, $p_{ff}^2(.)$ and $p_{sf}^2(.)$. We drop the superscript "^{a}" and simply write "s" to ease the exposition.

To obtain (16)-(17), we first take into account the probabilities of failure of each project for each state of S's information—that is, $(h, \varnothing)$ and $(\varnothing, \varnothing)$—to get

$$\Pr\left[(h, \varnothing) \,|2 \text{ failures}\right] = \frac{s\lambda\left(1-p_H\right)\left(1-\lambda p_H\right)}{s\lambda\left(1-p_H\right)\left(1-\lambda p_H\right) + (1-s)\left(1-\lambda p_H\right)\left(1-\lambda p_H\right)},$$

and

$$\Pr\left[(\varnothing, \varnothing) \,|2 \text{ failures}\right] = \frac{(1-s)\left(1-\lambda p_H\right)\left(1-\lambda p_H\right)}{s\lambda\left(1-p_H\right)\left(1-\lambda p_H\right) + (1-s)\left(1-\lambda p_H\right)\left(1-\lambda p_H\right)}.$$

Dividing above and below by $\left(1-\lambda p_H\right)^2$ and using (1) yields

$$\Pr\left[(h, \varnothing) \,|2 \text{ failures}\right] = \frac{s\lambda'}{s\lambda' + 1 - s}, \tag{39}$$

$$\Pr\left[(\varnothing, \varnothing) \,|2 \text{ failures}\right] = \frac{1-s}{s\lambda' + 1 - s}. \tag{40}$$

For an outside agent, the probability that a particular borrower is of type H can be written as

$$p_{ff}^2(s) = \Pr\left[(h, \varnothing) \,|2 \text{ failures}\right] \frac{1+\lambda'}{2} + \Pr\left[(\varnothing, \varnothing) \,|2 \text{ failures}\right] \lambda', \tag{41}$$

which, using (39) and (40) and rearranging yields (16) and (17) in the text.

Expressions (18)-(19) are obtained similarly. The probability that S has information h about the borrower who failed, conditional on the other borrower's success is given by

$$\Pr\left[h|\ldots\right] = \frac{s^a\lambda\left(1-p_H\right)\lambda p_H}{s^a\lambda\left(1-p_H\right)\lambda p_H + s^a\lambda p_H\left(1-\lambda p_H\right) + \left(1-s^a\right)2\lambda p_H\left(1-\lambda p_H\right)},$$
$$= \frac{s\lambda'}{s\lambda' + s + 2\left(1-s\right)}, \tag{42}$$

where the second step follows by dividing above and below by $\lambda p_H\left(1-\lambda p_H\right)$. For an outside agent, the probability that the borrower who failed is of type H then writes

$$p_{sf}^2\left(s\right) = \frac{s\lambda'}{s\lambda' + s + 2\left(1-s\right)}1 + \left[1 - \frac{s\lambda'}{s\lambda' + s + 2\left(1-s\right)}\right]\lambda', \tag{43}$$

which gives expression (18) in the text. (19) follows from a straightforward manipulation.

To conclude, we compare $p^1\left(.\right)$, $p_{ff}^2\left(.\right)$ and $p_{sf}^2\left(.\right)$. Rearrange (5) to get

$$p^1\left(s\right) = \lambda'\frac{1}{s\lambda' + 1 - s} = \lambda' + \frac{s\lambda'}{s\lambda' + 1 - s}\left(1-\lambda'\right). \tag{44}$$

It is straightforward to check that $p^1\left(.\right)$, $p_{ff}^2\left(.\right)$ and $p_{sf}^2\left(.\right)$ are strictly increasing functions (when $s^a > 0$). Direct inspection of (17) and (44) shows that $p_{ff}^2\left(s\right) < p^1\left(s\right) \quad \forall s > 0$. Finally $p_{sf}^2\left(s\right) < p_{ff}^2\left(s\right)$ as from (19) and (17) we have

$$p_2^{sf} < p_2^{ff} \Longleftrightarrow s\lambda' + 2 - s > 2\left(s\lambda' + 1 - s\right) \Longleftrightarrow 0 > s\left(\lambda' - 1\right),$$

which holds by the definition of λ'. Thus, $p_{sf}^2\left(s\right) < p_{ff}^2\left(s\right) < p^1\left(s\right) \quad (\forall s > 0)$.

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