Should lenders be able to observe who recently accessed a credit report? *

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Abstract

In this paper we investigate how the design of credit registers can influence competition in lending markets. We focus on a particular design choice, namely whether or not credit registers record loan requests from a borrower which were subsequently rejected by the lender. This design choice can be important because the fact that a prospective borrower has previously applied with other lenders for the same loan can be informative. This is particularly likely to be the case if the failed or withdrawn application was with an innovative lender that is better at screening prospective borrowers thanks to the use of BigData-driven methodologies (e.g. ML and AI) alongside the traditional credit scoring approach. We find that when credit registers record loan requests rates advertised to borrowers are lower than when credit registers do not record loan requests. Policy implications are discussed.

*The views expressed are those of the authors and do not necessarily reflect those of the Bank of England. This is preliminary work, please do not circulate.**

1 Introduction

When SoFi broadcast its first Super Bowl advert in January 2016, the San Francisco-based fintech start-up had a niche strategy of refinancing the student loans of professionals with upside career prospects, a demographic labelled as HENRY ("High Earners, Not Rich Yet"). The advert in question randomly focused on a number of pedestrians on a busy urban street during the morning rush-hour, with a voiceover labeling them as either "great" or "not great." The advert was meant to end with the strapline: "Find out if you're great at SoFi.com. You're probably not." However, the final three words were removed in a last minute edit.

That original strapline conveyed the impression that the lender in question had an edge in identifying creditworthy borrowers over not only competing lenders but also, and more unusually, prospective applicants. Traditionally the presence of asymmetric information in retail financial markets is assumed to be on the side of consumers holding private information that is relevant to their risk profile. However technological advancements enabled by big data, artificial intelligence and machine learning could flip the balance in favour of providers who are now able to infer relevant statistical correlations unbeknown to the consumer.[1]

Such technological advancements mean that the decision made by a lender with a superior screening technology can provide a useful signal to competing lenders. Besides the positive signal that comes from being granted a loan by a better informed lender, a rejection can be seen as a signal of the corresponding applicant being too risky. This in turn can affect the willingness of perspective borrowers to apply for a loan with the lender in question. The positive signal derived from being granted a loan has seldom been discussed in the literature (though Mistrulli & Casolaro (2008) model a closely related issue), and we are not aware of attempts to model the impact of a negative signal arising from previous rejections by a better informed lender.

We compare two information regimes whereby lenders either can or cannot observe those previous applications with competing lenders that were either rejected or withdrawn. When a borrower applies for credit the lender often issues a request for the borrower's credit report and bases its decision largely on the content of this report. As well as containing information such as payment history and the current amount of credit outstanding, credit reports may or may not contain information concerning other requests that have been made for this credit report. If such information about other recent requests is recorded, this information can be used as evidence that the borrower has tried and failed to secure credit from other lenders. Hence lenders may regard recent credit requests as a negative signal of a borrower's creditworthiness, and be less likely to offer credit to borrower's with many recent credit requests recorded on their credit report. For this reason the UK antitrust authority (the CMA) has argued that the disclosure of previous applications could distort competition by constraining the

[1] See Villeneuve (2005), Brunnermeier *et al.* (2020) and Abrardi *et al.* (2020) for applications of this informed principal assumption in the insurance market.

ability of prospective borrowers to shop around, given the concern that evidence of previous credit searches by competing lenders may negatively affect their scoring and thus reduce their likelihood of being approved. As a result, the CMA recommended the introduction of 'soft' searches, whereby a lender can interrogate a credit history profile provided by a credit reference agency without leaving a trace. Meanwhile Experian, a major credit reference agency, advises borrowers who are planning to apply for a major new credit product like a mortgage in the near future to avoid applications to any other new credit in order to keep their credit score as high as possible.[2] This shows that both regulators and credit rating agencies recognise that additional credit applications can undermine the ability of borrowers to access credit at favourable terms, even if these additional credit applications do not ultimately lead to additional borrowing.

In order to shed further light on this issue we model a lending market with two lenders with different proprietary screening methodologies. Each borrower aims to borrow a unit of funds, and lenders choose rates to offer borrowers. After observing the rates advertised by each lender borrowers submit an application to one of the lenders. This first lender approached issues a request for the borrower's credit report and uses the information contained in the credit report along with its proprietary screening methodology to determine the borrower's creditworthiness. After this screening procedure, the first lender decides whether or not to accept the borrower's application. If the first lender decides to reject the application, the borrower may approach another lender. Now when this second lender approached inspects the borrower's credit report they may or may not - depending on the amount of information recorded in the credit register - observe the request issued by the first lender. If the additional information is recorded, then the second lender can infer that the borrower's lending application was rejected by the first lender and so may be less inclined to accept the borrower's application.

We focus on how the amount of information recorded in the credit register – in particular whether or not the credit register records loan requests from a borrower which were subsequently rejected by the lender – influences competition in lending markets. We show that under mild assumptions this seemingly small choice concerning the exact level of detail at which information is recorded in credit registers can have a substantial impact on competitive behaviour, consumer welfare and lenders' incentives to invest in innovative screening technologies. This adds to the wider literature showing that the exact design of markets has a significant influence on market outcomes.

Our paper builds on existing literature concerning competition in lending markets. In a benchmark model we consider the scenario where lenders do not observe rejected loan requests, and show this is closely related to a situation where borrowers send multiple applications simultaneously and then compare the best rate. Lending markets where an uninformed lender competes against an informed lender in this way are modeled in Hauswald & Marquez (2006) and our benchmark model extends

[2] Experian website: *"If you plan to apply for a major new credit product like a mortgage in the next several months, experts say you should avoid applications for other new credit to keep your score as high as possible."*

this framework. In a first extension we consider a two period model where borrowers who borrow funds in the first period may approach lenders again to borrow funds in the second period. We find that borrowers are willing to pay a *verification premuim* to the innovative lender in the first period (sometimes choosing to borrow funds from the innovative lender even when a lower rate could be obtained from the traditional lender), in order to improve their reputation and hence be able to borrow at a lower rate in the second period. In a second extension we return to a framework where borrowers only borrow funds once, and consider the scenario where lenders observe rejected loan requests. In this case we find that borrowers demand an *insurance premium* from the innovative lender (sometimes choosing to borrow funds from the traditional lender even when a lower rate could be obtained from the innovative lender). Borrowers demand an insurance premium from the innovative lender since applying for credit from the innovative lender carries a higher risk of being rejected and revealed to be a risky borrower, which subsequently makes it more expensive (or impossible) to secure credit. We now turn to a discussion of the related literature.

1.1 Related literature

The traditional rationale for sharing credit data is to reduce the information asymmetry faced by competing lenders unable to observe the creditworthiness of perspective borrowers. This information asymmetry induces credit rationing due to the 'adverse selection' problem, whereby lenders raise interest rates or restrict loan amounts to discount the risk that prospective borrowers are not as good as claimed. This in turn penalises good borrowers in the absence of a credible signal of their creditworthiness. A 'moral hazard' problem can also be at play, as higher interest rates undermine the borrower's incentives to exert effort to improve the reduce the risk of default (Stiglitz & Weiss (1981)).

In the absence of credit data sharing, the existing lender can acquire proprietary information on the borrower's creditworthiness, thus being able to exercise market power over 'locked-in' customers, thanks to the fact that rival lenders would still be constrained by the same information asymmetry. On the one hand, this 'hold-up problem' drives competition among lenders to acquire borrowers without a shared credit history with low interest rates initially (Sharpe (1990)). On the other hand, it adversely affects the owner's incentive to exert effort (Rajan (1992)). Under information sharing credit availability would improve. Rival lenders would find it easier to target good borrowers with poaching offers, which would tend to put downward pressure on lending rates. In turn, borrowers would have strong incentives to do well, in the knowledge that the current lender will not be able to opportunistically engage in rent extraction via uncompetitive lending rates (Padilla & Pagano (1997)).

At the initial screening stage, lenders face a 'winner's curse' problem (Broecker1990 and vonThadden2004), whereby the fact that the borrower didn't obtain a loan from any of the competing lenders entails that the lender that approved the loan request might have overestimated the borrower's creditworthiness. When lenders differ in their ability to screen perspective borrowers the adverse selection problem faced by the less informed lenders is more severe. The larger this asymmetry and the weaker is pricing rivalry (Broecker (1990), von Thadden (2004), Hauswald & Marquez (2003) and Hauswald & Marquez (2006)). Hence, lenders have an incentive to invest in screening technologies to increase their advantage, although to a lesser extent as the number of competitors increases (Hauswald & Marquez (2006)). We add to these results by assuming that the more informed lender has a higher cost of funding, which can offset the informational advantage thereof.

This class of models is based on the spatial competition framework with firms symmetrically located and where the precision of their screening signal worsens with distance.[3] As firms compete simultaneously in a one-shot game, the issues of whether firms can observe rivals' decisions to either approve and / or reject an application and the effects of these two types of disclosures do not arise. Indeed, this standard specification is tantamount to assume that there is no disclosure at all, whereas in practice firms can normally observe whether an applicant has previously applied with rival lenders, thus including those deemed to have a screening advantage. This is potentially an important omission in the literature, given that the ability to observe previous approvals and / or rejections can not only alter lenders' strategies, but also add a novel strategic dimension to borrowers' conduct.

We expand the literature in two ways. First, we model the effect of the disclosure of previous approvals by extending the baseline one-shot, simultaneous model over two periods. Mistrulli & Casolaro (2008) develop a one-period model where borrowers can borrow from more than one lender who differs in their screening ability. Similarly to our result, under disclosure of (concurrent) approvals the more informed lender charges a verification premium.

Second, we model the effect of the disclosure of previous rejections by developing a two-stage sequential search process within the one-period model, and show that the opposite outcome emerges, with borrowers willing to pay a higher interest rate to borrow from the less informed lender.[4] To the best of our knowledge, this case has not been considered previously in the literature. Finally, we assess how these two different disclosure treatments affect firms' incentives to invest to achieve the screening advantage and show that it is indeed the firm with the higher cost of funding that has a stronger incentive to do so, especially under the disclosure of previous approvals, but not rejections.

The rest of the paper is structure as follows. Section 2 outlines a one period benchmark model where lenders do not observe credit requests made to other lenders. Section 3 contains an analysis of this benchmark model. Sections 4 and 5 discuss extensions of the model, covering the case where lenders

[3]Vives & Ye (2021) model duopolistic competition based on the linear 'city' framework. However, their model differs in two fundamental ways: (i) rejected borrowers exit the market, hence there is not adverse selection for the less informed lender; and (ii) the probability of borrower's success increases in the intensity of screening/monitoring. As a result, in contrast to Hauswald & Marquez (2006), borrowers benefit from a higher level of investment in the screening technology.

[4]In this respect, Agarwal *et al.* (2020) uncover evidence to suggest that less creditworthy borrowers are willing to accept higher interest rate because the chance of future rejection is high. However, the authors rationalise this empirical finding by assuming that lenders are equally informed and do not use the number of previous credit rejections to inform their lending decisions.

compete for borrowers over two period and the case where lenders observe credit requests made to other lenders respectively. Section 6 discusses modelling assumptions, while section 7 discusses policy implications and conclusions. .

2 Model

There are two lenders $j \in \{T, I\}$ and a continuum of borrowers $i \in [0,1]$. With probability $\mu_H > 1/2$ borrower i is a safe borrower and with probability $1 - \mu_H$ borrower i is a risky borrower. Each borrower seeks to borrow a unit of funds from one of the lenders in order to pursue a project. A safe borrower repays a loan in full with probability p_S, while a risky borrower repays a loan in full with probability p_R where $1/2 < p_R < p_S$. Any borrower who cannot repay a loan in full defaults and repays 0. Borrowers do not have any information that suggests whether they are safe or risky borrowers.

Lender T is a traditional lender who cannot distinguish between safe and risky borrowesrs. Meanwhile lender I is an innovative lender who has a screening technology and observes (for each borrower) a noisy signal s_I. If the borrower is safe then the borrower has type $\theta = H$ and in this case:

$$P(s_I = H|\theta = H) = \mu_H + \sigma(1 - \mu_H)$$

If the borrower is risky then the borrower has type $\theta = L$ and in this case:

$$P(s_I = H|\theta = L) = \mu_H - \sigma\mu_H$$

Note that (i) in the special case where $\sigma = 0$ the innovative lender has no private information and cannot distinguish between safe and risky borrowers and (ii) in the special case where $\sigma = 1$ the innovative lender observes a high signal (with $s_I = S$) exactly when the borrower is safe (with $\theta = S$) and hence can perfectly distinguish between safe and risky borrowers. With this in mind we say that lender I is *better informed* if the value of σ is higher.[5][6]

We assume that the two lenders have different business models and hence have different costs of capital. In particular we assume that the the traditional lender must pay c_T to raise a unit of funds, while the innovative lender pays a higher cost $c_I > c_T$ to raise a unit of funds. Meanwhile borrowers

[5] Note this set of assumptions implies the probability that the innovative lender receives a high signal (with $s_I = H$) equals μ_H, regardless of the value of σ.In particular $P(s_I = H) = \mu_H\Big(\mu_H + \sigma(1 - \mu_H)\Big) + (1 - \mu_H)\Big(\mu_H - \sigma\mu_H)\Big) = \mu_H$

[6] This differs somewhat from the setting of Hauswald and Marquez (2006) who assume $P(s_I = H|\theta = H) = P(s_I = L|\theta = L) = \frac{\sigma+1}{2}$. This alternative specification implies that the innovative lender receives a high signal (i) with probability 1/2 when the signal is uninformative (with $\sigma = 0$) and (ii) with probability μ_H when the signal is perfectly informative (with $\sigma = 1$). Our choice of specification ensures the probability that the innovative lender receives a high signal remains fixed - this simplifies the analysis but does not materially affect the results. Finally note that in the special case where $\mu = 1/2$ the two sets of assumptions coincide.

are only willing to borrow funds at a rate less than or equal to $r_0 > c_I$. Otherwise the borrower will take an outside option and will not pursue a project. Let $p_\mu = \mu_H p_S + (1 - \mu_H) p_R$ be the ex-ante probability that any given borrower has a successful project. We assume throughout that:

$$p_R r_0 < c_T < p_\mu r_0$$

This ensures that (i) if the innovative lender has no private information, then the traditional lender is willing to lend to any borrower at a rate r_0 (since $p_\mu r_0 > c_T$) and (ii) if a certain borrower is known to be risky, then the traditional lender is not willing to lend to this borrower at a rate r_0 (since $p_R r_0 < c_T$).

In the benchmark model first the innovative lender observes the informative signal s_I and then both the traditional and innovative lenders simultaneously offer each borrower an interest rate. If the lowest interest rate offered to a certain borrower is less than r_0, then this borrower borrows funds from the lender offering the lowest interest rate and starts a project. Otherwise the borrower chooses not to start a project.

2.1 Welfare

Let q_T^+ (and q_I^+) be the quantity of projects funded by the traditional lender (and innovative lender) that repay in full. Similarly let $q_T^{(-)}$ (and $q_I^{(-)}$) be the quantity of projects funded by the traditional lender (and innovative lender) that fail. Furthermore let r_T^+ and r_I^+ be the average interest rate the traditional lender (and lender innovative) lender charge to those projects that succeed. It follows that profits of lender $j \in \{T, I\}$ can be defined as follows:

$$\Pi_j = q_j^+ (r_j^+ - c_j) - q_j^- c_j$$

The first term captures the profits associated with projects that repay in full, while the second term captures the losses associated with projects that do not repay. Meanwhile consumer surplus W_c is defined as follows

$$W_c = q_T^+ (r_0 - r_T^{(+)}) + q_I^+ (r_0 - r_I^{(+)})$$

The first term (second term) captures the consumer surplus associated with the traditional lender (innovative lender) lending funds to projects that repay in full. Total welfare W can now be defined to be equal to the sum of firm profits and consumer surplus (with $W = W_c + \Pi_T + \Pi_I$) and hence:

$$W = q_T^{(+)} (r_0 - c_T) + q_I^{(+)} (r_0 - c_I) - q_T^{(-)} c_T - q_I^{(-)} c_I$$

Note the interest rate terms $r_T^{(+)}$ and $r_I^{(+)}$ do not appear in the total welfare term, since a small incresae in the average interest rate increases firm profits and decreases consumer surplus by an equal amount (as long as the quantity of lending to successful projects remains constant). With this in mind, we now turn to the analysis of the benchmark model.

3 Analysis - Benchmark model

We now turn to an analysis of the benchmark model. First we define the competitive interest rates that would arise under complete information. Secondly we introduce three critical thresholds for σ, namely the level of accuracy of the signal received by the innovative lender. Using these three critical thresholds we then consider four possible scenarios with varying degrees of adverse selection. Finally we discuss the consequences of the innovative lender becoming better informed and the impact on profitability and consumer surplus.

3.1 Competitive interest rates

First suppose the informed lender does not offer any borrower an interest rate. Then in this case there is no adverse selection and the probability that a borrower served by the uninformed lender repays equals $p_T = \mu_H p_S + (1 - \mu_H)p_R$. In this case the uninformed lender (with cost of funding c_T) breaks even as long as the interest rate $r \geq r_T$ where $r_T = c_T/p_T$.

Second suppose the informed lender observes a high signal. Then in this case the probability that a borrower repays equals:

$$p_{I|H} = \Big(\mu_H + \sigma(1 - \mu_H)\Big)p_S + \Big((1 - \mu_H) - \sigma(1 - \mu_H)\Big)p_R$$

Suppose also the borrower obtains funds from the informed lender. Then in this case the informed lender (with cost of funding c_I and observing a high signal) breaks even as long as the interest rate $r \geq r_{I|H}$ where $r_{I|H} = c_I/p_{I|H}$. Finally suppose the informed lender observes a low signal. Then in this case the probability that a borrower repays equals $p_{I|L} < p_{I|H}$ where:

$$p_{I|L} = \Big(\mu_H - \sigma\mu_H)\Big)p_S + \Big((1 - \mu_H) + \sigma\mu_H\Big)p_R$$

In this case (i) if the borrow obtains funds from the traditional lender then the traditional lender breaks even as long as the interest rate $r \geq r_{T|L}$ where $r_{T|L} = c_T/p_{I|L}$ and (ii) if the borrower obtains funds from the innovative lender then the innovative lender breaks even as long as the interest rate $r \geq r_{I|L}$ where $r_{I|L} = c_I/p_{I|L}$. We refer to r_T, $r_{T|L}$ $r_{I|H}$ and $r_{I|L}$ as the competitive interest rates, since (i) r_T would be the equilibrium interest rate in a situation of perfect competition where both lenders were uninformed and had cost of funding c_T, and (ii) $r_{T|L}$, $r_{I|H}$ and $r_{I|L}$ would be the equilibrium interest rates in a situation where both lenders were informed and had access to the same information (with cost of funding c_T and c_I respectively).[7] Having introduced these competitive interest rates, we now consider some cricital thresholds for the information parameter σ.

3.2 Critical thresholds

We now state three preliminary results that introduce three critical thresholds for the information parameter σ. First we introduce $\sigma^{(1)}$:

Lemma 3.1 *There is a unique value $\sigma^{(1)}$ such that when $\sigma = \sigma^{(1)}$ then:*[8]

$$r_{I|H} - r_T = (1 - \mu_H)(r_{I|L} - r_{T|L})$$

Secondly we introduce $\sigma^{(2)}$:

Lemma 3.2 *There is a unique value $\sigma^{(2)}$ such that when $\sigma = \sigma^{(2)}$ then:*[9]

$$r_{I|L} = r_0$$

Third we introduce $\sigma^{(3)}$:

Lemma 3.3 *There is a unique value $\sigma^{(3)} > \sigma^{(2)}$ such that when $\sigma = \sigma^{(3)}$ then:*[10]

$$r_{T|L} = r_0$$

We now state the following proposition:[11]

Proposition 3.4 *If the cost advantage of the traditional lender is sufficiently small (with $\Delta = c_I - c_T > 0$ sufficiently small) then $0 < \sigma^{(1)} < \sigma^{(2)} < \sigma^{(3)} < 1$*

From now on - unless otherwise stated - we will assume that the cost advantage of the traditional lender is sufficiently small and hence $0 < \sigma^{(1)} < \sigma^{(2)} < \sigma^{(3)}$. With this in mind, we now turn to four scenarios where the innovative lender has is increasingly well informed and the traditional lender suffers from an increasing amount of adverse selection.

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[7] Note that $(1 - \mu_H)\delta r_{I|L}/\delta\sigma \geq \mu_H \delta r_{I|H}/\delta\sigma$.

[8] Note if $\phi(\sigma) = r_{I|H} - r_T - (1 - \mu_H)(r_{I|L} - r_{T|L})$ then $\phi(\sigma^{(1)} = 0$. Since ϕ is decreasing in σ, it follows that $\sigma^{(1)}$ is uniquely defined.

[9] Note $\sigma^{(2)} = \frac{p_T - c_T/r_0}{\mu_H(p_S - p_R)}$

[10] Note $\sigma^{(3)} = \frac{p_T r_0 - c_I}{r_0 \mu_H(p_S - p_R)}$

[11] Note as $c_I \to c_T$, then $\sigma^{(1)} \to 0$ and $\sigma^{(2)} > 0$ remains unchanged. Hence if c_I sufficiently is close to c_T, then $\sigma^{(1)} < \sigma^{(2)}$.

3.3 No adverse selection

When σ is very low (with $\sigma < \sigma^{(1)}$) the innovative lender only enjoys a relatively small informational advantage over the traditional lender. In this case the fact that the traditional lender has lower funding costs than the innnovative lender is the dominant factor. This cost advantage leads to the traditional lender capturing the whole market, and this is reflected in the following proposition:

Proposition 3.5 *Suppose $\sigma \leq \sigma^{(1)}$. Then all borrrowers are offered the same interest rate $r = r_{I|H}$. All borrowers are served by the traditional lender and only the traditional lender makes positive profits.*

In this case if the informational advantage of the innovative lender grows (with a small increase in σ), then the traditional lender will price more competitively (in particular $r_{I|H}$ will fall) to ensure that the innovative lender does not find it profitable to enter the market.

3.4 Mild adverse selection

If σ is moderately low (with $\sigma \in [\sigma^{(1)}, \sigma^{(2)}]$), then the interest rate that the traditional lender would need to offer to deter entry of the innovative lender (namely $r_{I|H}$) is too low. In this case rather than excluding the innovative lender from the market (as was the case when $\sigma < \sigma^{(1)}$) the traditional lender instead finds it more profitable to set a higher interest rate (with $r > r_{I|H}$) and allow the innovative lender to enter the market. In this case the traditional lender always offers an interest rate $r \leq r_{I|L}$ and the innovative lender offers an interest rate $r \leq r_{I|L}$ only when it receives a high signal. This is captured in the following proposition:

Proposition 3.6 *Suppose $\sigma \in [\sigma^{(1)}, \sigma^{(2)}]$. Then all borrowers are offered an interest rate in the interval $[\underline{r}, r_{I|L}]$ where $\underline{r} = r_T + (1 - \mu_H)(r_{I|L} - r_{T|L})$. All borrowers secure funding and both lenders make profits.*

Note that in this case both the innovative lender and the traditional lender make profits and all borrowers secure funding. To the best of our knowledge, this case has not been considered previously in the literature.

3.5 Moderate adverse selection

Suppose now σ is moderately high (with $\sigma \in [\sigma^{(2)}, \sigma^{(3)}]$ and hence $r_{I|L} > r_0 > r_{T|L}$). In this case it becomes infeasible for the traditional lender to offer an interest rate $r_{I|L}$ since $r_{I|L}$ is now greater than the outside option of the borrower r_0. In this case (i) sometimes the traditional lender offers an interest rate $r \leq r_0$ and sometimes the traditional lender decides not to offer credit to the borrower. Meanwhile the innovative lender (i) always offers an interest rate $r \leq r_0$ when it receives a high signal and (ii) never offers an interest rate otherwies. This is captured in the following proposition:

Proposition 3.7 *Suppose $\sigma \in [\sigma^{(2)}, \sigma^{(3)}]$. Then some borrowers are offered an interest rate in the interval $[\underline{r}, r_0]$ where $\underline{r} = r_T + (1 - \mu_H)(r_0 - r_{T|L})$. Only some borrowers secure funding and both lenders make profits.*

Note that in this case both the innovative lender and the traditional lender make profits and only some borrowers secure funding. To the best of our knowledge, this case has not been considered previously in the literature.

3.6 Severe adverse selection

When σ is sufficientlly high (with $\sigma > \sigma^{(3)}$ and hence $r_{T|L} > r_0$), then the informational advantage enjoyed by the innovative lender creates such a strong adverse selection effect that the traditional lender is unable to make any profits. This is captured in the following proposition:

Proposition 3.8 *Suppose $\sigma > \sigma^{(3)}$. Then some borrowers are offered an interest rate in the interval $[r_T, r_0]$. Only some borrowers secure funding and only the innovative lender makes profits.*

This type of mixed strategy equilibrium - where only the innovative (or informed) lender makes positive profits - is considered by Hauswald and Marquez (2006)

3.7 Consequences of better information

First we consider the case when there is no adverse selection and $\sigma < \sigma^{(1)}$

Proposition 3.9 *If $\sigma_A < \sigma_B < \sigma^{(1)}$, then an increase in σ from σ_A to σ_B will (i) increase consumer surplus, (ii) decrease profitability of the traditional lender, (iii) leave profitability of the innovative lender unchanged and (iv) leave total welfare unchanged.*

When $\sigma < \sigma^{(1)}$ a small increase in σ leads to the traditional lender offering borrowers a more competitive interest rates in order to deter the innovative lender from entering the market. This decrease in interest rate leads to an increase in consumer surplus and decreases the profitability of the traditional lender. The profitability of the innovative lender (who does not serve any borrowers) who does not serve any borrowers remains at 0. Since all borrowers are served by the traditional lender whenever $\sigma < \sigma^{(1)}$, it follows that (i) the profit of the innovative lender (who does not serve any borrowers) remains at 0 and (ii) total welfare remains unchanged. We now turn to the case of severe adverse selection when $\sigma > \sigma^{(3)}$:

Proposition 3.10 *If $\sigma^{(3)} < \sigma_A < \sigma_B$, then an increase in σ from σ_A to σ_B will (i) decrease consumer surplus, (ii) increase profitability of the innovative lender and (iii) leave profitability of the traditional lender unchanged*

When $\sigma > \sigma^{(3)}$ as the innovative lender becomes more informed (and σ increases) the minimum rate offered to each borrower increases (in expectation). This leads to a decrease in consumer surplus and increases the profitability of the innovative lender (who benefits both from less aggressive pricing from the traditional lender and better information). On the one hand higher pricing from the innovative lender benefits the traditional lender, but on the other hand the traditional lender is increasingly affected by an adverse selection problem. These two factors exactly cancel out as the innovative lender becomes better informed, and the profitability of the traditional lender remains unchanged at 0.

The welfare implications of the innovative lender becoming more informed in the cases of mild adverse selection and moderate adverse selection (when $\sigma \in [\sigma^{(1)}, \sigma^{(3)}])$) is more involved, and we relegate a discussion of this to the appendix. We close this section with a further result regarding total welfare:

Corollary 3.11 *If $\sigma_A < \sigma^{(1)}$ and $\sigma_B \in (\sigma^{(1)}, \sigma^{(2)})$ then an increase in σ from σ_A to σ_B will lead decrease total welfare*

This result is driven by the higher cost of funding of the innovative lender. Since all borrowers are funded whenever $\sigma < \sigma^{(2)}$ it follows that the cost of capital is higher when all borrowers are served by the traditional lender (ie when $\sigma < \sigma^{(1)}$) rather than when only some borrowers are served by the traditional lender (ie when $\sigma \in (\sigma^{(1)}, \sigma^{(2)})$. This provides a novel reason why increased screening may be detrimental to welfare, since it can divert lending from lenders with a low cost of funding to lenders with a higher cost of funding, while the overall amount of lending remains constant.

4 Extension - Two periods

In this extension we study a situation with two periods. The first period proceeds as described in the benchmark model. Meanwhile in the second period a proportion β of the borrowers who repaid in full in the first period attempt to borrow again (those borrowers who did not repay in full in the first period always leave the market). At the start of the second period both lenders can observe the borrower's credit history, and in particular the identity of the lender who extended credit in the first period. We now state a preliminary result:

Lemma 4.1 *In both periods the innovative lender only lends to borrowers with a high signal (with $s_I = H$)*

This follows from the fact that the traditional lender has a cost advantage over the innovative lender (with $c_T < c_I$). Hence the innovative lender cannot compete for borrowers with a low signal (when $s_I = L$) and these borrowers either borrow from the traditional lender or not at all. We now state another preliminary result:

Lemma 4.2 *Suppose in the first period a borrower borrows from the innovative lender. Then in the second period (i) with probability β the borrower borrows from the traditional lender at rate $r_{I|H}$ and (ii) with probability $(1-\beta)$ the borrower does not borrow funds from either lender*

This follows from the fact that if a borrower in the first period is served by the innovative lender then in the second period the traditional lender can deduce that the innovative bank - who only lends to borrowers with a high signal - must have observed a high signal (with $s_I = H$). It follows that in the second period both lenders know that the borrower has a high signal ($s_I = H$), and the traditional lender can use its cost advantage to deter the innovative lender from lending to the borrower by setting a (risk-adjusted) rate equal to the cost of funding of the innovative lender (with $r = r_{I|H}$).

If the borrower is served by the traditional lender in the first period then the probability that the borrower is safe equals $\mu^{(2)}_{|r^{(1)}}$.[12] Furthermore the corresponding probability that a borrower will default in the second period (given that it borrowed funds from the traditional lender with probability r in the first period) equals $p^{(2)}_{|r^{(1)}}$.[13]. We now state a preliminary result:

Lemma 4.3 *Suppose in the first period a borrower borrows funds from the traditional lender at an interest rate $r^{(1)}$. Then both the probability that the borrower is safe - namely $\mu^{(2)}_{|r^{(1)}}$ - and the expected minimum interest rate offered - namely $p^{(2)}_{|r^{(1)}}]$ - are strictly decreasing in $r^{(1)}$*

This result stems from an adverse selection effect since the innovative lender only offers acceptable rates to borrowers with a high signal (with $s_I = H$). In particular the higher the interest rate accepted, the higher the chance that the innovative lender observed a low signal in the first period (with $s_I = L$). Now given that a borrower borrows funds from the traditional lender in the first period at rate $r^{(1)}$, repays in full and then seeks to borrow funds again in the second period, we define (i) $\lambda^{(2)}_{|r^{(1)}}$ to be the expected probability of receiving an acceptable rate (ie a rate less than or equal to r_0) in the second period and (ii) $E[r^{(2)}_{|r^{(1)}}]$ to be the expected minimum rate offered *given an acceptable rate is offered*. We now state a third preliminary result:

Lemma 4.4 *Suppose in the first period a borrower borrows funds from the traditional lender at an interest rate $r^{(1)}$. Then in the second period the expected probability of this borrower receiving an acceptable rate - namely $\lambda^{(2)}_{|r^{(1)}}$ - is weakly decreasing in $r^{(1)}$ and (given an acceptable rate is offered) the expected minimum rate offered - namely $E[r^{(2)}_{|r^{(1)}}]$ - is strictly increasing in $r^{(1)}$*

This result stems from the fact that when the traditional lender offers an interest rate $r^{(1)}$ and this offer is accepted, the traditional lender can infer that the innovative lender chose not to offer the borrower a very competitive interest rate. Since the innovative lender only offers competitive interest

[12] Suppose $F^{(1)}_{I|H}(r) = P(\text{in first period innovative lender offers rate } r^{(1)} \leq r | s_I = H)$. Then note that $\mu^{(2)}_{|r^{(1)}} = \frac{p_S \mu_H(\mu_H + \sigma(1-\mu_H))(1-F^{(1)}_{I|H}(r)) + p_R(1-\mu_H)(\mu_H - \sigma\mu_H)}{\mu_H}$

[13] Note that $p^{(2)}_{|r^{(1)}} = \mu^{(2)}_{|r^{(1)}} p_S + (1-\mu^{(2)}_{|r^{(1)}}) p_R$

rates to borrowers with a high signal (with $s_I = H$), the traditional lender gains partial information about the signal θ whenever $r^{(1)} > \underline{r}$. In particular if a higher interest rate is offered in the first period, then the traditioal lender will make a more negative assessment of the borrower's type in the second period. This leads to the borrower being offered higher interest rates in the second period (and a lower probability of the borrower being offered an interest rate at all). Building on the previous discussion, we now state a proposition:

Proposition 4.5 *Suppose in the first period the traditional lender offers an interest rate $r^{(1)}$ and the innovative lender offers an interest rate $\hat{r}^{(1)}$. then the borrower chooses to borrow funds from the innovative lender whenever $\hat{r}^{(1)} < r^{(1)} + \Delta^{(1)}_{|r^{(1)}}$ where the verification premium $\Delta^{(1)}_{|r^{(1)}}$ equals:*

$$\Delta^{(1)}_{|r^{(1)}} = \beta\Big(E[r^{(2)}_{|r^{(1)}}] - r_{I|H}\Big)$$

Furthermore the verification premium is strictly increasing in $r^{(1)}$, namely the interest rate offered by the traditional lender in the first period.

In the first period borrowers do not necessarily accept the lowest interest rate, but instead will only accept an offer from the traditional lender if the rate offered by the traditional lender is sufficiently below the rate offered by the innovative lender. This is because borrowers anticipate the fact that being served by the innovative rather than the traditional lender in the first period will lead to the traditional bank making a more favourable assessment of them in the second period. This more favourable assessment may in turn lead to them being offered a more competitive rate in the second period. Hence borrowers are willing to pay a *verification premium* to the innovative lender in the first period in order to demonstrate to the traditional lender that they are likely to be a safe borrower. Since there are only two periods, in the second period the borrower simply selects the lowest interest rate offered by either lender (as in the benchmark model).

5 Extension - Loan requests observable

In this extension we return to studying a situation where borrowers only borrow funds at most once. However in this extension borrowers apply to lenders sequentially and lenders observe whether or not borrowers have previously approached other lenders when making a credit decision. We now describe this more formally below.

Suppose that there are two time periods $t \in \{1, 2\}$. In period 1 both lenders offer the borrower a rate conditional on screening. The borrower then applies for funding from one of the lenders (referred to as the *initial lender*). This initial lender may then conduct screening, and based on this information accepts or rejects the borrower's application. If the borrower's application is accepted by the initial lender, then the borrower receives funds from this lender at the advertised rate.

If the borrower is rejected by the initial lender in period 1, we move to period 2 where again both lenders offer the borrower a rate conditional on screening. We assume that period 1 decisions (in particular the decision of the initial lender to reject the borrower) are observable by both lenders, and that both lenders take this information into account when deciding on what rate to offer in period 2. Having observed rates from both lenders, the borrower may choose to apply for funding from one of the lenders (referred to as the *secondary lender*). This secondary lender may then conduct screening, and based on this information accept or reject the borrower. If the borrower's application is accepted by the secondary lender, then the borrower receives funds from this lender at the advertised rate. If the borrower's application is rejected by the secondary lender, then the borrower does not receive funding. Having described the model, we now turn to the analysis.

5.1 Analysis

We first state a preliminary result concerning the traditional lender:

Lemma 5.1 *The traditional lender never conducts screening and always accepts all borrower applications*

This result stems from the fact that the traditional lender does not have access to an informative screening technology, and so has no incentive to conduct screening. Since the traditional lender receives no information between (i) offering a rate and (ii) deciding whether or not to accept a borrower's application, it follows that the traditional lender has no incentive to reject a borrower's application. We now turn to a preliminary result concerning the innovative lender:

Lemma 5.2 *The innovative lender always conducts screening and accepts borrower applications exactly when it receives a high signal (with $s_I = H$)*

Recall that - unlike the traditional lender - the innovative lender does have access to an informative screening technology and so will always conduct screening. Moreover since the innovative lender has higher funding costs than the traditional lender (with $c_I > c_T$), it follows that the innovative lender cannot afford to offer a rate targeted for the whole market (which the traditional lender would be able to under cut) and instead chooses to offer a rate $r_I^{(1)}$ targeted only at those borrowers with a high signal (with $s_I = H$). Since screening happens after borrowers submit applications, the rate $r_I^{(1)}$ will initially be advertised to all borrowers. However after first period screening only applications from borrowers with a high signal (with $s_I = H$) will be accepted.

Building on these two preliminary results, we now discuss behaviour in the second period. Since the traditional lender always accepts all borrower applications and the innovative lender accepts borrower applications whenever it receives a high signal (with $s_I = H$), it follows that the borrower's application is rejected in the first period only when (i) the borrower approaches the innovative lender and (ii) the innovative lender receives a low signal (with $s_I = L$). In the second period the traditional lender can observe that the innovative lender rejected the borrower's application in the first period and can hence deduce that the innovative lender must have observed a low signal (with $s_I = L$). It follows that both the traditional and innovative lender have the same information in the second period and since the traditional lender has a lower cost of funding (with $c_T < c_I$), either the traditional lender lends to the borrower (when $r_0 > r_{T|L}$) or the borrower does not apply for credit in the second period (when $r_0 < r_{T|L}$). This is captured in the following result:

Proposition 5.3 *Suppose a borrower's application has been rejected in the first period. Then it must be the case that the borrower applied to the innovative lender in the first period and the innovative lender received a low signal (with $s_I = L$). In this case in the second period:*

- *If $r_0 < r_{T|L}$, then the borrower does not borrow funds*
- *If $r_{T|L} \leq r_0 \leq r_{I|L}$, then the traditional bank lends to the borrow at rate $r_T^{(2)} = r_0$*
- *If $r_0 > r_{I|L}$, then the traditional bank lends to the borrower at rate $r_T^{(2)} = r_{I|L}$*

When the borrower's application is rejected in the first period, then decisions in the second period are similar to those in the case of no adverse selection discussed above in the benchmark model where (i) both lenders offer rates simultaneously and (ii) the innovative lender has no informational advantage. In particular when the outside option of the borrower is sufficiently high (with $r_0 > r_{I|L}$) there is a deterrent equilibrium where the traditional lender chooses a rate $r_T^{(2)} = r_{I|L} < r_0$ to ensure the innovative lender cannot gain market share. Meanwhile when the outside option of the borrower is lower (with $r_0 < r_{I|L}$) then the traditional lender either offers the borrower a rate $r_T^{(2)} = r_0$ equal to the borrower outside option (when $r_{T|L} \leq r_0 \leq r_{I|L}$) or chooses not to offer a rate at all (when $r_0 < r_{T|L}$). It follows that a borrower who is rejected by the innovative lender in the first period receives a surplus $W_c^{(2)}$ with certainty in the second period, where $W_c^{(2)} = \max\{r_0 - r_{I|L}, 0\}$.

Now suppose $r_T^{(1)}$ and $r_I^{(1)}$ are the rates offered by the traditional and innovative banks respectively in the first period. Then the borrower accepts funds from the traditional bank when:

$$r_0 - r_T^{(1)} > \mu_H(r_0 - r_I^{(1)}) + (1 - \mu_H)\max\{r_0 - r_{I|L}, 0\}$$

Here the left hand-side captures the surplus the borrower can achieve with certainty by applying to the traditional bank in the first period (namely $r_0 - r_T^{(1)}$), while the right-hand side captures the weighted sum the borrower may acheive by applying to the innovative bank in the first period: with probability μ_H the signal received by the innovative bank is high (with $s_I = H$) and the borrower receives a larger surplus (namely $r_0 - r_I^{(1)}$); whereas with probability $(1 - \mu_H)$ the signal received by the innovative bank is low (with $s_I = L$) and the borrower receives either a lower surplus or no surplus (namely $W_c^{(2)} = \max\{r_0 - r_{I|L}, 0\}$). Re-arranging this inequality leads to the following expression:

$$r_T^{(1)} > r_I^{(1)} - (1 - \mu)\Big(\min\{r_{I|L}, r_0\} - r_I^{(1)}\Big)$$

With this in mind for a given rate $r_I^{(1)} = r$, we define the insurance premium $\Delta^{(ip)}_{|r_I^{(1)}=r}$ as follows:

$$\Delta^{(ip)}_{|r_I=r} = (1-\mu)\Big(\min\{r_{I|L}, r_0\} - r\Big)$$

Hence if the traditional lender offers a rate $r_T^{(1)}$ in the first period, the borrower will only apply to the traditional lender if $r_T^{(1)} \leq r_I^{(1)} - \Delta^{(ip)}_{|r_I=r_I^{(1)}}$. We now state a preliminary result:

Definition 1 *Define $\sigma^{(rp)} > 0$ to be the highest value $\sigma \in [0,1]$ such that:*

$$r_{I|H} + \Delta^{(ip)}_{|r_I=r_{I|H}} - r_{T,\mu} \geq (1-\mu)\max\Big\{0, \min\Big\{r_0 - r_{T|L}, r_{I|L} - r_{T|L}\Big\}\Big\}$$

Note that the left hand side captures the profits of a traditional lender who chooses to price competitively against an innovative lender offering a rate $r_I^{(1)} = r_{I|H}$ in the first period. In this case the traditional lender out competes the innovative lender, and serves all borrowers offering them a rate $r_T^{(1)} = r_{I|H} + \Delta^{(ip)}_{|r_I=r_{I|H}}$. Meanwhile the right hand side captures the profits of a traditional lender who allows borrowers with a high signal (with $s_I = H$) to be served by the innovative bank in the first period, and only serves those borrowers with a low signal (with $s_I = L$) in the second period who have been turned away by the innovative bank in the first period. In this case the traditional bank serves a proportion $(1-\mu)$ of the borrowers (when $r_0 > r_{T|L}$) or does not serve any borrowers (when $r_0 < r_{T|L}$), and earns a profit of $\pi_T^{(2)} = \max\Big\{0, \min\Big\{r_0 - r_{T|L}, r_{I|L} - r_{T|L}\Big\}\Big\}$. Using this notation, we now state a result concerning the case where the innovative lender has a small information advantage with $\sigma < \sigma^{(ip)}$:

Proposition 5.4 *If $\sigma < \sigma^{(ip)}$, then in the first period (i) the innovative lender offers a rate $r_I^{(1)} = r_{I|H}$ (earning no profits) and (ii) borrowers always approach the traditional lender. The rate offered by the traditional lender $r_T^{(1)} > r_I^{(1)}$ satisfies the following equation:*

$$r_T^{(1)} = r_{I|H} + \Delta^{(ip)}_{|r_I=r_{I|H}}$$

}

In this case the traditional lender offers a rate $r_T^{(1)}$ that is just high enough so that borrowers prefer to borrow funds from the traditional lender, rather than approaching the innovative lender who offers a rate $r_I^{(1)} = r_{I|H}$. Note that the innovative lender cannot afford to offer a lower rate $r < r_{I|H}$, and is competed out of the market. This is similar to the deterrent equilibrium discussed above when there is no adverse selection and $\sigma < \sigma^{(1)}$. We now turn to the case where the information advantage of the innovative lender is significant:

Proposition 5.5 *If $\sigma > \sigma^{(ip)}$, then in the first period the traditional lender offers a rate $r_T^{(1)} = r_{T,\mu} + (1-\mu)\pi_T^{(2)}$ where $\pi_T^{(2)} = \max\Big\{0, \min\Big\{r_0 - r_{T|L}, r_{I|L} - r_{T|L}\Big\}\Big\}$. Meanwhile in the first period borrowers always approach the innovative lender. The rate offered by the innovative lender $r_I^{(1)} < r_T^{(1)}$ is equal to the following:*

$$r_I^{(1)} = r_T^{(1)} - \frac{1-\mu}{\mu}\Big(\min\{r_{I|L}, r_0\} - r_T^{(1)}\Big)$$

In this case the innovative lender has a significant information advantage and in the first period sets a competitive interest rate in order to deter the traditional lender from competing in the first period. In the second period - when both lenders can infer that all remaining borrowers have a low signal (with $s_I = L$) - the traditional lender may decide to target the remaining borrowers (offering them a rate $r_T^{(2)} = r_0$ in the case that $r_0 > r_{T|L}$), or they may decide not to offer loans to the remaining borrowers (when $r_0 \leq r_{T|L}$). We now state a corollary:

Corollary 5.6 *The critical threshold $\sigma^{(rp)}$ is such that $\sigma^{(rp)} > \sigma^{(2)}$. Moreover - as long as σ remains sufficiently low with $\sigma < \sigma^{(2)}$ - an increase in σ will lead to the traditional lender offering a higher rate in the first period and a corresponding drop in consumer surplus.*

Note that when the level of innovation rises (i) the minimum rate that the innovative lender can afford to lend at (namely $r_{I|H}$) falls and (ii) the insurance premium $\Delta^{(ip)}$ rises. When $\sigma < \sigma^{(2)}$, then $r_{I|L} < r_0$ and the second effect dominates the first with the insurance premium rising steeply. It follows that when the level of innovation rises (while still remaining below $\sigma^{(2)}$) the traditional lender can capture the market more easily and is able to offer consumers a higher rate. This subsequently leads to a fall in consumer surplus.

6 Discussion of modelling assumptions

In this section we now discuss the key assumptions that underpin the results presented in the previous section, and discuss the impact of relaxing some of these assumptions.

6.1 Information accessible to borrower is also accessible to both lenders

As discussed in the introduction, this assumption has been used elsewhere in the literature [], and is an important driver for our results. Indeed if the borrower has a strong information advantage - and in particular the borrower is much better informed than the lenders about their likely ability to repay the loan - both lenders become unable to effectively screen borrowers and all borrowers are offered the same interest rate. In a hybrid scenario lenders would have information about the borrower's likely ability to repay that was not accessible to the borrower (perhaps due to access to large data sets), while borrowers would have information about their likely ability to repay that was not accessible to the lenders (perhaps due to private information about future employability). The model and results discussed above are appropriate for modelling such a hybrid scenario as long as borrowers do not have too much private information about their ability to repay and at least one lender has a significant information advantage. As digital footprints grow and lenders become better at assessing borrowers' current financial positions and future employment prospects, there will be less and less information accessible to borrowers which is not also accessible to lenders. This means the model presented above is particularly suitable for lending markets where lenders assess large amounts of borrower data.

6.2 Information accessible to traditional lender is also accessible to innovative lender

In the model presented above it was assumed that both the borrower and the traditional lender are uninformed about borrower type, while the innovative bank receives a (binary) informative signal. We can relax this assumption as follows by assuming: (i) borrowers receive no signal about their type (ii) the traditional lender receives an informative signal and (iii) the innovative lender observes the informative signal observed by the traditional lender and an additional (binary) informative signal. This shows that the results discussed above do not depend on the traditional lender having no information advantage over the borrowers, but rather that the traditional lender has no information that the innovative lender does not also have.

What happens when we relax this assumption and allow the traditional lender to have access to some information that the innovative lender does not have? This could be the case if there are two lenders each of whom specialise in collecting and processing different types of information. On the one hand if there are two symmetric lenders (and in particular each lender has access to a different but equally informative binary signal) borrowers will choose to approach the lender offering the lowest rate and there will be no premia (rejection premium / verification premium). On the other hand if the signal obtained by the first lender is much more reliable than the signal obtained by the second lender, then similar dynamics to those described above will emerge with borrowers demanding premia (rejection premium / verification premium) depending on the specification. This discussion shows that the key assumptions concerning information on borrower type are that (i) the borrower has no information not accessible to lenders and (ii) the traditional lender has no information not accessible to the innovative lender. Although both these assumptions can be relaxed somewhat while preserving the main characteristics of the market, a significant departure from either of these assumptions is likely to lead to very different market dynamics.

6.3 Borrower is informed about lenders' level of innovation

So far we have discussed assumptions relating to information different parties (namely the borrower and each lender) has concerning borrower type. We now turn to the assumption that the borrower is perfectly informed about the level of innovation of each lender which we refer to as lender type. The assumption that borrowers are well-informed about lender type is crucial for the results, since it ensures borrowers can anticipate (i) which lender is more likely to reject them (leading to a rejection premium) and (ii) which first period lender will enhance their reputation in the second period (leading to a verification premium)

We now discuss the combination of assumptions concerning borrowers namely that (i) borrowers are uninformed about their type (or at least less informed than lenders) and (ii) borrowers are well-informed about lender type. The first assumption seems to capture a situation with unsophisticated borrowers who are unable to accurately anticipate their own type, while the second assumption seems to capture a situation with sophisticated borrowers who choose to approach a lender based not only on the price offered but also the type of the lender. Although this combination of assumptions seems to give the borrower access to an unusual set of information, these assumptions are appropriate to model situations where (i) it is hard for the borrower to second guess the decision-making process of lender with an intensive screening process (i.e. it is hard for the borrower to predict their own type), and (ii) it is easy for the borrower to assess whether any given lender will undertake intensive screening (i.e. it is easy for the borrower to distinguish between different types of lenders). In practice we believe there are many credit markets that fit these criteria, for instance when certain (innovative) lenders request a large amount of information before making a credit decision and other (traditional) lenders are willing to make a credit decision very quickly based on little information.

We close this section with a discussion of the incentives for the innovative lender to under-state or over-state their level of innovation, in order to try and give borrowers and other lenders the impression that they are either more or less innovative than they truly are. In the scenario where there is a rejection premium, the innovative lender is penalised for being innovative and so the innovative lender may want to under-state their level of innovation. Meanwhile in the scenario where there is a verification premium, the innovative lender is rewarded for being innovative and so the innovative lender may want over-state the level of innovation. While it is often possible for borrowers to distinguish a traditional lender from an innovative lender (based for instance on the amount of data requested for a credit application), it is much harder for borrowers and other potential lenders to assess the level of success an innovative lender has had in embracing new screening methodologies. Innovative lenders may exploit this uncertainty by under-stating or over-stating the accuracy of their screening techniques.

6.4 Lenders compete only on interest rate

In the analysis above we assume that lenders compete only on interest rate (ie price). Other terms of the lending contract such as the size of the loan or the time period over which the borrower must repay are taken as given. Expanding the set of possible loan contracts would complicate the analysis significantly - however it seems highly likely that the premia identified above (verification premium / rejection premium) would still be present in a more complex multi-dimensional model

7 Policy implications and conclusion

The sharing of credit histories among competing lenders can be beneficial not only for ‘locked-in’ borrowers, thus maintaining their incentives to exert effort, but also for lenders collectively, as it reduces adverse selection. However, it has been argued that the disclosure of previous applications (i.e., those that did not result in loan originations) can distort competition by dissuading prospective borrowers to shop around, wary that the observation of credit searches logged by other lenders could be attributed to previous rejections.

We identify another problem with this type of disclosure. When competing lenders differ in their screening ability and the prospective borrower is less informed about her creditworthiness, then the latter might shun the lender with a screening advantage in order to maintain opacity. This is because if the prospective borrower approaches the innovative lender then there is a risk of being rejected and thus exposed as a risky borrower. With this in mind, the prospective borrower will only approach the innovative lender if the rate offered by the innovative lender sufficiently compensates the borrower for the possibility of rejection. This in turn could undermine the incentive for the innovative lender to invest in better screening technology in the first place.

It follows that the welfare implications of disclosing previous applications are ambiguous. On the one hand disclosing previous applications lead to lower rates as the innovative lender must pay a *rejection premium* and price below the traditional lender to attract borrowers. Lower rates increases welfare by improving the supply of credit for borrowers that are deemed to be low risk. On the other hand an increase in innovation is associated with a larger *rejection premium*, and so disclosing previous applications may weaken the incentive for the innovative lender to invest in the innovative technology. Less innovation means that the innovative lender evaluates the riskiness of borrows less accurately and this leads to worse investment decisions.

Further research is needed to determine when disclosing previous applications improves welfare and in particular under what conditions the welfare effects of lower rates dominate the welfare effects associated with lenders' reduced incentive to innovate. If the latter effect dominates - and disclosure has a significant effect on lenders' incentives to innovate - then ruling out the disclosure of previous applications is an important policy consideration. This is particularly true given that disclosure currently appears to be the standard design choice.

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8 Appendix

Proof of Lemma 3.1:

Suppose $1 < c_I/c_T < 1 + \Delta$ where Δ is sufficiently small. In particular suppose that:[14]

$$1 < \frac{c_I}{c_T} < \frac{p_R/p_T - (1-\mu_H)}{p_R/p_S - (1-\mu_H)}$$

Now define $\phi(\sigma)$ as follows:

$$\phi(\sigma) = r_{I|H} - r_T - (1-\mu_H)(r_{I|L} - r_{T|L})$$

We aim to prove that there is a unique $\sigma^{(1)}$ (where $0 < \sigma^{(1)} < 1$) such that $\phi(\sigma^{(1)}) = 0$. To do this it is sufficient to prove (i) $\phi(0) > 0$, (ii) $\phi(1) < 0$ and (iii) $\phi(\sigma)$ is continuous and strictly decreasing in σ. We now prove (i), (ii) and (iii).

To prove (i), note that when $\sigma = 0$ the signal is uninformative and hence $p_{I|H} = p_{I|L} = p_T$. In this case:

$$\begin{aligned}
\phi(0) &= \frac{c_I}{p_{I|H}} - \frac{c_T}{p_T} - \Big(1-\mu_H\Big)\Big(\frac{c_I}{p_{I|L}} - \frac{c_T}{p_{T|L}}\Big) \\
&= \frac{1}{p_T}\Bigg[c_I - c_T - (1-\mu_H)(c_I - c_T)\Bigg] \\
&> 0
\end{aligned}$$

To prove (ii), note that when $\sigma = 1$ the signal is perfectly informative. Hence in this case $p_{I|H} = p_S$ and $p_{I|L} = p_R$. We now use the condition above stating that $(c_I - c_T)/c_I$ is sufficiently small and re-arrange. In particular:

$$\begin{aligned}
\frac{c_I}{c_T} &< \frac{p_R/p_T - (1-\mu_H))}{p_R/p_S - (1-\mu_H))} \\
c_I\left(\frac{1}{p_S} - \frac{1-\mu_H}{p_R}\right) &< c_T\left(\frac{1}{p_T} - \frac{1-\mu_H}{p_R}\right) \\
r_{I|H} - (1-\mu_H)r_{I|L} &< r_T - (1-\mu_H)r_{T|L} \\
r_{I|H} - r_T - (1-\mu_H)(r_{I|L} - r_{T|L} &< 0 \\
\phi(1) &< 0
\end{aligned}$$

[14]Note the condition $\mu_H > 1 - p_R/p_S$ ensures the numerator and denominator of RHS are both positive.

Finally to prove (iii), all terms in $\phi(\sigma)$ are continuous in σ and hence $\phi(\sigma)$ is also continuous in σ. To show $\phi(\sigma)$ is strictly decreasing and continuous in σ it is enough to show that (a) $r_{I|H} = c_I/p_{I|H}$ is strictly decreasing in σ and (b) $r_{I|L} - r_{T|L} = -(c_I - c_T)/p_{I|L}$ is strictly decreasing in σ. Both (a) and (b) follow directly from the definitions of $p_{I|H}$ and $p_{I|L}$ respectively. Hence there is a unique value $\sigma^{(1)} \in (0, 1)$ such that $\phi(\sigma^{(1)}) = 0$. This completes the proof.

Proof of Lemma 3.2:

Suppose $r_{I|L} = r_0$. Recall that (i) $r_{I|L} = c_I/p_{I|L}$ and (ii) $p_{I|L} = (\mu_H - \mu_H\sigma)p_S + (1 - \mu_H + \mu_H\sigma)p_R$. From (i) and (ii) it follows that:

$$\frac{c_I}{\Big(\mu_H - \mu_H\sigma^{(2)}\Big)p_S + \Big(1 - \mu_H + \mu_H\sigma^{(2)}\Big)p_R} = r_0$$

Rearranging this expression gives:

$$\sigma^{(2)} = \frac{\mu_H(p_S - p_R) - (c_I/r_0 - p_R)}{\mu_H(p_S - p_R)}$$

Hence there is a unique value of $\sigma = \sigma^{(2)}$ such that $r_{I|L} = r_0$. Now recall that $r_0 < c_I/p_R$ and hence $(c_I/r_0 - p_R) > 0$. From this it follows $\sigma^{(2)} < 1$.

Now using the fact that $p_T = \mu_H p_S + (1 - \mu_H)p_R$ we reach the following:

$$\sigma^{(2)} = \frac{p_T - c_I/r_0}{\mu_H(p_S - p_R)}$$

Recall that $r_0 > c_I/p_T$ and hence $p_T - c_I/r_0 > 0$. From this it follows $\sigma^{(2)} > 0$. Hence $\sigma^{(2)} \in (0, 1)$ and this completes the proof.

Proof of Lemma 3.3:

This is proved in the same way as Lemma 3.2 by replacing c_I with c_T.

Proof of Proposition 3.4:

Define $\phi(\sigma; c)$ as follows:

$$\phi(\sigma; c) = \frac{c_I}{p_{I|H}} - \frac{c}{p_T} - (1 - \mu_H)\Big(\frac{c_I - c}{p_{I|L}}\Big)$$

Recall $\mu_H > 1 - p_R/p_S$ and hence $1/p_S > (1 - \mu_H)/p_R$. Recall also that (i) $p_T < p_S$ and (ii) $p_{I|L} > p_R$, and so $1/p_T > (1 - \mu_H)/p_{I|L}$. Rearranging this yields:

$$\frac{\delta\phi}{\delta c} = -1/p_T + (1-\mu_H)p_{I|L} < 0$$

Note that (i) $\phi(0; c_I) = 0$. Above we have shown that (ii) $\phi(\sigma; c)$ is decreasing and continuous in c and (iii) ϕ is also decreasing and continuous in σ (see proof of Lemma 3.1). Finally note that (iv) $\sigma^{(2)}$ does not depend on c_T.

From (i), (ii), (iii) and (iv) for any $\sigma^* = \sigma^{(2)}/2$ there exists c_T^* such that $\phi(\sigma^*; c_T^*) = 0$. Furthermore for any $\hat{c}_T > c_T^*$ there exists $\hat{\sigma} < \sigma^*$ such that $\phi(\hat{\sigma}; \hat{c}_t) = 0$. Hence if c_T is sufficiently small (with $c_T^* < c_T < c_I$), then $\sigma^{(1)} < \sigma^{(2)}$.

Finally to prove $\sigma^{(2)} < \sigma^{(3)}$ follows directly. This completes the proof that $\sigma^{(1)} < \sigma^{(2)} < \sigma^{(3)}$ as long as c_T is sufficiently close to c_I (with $c_T^* < c_T < c_I$).