Credit Registries, Relationship Banking and Loan Repayment

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Abstract

This paper examines the impact of a public credit registry on the repayment behavior of borrowers. We implement an experimental credit market in which loan repayment is not third-party enforceable. We compare market outcome with a credit registry to that without a credit registry. This experiment is conducted for two market environments: first a market in which interactions between borrowers and lenders are one-off and, second, a market in which borrowers and lenders can choose to trade repeatedly with each other. In the market with one-off interactions the credit market collapses without a credit registry as lenders rightly fear that borrowers will default. The introduction of a registry in this environment significantly raises repayment rates and the credit volume extended by lenders. In the market where repeat transactions are possible a credit registry is not necessary to sustain high market performance. In such an environment relationship banking enforces repayment even when lenders cannot share information, so that there is little value added of a public credit registry.

Keywords: Credit Market, Information Sharing, Relationship Banking
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1 Introduction

In credit markets borrowers typically have more information about their investment opportunities, their own character and their prior indebtedness than lenders. This asymmetry of information gives rise to selection problems for lenders and potential moral hazard of borrowers, which may lead to a rationing of credit (Stiglitz and Weiss, 1981). In many countries problems of assymetric information are aggravated by the fact that loan contracts are costly to enforce.

One response to asymmetric information and costly enforcement is information sharing between lenders. Recent surveys show that information sharing institutions such as private credit bureaus and public credit registries exist in a wide range of countries (Miller, 2003). Cross country studies suggest that these institutions do enhance the performance of the financial sector. Japelli and Pagano (2002) and Djankov et al. (2005) show that bank credit to the private sector is higher in countries where information sharing is more developed. Analyzing firm-level survey data Galindo and Miller (2001) and Love and Mylenko (2003) show that access to bank credit is easier in countries where credit bureaus or registries exist.

How do credit bureaus and registries enhance the performance of credit markets? Theoretical models suggest that information sharing can reduce selection costs for lenders in markets where borrowers approach different lenders sequentially (Japelli and Pagano, 1993). Indeed, recent evidence suggests that private credit bureaus do reduce the selection costs of lenders by accurately predicting loan defaults (Kallberg and Udell, 2003; Barron and Staaten, 2003).

Information sharing can also have a strong disciplining effect on borrowers. Diamond (1989) shows that a public credit registry can motivate borrowers to choose agreed projects. Further models show that information sharing can discipline borrowers into exerting high effort in projects (Vercammen, 1995; Padilla and Pagano, 2000) and repaying loans (Klein, 1992). So far, empirical studies have not been able to confirm the disciplining effect of information sharing institutions[1]. This is not at all surprising, seeing that is difficult to identify whether a borrower has exerted more effort in repaying a loan than he would have done without the presence of a credit registry.

The objective of this paper is to provide direct evidence that a public credit registry can discipline borrowers into repaying loans. To this end we take an ex-

[1] Japelli and Pagano (2002) show that loan defaults, measured by country risk indicators, are lower in countries where credit registries and bureaus are mode developed. However, this result can obviously result from better selection of borrowers rather from actual disciplining of them to repay.

perimental approach. Experimental studies have proven highly valuable in testing theoretical conjectures which cannot be isolated using field data. In financial markets, experiments have, for example, been used to study the emergence of bubbles (Smith et. al, 1988; Lei et. al., 2001), the dissemination of information (Sunder, 1992), herd behavior (Celan and Kariv, 2004), and more recently the emergence of banking relationships (Fehr and Zehnder, 2005). We examine an experimental credit market in which loan repayment is not third-party enforceable. We first implement a market in which there is no opportunity for information sharing between lenders. We then implement an identical market, but with a public credit registry which collects and disburses credit information to lenders. By comparing repayment behavior and credit volumes between the two markets we can identify the impact of a credit registry on credit market performance.

The impact of a credit registry on repayment behavior may depend strongly on the nature of the credit market. In particular, the extent to which lending is a one-off or a repeated transaction may affect the potential benefits of information sharing between lenders. In a credit market dominated by one-off transactions (e.g. trade credit for rare purchases), borrowers cannot be disciplined to repay loans in the absence of an information sharing mechanism. In contrast in credit markets with repeated interactions (e.g. working capital loans) theoretical models suggest that information sharing may not be required to discipline borrowers. In such markets self-enforcing implicit contracts between lenders and borrowers, i.e. banking relationships, can motivate high effort and timely repayments (Bull, 1987; Boot and Thakor, 1994). Empirical studies show indeed that some credit market segments (in particular small business lending) are pervaded by relationship-banking and that these relationships improve the access of potential borrowers to credit (Petersen and Rajan, 1994, Elsas and Krahnen, 1998). Experimental studies (Brown et al., 2004; Fehr and Zehnder, 2005) also confirm that long-term relationships are a powerful disciplinary device.

In this paper we examine how the impact of a credit registry depends on the nature of credit transactions. We implement our experimental credit market in two environments. In one environment information conditions imply that all lending transactions are inherently one-off. In the second environment information conditions are such that borrowers can choose to trade with the same lender repeatedly and banking relationships can emerge.

Our results indicate that the impact of a credit registry on market performance is highly dependent on the nature of credit transactions. When the credit market is characterized by one-off transactions the absence of a credit registry causes the

market to essentially break-down. As repayments are not third-party enforceable many borrowers default and lenders cannot profitably offer credit contracts. The introduction of a credit registry in this environment greatly enhances the performance of the credit market. The availability of information on past repayment behavior allows lenders to condition their offers on the borrowers' reputation. As borrowers with a good track record get better credit offers, all borrowers have a strong incentive to sustain their reputation by repaying their debt. As a consequence a well functioning credit market is established in which a large percentage of the available gains from trade is realized.

When repeated interaction between borrowers and lenders is possible the presence of a credit registry has no such effect on market performance. In this environment the market participants solve the moral hazard problem even in the absence of a credit registry. By repeatedly interacting with the same borrower, lenders establish long-term relationships which enable them to condition their credit terms on the past repayments of their incumbent borrower. As only a good reputation leads to attractive credit offers from the incumbent lender borrowers have strong incentives to repay. The disciplining effect of these banking relationships is strong enough such that the introduction of a credit registry only slightly improves credit market performance.

The plan of the paper is as follows: Part 2 presents our experimental design and part 3 the corresponding predictions. Part 4 presents our results. Part 5 concludes.

2 Experimental Design

Our experimental credit market involves 17 participants. These participants are randomly assigned to the role of a borrower or a lender at the beginning of a session. Ten subjects are in the role of lenders and seven subjects are in the role of borrowers. Each session lasts for 20 periods and roles of subjects are fixed for the whole session.

We implement two different credit market environments: The first environment involves a market in which particular lenders and borrowers interact only in a one-off situation. We implement transactions with a one-off nature by randomly assigning identification numbers (ID's) to borrowers and lenders in each new period (henceforth treatments in this environment are called R- treatments). This procedure guarantees that no market participant can identify his former trading partners at the beginning of a period and therefore intentional repeated interactions of lenders and borrowers are ruled out. This environment captures a credit market in which,

for example, borrowers are highly mobile, or they seek trade credit for rare purchases.

Table 1: Experimental Treatments

		Market Environment	
		Random ID	Fixed ID
Credit Registry	yes	R-CR	F-CR
	no	R-NO	F-NO

Our second environment involves a market in which lenders and borrowers have the opportunity to engage in long-term relationships. Repeated interactions with the same trading partner are possible because subjects have fixed ID's for the entire experimental session (henceforth treatments in this environment are called F- treatments). Consequently, lenders can offer credit to the same borrower (i.e., to the same ID number) in consecutive periods and, if the borrower accepts these offers, a long-term relationship is established. This environment captures a credit market in which particular lenders and borrowers typically trade repeatedly with each other (working capital loans, credit card loans).

Table 1 provides an overview of our experimental treatments. In order to study the impact of a credit registry on credit market performance we conduct two treatments in each environment: one treatment with a credit registry (CR treatment) and one treatment without (NO treatment). This gives us a total of four treatments.

In all four treatments we implement the same credit market. At the beginning of every period each lender is endowed with 50 capital units ($\bar{k}$). A lender has two opportunities to make use of his endowment. He can either invest the endowment in an endowment-storing technology or he can use the endowment to extend credit to a borrower. The first stage of each period is a continuous one-sided auction, in which lenders and borrowers can seal credit contracts. The lenders are the contract makers, i.e. they alone can make credit offers to the borrowers, who themselves can not apply for credit. When making a credit offer the lender has to specify four items: the size of the loan (k), the requested repayment ($\tilde{r}$), who can observe the offer and finally, which borrowers are authorized to accept the offer. Lenders

can freely decide how they want to split their endowment between the endowment-storing technology and a credit offer, i.e. the loan size k can be picked from the set $\{5, 10, 15, ..., 50\}$. The set for the requested repayment $\tilde{r}$ is given by $\{5, 10, 15, ..., 100\}$. There are two types of credit offers: Public credit offers and private credit offers. A private credit offer is only addressed to one specific borrower. It cannot be seen or accepted by other borrowers and is also not visible to other lenders. A public offer is always shown to all borrowers and all other lenders. However, even with public offers the lender must specify which borrowers are authorized to accept the offer. Hereby the lender can choose, or exclude as many borrowers as he wants.[2] During the auction a lender can make as many public and private offers as he wants. However, each lender can only conclude one credit contract per period. As soon as a borrower accepts an offer of a certain lender a contract is concluded and all other outstanding offers of this lender disappear from the market and can no longer be accepted by other borrowers. Each borrower can accept at most one contract per period so that our credit market implements an excess supply of credit.

Borrowers are endowed with 5 capital units in each period. At the second stage of a period borrowers automatically yield an investment income which is twice the size of this endowment and their borrowed capital, $2(5 + k)$. At the third stage of a period, borrowers who received a loan decide whether they want to make the repayment requested by the lender ($r = \tilde{r}$) or not repay at all ($r = 0$). Partial repayments are not possible.[3]

Finally, each lender is informed about his borrower's repayment decision, profits are calculated and all market participants get to know their own and their partner's payoffs for the period. Payoff functions, the number of lenders and borrowers and the number of trading periods are common knowledge. The monetary payoffs of the market participants are calculated as follows:

$$\begin{array}{ll} \text{Payoff of lender:} & \pi = 50 - k + r \\ \text{Payoff of borrower:} & v = 2(5 + k) - r \end{array}$$

In the treatments with a credit registry (R-CR and F-CR) all lenders get a credit report at the beginning of every period. The credit report is free and lists for each borrower and all past periods whether the borrower received a loan and whether he repaid it. The report thus contains complete information on the past repayment behavior of all borrowers. However, information on loan sizes and requested

[2] This implementation of public offers intends to capture public anouncements of credit conditions by banks who can always choose not to extend credit to some clients on these terms.

[3] In reality some borrowers obviously become delinquent without fully defaulting. However due to the deterministic nature of investment earnings in our design we exclude partial repayments.

repayments is not provided. All borrowers and lenders are aware that the credit registry automatically collects and disburses information on repayment behavior in each period.

To make sure that all participants fully understand the decision process and the payment structure of the game, each subject has to read a detailed set of instructions before a session is started. After reading the instructions participants have to pass a test with control questions. No session starts before all subjects have correctly answered all control questions. Additionally there are two practice periods before an actual session is started in order to make the participants familiar with the bidding procedures. In both practice periods subjects only go through the offering stage of a period, i.e. there are no repayment choices and subjects cannot earn money in the practice periods.

In total we conducted 20 experimental sessions, five for each of our four treatments. We had 17 subjects in each session, which makes a total of 340 participants. All experimental subjects were volunteers. They were all participating for the first time in such an experiment, and each participant could only participate in one session (i.e., each subject experienced only one of the treatments). All participants were students of the University of Zurich or the Swiss Federal Institute of Technology Zurich (ETH). The computerized experiment was programmed and conducted with the experimental software z-Tree (Fischbacher (1999)). A session lasted approximately ninety minutes and subjects earned on average 55 Swiss Francs (1.2 CHF $\approx$ 1 US$ in January 2005).

3 Predictions

Under the assumption of common knowledge of rationality and selfishness of all market participants the prediction for all four treatments is straight forward: Since credit repayments are not enforceable, the borrowers' best reply in the stage game is to never repay their debt. Lenders, anticipating this behavior, will never offer credit so that the credit market collapses in the stage game equilibrium. As our experiment lasts for a finite number of periods a simple backward induction argument ensures that the stage game equilibrium is played in every period of the game. The different treatment conditions do not affect this prediction. If lenders are certain that all borrowers are selfish, neither public information on past repayment behavior of borrowers nor the possibility to establish long-term relationships can overcome this inefficient outcome.

However, empirical evidences suggests that not all people simply maximize mon-

etary payoffs. It has been shown that in a wide range of economic settings some people are also motivated by social motives (for an overview see, e.g., Fehr and Schmidt (2002) and Camerer (2003)). Recent research by Giuso et al. (2004) suggests that social concerns may also be important in the context of financial markets. In our experiment social motives could lead some borrowers to repay loans because they would otherwise suffer from a bad conscience or because they would like to reciprocate "fair" financing conditions provided by lenders. In the following we therefore examine predictions for our treatments under the assumption that a fraction p of the borrowers are "conditionally honest". We assume that these borrowers are willing to meet their repayment obligations ($r = \tilde{r}$) on a voluntary basis as long as the repayment requested by the lender does not exceed a certain threshold value $\tilde{r}(k) \leq \bar{r}(k) = \phi k$, whereby $\phi > 1$ (this implies that an honest borrower is prepared to repay a loan which demands some positive interest rate). Guided by existing experimental evidence (see e.g. Fehr and Schmidt, 2002) we also assume that honest borrowers only repay if they get at least an equal share of gains from trade, i.e. $2k$-$\bar{r}(k) \geq \bar{r}(k) - k$ or $\phi \leq 1.5$. These considerations lead us therefore to assume a parameter range of $\phi \in (1, 1.5]$.

3.1 Predictions for the R- Treatments

In the **R-NO treatment** lenders have no information on the prior behavior of any particular borrower in the market. This treatment essentially implements a series of one-shot interactions so that each period can be analysed as a one-period game. In such a game selfish borrowers never repay their debt while honest borrowers repay as long as they are offered a contract of the form $[k, \tilde{r} \leq \phi k]$. Proposition 1 shows that under these conditions lenders are only willing to offer credit if the fraction of honest borrowers p is large enough.

Proposition 1: If $p \geq \frac{1}{\phi}$ there exists a perfect Bayesian equilibrium in which all borrowers receive maximum credit of 50. If, however, $p < \frac{1}{\phi}$ the credit market collapses.

(Proof: see Proposition A1 in the Appendix).

Proposition 1 suggests that a substantial share of honest borrowers are required to guarantee the existence of a functioning credit market. We assumed above that $\phi \in (1, 1.5]$. In this case the necessary fraction of honest borrowers to make credit offers profitable for lenders is $p \geq 2/3$. Experimental evidence suggests, however, that only 40 to 60 percent of subjects are motivated by social preferences (see e.g.

Fehr and Schmidt, 2002). We therefore predict that the credit market will collapse in our R-NO treatment. Empirically, however, a full collapse of the market would require that all lenders have an accurate initial belief about the fraction of honest borrowers. This is a relatively strong assumption. If some lenders start with too high beliefs, there may be some trading in the early periods. However, as soon as learning takes place and beliefs are updated the credit market should break down.

In the **R-CR treatment** lenders receive a credit report at the beginning of each period stating the repayment behavior of each borrower in all prior periods. In contrast to the R-NO treatment, lenders in the R-CR can therefore condition their credit offers on the past repayment behavior of borrowers. This means, for example, that lenders can decide to only offer credit to those borrowers who have always repaid their debt in all past periods. If selfish borrowers anticipate this behavior of lenders they have a strong incentive to hide their type and imitate the behavior of honest borrowers. Repaying a loan is the only way for selfish borrowers to build up a reputation as a honest type and to get access to profitable future credit offers of lenders. Similar to Kreps et al. (1982) Proposition 2 shows that this mechanism allows us to sustain an equilibrium with a substantial credit volume, even if the share of honest borrowers p is such that the credit market collapses in the R-NO treatment.

Proposition 2: Suppose that $p < \frac{1}{\phi}$ so that the market collapses in the R-NO treatment. In the R-CR treatment a perfect bayesian equilibrium exists with the following characteristics:

(i) in all periods $t < 20 - s$ each borrower receives a contract $[k, \tilde{r}] = [\bar{k}, \bar{k}]$ and repays $r^*(\bar{k}) = \bar{k}$ with certainty, whereby s is the smallest integer that satisfies $p \geq \frac{1}{\phi^{s+1}}$.

(ii) in all periods $20 - s \leq t < 20$ each borrower who did not default in any prior period receives a contract $[k, \tilde{r}] = [\bar{k}, \phi\bar{k})]$ with probability $\lambda_t^* \in (0, 1)$. Selfish borrowers repay with probability $\gamma_t^* \in (0, 1)$ and honest borrowers repay with certainty.

(iii) in period t=20 each borrower who did not default in any prior period receives a contract $[k, \tilde{r}] = [\bar{k}, \phi\bar{k})]$ with probability $\lambda_{20}^* \in (0, 1)$. Selfish borrowers default, while honest borrowers repay with certainty.

(Proof: see Proposition A2 in the Appendix).

Proposition 2 suggests that in early periods of the R-CR treatment full credit will be provided and all selfish borrowers will repay loans out of reputational concerns. In later periods reputational incentives decline and repayment rates fall as selfish borrowers begin to default. The aggregate credit volume also falls as those borrowers who defaulted in prior periods receive no further loans and those who repaid receive loans only with a probability less than 1.

Consider the case of $\phi = 1.2$ (honest borrowers are willing to repay 60 if they receive a loan of size 50) and $p = 0.5$ ($\frac{1}{2}$ of borrowers are honest). In this case Proposition 1 shows that the credit market collapses in the R-NO treatment. Proposition 2 tells us that in the R-CR treatment all borrowers could get full credit provision until period 16 and from then on they still get maximum credit with a positive probability. This implies that the credit registry can have a significant positive effect on credit market efficiency. Propositions 1 and 2 therefore lead us to the following hypotheses for our R- treatments:

Hypothesis R-Treatments: In the R-CR treatment the repayment rate of borrowers is significantly higher than in the R-NO treatment. In the R-NO treatment the low repayment rate leads to a collapse of the credit market. In the R-CR treatment credit volumes are significantly higher than in the R-NO, albeit with decreasing volumes towards the end of the experiment.

3.2 Predictions for the F- Treatments

In the **F-NO treatment** lenders do not have information on the behavior of all borrowers in all prior periods. However, lenders do have information on past behavior of those borrowers with whom they themselves have traded in prior periods. Thus in contrast to the R-NO treatment lenders have the possibility to engage in a long-term relationship with a specific borrower. By conditioning their future offers on the past repayment behavior of a borrower, they can motivate repayments, because repaying rather than defaulting may provide future benefits for selfish borrowers.

However, given that there are more lenders than borrowers in the market, establishing a relationship is anything but trivial. The problem is that a borrower always has the possibility to default on one lender and then switch to another lender who is not informed about his past behavior. In order to prevent borrowers from switching lenders, incumbent lenders must make offers which "outside" lenders cannot compete with. This requires that relationships generate superior information for

incumbent lenders on a borrower's type. Proposition 3 shows that equilibria exist in which this is the case:

Proposition 3: Suppose that $p < \frac{1}{\phi}$ so that the market collapses in the R-NO treatment. In the F-NO treatment there exists a perfect Bayesian equilibrium with the following characteristics:

(i) in period 1 all lenders offer a contract of the form $[\bar{k}, \tilde{r}_1^* \in (\bar{k}, \phi\bar{k})]$. Selfish borrowers accept a contract and repay with probability $\lambda_1^* \in (0,1)$, while honest borrowers accept a contract and repay with certainty.

(ii) in all periods $2 \leq t < 20$ lenders who were repaid in the previous period $t-1$ offer a contract $[\bar{k}, \bar{k}]$ with probability $\lambda_t^* \in (0,1)$ to their incumbent borrower and all borrowers who get a contract repay with certainty. Lenders who were not repaid in the prior period and "outside lenders" offer no credit.

(iii) in period 20 lenders who were repaid in period 19 offer a contract $[\bar{k}, \tilde{r}_{20}^* \in (\bar{k}, \phi\bar{k})]$ with probability $\lambda_t^* \in (0,1)$ to their incumbent borrower. Selfish borrowers never repay while honest borrowers repay with certainty. Lenders who were not repaid in the prior period and "outside lenders" offer no credit.

(Proof: see Proposition A3 in the Appendix).

Proposition 3 shows that in a market with potential repeat transactions but no credit registry not all borrowers can repay loans in the first period. If this were the case incumbent lenders would have the same information as outside lenders and thus could not motivate repayment by promising better future contracts. As some selfish borrowers default in period 1 incumbent lenders know that those who repaid are honest with a probability exceeding p. This allows them to profitably offer credit in all periods $t > 1$ while outside lenders cannot. As incumbent lenders promise better credit access than outside lenders selfish borrowers are motivated to repay their loans.

In the **F-CR treatment** the credit registry provides lenders with information on past repayment behavior of all borrowers. Given these information conditions we can again apply Proposition 2 which describes equilibria for the R-CR treatment[4].

[4]Note that in the F-CR treatment lenders actually have more information than in the R-CR treatment. For their own past borrowers they know not only whether a borrower repaid, as is stated in the credit registry, but also the corresponding contract terms. However, this additional information obviously does not mean that the equilibrium described in Proposition 2 (which only requires credit registry information) no longer applies also in the F-CR treatment.

As discussed above this proposition shows that lenders condition their credit offers on the credit record of a borrower. In initial periods this motivates all selfish borrowers to repay and makes it profitable for lenders to extend maximum credit volumes. In contrast to the F-NO treatment incumbent lenders do not need superior information to motivate borrowers in the F-CR treatment. This is the case because the credit registry prevents borrowers from "escaping" to another lender after defaulting. Thus, in the F-CR treatment full repayment of all borrowers is possible in initial periods while in the F-NO partial defaulting is necessary to generate superior information for incumbent lenders. This implies higher aggregate credit volumes in the F-CR than in the F-NO treatment as all borrowers receive credit contracts in initial periods of the F-CR, while in the F-NO the mixed strategy of lenders implies that borrowers are subsequently excluded from the credit market. This leads to our hypothesis for the F- treatments:

Hypothesis F- Treatments: In the F-CR treatment the aggregate repayment rate is slightly higher than in the F-NO treatment because defaulting is disciplined by all lenders. In the F-CR treatment the aggregate credit volume is also slightly higher than in the F-NO treatment.

4 Results

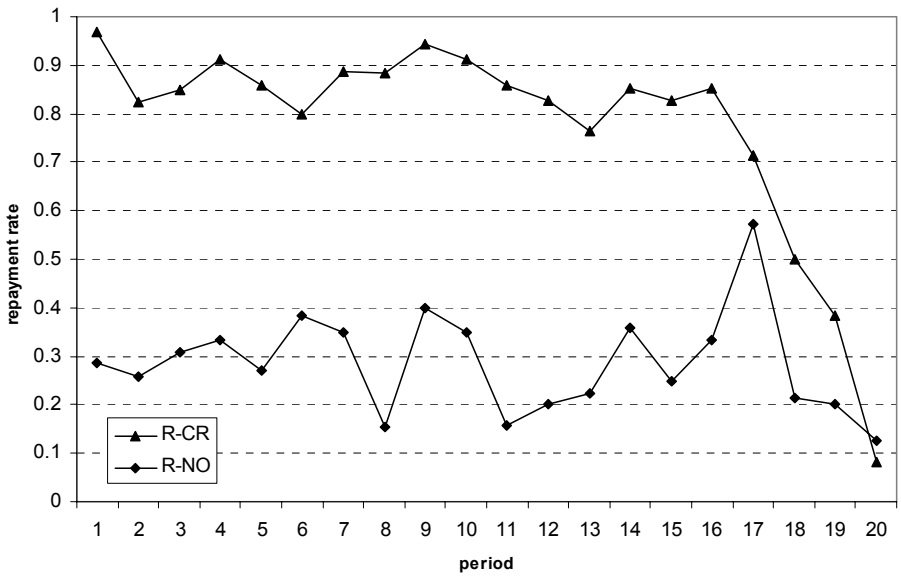
We present our results in two sections. Section 4.1 analyses our R- treatments and thus examines the impact of a credit registry in a market with one-off transactions. Section 4.2 analyses our F- treatments and thus looks at the impact of a credit registry in a market where repeat transactions are possible.

4.1 Results for the R-Treatments

In this section we examine the impact of a credit registry in a market with one-off transactions by comparing the outcome of the R-CR to that of the R-NO treatment. We begin by examining the repayment behavior of borrowers. Figure 1 presents the repayment rate of borrowers by period for both treatments.

Our predictions suggest that in the R-NO treatment selfish borrowers will default while honest borrowers repay loans with fair terms. Figure 1 shows that loan repayment in the R-NO treatment is actually very low. The repayment rate hovers around 30% throughout the experiment, resulting in a total repayment rate of 29%.

Figure 1: Repayment Rates in R- Treatments



As predicted the repayment rate in the R-CR treatment is substantially higher. In this treatment the aggregate repayment rate is 80 % and thus more than twice that of the R-NO treatment. A non-parametric test confirms that the difference in repayment rates between the R-CR and R-NO treatments is statistically significant. We conduct a Mann-Whitney Test using average repayment rates per session as observations. The 5 sessions of the R-CR treatment display repayment rates of 87, 85, 81, 77 and 70 percent respectively. Every session of the R-CR treatment has a higher repayment rate than any session in the R-NO treatment. In that treatment the five sessions have repayment rates of 39, 31, 29, 26 and 16 percent respectively. A one-sided test thus confirms that repayment is more frequent in the R-CR treatment ($p = .004$).

Figure 1 suggests that a credit registry prevents potential loan defaults in one-off transactions because selfish borrowers are aware that their current repayment behavior may affect their future access to credit. This interpretation is supported by fact that the repayment of loans in the R-CR treatment falls over time. Our predictions suggest that the value of a good reputation declines towards the end of our experiment, due to the finite horizon of 20 periods. We therefore expect that selfish borrowers who repay in earlier periods out of reputational concerns, will default in the final periods. Indeed the figure shows that in the final periods of the R-CR treatment loan repayments decrease steadily. While 86% of all loans are

repaid in period 1 through 15 this falls to less than 50% in the last five periods of the R-CR treatment. Moreover, as predcited the repayment rate in the final period of the R-CR treatment falls to that of the R-NO treatment.

Figure 1 strongly suggests that a credit registry motivates loan repayments from selfish borrowers in one-off transactions, when they would otherwise default. However, an alternative explanation for our finding could be that selfish borrowers default in both treatments while honest borrowers repay more often in the R-CR than in the R-NO treatment. We would predict such behavior if better contract terms were offered in the R-CR than in the R-NO treatment so that honest borrowers have more scruples to default. In order to control for such differences in contract terms we conduct a multivariate analysis of repayment behavior.

Table 2 reports a probit analysis of repayment decisions in the R-CR and R-NO treatments. Note that in our experiment borrowers could only choose to make the desired repayment in full or default. Our dependant variable is therefore a dummy variable which is 1 if a borrower repaid and 0 if he defaulted. We pool all observations from the R-CR and R-NO treatment. Our main explanatory variable is the dummy variable "R-CR" which is 1 for all observations in the R-CR treatment and 0 for all those in the R-NO treatment. If repayment rates are higher ceteris paribus we should see a positive coefficient on this variable.

We control for the size of loans and the desired repayment by including the variables "CreditSize" and "RepaymentSize". If honest borrowers reciprocate better contract terms with higher repayment probabilities we expect a positive coefficient for "CreditSize" and a negative coeficient for "RepaymentSize". This prediction applies to both treatments. The regression also includes the interaction variables "R-CR*CreditSize" and "R-CR*RepaymentSize". These variables should capture the additional incentive effects of high loans and low repayment demands on selfish borrowers in the R-CR treatment. Our predictions suggest that selfish borrowers will be more likely to repay if their expected future rents from a good reputation and the cost of current repayment is low. Our data does not allow us to capture the expectations of borrowers concerning future rents. However, we suggest that the size of a borrowers current loan is a good indicator for potential loans in the future. Thus "R-CR*CreditSize" is a measure for the impact of expected rents on selfish borrowers repayment in the R-CR treatment and we expect a positive coefficient. The cost of repaying a loan to the borrower is the repayment requested by the lender in the current period. The variable "R-CR*RepaymentSize" captures the potential effect of higher repayment demands on selfish borrowers' repayments in the R-CR and should be negative. Our final explanatory variables are the dummy

variable "FinalPeriods" and the interaction term "SCR*FinalPeriods". The variable "FinalPeriods" takes on the value 1 if the decision was made in period 16 or later and 0 for earlier periods. We expect no time effects on repayment in the R-NO treatment and therefore that "FinalPeriods" should be insignificant. However, as the disciplining effect of a credit registry on selfish borrowers declines in the final periods of the experiment we expect a negative coefficient for the interaction term "SCR*FinalPeriods".

Table 2: Repayment Behavior in R- Treatments [a]

Dependant Variable:	Prob. of Repayment
R-CR	.642*** (.074)
CreditSize	.028*** (.008)
R-CR *CreditSize	.03 ** (.012)
RepaymenSize	-.024*** (.006)
R-CR *RepaymentSize	-.023** (.01)
FinalPeriods	-.058 (.589)
R-CR*FinalPeriods	-.383*** (.115)
	N = 1067
	Wald (7) = 297.71
	Prob = .000
	Pseudo R^2 =.32

[a] Probit regression with clustering per session. Coefficients are maximum likelihood estimators of marginal effect of an increase of explanatory variables on probability to repay. *** indicates significance at the 1-percent level, **at the 5-percent level and * at the 10-percent level.

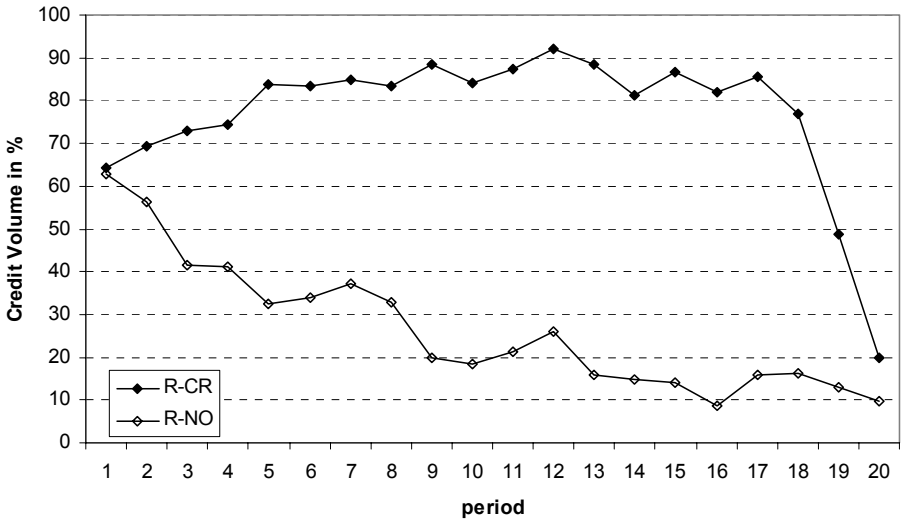
The results presented in Table 2 suggests that repayment rates are higher in the R-CR treatment ceteris paribus.[5] Our main explanatory variable "R-CR" is significantly positive. The table reports maximum likelihood estimators of the marginal effect of each explanatory variable. The coefficient on "R-CR" thus suggests that the probability of a loan being repaid in the R-CR treatment was 64% higher than in the R-NO treatment. The interaction term "R-CR*FinalPeriods" shows that this margin was significantly lower in the final periods of the experiment, confirming that reputational effects were weaker towards the end of the experiment. As expected larger loans and lower repayments lead to higher repayment even in the R-NO treatment. The positive coefficient on "CreditSize" and negative coefficient on "RepaymentSize" suggest that honest borrowers also considered the generosity

[5] Since observations within sessions may be dependent we report for all regressions in this paper robust standard errors with clustering on sessions.

of an offer when making their repayment choice in this treatment. More important, the incentive effects of high loans and low repayments are stronger in the R-CR treatment. The positive coefficient of "R-CR*CreditSize" and the negative coefficient "R-CR*RepaymentSize" confirm our predictions that favourable contract terms have a positive impact on loan repayment by selfish borrowers in the R-CR treatment. Table 2 thus confirms that a credit registry can motivate selfish borrowers to repay loans, which they would otherwise default upon.

If lenders anticipate the disciplining effect of the credit registry in the R-CR treatment we expect them to extend a higher volume of credit than they do in the R-NO treatment. Figure 2 shows that this is the case. Market performance in our experiment is determined uniquely by the total credit volume. As the maximum loan size was 50 units and 7 loans were possible in each period the maximum credit volume per period in a session was 350 units. The figure displays the realised credit volume per period as a percentage of this maximum credit volume accross sessions for the R-CR and R-NO treatments.

Figure 2: Credit Volume in R-Treatments



In the R-CR treatment almost the maximum number of loans are made from period 1 through to period 18. The average credit size was also constantly high in this treatment with mean credit size rising from an initial level of 34 to over 45 in period 13. As a consequence the total volume of credit rises from 64 percent in period 1 to 92% in period 12 and remains above 80% until period 17. Not surprisingly credit volume then falls in the final periods of the R-CR treatment.

We saw in Figure 1 that the repayment rate of borrowers declines towards the end of the experiment in this treatment. Figure 2 shows that this is anticipated by lenders who extend lower credit volumes.

Figure 2 shows a completely different picture for the R-NO treatment. Surprisingly, this treatment also starts off with a substantial credit volume. In period 1 of the R-NO treatment 7 loans were made in all sessions at an average loan size of 31. However, the number and size of loans falls rapidly in the R-NO treatment. From period 11 onwards less than 4 trades are made on average per period and this falls to less than 2 credits in the final periods. In addition, the mean credit size is lower than 20 from period 9 onwards. As a consequence Figure 2 shows that total credit volume falls steadily in the R-NO treatment and is less than 20% from period 13 onwards.

A one-sided Mann-Whitney test using total credit volume per session as observations confirms that market performance is significantly higher in the R-CR than in the R-NO treatment ($p = .004$). In the R-NO treatment the five sessions display a credit volume (measured in percentage of the total potential volume) of 36, 29, 29, 24 and 16 percent respectively. In the R-CR treatment the credit volume per session was 84, 81, 78, 76 and 66 percent respectively. On aggregate lenders in the R-CR treatment extended 77% of potential credit, while in the R-NO treatment aggregate credit was only 27% of its potential volume. Thus market performance was nearly three times higher in the R-CR than in the R-NO treatment.

Our results so far suggest that in the R-CR treatment, where credit volume and repayment rate are high, borrowers must benefit from repaying loans, while lenders are at least as well off from making loans as they would be from not doing so. In contrast, in the R-NO treatment, where the credit volume and repayment rate collapse, we should see that borrowers do not benefit at all from repaying loans while lenders who extend credit actually make losses. Table 3 analyzes the benefits of extending credit and repaying loans in both treatments. Columns 1 and 2 of the table report a regression analysis of lenders profits per period. We expect that in the R-NO treatment those lenders who make high loans earn less than those who make small loans or no loans at all. In contrast, we expect that those lenders who make higher loans in the R-CR treatment yield at least as high profits as those who extend no or little credit. Due to competition for borrowers, however, we do not expect significant positive profits of any lender. Our main explanatory variable in this regression is the size of credit extended in a period. We control for time effects by including the variable "FinalPeriods" which is 1 for periods 16 through 20 and 0 otherwise. The results in column (1) and (2) meet our expectations. In the R-CR

treatment lenders who extended large loans make at least as high profits as those who make small loans. In column (1) the coefficient of "CreditSize" is positive, but as predicted not significant. The constant term implies that in this treatment lenders earn just their outside option of 50 irrespective of the credit volume they extend. In the R-NO treatment the significantly negative coefficient of "CreditSize" and the constant of 50.1 show that lenders who make high loans end up earning less than their outside option. The regression analyses in columns (1) and (2) thus shows that the presence of a credit registry in the R-CR treatment makes it (just) profitable to lend while in the R-NO treatment lenders can only make losses. This explains our finding that the credit market is sustained in the presence of a credit registry while it collapses otherwise.

Table 3: Benefits of Lending and Repaying in R- Treatments

Dependant Variable:	Lenders Profits		Borrowers Next Period Credit	
Treatment	(1) R-CR	(2) R-NO	(3) R-CR	(4) R-NO
CreditSize	.011 (.037)	-.651*** (.069)		
RepaymentChoice			10.23*** (1.19)	1.99 (2.25)
FinalPeriods	-7.51*** (.973)	-.024 (.722)	-8.57*** (1.50)	-8.31*** (1.65)
Constant	52.19*** (.413)	50.1*** (.353)	32.76*** (2.19)	15.14*** (1.36)
	N = 1000	N = 1000	N = 644	N = 403
	F (2,4) = 29.82	F (2,4) = 48.17	F (2,4) = 205.39	F (2,4) = 106.26
	Prob = .004	Prob = .002	Prob = .000	Prob = .000
	R^2 =.04	R^2 =.48	R2 =.19	R^2 =.04

[a] Linear regression with clustering per session. *** indicates significance at the 1-percent level, ** at the 5-percent level, and * at the 10%-percent level respectively.

Table 3 also analyzes the benefits to borrowers from repaying loans in the R-CR and R-NO treatments. Columns (3) and (4) of the table present a regression analysis of the impact of repayment behavior on the future credit access of a borrower. Our dependent variable is the loan received by a borrower in period t. Our main explanatory variable "RepaymentChoice" is a dummy variable which is 1 if the borrower repaid his loan in the prior period $t-1$ and 0 otherwise. Note that "RepaymentChoice" does not capture the full reputation of borrower, nor does our dependant variable capture the full future rent of a good versus a bad reputation. We predict though that even with our simple measure of a borrowers rents the variable "RepaymentChoice" yields a positive coefficient. In contrast, in the R-NO treatment the coefficient of "RepaymentChoice" should be insignificant. Again we

control for time effects by including the dummy variable "FinalPeriods". Column (3) shows that in the R-CR treatment borrowers who repaid loans were rewarded with substantially higher credit in the next period. The coefficient of "RepaymentChoice" is positive and significant in column (3). Apparently the credit registry in the R-CR treatment allowed lenders to identify borrowers with good track records and to extend large loans to these trustworthy clients. In contrast, column (4) shows that borrowers who repaid loans in the R-NO treatment did not receive higher future loans than those borrowers who defaulted. This is by no means surprising given that borrower identities were changed randomly in each period. As a consequence, there was no incentive at all in the R-NO treatment for selfish borrowers to repay loans.

Our results in this section suggest that a credit registry can greatly enhance the performance of a credit market which is dominated by one-off transactions. The exchange of information between lenders generates incentives for borrowers to repay loans which they would otherwise default upon. This makes it profitable for lenders to extend high credit volumes, despite the fact that repayment is not third-party enforceable.

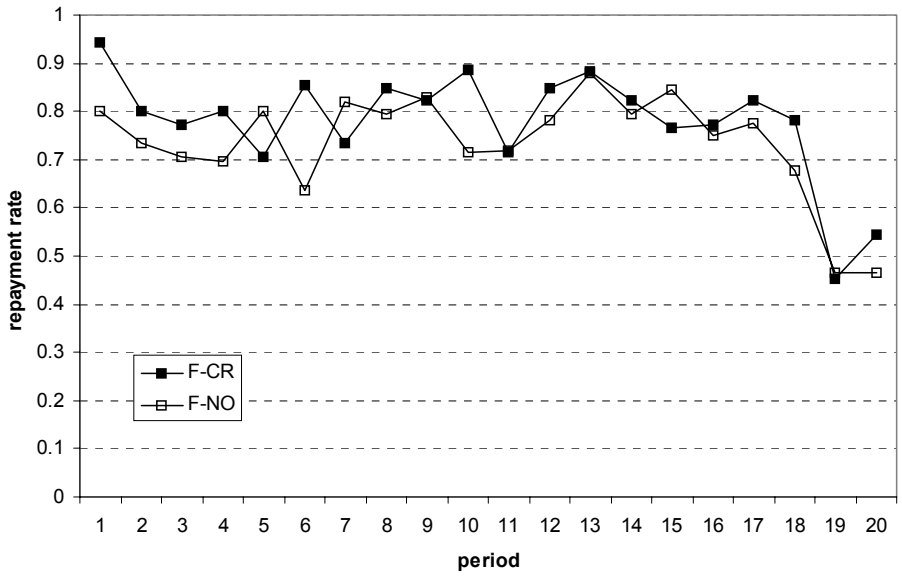
4.2 Results for the F- Treatments

In this section we examine the impact of a credit registry in a market where banking relationships can emerge by comparing market outcomes between the F-CR and F-NO treatments. We begin again by comparing the repayment behavior of borrowers between treatments. Our predictions suggest that in both treatments selfish borrowers will repay loans (in non-final periods) out of reputational concerns. In the F-CR treatment selfish borrowers can build a public reputation for being honest because their behavior is communicated to all lenders through the credit registry. In the F-NO treatment borrowers cannot build a public reputation for themselves as there is no credit registry. However, by repaying loans the borrower can build a reputation with a particular lender. Our predictions showed that a credit registry can lead to stronger reputational incentives than a potential relationship with one lender. Thus while we expect repayment levels to be high in the F-NO treatment, we predict that the credit registry in the F-CR may lead to even higher repayment rates.

Figure 3 shows that repayment behavior of borrowers is very similar in the two treatments. In the first four periods repayment rates are slightly higher in the F-CR treatment than in the F-NO. This suggests that reputational incentives

are more obvious in a market where a credit registry is present. However, from period 5 onwards repayment rates are identical in both treatments, hovering around 80% up until period 17. As predicted repayment rates fall towards the end of the experiment in both treatments. In period 19 and 20 repayment rates in both treatments are roughly 50%. This result suggests again that high levels of repayment in earlier periods are due to strategic behavior of selfish borrowers rather than an overwhelming presence of honest borrowers.

Figure 3: Repayment Rates in F- Treatments



The aggregate repayment rate in the F-CR treatment (79%) is slightly higher than that of the F-NO treatment (74%). However, a comparison of repayment rates per session shows that repayment behavior does not differ significantly between the treatments. In the five sessions of the F-CR treatment repayment rates are 86, 82, 78, 76 and 72 percent respectively. In comparison the five F-NO sessions have repayment rates of 79, 77, 76, 72 and 68 percent respectively. A one-sided Mann-Whitney test using these session averages as observations suggests that repayment is not more frequent in the F-CR than it is in the F-NO treatment ($p = .11$).

In contrast to our predictions Figure 3 shows that a credit registry does not increase repayment rates signficantly in a market where repeat transactions are possible. This result suggests that credit relationships alone provide a sufficient disciplinary mechanism in such a market. As a consequence we should also see

that the credit volume extended by lenders does not depend on the existence of a credit registry. Figure 4 confirms that this is the case. The figure displays the total credit volume extended in the F-CR and F-NO treatments by period (again as a percentage of the maximum volume). The figure shows that the high repayment rates encourage lenders to disburse large volumes of credit in both treatments. On aggregate, 94% of potential loans are made in the F-CR treatment and 91.6% in the F-NO treatment. Moreover, the average size of these loans is very high in both treatments. From an initial level of 35 average loan size climbs to above 40 during the first ten periods and then remains between 40 and 45 for the rest of the experiment. As a consequence total credit volume rises to more than 80% in both treatments. Not surprisingly both treatments display a fall in credit volume in the final periods. Again lenders anticipate the wearing off of reputational incentives for selfish borrowers and decrease their lending activities.

Aggregate market performance is slightly higher in the F-CR (79%) than in the F-NO (74%) treatment. However, a one-sided Mann-Whitney using session totals as observations finds that this difference is only of weak significance ($p = .075$). In the five sessions of the F-CR treatment credit volume was 82, 82, 80, 76 and 76 percent of their potential credit volumes respectively. In comparison the five F-NO sessions yielded 81, 78, 72, 69 and 69 percent respectively.

Figure 4: Credit Volume in F- Treatments

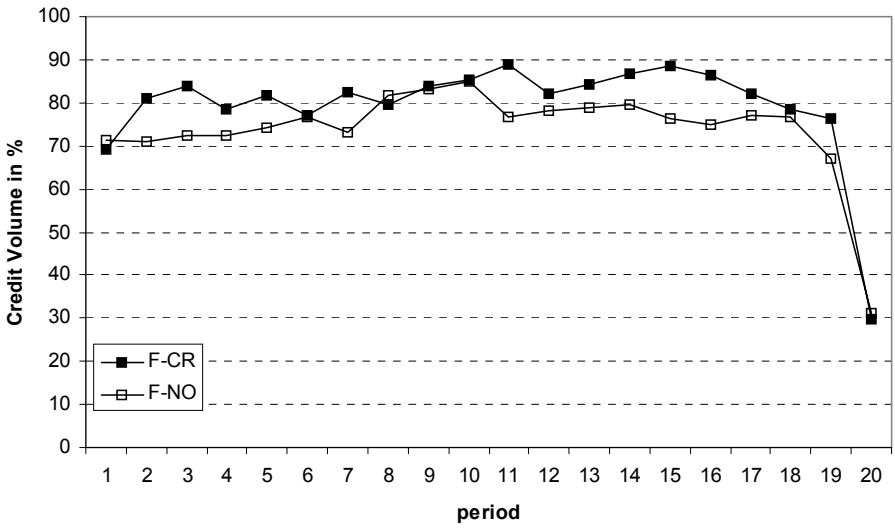


Table 4 examines the profitability of extending credit and repaying loans in the F-CR and F-NO treatments. Columns (1) and (2) analyze the impact of a borrowers repayment decision, measured by the dummy variable "RepaymentChoice" on his next period loan, our explanatory variable. Table 4 shows that in the F-CR treatment borrowers who repay loans receive significantly higher future loans than those borrowers who default. The coefficient of the dummy variable "RepaymentChoice" in column (1) is strongly positive and significant. The table also shows that good borrowers are rewarded with equally high benefits in the F-NO treatment. The coefficient of "RepaymentChoice" is equally high in column (2) and also significantly positive.

Table 4: Benefits of Lending and Repaying - Relational Market

Dependant Variable:	Borrowers Next Period Credit		Lenders Profits	
Treatment	(1) F-CR	(2) F-NO	(3) F-CR	(4) F-NO
CreditSize			-.012 (.008)	-.017 (.032)
RepaymentChoice	13.33*** (1.22)	12.82** (3.32)		
FinalPeriods	-5.69* (2.65)	-2.82** (1.89)	-2.97* (1.29)	-4.14 (2.22)
Constant	31.02*** (1.23)	29.24*** (3.15)	49.57*** (.707)	51.38*** (.826)
	N = 646	N = 626	N = 1000	N = 1000
	F (2,4) = 62.89	F (2,4) = 13.06	F (2,4) = 2	F (2,4) = 2.66
	Prob = .000	Prob = .018	Prob = .25	Prob = .18
	R2 =.21	R^2 =.16	R^2 =.01	R^2 =.01

[a] Linear regression with clustering per session. *** indicates significance at the 1-percent level, ** at the 5-percent level, and * at the 10%-percent level respectively.

Table 4 also confirms that it is profitable for lenders to extend credit in both treatments. Columns (3) and (4) of the table present a regression analysis of a lenders credit size per period, "CreditSize", on his period profits. Columns (3) and (4) both display constants of roughly 50 and insignificant coefficients for "CreditSize". This result suggests that in both treatments lenders who made large loans were neither better nor worse off than lenders who made small or no loans. This confirms our prediction that competition for borrowers should leave lenders who extend credit with zero net profits.

Table 4 suggests that in a market with repeat transaction reputational incentives for borrowers do not depend on the presence of a credit registry. Our conjecture is that in a market wothout a credit registry borrowers and lenders establish credit relationships and that quasi-rents in these relationships motivate loan repayment.

We should therefore find that credit relationships dominate market interaction in the F-NO treatment. As Table 5 shows, this is indeed the case. The table reports the share of renewed loans, i.e. the share of credit transactions which involved the same lender - borrower pair as in the previous period, in the F-NO (and the F-CR) treatment. Note that if borrowers randomly chose which lender to borrow from the share of renewed loans in our experiment should be very minimal. Indeed, the chance that no loan is renewed at all is 89%[6]. Table 5 shows that credit renewals in the F-NO treatment were much more frequent. In that treatment the share of credit renewals climbs from just below 40% in the initial periods to over 50% in period 11 through 20. Aggregated over all periods the share of renewed credit in the F-NO treatment is 48%. Thus roughly half of all loans made in this treatment involve the same lender and borrower as in the previous period. This result confirms our prediction that market interaction will be pervaded by credit relationships in the absence of a credit registry, as such relations are the only means of enforcing loan repayment.

Table 5: Share of Renewed Loans

	Periods				
	2 - 5	6 - 10	11 - 15	16 - 20	Total
F-NO	0.38	0.44	0.58	0.50	0.48
F-CR	0.24	0.39	0.39	0.54	0.39

Surprisingly, Table 5 shows that credit relationships are also very common even when a credit registry is present. In the F-CR treatment the share of credit renewals is initially less than 25%, but rises steadily over the course of the experiment, also exceeding 50% in the final phase of the experiment. Aggregated over all periods the share of renewed credit in the F-CR treatment is lower than that in the F-NO at 39%. However, due to a strong variation accross sessions a comparison of session aggregates indicates that this difference is not significant. In the five sessions of the F-NO average renewal rates are 53, 53, 52, 36 and 34 percent respectively. In comparison the five F-CR sessions have renewal rates of 52, 41, 40, 30 and 21 percent respectively. A one-sided Mann-Whitney test using these session averages as observations suggests that credit relationships are not more frequent in the F-NO than in the F-CR treatment ($p = .15$).

[6]Suppose that the one after another the 7 borrowers could randomly choose which of 10 lenders to deal with. The probability of only 1 loan being renewed is then $\frac{1}{10}$, that of 2 loans being renewed is $\frac{1}{10} \cdot \frac{1}{9}$ etc.

The data presented in Table 5 is quite astonishing. Although lenders have access to a credit registry in the F-CR treatment it seems that they still rely strongly on credit relationships to motivate loan repayment. This finding is less surprising when we consider the information available within a relationship to that available from a credit registry. Within a long term relationship lenders typically have much more information about a borrower than they could elicit from a credit report. In our experiment this was also the case. Our credit registry only provided information on whether a borrower repaid a loan or not. Within a relationship, however, the lender had additional information on contract terms (credit size, repayment size) which a lender had accepted and repaid. Table 5 suggests that this additional information encouraged lenders to maintain relationships with a particular borrower, although they could easily obtain the credit record of each borrower at no cost.

5 Conclusions

In this paper we applied experimental methods to examine the impact of a public credit registry on the repayment behavior of borrowers in a competitive credit market. Our results suggest that the impact of a credit registry depends strongly on the nature of a credit market. Credit registries are highly valuable in markets which are dominated by one-off transactions, for example due to highly mobile borrowers. In such markets banking relationships cannot emerge and the credit market may collapse without the existence of an information sharing mechanism. In contrast, in markets dominated by repeat transactions relationship banking may already solve major information problems, so that a credit registry offers little added value.

Our results point to important consequences for policy makers in developing (and developed) countries. They suggest that policy makers should concentrate on establishing or encouraging credit registries which cover market segments dominated by one-off transactions, such as occasional trade credit. In other market segments, such as working capital credit, relationship banking may already be solving the informational problems to be targeted by a credit registry.

Our methodology and results suggest several avenues of future research. First, experimental methods could be applied to study the endogenous emergence of information sharing. Theoretical models (Klein, 1992; Japelli and Pagano, 1993) suggest that private credit bureaus are more likely to emerge when they are most valuable to lenders. Experimental methods would allow to examine this hypothesis by studying the emergence of credit bureaus under a variety of market environments. Experimental methods could also be applied to study alternative designs

of credit bureaus and credit registries. As suggested by theoretical work (Padilla and Pagano, 2000; Vercammen, 1995) the type of information recorded by a credit registry, the history of credit records provided but also the incentive mechanisms related to providing and retrieving information, may affect the functioning and impact of a credit registry. These effects could be studied in a controlled manner through carefully designed experiments.

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A Appendix

A.1 Model and Assumptions

There are m lenders and $n < m$ borrowers in a game which lasts for $T > 1$ periods. In each period t each lender has $\bar{k}$ units of capital to lend. Capital has an opportunity cost of 1 (repayment plus interest) per unit. The lender can lend any part of this capital $k_t \in \left[0, \bar{k}\right]$ in each period to any one borrower. In order to do so, the first stage of each period is such that all lenders can simultaneously submit a credit offer to any subset of borrowers[7]. A credit offer $[k_t, \tilde{r}_t]$ consists of a loan size k_t and a desired repayment $\tilde{r}_t$ (principal plus interest). At the second stage of each period borrowers choose in random order from the available offers. In each period borrowers are free to accept one of the available loans or not to borrow at all. The repayment of a loan cannot be enforced by the lender. At stage three of each period the borrower can choose to either make the requested repayment $r_t = \tilde{r}_t$ or not repay at all $r_t = 0$ (gradual repayments are not possible).

The period payoff of a lender π_t is calculated as follows:

$$\pi_t = \bar{k} - k_t + r_t$$

Each borrower has a fixed return a from self-financed projects in each period. Additionally, the borrower can invest any capital k_t borrowed in a safe project which yields a safe return of $e(k_t) = bk_t$, whereby $b > 1$.

The period payoff of a borrower v_t is therefore given by:

$$v_t(k_t, r_t, \tilde{r}_t) = a + e(k_t) - r_t$$

There are 2 types of borrowers: A share p are honest types who suffer mental costs $g(\tilde{r}_t, k_t)$ (bad conscience / inequity aversion) if they don't repay in cases where they perceive the financing conditions as "fair" (i.e., in cases where the desired repayment does not exceed a certain reference value r_t), the rest of the borrowers are purely selfish profit-maximizers:

$$\begin{aligned} g(\tilde{r}_t, k_t)^{\text{honest}} &= \begin{cases} \infty & \text{if } r_t < \tilde{r}_t \text{ and } \tilde{r}_t \leq \bar{r}\left(k_t\right) \\ 0 & \text{if } r_t \geq \tilde{r}_t \text{ or } \tilde{r}_t > \bar{r}\left(k_t\right) \end{cases} \\ g(\tilde{r}_t, k_t)^{\text{selfish}} &= 0 \end{aligned}$$

Thus, the period utility of borrower can be written as:

$$u_t(k_t, r_t, \tilde{r}_t) = v_t - g(\tilde{r}_t, k_t)$$

As a consequence honest borrowers always repay their loans as long as they have received "fair" financing conditions in a given period.

The total material surplus per trade is given by

$$\pi_t(k_t, r_t) - \bar{k} + u_t(k_t, r_t, \tilde{r}_t) - a = e(k_t) - k_t = (b-1)\, k_t$$

With respect to the reference repayment of honest borrowers, we assume that $\bar{r}(k) = \phi k$, whereby $\phi \in (1, (b+1)/2]$. This means that the reference repayment

[7] Since continuous auctions have defied a fully rigorous analysis so far we make this assumption on the trading mechanism for tractability reasons

is somewhere in between the repayment where all the gains from trade go to the borrower and the repayment where the gains from trade are equally split between lender and borrower.

Since we assume that $b > 1$ it is value maximizing if the maximum credit volume $\bar{k}$ is provided in each transaction period.

A.2 Lending with Random Identification Numbers

In each period all market participants receive freshly assigned identification numbers. Lenders therefore cannot recognize any of the borrowers, even if they have financed them before.

A.2.1 Market without Credit Registry

Lenders do not receive any information on the prior behavior of any borrower in the market. Each period t can therefore be viewed as a one-period game. In the following we consequently drop the time index t and analyze the one-period outcome.

Proposition A1: If $p \geq \frac{1}{\phi}$ there exists a perfect bayesian equilibrium in which all borrowers receive maximum credit $\bar{k}$. If $p < \frac{1}{\phi}$ no credit is extended in equilibrium

Proof of Proposition A1: Lenders anticipate that honest borrowers will always repay a loan k only if $\tilde{r}(k) \leq \bar{r}(k)$, while selfish borrowers will never repay a loan. The expected profit of a lender is thus:

$$E\pi(k,r) = \begin{cases} \bar{k} - k + pr^*(k) & \text{if } \tilde{r}^*(k) \leq \bar{r}(k) \\ \bar{k} - k & \text{if } \tilde{r}^*(k) > \bar{r}(k) \end{cases}$$

Thus only if there exists a $k > 0$ for which $p\bar{r}(k) > k$ will any lender offer any credit. As $\bar{r}(k) = \phi k$ this requires that $p \geq \frac{1}{\phi}$.

If condition [6] is fulfilled lenders can profitably offer credit $k > 0$ at a rate $\tilde{r}^*(k) \leq \bar{r}(k)$ to borrowers. Due to competition among lenders these will earn zero profits so that $pr^*(k) = k$. Honest borrowers thus earn $u(k^*, r^*) = a + bk - r^*(k) = a + (b - \frac{1}{p})k^*$. Borrowers prefer the highest possible credit level as our parameter assumptions imply $bp > 1$. We have therefore established that in a one-period game the equilibrium contract offer of lenders will be

$$[k^*, r^*] = \begin{cases} \left[\bar{k}, \frac{\bar{k}}{p}\right] & \text{if } p \geq \frac{1}{\phi} \\ [0,0] & \text{if } p < \frac{1}{\phi} \end{cases}$$

This concludes our proof of Proposition 1.

A.2.2 Market with Credit Registry

Lenders are exogenously forced (legal obligation) to submit information on their previous lending to a public credit registry. In return they receive a credit report which states which borrowers repaid their loans and which borrowers defaulted in each period. The provision of information and access to the credit registry information has no cost for lenders.

Proposition 2 shows that even if the share of honest borrowers would lead to a market collapse in a one-shot transaction (i.e., if $p < \frac{1}{\phi}$ then in equilibrium no credit is issued (Proposition 1)), a public credit registry can sustain a considerable credit provision. In this equilibrium selfish borrowers partly default in some initial periods generating valuable information for lender. Since $p < \frac{1}{\phi}$ selfish borrowers must do something to ensure that lenders strongly enough believe in the honesty of repaying borrowers in order to offer credit in periods where the end of the game draws near.

Proposition A2: Consider a game of $T \geq 2$ periods and suppose that $p < \frac{1}{\phi}$. With exogenous credit reporting The following strategies and beliefs form a perfect bayesian equilibrium.

- In all periods $t < T - s$ all lenders offer the contract $[k_t^*, r_t^*] = \left[\bar{k}, \bar{k}\right]$ to all borrowers who always repaid in the past. No lender offers any credit to a borrower who defaulted in any previous period $j < t$.
- In period $T - s$ all lenders offer the contract $[k_t^*, r_t^*] = \left[\bar{k}, \bar{r}(\bar{k})\right]$ only to those borrowers who always repaid in the past. No lender offers any credit to a borrower who defaulted in any previous period $j < T - s$.
- In all periods $T - s < t \leq T$ all lenders offer the contract $[k_t^*, r_t^*] = \left[\bar{k}, \bar{r}(\bar{k})\right]$ with probability $\lambda_t^* = \frac{\phi}{b}$ only to those borrowers who have a clean record. No lender offers any credit to a borrower who defaulted in any previous period $j < t$.
- Honest borrowers accept the contract $[k_t^*, r_t^*]$ in all periods t and repay the loan in each period.
- Selfish borrowers accept the contract $[k_t^*, r_t^*]$ in all periods t. Their repayment probability γ_t^* is given by

$$\gamma_t^* = \begin{cases} 1 & \text{if } t < T - s \\ \frac{(\phi^s - 1)p}{1-p} & \text{if } t = T - s \\ \frac{\phi^{s-l} - 1}{\phi^{s+1-l} - 1} & \text{if } t = T - s + l \text{ for all } l \in \{1, 2, ..., s-1\} \\ 0 & \text{if } t = T \end{cases}$$

- All lenders believe that any borrower who defaults on a loan in periods $t < T - s$ is selfish.

Proof of Proposition A2: Proof is by construction and is established in 4 steps:

Step 1 (repayment by honest borrowers): Honest borrowers will repay in each period as long as their financing conditions are fair; i.e. $\tilde{r}_t^* \leq \bar{r}(k^*) = \phi k^*$. Given the strategies of lenders this condition is satisfied in every period.

Step 2 (repayment by selfish borrowers): In period T selfish borrowers will always default. In non-final periods $t < T$ selfish borrowers will repay with a positive probability if their following incentive constraint is met:$-r_t + V^R_{t+1} \geq V^D_{t+1}$, whereby V^R_{t+1} and V^D_{t+1} represent the future expected utilities of a selfish borrower at the beginning of period t+1 after repaying respectively defaulting in period t. We first consider a selfish borrower's incentives in the next to last period $T-1$: Given the lenders' strategies above we have $V^R_T = a+\lambda^*_T b\bar{k} = a+\phi\bar{k}$ and $V^D_T = a$. As $r^*_{T-1} = \bar{r}(\bar{k}) = \phi\bar{k}$ the incentive constraint is met with equality in period $T-1$. It is therefore a best strategy for the selfish borrower to repay with any probability $\gamma^*_{T-1} \in [0,1]$. Concerning the decision in $T-2$ we have $V^R_{T-1} = 2a + \lambda^*_{T-1}[b\bar{k} - \bar{r}(\bar{k}) + \lambda^*_T b\bar{k}] = 2a + \phi\bar{k}$ and $V^D_T = 2a$. As $r^*_{T-2} = \bar{r}(\bar{k}) = \phi\bar{k}$ the incentive constraint is again met with equality in period $T-2$ and it is therefore a best strategy for the selfish borrower to repay with any probability $\gamma^*_{T-2} \in [0,1]$. The same argument can be made for all periods $t \geq T-s$. In periods $t < T-s$ all lenders offer the contract $[k^*_t, r^*_t] = [\bar{k}, \bar{k}]$ with certainty. As $r^*_t = \bar{k} < b\bar{k}$ the incentive constraint is met with inequality in these periods. It is therefore a best strategy for selfish borrowers to repay with probability $\gamma^*_t = 1$ in all periods $t < T-s$.

Step 3 (contracts of lenders): In each period all lenders have identical information concerning borrowers. Competition for clients implies that lenders earn zero profits in each period. In periods $t < T-s$ all borrowers repay with probability 1 so that competition bids repayment demands down to $\bar{k}$. In all periods $t \geq T-s$ the repayment $\bar{r}(\bar{k}) = \phi\bar{k}$ yields zero profits if $[p^e_t + (1-p^e_t)\gamma^*_t]\,\bar{r}(\bar{k}) = \bar{k}$, whereby p^e_t is the lenders' belief at the beginning of period t about the honesty of a borrower who repaid in all former periods. Bayesian updating implies that this belief is calculated as $p^e_t = \frac{p^e_{t-1}}{p^e_{t-1}+(1-p^e_{t-1})\gamma^*_{t-1}}$. In the final period T selfish borrowers default ($\gamma^*_T = 0$) so that lenders' belief must be at least $p^e_T \geq \frac{1}{\phi}$ in order for them to offer a contract to borrowers (see Proposition A1). In equilibrium selfish borrowers must choose their repayment probability in period $T-1$ so that this necessary belief in T is achieved: $\gamma^*_{T-1} \leq \frac{p^e_{T-1}(\bar{r}(\bar{k})-\bar{k})}{\bar{k}(1-p^e_{T-1})}$. Given the zero-profit condition for lenders (see above) this implies that at the beginning of period $T-1$ the lenders' belief must be at least $p^e_{T-1} \geq \frac{1}{\phi^2}$. Accordingly we can calculate the minimally necessary belief of lenders at the beginning of each period $T-j$ for all $j \leq s$: $p^{min}_{T-j} = \frac{1}{\phi^{j+1}}$. By definition the period $T-s$ is the last period in which the population fraction of honest borrowers is above the minimal belief of lenders $\frac{1}{\phi^s} \geq p \geq \frac{1}{\phi^{s+1}}$. It is therefore in this period that borrowers start to partly default, such that the minimal belief can be sustained in all subsequent periods. The equilibrium repayment probabilities of borrowers in all periods $t \geq T-j$ for $0 < j \leq s$ are given by solving the following equation for λ^*_t: $\frac{p^e_t}{p^e_t+\lambda^*_t(1-p^e_t)} = p^{min}_{t+1}$, whereby $p^e_{T-s} = p$ and $p^e_{T-j} = p^{min}_{T-j}$:

$$\gamma^*_t = \begin{cases} 1 & \text{if } t < T-s \\ \frac{(\phi^s-1)p}{1-p} & \text{if } t = T-s \\ \frac{\phi^{s-l}-1}{\phi^{s+1-l}-1} & \text{if } t = T-s+l \text{ for all } l \in \{1,2,...,s-1\} \\ 0 & \text{if } t = T \end{cases}$$

Given the repayment strategies of borrowers the zero-profit condition is satisfied with equality in each period and therefore lenders are always indifferent between offering a credit contract and keeping their capital to themselves: $\lambda_t^* \in [0,1]$ for all t.

Step 4 (beliefs of lenders): In periods $t < T - s$ lenders believe that any borrower without a clean record is selfish. This is an out of equilibrium belief as in equilibrium no borrower defaults prior to period $T - s$. In periods $t \geq T - s$ lenders believe that any borrower who defaulted in a period is selfish. This is the only rational belief as in equilibrium only selfish borrowers default with a positive probability.

A.3 Lending with Fixed Identities

We now assume that borrowers have fixed ID numbers so that lenders can identify those borrowers who they have traded with in the past.

A.3.1 Market without Credit Registry

Proposition A3 shows that even without a credit registry substantial credit volumes can be sustained due to relational contracts between particular lenders and borrowers. Selfish borrowers partly default in the first period so that the incumbent lenders' belief increases to the level necessary in order to make a zero-profit loan in a one-shot environment. In all non-final subsequent periods incumbent lenders offer loans with such a probability that it is a (non-unique) best response for selfish borrowers to repay with certainty. In the final period incumbent lenders offer the "one-shot"-zero-profit contract and only honest borrowers repay while all selfish borrowers default.

Proposition A3: Consider a game of $T \geq 2$ periods and suppose that $p < \frac{1}{\phi}$. Without exogenous credit reporting the following strategies and beliefs form a perfect bayesian equilibrium.

- In period 1 all lenders offer the contract $[k_t^*, \tilde{r}_1^*] = \left[\bar{k}, \frac{1}{p\phi}\bar{k}\right]$ to all borrowers.
- In period 2 all lenders who concluded a contract in period 1 offer the contract $[k_t^*, \tilde{r}_t^*] = \left[\bar{k}, \bar{k}\right]$ to their first-period-borrower with probability $\lambda_t^* = \frac{1}{bp\phi}$ if this borrower repaid in period 1. If the incumbent borrower of a lender defaulted in a period 1 or if the lender didn't conclude a contract in the first period, the lender does not offer any credit at all.
- In all periods $3 \leq t < T$ all lenders who concluded a contract in the last period offer the contract $[k_t^*, \tilde{r}_t^*] = \left[\bar{k}, \bar{k}\right]$ to their first-period-borrower with probability $\lambda_t^* = \frac{1}{b}$ if this borrower repaid in all past periods. If the incumbent borrower of a lender defaulted in a past period or if the lender didn't conclude a contract in the first period, the lender does not offer any credit at all.
- In period T all lenders who concluded a contract in period $T - 1$ offer the contract $[k_t^*, \tilde{r}_t^*] = \left[\bar{k}, \phi\bar{k}\right]$ to their first-period-borrower with probability $\lambda_t^* = \frac{1}{b}$ if this borrower repaid in all past periods. If the incumbent borrower of a lender defaulted in a past period or if the lender didn't conclude a contract in the first period, the lender does not offer any credit at all.

- Honest borrowers accept the contract $[k_t^*, r_t^*]$ in all periods t and repay the loan in each period.

- Selfish borrowers accept the contract $[k_t^*, r_t^*]$ in all periods t. Their repayment strategy is given by

$$\gamma_t^* = \begin{cases} \frac{p(\phi-1)}{1-p} & \text{if } t = 1 \\ 1 & \text{if } 2 \leq t < T \\ 0 & \text{if } t = T \end{cases} .$$

- All lenders believe that any borrower who defaults on a loan in any period $2 \leq t < T-1$ is selfish. Furthermore, lenders believe that selfish borrowers always default in any period $2 \leq t < T-1$ if $\tilde{r}_t(k_t) \geq \bar{k}$. Finally, outside lenders believe that if a selfish borrower does switch in any period $t > 1$ he will default and switch again in the following period.

Proof of Proposition A3: Proof is by construction and is established in 4 steps:

Step 1 (repayment by honest borrowers): Honest borrowers will repay in each period as long as their financing conditions are fair; i.e. $\tilde{r}_t^* \leq \bar{r}(k^*) = \phi k^*$. Given the strategies of lenders this condition is satisfied in every period.

Step 2 (repayment by selfish borrowers): In period T selfish borrowers will always default. In non-final periods $t < T$ selfish borrowers will repay with a positive probability if their following incentive constraint is met:$-r_t + V_{t+1}^R \geq V_{t+1}^D$, whereby V_{t+1}^R and V_{t+1}^D represent the future expected utilities of a selfish borrower at the beginning of period $t+1$ after repaying respectively defaulting in period t. We first consider the a selfish borrower's incentives in the next to last period $T-1$: Given the lenders' strategies above we have $V_T^R = a + \lambda_T^* b\bar{k} = a + \bar{k}$ and $V_T^D = a$. As $r_{T-1}^* = \bar{k}$ the incentive constraint is met with equality in period $T-1$. It is therefore a best strategy for the selfish borrower to repay with any probability $\gamma_{T-1}^* \in [0,1]$. Concerning the decision in $T-2$ we have $V_{T-1}^R = 2a + \lambda_{T-1}^*[b\bar{k} - \bar{k} + \lambda_T^* b\bar{k}] = 2a + \bar{k}$ and $V_T^D = 2a$. As $r_{T-2}^* = \bar{k}$ the incentive constraint is again met with equality in period $T-2$ and it is therefore a best strategy for the selfish borrower to repay with any probability $\gamma_{T-2}^* \in [0,1]$. The same argument can be made for all periods $2 \leq t \leq T-3$ such that in each of these periods all feasible repayment probabilities are optimal: $\gamma_t^* \in [0,1]$. In period 1 the following terms are relevant: $r_1^* = \frac{1}{p\phi}\bar{k}$, $V_2^R = (T-1)\,a + \lambda_2^* b\bar{k} = (T-1)\,a + \frac{1}{p\phi}\bar{k}$ and $V_2^D = (T-1)\,a$. In the first period the incentive constraint is therefore also met with equality and any repaying strategy $\gamma_1^* \in [0,1]$ is a (non-unique) best response of a selfish borrower.

Step 3 (contracts of incumbent lenders): Competition among lenders implies that in equilibrium expected profits of lenders are equal to zero. In the last period T a lender's belief about the honesty of a borrower must satisfy $p_T^e \geq \frac{1}{\phi}$ in order for the lender to be willing to offer a contract to this borrower (in the last period borrowers have the same incentives as in one-shot interactions, the condition above therefore corresponds to the condition derived in Proposition 1). The repayment strategy of borrowers described above implies that a lender who concluded a contract in period 1 and got a positive repayment has the following belief about the honesty of his incumbent borrower in all periods

$t \geq 2$: $p_t^e = p_2^e = \frac{p}{p+(1-p)\gamma_1^*} = \frac{1}{\phi}$. Offering the contract $[k_T^*, r_T^*] = [\bar{k}, \bar{r}(\bar{k}]$ with any probability $\lambda_T^* \in [0,1]$ in period T is therefore a (non-unique) optimal choice of lenders. In all periods $2 \leq t < T$ selfish borrowers repay with certainty. Therefore lenders who concluded a contract in the last period can offer the zero-profit contract $[k_t^*, \tilde{r}_t^*] = \left[\bar{k}, \bar{k}\right]$ to their incumbent borrower. Since lenders believe that their borrower defaults if $\tilde{r}_t(k_t) \geq \bar{k}$ this is the optimal offer and because they make zero-profits it is optimal to offer the contract with any probability $\lambda_t^* \in (0,1)$. In period 1 a borrower who gets a contract repays with probability $\frac{p(\phi-1)}{1-p}$. Offering the following zero-profit contract $[k_t^*, \tilde{r}_1^*] = \left[\bar{k}, \frac{1}{p\phi}\bar{k}\right]$ is therefore an (non-unique) optimal choice for all lenders in period 1.

Step 4 (contracts of outside lenders): Outside lenders have the (out of equilibrium) belief that if a selfish borrower switches in any period $t > 1$ he will default and switch again in the following period. The probability for an outside lender of being repaid is thus at most $p < \frac{1}{\phi}$. From Proposition A1 we know that it is not profitable for the outside lender to offer any loan in this case.

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