Voluntary Prepayments and Credit Rationing*

Xunhua Su†

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Abstract

I construct a model to illustrate how voluntary prepayments induce credit rationing. In the model, the borrower signs a loan contract with the lender to finance an investment project. After the project is started, there arrives a signal concerning the project's payoff. With a "good" signal, the borrower prepays the loan if prepayment is not forbidden explicitly in contract terms and the lender breaks even. With a "bad" signal, the project has negative NPV and the lender loses money. As a result, no matter how high the loan interest rate is, the lender always loses money ex ante and increasing the interest rate alone is not sufficient to compensate for the prepayment risk, resulting in credit rationing. Then to avoid rationing, a minimum requirement of collateral or net worth is necessary to guarantee the downside payment to the lender, especially for borrowers with higher ex-ante risk. I also illustrate that the option of prepayments keeps the financial flexibility of the borrower to modify leverage and hence maintains her competitive position by deterring predations in the product market. The model predictions are consistent with existing empirical evidence.

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†Department of Finance and Management Science, NHH. Helleveien 30, 5045 Bergen, Norway. Email: xunhua.su@nhh.no.

1 Introduction

Credit rationing describes the situation in which many borrowers cannot get the loan they demand even if they are willing to pay a higher interest rate than the lenders are asking. As a widely observed phenomenon, credit rationing seems to be the very nature of the credit markets and exists as a long-term equilibrium phenomenon (Tirole (2006)).[1] As a result in practice, the interest rate spread is remarkably low while the other contract instruments, e.g., costly collateral, are widely-observed debt features.[2]

The current paper constructs a simple model to provide a rationale for the occurence of credit rationing. We first illustrate that keeping the option of voluntary prepayments in loan contracts can induce credit rationing. In the model, the borrower signs a loan contract with the lender to finance an investment project. Shortly after the project is started, there arrives a (borrower-) privately observed signal concerning the project's payoff. This signal induces strategic prepayments and renegotiations. If the signal is "good", the original interest rate is not the currently *fair* interest rate anymore, so the borrower may choose to refinance the original loan and in this case, the lender breaks even. If the signal is "bad", the project has negative NPV and the lender will lose money for sure. In total, given a positive probability of prepayments, the lender always loses money ex ante and increasing the interest rate alone is not sufficient to compensate the lender for prepayment risk resulting in the occurrence of credit rationing. We further illustrate that, even if the signal is publicly observed, credit rationing can still occur, but a performance sensitive debt (PSD) contract contingent on the signal reduces the possibility of prepayments and hence mitigates credit rationing.

There are three important issues concerning our arguments above. *First*, we assume that the signal comes shortly after the project starts. This assumption is motivated by the empirical

[1]This is the case in particular during a credit crunch. For example, the lead article in the Wall Street Journal [Octobor 1, 1991] states: "Credit Crunch appears to Linger on for Years, Some Say - Despite Bush's move to spur loans, Many Banks Cling to Cautious Policies, Profitable Firm gets Rejected".

[2]For example, Roberts & Sufi (2009) find that, for around 16,000 US loans in the Dealscan database between 1996 and 2005, the interest spread over LIBOR has a mean 2.06% and standard deviation 1.37%. Berger & Udell (1992) study the dataset from the Federal Reserve's Survey of Terms of Bank Lending. For over 1.1 million US commercial loans from 1977 to 1988, they report the mean and standard deviation of the interest spread are 2.47% and 2.59% respectively. Black & de Meza (1992) states that the interest spread is rarely over 3%-4% in UK. For the wide use of collateral, Berger & Udell (1992) find that over 70% of loans in their data set are secured (see also Berger et al. (2010) or the review by Steijvers & Voordeckers (2009)).

evidence that prepayments usually occur in the early stage of the debt maturity (Roberts & Sufi (2009)).[3] In this early stage, the borrower is liquidity-constrained, so a high upfront fee, prepayment penalty or interest claim before the signal is infeasible to implement for commercial and industrial (C&I) borrowers.

Second, one may think that prepayments can be explicitly forbidden in contract terms. In practice, prepayment exclusion and prepayment penalty are very rarely observed in C&I loan agreements (e.g., Asquith et al. (2005); Roberts & Sufi (2009)) and the literature has paid little attention to this fact and the underlying reasons. We fill in this gap by illustrating that the option of prepayments keeps a firm's *financial flexibility* to adjust leverage and, through deterring predations, it maintains the borrower's competitive position in the product market. To see the point, note that debt is a *hard* claim, so a high-leveraged firm is subject to bankruptcy risk. If prepayments are forbidden, rivals of the borrower may pursue predatory strategies in the product market to drive the firm out of business and then to obtain a monopolist profit later (e.g., Bolton & Scharfstein (1990)). Therefore, the option to prepay has to be kept for the debtor to deter predations. The survey by Graham & Harvey (2001) indicates that financial flexibility is the most important concern for firms' debt policy. To some extent, this is consistent with our arguments.

Third, ex ante increasing the interest rate is not sufficient to compensate the lender for prepayment risk. With the option of prepayments for the borrower, no matter how high the original interest rate is, the lender cannot benefit from the high payoff of the project with a good signal, while she always loses money with a bad signal. Therefore, ex ante increasing the interest rate alone is not sufficient to compensate the lender. We conjecture that, mainly for this reason, the interest rate spread in practice is remarkably low. Several other types of debt have high interest rates because of their specific features different from C&I loans, e.g., an extremely short maturity and a high upfront fee of usuries, the dispersed ownership of junk bonds, and tight monitoring, convertible feature and stage-by-stage financing of venture capital.

[3] It is very common that the following term is included in a bank loan: "the borrower may prepay any base rate borrowing in whole at any time, or from time to time in part in amounts aggregating at least $1,000,000 with additional increments of $500,000, without premium or penalty..."(see the 3270 contracts given by Amir Sufi in his website - `http://faculty.chicagobooth.edu/amir.sufi/data.htm`).

To sum up, the threat of predations keeps the option of voluntary prepayments for the borrower, while with this option, increasing the interest rate alone is not sufficient for the two contract parties to reach an agreement resulting in the occurrence of credit rationing. To eliminate credit rationing, some other contracting instruments are necessary to ration credit. Given the project under finance, the probability of prepayment is lower with a shorter loan maturity, a smaller loan size or a higher collateral requirement. We derive the minimum requirement of collateral or net worth for a firm to avoid being rationed and especially more risky firms require a higher level of collateral or net worth. In practice, more risky and more poor-in-cash firms are more likely to be rationed. This coincides with our model prediction. Furthermore, our model implies a debt maturity structure - the more likely to be prepaid, the shorter maturity the debt has.

Our paper is related to two strands of the literature, one on credit rationing and the other on financial contracting under predations. Stiglitz & Weiss (1981) are among the first to explain the rationale for credit rationing. In their adverse selection model, ex-ante asymmetric information concerning risk of the project under finance is the key reason for credit rationing. However, most other models focus on illustrating how credit rationing occurs due to ex-post agency problems, e.g., risk-shifting (e.g., Stiglitz & Weiss (1981)), costly state verification (e.g., Williamson (1987)), money diversion (e.g., Hart & Moore (1998)), hidden effort (e.g., Holmstrom & Tirole (1997)) and limited enforcement (e.g., Krasa & Villamil (2000)). In line with these "ex-post agency" models, we contribute to the literature by identifying the case in which voluntary prepayments result in credit rationing. The model is motivated by the empirical evidence of widely observed prepayments (e.g., Asquith et al. (2005) and Roberts & Sufi (2009)). Very few papers in the literature explain why C&I loans allow for prepayments. Our model attributes this allowance to the threat of predations from rivals of the borrower in the product market. To our best knowledge, we are the first to address this issue and then to specify interactions among competitors as the rationale for credit rationing.

In form, our model is quite similar to the Holmstrom & Tirole (1997) model. Like them, we identify sufficient conditions for the occurrence of credit rationing and a minimum collateral (or net worth) requirement to eliminate credit rationing. However, in the Holmstrom & Tirole (1997) model, implicitly the borrower commits to the original contract, but we allow for strategic prepayments to capture the dynamic behavior of the borrower.[4] The widely observed renegotiations of financial contracts empirically motivate our original intention (e.g., Roberts & Sufi (2009)). We further derive a positive correlation between risk of the borrower and the likeliness of credit rationing, which are not considered in the Holmstrom & Tirole (1997) model. In addition, refinancing the original loan to reduce payment to the lender is very similar to money diversion (e.g., Hart & Moore (1998)). But there are at least two important differences between our model and the money diversion models. First, in our model, the borrower has incentive to report a higher payoff to get a cheaper refinance loan, while in the money diversion models the borrower has incentive to report a lower payoff in order to divert the money. Second, money diversion is hidden actions of the borrower, while prepayment or refinance is publicly observable. If we think that the borrower "diverts" money through prepayment when the good signal arrives, our model extends the money diversion story.

The literature on financial contracting under predations is pineered by Bolton & Scharfstein (1990). They illustrate how financial constraints emerge endogenously as a way of mitigating incentive problems (e.g., unobservable money diversion) and then give rise to rational predation. The main objective of our paper is to address how predation induces credit rationing, so the debt payment constraint and hence predation are exgeously assumed. As long as debt has a shorter maturity than equity, as we observe in practice, this assumption makes sense. In addition, the Bolton & Scharfstein (1990) model excludes competitions among investors so that the financial constraint or, equivalently to say, the threat to terminate future funding, is crediable to prevent money diversion, but the borrower is then subject to predation. Instead, we assume a competitive credit market, so the borrower can release the debt payment constraint through equity financing and hence predation is an out-of-equilibrium phenomenon.

In nature, our credit rationing model is independent of the predation model. As long as prepayments are not explicitly forbidden in contract terms, credit rationing may occur in spite of the reasons that allow for prepayments. Beyond the threat of predations, there

[4] In the literature, strategic default usually means that a borrower stops making payments (i.e., to default) on a debt despite having the financial ability to make the payments (see, e.g., Hart & Moore (1998)). We model a different situation in which strategic default means that the borrower prepays or renegotiates the original loan after observing a good signal and then gets a cheaper refinance loan.

might be other possible reasons. One is the threat to "walk-away" or the hold-up problem (e.g., Hart & Moore (1994)). The threat to "walk-away" is incredible when it is very costly especially for larger firms, so the threat of predations might be more plausible in some situations. Another important reason is debt overhang (Myers (1977) and Tirole (2006)). If prepayments are forbidden, the entrepreneur may pass up valuable invetment opportunities because the gains from these opportunities will go to the outstanding debtholders due to reduced risk. In this sense, without the option of prepayments, the entrepreneur is more likely to pursue risk-shifting strategies.

In the rest of the paper, section 2 constructs the model of credit rationing and section 3 does the model of predation. In section 4, we discuss some relevant issues especially empirical implications of the models. Section 5 concludes.

2 Prepayments and Credit Rationing

2.1 The Model

We consider a borrower and her lender in a competitive credit market. The borrower is a firm with limited liability. The lender is a bank or some other lending institutions. Both parties are risk neutral. The borrower has a project that requires one unit of initial investment. The initial net worth of the borrower is simply assumed to be zero. We assume that, for some reason(e.g., a Pecking Order of external finance (Myers (1984))), debt is the first choice of the borrower. Then at date 0, the lender and the borrower agree on a specific loan contract to finance the project. Let normalize the maturity of the loan contract as one, that is, the loan has to be repaid at date 1. For simplicity reason, the discount rates for both parties are zero.

After the loan contract is signed, the borrower launches the investment. Then at an intermediate date t shortly after the project is started but before date 1, there arrives a signal concerning the date-1 payoff of the project. With probability p, the signal is good and otherwise, the signal is bad. If the signal is good, the date-1 payoff of the project is U with probability g and D with probability $1-g$ where $U > 1 > D$. If the signal is bad, the date-1

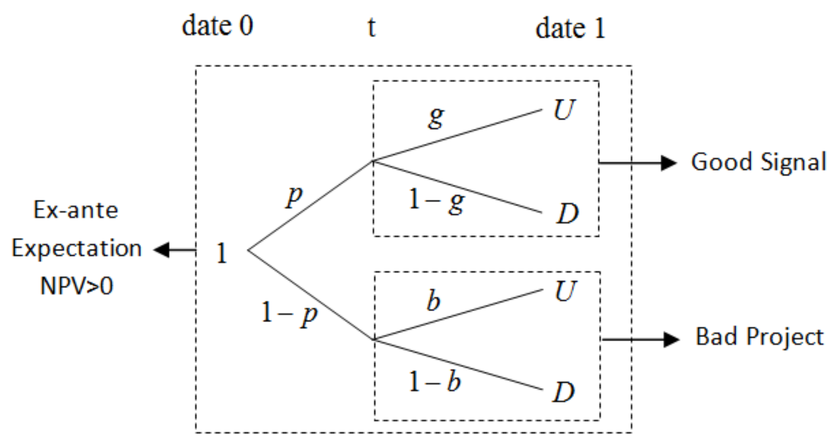

Figure 1: The Payoff Struture of the Investment Project

payoff of the project is U with probability b and D with probability $1-b$ (see *Figure* 1 for an illustration). Let $s = pg + (1-p)b$ and then ex ante, the date-1 payoff of the project is U with probability s and D with probability $1-s$. We assume that the project has positive NPV ex ante, i.e., $sU + (1-s)D > 1$, and the date-1 payoff distribution of the project is common knowledge when signing the contract at date 0.

If prepayments are not forbidden explicitly in contract terms, after observing the good signal, the borrower has incentive to prepay the original loan and get refinanced through a "cheaper" loan. In practice, prepayment exclusion and prepayment penalties are very rarely observed in C&I loan agreements (e.g., Asquith et al. (2005); Roberts & Sufi (2009)). For this reason, we take prepayments as granted in this section to identify the case of credit rationing. In the next section, we will provide the rationale that allows for voluntary prepayments in C&I loan contracts.

The motivations for exercising the option of prepayments are wide-ranging in practice. For mortgages, prepayments are mainly induced by changes in market interest rates. However, most C&I loans have floating rate and many corporations engage in hedging strategies. For these borrowers, the impetus of refinance is beyond changes of the market interest rates. Roberts & Sufi (2009) find that the accrual of new information concerning credit quality and outside options is a strong predictor of the incidence of renegotiations including prepayments. We have introduced the interim signal (new information) about changed credit quality and, inspired by the empirical finding of Roberts and Sufi, let further define θ as the cost of refinance for the borrower to access outside financing options. This cost may be an upfront fee of each deal and time and effort spent by the contract parties in making the new deal.

2.2 Private Signal

In this subsection, we consider the case in which the date-t signal is privately observed by the borrower (or publicly observed by both contract parties but non-verifiable to the court). What we keep in mind here is the situation in which, before the investment is started, both contract parties only agree on a rough estimation of the future payoff of the project (this is true especially for new projects) and sign the loan contract, while after the project starts, the borrower learns more product and market information from practice and privately gets a more precise estimation.[5] As being privately observed, the signal is uncontractible, so the loan contract can only be contingent on the realized payoff at date 1. To address credit rationing, we first assume that the loan contract is specified by the gross interest rate alone, R. Latter we will consider the other contract variables such as collateral or the loan size (net worth). Assume the loan contract is a standard debt contract, namely, for one unit of debt, at date 1 the borrower pays R to the lender when no default occurs and loses everything (including the collateral) in default.

The first-best with perfect commitment

If the interim signal has no influence on the borrower's behavior, the two contract parties perfectly commit to the original contract like what they would do in a perfect world. For a competitive credit market, the lender breaks even ex ante.

$$sR + (1 - s)D = 1 \tag{1}$$

Given that the project has ex-ante positive NPV, there is a unique solution to (1) that is the first-best interest rate, $R^* = [1 - (1 - s)D]/s$. With this interest rate, the project can be

[5]The literature usually assumes that information concerning future payoffs of the project arrives continuously and steadily, for example, following a prespecified stochastic process. However, in our model, we assume that much information comes shortly after the investment is launched.

financed. Therefore, under the assumption of perfect commitment, the two contract parties are able to change only the loan interest rate to reach an agreement leaving no space for the occurrence of credit rationing.

Prepayments and credit rationing

Perfect commitment in the first-best case is not always credible when prepayments are allowed. Assume that the borrower is able to successfully release the signal to the credit market after observing the good signal and then to get a refinance loan with lower interest rate.[6] It then follows that with the good signal, prepayment and refinance will be chosen by the borrower as long as the cost of refinance is not too high to offset the benefit from the lower interest rate. Given the payoff struture in *Figure* 1, refinance occurs if and only if

$$gR^* + (1-g)D > 1 + \theta \tag{2}$$

Note that the left side of (2) is the cost of the borrower to keep the original contract after observing the good signal, while the right side is the cost of the refinance loan with a good signal in a competitive credit market. For some *very safe* borrowers, the required interest rate is quite low and thus perfect commitment is possible, so credit rationing is irrelevant. This is consistent with the fact that roughly safer borrowers are hardly rationed in practice. We from now on assume (2) holds. Then when observing a good signal, the borrower has incentive to prepay the original loan and to get refinanced. It follows that, with a good signal and conditional on prepayment, the lender can only break even no matter how high the original interest rate is. Then to recoup her investment, the lender must also break even when the signal is bad. We consider two possible cases of the bad signal as follows.

Case 1: the NPV of the project with a bad signal is positive, i.e., $bU + (1-b)D \geq 1$. In this case, the lender is able to break even with an interest rate R that satisfies $bR + (1-b)D = 1$.

[6]The ability of the entrepreneur to successfully transit her private information to lenders is a crucial assumption in our model. Without this assumption, our model breaks down. The transmission might be costly, but for simplicity we assume the cost is zero here. Myers & Majluf (1984) assume that private inside information is not able to be transmitted to investors. This is not inconsistent with our assumption because, in their model, the stock market investors are dispersed, while we consider bank loans for which communication is important.

For this $R = [1-(1-b)D]/b$, the borrower chooses to refinance when observing a good signal and to keep the original loan when observing a bad signal. The project will be financed and there is no credit rationing. However, when a good signal arrives, refinance will be sure to occur and there will be an efficiency loss due to the deadweight refinance cost. Ex ante, this expected efficiency loss is $p\delta$. In practice, prepayments are frequently observed (e.g., Asquith et al. (2005)) indicating the possible prevalence of this case.

Case 2: the NPV of the project with a bad signal is negative, i.e., $bU + (1-b)D < 1$. In this case, conditional on a positive probability of prepayment, ex ante the lender is sure to lose money and increasing the loan rate alone is not sufficient to compensate the lender for prepayment risk resulting in the occurence of credit rationing.

Implicitly the above arguments is based on the assumption that the loan interest is paid at date 1 (bullet payment). One may think that, for ***case 2***, a high enough interest paid before the signal (or a high enough upfront fee) may offset the loss of the lender in the bad state. Given that the signal comes shortly after the project is started, the accrued interest before the signal cannot be large. Especially in the early stage, it is plausible to assume that the firm is liquidity-constrained and thus is unable to pay a high interest. Then to simplify our analysis, we ignore the accrued interest before the signal.

The minimum requirement of collateral

We have documented that ***case 2*** is charecterized by credit rationing. Then to eliminate credit rationing, some other contract variables than the loan rate are necessary. We first consider collateral, C. Denote (R, C) as the contract where $C \leq 1 - D$.[7] Given that the option of prepayments is kept for the borrower, the lender ex ante loses money conditional on a positive probability of prepayments, so any feasible contract should incentive-compatibly deter prepayments, i.e., be *renegotiation-proof.* This calls for the incentive-compatibility constraint of the borrower when the good signal is observed,

$$gR + (1-g)(D + C) \leq 1 + \theta. \tag{3}$$

[7] We assume the debt contract is risky to focus on the interesting cases.

The left-side of (3) is the payment if the borrower continues the original contract. The right-side of (3) is the cost if the borrower refiannce the loan. Equation (3) means that prepayment is deterred only when the refinance cost is higher than its benefit. Another constraint for the feasible contract is the ex-ante break-even constraint of the lender,

$$sR + (1 - s)(D + C) = 1. \tag{4}$$

Combining (3) and (4), we get

$$C \geq 1 - D - \frac{s\theta}{g - s} \tag{5}$$

Proposition 1: *In* ***case 2*** *with a private signal, as long as prepayments are not excluded explicitly in contract terms, borrowers with less collateral than a minimum level* $\underline{C} = 1 - D - s\theta/(g - s)$ *will be creditly rationed.*

Proposition 1 is simply illustrated in *Figure* 2. In the figure, the steeper curve (say Ω) represents (4) and the flater curve (say Ψ) represents the binding (3). The slopes of Ω and Ψ are respectively $-s/(1 - s)$ and $-g/(1 - g)$. Since $g > s$, Ω is steeper than Ψ. Recalling (1), the intercept of Ω is R^* and, recalling (2), the intercept of Ψ is below R^*. Therefore, the two curves have a unique intersection, say $(\overline{R}, \underline{C})$. Any feasible contract that incentive-compatibly deters prepayments must lie on Ω but below Ψ. Then we get the minimum collateral requirement, $\underline{C} = 1 - D - s\theta/(g - s)$, and the maximum interest rate, $\overline{R} = 1 + (1 - s)\theta/(g - s)$.

Till now, we consider only outside collateral. The arguments can be smoothly expanded to inside collateral and net worth. The borrower must have enough collateral (or net worth) in order to be granted a loan. Note that, if $C < \underline{C}$, the project has positive NPV but cannot be funded. With insufficient collateral to compensate the lender in bad states, the borrower must promise a high interest in good states. Yet this promise is not credible due to voluntary prepayments. The two contract parties cannot reach an agreement that both avoids prepayments and allows the lender to recoup her investment. This is the case of credit rationing (Tirole (2006)). A borrower with insufficient collateral (or net worth) will be rationed even if she is willing to pay a higher interest rate and even if her project has

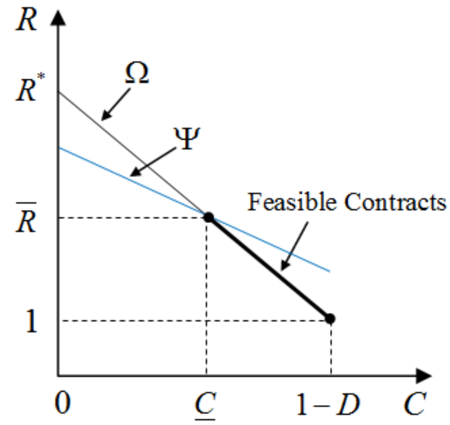

Figure 2: Feasible Contracts to Finance the Project

positive NPV.

From $\underline{C} = 1 - D - s\theta/(g - s)$, it is also easy to get

Proposition 2: *Ceteris paribus, the minimum requirement of collateral or net worth to avoid rationing is higher with:* **(a)***, a lower refinance cost;* **(b)***, a higher ex-ante default risk and;* **(c)***, a lower recovery rate in default.*

The magnitude of refinance cost is determined by outside options of financing sources. In the past two decades, the increased liquidity in credit markets and the intensified competition among banks and other institutional investors significantly reduce the refinance cost. This may explain the fact that more and more loans, especially those for small and medium businesses, are secured over time in the past two decades.[8] In addition, the principal credit risk factors are default risk and loss-given-default risk (Standard & Poor's 2009). Proposition 2 captures both risk in (b) and (c) respectively. In practice, more risky and more poor-in-cash firms are more likely to be rationed. This fact coincides with our model predictions.

The Holmstrom & Tirole (1997) model illustrates in a moral hazard setting that a minimum

[8]The National Survey of Small Business Finance (NSSBF) conducted in 1998 revealed that, for 30.3% of the loans, business (or inside) collateral had to be provided. In 2003, the use of business collateral increased to 45% of the loans granted. In addition, the NSSBF of 2003 shows that for 53% of the loans granted personal (or outside) collateral was pledged, while in the NSSBF of 1987 only 28% of the loans required personal collateral pledging. See Steijvers and Voordeckers (2009) for more details.

level of initial net worth is necessary to extract effort and hence avoid credit rationing (see also Tirole (2006)). The conclusion from proposition 1 is quite similar to theirs. In the spirit, our model shares the same logic with the Holmstrom & Tirole (1997) model and the other models that address ex-post agency problems as the reason of credit rationing (e.g., Williamson (1987) and Hart & Moore (1998)). However, these models do not specify the relationship between the expected risk of the project and credit rationing. To our knowledge, we are the first to address this relationship theoretically.

2.3 Public Signal and Performance Sensitive Debt

If the interim signal is publicly observed, the original loan contract can be contingent on this signal. In practice, the interest payment of performance sensitive debt (PSD) depends on some measure of the borrower's performance, e.g., credit rating for investment-grade loans and financial ratios for leveraged loans (Standard & Poor's 2009). In this subsection, we consider prepayments and credit rationing with a public signal while keeping all the other model settings in the previous two subsections. Denote the PSD contract as $((R_g, C_g), (R_b, C_b))$ where (R_g, C_g) and (R_b, C_b) are standard debt contracts for the good signal and the bad signal respectively.[9] It should be noticed that the lender can ignore the signal as if it is unobserveable to her, so a public signal at least obtains the same efficiency as a private signal. Let us also consider the two cases concerning the bad-state payoff of the project in turn.

Case 1: $bU + (1 - b)D \geq 1$. In this case, as we showed when the signal is private, a traditional contract without collateral requirement (contingent on the date-1 payoff only) is feasible to finance the project, but there is an efficiency loss due to the deadweight refinance cost when the signal is good. Actually, a PSD contract can obtain a better outcome by deterring prepayment. Consider $((R_g, 0), (R_b, 0))$ where $gR_g + (1-g)D = 1$ and $bR_b + (1-b)D = 1$. This PSD contract allocates the date-1 payoff between the two parties in the same way as the traditional contract $([1 - (1 - b)D]/b, 0)$does, while the interest rate will be automatically adjusted at date t according to the performance of the borrower. It is not difficult to conclude that there are an infinite number of PSD contracts without collateral pledging that

[9] For simplicity reason, we also ignore the accrued interest before the signal.

bring about the same outcome. These PSD contracts are more efficient than the traditional ones through saving the refinance cost.

Case 2: $bU + (1-b)D < 1$. In this case, to avoid rationing, any feasible contract must incentive-compatibly deter prepayments whether the signal is public or private. Let also consider a PSD contract with collateral, $((R_g, C_g), (R_b, C_b))$. The incentive-compatibility constraint of the borrower is

$$gR_g + (1-g)(D + C_g) \leq 1 + \theta. \tag{6}$$

With a good signal, the maximum plegeable date-1 payoff is $1+\theta$ and the minimum collateral requirement is $\underline{C_g} = 0$. To allow the lender to recoup her her investment, ex ante the break-even constraint is required, i.e.,

$$p(1+\theta) + (1-p)[bR_b + (1-b)(D + C_b)] \geq 1. \tag{7}$$

Note that $R_b \leq U$ and then (7) can be rewritten as

$$C_b \geq \underline{C_b} = \frac{1}{1-b}\{1 - \frac{p\theta}{1-p} - [bU + (1-b)D]\}. \tag{8}$$

We also get a minimum collateral requirement C_b. Equation (8) shows that $\underline{C_b} > 0$ if and only if $bU + (1-b)D < 1 - p\theta/(1-p)$, that is, the NPV of the bad project is less than $1 - p\theta/(1-p)$. In addition,

$$\underline{C} - \underline{C_b} = \frac{b}{1-b}(U + p\theta/(1-p) - 1) \geq 0. \tag{9}$$

That is, the collateral requirement for a public signal is smaller than that for a private signal.

Proposition 3: *In **case 2** with a public signal,* **(a)**, *the optimal debt contract is a PSD contract;* **(b)**, *only projects with an expected date-1 payoff less than $1 - p\theta/(1-p)$ when observing a bad signal will be credit rationed, so this optimal PSD contract reduces the possibility of credit rationing;* **(c)**, *comparing with a private signal, the collateral requirement to finance the project is lower for a public signal.*

The PSD contract contingent on the public signal obtains some efficiency gain through saving the refinance cost. Consistent with this prediction, Asquith et al. (2005) find empirical evidence that loan contracts are more likely to have interest-decreasing performance pricing the higher the borrower's probability of prepayment.[10] Our model identifies the role of PSD to reduce the possibility of credit rationing and thus to ease financing, which may be one explanation of the prevalent use of this kind of contracts. However, in ***case 2***, credit rationing still occurs even if the signal is public and even if a PSD contract is designed. This result may mislead us to conclude that credit rationing can occur under perfect information. Note that till now we have only taken prepayments as granted. In the next section, we will see that asymmetric information plays a key role in allowing the borrower to keep the option of prepayments.

2.4 Possible Ways to Mitigate Prepayment Risk

When the option of prepayments is kept for the borrower, the loan interest rate alone may not be sufficient for the two contract parties to reach an agreement. Then pledging collateral or increasing the initial net worth is able to solve the credit rationing problem. Other than pledging collateral or increasing net worth, there are many ways to deter prepayments and hence avoid rationing.

First, maturity reduction. If the debt maturity is very short so that the accrued interest before the signal is relatively significant, the borrower has less incentive to refinance the loan. This indicates that a shorter maturity may mitigate credit rationing due to voluntary prepayments. Therefore, our model implies a maturity struture of debt. Ceteris paribus,

[10] Roberts & Sufi (2009) find that the initial terms of the contract (e.g., a contingent-on-performance feature) have a limited impact on whether or not renegotiation occurs, but they have a significant impact on the sensitivity of renegotiation to changes in the borrower's condition. They hence argue that contingencies can influence the outcome of ex-post renegotiation by allocating bargaining power to either the borrower or lender in different states of the world, as opposed to staving off costly renegotiation. In their work, renegotiations are motivated by many kinds of reasons including refinance due to changed credit quality of the borrower. If most renegotiations are due to reasons other than that. It is possible that a contingent-on-performance feature which is employed to reduce only the refinance cost as we argued has weak impact on whether or not renegotiation occurs. In addition, only interest-decreasing PSD aims to reduce refinance cost. The purpose of interest-increasing PSD is not considered in our model. Therefore, their finding does not contradict with our model indications.

the higher probability of prepayments, the shorter maturity the debt contract has. This is consistent with the empirical observations about maturities of different types of debt. On average, traditional bank loans have the shortest maturities, and then syndicated loans, bonds and mortgages in turn. The dispersed ownership structure of public debt destroys the renegotiation mechanism of the borrowing-lending relationship and thus deters prepayments allowing for its longer maturity than bank loans. The convetible feature of some bonds eliminates voluntary prepayments. A similar reason is for syndicated loans that have multiple lenders and incur higher refiance costs. For mortgages, the story is a little different. Prime mortgages are fully secured and hence almost risk free, so prepayment in our sense is not a relevant issue, while subprime mortgages usually carry prepayment penalties or some upfront fees that reduce prepayments. Moreover, although maturity reduction reduces the possibility of prepayments, it has a limitation for C&I loans. On one hand, a shorter maturity reduces the financial flexibility of the borrower and incurs more refinance cost. On the other hand, the borrower is usually liquidity constrained in the early stage of her project. Therefore, maturity reduction may be more costly than collateral pledging for some borrowers. Above all, maturity reduction is also an indication of credit rationing that describes the situation when the borrower cannot be financed by increasing the interest rate alone.

Second, an upfront fee or a prepayment penalty may work theoretically but, in practice, they are not frequently used in C&I loans (Roberts & Sufi (2009)), at least not by a high level, but very common in subprime mortgages (Carr & Kolluri (2001)). As we pointed out earlier, liquidity constraint of C&I borrowers in the early stage of the investment might be one of the reasonable explanations.

Third, tight monitoring may reduce information asymmetry and, if credible information can be used to implement PSD contracts, it mitigates credit rationing. Essentially, PSD is based on public information or information collection to shorten debt maturity. However, as we show in subsection 2.3, even if the signal is public, credit rationing cannot be eliminated as long as the option of prepayments are allowed. Moreover, public information, especially accounting ratios, might be incredible due to manipulation and thus uncontractable, so implementment of PSD requires tight monitoring.

3 Why Prepayments Are Allowed?

In the previous section, we illustrate that the lender ex ante loses money given a positive probability of the occurrence of prepayments and then pledging collateral can incentive-compatibly deter prepayments and thus eliminate credit rationing. However, pledging collateral may incur some cost. For example, the lender and the borrower possibly have divergent valuations of collateral (Barro (1976)), so there might be some efficiency loss due to the inefficient delivery of collateral from the borrower to the lender in default. Furthermore, the borrower loses the full control of the pledged assets, and may not be able to make the best use of these assets. This also brings about some efficiency loss. Then it is natural to think that ex ante prepayments should be forbidden explicitly in contract terms in order to reduce the cost of pledging collateral. In practice, most private debt agreements do not carry any prepayment penalties, while collateral is a widely observed debt feature. These stylized facts indicate that there must be some efficiency gain from keeping the option of prepayments in C&I loans which offsets the efficiency loss from pledging collateral.[11] In the literature, to our best knowledge, there is almost no paper explaining the rationale that allows for voluntary prepayments in C&I loans.[12] We fill in this gap in this section by illustrating that the threat of predations in the product market requires the borrower to keep the option of voluntary prepayments.

It is worth mentioning that, as long as prepayments are allowed in the contract, our model of credit rationing holds no matter what the reason is to allow prepayments. In this sense, our model of credit rationing is independent of the following model of predation. The threat of predation provides a possible explanation of the rationale that allows for voluntary prepayments in C&I loans, but we do not claim that it gives a complete answer. As we will discuss later, there might be reasons other than the threat of predations that allow for voluntary prepayments.

[11] Pledging collateral mitigates credit rationing through many ways as we discussed in the previous section.

[12] According to Tschirhart et al. (2007), "for the majority of banks, the dependency of prepayment on potential credit migration of the obligator is not modeled...". In addition, concerning the issue, the *2007 White Paper* of the McGuire Performance Solutions Inc. states, "the industries' understanding of underlying prepayment behavior is limited...".

3.1 Predations and Prepayments

From now on, let us name the borrower in the previous section as "firm A". We also consider another firm in the same product market labeled as "firm B" that has a *deep pocket* (plenty of cash). Recall that the maturity of firm A's debt is normalized as one, so firm A faces a hard financial constraint at date 1. That is, if firm A is not able to pay back the due debt, it will be liquidated at date 1. This hard constraint is one of the crucial disadvantages of debt financing comparing with equity financing. Accordingly, firm B may have incentive to undertake predatory strategies to reduce firm A's date-1 payoff in order to make firm A default its debt and hence be liquidated at date 1. Then firm B can enjoy the monopolist profit in the following period.[13]

To address predations, we introduce the second period to the model that lasts from date 1 until the product market disappears and the two firms are cleared and closed. To realize the date-2 payoff, firm A still need external fund to finance an initial investment, e.g., a replacement cost, at date 1. We assume that, if both firms follow a duopoly competition without predatory pricing in the first period, the date-2 payoff will be positively correlated with the realized date-1 payoff.[14] Specifically, to simplify the analysis, we excludes uncertainty in the second period after the realization of the first-period payoff at date 1 and assume that firm A will get a net profit, α, at the end of the second period if the date-1 payoff is U and a net profit, $-\beta$, if the date-1 payoff is D, where $\alpha > 0$ and $\beta > 0$. It should be emphasized that the payoff structure overtime in the current two-period predation model ensures that the ex-ante optimal debt contract keeps the same as that in the oen-period credit rationing model of section 2. This is important because it makes payment delay at date 1 impossible and hence predation is relevant.

We further assume that it incurs firm B a net cost, $\delta(U - D)$, to reduce the probability of success (i.e., to realize U) of firm A in the first period by δ. Namely, predation incurs the two firms the same amount of loss. If firm A is liquidated at date 1, firm B will get a net profit π^m

[13] One may think that new entreies compete with the predator to reduce her profit. Then the "monopolist profit" here can be thought as profit after deterring entries.

[14] Bolton & Scharfstein (1990) discuss a case when payoffs of the investment project are independently distributed over periods.

in the second period and, if firm A remains in the market, the net profit is π^d .[15] It follows that predation will occur only in the first period and under two necessary conditions: *first*, firm A does face the hard debt-payment constraint at date 1; *second*, predation is profitable, i.e.,

$$\delta(\pi^m - \pi^d) - \delta(U - D) > 0 \tag{10}$$

or

$$\pi^m - \pi^d > U - D \tag{11}$$

Suppose that (11) holds and then consider the option of prepayments in the debt contract. If prepayments are not explicitly forbidden in debt contract terms, during the first period after perceiving the initiation of predatory pricing in the product market, firm A can modify its leverage through issuing equity and buying back debt to release its debt-payment constraint at date 1. As long as firm A continues operating in the second period, predation is not profitable and hence is deterred. For small or medium-size businesses, it might be difficult to access a public equity market, but possibly with some cost they can go to private investors. For convenience, we assume the change of leverage of firm A can be done with a cost d at any time during the operation given that voluntary prepayments are allowed. We assume $d < U - 1 + \alpha$, that is, it is profitable to deter prepayments through modifying leverage.

In the following, we mainly analyze the simplest case when the interim signal is publicly-observed. For private signals, the analysis is similar except that we have to specify the belief of the lender on the unobserved signal, which complicates the analysis but add no more insights to the issue of interest. Let first consider the case of the good signal. Clearly if prepayments for firm A's debt are allowed, the first necessary condition for predation does not hold so that predation cannot occur. However, if prepayments are forbidden, firm B may prey by choosing the optimal δ. Predation (e.g., predatory pricing) is probably illegal, so the predator has incentive to hide its predatory strategies from the public (Pepall et al. (2008)). Therefore, we assume that predation can only be observed by the competing firms but not by the lender. Then given that firm B chooses a predatory strategy δ, the date-1 payoff of firm A is U with probability $g - \delta$ and D with probability $1 - g + \delta$. One necessary

[15] Implicitly here the net profit of firm B in the second period is independent of firm A's signal at date t. The only purpose of this assumption is to simplify our following analysis. Positive correlated payoffs of the two firms do not deny our model conclusion.

condition for the success of predation is that the lender will not continue financing firm A in the second period. Obviously, this is not the case when observing a date-1 payoff U. Suppose the realized date-1 payoff of firm A is D and then firm A will be liquidated at date 1 if and only if

$$\delta\alpha - (1-g)\beta \leq 0 \tag{12}$$

and

$$(g-\delta)U + (1-g+\delta)D < 1 \tag{13}$$

Inequality (12) means that the net profit of firm A in the second period is negative, which induce the lender to liquidate firm A. Inequality (13) means that the date-1 payoff of firm A is less than the initial investment conditional on predations, which makes it necessary that any feasible date-1 debt contract allows for voluntary prepayments to deter predations. Combining (12) and (13), we get

$$\frac{gU + (1-g)D - 1}{U - D} < \delta \leq \frac{(1-g)\beta}{\alpha} \tag{14}$$

Inequality (14) gives a necessary condition for the existence of a feasible predatory strategy δ. That is,

$$\frac{gU + (1-g)D - 1}{U - D} < \frac{(1-g)\beta}{\alpha} \tag{15}$$

Proposition 4: *As long as* $\pi^m - \pi^d > U - D$ *and* $[gU + (1-g)D - 1]/(U-D) < (1-g)\beta/\alpha$, *firm B will prey after observing the "good" signal and the lender will not continue financing firm A at date 1. In this case, the option of prepayments has to be kept for the borrower in the date-0 contract to deter predations.*

We can draw similar conclusions for the case after observing the "bad" signal. In addition, (15) indicates that, with the bad signal, predation is more likely to occur if prepayments are forbidden. Given the threat of predations, any feasible debt contract for firm A must allow for voluntary prepayments to deter predations. The option of prepayments keeps firm A's financial flexibility to modify leverage and hence maintains its competitive position in the product market. In the model, debt has a bullet payment schedule. If interest has to be paid before the maturity date and default occurs when firm A is not able to pay any interim interest, predations are more likely to be the case. Therefore, the argument here has broader applicability.

The key in our model is that debt, as a hard claim, is subject to predations, so the debt contract has to be designed to deter predations, e.g., to allow for loan prepayments.

Long-term Debt. One way to release the financial constraint is to choose long-term debt. The lender may sign a debt contract with firm A that lasts for two periods until the product market disappears (e.g., Bolton & Scharfstein (1990)) or equivalently to say, if debt has the same maturity as equity, predation is irrelevant. Essentially, this issue calls for the answer to why debt exists and why debt is different from equity. In our model, we take as given the existence of debt and its distinction from equity while focus on our main interest, credit rationing. Note that we have not imposed any restriction on the length of the second period, so our model holds as long as the maturity of debt is less than equity as we observed in practice.

Predation and Capital Struture. Instead of using debt, equity financing is not subject to predations. Note that, if the cost of refinance through issuing equity and buying back debt is very high, ex ante firm A can only choose a low leverage under the threat of predations. Therefore, our model implies a theory of capital structure. The more vulnerable to prepdations and the more costly to modify leverage, the lower leverage the firm chooses. Chevalier (1995) and Campello (2003, 2006) find that, when a firm increases its financial leverage, rival firms increase investment in an attempt to gain market share and drive the more leveraged firm out of business (see also Haushalter et al. (2007)). Almazan & Molina (2005) show evidence that strong competitive pressures decrease the intra-industry differences in leverage. These findings are consistent with our conclusion.

3.2 Alternative Ways to Allow for Loan Prepayments

In nature, our credit rationing model is independent of the predation model. As long as prepayments are not explicitly forbidden in contract terms, credit rationing may occur in spite of the reasons that allow for prepayments. Beyond the threat of predations, there might be other possible reasons that allow for voluntary prepayments for C&I loans, for example, the inalienability of humen capital (e.g., Hart & Moore (1994)) and debt overhang (e.g., Myers (1977)). *First*, if the borrower is denied to prepay the loan, she might choose to walk away. This hold-up problem may force the lender to accept prepayments ex post and then induce credit rationing ex ante for some borrowers with severe hold-up problems. The influence of human capital on the firm is larger for small firms, especially start-ups. For this reason, venture capital widely uses non-compete and vesting provisions (e.g., Kaplan & Strömberg (2003)). However, the threat to "walk-away" is incredible when it is very costly especially for larger firms. *Second*, reducing firm risk subsidizes holders of risk debt. This is an opposite way of asset substitution. Without the option of prepayments, the firm may pass up valuable investment opportunities if these opportunities reduce the firm risk and hence their gains will go directly to the outstanding debtholders. In contrast, for subprime mortgage loans, the threat of predations, the hold-up problem and the debt-overhang problem are all relatively irrelevant, so they usually carry prepayment penalties.

4 Further Discussions

Information Imperfection and Credit Rationing

In a perfect world, lenders can always increase the price (or the interest rate) of loans to clear the market leaving no space for credit rationing. Therefore, the literature usually resorts to some imperfections in the credit markets to explain the rationale behind this phenomenon. Our credit rationing model in section (2) shows that, even if the signal is publicly oberved, credit rationing still occurs as long as the NPV of the project is negative with a bad signal. It seems that market imperfection is not necessary for cerdit rationing. However, as we mentioned earlier, this is not correct. One key assumption of our predation model is that predations are not observable to investors. Although this information asymmetry concerning market strategies is some kind different from that concerning project payoffs in the existing credit rationing literature, information imperfection is also the key to induce credit rationing in our model.

Collateral (or Net Worth) and Credit Rationing

The credit channel of monetary transmission is based on that collateral (or net worth) is set as a binding financial constraint when banks ration credit, so monetary policy works partly through changing the balance sheets of firms and then their borrowing capacity (see e.g., Bernanke & Gertler (1995), Bernanke (2007)). For this argument, it is well documented in the literature that pledging collateral mitigates credit rationing, or reduces the *external finance premium*, through two roles (see the review by Steijvers & Voordeckers (2009)). The *disciplinary* role of collateral (or net worth) solves the moral hazard problem by mitigating risk-shifting or by extracting more effort (e.g., Holmstrom & Tirole (1997)), and the *signaling* role solves the adverse selection problem through risk-sorting (e.g., Bester (1985)).

Complementary to these arguments, our model illustrates how collateral mitigates credit rationing through incentive-compatibly deterring prepayments. More specifically, pledging collateral raises the compensation to the lender in bad states and thus reduces the required payment in good states. With less required payment when the good signal arrives, prepayment is less likely to occur. Accordingly, pledging collateral keeps the option of prepayments for the borrower which is important to maintain her competitive position in the product market. We are the first to identify the role of collateral in maintaining the financial flexibility of borrowers by deterring predations. Furthermore, we illustrate that more risky borrowers are more likely to be credit rationed and thus require more collateral or net worth to get financed. Consistent with our model prediction, many empirical studies have found a positive correlation between collateral and the expected risk of a borrower (e.g., Berger & Udell (1990, 1992)) and a negative correlation between leverage and the expected risk of borrowers (e.g., Wald (1999) and Booth et al. (2001)).[16]

High-interest Debt in Practice

Beyond C&I loans, several other types of debt agreements have high interest rates, e.g., junk bonds, usuries and venture capital. One natural question is whether they are subject to prepayment risk and predations.

[16] An alternative explanation for more risky firms' more collateral pledging is that agency problems are more severe for more risky borrowers (Stulz & Johnson (1985)).

First, the free-rider problem due to the widely dispersed holding structure of bonds destroys the mechanism of renegotiations, so bonds are almost not subject to prepayment risk. Callable bonds seems to be an exception, because the issuer retains the privilege of redeeming the bond at some point before maturity. However, the majority of callable bonds are issued by government sponsored entitites for whom default and credit rationing are almost irrelevant issues (see our *Case 1* in section 2). Moreover, junk bond issuers are mostly public firms (Gilson & Warner (1998)), which have medium and large sizes and are less vulnerable to predations. Similar to bonds, syndicated loans have multiple lenders and thus are associated with higher refinance or renegotiation cost. For this reason, syndications are more likely distributed to leveraged borrowers with speculative credit grades and higher interest rates on average than traditional bank loan borrowers (Standard & Poor's 2009).

Second, usuries usually have very short maturity and depend on some special penalties to prevent prepayments. For instance, the high interest in usurious loans is frequently deducted in advance like an upfront fee, so the borrower only needs pay back the principal at the maturity date. This feature of usury leaves no profit for prepayments.

Finally, venture capital has very special features to deal with prepayment risk. Venture capitalists usually provide the entrepreneur with very limited capital up front to see a new product from its early test-marketing stage to full-scale production (see e.g., Kaplan & Strömberg (2003)). This stage-by-stage financing is like shortening contract maturities. Venture capitalists also share control right with entrepreneurs, which reduces information asymmetry, and most venture capital uses convertible provisions to deter prepayments. Furthermore, concerning predations, start-ups that face severe threat of predations might not be able to get financed through venture capital. For these reasons, venture capitalists can pursue very risky investments and get a high premium.

5 Conclusion

To explain the rationale for credit rationing, the literature resorts to various ex-post agency problems due to information imperfection, e.g., risk-shifting (Stiglitz & Weiss (1981)), costly state verification (Williamson (1987)), money diversion (Hart & Moore (1998)), hidden effort

(Holmstrom & Tirole (1997)), limited enforcement (Krasa & Villamil (2000)) and so on. In this paper, we contribute to the literature by illustrating how the threat of predation allows for voluntary prepayments and how prepayments induce credit rationing.

In our model, under the threat of predations, the debtor has to keep the option to adjust leverage or to prepay the outstanding loan. Then it is difficult for the creditor to recoup her investment because voluntary prepayments limit her gain from the upside of the investment project. If the downside NPV of the project is negative, ex ante it is impossible for the two contract parties to sign a mutually beneficial loan agreement by altering the interest rate alone, resulting in the occurence of credit rationing. Then to eliminate credit rationing, collateral pledging (or net worth increase) or maturity reduction is required to incentive-compatibly deter prepayments. For more risky borrowers, the minimum requirment of collateral (or net worth) is higher and the debt maturity is shorter. Our model also implies that leverage should be lower for firms facing severer threat of predations.

Voluntary prepayments in C&I loan markets are not well studied. We are the first to identify the role of collateral and the role of performance sensitive debt (PSD) in deterring prepayments and easing project finance. Since the option of prepayments in our model has to be kept due to predations, we are the first to identify the interactions between rivals as the rationale for allowing for voluntary prepayments and for credit rationing. However, we do not claim that predation provides the only rationale. For example, the hold-up problem or the debt overhang problem may also be possible reasons.

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