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Credit Risk Transfer and Bank Competition†

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Abstract: We present a banking model with imperfect competition in which borrowers' access to credit is improved when banks are able to transfer credit risks. However, the market for credit risk transfer (CRT) works smoothly only if the quality of loans is public information. If the quality of loans is private information, banks have an incentive to grant unprofitable loans in order to transfer them to other parties, leading to an increase in aggregate risk. Nevertheless, the introduction of CRT generally increases welfare in our setup. However, under private information, higher competition induces an expansion of loans to unprofitable firms, which in the limit offsets the welfare gains from CRT completely.

Keywords: Credit risk transfer, credit derivatives, public and private information, access to credit, bank competition.

JEL Classification: G21, L11, G13.

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1 Introduction

In the years before the subprime crisis, many countries have seen an explosion in the use of instruments for credit risk transfer (CRT) by financial institutions. At that time, this development was welcomed by many observers. Most prominently, it was argued that CRT leads to a desirable redistribution and better diversification of credit risks (see, e. g., Allen and Gale, 2005). Another advantage is the potential of CRT to improve the access to credit for firms and households (or, put differently, the ability of banks to free up capital; see, e. g., Chiesa, 2008).[1] However, the advent of the subprime crisis has raised doubts about the overall benefits of credit risk transfer. The recent experience suggests that CRT may also lead to a deterioration of loan quality, with detrimental consequences for financial stability.

From a theoretical perspective, this decline in loan quality did not come unexpectedly. The early literature on credit risk transfer emphasized the reduced monitoring incentives of banks, once a loan has been transferred to a third party (see, e. g., Pennacchi, 1988; Gorton and Pennacchi, 1995).[2] However, recent empirical findings also suggest that there has been an expansion of low quality loans.[3] Many of the loans granted during the credit boom preceding the subprime crisis were of such a bad quality that banks must have been aware of the poor loan quality when the loan was granted (an extreme example are the notorious "ninja" loans). It seems that banks granted low quality loans and transferred them to other parties afterwards.[4]

In addition, the decrease in lending standards on the eve of the subprime crisis has been shown to be related to the market structure in the banking sector. Dell'Ariccia,

[1] For an excellent survey on credit risk transfer, see Duffie (2007).

[2] Other papers dealing with the effects of CRT on monitoring incentives include Morrison (2005), Chiesa (2008), Parlour and Plantin (2008), and Cerasi and Rochet (2008). See Ashcraft and Santos (2008) for empirical evidence.

[3] Dell'Ariccia, Igan, and Laeven (2008) document a decline in loan denial rates, which they interpret as a decrease in lending standards.

[4] This view is supported by the finding of Dell'Ariccia, Igan, and Laeven (2008) that the decline in loan denial rates was more pronounced in regions with higher securitization rates. Moreover, Keys, Mukherjee, Seru, and Vig (2009a) show that loans eligible for securitization on average defaulted much more frequently than loans with similar observable risk characteristics that were not eligible for CRT. They interpret their finding as evidence for laxer screening of loans that were to be securitized.

Igan, and Laeven (2008) show that loan denial rates in the subprime segment decreased more in areas with highly competitive banking markets and that the market entry of new financial institutions induced a further decrease in lending standards. The role of banking competition in the presence of credit risk transfer has to our knowledge not yet been dealt with in the theoretical literature.

Our paper models banks' moral hazard problem in the *origination* of loans and shows how it is affected by the degree of competition in the banking sector. We start from a banking model with imperfect competition, in which the access of risky, but profitable borrowers to bank credit is constrained due to banks' limited risk-bearing capacities. Such constraints may arise from regulatory constraints, bankruptcy costs, or bankers' risk aversion. We show that the credit constraints are especially tight if banking markets are highly competitive. The reason is that the rents from relatively safe loans, which can serve as a buffer for riskier activities, will be small in the presence of fierce competition.

We then show that such credit constraints may be relaxed by allowing banks to transfer risks to outside investors. However, the functioning of CRT markets depends crucially on the type of information on which bank loans are based. If loans are granted on the basis of publicly observable information, a transfer of credit risk works smoothly and the access to credit for risky, but profitable borrowers is improved. Since the information is public, there is no moral hazard problem at the originating bank. The bank does not have an incentive to grant unprofitable loans because nobody will be willing to insure the risks from such loans. Hence, CRT is desirable from a welfare perspective.

If, however, loans are granted on the basis of privately observable information, the transfer of credit risk is hampered by problems of asymmetric information. If credit insurers cannot observe a loan's quality, banks have an incentive to grant unprofitable loans and to transfer the risks from these loans to the insurers. This is anticipated by the credit insurers who will demand a lemons premium for credit risk transfer. CRT generally still improves the access to finance for risky, but profitable borrowers, but it also improves the access to finance for unprofitable borrowers. As a result, the aggregate risk in the economy increases. Note that, in our model, the overall welfare effect of CRT is positive even with private information. The reason is that the positive welfare effects from a better access to finance for profitable borrowers overcompensate the welfare losses from financing projects with negative net present values (NPV).[5]

[5]The paper by Parlour and Plantin (2008) yields similar findings regarding the incentive effects of

We show further that competition generally reinforces the positive effects of credit risk transfer. The higher competition in the banking sector, the better is the access to credit. However, with private information, an increase in competition may reduce welfare when the loan market for profitable loans is saturated. Then, a further increase in competition only improves the access to credit for unprofitable borrowers. In the limit, this completely offsets the welfare gains from credit risk transfer. This finding coincides nicely with the observations from the current crisis. During the late years of the credit boom preceding the crisis, most of the newly extended loans seem to have been of relatively poor quality; at the same time, these years saw an increase in competition through the market entry of new financial institutions (see Dell'Ariccia, Igan, and Laeven, 2008).

Finally, we show that the CRT market breaks down if competition is very low. The reason is that low competition goes along with large risk-bearing capacities, which implies that banks keep most profitable loans on their own balance sheets, such that the average quality of loans to be insured is low and insurers are no longer willing to insure such loans. This may explain why CRT markets developed in an environment of banking deregulation and increasing competition.

To sum up, our paper illustrates two important points. First, it describes how CRT may lead to a moral hazard problem in the origination of loans. When information is private, CRT induces banks to knowingly extend negative NPV loans, leading to an increase in aggregate risk as seen in the recent crisis. Second, and more importantly, it shows that the welfare consequences of CRT depend on the degree of competition in the banking sector and on the type of information on which loans are based. The introduction of CRT markets generally leads to an increase in welfare because it improves the access to finance for profitable borrowers. However, under private information, higher competition leads to an expansion of negative NPV loans, which in the limit offsets the welfare gains from CRT completely.

The paper proceeds as follows. Section 2 presents the basic model setup. Section 3 describes the equilibrium of the model in the absence of credit risk transfer. Section 4 analyzes the functioning of CRT markets when loans are granted on the basis of public and private information, respectively. Section 6 concludes. Proofs are in the Appendix.

CRT, although it deals with monitoring rather than screening. Interestingly, their results on welfare are contrary to ours. We will discuss the reasons behind this difference at the end of the paper.

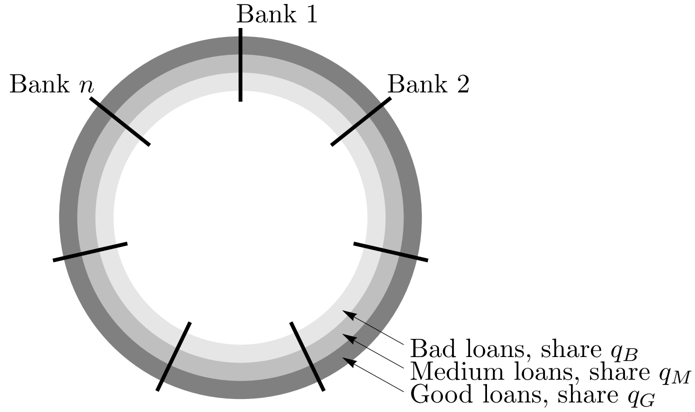
2 Model Setup

Our model has several important ingredients. First, borrowers are heterogenous; they differ in their creditworthiness. Second, competition among banks is imperfect; specifically, we use a model of Salop competition. Third, banks have limited risk-bearing capacities, for example due to regulation. These features allow us to model lemons problems in CRT markets and the impact of competition on banks' risk-bearing capacities and hence on the potential of CRT to improve borrowers' access to credit. Later, we will distinguish between loans based on public or private information. This will be important in the discussion of CRT markets because the type of information will substantially affect the functioning of these markets.

Entrepreneurs. Consider an economy with a continuum of entrepreneurs. Each entrepreneur has access to a project that requires an investment of one unit of money. In order to finance their projects, entrepreneurs must take up a bank loan. Projects have one of three qualities, they are either good (G), medium (M), or bad (B).[6] Entrepreneurs with good (medium, bad) projects are called good (medium, bad) entrepreneurs. Projects have a positive return of Y with probability p_i, $i \in \{G, M, B\}$; otherwise they fail and return nothing. Projects of the same type are perfectly correlated. A share q_G of all projects is good. Good projects succeed with probability $p_G = 1$. They have a positive net present value, $p_G Y - r = Y - r > 0$, where r is the opportunity cost of one unit of money. A share q_M of all projects is medium. Medium projects succeed with probability $p_M < 1$, but they also have a positive net present value, $p_M Y - r > 0$. A share $q_B = 1 - q_G - q_M$ of all projects is bad. Bad projects succeed with probability $p_B < p_M < 1$, and their net present value is negative, $p_B Y - r < 0$. As a result, there are two kinds of projects that are desirable from a social perspective: the good projects, which are safe, and the medium project, which are risky. The third class of projects is so risky that they are undesirable from a social perspective.

[6] These entrepreneurs can also be interpreted as borrowing households with different risk profiles.

Figure 1: Structure of the Market for Loans



The figure shows a Salop circle with $n = 7$ banks that are distributed equidistantly on the Salop circle. The three types of entrepreneurs, continuously located on the Salop circle, all have equal shares, $q_G = q_M = q_B = 1/3$. Dark gray stands for good entrepreneurs, medium gray for medium ones, and light gray for bad ones.

Banking Market Structure. Banks compete for loans à la Salop (1979).[7] They announce loan rates R_G, R_M, and R_B for entrepreneurs with good, medium, and bad projects.[8] The entrepreneurs are uniformly distributed on a circle of length L, which is normalized to 1 (see Figure 1). Hence, the aggregate volume of potential projects is $L = 1$, and $q_i\,L = q_i$ is the aggregate volume of potential projects of type i. In order to obtain a loan, an entrepreneur must travel to the bank, incurring transportation costs t per unit of distance.[9] When choosing a bank, the entrepreneurs take into account both transportation costs and interest rates. The banks are distributed equidistantly on the Salop circle. There is no equity; the only source of refinancing is deposits, which are offered at a gross interest rate r, including the repayment of the principal. Deposits are fully insured, and the costs of deposit insurance are normalized to zero. If a bank's liabilities exceed the returns from its loans, it defaults. We assume that the number of banks, n, is fixed. Below, we will consider free entry in the banking sector.

[7]The Salop model has frequently been used to model loan market competition in the banking sector. See Freixas and Rochet (1997) for an overview. Alternative models of price competition, e. g. monopolistic competition as in Monti (1972), Klein (1973), and Shubik and Levitan (1980), yield similar results.

[8]The Salop model assumes that banks do not price discriminate among entrepreneurs at different locations. In Section 5, we discuss a model with observable locations.

[9]See Degryse and Ongena (2005) for empirical evidence that transportation costs are important in loan markets.

Figure 2: Timing

- $t = 0$: Banks announce loan rates, depending on the borrowers' qualities
- Borrowers choose a bank and invest
- Banks enter the market for credit risk transfer (if applicable)
- $t = 1$: Borrowers repay their loans if they are successful, otherwise they fail. If a loan to a failing borrower has been insured, the credit insurer repays the loan. Banks repay deposits if they can, otherwise they fail.

Screening Technology. Banks have access to a screening technology to find out the quality of an entrepreneur's project. The technology produces a noiseless signal. Later in the paper, we will distinguish between two kinds of screening technologies, based on either public or private information.

Banks' Probability of Default. Finally, we assume that banks are regulated to have a probability of default below some level α.[10] As we will see later, this assumption constrains the banks' risk-bearing capacities and hence firms' access to credit, yielding a rationale for credit risk transfer.[11]

The time structure of the game is given in Figure 2.

3 No Credit Risk Transfer

We will now show that the described setup with no possibility of transferring risks to other parties leads to a situation where banks are constrained in their lending due to their restricted risk-bearing capacities. In particular, loans to medium entrepreneurs will

[10] This could be achieved by imposing capital requirements on the basis of a bank's value at risk at a confidence level $1 - \alpha$.

[11] Pennacchi (1988) was the first to motivate credit transfer by regulation. Alternatively, the desire for CRT could arise from bankruptcy costs (as in Wagner and Marsh, 2006) or from bankers' risk aversion (as in Morrison, 2005).

be below their optimal level. Interestingly, fiercer competition (through bank entry) is shown to tighten banks' lending constraints.

Access to credit. The loan volume granted by a single bank to borrowers of type i is denoted by l_i; the aggregate volume of loans of type i is denoted by $L_i = n\, l_i$. Bad projects have a negative net present value, hence bad entrepreneurs do not have access to loans in equilibrium, i. e. $l_B = 0$. A bank's probability of default is determined by its loan volumes and loan rates. With probability p_M, both good and medium loans repay, and the bank's profit is $(R_G - r)\, l_G + (R_M - r)\, l_M > 0$. With probability $1 - p_M$, only the good loans repay, and the profit is $(R_G - r)\, l_G - r\, l_M$. If this term is (weakly) positive, then the bank's probability of default is zero. If this term is negative, then the bank's default probability is $1 - p_M$. For the solvency regulation to be effective, the required maximum default probability α has to be smaller than $1 - p_M$, implying that

$$(R_G - r)\, l_G - r\, l_M \geq 0. \tag{1}$$

In the following, we assume that the regulation has an effect, such that condition (1) binds in equilibrium. We restrict our attention to situations where the good loan market is covered completely, such that banks compete for loans at least in this loan segment. This will always be true when banking markets are sufficiently competitive (e. g., n is sufficiently large or t is sufficiently small). We can then calculate l_G by deriving the distance x_G between a bank and a good borrower who is just indifferent between a loan from the bank at a loan rate R_G and a loan from the neighboring bank at a loan rate R'_G,

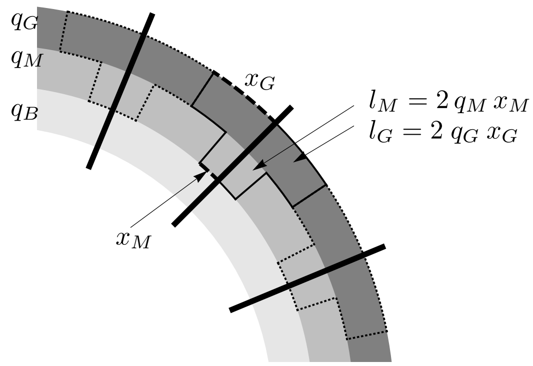
$$(Y - R_G) - t\, x_G = (Y - R'_G) - t\,(1/n - x_G). \tag{2}$$

Solving for x_G and considering that $l_G = 2\, q_G\, x_G$, we get

$$l_G = q_G \left(\frac{1}{n} + \frac{R'_G - R_G}{t} \right). \tag{3}$$

Condition (1) implies that banks cannot grant as many medium loans as they would like to in the absence of regulation; the access to credit is constrained for medium entrepreneurs due to limited risk-bearing capacities of banks. Hence, the market for medium loans is not covered and banks enjoy local monopolies in the segment for medium loans, as depicted in Figure 3.

Figure 3: Market Penetration



The figure shows a typical market share of a bank. Note that the good loan segment is covered completely, but not the medium loan segment. Banks do not grant any bad loans.

We can then calculate the distance of a medium borrower (x_M) who is just indifferent between a loan from a bank at a loan rate R_M and no loan at all,

$$p_M\,(Y - R_M) - t\, x_M = 0. \tag{4}$$

Solving for x_M and considering that $l_M = 2\, q_M\, x_M$, we get

$$l_M = 2\, p_M\, q_M\, \frac{Y - R_M}{t}. \tag{5}$$

Banks maximize their expected profits,

$$\Pi = (R_G - r)\, l_G + (p_M\, R_M - r)\, l_M, \tag{6}$$

subject to condition (1). This maximization yields R_G, R_M and λ, the shadow price of condition (1). Proposition 1a characterizes the described equilibrium.[12]

Proposition 1a (Equilibrium without CRT) *There is an equilibrium in which the market for good loans is covered completely, the market for medium loans is not covered completely, and the shadow price λ of condition (1) is strictly positive. This equilibrium obtains if*

- $q_M/q_G > (Y - r)/(2\, r)$,

[12]The proofs of all propositions can be found in the Appendix.

- *$n \geq t/(Y - r)$, and*

- *$n > t\,\sqrt{q_G}/\sqrt{q_M\, r\,(p_M\, Y - r)}$.*

The first two conditions guarantee that the good market is covered, but not the medium market. The third condition implies that the shadow price λ is strictly positive.

Some socially beneficial, but risky projects (of type M) are not carried out because banks have to avoid default to satisfy regulatory constraints. We will see later that this restriction can be eased by introducing a market for credit risk transfer (Section 4).

Competition. According to condition (1), a bank's risk-bearing capacity is determined by its profits from the good loan segment. These depend on the intensity of competition in the banking sector. This leads to the interesting result that the access to credit for medium firms is *reduced* by fiercer competition. Proposition 1b summarizes the effects of competition on firms' access to credit.

Proposition 1b (Competition) *Higher competition (higher n)*

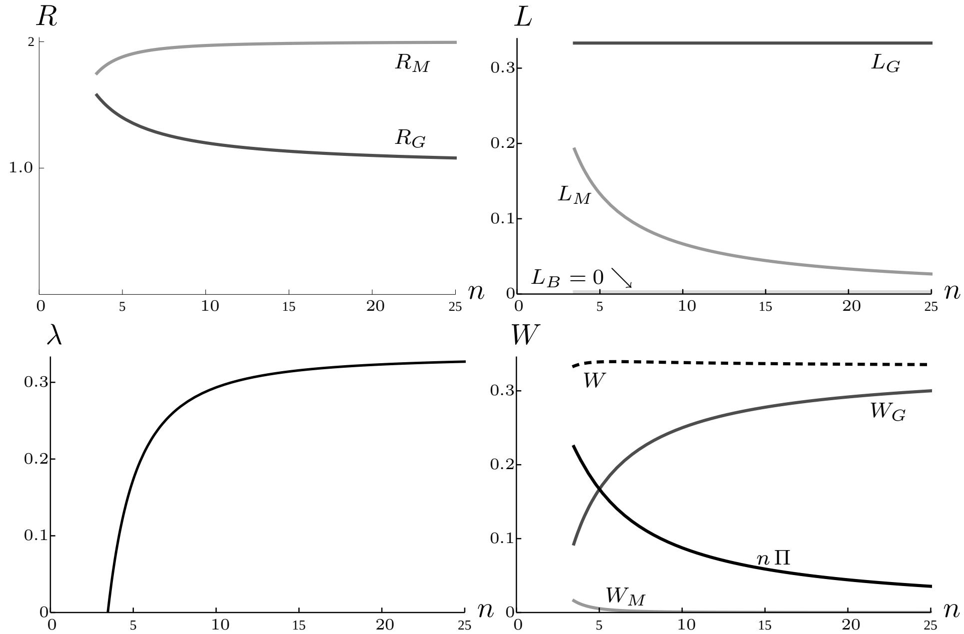
- *leaves the aggregate amount of good loans unaffected, $dL_G/dn = 0$,*

- *lowers the aggregate amount of medium loans, $dL_M/dn < 0$,*

- *increases the shadow price of condition (1), $d\lambda/dn > 0$.*

Surprisingly, *more* banks lead to a *lower* market penetration for medium loans (see the second chart of Figure 4, which is based on a numerical example). The reason is the following. When competition intensifies, the banks' margins in the good loan segment shrink due to decreasing loan rates for good loans, R_G (see the first chart of Figure 4). These margins determine how aggressive banks are in the medium loan segment because banks have to comply with condition (1). The lower the profits in the good loan segment, the lower are the banks' buffers against default, and the fewer medium loans they are willing to grant. Hence, loan rates R_M increase, and the market penetration in the medium loan segment declines. In other words, the underprovision of loans in the medium segment (i. e. profitable, but risky loans) is most severe when there is fierce competition

Figure 4: Comparative Statics with Respect to n



Colors are the same as in Figure 1: Light gray stands for bad borrowers, medium gray for medium borrowers, and dark gray for good borrowers. Parameters for the numerical example are $q_G = q_M = q_B = 1/3$, $p_G = 1$, $p_M = 2/3$, $p_B = 1/3$, $Y = 2$, $r = 1$, and $t = 2$. The larger the number of banks, the higher the competition for good borrowers, which shows up in a lower loan rate R_G. The volume of good loans L_G is constant because the whole market is always covered. As n increases, banks' buffers decrease and banks become less aggressive in the medium loan segment and raise R_M. Hence, the aggregate volume of medium loans L_M decreases. The shadow price of condition (1) increases in n because banks are more constrained in their lending to medium borrowers. The rents of good entrepreneurs (W_G) increase in n, due to the decrease in loan rates R_G. The rents of medium entrepreneurs (W_M) decrease in n due to higher loan rates R_M and a lower loan volume L_M. Finally, banks' profits ($n\,\Pi$) decrease. Aggregate welfare (W) is non-monotonic. For this numerical example, it reaches its maximum at $n^* = 6$.

in the banking sector. λ is a measure of how much a bank suffers from having to adhere to condition (1). A higher λ implies a higher marginal profit of the banks when condition (1) is relaxed. The third chart of Figure 4 shows that a higher number of banks leads to an increase in λ, reflecting the tighter constraints on banks' lending in the medium segment.

In Proposition 1b, the degree of competition is identified with the number of banks n. However, the intensity of competition is also affected by transportation costs t. When transportation costs decrease, "shopping around" for loans becomes easier. As can be seen from the proof of Proposition 1b in the Appendix, a decline in t has similar consequences as an increase in n. In particular, the volume of medium loans decreases, and the shadow price λ increases.

Welfare. Within this setting, utilitarian welfare consists of four parts: aggregate rents of the three types of entrepreneurs, and aggregate profits of banks. Bad entrepreneurs do not receive any loans, hence their rents are zero. Welfare for good and medium entrepreneurs is equal to the rents of entrepreneurs who receive a loan. Interestingly, and in contrast to the ordinary Salop model, aggregate welfare is *not* strictly increasing in the number of banks n, although there are no entry costs.

Proposition 1c (Welfare) *If $4\,p_M\,Y > 5\,r$, the welfare function is non-monotonic in the number of banks n and reaches a maximum at*

$$n^* = t\,\sqrt{\frac{3\,q_G}{q_M\,r\,(4\,p_M\,Y - 5\,r)}}. \tag{7}$$

For large n, welfare converges to $q_G\,(Y - r)$, the aggregate NPV of good projects.

The reason behind this result is the banks' lending constraints. Increasing competition decreases banks' ability to lend to (profitable) medium entrepreneurs.[13] Since the banks' margins in the good loan segment converge to zero, banks cannot grant any medium loans in the limit. Therefore, for $n \to \infty$, welfare converges to the aggregate NPV of good projects. The welfare loss of excessive competition in the banking sector can be arbitrarily large, for example if medium projects have a large net present value, $p_M\,Y \gg r$.

Summing up, there is a welfare-optimal degree of competition. Welfare reaches a maximum when (7) holds. As before, competition can be identified just as well with the size of transportation costs t.

Market Entry. In order to analyze the effects of free entry in the banking sector, let us assume that there are fixed entry costs f. Banks will then enter until $\Pi = f$. Hence, the number of entering banks is

$$n = \sqrt{q_G\,t\,\frac{p_M\,Y + \sqrt{p_M^2\,Y^2 - 2\,f\,t/q_M}}{2\,f\,r}}. \tag{8}$$

Here, the fixed entry costs f deter banks from entering, $dn/df < 0$, as is always the case in Salop models with free entry. The reason is that the higher fixed costs can only be

[13] In the absence of medium entrepreneurs, q_M would be zero, and n^* would converge to ∞, which means that welfare would be a strictly increasing function.

earned in equilibrium if there is less competition and, hence, higher margins. As a result, all other endogenous variables (l_G, l_M, R_G, R_M, and λ) respond to a change in fixed costs f. The comparative statics with respect to f are analogous to those with respect to n (but with the opposite sign). An increase in f leaves the aggregate amount of good loans unchanged, but it increases the market penetration in the medium loan segment. The shadow price of condition (1) decreases in f because banks are less constrained in their lending to medium borrowers. As a result, higher entry costs lead to larger banks for two reasons. First, fewer banks enter, increasing the loan volume in the good market segment. Second, banks expand their medium loans due to higher buffers in the good segment.

As in the traditional Salop model, there is excessive entry in this model. The reason is that firms do not take into account the negative externality that their entry has on the other firms' profits. In this model, there is a second externality that exacerbates the excessive entry problem. Banks do not take into account the negative externality that their entry has on their competitors' risk-bearing capacities, and hence on the credit availability for medium entrepreneurs.

4 Credit Risk Transfer

We now allow banks to transfer risks from their balance sheets to other investors. For simplicity, we model credit risk transfer as an insurance contract with outside investors. The possibility of trading credit risk relaxes condition (1). Hence, CRT may improve the access to credit for medium entrepreneurs. The higher the shadow price of condition (1), the higher the benefits of banks from transferring their credit risks. We will see, however, that the functioning of CRT markets depends crucially on the type of information underlying the banks' loans. We will distinguish between two types of information: public information and private information.

4.1 Model Setup

Insurers. Outside of the banking system, there is a continuum of risk neutral investors who are willing to insure the banks against credit default at a fair premium.[14] We assume

[14] As an alternative, one could assume that there are several economies, each of which contains a Salop circle. Then banks in different economies can share their credit risk. For a large number of economies,

that the market for CRT is anonymous, such that the amount of transferred credit risk is unobservable by the insurers. This seems to be reasonable given the opaqueness and complexity of CRT markets.

Public vs. Private Information. We assume that the information produced by a bank in the screening process is either publicly or privately observable by the bank. If the information is publicly observable, it can also be observed by potential insurers. If the screening information is privately observable, it is not observable by potential insurers. The distinction between public and private information is related to that between *hard* and *soft* information, popularized by Stein (2002) (see also Petersen, 2004). For example, a credit rating that is produced by a standardized statistical rating system on the basis of balance sheet information is hard information and is publicly observable by other parties. In contrast, the personal impression of the loan officer during the loan interview is soft information and cannot be publicly observed.

In the following, we will discuss the properties of an equilibrium with credit risk transfer under public and private information. In each case, we will start by analyzing the effect of CRT, holding the number of banks fixed; we will then allow for free market entry.

4.2 Public Information

In this section, we assume that the banks' screening technologies produce publicly observable information about the entrepreneurs. Hence, if a bank wants to transfer its credit risk, it can communicate the quality of the underlying loans to the insurer. As a consequence, only medium loans are insured. Good loans do not entail any risk, so there is no benefit from credit insurance; bad loans are not granted in the first place.

An insurance contract will allow the bank to turn a risky loan into a safe payment. If a bank insures a medium loan, it pays a premium $\pi_M \, R_M$ to the insurer at date $t = 0$, independent of whether the loan eventually fails or not.[15] Risk neutral competitive

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the effect would be the same as with risk neutral insurers. Potentially, banks could perfectly diversify their risk at zero cost.

[15] Since banks choose not to default in equilibrium, it is irrelevant whether they settle the insurance premia in $t = 0$ or $t = 1$.

insurers break even if $\pi_M - (1-p_M)/r = 0$, hence $\pi_M = (1-p_M)/r$. The bank has to refinance the premium by taking up more deposits, implying an additional repayment to depositors at date $t = 1$ of $\pi_M\, r\, R_M = (1-p_M)\, R_M$. At date $t = 1$, the insurer pays R_M to the bank if a medium loan fails; if the loan does not fail, the bank receives R_M from the debtor. Therefore, the bank receives $R_M\,(1-(1-p_M)) = p_M\, R_M$ with certainty. Hence, the bank has used insurance contracts to turn a risky loan with an expected payment of $p_M\, R_M$ into a safe payment of $p_M\, R_M$.

Due to the possibility of unloading credit risk, condition (1) no longer applies. The bank can grant more medium loans. Hence, the introduction of credit risk transfer improves firms' access to finance in the case of public information. We start by considering the effects of the introduction of a CRT market, holding the number of banks constant. Two kinds of equilibria may result. First, the market penetration for medium loans improves, but banks still do not cover the entire circle. Second, the market for medium loans may be covered completely, like the market for good loans. In the second case, the analysis boils down to that of a standard Salop model with two separate loan markets. Let us therefore concentrate on the first case.[16]

The bank again maximizes its expected profits,

$$\Pi = (R_G - r)\, l_G + (p_M\, R_M - r)\, l_M, \tag{9}$$

where $p_M\, R_M\, l_M$ is now a safe payment because medium loans are covered by credit insurance. Condition (1) is no longer binding, implying that λ is equal to 0. Hence, profits are higher than in the absence of a CRT market. The market for good loans is again covered completely. The market for medium loans is not covered, but the penetration is larger than in the situation with CRT. The following proposition summarizes the effects of the introduction of a CRT market with public information. See Figure 5 for a graphical illustration.

Proposition 2a (Credit Risk Transfer with Public Information) *With public information, the introduction of credit risk transfer*

- *leaves the aggregate amount of good loans unaffected,*

[16]The second case is discussed in the Appendix.

- *increases the aggregate amount of medium loans,*
- *reduces the shadow price of condition (1) to zero,* $\lambda = 0$*,*
- *increases banks' expected profits.*

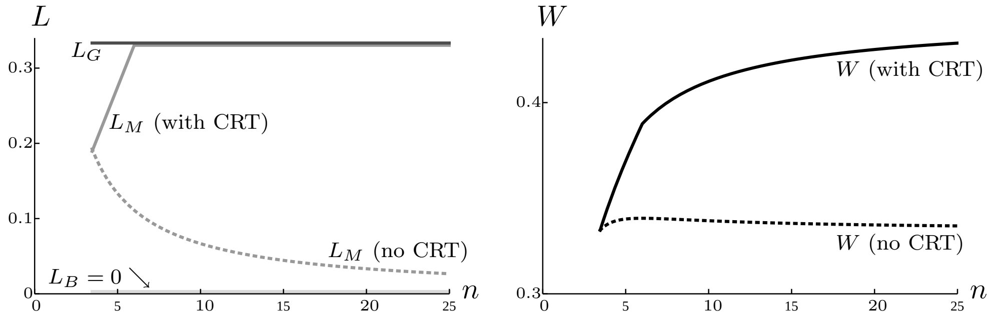
Competition. We can now analyze how competition affects banks' behavior in the presence of CRT with public information. In the presence of credit risk transfer, as long as the medium loan segment is not covered completely, banks act as monopolists on the medium loan market. Hence the medium loan volume of a single bank does *not* depend on the number of banks. As a direct consequence, the penetration in the medium segment is proportional to n. This result stands in contrast to Proposition 1b. A higher number of banks and the resulting increase in competition *improve* the access to credit for medium entrepreneurs when there is a functioning CRT market, whereas they worsen the access to loans in the absence of credit risk transfer (see Figure 5). Proposition 2b summarizes these results.

Proposition 2b (Competition) *In the presence of credit risk transfer with public information, higher competition (higher n)*

- *leaves the aggregate amount of good loans unaffected,* $dL_G/dn = 0$*,*
- *increases the aggregate amount of medium loans until the market is covered completely,* $dL_M/dn \geq 0$*.*

Welfare. The introduction of CRT with public information leads to a Pareto improvement. We have seen already that banks' expected profits increase (see Proposition 2a). Moreover, medium borrowers benefit for two reasons. First, the borrowers who had access to credit even in the absence of CRT benefit from lower loan rates. Second, other medium borrowers profit from gaining access to credit. For $n \to \infty$, all good and medium entrepreneurs get loans and carry out projects, and transportation costs converge to zero. Welfare converges to the aggregate NPV of good and medium projects.

Figure 5: Credit Risk Transfer with Public Information



Colors are the same as in Figure 1: Light gray stands for bad borrowers, medium gray for medium borrowers, and dark gray for good borrowers. The solid lines refer to a situation with public-information CRT. In the left picture, the dashed line shows the loan volume in the medium loan segment in the absence of CRT (for good and bad loans the volumes are unchanged by the introduction of CRT). We see that CRT leads to a higher market penetration in the medium loan segment. Moreover, the market penetration for medium loans now weakly increases in n; for large enough n, the market is covered completely. In the right picture, the solid line refers to aggregate welfare in the presence of CRT, the dashed line to aggregate welfare in the absence of CRT (as in Figure 4). The welfare function has a kink at the point where the medium loan market is saturated.

Proposition 2c (Welfare) *The introduction of credit risk transfer with public information increases aggregate welfare. The welfare function is strictly increasing in the number of banks n and converges to $q_G\,(Y - r) + q_M\,(p_M\,Y - r)$, the aggregate NPV of good and medium projects.*

Note that this welfare result hinges on the fact that the credit risk transfer leads to an efficient transfer of (macroeconomic) risk to insurers who are better able to bear the risks than banks. However, it is not necessary to assume that insurers are strictly risk neutral. If they were risk averse, they would demand a risk premium for taking the (macroeconomic) risk. In equilibrium, this would result in higher loan rates for medium entrepreneurs and smaller loan volumes. Nevertheless, welfare would still increase due to the introduction of CRT markets. Insurers would earn a non-negative rent (otherwise, they would not participate), medium entrepreneurs would benefit from increased access to loans and from reduced interest rates, and banks would benefit from increased profits. Welfare gains would, however, depend negatively on the degree of insurers' risk aversion. If the insurers' risk aversion is too large, there will be no CRT. The maximum premium that banks are willing to pay will depend on the shadow price λ.

Market Entry. Consider again a situation in which, in the long run, banks enter until their expected profits Π equal some fixed entry costs f. On the basis of Propositions 2a and 2b, we can derive the long-run effects of the introduction of a CRT market with public information, allowing for market entry. The number of banks in equilibrium is

$$n = t\sqrt{\frac{q_G}{f\,t - q_M\,(p_M Y - r)^2/2}}. \tag{10}$$

Since the introduction of CRT increases expected profits in the short run (cf. Proposition 2a), it attracts more banks in the long run. This implies that there is more competition for good loans. As a consequence, the loan rate R_G decreases. The aggregate volume of good loans cannot change because the market is already completely covered. For medium loans, banks have local monopolies. As argued above, the volume of medium loans l_M of a single bank does not depend on n. Hence, the market penetration for medium loan is proportional to n; it increases as more banks enter the market. Hence, the effects of CRT on medium loans are reinforced in the long run through market entry.

4.3 Private Information

When loans are based on private information, banks cannot credibly communicate the quality of a loan underlying an insurance contract. Therefore, the transfer of credit risk becomes more difficult. The asymmetric information about loan qualities leads to a moral hazard problem. Banks knowingly grant bad loans only to resell them to the insurers.[17] This is anticipated by the insurers who demand a lemons premium. Under some circumstances, the market for credit risk transfer even breaks down completely.

In equilibrium, the insurers anticipate the underlying credit risk and set their insurance premia accordingly. When deciding whether to grant a loan and whether to insure the risk from that loan, banks take insurance premia, and hence the price of CRT, as given. Let β denote the insurers' anticipated probability that an underlying loan has *medium* quality. The loan is then expected to be *bad* with probability $1-\beta$. Good loans are not risky, hence banks never insure such loans. Therefore, the insurer expects an underlying firm of an insurance contract to be successful with an average probability of $\bar{p} \equiv \beta\,p_M + (1-\beta)\,p_B$.

[17] This is different from the incentive problem analyzed by Pennacchi (1988), Gorton and Pennacchi (1995), and Chiesa (2008), where banks have suboptimal incentives to monitor loans transferred to other parties. Here, banks know that a loan is of low quality, but they still decide to grant it.

The insurer anticipates a firm to default with probability $1 - \bar{p}$, entailing a payment to the bank.[18]

As above, with an insurance contract, a bank can turn a risky yield from a loan into a safe payment. Let us give an example. A medium loan allows the bank to claim R_M from the entrepreneur. In order to completely insure this loan, the bank must buy a volume R_M of credit protection. The premium will be $R_M\,\pi = R_M\,(1-\bar{p})/r$. Taking into account the loan, the insurance contract and the costs of refinancing the insurance premium, the bank will then receive a safe payment of $\bar{p}\,R_M$ at date $t = 1$. Hence, a bank makes a negative expected profit from insuring a medium loan ($\bar{p}\,R_M < p_M\,R_M$); in contrast, the bank makes a positive expected profit from insuring a bad loan. In both cases, selling risk has the positive effect that condition (1) is relaxed. The bank can thus expand and grant more loans. As a consequence, the bank never resells the entire risk within its portfolio. Condition (1) must bind in equilibrium. If it did not bind, the bank could increase profits by insuring fewer medium risks. Also, a bank never grants a bad loan and keeps it in its balance sheet. All bad loans are resold in equilibrium.

As in (5), a single bank's volume of medium loans is $l_M = 2\,p_M\,q_M\,(Y - R_M)/t$, and the volume of bad loans is $l_B = 2\,p_B\,q_B\,(Y - R_B)/t$, accordingly. Let κ be the fraction of medium loans that a bank insures, and $1 - \kappa$ the fraction of medium loans that remain in the bank's balance sheet. A bank's total loan volume (and hence the balance sheet total) is $l_G + l_M + l_B$, and refinancing costs are $(l_G + l_M + l_B)\,r$. In the best possible case (with probability p_M), all loans are repaid; the bank gets $R_G\,l_G$ from the good loans, $\bar{p}\,(l_B\,R_B + \kappa\,l_M\,R_M)$ from the insured bad and medium loans (net of the payments to insurers), and $(1 - \kappa)\,l_M\,R_M$ from uninsured medium loans. In the worst possible case (with probability $1 - p_M$), medium entrepreneurs do not repay, all other payments are identical. Hence, condition (1) is modified to

$$(R_G - r)\,l_G + \bar{p}\,(l_B\,R_B + \kappa\,l_M\,R_M) - (l_M + l_B)\,r \geq 0. \qquad (11)$$

Obviously, an increase in the sale of credit risk (i. e. an increase in κ) relaxes (11).

[18]Note that, with private information, there can be multiple equilibria, depending on whether insurers expect a high or a low average success probability. Both types of beliefs can be justified in equilibrium. In the following, we will focus on the Pareto-efficient equilibrium with larger $\bar{p}$ and lower interest rates. A discussion of the other equilibrium can be found in the proof of Proposition 3a in the Appendix.

Because this condition is binding, it implicitly defines κ. Banks choose loan rates in order to maximize their expected profits,

$$\Pi = [R_G - r]\, l_G + [(\bar{p}\,\kappa + p_M\,(1-\kappa))\, R_M - r]\, l_M + [\bar{p}\, R_B - r]\, l_B, \tag{12}$$

subject to condition (11) and taking β (and hence $\bar{p}$) as given. $\bar{p} = \beta\, p_M + (1-\beta)\, p_B$ can be determined by using Bayes' law. The probability that an insured loan has medium quality is

$$\beta = \frac{\kappa\, l_M}{\kappa\, l_M + l_B}. \tag{13}$$

Substituting the binding constraint (11) in the bank's profit function (12) and considering the first-order conditions with respect to R_M and R_B yields the interesting result that

$$R_M = R_B = \frac{\bar{p}\, Y + r}{2\,\bar{p}}. \tag{14}$$

Although bad loans are riskier than medium ones, and hence have a lower NPV, the loan rate for both types of entrepreneurs is identical. The intuition goes as follows. In each market, the loan rate is determined by the expected payments that the last infinitesimal loan (the marginal loan) earns. However, given that the bank is constrained and inequality (11) binds, the bank must insure the marginal loan. Consequently, the probability of success becomes irrelevant. In equilibrium, the bank offers the same loan rates for medium and bad loans.

Proposition 3a summarizes the effects of the introduction of a CRT market with private information.

Proposition 3a (Credit Risk Transfer with Private Information) *With private information, if the market for credit risk transfer does not break down, its introduction*

- *leaves the aggregate amount of good loans unaffected,*
- *increases the aggregate amount of medium loans, but less than with public information,*
- *increases the aggregate amount of bad loans,*
- *reduces the shadow price of condition (1), but not to zero,* $\lambda > 0$*,*

- *increases banks' expected profits, but less than with public information.*

The directions of all effects are the same as for CRT with public information. However, because banks also insure bad loans, they have to pay a lemons premium. As a result, the loan rate for medium loans R_M is higher than under CRT with public information, and the volume L_M is lower. Because $R_B = R_M$, the volume of bad loans is positive. Hence, the introduction of CRT improves the access to credit for medium entrepreneurs less than with public information. In addition, CRT improves the access to credit for bad entrepreneurs with negative net present values. Given that the reason for CRT, and hence ultimately the reason for the existence of negative NPV loans, is condition (1), this result is in line with the findings of Keys, Mukherjee, Seru, and Vig (2009b). The quality of loans may be worse in a more regulated banking system.

Competition. Consider now an increase in the number of banks. Due to stronger competition for good loans, R_G decreases, but L_G remains constant. As a consequence, the profits from the good loan segment that banks can put at risk in the other loan segments decrease. We have argued above that banks keep only medium loans in their balance sheets; all bad loans are insured. When buffers decrease, banks can keep relatively fewer medium loans in their own balance sheets. The average quality of insured loans improves, and the lemons premium drops. Since the lemons premium is a component of the price of credit risk transfer, the price of CRT drops, and banks can grant more loans. The loan rates R_M and R_B drop.

The opposite happens when the number of banks goes down. Then, CRT becomes more expensive because the banks prefer to keep more medium loans on their own balance sheets. At some point, for small enough n, the market for CRT breaks down completely. Analogously, the market will break down for large enough transportation costs t. These results are summarized in the following proposition.

Proposition 3b (Competition) *In the presence of credit risk transfer with private information, if the market does not break down, higher competition (higher n)*

- *leaves the aggregate amount of good loans unaffected, $dL_G/dn = 0$,*

- *increases the aggregate amount of medium loans until the market is covered completely,* $dL_M/dn \geq 0$*,*

- *increases the aggregate amount of bad loans,* $dL_B/dn > 0$*,*

- *increases the fraction of medium loans that is insured,* $d\kappa/dn > 0$*.*

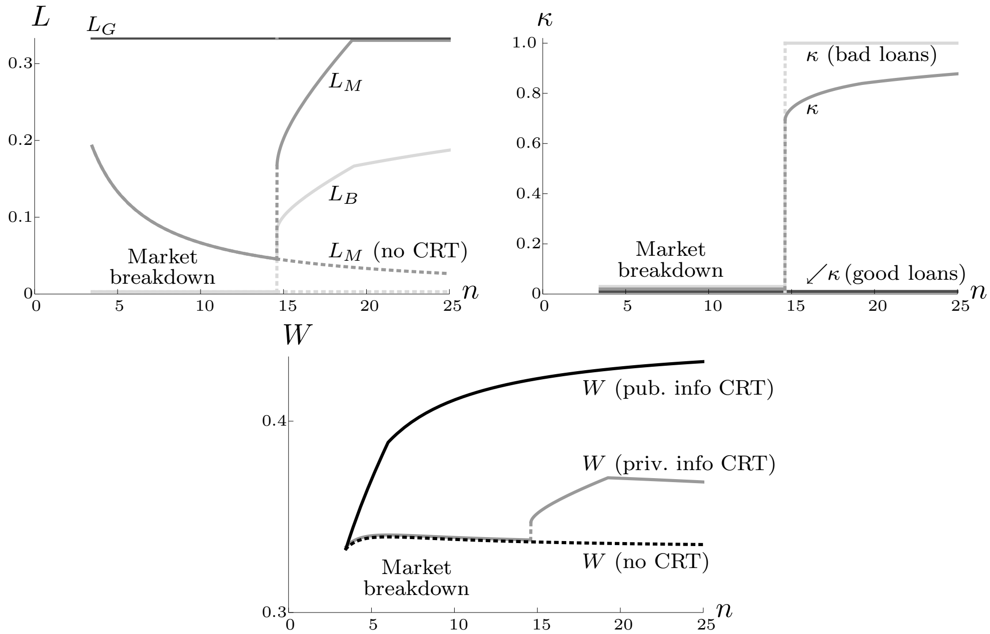
For some $\bar{n} > 0$*, the market for credit risk transfer breaks down for* $n \leq \bar{n}$*.*

The last part of Proposition 3b offers a new explanation for the evolution of CRT markets before the crisis. In the interpretation of our model, the strong increase in the use of CRT instruments before the financial crisis may have been due to the intensification of competition in the banking sector. When competition in the banking sector was low, banks' balance sheets were healthy enough to absorb large amounts of risk. Consequently, CRT was not necessary, and banks granted loans with an efficient risk-return structure. When competition increased, e. g., due to financial deregulation such as the abolishment of the Glass-Steagall act in 1999, or the branching deregulation initiated in the Riegle-Neal act of 1994, capital buffers of banks shrank and banks needed to shed more risk. The market for CRT became active, and banks had an incentive to grant negative-NPV high-risk loans, just in order to resell them. Hence, financial deregulation may have been one reason for financial instability. The proposition is also in line with Vickery (2007) who shows that savings banks (operating in a less competitive environment) retain mortgages on their own balance sheet and originate loans with low levels of risk, whereas finance companies (operating in a more competitive environment) choose an originate-and-distribute strategy and grant riskier loans. Note again that fiercer competition can also be caused by a reduction in "transportation costs." In fact, it seems that in the years before the current crises, "shopping around" for loans has become much easier in retail banking in the U. S., not least due to the advent of the internet and the resulting increase in price transparency.[19]

The results of Proposition 3b are illustrated in Figure 6. There is a critical n (in the numerical example $n \approx 14$) below which the market for CRT breaks down. Only for higher n, a market for CRT with private information can be maintained. The reason is the following. For low levels of competition, banks earn high profits on good loans,

[19]We thank an anonymous referee for bringing this point to our attention.

Figure 6: Credit Risk Transfer with Private Information



Colors are the same as in Figure 1: Light gray stands for bad borrowers, medium gray for medium borrowers, and dark gray for good borrowers. The first chart of the figure shows aggregate loan volumes. The solid lines again refer to a situation with CRT. The dashed lines show the loan volumes in the medium and bad loan segments in the absence of CRT (for good loans the volume is unchanged by the introduction of CRT). If the market for CRT does not break down, there is an increase in both medium and bad loans due to CRT; the market penetration for medium and bad loans increases in n. The second chart shows the fraction of transferred medium loans κ, together with the fractions of transferred good loans (which is always zero) and bad loans (which is equal to 1 as long as the market for CRT is active). The higher n, the fewer medium loans can banks keep in their books. Notice the discontinuity of most curves at $n \approx 14$, which is where the CRT market starts to exist. Most curves also exhibit a kink at $n \approx 19$, at which point the market for mediums loans is saturated. The third chart shows welfare. Welfare without CRT is dashed black, welfare with public-information CRT is solid black, and welfare with private-information CRT is gray. The gray welfare function increases as long as the medium loan market expands. Above the kink, only the bad loan market expands, and welfare decreases.

hence they need to insure fewer medium loans; as a consequence, the price for CRT is high, leading to a complete market breakdown because the lemons problem becomes too severe. All variables are then equal to those in the absence of CRT (cf. Figure 4). For higher n, the CRT market is active. As n becomes larger, the penetration of the medium loan segment increases, until at some point ($n \approx 19$ in the figure) the medium market is covered completely. The bad loan segment keeps growing. As a consequence, the lemons premium for CRT increases, and the growth of bad loans is (slightly) smaller. Consequently, competition has the beneficial effect of increasing the market penetration for medium loans, but it inflates the volume of bad loans at the same time.

When the medium market is covered completely, a further increase in competition improves only the access to credit for negative NPV firms. Given that $l_M = 2\, q_M\, p_M\, (Y - R_M)/t$, the medium market is saturated when $R_M = Y - t/(2\, n\, p_M)$. Since $R_B = R_M$, the volume of bad loans will be $L_B = q_B\, p_B/p_M < q_B$ at this point, hence the bad market is not saturated. The reason is the following. For a given loan rate and a given distance to the closest bank, expected profits of medium entrepreneurs are higher than those of bad entrepreneurs, due to the higher success probability of medium projects. Consequently, the medium loan market is always penetrated more than the bad market. When the medium market is saturated, fiercer competition cannot lead to a further increase in L_M. Consequently, the price of credit insurance increases, which makes bad loans L_B grow more slowly. This is also visible in Figure 6.

The maximum volume of bad loans is bounded not only by the size of the bad loan segment, but also by the banks' capacity to grant bad loans. This capacity depends on the price of credit insurance, which in turn depends on the relative number of medium and bad entrepreneurs, q_M and q_B, and the NPV of loans. Of course, if the NPV of bad loans is only slightly negative, then banks' capacity to grant bad loans will be large. For $n \to \infty$, the volume of bad loans converges towards

$$\lim_{n\to\infty} L_B = \min\{q_B; \bar{L}_B\}, \quad \text{where} \quad \bar{L}_B = q_M\, \frac{p_M\, Y - r}{r - p_B\, Y} \tag{15}$$

is the banks' lending capacity to bad entrepreneurs.[20] Hence, the market for bad loans will *never* be saturated if the banks' lending capacity for bad loans is smaller than q_B, which happens if and only if

$$q_M\, (p_M\, Y - r) + q_B\, (p_B\, Y - r) < 0. \tag{16}$$

This condition implies that the aggregate NPV of all available medium and bad projects is negative; the (negative) NPV of all bad projects exceeds the (positive) NPV of all medium projects in absolute value. In reality, (16) is likely to hold. For a potential entrepreneur, it is relatively simple to come up with a negative-NPV investment, whereas it is much more difficult to find a positive-NPV project. Consequently, the potential amount of bad projects q_B will be large relative to q_M. Because the NPV of bad projects, $p_B\, Y - r$, is negative, (16) will hold. The bad market will never be saturated. This result will be important for the welfare assessment of credit risk transfer under private information.

[20]See the Appendix for a proof of equation (15).

Welfare. When CRT is based on private information, the effects of an introduction of CRT on welfare are less clear-cut than before. The improved access to credit for medium borrowers raises welfare, but the extension of loans to negative NPV borrowers decreases welfare. Still, the overall effect on welfare is positive. Bad borrowers benefit from gaining access to credit. Medium borrowers benefit due to lower loan rates and to an improved access to loans. The banks ultimately bear the costs of the negative NPV projects of bad borrowers, but they still benefit from CRT due to the possibility of expanding in the medium market. Summing up, we have the following result.[21]

Proposition 3c (Welfare) *If the CRT market does not break down, the introduction of credit risk transfer with private information strictly increases aggregate welfare. For large n, welfare converges to*

$$\lim_{n\to\infty} W = q_G\,(Y-r) + \max\{0;\, q_M\,(p_M Y - r) + q_B\,(p_B Y - r)\}. \tag{17}$$

Remember that, in the absence of CRT, welfare converges to $q_G\,(Y-r)$ for large n. The same is true here if condition (16) holds. Hence, this proposition implies that the potential welfare gains from the introduction of CRT are completely offset at high levels of competition.

The proposition is illustrated by the third panel of Figure 6. As long as the CRT market breaks down, it does not affect welfare. The gray and the dashed welfare curves are identical for $n < 14$. At $n \approx 14$, the CRT market becomes active. Welfare jumps up, and further competition raises welfare even more. At $n \approx 19$, the medium market is saturated, and further competition only increases the volume of bad loans. From this point onwards, welfare decreases in competition. In the limit, the two curves (welfare without CRT and welfare with private-information CRT) converge. Again, the same results hold true also for decreasing t.

These welfare effects are interesting because they differ from the results found in the literature. In the paper by Parlour and Plantin (2008) (PP), the introduction of CRT may decrease welfare. The diverging results stem from differences in model structures. In PP, CRT affects banks in two ways. First, banks face unknown future investment opportunities (modelled through a stochastic discount factor). CRT allows banks to

[21] As in Proposition 2c, the fact that welfare increases does not hinge upon the risk neutrality of insurers.

exploit profitable investment opportunities, which may lead to a positive welfare effect. This is comparable to the positive welfare effect of our static model, where CRT helps banks to grant additional loans that could not be financed otherwise. Second, banks have to monitor loans because firms face a moral hazard problem. If banks do not monitor, firms shirk and their projects' NPV decreases. If a bank's stakes in a firm's returns are too small (for example because the bank makes use of CRT to insure part of a loan), monitoring incentives of the bank are reduced. In order to preserve monitoring incentives, the bank must increase its relative stake in the firm. The borrowing capacity and size of the firm decline, which leads to a negative welfare effect. Hence, banks exert a negative externality on firms. Either of these two channels can dominate, which explains the ambiguous welfare result in PP. In their paper, if the welfare effect of CRT is negative, banks would like to commit to *not* using CRT instruments.

Instead of monitoring, banks screen firms in our paper before granting loans. After screening, they hold information on the firms' types that insurers do not have. As in PP, CRT distorts incentives because it induces banks to originate bad loans. However, in PP, banks harm firms by not monitoring (if this is anticipated by other investors). In our paper, the origination of bad loans is beneficial for firms (who obtain better access to loans and lower loan rates), irrelevant for insurers (who are always at their participation constraint), and beneficial for banks (who otherwise would not use CRT). Consequently, although monitoring and screening are comparable activities, the welfare effects of CRT can be quite different.

Market Entry. Let us now discuss the long-run effects of CRT with private information. Since the introduction of CRT increases expected profits in the short run (see Proposition 3a), it attracts more banks in the long run. Because CRT with private information increases expected profits less then CRT with public information, fewer additional banks will enter the market.

If competition is not too fierce, long-run effects of CRT reinforce short-run effects, as was the case with public information. Increasing competition through market entry further improves the access to credit for both medium and bad borrowers. However, if competition is so strong that the medium market is covered completely, market entry improves the access to credit only for bad borrowers. In this case, only the detrimental effects of CRT are reinforced.

Under CRT with private information, entry is again excessive. First, as in any Salop model, firms do not take into account the negative externality that their entry has on the other firms' profits. Second, bank entry exacerbates the problem that banks lend to bad entrepreneurs to finance negative NPV projects.

5 Extensions

We will now briefly consider two extensions of our model. First, we analyze a modification of the Salop model where the entrepreneurs' locations can be observed by banks. Second, we will discuss what happens when insurers can observe a bank's retention of credit risk.

Observable Locations The Salop model assumes that banks cannot observe the entrepreneurs' locations. We will now show that this assumption is not crucial for our results. Consider the setup of Section 2, the only difference being that banks can observe the entrepreneurs' locations x. Consequently, they can (and will) price discriminate among entrepreneurs. We first examine the market for good entrepreneurs. Assume that the number of banks is so large that at least two banks compete for each entrepreneur. There is Bertrand competition for each entrepreneur. Consequently, an entrepreneur always takes the loan from the closest bank, at a loan rate that cannot be matched by the second closest bank. Take an entrepreneur at position $x < \frac{1}{2n}$, with the closest bank at position 0. The second closest bank is at position $\frac{1}{n}$, with a break-even loan rate of $R_G = r$. With this loan rate, the expected profit of the entrepreneur would be $(Y - r) - t\,(\frac{1}{2n} - x)$. Hence, the closest bank must offer a rate such that

$$\begin{aligned}(Y - R_G) - t\,x &= (Y - r) - t\,(\frac{1}{2\,n} - x),\\ R_G &= r + t\,(\frac{1}{n} - 2\,x).\end{aligned} \tag{18}$$

Each bank can extract exactly the difference in transportation costs from an entrepreneur. The bank's clientele reaches from $-\frac{1}{2n}$ to $\frac{1}{2n}$, hence aggregate profits from G-type entrepreneurs are

$$\Pi_G = 2\int_0^{\frac{1}{2n}} \left[r + t\,(\frac{1}{n} - 2\,x)\right] dx = \frac{t}{2\,n^2}. \tag{19}$$

In analogy to (1), $\Pi_G - r\, l_M \geq 0$ must hold. In equilibrium, $l_M = \Pi_G / r$. Consequently, we immediately get an analogy to Proposition 1b: As the number of banks n increases, profits in the good loan segment decrease; hence banks have less money to put at risk in the medium loan segment, hence the market penetration in the medium segment decreases. This mechanism is the driving force of the main results of this paper. Therefore, the results of the paper will also go through with observable locations. The comparative statics with respect to the degree of competition are identical to those with unobservable locations of entrepreneurs. Especially welfare can again be non-monotonic in the case of private-information CRT.

Observable Retention Rates In the private information case, we have based our calculations on the assumption that insurers can observe neither the type of an entrepreneur, nor the fraction of a loan's risk that is retained in a bank's portfolio. As a consequence, the retention rate was zero for bad loans, and $1 - \kappa$ for medium loans (and 1 for good loans). With an observable retention rate, banks can commit to granting and insuring only medium loans. In equilibrium, the retention rate has to be high enough to destroy a bank's incentives to grant bad loans and then insure them.

The expected profit from a bad loan, insured at the premium of a medium loan, is $\kappa\, p_M\, R_M + (1 - \kappa)\, p_B\, R_M - r$. The profit from granting and insuring bad loans has to be negative,

$$\kappa\, p_M\, R_M + (1 - \kappa)\, p_B\, R_M - r < 0,$$

defining a minimum retention rate $1 - \kappa$, where

$$\kappa = \frac{r/R_M - p_B}{p_M - p_B}.$$

Furthermore, a modified version of (1) holds. A bank's profits from good loans are unaffected and are equal to $\Pi_G = q_G\, t/n^2$. Now there is a multiplier effect. Banks can use the profits from good loans to grant medium loans, of which they insure a fraction κ. The insured fraction leads to new safe cash streams, which again can be used to grant medium loans. Since the multiplier is smaller than one, the equilibrium volume of medium loans can fall short of a bank's desired volume. The shadow price λ will then still be positive.

Note that observable retention rates can prevent the granting of bad loans and will therefore increase welfare relative to the situation considered before. However, rising competition will still be welfare-decreasing for large n because fiercer competition reduces banks' risk-bearing capacities (but less than without CRT). Therefore, welfare will be lower than under public information, especially for high levels of competition. In the limiting case of extreme competition ($n \to \infty$), banks' profits in the good loan segment vanish. The volume of medium loans converges to zero, and welfare drops to $W = q_G (Y - r)$, as in Proposition 3c.

6 Conclusion

This paper has shown how credit risk transfer can improve the access to finance for risky borrowers by increasing banks' risk-bearing capacities and thereby relaxing lending constraints. Without CRT, a bank may be reluctant to grant loans to risky borrowers because such loans threaten its solvency. An introduction of markets for CRT generally leads to a loan expansion and thereby to an increase in welfare because it enables borrowers to finance profitable projects that would otherwise not have been carried out.

However, a bank's ability to transfer risks depends on whether the bank grants loans on the basis of public or private information. If loans are granted on the basis of public information, credit risk transfer works smoothly because banks can easily convey the quality of their borrowers to insurers and will not have an incentive to grant (and transfer) unprofitable loans. If loans are granted on the basis of private information, the transfer of credit risk is more difficult because the insurers cannot observe the quality of a bank's borrowers. This leads to a moral hazard problem at the originating bank. It can exploit the informational asymmetry by granting unprofitable loans and transferring the risk to the insurers. The insurers anticipate this and demand a lemons premium. As a consequence, banks do not insure their loan portfolio to the same degree as with public information. Here the possibility of transferring risks improves the access to finance not only for medium (i. e. risky, but profitable) borrowers, but also for bad (i. e. unprofitable) borrowers, which leads to an increase in aggregate risk in the economy.

Nevertheless, the overall welfare effect of an introduction of CRT markets is always positive in our setup. Even with private information, CRT is beneficial because the welfare gains from the improved access to credit for medium borrowers overcompensate the welfare losses from the improved access to credit for bad borrowers.

Furthermore, we have emphasized the role of banking competition. In our basic setup, we find that the undersupply of risky loans is most severe in a highly competitive environment. The reason is that the banks' margins in other types of business (the good loan segment) and hence the potential to absorb losses from risky loans are small under such circumstances. With CRT, increasing competition no longer leads to a deterioration in borrowers' access to finance; in fact, the borrowers' access to finance improves both with public and private information. However, increasing competition may be harmful in the presence of CRT with private information. When the medium loan market is saturated, a further increase in competition improves the access to finance only for bad borrowers, and welfare decreases. In the limit, this completely offsets the welfare gains from credit risk transfer.

CRT markets break down when banking competition is very low. Low competition implies that banks have large risk-bearing capacities and can keep most of their medium loans in their own balance sheets. This reduces the average quality of loans to be insured, such that insurers are no longer willing to participate. This may explain why CRT markets appeared in an environment of intensifying banking competition, after banking markets had been deregulated in the 1980s and 1990s and banks' margins had been reduced by competition from non-bank intermediaries.

The sharp distinction between banking markets with public and private information should not be taken too literally. The pure public information case can hardly be found in the real world and should rather be seen as a benchmark case in which CRT markets work perfectly. In reality, loan markets are always characterized by some degree of asymmetric information; hence, CRT markets will never work perfectly and will always involve some moral hazard in the origination of loans. Moreover, the welfare analysis presented in this paper abstracts from the costs arising from financial instability. Such costs would have to be balanced against the benefits from CRT, such as the improved access to finance for profitable borrowers.

Our results on the destabilizing role of highly competitive banking markets in the presence of credit risk transfer are well in line with the traditional literature on the harmful effects of banking competition on financial stability. Our paper yields a number of interesting testable implications regarding the effect of competition on banking markets. First, CRT markets are most likely to develop in an environment of intensive banking competition. Second, in the presence of CRT with private information, a rise in competition tends to lower average loan quality when most profitable lending opportunities have already been exploited; then new loans tend to be low quality loans. Both predictions are in line with the observations from the current subprime crisis. The development of CRT markets coincided with intensifying competition in the banking market due to deregulation and the entry of non-bank competitors. Moreover, the late years of the credit boom preceding the crisis were characterized by both increasing competition in the banking sector and decreasing loan quality. Further research is needed to explore in more detail the relationship between banking competition and financial stability in the presence of CRT markets.

A Appendix

A.1 Proofs

Proof of Proposition 1a. We will first solve for the endogenous variables of our model in an equilibrium where the good market is covered, the medium market is not covered, and the shadow price λ is strictly positive. Then we will derive the conditions under which this equilibrium obtains.

Banks maximize their expected profits given by (6), subject to condition (1). We set up the Lagrangian Λ and plug in the loan demand functions l_G and l_M from (3) and (5),

$$\begin{aligned}\Lambda &= (R_G - r)\, l_G + (p_M\, R_M - r)\, l_M + \lambda \left[(R_G - r)\, l_G - r\, l_M\right] \\ &= (R_G - r)\, q_G \left(\frac{1}{n} + \frac{R'_G - R_G}{t}\right) + (p_M\, R_M - r)\, 2\, p_M\, q_M\, \frac{Y - R_M}{t} \\ &+ \lambda \left[(R_G - r)\, q_G \left(\frac{1}{n} + \frac{R'_G - R_G}{t}\right) - r\, 2\, p_M\, q_M\, \frac{Y - R_M}{t}\right]. \end{aligned} \tag{20}$$

Taking the first-order conditions of the Lagrangian Λ with respect to R_G, R_M, and λ, and setting $R'_G = R_G$ in a symmetric equilibrium, we obtain

$$R_G = r + \frac{t}{n}, \tag{21}$$

$$R_M = Y - \frac{q_G\, t^2}{2\, n^2\, p_M\, q_M\, r}, \text{ and} \tag{22}$$

$$\lambda = \frac{p_M\, Y}{r} - 1 - \frac{q_G\, t^2}{n^2\, q_M\, r^2}, \tag{23}$$

where λ is the shadow price of constraint (1). Equilibrium loan volumes and profits are

$$l_G = \frac{q_G}{n}, \quad L_G = n\, l_G = q_G, \tag{24}$$

$$l_M = \frac{q_G\, t}{n^2\, r}, \quad L_M = n\, l_M = \frac{q_G\, t}{n\, r}, \text{ and} \tag{25}$$

$$\Pi = \frac{q_G\, t}{2\, n^4\, q_M\, r^2} \left(2\, n^2\, p_M\, q_M\, r\, Y - q_G\, t^2\right). \tag{26}$$

We now show under which conditions this equilibrium obtains. We first derive the condition under which the good market is covered for lower n than the medium market. Consider a situation in which the market for good loans is not covered. Then banks enjoy local monopolies in this loan segment. The critical, indifferent entrepreneur at position x_G would have $(Y - R_G) - t\, x_G = 0$, hence $x_G = (Y - R_G)/t$ and $l_G = 2\, q_G\, (Y - R_G)/t$. Denote by Π_G a bank's profits in the good loan segment. Then $\Pi_G = (R_G - r)\, l_G = (R_G - r)(Y - R_G)\, 2\, q_G/t$. The first-order condition $\partial \Pi_G / \partial R_G = 0$ implies that $R_G = (Y + r)/2$, $l_G = q_G\, (Y - r)/t$, and $\Pi_G = q_G\, (Y - r)^2/(2\, t)$. Since there is no competition among banks, these values do not depend on n. Equation (1) is equivalent to $\Pi_G = r\, l_M$, which implies that $l_M = \Pi_G/r$ if (1) binds. Hence, as long as banks do not interact at all, $L_G = n\, l_G$ and $L_M = n\, l_M$ are proportional to n.

The question is now under which condition the good market is covered ($L_G = q_G$) for lower n than the medium market. Clearly, the answer must depend on the ratio between q_G and q_M. If the good market is relatively small, the banks' risk-bearing capacity will be small and banks can cover only part of the medium market. Then the good market will be saturated first. The good sector is saturated if $L_G = n\, q_G\, (Y - r)/t = q_G$, hence if $n = t/(Y - r)$. The medium sector is saturated if $L_M = n\, q_G\, (Y - r)^2/(2\, t\, r) = q_M$, hence if $n = 2\, q_M\, r\, t/[q_G\, (Y - r)^2]$. Comparing these two critical values for n, one finds that the good segment is saturated for a lower n than the medium segment if

$$\frac{q_M}{q_G} > \frac{Y - r}{2\, r}. \tag{27}$$

This yields the first condition of Proposition 1a. Note that this condition is very likely to be satisfied in reality. The fraction $(Y - r)/r$ gives the return of a project in the good segment. This number will not exceed a few percentage points; the right hand side of (27) will thus typically be well below 1. Hence, q_M could even be well below q_G under this condition.

For $n \geq t/(Y - r)$, the good market is covered. This is the second condition in the proposition. If this condition were violated, banks would not compete at all. All interest rates would be independent of n, and aggregate loan volumes (and welfare) would be proportional to n. At the critical $n = t/(Y - r)$, the medium market is not covered due to condition (27). For larger n, L_M decreases (see (25)). Hence, the medium market is not covered.

Finally, condition (1) binds in equilibrium if $\lambda > 0$, hence if $n > t\,\sqrt{q_G}/\sqrt{q_M\, r\,(p_M\, Y - r)}$. This is the third condition in the proposition. □

Proof of Proposition 1b. We see that, for an individual bank, $dl_G/dn < 0$ and $dl_M/dn < 0$, see (24) and (25). In the aggregate, $L_G = q_G$. The market is still covered completely, such that $dL_G/dn = 0$, which proves the first statement of the proposition. In the medium market, $L_M = (q_G\, t)/(n\, r)$, see (25), which depends negatively on n. This proves the second statement of the proposition. Finally, taking the derivative of (23) with respect to n, we find that $d\lambda/dn > 0$, proving the third statement of the proposition. □

Proof of Proposition 1c. Welfare consists of the expected profits and rents of banks, depositors, and borrowers. Depositors' participation constraints are binding, their rents are equal to zero. Aggregate welfare for good and medium entrepreneurs is

$$W_G = q_G\, 2\, n \int_0^{\frac{1}{2n}} ((Y - R_G) - t\, x)\, dx = q_G \left(Y - r - \frac{5\, t}{4\, n} \right), \text{ and} \tag{28}$$

$$W_M = q_M\, 2\, n \int_0^{x_M} (p_M\, (Y - R_M) - t\, x)\, dx = \frac{q_G^2\, t^3}{4\, n^3\, q_M\, r^2}, \tag{29}$$

where x_M is defined by (4). The banks' profits Π are given by (6). Aggregate welfare is then

$$W = W_G + W_M + n\,\Pi = q_G \left((Y - r) + t\, \frac{p_M\, Y - 5/4\, r}{n\, r} - \frac{q_G\, t^3}{4\, q_M\, n^3\, r^2} \right). \tag{30}$$

The first-order condition with respect to n yields

$$\frac{\partial W}{\partial n} = q_G \left(-t\, \frac{p_M\, Y - 5/4\, r}{n^2\, r} + 3\, \frac{q_G\, t^3}{4\, q_M\, n^4\, r^2} \right) = 0.$$

Solving for n gives the optimal n^* as in (7). For $n \to \infty$, W converges to $q_G\,(Y - r)$. □

Proof of Proposition 2a. The bank's profit function is given by (9). Banks can swap risky loans against safe payments with the same expected return by insuring a loan, hence condition (1) is no longer binding. This implies that λ is equal to 0, proving the third statement of the proposition.

Loan volumes are as in (3) and (5), given that the medium loan market is not covered completely. Plugging in loan volumes, taking the derivative of a bank's expected profits Π with respect to R_G and R_M, and taking into account the symmetry of banks ($R'_G = R_G$), we obtain

$$R_G = r + \frac{t}{n} \quad \text{and} \quad R_M = \frac{Y}{2} + \frac{r}{2\,p_M}. \tag{31}$$

Hence, R_G is unchanged by the introduction of CRT, and the market is covered completely as before, $L_G = q_G$. Hence, $dL_G/dn = 0$, which proves the first statement of the proposition.

Comparing R_M before and after the introduction of CRT, we find that R_M decreases due to the introduction of CRT markets if and only

$$\begin{aligned}
\frac{Y}{2} + \frac{r}{2\,p_M} &< Y - \frac{q_G\,t^2}{2\,n^2\,p_M\,q_M\,r}, \\
\frac{r}{p_M} &< Y - \frac{q_G\,t^2}{n^2\,p_M\,q_M\,r}, \\
0 &< \frac{p_M\,Y}{r} - 1 - \frac{q_G\,t^2}{n^2\,q_M\,r^2},
\end{aligned}$$

hence if λ is positive in the absence of CRT, see (23). Therefore, individual and aggregate loan volumes in the medium loan segment, l_M and L_M increase, see (5), which proves the second statement of the proposition.

Finally, expected profits are

$$\Pi = q_G\,\frac{t}{n^2} + q_M\,\frac{(p_M\,Y - r)^2}{2\,t}. \tag{32}$$

The condition $\lambda > 0$ is sufficient for an increase in expected profits due to the introduction of CRT. This proves the final statement of the proposition.

The expansion of medium loans due to the introduction of CRT may lead to a complete coverage of the medium loan segment. As before, the market for good loans is not affected by CRT. Since the medium market is covered, banks no longer enjoy local monopolies, but they compete à la Salop, as in the good loan segment. Banks maximize $\Pi_M = (p_M\, R_M - r)\, l_M$ subject to $l_M = q_M\,(1/n + (R'_M - R_M)/t)$, in analogy to (3). Taking the first-order condition, setting $R'_M = R_M$ due to symmetry, and solving for R_M, we obtain

$$R_M = \frac{r}{p_M} + \frac{t}{n}.$$

Loan volumes are $l_M = q_M/n$ due to symmetry, banks' profits are $\Pi_M = p_M\, q_M\, t/n^2$.

Let us again go through the statements of the proposition. First, the amount of good loans is unaffected. Second, the amount of medium loans has increased (the market was not covered before). Third, condition (1) is not binding, hence the shadow price λ is zero. Finally, profits increase if condition (1) was binding in the absence of CRT. Hence, all four statements of the proposition are also true when the medium market is covered after the introduction of CRT. □

Proof of Proposition 2b. As argued above, the aggregate loan volume in the good loan segment, $L_G = q_G$, does not depend on n, as the market is already saturated. This gives us the first part of the proposition. Moreover, we can plug R_M from (31) in (5) to obtain $l_M = q_M\,(p_M\, Y - r)/t$. We see that the medium loan volume of a single bank does *not* depend on the number of banks. As a result, $L_M = n\, l_M$ increases monotonically in n until the medium loan market is covered completely. This proves the second part of the proposition. □

Proof of Proposition 2c. Welfare now consists of the expected profits and rents of banks, depositors, borrowers, and insurers. Risk insurance is fair, hence insurers' expected profits are zero. Depositors' rents are also zero. Consequently, $W = W_G + W_M + n\,\Pi$, as before. If the market for medium loans is not covered completely, we obtain the following results. W_G is as in (28),

$$\begin{aligned}
W_M &= q_M\, 2\, n \int_0^{x_M} (p_M\,(Y - R_M) - t\, x)\, dx = n\, q_M\, \frac{(p_M\, Y - r)^2}{4\, t}, \quad \text{and} \\
\Pi &= q_G\, \frac{t}{n^2} + q_M\, \frac{(p_M\, Y - r)^2}{2\, t}, \quad \text{hence} \\
W &= q_G \left((Y - r) - \frac{t}{4\, n} \right) + q_M\, \frac{3\, n\, (p_M\, Y - r)^2}{4\, t}. \qquad (33)
\end{aligned}$$

For $n = t/(p_M Y - r)$, the medium market is covered. The welfare components are then

$$\begin{aligned}
W_M &= q_M \left((p_M Y - r) - \frac{5\,t}{4\,n}\right) \quad \text{and} \\
\Pi &= (q_G + q_M)\,\frac{t}{n^2}, \quad \text{hence} \\
W &= q_G \left((Y - r) - \frac{t}{4\,n}\right) + q_M \left((p_M Y - r) - \frac{t}{4\,n}\right).
\end{aligned} \tag{34}$$

The aggregate deposit supply is perfectly elastic, hence depositors' expected utility does not change although the aggregate deposit volume increases due to the introduction of CRT. For good borrowers, loan rates R_G remain unchanged. CRT does not help bad borrowers to gain access to credit. Medium borrowers, however, profit from the introduction of CRT in two ways. Those borrower who already had access to credit in the absence of CRT benefit from lower loan rates R_M. Additionally, the volume L_M expands; some medium borrowers gain access to credit due to CRT. Finally, consider the banks' expected profits. Introducing CRT, banks' profits in the good loan segment do not change; expected profits from the medium loan segment increase. Consequently, aggregate welfare increases.

This can also be shown formally. Comparing (30) with (33), we obtain

$$\begin{aligned}
q_G\Big((Y-r) - \frac{t}{4n}\Big) + q_M \frac{3n(p_M Y - r)^2}{4t} &> q_G\Big((Y-r) + t\frac{p_M Y - 5/4r}{nr} - \frac{q_G t^3}{4 q_M n^3 r^2}\Big) \\
-\frac{t}{4n} + \frac{q_M}{q_G}\frac{3n(p_M Y - r)^2}{4t} &> t\frac{p_M Y - 5/4r}{nr} - \frac{q_G t^3}{4 q_M n^3 r^2} \\
\frac{q_M}{q_G} 3n^4 (p_M Y - r)^2 - n^2 t^2 &> t^2 \frac{n^2(4p_M Y - 5r)}{r} - \frac{q_G t^4}{q_M r^2}.
\end{aligned}$$

Solving for n, we get

$$n > t\,\frac{\sqrt{q_G}}{\sqrt{q_M\, r\,(p_M\, Y - r)}},$$

which is the condition for a positive shadow price λ at the end of Proposition 1a. Analogously, a comparison of (30) and (34) shows that, in the case of saturated medium loan markets, welfare increases through the introduction of CRT markets for any positive n.

Finally, we see immediately that both welfare functions, (33) and (34), are strictly increasing in n. However, welfare increases more slowly once the medium market is covered. For large n, the medium market is eventually saturated, and welfare in (34) converges to $q_G\,(Y - r) + q_M\,(p_M\, Y - r)$. □

Proof of Proposition 3a. We already noted that profit-maximizing banks that respect the constraint (11) set identical loan rates for medium and bad entrepreneurs, as given by (14). For good entrepreneurs, the loan rate is $R_G = r + t/n$, as in (21). Furthermore, in (14), $\bar{p}$ is determined by β, and β is determined by κ in (13). Hence, the symmetric perfect Bayesian equilibrium is defined by (21) and (14), reflecting the profit maximizing behavior of banks, and (13), reflecting the rational beliefs of the insurers. Consequently, we have three equations for three variables, R_G, $R = R_M = R_B$, and $\bar{p}$ (the last of which defines κ).

We can solve this system of equations for R_G, R, and $\bar{p}$. We find two solutions for $\bar{p}$,

$$\begin{aligned} \bar{p} &= \frac{n^2\,(p_B\,q_B + p_M\,q_M)\,r\,(p_M\,Y + r) - p_M\,q_G\,t^2 \pm \sqrt{A}}{n^2\,Y[\,p_B\,q_B\,Y\,(p_M - p_B) + 2\,r\,(p_M\,q_M + p_B\,q_B)] - 2\,q_G\,t^2}, \text{ where} \\ A &= p_M^2\,q_G^2\,t^4 + n^4\,r^2[\,p_M\,q_M\,(p_M\,Y - r) + p_B\,q_B(p_B\,Y - r)]^2 \\ &\quad - 2\,n^2\,q_G\,r\,t^2[\,p_B\,q_B\,(p_M^2\,Y - p_B r) + p_M\,q_M\,(p_M^2\,Y - p_M\,r)]. \end{aligned} \tag{35}$$

Hence, there are also two solutions for R, whereas $R_G = r + t/n$ in both cases. There are two equilibria with different values for R and $\bar{p}$, but identical R_G. The existence of multiple equilibria is intuitive. Assume that $\bar{p}$, the success probability expected by insurers, is relatively low. Then the insurers will demand a high premium for insuring credit risk. Therefore, banks have high marginal costs of granting medium and bad loans, and banks will pass on part of these costs to the entrepreneurs. $R = R_M = R_B$ will be high, and the loan volumes l_M and l_B will be low. However, the profits from good loans do not depend on $\bar{p}$. Consequently, a bank can keep a larger fraction of medium loans on its books, so that κ is relatively low, and the average quality of insured loans is also low (implying a low $\bar{p}$). Hence, the insurers' initial belief is justified in equilibrium. An analogous argument can be made for relatively large $\bar{p}$. Hence, the existence of multiple equilibria is intuitive, and it is confirmed by the algebraic expression of (35).

However, the equilibrium with the larger $\bar{p}$ is Pareto-efficient. Insurers are indifferent between the two equilibria. Entrepreneurs prefer the equilibrium with higher loan volumes and lower loan rates, i. e. that with higher $\bar{p}$. Banks prefer the equilibrium with lower credit insurance premia, i. e. that with higher $\bar{p}$. Consequently, in the following, we will concentrate on the Pareto-efficient equilibrium, that with the positive sign in (35).

Some statements of Proposition 3a follow immediately. *First* statement: R_G is unaffected by CRT; the determining equation is the same as in the absence of CRT. Consequently, the coverage of the good loan segment does not change, $L_G = q_G$. *Third* statement: The amount of bad loans is strictly positive under private-information CRT, hence it increases due to CRT. *Fifth* statement: Expected profits of banks increase less than under public-information CRT because banks cannot commit to not granting loans to bad borrowers. In equilibrium, insurers will demand higher premia for insuring loans than with public-information CRT. Consequently, the costs of providing an additional loan are higher. Banks ultimately bear the costs arising from the lemons problem. *Second* statement: Banks' eagerness to lend to medium entrepreneurs is determined by marginal costs. These consist of refinancing costs r and of the costs from CRT (banks always insure the risk of the marginal medium loan). The latter costs are determined by β. The higher the probability β that an insured loan is medium, the lower are the costs of insurance. With public-information CRT, $\beta = 1$ because no bad loans are granted; with private-information CRT, $\beta < 1$. As a consequence, the marginal costs are higher with private-information CRT, the loan volume l_M is smaller, and the loan rate R_M is higher. However, with a volume l_M like in the absence of CRT, banks do not need CRT. Hence with a positive volume of CRT, l_M must have increased. *Fourth* statement: λ is the shadow price of condition (11), which is identical to (1) for $l_B = 0$. A marginal increase in the capital buffer increases expected profits by λ. This increase in expected profits is due to the bank's ability to expand lending to medium (and bad) borrowers, and it hence depends on R_M (and R_B). Since R_M is larger under private-information CRT than under public-information CRT, the shadow price λ must be larger. In comparison to the case without CRT, however, λ must decrease. As the volume of loans l_M and l_B increases, the according interest rate R falls, hence the shadow price of the binding condition (11) is smaller than in the absence of CRT. $\square$

Proof of Proposition 3b. Consider equation (11),

$$(R_G - r)\, l_G + \bar{p}\, R\, (l_B + \kappa\, l_M) - (l_M + l_B)\, r \geq 0,$$

and let the number of banks n increase. Competition and loan rates on the market for good loans are the same as in the absence of CRT (and as with public information). Hence, the good loan market is completely covered as before, $dL_G/dn = 0$, which proves the first statement of the proposition. An increase in n implies that $(R_G - r)\, l_G$ decreases; R_G decreases, l_G decreases, and r remains constant. Let us keep R fixed for the moment. Then, both l_M and l_B do not change as n increases. Hence, banks need to raise κ in order to fulfill (11). (13) reveals that β increases when a larger fraction of medium loans is insured (with constant loan volumes). Insurers anticipate a better quality of insured loans, and $\bar{p} = \beta\, p_M + (1-\beta)\, p_B$ increases as well. This means that the marginal profit from an insured loan, $\bar{p}\, R - r$, increases. Consequently, banks will expand loan volumes l_M and l_B by lowering loan rates $R_M = R_B = R$. This triggers off a reinforcing multiplier effect. Due to (11), banks need to increase κ even further. The final equilibrium has higher aggregate loan volumes $L_M = n\, l_M$ and $L_B = n\, l_B$ at lower loan rates R, and a higher share of insured medium loans κ. Of course, L_M and L_B can only rise until the loan segments are covered completely.

All these comparative statics hold only if the market for CRT does not break down. Mathematically, this happens if the term under the square root in (35), A, becomes negative, such that no real solution obtains. The critical $\bar{n}$ below which the market for CRT breaks down is hence defined implicitly by

$$\begin{aligned} &\bar{n}^4\, r^2 \left[p_B\, q_B\, (p_B\, Y - r) + p_M\, q_M\, (p_M\, Y - r)\right]^2 \\ &-2\,\bar{n}^2\, q_G\, r\, t^2 \left[p_B\, q_B\, (p_M^2\, Y - p_B\, r) + p_M^2\, q_M\, (p_M\, Y - r)\right] = p_M^2\, q_G^2\, t^4. \end{aligned} \tag{36}$$

Below this $\bar{n}$, all parameters are as in Section 3 (no CRT). □

Proof of Equation (15). When the number of banks n increases, the bad loan segment will not necessarily be covered completely. To show this, we will derive the equilibrium where the bad loan segment is never covered and will then derive the condition, under which this equilibrium obtains.

If n goes to ∞, the profits from good loans go to zero. Consequently, banks must insure *all* loans that they grant, $\kappa = 1$. In an equilibrium where the bad market is not covered even for large n, banks always enjoy local monopolies over bad entrepreneurs. The expected profit on bad loans is

$$l_B\, (\bar{p}\, R_B - r) = 2\, q_B\, p_B\, \frac{\bar{p}\, R_B - r}{\bar{p}\, t}\, (Y - R_B),$$

which is maximized for

$$R_B = \frac{\bar{p}\, Y - r}{2\, \bar{p}},$$

which yields an aggregate bad loan volume of

$$L_B = n\, q_B\, p_B\, \frac{\bar{p}\, Y - r}{\bar{p}\, t}.$$

The aggregate medium loan volume is $L_M = q_M$. Considering that $\beta = \kappa\, l_M/(\kappa\, l_M + l_B)$, $\kappa = 1$, and $l_M = q_M/n$, we obtain

$$\bar{p} = \beta\, p_M + (1-\beta)\, p_B = \frac{\bar{p}\, p_M\, q_M\, t + n\, p_B^2\, q_B\, (\bar{p}\, Y - r)}{\bar{p}\, q_M\, t + n\, p_B\, q_B\, (\bar{p}\, Y - r)}.$$

The solution for $\bar{p}$ is

$$\bar{p} = \frac{Z \pm \sqrt{Z^2 - 4\, n\, r\, p_B^2\, q_B\, X}}{2\, X},$$

where $X = q_M\, t + n\, q_B\, p_B\, Y$ and $Z = n\, p_B\, q_B\, (p_B\, Y + r) + p_M\, q_M\, t$. For large $n \to \infty$, we obtain $X \approx n\, q_B\, p_B\, Y$ and $Z \approx n\, p_B\, q_B\, (p_B\, Y + r)$. n drops out of the expression for $\bar{p}$, hence now

$$\bar{p} = \frac{p_B\, q_B\, (p_B\, Y + r) \pm [p_B\, q_B\, (P_B\, Y - r)]}{2\, p_B\, q_B\, Y}.$$

The two solutions are $\bar{p} = p_B$ and $\bar{p} = Y/r$, the first of which is economically meaningless (it would imply that only bad loans are insured, but in this case, CRT would be prohibitively expensive).

With $\kappa = 1$, we have $\beta = l_M/(l_M + l_B)$ and $L_B = n \cdot l_B = \frac{n\,(1-\beta)}{\beta}\, l_M$. Considering that $\bar{p} = r/Y = \beta\, p_M + (1-\beta)\, p_B$ and $l_M = q_M/n$, we obtain

$$L_B = q_M\, \frac{p_M\, Y - r}{r - p_B\, Y}. \tag{37}$$

This volume can only be reached if it does not exceed q_B. This will happen if condition (16) holds; then, the market for bad loans is never covered completely, and the maximum volume of bad loans is as calculated above. If condition (16) does *not* hold, all bad entrepreneurs will get loans if competition is strong enough. $\square$

Proof of Proposition 3c. Aggregate welfare consists of the expected profits and utilities of banks, depositors, (good, medium, and bad) borrowers, and insurers. Depositors, good borrowers, and insurers are unaffected by the introduction of private-information CRT; banks and medium borrowers profit. Given that CRT is now based on private information, loans are also granted to bad borrowers with negative NPV projects. Bad borrowers profit from the improved access to credit. Summing up, the introduction of CRT increases aggregate welfare in spite of the expansion of negative NPV loans.

Now consider the limit of $n \to \infty$. The consequences of equation (15) for welfare are immediate. For $n \to \infty$, aggregate transportation costs vanish, and aggregate welfare equals the aggregate NPV of projects. If condition (16) holds, aggregate welfare is thus

$$\begin{aligned} W &= L_G(Y-r) + L_M(p_M\,Y-r) + L_B(p_B\,Y-r) \\ &= q_G\,(Y-r) + q_M\,(p_M\,Y-r) + q_M\,\frac{p_M\,Y-r}{r-p_B\,Y}\,(p_B\,Y-r) \\ &= q_G\,(Y-r). \end{aligned}$$

The welfare gain from loans to medium entrepreneurs due to CRT is completely offset by the negative NPV of bad projects for high levels of competition.

If condition (16) does not hold, aggregate welfare is simply

$$W = q_G\,(Y-r) + q_M\,(p_M\,Y-r) + q_B\,(p_B\,Y-r).$$

All markets are covered for large n, hence the only effect of an increase in n is a reduction of transportation costs. □

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