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Credit Derivatives in Banking: Useful Tools for Loan Risk Management?

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Abstract

We model the effects on banks of the introduction of a market for credit derivatives; in particular, credit default swaps. A bank can use such swaps to temporarily transfer credit risks of their loans to others, reducing the likelihood that defaulting loans trigger the bank's financial distress. Because credit derivatives are more flexible at transferring risks than are other, more established tools such as loan sales without recourse, these instruments make it easier for banks to circumvent the "lemons" problem caused by banks' superior information about the credit quality of their loans. However, we find that the introduction of a credit derivatives market is not necessarily desirable because it can cause other markets for loan risk-sharing to break down. If so, the existence of a credit derivatives market will lead to a greater risk of bank insolvency.

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1. Introduction

Credit derivatives are over-the-counter financial contracts that have payoffs contingent on changes in the credit quality of a specified firm or firms; the specified firm is typically not a party to the contract. The market for credit derivatives was developed during the early 1990s by large money-center commercial banks and investment banks. The market is small but is apparently growing quickly.[1]

Prior to the development of credit derivatives, there were very few ways to trade the credit risk of a given firm other than buying and selling obligations of the firm, such as bank loans, corporate bonds or stock. Dealer banks emphasize this flexibility in their efforts to market credit derivatives to potential customers and to persuade regulatory agencies to look favorably on these new instruments. In this paper we investigate some implications of this flexibility for banks in managing the risks of their loan portfolios. (Here we view banks as end-users of credit derivatives, and ignore the potential profits to be made by money-center banks as dealers in the credit derivatives market.) Can banks use credit derivatives to better control the risks that they face? Is this use beneficial to banks?

We focus on the role of banks as financial intermediaries. In this role, banks observe private information about potential borrowers in order to make good-quality loans. When banks make loans they incur the risk of their own insolvency. This risk carries with it deadweight costs, so banks must trade off their (ex-ante) profitable loan activity with the risk of their own failure. One way to reduce the risk of bank failure is for the bank to sell off parts of the loans that it originates, but this mechanism can be of limited use because of a lemons problem: Banks know more about the value of their loans than do outsiders. Banks with high-quality loans will tend to refrain from selling pieces of their portfolio if outsiders cannot distinguish such loans from low-quality loans.

We follow an observation by Duffee (1996) that in some circumstances, the uncertainty in a loan's payoff can be decomposed into a component (or components) for which the bank's informational advantage is relatively small and a component (or components) for which the bank's informational advantage is relatively large. The bank can then use a credit derivative contract to transfer the former risks to outsiders, while retaining the latter risks at the bank.

[1] Neal (1996) surveys the issues related to credit derivatives. Recent discussions in the financial press include Irving (1996) and Parsley (1996).

In particular, we argue that the bank's informational advantage is unlikely to be constant over the life of the loan. Thus the introduction of credit derivatives that temporarily transfer loan risk to outsiders could promote better risk sharing, thereby reducing the expected deadweight costs associated with bank insolvency.

This logic suggests that the use of credit derivatives to fine-tune credit risk management can benefit banks. We formalize these benefits in the context of a simple model. However, we also show that the introduction of a credit derivatives market can harm banks even as they use it to transfer credit risks to others. Banks will be worse off if the introduction of the credit derivatives market leads to the breakdown of other risk-transferring mechanisms, such as loan sales without recourse, that pool the risks of banks that make high-quality and low-quality loans. With the introduction of credit derivatives, banks with high-quality loans may choose to shed part of their risk with credit derivatives and refrain from selling any other part of their risk, destroying the pooling equilibrium in the loan sale market and *raising* the expected deadweight costs associated with bank insolvency.

This seemingly paradoxical conclusion is a standard result in the economics of insurance. For example, if individuals without genetic markers for certain diseases are allowed to buy private insurance at cheaper rates than are individuals with the markers, adverse selection problems are reduced but people may be worse off ex ante because the costs of having a bad gene are not as widely shared.[2] More generally, the argument in this paper is an example of Hart's (1975) seminal point that when markets are incomplete, the opening of a new market can make everyone worse off.

To our knowledge, this paper is the first in the academic literature to consider rigorously the implications of credit derivatives for banks' risk-sharing. A related literature examines the ability of banks to sell loans about which they have private information. Carlstrom and Samolyk (C&S, 1995) assume, as we do, that there is a deadweight cost to bank insolvency. The cost of bank insolvency gives the bank an incentive to sell some of its loan opportunities instead of directly funding the loans. The quality of loans a bank can make is unobservable by others, which typically gives rise to adverse selection. However, in their model, the deadweight cost of bank insolvency is infinite—thus banks face no real tradeoff between

[2] An example closer in spirit to this paper is if individuals are allowed to buy health insurance that specifically excludes coverage for illnesses related to certain genetic diseases.

holding their loans or selling them. Therefore C&S circumvent the standard lemons problem in which banks with high-quality loans refrain from selling them at poor prices.

Gorton and Pennacchi (1995) also model a bank's choice between holding loans and selling them, although they focus on moral hazard. If a bank holds a loan, it has a greater incentive to monitor the loan (and thus increase its probability of repayment) than if it sells it. They note that if a bank can implicitly commit to holding a certain fraction of a loan (or to provide limited recourse), the moral hazard associated with loan sales is reduced. We note that Gorton and Pennacchi's point is broadly applicable to any mechanism that transfers loan risk outside of the bank, including credit derivatives. Further, we find that moral hazard considerations strengthen the case for credit derivatives. If the introduction of a credit derivatives market leads to a breakdown of the loan sales market, banks will tend to monitor their loans more aggressively.

The next section describes some of the institutional features of the credit derivatives market in order to motivate the model of adverse selection that is presented in the third section. The fourth section uses the model to evaluate the value to banks of the credit derivatives market. In the fifth section we discuss the extent to which our stylized model captures the key features of bank behavior. This section also extends the model to consider moral hazard and to address some effects that credit derivatives may have on capital allocation. The latter extension suggests that credit derivatives can reduce banks' investment in poor-quality projects. The final section concludes.

2. Some institutional details

The credit derivatives market has existed for only a few years and remains quite small. There are only a few major dealers, and the total notional principal of outstanding credit derivative contracts is much less than one percent of the total notional principal of all outstanding over-the-counter derivative contracts.[3] Nonetheless, the market is developing rapidly, as measured by both increasing activity and declining spreads. At present, the market for credit derivatives consists almost entirely of two types of instruments: Credit default swaps and total rate of return swaps.

[3] This discussion is based on press reports, industry seminars, and conversations with dealers and regulators.

Credit default swaps can be thought of as insurance against the default of some underlying instrument, or as a put option on the underlying instrument. In a typical credit default swap, the party "selling" credit risk (or buying credit protection) makes periodic payments to the other party of a negotiated number of basis points multiplied by a notional principal. The party "buying" credit risk (or selling credit protection) makes no payment unless a specified *reference credit* defaults. In the event of default, the credit risk buyer pays the notional principal (often multiplied by some measure of the writedown rate on the reference credit) to the credit risk seller.

Total rate of return swaps mirror the return on some underlying instrument. In a typical total rate of return swap, the party "buying" credit risk makes periodic floating rate payments (typically tied to LIBOR) multiplied by some notional principal. The party "selling" credit risk makes periodic payments tied to the total return to some underlying reference credit, multiplied by the notional principal.

A common feature of existing credit derivatives is that their maturities are less than the maturities of the underlying instruments. For example, a credit default swap may specify that a payment is to be made if a ten-year corporate bond defaults at any time during the next two years. We emphasize this feature in the model of banks and loans that follows.

The underlying instruments on which credit derivatives are written are typically corporate bonds, Brady bonds, or large leveraged bank loans. All of these instruments can be priced easily using dealer polls. To date, the market has not been extended to instruments for which pricing is more opaque, such as small and medium-sized bank loans. However, some credit derivative dealers view local and regional banks as a prime source of business in the future, because bank loan portfolios are typically concentrated across business sectors and geographic regions. The dealers view credit derivatives as a useful tool with which banks can reduce their concentration risk. The following section models this potential use of credit derivatives.

3. A model

3.1. Overview and intuition

We consider a bank with the opportunity to make a single loan. The quality of the potential borrower is random and observed by the bank, but not by outsiders. These assumptions are designed to capture the incentives of a bank with a concentrated loan portfolio owing to its ability to evaluate prospective borrowers in a narrow geographic region or industry. We assume that neither the bank nor the borrower can credibly announce the credit quality of the borrower, nor can the bank convey the quality through the interest rate charged on the loan.[4]

Large loan losses will push the bank toward insolvency. Insolvency carries with it deadweight costs, but deadweight costs can be incurred simply by approaching the insolvency boundary, in the form of underinvestment. We are not concerned with the precise nature of the deadweight costs here, hence we avoid formally modeling insolvency and simply assume that loan losses beyond a given point trigger a deadweight cost to the bank. This assumption simplifies the model considerably because we do not need to explicitly model the bank's capital structure or any regulatory restrictions placed on a bank that is near insolvency.

Although everyone in this economy is risk-neutral, the bank has an incentive to sell part of the loan, without recourse, to outsiders in order to avoid the possibility of bank insolvency. However, the informational asymmetry between banks and outsiders can limit the market for loan sales without recourse. If a bank with high-quality loans must sell its loans at the same price as a bank with low-quality loans, it is possible that the bank with high-quality loans will forego the loan sales market and instead face the risk of its own insolvency.

As long as the structure of the asymmetric information varies over the life of the loan, credit derivatives contracts can be more useful risk management tools than loan sales. In our model, we assume that the bank's information advantage is greater near the maturity of the loan than near the time the loan is issued. This particular structure is not critical, but deserves some motivation.

Consider an firm with some existing assets that generate stochastic cash flows. The firm wants to invest in some new project. The firm has insufficient internally-generated funds and it cannot credibly convey the value of its new project to most outsiders. A bank, however, can observe the value of the project and decide whether to make a loan to fund

[4] In a more general model, the interest rate on the loan would depend on the extent of the bank's monopoly power in lending to the borrower. The important point here is that the interest rate is not uniquely determined by the credit quality of the borrower.

it. Following standard practice, any loan the bank makes will have cross-default provisions that trigger default on the loan in case of default on any other obligations of the firm.

Now consider the types of events that will trigger default on the new-project loan early in the loan's life. Typically, such events will be related to a decline in the value of the firm's existing assets, not a decline in the value of the new project. The reason is that even in the best of circumstances, the new project will not produce positive cash flows until it is completed. Therefore early in the life of the loan, the firm will not rely on income from the new project to make any interest or principal payment. Thus even a precipitous decline in the value of the new project will not trigger an early default. By contrast, a decline in the value of the firm's existing assets (resulting from, say, a permanent drop in the cash flows associated with these assets) can trigger an early default, most likely through cross-default provisions.

Existing assets are much easier for outsiders to value than are new projects. Therefore the bank and outsiders are likely to agree on the probability that the new-project loan defaults early in the life of the loan. But because the bank has better information about the value of the new project, the bank's assessment of the likelihood of default on the loan late in its life is likely to be different from outsiders' assessments. Therefore banks with high-quality loans can use a credit derivative to shift the risk of early default to outsiders, retain the risk of late default, and thereby avoid any lemons problem. These ideas are formalized below.

3.2. Setup

This is a three period model (0, 1, and 2). In period 0 the bank has the option to make a two period loan to some firm. There are two types of possible borrowers: low quality and high quality. At the start of period 0, the firm to which the bank has the option of lending money is exogenously, randomly chosen. With probability 1/2 the firm is low quality. The bank observes the firm's credit quality in period 0, but the firm's credit quality is never directly observed by others.

The loan has a fixed size L. The firm is obligated to pay a fixed interest rate R in both periods 1 and 2. The principal is to be repaid in period two. With probability p_1, the loan defaults in period 1. Conditional on the firm not defaulting on the loan in period 1, the

Table 1. Structure of Payoff on Loan. Probability p_1 is common knowledge, while probability p_2 is a random variable that is observed by the lending bank but not by outsiders.

	Default in Period 1	Default in Period 2	No Default
Probability	p_1	$(1-p_1)p_2$	$1-p_1-(1-p_1)p_2$
Period 1 Payoff	$[R+(1-w)]L$	RL	RL
Period 2 Payoff	0	$[R+(1-w)]L$	$(1+R)L$

probability that the firm defaults in period 2 is denoted p_2. This probability is p_h for high-quality firms and p_l for low-quality firms ($p_h < p_l$). In order to simplify the algebra, we assume that if the borrower defaults in a given period, the borrower will make the entire interest payment RL for that period and repay part of the principal $(1-w)L$. In other words, the bank recovers $(1+R-w)L$ in the event of default. The probabilities p_1, p_h, and p_l, as well as the writedown rate w, are exogenously fixed and common knowledge. The structure of the payoff on the loan is summarized in Table 1.

For simplicity, we assume that everyone in the economy is risk-neutral and that the default-free interest rate is zero. We also assume that both high-quality and low-quality loans are positive net-present-value (NPV) projects given risk-neutral discounting. Mathematically we can characterize this as

$$R + (1-p_1)R - w(p_1 + (1-p_1)p_l) > 0$$

which is the required condition for low-quality loans. We relax this assumption in Section 5.

We do not explicitly model the bank's capital structure, thus we do not explicitly model the conditions under which the bank defaults. Instead, we assume that if the bank experiences a loss of principal of at least L_0 on the loan ($wL > L_0$), it incurs an additional deadweight loss of $B > 0$. This setup drastically simplifies calculation of possible model equilibria while capturing the critical concept that as the bank gets closer to insolvency, expected deadweight costs rise.

3.3. The solution with loan sales

Here we assume that credit derivatives do not exist but that there is a market for loan sales without recourse. The bank may sell a nonnegative fraction f_i of its loan in period $i, i = 0, 1$. The bank cannot sell more than the total loan: $f_0 + f_1 \leq 1$. The total sale price for selling $f_0 L$ in period 0 is S_0, while the total sale price for selling $f_1 L$ in period 1 is S_1. In return for S_i, the buyer of the loan receives a fraction f_i of any future cash flows from the loan. As in Gorton and Pennacchi (1995), we assume that the bank can implicitly commit to these fractions.

Competitive risk-neutral outsiders purchase $f_i L$ in period i. The purchase price will depend on outsiders' expectations of p_2. Denote their expectation of p_2 formed in period 0 as p_2^{e0} and their expectation formed in period 1 as p_2^{e1}. These expectations will be, in general, dependent on the bank's choices of $f_i, i = 0, 1$. We suppress this dependence for the moment and write the total loan sale revenues to the bank as functions of the amount sold and outsiders' expectations:

$$\begin{aligned} S_0(f_0, p_2^{e0}) &= f_0 L\left[1 + R + (1-p_1)R - w\left(p_1 + (1-p_1)p_2^{e0}\right)\right] \\ S_1(f_1, p_2^{e1}) &= f_1 L\left[1 + R - w p_2^{e1}\right] \end{aligned} \tag{1}$$

The revenues in (1) are simply outsiders' expectations of the future cash flows that they buy.

We now consider the net present value of the bank's profits. Because the bank is risk-neutral and the riskfree interest rate is zero, this profit is simply the sum of its total cash flows. Denote the realization of this sum as V. The cash flows depend on the loan's quality p_2 and the bank's loan sale strategy (f_0, f_1), both directly and indirectly through the effect of this strategy on outsiders' expectations p_2^{e0} and p_2^{e1}, which affect the loan sale prices. We summarize this dependence by writing the bank's profit as

$$\text{profit} = V\left[f_0, f_1, S_0\left(f_0, p_2^{e0}(f_0)\right), S_1\left(f_1, p_2^{e1}(f_0, f_1)\right), p_2\right].$$

Note that the bank will incur a deadweight cost of B in period 1 if the loan defaults in that period and $(1-f_0)wL > L_0$, and will incur a deadweight cost of B in period two if the loan defaults in that period and $(1-f_0-f_1)wL > L_0$. We denote $\overline{f}$ as the minimum fraction of loan sales that allows the bank to avoid the deadweight cost:

$$(1-\overline{f})wL = L_0 \;\Rightarrow\; \overline{f} = 1 - \frac{L_0}{wL}$$

We define two indicator functions. The first, $I_{f_0<\overline{f}}$, is zero for $f_0 \geq \overline{f}$ and one elsewhere. The second, $I_{f_0+f_1<\overline{f}}$, is zero for $f_0 + f_1 \geq \overline{f}$ and one elsewhere. Then, suppressing the arguments of the loan sale prices S_0 and S_1, bank profits can be written as

$$V = \begin{cases} L[(1-f_0)(R+(1-w))-1]+S_0 & \text{if loan defaults in} \\ \qquad -\,BI_{f_0<\overline{f}}, & \text{period 1 (prob} = p_1); \\ L[(1-f_0)R\;+(1-f_0-f_1)(R+(1-w)) & \text{if loan defaults in} \\ \qquad -\,1]+S_0+S_1-BI_{f_0+f_1<\overline{f}}, & \text{period 2 (prob} = (1-p_1)p_2); \\ L[(1-f_0)R+(1-f_0-f_1)(R+1)-1], & \text{if no default} \\ \qquad +\,S_0+S_1 & (\text{prob} = 1-p_1-(1-p_1)p_2). \end{cases} \tag{2}$$

3.3.1. Equilibrium

An equilibrium must satisfy two conditions. First, the bank's choice of (f_0, f_1) as a function of its private observation p_2 must maximize its expectation, conditional on p_2, of its profit.[5] Denote the optimal loan sale strategy as $(f_0^*(p_2), f_1^*(p_2))$. It satisfies

$$(f_0^*(p_2), f_1^*(p_2)) = \text{argmax}\; E\left\{ V\left[f_0, f_1, S_0\left(f_0, p_2^{e0}(f_0)\right), S_1\left(f_1, p_2^{e1}(f_0,f_1)\right), p_2\right] \mid p_2 \right\}$$

Second, outsiders' expectations must be rational:

$$\begin{aligned} p_2^{e0}(f_0) &= E(p_2|f_0), \\ p_2^{e1}(f_0,f_1) &= E(p_2|f_0,f_1). \end{aligned}$$

[5] Although technically f_1 is chosen in period 1, nothing is lost by assuming that the bank chooses f_1 in period 0, where f_1 is then interpreted as the fraction of the loan that the bank sells in period 1 conditional on the loan not defaulting in that period. (The bank need not reveal its choice of f_1 to anyone until period 1.) If the loan does default in period 1, the choice of f_1 is irrelevant because there is nothing of value to sell.

We conjecture, and later verify, that no generality is lost by assuming that the bank's optimal strategy is to sell either no part of the loan or the fraction $\overline{f}$ of the loan. Thus there are only three loan sale strategies that we need to consider. They are

1) The bank sells a fraction $\overline{f}$ of the loan in period 0 and does not sell any additional fraction in period 1 ($f_0 = \overline{f}, f_1 = 0$).

2) The bank engages in no loan sales in period 0, and sells a fraction $\overline{f}$ of the loan in period 1 ($f_0 = 0, f_1 = \overline{f}$).

3) The bank makes no loan sales ($f_0 = f_1 = 0$).

For each of these three strategies, the bank's expected profit conditioned on p_2 can be calculated as a function of f_0, f_1, outsiders' expectations p_2^{e0}, p_2^{e1}, and p_2 using (1) and (2). The respective profit expectations are:

$$E\Big[V(\overline{f},0,S_0(\overline{f},p_2^{e0}),S_1(0,p_2^{e1}),p_2) \mid p_2\Big] = L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_2)\Big]+ \overline{f}L\Big[w(1-p_1)(p_2-p_2^{e0})\Big] \tag{3}$$

$$E\Big[V(0,\overline{f},S_0(0,p_2^{e0}),S_1(\overline{f},p_2^{e1}),p_2) \mid p_2\Big] = L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_2)\Big]+ \overline{f}L\Big[w(1-p_1)(p_2-p_2^{e1})\Big]-Bp_1 \tag{4}$$

$$E\Big[V(0,0,S_0(0,p_2^{e0}),S_1(0,p_2^{e1}),p_2) \mid p_2\Big] = L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_2)\Big]- B\Big[p_1+p_2(1-p_1)\Big] \tag{5}$$

The first terms on the right-hand-sides of (3), (4), and (5) represent the expected profit from making the loan, which depends on the loan quality p_2. The second terms of (3) and (4) represent the profit (or loss) associated with asymmetric information. If the loan's actual probability of default is greater (less) than outsiders believe, the bank profits (loses) by selling part of the loan to outsiders. The third term of (4) and the second term of (5) represent the expected deadweight cost of the bank's financial distress owing to the failure of the loan.

We develop the equilibrium in a series of lemmas.

Lemma 1. If $p_2 = p_l$, the bank will not choose the no-loan-sale strategy ($f_0 = f_1 = 0$).

Proof. Outsiders' expectation p_2^{e0} is bounded above by p_l. From (3), the expected bank profit given the loan sale strategy ($f_0 = \overline{f}, f_1 = 0$) is decreasing in p_2^{e0}, hence, given $p_2 = p_l$, it is bounded below by $L[R + (1 - R) - w(p_1 + (1 - p_1)p_l)]$. This lower bound exceeds the expected bank profit given the no-loan-sale strategy in (5). Therefore the no-loan-sale strategy is strictly dominated by ($f_0 = \overline{f}, f_1 = 0$). **Q.E.D.**

Lemma 2. If, in equilibrium, $p_2^{e0} = p_2^{e1}$, the bank will not choose the strategy ($f_0 = 0, f_1 = \overline{f}$), regardless of the realization of p_2.

Proof. From (3) and (4), if $p_2^{e0} = p_2^{e1}$, the expected profit of the strategy ($f_0 = \overline{f}, f_1 = 0$) exceeds that of ($f_0 = 0, f_1 = \overline{f}$) by Bp_1, regardless of p_2. **Q.E.D.**

Lemma 2 formalizes the idea that selling a fraction $\overline{f}$ of the loan early versus late avoids the financial distress associated with a period-one loan default. The final lemma is

Lemma 3. If, in equilibrium, the bank does not choose the no-loan-sale strategy when $p_2 = p_h$, then the bank's loan sale strategy is independent of p_2.

Proof. By the assumption of this Lemma and by Lemma 1, we need not consider the no-loan-sale strategy. Therefore the bank's choice of strategy depends on the difference between the expected profit in (3) and the expected profit in (4). Subtracting (4) from (3) produces

$$\overline{f}L\left[w(1 - p_1)(p_2^{e1} - p_2^{e0})\right] + Bp_1 \tag{6}$$

The expression in (6) is independent of p_2, unless outsiders' expectations are affected by p_2. But these expectations are formed entirely by the bank's choice of loan-sale strategy, thus the bank's choice is independent of p_2. **Q.E.D.**

Lemma 3 means that there is no equilibrium in which, say, the bank sells $\overline{f}$ of the loan in period 0 if $p_2 = p_l$ but waits until period 1 to sell $\overline{f}$ if $p_2 = p_h$. Using these lemmas, we can prove the following theorems that describe the equilibria in this market.

Theorem 1. There is a pooling equilibrium in which the bank sells the fraction $\overline{f}$ of the loan in period 0 regardless of its observation of p_2. Outsiders' expectations of loan quality are given by $p_2^{e0} = p_2^{e1} = (p_h + p_l)/2$. The pooling equilibrium can exist if

$$B > \frac{\overline{f}Lw(1-p_1)(p_l - p_h)/2}{p_1 + (1-p_1)p_h} \tag{7}$$

Proof: Assume an equilibrium in which the bank does not choose the no-loan-sale strategy even if it observes $p_2 = p_h$. Then, by Lemma 3, outsiders' cannot use the bank's strategy to determine the quality of the loan. Therefore outsiders' expectations of loan quality in the loan sale market are

$$p_2^{e0} = p_2^{e1} = \frac{p_l + p_h}{2} \tag{8}$$

Because $p_2^{e0} = p_2^{e1}$, all loan sales take place in period 0, by Lemma 2. Therefore we know that a bank observing $p_2 = p_h$ will choose such a strategy if the expected profit in (3) exceeds that in (5), given outsiders' expectations in (8). This inequality holds whenever (7) holds. **Q.E.D.**

Theorem 2. There is a separating equilibrium in which the bank sells the fraction $\overline{f}$ of the loan in period 0 if it observes $p_2 = p_l$, but sells no part of the loan if $p_2 = p_h$. Outsiders' expectations of loan quality are $p_2^{e0} = p_2^{e1} = p_l$ if there are loan sales and $p_2^{e0} = p_2^{e1} = p_h$ if there are no loan sales. The separating equilibrium can exist if

$$B < \frac{\overline{f}Lw(1-p_1)(p_l - p_h)}{p_1 + (1-p_1)p_h} \tag{9}$$

Proof: Assume an equilibrium in which a bank observing $p_2 = p_h$ chooses to sell no loans. Because outsiders are rational, they know a loan sale signals $p_2 = p_l$, hence

$$p_2^{e0} = p_2^{e1} = p_l \tag{10}$$

By (10) and Lemma 2, all loan sales take place in period 1. Therefore we know that a bank observing $p_2 = p_h$ will avoid the loan sale market if the expected profit in (5) exceeds that in (3), given the expectations of (10). This inequality holds whenever (9) holds. **Q.E.D.**

3.3.2. Comments on the equilibria

The bank's unconditional expected profit in the pooling equilibrium is the mean, across the possible states $p_2 = p_h$ and $p_2 = p_l$, of its expected profits conditioned on observing p_2. The mean is

$$\text{Pooling:} \qquad E(V) = L\left[R + (1-p_1)R - w\left(p_1 + (1-p_1)\frac{p_l + p_h}{2}\right)\right] \tag{11}$$

This expected profit is simply the mean return to a loan. The bank's unconditional expected profit in the separating equilibrium is

$$\text{Separating:} \qquad \begin{aligned} E(V) = {} & L\left[R + (1-p_1)R - w\left(p_1 + (1-p_1)\frac{p_l + p_h}{2}\right)\right] \\ - {} & B(p_1 + p_h(1-p_1))/2 \end{aligned} \tag{12}$$

Eq. (12) has one more term than does (11). The additional term represents the probability that the bank makes a high-quality loan and the loan subsequently defaults, leading to a deadweight cost of B. Note that from (7) and (9), either equilibrium is possible in the region

$$\frac{p_l - p_h}{2} < \frac{B[p_1 + (1-p_1)p_h]}{\overline{f}Lw(1-p_1)} < p_l - p_h. \tag{13}$$

In this region, if outsiders believe that the separating equilibrium holds, they will assume that any loan sold is of poor quality. Therefore a bank with a high-quality loan loses so much by selling a fraction $\overline{f}$ of it that it chooses not to sell. If, however, outsiders believe that a pooling equilibrium holds, they will pay more for any fraction $\overline{f}$ of a loan than they would in a separating equilibrium. This higher price induces a bank with a high-quality loan to sell $\overline{f}$ of it. It is easy to show that banks are better off with the pooling equilibrium, regardless of the realization of p_2. Therefore we simplify the discussion that follows by assuming that the pooling equilibrium holds in the region characterized by (13). Nothing important is lost with this assumption.

We now informally justify our conjecture that if the bank sells any fraction of the loan, it sells the fraction $\overline{f}$. First consider the pooling equilibrium. If the bank observes $p_2 = p_h$, it wants to sell as little of the loan as possible while avoiding the deadweight cost B, because it is selling a high-quality loan at a bad price. Therefore it will never choose an f_i greater than $\overline{f}$. It will also never choose to sell a fraction of the loan less than $\overline{f}$ but greater than zero, because such a strategy would not avoid the deadweight cost B but would cause losses on the loan sales. But then the same strategies will be followed by bank if it observes $p_2 = p_l$, because if it chooses a different strategy, it will signal that it has a low-quality loan.

With the separating equilibrium the restriction that only a fraction $\overline{f}$ is sold is arbitrary but has no effect on any interesting features of the equilibrium. If the bank observes $p_2 = p_l$, it is indifferent between selling $\overline{f}$ and selling any amount above $\overline{f}$: in either case, it avoids the deadweight cost B. Similarly, if the bank observes $p_2 = p_h$, it is indifferent between selling none of the loan and selling an amount greater than zero but less than $\overline{f}$: in either case, it does not avoid the deadweight cost B but avoids a pooling equilibrium in which it sells high-quality loans at a bad price.[6]

3.4. The solution with loan sales and credit derivatives

We now introduce a new financial instrument. The instrument, which can be purchased in period 0, pays off w units (the writedown rate on the loan) in period 1 if the bank loan defaults in period 1. If the bank loan does not default, the instrument pays off nothing. We call the instrument a "credit default swap" because it mimics the structure of existing credit default swaps. We could also introduce a slightly different instrument that would mimic a total rate of return swap (where the value of the loan is determined by a poll of outsiders), but such an instrument would behave much like a credit default swap. From the perspective of outsiders, the change in the value of the loan from period 0 to period 1 is entirely determined by the default status of the loan in period 1.

[6] This statement is somewhat loose. It is not necessarily true that the bank, upon observing $p_2 = p_h$, can choose any loan sale amount between 0 and $\overline{f}$. Depending on the model's parameters, there may be some upper bound less than $\overline{f}$. If the bank, upon making a high-quality loan, were to choose a loan sale strategy in the separating equilibrium that exceeded this upper bound, it would be profitable for the bank, upon making a low-quality loan, to mimic this strategy and thus sell its low-quality loan at a high price.

The bank buys an amount X of the credit default swap from risk-neutral, competitive outsiders. Because the probability of a default in period 1 is fixed at p_1, the bank pays a total price

$$P(X) = p_1 w X. \tag{14}$$

Following the approach taken in Section 3.3, we define the indicator function $I_{f_0+X<\overline{f}}$ as zero for $f_0 + X \geq \overline{f}$ and one elsewhere. The bank's ability to enter into credit default swaps alters its payoff structure. The new payoff structure, which is a slight modification of the old structure in (2), is

$$V = \begin{cases} L[(1-f_0)(R+(1-w))-1]+S_0 & \text{if loan defaults in} \\ \quad +(1-p_1)X - \ BI_{f_0+X<\overline{f}}, & \text{period 1 (prob} = p_1); \\ L[(1-f_0)R \ +(1-f_0-f_1)(R+(1-w)) & \text{if loan defaults in} \\ \quad -1]+S_0+S_1-p_1X-BI_{f_0+f_1<\overline{f}}, & \text{period 2 (prob} = (1-p_1)p_2); \\ L[(1-f_0)R+(1-f_0-f_1)(R+1)-1], & \text{if no default} \\ \quad +S_0+S_1-p_1X & \text{(prob} = 1-p_1-(1-p_1)p_2). \end{cases} \tag{15}$$

We continue to denote the bank's ex-post profits as V, which we now write as

$$\text{profit} = V\left[f_0, f_1, X, S_0\Big(f_0, p_2^{e0}(f_0, X)\Big), S_1\Big(f_1, p_2^{e1}(f_0, f_1, X)\Big), p_2\right]$$

As in the equilibrium for loan sales, the new equilibrium is simplified by conjecturing that the bank's optimal strategy in period 0 is augmented by two new strategies: $(f_0 = 0, f_1 = \overline{f}, X = \overline{f})$ and $(f_0 = 0, f_1 = 0, X = \overline{f})$. The expected profits from these two strategies conditional on the bank's observation of p_2 are

$$E\Big[V(0,\overline{f},\overline{f},S_0(0,p_2^{e0}),S_1(\overline{f},p_2^{e1}),p_2) \mid p_2\Big] = L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_2)\Big]+ \overline{f}L\Big[w(1-p_1)(p_2-p_2^{e1})\Big] \tag{16}$$

$$E\Big[V(0,0,\overline{f},S_0(0,p_2^{e0}),S_1(0,p_2^{e1}),p_2) \mid p_2\Big] = L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_2)\Big]- B[p_2(1-p_1)] \tag{17}$$

We derive the new equilibrium using the following lemmas.

Lemma 4. The strategy ($f_0 = f_1 = 0, X = \overline{f}$) strictly dominates the strategy ($f_0 = f_1 = 0, X = 0$).

Proof. Immediate from a comparison of (5) and (17). **Q.E.D.**

Lemma 5. If $p_2 = p_l$, the bank will not choose the no-loan-sale strategy ($f_0 = f_1 = 0, X = \overline{f}$).

Proof. Identical to the proof of Lemma 1 with references to (5) replaced by references to (17). **Q.E.D.**

Lemma 6. If, in equilibrium, the bank does not choose the no-loan-sale strategy ($f_0 = f_1 = 0, X = \overline{f}$) when $p_2 = p_h$, then the bank's strategy is independent of p_2.

Proof. Similar to that of Lemma 3. The differences among the expected profits in (3), (4), and (16) are not functions of p_2. Thus the logic of Lemma 3 applies. **Q.E.D.**

These lemmas allow us to prove the following theorems that describe the possible equilibria.

Theorem 3. There is a pooling equilibrium in which the bank's strategy satisfies $f_0 + X = \overline{f}$ and $f_0 + f_1 = \overline{f}$ regardless of its observation of p_2. Outsiders' expectations of loan quality are given by $p_2^{e0} = p_2^{e1} = (p_h + p_l)/2$. The pooling equilibrium can exist if

$$B > \frac{\overline{f} Lw(1 - p_1)(p_l - p_h)/2}{(1 - p_1)p_h} \tag{18}$$

Proof: Essentially identical to that of Theorem 1 and left for the reader.

Theorem 4. There is a separating equilibrium in which the bank's strategy satisfies $f_0 + X = \overline{f}, f_0 + f_1 = \overline{f}$ if it observes $p_2 = p_l$, but satisfies $f_0 = f_1 = 0, X = \overline{f}$ if $p_2 = p_h$. Outsiders' expectations of loan quality satisfy $p_2^{e1} = p_l$ if there are loan sales in either period 0 or 1, and satisfy $p_2^{e0} = p_l$ if there are loan sales in period 0. If there are no loan sales in periods 0 and 1, the expectations satisfy $p_2^{e1} = p_h$.

The separating equilibrium can exist if

$$B < \frac{\overline{f}Lw(1-p_1)(p_l-p_h)}{(1-p_1)p_h} \tag{19}$$

Proof: Essentially identical to that of Theorem 2 and left for the reader.

Theorems 3 and 4 illustrate an indeterminacy in the possible equilibria. The sale of $\overline{f}$ in the loan sale market in period 0 is economically equivalent to buying a credit default swap that protects $\overline{f}$ in period 0 and then selling $\overline{f}$ in the loan sale market in period 1. Therefore we cannot say when loan sales will occur. Therefore there is also an indeterminacy in outsiders' expectation p_2^{e0} when (19) holds. However, if loan sales occur in period 0, the indeterminacy in this expectation is resolved.

In this section we have described various possible equilibria both with and without a market for credit derivatives; in particular, a market for credit default swaps. In the next section we investigate the value of this market.

4. The value of the market for credit derivatives

We now consider whether introducing a market for credit default swaps is beneficial to banks who previously had access to only a market for loan sales. We do so by comparing expected bank profits across the possible equilibria. We do so in the following three corollaries.

Corollary 1. Expected bank profits are *higher* with the credit derivatives market than without if

$$B < \frac{\overline{f}Lw(1-p_1)(p_l-p_h)/2}{p_1+(1-p_1)p_h} \tag{18}$$

Proof. Given (18), a pooling equilibrium is impossible regardless of whether the credit derivative market exists, by Theorem 1 and Theorem 3 (note $[\overline{f}Lw(1-p_1)(p_l-p_h)/2]/[p_1+(1-p_1)p_h] < [\overline{f}Lw(1-p_1)(p_l-p_h)/2]/[(1-p_1)p_h]$). Therefore the relevant comparision is between bank profits given the separating equilibrium with loan sales, shown in (12), versus bank profits given the separating equilibrium with loan sales and credit derivatives. These profits are given by the mean of (3) with $p_2 = p_2^{e0} = p_l$ and (17) with $p_2 = p_h$, which is

$$\text{Separating:} \qquad \begin{aligned} E(V) = {} & L\left[R + (1-p_1)R - w\left(p_1 + (1-p_1)\frac{p_l + p_h}{2}\right)\right] \\ & - \; B(p_h(1-p_1))/2 \end{aligned} \tag{20}$$

The profits in (20) exceed those in (12) by $Bp_1/2$, which is the deadweight cost of financial distress multiplied by the probability of the bank making a high-quality loan that subsequently defaults in period 1. **Q.E.D.**

The intuition behind Corollary 1 is straightforward. First consider the economy without credit derivatives. When the loss to the bank of selling a high-quality loan at a bad price exceeds the benefit of avoiding the risk of financial distress, the bank will choose to be exposed to the entire risk of a high-quality loan. If the bank has the opportunity to shed part of this risk at a fair price using credit derivatives, it will do so, and thus reduce the possibility of its own financial distress. However, Corollary 1 is only part of the story.

Corollary 2. Expected bank profits are *lower* with the credit derivatives market than without if

$$B[p_1 + (1-p_1)p_h] > \overline{f}Lw(1-p_1)\frac{(p_l - p_h)}{2} > B(1-p_1)p_h \tag{21}$$

Proof. Given (21), a pooling equilibrium in the loan sale market can exist if there is no credit derivatives market (Theorem 1), but cannot exist if there is a credit derivatives market (Theorem 3). But unconditional expected bank profits are higher with a pooling equilibrium (given by (11)) than with credit derivatives combined with a separating equilibrium in the loan sale market (given by (20)). **Q.E.D.**

To understand the intuition behind this result, consider the economy without credit derivatives. In the pooling equilibrium, low-quality and high-quality loans are sold at the same price. Therefore from a bank's perspective, part of the cash flow of the state of the world in which high-quality loan is made is transferred to the state of the world in which a low-quality loan is made.

If a bank makes a high-quality loan, it accepts the low price it can get in the loan sale market because doing so is better than facing the risk of financial distress. However, when credit derivatives are introduced, the bank making a high-quality loan can reduce its risk of financial distress at a fair price. Therefore its incentive to participate in the loan sale market is reduced. If condition (21) holds, this incentive disappears and the pooling equilibrium in the loan sale market breaks down. This reduces the profits of the bank when it makes a low-quality loan because it can no longer sell such a loan at a high price. Thus the credit derivatives market benefits the bank when it makes a high-quality loan, but this benefit is a combination of a positive transfer of profits away from the low-quality loan state and an increase in deadweight costs. Therefore bank profits fall on average across both high-quality and low-quality loan states.

It is also possible that the introduction of a credit derivatives market is unimportant, as shown in the next corollary.

Corollary 3. Expected bank profits are unaffected by the credit derivatives market if

$$B(1-p_1)p_h > \overline{f}Lw(1-p_1)\frac{(p_l - p_h)}{2} \tag{22}$$

Proof. Condition (22) satisfies the requirements for a pooling equilibrium in the loan sales market both without credit derivatives (shown in (7)) and with credit derivatives (shown in (18)). The two pooling equilibria have identical unconditional expected bank profits because in both equilibria there is no possibility of any deadweight cost of financial distress. **Q.E.D.**

Corollary 3 says that if the cost of financial distress is high enough, the bank is unwilling to face the possibility of incurring it in period 2 even if its loans are of high quality. Therefore both before and after the introduction of credit derivatives, the bank shifts $\overline{f}$ of the loan to outsiders.

To summarize, the value of introducing a market for credit derivatives is ambiguous. If, prior to the introduction of the market, the bank did not share the risk of borrower default in period one, then credit derivatives are beneficial: they allow this risk to be shared. If, however, the bank used the loan sale market to share the risk of borrower default in both periods one and two, introducing credit derivatives could reduce the ability of banks to share the risk of borrower default in period two. This is an illustration of a more general proposition. In an economy with asymmetric (i.e., private) information, the introduction of a new market will typically alter equilibria in existing markets by changing the economy's information structure. Even if agents behave optimally, this change can be welfare-reducing (Stein 1987).

5. Interpretations and extensions

5.1. How innovative are credit derivatives?

In the above model, credit derivatives are an innovative instrument because they are the only tool available to trade the risk of borrower default in period one. But it is fairly easy to tweak the model to make credit derivatives redundant. For example, the bank can make a sequence of one-period loans to the borrower instead of a single two-period loan. The first one-period loan would not be subject to a lemons problem, thus the bank could easily sell it to outsiders. In a broader sense, however, a sequence of one-period loans cannot replicate the combination of a two-period loan and a credit derivative. There are well-known reasons why a bank's borrowers may prefer multiperiod loans to a sequence of one-period loans; e.g., liquidity risk (Diamond 1991) or tax timing (Mauer and Lewellen 1987).

Short-term letters of credit are also similar to credit derivatives. This model could be modified to allow the borrowing firm to purchase from an outsider a letter of credit that provides the bank insurance in the first period. But a key difference between credit derivatives and a letter of credit is that a bank can enter into a credit derivative transaction without the approval or knowledge of the borrowing firm. Recall that in the model, the value of the credit derivative derives from an asymmetric information problem about loan quality. This type of problem does not arise when large banks are lending to large, well-known firms; it arises when a local or regional bank is lending to a local firm with which it has a relationship. The local bank is typically hesitant to risk degrading the relationship by asking the borrowing firm to restructure its loan demands or to turn to other lenders for guarantees.[7] A credit derivative can be used to sell the risk of the loan without putting the

[7] Anecdotal evidence that banks and borrowers are hesitant to use loan sales for this reason is in Edwards (1995). Academic evidence concerning the value of bank-borrower relationships is in Petersen and Rajan (1994, 1995) and Berger and Udell (1995).

relationship at risk, thus, all else equal, it is more likely to be used than are letters of credit.

An important characteristic of real-world banking relationships that is missing from our model is the repeated game nature of banking. Reputation effects can help mitigate the adverse selection problem that we model. For example, a bank can establish a reputation for selling a fraction of all loans that it makes, regardless of credit quality. Although reputation is no substitute for credit derivatives (reputation effects do not help split loan risk into components with different degrees of asymmetric information), they might help preserve the loan sale market after the introduction of credit derivatives. An investigation of this issue is beyond the scope of our current paper.

5.2. Capital allocation and negative NPV loans

In the model of Section 3, both low-quality and high-quality loans were positive NPV projects from the bank's perspective. This assumption trivializes the role of the bank in allocating capital. An important part of financial intermediation is knowing which potential borrowers should get loans and which should not. In this section we make the more realistic assumption that the low-quality loan is a negative NPV project when its expected cash flows are discounted at the riskfree interest rate (zero here). We assume

$$R + (1 - p_1)R - w(p_1 + (1 - p_1)p_l) < 0 \tag{23}$$

Rather than exhaustively examining the various possible equilibria given (23), we give a flavor for the results by considering an interesting special case. We assume that the average potential loan is a positive NPV project. In other words, the positive NPV of high-quality loans exceeds the absolute value of the negative NPV of low-quality loans. Moreover, we assume that it is profitable for the bank to make the low-quality loan as long as the loan sale equilibrium is a pooling equilibrium. In other words, even though the bank expects the net cash flow from the loan to be negative, it can sell $\overline{f}$ of the loan at a sufficient profit to offset the expected loss on the remaining $(1-\overline{f})$ of the loan. The mathematical formulation of this assumption is discussed below, where we consider various equilibria given these assumptions.

We first examine equilibrium when there is a market for loan sales but not for credit derivatives. The following corollaries illustrate that the possible equilibria are similar to those in Section 3.

Corollary 4. There is a pooling equilibrium in which the bank makes the loan and sells $\overline{f}$ of it in period 0 regardless of its observation of p_2. The pooling equilibrium can exist if (7) holds and if

$$R + (1 - p_1)R - w\left[p_1 + (1 - p_1)\left(\frac{\overline{f}p_h + (2 - \overline{f})p_l}{2}\right)\right] > 0 \tag{24}$$

Proof. Assume a pooling equilibrium, so that $p_2^{e0} = (p_l + p_h)/2$. Eq. (7) is the condition from Theorem 1 that the bank will sell $\overline{f}$ of the loan in a pooling equilibrium if the bank observes $p_2 = p_h$. Eq. (24) is the same condition for the bank when it observes $p_2 = p_l$. It is derived by setting expected profits in (3) greater than zero with $p_2 = p_l$ and $p_2^{e0} = (p_l + p_h)/2$. **Q.E.D.**

Note that if $\overline{f} = 1$, (24) reduces to the requirement that the average potential loan is a positive NPV project. If $\overline{f} = 0$, (24) violates (23). We therefore require that $\overline{f}$ is sufficiently close to one to satisfy (24); i.e., that L_0/wL is sufficiently close to zero. The next corollary is a modification of Theorem 2.

Corollary 5. There is a separating equilibrium in which the bank does not make a loan if it observes $p_2 = p_l$. If the bank observes $p_2 = p_h$, it makes the loan and sells no part of it. The separating equilibrium can exist if (9) holds and if

$$R + (1 - p_1)R - w\left[p_1 + (1 - p_1)\left(\overline{f}p_h + (1 - \overline{f})p_l\right)\right] > 0 \tag{25}$$

Proof. Assume a separating equilibrium. Then the bank will not make a loan if $p_2 = p_l$ because such a loan is a negative NPV project and the bank does not have superior information about the quality of the loan. When (9) holds, the bank will make the loan if $p_2 = p_h$ because of the same logic as in Theorem 2: The risk of deadweight loss does not outweigh the expected positive net cash flow of the loan. The market for loan sales will not exist when (25) holds. If outsiders expect the bank to sell $\overline{f}$ of the loan when $p_2 = p_h$, eq. (25) ensures that the bank will then choose to make the loan when $p_2 = p_l$ and sell $\overline{f}$ of this low-quality loan at a high price. Thus the separating equilibrium is incompatible with loan sales. **Q.E.D.**

There is no market for loan sales with (25) because the asymmetric information problem is too severe. There is no price at which loans could be purchased that would simultaneously 1) keep banks from making a low-quality loan and then selling $\overline{f}$ of it, and 2) allow the bank to profitably sell $\overline{f}$ of a high-quality loan. Note that (25) is a consequence of (24).

Corollaries 4 and 5 make two points. First, depending on the model's parameters, there may exist a pooling equilibrium in the loan sale market that makes it profitable for the bank to make a loan for which the expected net cash flow is negative. Second, again depending on the parameters, there may be an equilibrium in which there is no loan sale market because of the extent of asymmetric information problem.

We now turn to an examination of credit derivatives. If the bank is able to use both loan sales and credit default swaps to shed some of its loan risk, a pooling equilibrium identical to that described in Theorem 3 exists.

Corollary 6. There is a pooling equilibrium in which the bank makes the loan and its subsequent strategy satisfies $f_0 + X = \overline{f}$ and $f_0 + f_1 = \overline{f}$ regardless of its observation of p_2. Outsiders' expectations of loan quality are given by $p_2^{e0} = p_2^{e1} = (p_h + p_l)/2$. The pooling equilibrium can exist if (18) and (24) hold.

Proof: A combination of Theorem 3 and Corollary 4, left for the reader.

A separating equilibrium similar to that described in Theorem 4 is also possible. The separating equilibrium of Theorem 4 must be modified so that the bank does not make the low-quality loan, and instead the market for loan sales is inoperative. The new equilibrium is summarized in the following corollary.

Corollary 7. There is a separating equilibrium in which the bank does not make the loan if it observes $p_2 = p_l$, but makes the loan and chooses the strategy $f_0 = f_1 = 0, X = \overline{f}$ if $p_2 = p_h$. There are no loan sales. The separating equilibrium can exist if (19) and (25) hold.

Proof: A combination of Theorem 2 and Corollary 5, and left for the reader.

We now summarize the effects on the bank of the option to use credit derivatives. Throughout the following discussion, we assume that the inequalities in (23) and (24) are satisfied. The conclusion of Corollary 1, which states that the bank is better off with the ability to use credit derivatives as long as there is a separating equilibrium in the loan sale market, is unchanged by assumptions (23) and (24). Similarly, the conclusion of Corollary 3, which states that the bank is indifferent as long as a pooling equilibrium in the loan market exists in the presence of credit derivatives, is unchanged by these assumptions. Of more interest is the effects of these assumptions on the conclusion of Corollary 2. Recall that Corollary 2 states that over the parameter region satisfying (21), the introduction of a market in credit default swaps lowers the bank's expected profits because the pooling equilibrium in the market for loan sales breaks down. However, when low-quality loans are negative NPV projects, this can benefit the bank.

When (21) holds and there is no market for credit derivatives, outsiders believe that the bank will sell part of both a high-quality and a low-quality loan, hence if the bank makes a high-quality loan, part of the expected profit of the loan is reaped by outsiders. The bank can partially make up for this loss by making a loan when faced with a low-quality borrower and selling part of the low-quality loan to outsiders. But because the low-quality loan is a negative NPV project and outsiders set prices in the loan sale market to satisfy a zero-profit condition, the bank is worse off than it would be if it could commit to making only a high-quality loan and sell part of it in the loan sale market.

Given assumption (21), the introduction of credit derivatives causes the pooling equilibrium in the loan sale market to break down. As in Corollary 2, this is costly because it exposes the bank to the deadweight cost of bankruptcy associated with the state in which a high-quality loan is made that subsequently defaults in period 2. The deadweight cost associated with this increased risk of insolvency is $Bp_h(1-p_1)$. However, unlike the situation examined in Corollary 2, the market for loan sales disappears, hence the bank refrains from making low-quality, negative NPV loans. The expected loss on a low quality loan is the loan amount L multiplied by the loan's net return, which is the left-hand-side of (23). The net effect on expected bank profits is ambiguous. The bank is better off with the introduction of the credit derivatives market if the expected savings exceed the expected costs, as expressed in (26).

$$-L\Big[R + (1-p_1)R - w(p_1 + (1-p_1)p_l)\Big] > Bp_h(1-p_1). \tag{26}$$

To summarize, if the model's parameters satisfy (21), (23), and (24), the introduction of a credit derivatives market results in better capital allocation (by inducing banks to stop making low-quality loans) and worse risk sharing (by inducing banks to no longer sell the second-period risk of high-quality loans). If (26) holds, the net effect is positive.

5.3. Credit derivatives and moral hazard

This paper has concentrated on an adverse selection problem caused by private information that banks have about the creditworthiness of their borrowers. Implicitly, we are defining a bank as an institution with access to such private information. Another characteristic that is commonly attributed to banks is a special ability to monitor borrowers so as to increase the probability of repayment. This monitoring cannot be observed by those outside of the bank, which leads to a moral hazard problem if the bank attempts to sell some of its loans. This is the perspective of Gorton and Pennacchi (1995).

The question we address here is how the introduction of a credit derivatives market affects banks when moral hazard, not adverse selection, puts limits on bank loan sale activity. We document below that in one sense our conclusions from a model of adverse selection carry over to a model of moral hazard. In the presence of moral hazard, the introduction of a market in credit default swaps can alter the equilibrium in the loan sales market, causing banks to reduce their loan sales and thus increasing the likelihood of their own insolvency. However, there is an additional effect at work when moral hazard is present. When banks refrain from selling their loans, they typically will choose to increase their monitoring efforts. The value of this increase in monitoring will offset the cost to the bank of the altered loan sale equilibrium; thus a market for credit default swaps can benefit banks even if the loan sale market is adversely affected.

To focus on moral hazard, we slightly alter the model in Section 3 (while returning to the assumption that both low-quality and high-quality loans are positive NPV projects). There are two new features. First, the bank can spend an amount D in period one to transform a low-quality loan into a high-quality loan. This expenditure cannot be observed by outsiders. Second, the initial quality of a loan (i.e., the quality prior to the bank's expenditure of D) is common knowledge. Thus the adverse selection problem is replaced by a moral hazard problem.

Note that bank monitoring has no effect on the probability that a loan defaults in period one, nor does monitoring affect the likelihood of default of an initially high-quality loan. For simplicity, we assume that the bank's expenditure of D, if any, is made after the bank has learned whether the loan will default in period one. As in Section 3, we assume the bank needs to sell a fraction $\overline{f}$ of the loan's risk in order to avoid the risk of its own insolvency. For simplicity, this fraction is unaffected by the expenditure on monitoring. We also assume that the monitoring cost D satisfies

$$(p_l - p_h)wL > D > (1 - \overline{f})(p_l - p_h)wL. \tag{27}$$

The first inequality makes monitoring a low-quality loan valuable. If the bank holds the entire risk of an initially low-quality loan, it has an incentive to spend D to monitor the loan. The second inequality in (27) creates the moral hazard problem. It ensures that the bank has no incentive to monitor a low-quality loan if it has sold off a fraction $\overline{f}$ of the loan.

We first consider possible equilibria without a market for credit derivatives. We state the results without proof; the derivations are almost identical to those in Section 3. In equilibrium, the bank sells a fraction $\overline{f}$ of all loans that are initially of high quality. The bank must choose between selling $\overline{f}$ of its low-quality loans and not monitoring them, or holding on to the loans and monitoring them. The first choice avoids the expected deadweight cost of its own insolvency, while the second reaps the benefit of monitoring. Thus the bank holds on to the loan if the value of monitoring exceeds the associated expected deadweight cost of its own insolvency—i.e., it holds on to low-quality loans and monitors them if (28) is satisfied.

$$B[p_1 + (1 - p_1)p_h] < (1 - p_1)[(p_l - p_h)wL - D] \tag{28}$$

In this equilibrium, the bank is worse off relative to a hypothetical equilibrium in which it could costlessly commit to monitoring low-quality loans. The bank could then sell both types of loans and avoid the risk of its own insolvency, thereby increasing its expected profit by the product of the likelihood of making a initially low-quality loan (1/2) and the expected deadweight cost of insolvency created by the risk that the loan, though monitored, subsequently defaults. The total amount, $(1/2)(p_1 + (1 - p_1)p_h)B$, can be thought of as the deadweight cost owing to moral hazard given this equilibrium.

If the inequality in (28) is reversed, a fraction $\overline{f}$ of both high and low quality loans are sold. No monitoring takes place, thus high-quality loans are sold at a higher price than are low-quality loans. Again, the bank would prefer a hypothetical equilibrium in which it could commit to monitoring. Such an equilibrium would increase expected bank profits by the product of the probability of making a low-quality loan and the increase in the loan's value owing to monitoring, or $(1/2)(1 - p_1)[(p_l - p_h)wL - D]$. Again, we can think of this as the deadweight cost of the equilibrium.

Now consider the introduction of credit default swaps. If (28) holds, this introduction unambiguously benefits the bank. If the bank makes a low-quality loan, it uses a credit default swap to protect itself in the event that the loan defaults in the first period. The bank continues to face the risk of the loan's default in the second period, and hence it monitors the loan to raise the likelihood that it is paid back. Expected bank profits rise by $(1/2)p_1 B$, which is the insolvency deadweight cost B multiplied by the probability that the bank makes a low-quality loan that defaults in period one. In other words, the deadweight cost owing to moral hazard falls from $(1/2)(p_1 + (1 - p_1)p_h)B$ to $(1/2)(1 - p_1)p_h B$.

Now assume that the reverse of (28) holds. Then the introduction of credit default swaps will either raise the bank's expected profit or have no effect, depending on the model's parameters. One case is when (29) holds.

$$\frac{(1 - p_1)[(p_l - p_h)wL - D]}{(1 - p_1)p_h} > B > \frac{(1 - p_1)[(p_l - p_h)wL - D]}{p_1 + (1 - p_1)p_h} \tag{29}$$

Note that the second inequality in (29) is simply the reverse of (28), which we are assuming holds here. If the parameters satisfy (29), the bank will choose to use a credit default swap to sell the loan's period one risk, retain the loan's period two risk at the bank, and spend D to monitor the loan. Thus the loan sale market dries up. Unlike the model of adverse selection, the disappearance of the loan sale market does not correspond to lower bank profits. Here, total deadweight costs *fall* when credit default swaps are introduced, from $(1/2)(1 - p_1)[(p_l - p_h)wL - D]$ to $(1/2)(1 - p_1)p_h B$. Eq. (29) assures that the former is larger than the latter.

The other relevant case is when (30) holds.

$$B > \frac{(1-p_1)[(p_l - p_h)wL - D]}{(1-p_1)p_h} \tag{30}$$

Given (30), the introduction of a market in credit default swaps does not alter bank behavior in any meaningful way. The bank still chooses to sell off $\overline{f}$ of the loan, although now it has the choice of doing so either with a loan sale in period one or a combination of a credit default swap in period one and a loan sale in period two. The bank does not spend D to monitor low-quality loans. Bank profits are unchanged, as are the deadweight costs owing to moral hazard.

We emphasize that the introduction of a credit default swap market cannot eliminate the moral hazard problem associated with monitoring loans. As long the basic condition for moral hazard is satisfied (eq. (27)), any equilibrium with credit derivatives results in lower bank profits than a hypothetical equilibrium in which the bank could commit to monitoring initially low-quality loans.

6. Concluding remarks

We construct a model of a bank that has an opportunity to make loans. The risk of loan default can expose the bank to its own financial distress. The bank can sell any fraction of the loan in order to reduce its expected costs of distress, but because the bank has superior information about loan quality, the loan sale market is affected by a lemons problem. We build in a role for credit derivatives in the model by assuming that the magnitude of the asymmetric information varies during the life of the loan. A credit derivative contract that transfers the loan's risk when the lemons problem is smallest can be used by the bank to reduce its risk of financial distress. If the adverse selection problem is sufficiently severe, the loan sale market will be of only limited use to banks, and thus the opportunity to use credit derivatives will be valuable to the bank.

However, the introduction of a credit derivatives market does not necessarily benefit the bank. If, prior to this introduction, the asymmetric information problem was not severe enough to limit the use of the loan sale market, the addition of a market in credit derivatives can be harmful. The new market can alter investors' expectations of the quality of loans sold in the loan sale market and thereby dramatically change the nature of equilibrium in this market. Thus, although the credit derivatives market will be useful to the bank, its presence makes the loan sale market much less useful, leaving the bank worse off.

Therefore the increased risk-sharing flexibility created by credit derivatives is not enough to guarantee that such instruments are beneficial. Note that we are not, in any way, claiming that banks should refrain from entering into credit derivative contracts. Indeed, we find that credit derivatives may improve capital allocation by reducing investment in poor-quality projects, and may mitigate the moral hazard problem caused by the inability of outsiders to observe the extent to which banks monitor their borrowers. Instead, the conclusion that should be drawn from our arguments is that theory alone cannot determine whether a market for credit derivatives will help banks better manage their loan credit risks. This issue is ultimately an empirical one. For example, the potential value of this market depends, in part, on the extent to which the loan sale market is currently used to share the risks of loans about which originating banks have private information. This is an empirically unresolved issue (see, e.g., Berger and Udell (1993) and Gorton and Pennacchi (1995)). If credit derivatives will simply replace loan sales as risk-sharing tools, the consequences for banks are ambiguous.

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