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Credit Derivatives in Banking: Useful Tools for Managing Risk?

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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.

Keywords: credit-default swaps, bank loans, loan sales, asymmetric information
JEL#: G21, D82

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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 growing quickly.

To date, credit derivatives are used to trade risks that are already traded in existing markets. The underlying instruments on which credit derivatives are written are typically corporate bonds, Brady bonds, large leveraged bank loans, or pools of homogeneous small loans such as credit card receivables. Thus for now, credit derivatives can be thought of as instruments that repackage traded risks into more convenient forms. The question we address here is whether, from a theoretical perspective, credit derivatives can also be used to trade heretofore nontraded credit risks. In particular, we focus on small and medium-sized bank loans for which asymmetric information concerns outweigh reputation concerns of the lending bank.

If credit derivatives could penetrate this market of untraded risks, the effects on banks likely would be large. (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.) Bank loan portfolios are typically concentrated across business sectors and geographic regions. An important reason for this concentration is an asymmetric information 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. Reputation effects in the loan-sales market can help mitigate problems caused by asymmetric information, but the inherent limitations of such effects are evident in the continued concentration of banks' portfolios.

We argue that credit derivatives' flexibility in repackaging risks can, in some circumstances, allow banks to trade previously untradeable credit risks. The analysis follows an observation by Duffee (1996) that, depending on the nature of a bank's private informa-

tion about a loan, the uncertainty in a loan's payoff potentially 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. If so, the bank can use a credit-derivative contract to transfer the former risks to outsiders, while retaining the latter risks at the bank. For example, 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 can 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. The net effect can be an increase in the expected deadweight costs associated with bank insolvency.

This seemingly paradoxical conclusion is a standard result in the economics of insurance, and an example of Hart's (1975) seminal point that when markets are incomplete, the opening of a new market can make everyone worse off. The health-insurance market provides a useful analogy. Imagine insurance companies allowed individuals to purchase health insurance that excluded coverage for a particular genetically-linked disease. The existence of such lower-cost insurance policies would reduce the impact of both adverse selection and moral hazard; low-risk individuals could purchase more insurance and high-risk individuals would take better care of themselves. But society as a whole might be worse off because the costs of exogenously having a bad gene are not shared as widely.

We find that the value of the credit-derivatives market critically depends on whether

the asymmetric information associated with bank loans is primarily an adverse-selection problem or a moral-hazard problem. For example, if the quality of a bank's loan portfolio is entirely exogenous (the bank does the best job it can of lending money, but sometimes its pool of potential borrowers is weak), a breakdown in the loan-sales market caused by the introduction of credit derivatives would be, on net, socially costly. At the other extreme, if the portfolio's quality is entirely endogenous (potential borrowers are homogeneous, and the bank can spend money to monitor its loans aggressively), the loss in risk-sharing owing to a breakdown in the loan-sales market would be offset by a reduction in moral-hazard problems, and hence the introduction of a credit-derivatives market would be beneficial.

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 (1995) adopt the standard assumption 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 holding their loans or selling them. Therefore Carlstrom and Samolyk circumvent the standard lemons problem in which banks with high-quality loans refrain from selling them at low prices.

Gorton and Pennacchi (1995) also model a bank's choice between holding loans and selling them, focusing 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 conclude 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.

The next section describes some of the institutional features of the credit-derivatives market. The third section presents a model in which only adverse selection, not moral hazard, limits the ability of banks to sell their loans. The fourth section uses the model

to evaluate the value to banks of the credit-derivatives market. The fifth section extends the model to consider moral hazard. This section also addresses some effects that credit derivatives can have on capital allocation. 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 handful of major dealers, and the total notional principal of outstanding credit-derivative contracts is well below one percent of the total notional principal of all outstanding over-the-counter derivative contracts. Nonetheless, the market is developing rapidly. For example, the notional principal of credit derivatives on the books of U.S. commercial banks increased by over 400 percent between the second quarters of 1997 and 1998. The British Bankers Assocation (BBA), which periodically surveys market participants, estimates that the global market totaled $180 billion in notional principal at year-end 1997, and forecasts the market will exceed $700 billion by year-end 2000.[1]

As of late 1999, the bulk of activity in the credit-derivatives market is distributed among credit-default swaps, total-return swaps, credit-spread derivatives, and credit-linked notes. These instruments are described briefly below. More detailed descriptions are in Das (1998a, 1998b) and Neal and Rolph (1999).

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* experiences a *credit event* such as a default. When a credit event occurs, 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.[2] Basket swaps also exist, such as first-to-default swaps in which payments under

[1] These figures and a more detailed discussion of them are in Spraos (1998a, 1998b).

[2] An important restriction on the growth of the market is a lack of standardized documentation that unambiguously defines a 'credit event.' A discussion of this issue is in Roberts and Mahrotri (1999).

the swap are determined by the first credit event to occur among a set of reference credits. Credit-default swaps and related products account for roughly half of the credit derivatives market today.[3]

Total-return swaps mirror the return on some underlying instrument. In a typical total-return swap, the party 'buying' credit risk makes periodic floating rate payments (say, 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. The underlying reference can be either a single instrument, such as a corporate bond, or an index, such as those produced by Lehman and other broker-dealers. Total-return swaps account for approximately one-sixth of the current credit-derivatives market.

Credit-spread derivatives have payoffs tied to changes in yield spreads over time. For example, credit spreads can be swapped between two counterparties. One party pays the yield spread, over Treasuries, on a credit-risky instrument, and the other party pays the yield spread on a different credit risky instrument. The net payment is determined by the notional principal times the difference between these two yield spreads. Another credit-spread derivative is a call option. If the yield spread on some credit-risky instrument exceeds the strike spread, the option pays off a notional principal times the difference between the spread at exercise and the strike spread.

A credit-linked note is an obligation of some issuing firm that, like any other note, promises to pay periodic coupons and a final principal. The promised payments are affected by credit events of one or more reference credits. Two interesting examples are synthetic bonds created by J.P. Morgan. Das (1998b) describes a transaction that essentially replicated a Wal Mart bond, although Wal Mart had nothing to do with the transaction. Masters and Bryson (1999) describe Morgan's BISTRO credit-linked note that has payments linked to credit events of hundreds of reference credits. Credit-linked notes and credit-spread derivatives each account for approximately fifteen percent of the current credit-derivatives market.

[3] Market share figures in this section are from BBA survey evidence discussed in Spraos (1998b).

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. The majority of credit derivative transactions booked in the U.S. exhibit maturity mismatches. Masters and Bryson (1999) report that the maturities of total-return swaps "rarely" match the maturities of the underlying instruments. Dealers estimate that the fraction of credit-default swap contracts with maturity mismatches ranges from somewhat above 50 percent to close to 100 percent. We emphasize this feature in the model of banks and loans that follows.

As mentioned in the introduction, the underlying instruments on which credit derivatives are written either are publicly-reported indexes or are traded, typically in over-the-counter markets. Therefore they can be priced easily using dealer polls. Although some credit derivative dealers view local and regional banks as a prime source of business in the future, the market has not yet been extended to instruments for which pricing is more opaque, such as small and medium-sized bank loans.

Two explanations for this limitation are offered by derivatives dealers. The first is the asymmetric information problem, which affects all credit derivatives that have payoffs tied to credit events that are partially controlled by one of the counterparties. (This problem helps explain the relatively heavy activity in credit derivatives that are based on indexes instead of firm-specific events.) The second is regulatory disincentives. At present, if only a portion of the credit risk of a bank loan is transferred out of a bank, bank supervisors may not give the bank selling its credit risk any relief in regulatory capital requirements, but will impose additional capital charges on a bank that is buying a portion of the loan's credit risk.[4] This asymmetric treatment is potentially important, because as the following model makes clear, a large part of the value of credit derivatives flows from the ability to decompose a loan's credit risk into tradeable and nontradeable components.

[4] Regulatory treatment for credit derivatives is described in Staehle and Cumming (1999).

3. A model of adverse selection

In this section we consider only the adverse-selection problem associated with banks' loan-making behavior. The moral-hazard problem is considered in Section 5.

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. Because this is a one-shot model, there are no reputation effects; the bank cannot commit to a truthful strategy. In reality, reputation effects are often important in the loan-sale market. Thus, this model should be viewed as applicable to loan portfolios for which asymmetric information concerns outweigh the strength of any reputation effect.

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 a firm with some existing assets that generate stochastic cash flows. The firm wants to invest in a new project and lacks sufficient internally-generated funds to finance it. Although the firm has other sources of revenue, as long as the new project is sufficiently large relative to the size of the firm, the firm's future ability to pay back funds borrowed to finance the project will depend on the return to the new project. Because the firm cannot credibly convey the value of its new project to most outsiders, an asymmetric information problem arises. A bank, however, can observe the ex ante value of the project and decide whether to make a loan to fund 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.

Revenues from the project will not be produced for some time. Until the project is complete, the firm's income will continue to be derived from its existing sources. Now consider the types of events that will trigger default on the new bank loan early in the loan's life—before the loan is generating revenue. Such events likely 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 until the project is completed, the firm will not rely on income from the new project to pay any of its obligations. Thus even a precipitous decline in the value of the new project may 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 a default on one or more of the firm's obligations, and thus trigger a default on the bank loan 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 borrower defaults on

the new bank loan 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 with a maturity mismatch 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. Model structure

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. The loan has a fixed size L. 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 borrower is obligated to pay a fixed interest rate R in periods 1 and 2, regardless of its quality. The principal is to be repaid in period two. Because both low-quality and high-quality borrowers borrow at rate R, outsiders cannot infer a borrower's credit quality by looking at the interest rate paid. This is an important point that is worth discussing in detail.

In the real world, lower-quality borrowers pay, on average, higher interest rates than do higher-quality borrowers. However, there is not a one-to-one relation between borrower quality, as observed by the bank, and the interest rate charged by the bank. One reason for this is that the loan is merely one part of the overall relationship between the bank and the borrower. The bank's profit from the loan can be embedded in other parts of this relationship, such as a greater volume of the borrower's over-the-counter transactions shifted to the bank's traders. A related reason is that the interest rate charged by the bank depends on the extent of the bank's monopoly power in lending to the customer. (How easily can the borrower switch banks?) Borrowers with substantial bargaining power will tend to be charged lower interest rates.

Stiglitz and Weiss (1981) provide an additional reason for the lack of a one-to-one

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	$[R+(1-w)]L$	$(1+R)L$

relation between borrower quality and the loan's interest rate. They note that the asymmetric information problem between the borrower and the bank complicates the bank's choice of interest rate to offer potential borrowers. The form and magnitude of this asymmetric information will affect the interest rate charged by the bank, and there may not be a monotonic relation between the interest rate and the bank's subjective probability that the borrower repays the loan.

Outsiders (that is, those outside of both the borrower and the bank) will be unable to infer the bank's view of the borrower's credit quality unless they can judge precisely the overall relationship between the borrower and the bank. In a more realistic model, the interest rate would be a noisy signal of the borrower's credit quality. However, the qualitative results in our paper only require that the signal not be perfect. Therefore, rather than explicitly modeling the relationship between the borrower and the bank, we simply assume that all borrowers pay R.

With probability p_1, the borrower defaults on the loan in period 1. Conditional on no default in period 1, the probability that the borrower defaults on the loan 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. What we have in mind here is that the bank has a variety of potential borrowers come through its doors. The bank uses its special skills to quickly reject all bad risks, leaving only positive NPV loan opportunities. Alternatively, we can assume that all potential loans are positive NPV projects, but barriers to entry prevent nonbanks from becoming banks and making loans. In Section 5, we take a closer look at what happens when a bank has the option to make loans that are not positive NPV projects.

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. Risk-sharing mechanisms

We first describe the market for loan sales without recourse. The bank may sell a nonnegative fraction f_i of its loan for a total price S_i in period $i, i = 0, 1$. The bank cannot sell more than the total loan: $f_0 + f_1 \leq 1$. The sale prices are endogenously determined in the model. In exchange 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. The bank sells these fractions to competitive risk-neutral outsiders.

The prices S_i depend on outsiders' expectations of p_2. Denote the information sets used by outsiders to calculate these expectations as $\Omega_i, i = 0, 1$. The contents of Ω_i will be discussed below. In equilibrium, risk-neutral outsiders expect to earn zero profits from the loan sales, thus the prices are

$$\begin{aligned} S_0(f_0, E(p_2|\Omega_0)) &= f_0 L\Big[1 + R + (1 - p_1)R - w\Big(p_1 + (1 - p_1)E(p_2|\Omega_0)\Big)\Big], \\ S_1(f_1, E(p_2|\Omega_1)) &= f_1 L\Big[1 + R - wE(p_2|\Omega_1)\Big]. \end{aligned} \tag{1}$$

We now describe a credit derivative 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-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.

The bank buys an amount XL of the credit-default swap from competitive risk-neutral outsiders. The price paid by the bank is $P(XL)$. Because the probability of a default in period 1 is known by all to equal p_1, the zero-profit condition for outsiders implies that this price is

$$P(XL) = p_1 w XL. \tag{2}$$

Outsiders observe the bank's activities in the loan-sales and credit-default swap markets. They use this information to form their expectations of p_2. Formally, their information sets are

$$\Omega_0 = \{f_0, X\},$$
$$\Omega_1 = \{f_0, f_1, X\}.$$

3.4. The bank's objective function and possible strategies

The bank maximizes its expected discounted profits. Because the bank is risk-neutral and the riskfree interest rate is zero, its discounted profit is simply the sum of its total cash flows. Denote the realization of this sum as Π. It is a function of both the bank's risk-sharing strategy (f_0, f_1, X) and the outcome of the loan. To express this outcome, the indicator function I_i equals one if the loan defaults in period i, otherwise it equals zero. Formally,

$$\text{profit} = \Pi(f_0, f_1, X; I_0, I_1).$$

The bank chooses (f_0, f_1, X) as a function of its private observation p_2 to maximize its expectation, conditional on p_2, of Π.[5] Denote the optimal risk-sharing strategy as (f_0^*, f_1^*, X^*). It satisfies

$$(f_0^*, f_1^*, X^*) = \text{argmax } E[\Pi(f_0, f_1, X; I_0, I_1)|p_2].$$

The bank's profit depends on whether the bank incurs the deadweight cost associated with large loan losses. The bank will incur a deadweight cost of B in period 1 if the loan defaults in that period and $(1 - f_0 - X)wL > L_0$, 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 the loan that the bank must transfer to others in order to avoid the deadweight cost:

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

[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 define two more indicator functions to express whether the bank has transferred less than $\overline{f}$ of its loan risk in periods 0 and 1. The first, $I_{f_0+X<\overline{f}}$, is zero for $f_0 + X \geq \overline{f}$ 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 are

$$\Pi = \begin{cases} L[(1-f_0)(R+(1-w))-1] + S_0 & \text{if loan defaults in} \\ \quad +(1-p_1)wXL - \ BI_{f_0+X<\overline{f}}, & \text{period 1 (prob} = p_1); \\ L[(1-f_0)R \ + (1-f_0-f_1)(R+(1-w)) & \text{if loan defaults in} \\ \quad -1] + S_0 + S_1 - p_1 wXL - BI_{f_0+f_1<\overline{f}}, & \text{period 2 (prob} = (1-p_1)p_2); \\ L[(1-f_0)R + (1-f_0-f_1)(R+1) - 1], & \text{if no default} \\ \quad + S_0 + S_1 - p_1 wXL & (\text{prob} = 1 - p_1 - (1-p_1)p_2). \end{cases} \tag{3}$$

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

[1] The bank sells a fraction $\overline{f}$ of the loan in period 0 ($f_0 = \overline{f}, f_1 = X = 0$). With this strategy, the bank reduces its exposure to a loan default in both periods. An economically equivalent strategy is ($f_0 = 0, f_1 = X = \overline{f}$), where the bank uses a credit-default swap to protect $\overline{f}$ of the loan in period 0 and sells the fraction $\overline{f}$ in the loan-sale market in period 1. For simplicity, we consider only the former strategy here.

[2] The bank uses a credit-default swap to protect $\overline{f}$ of its loan in period 0 and makes no loan sales ($X = \overline{f}, f_0 = f_1 = 0$). With this strategy, the bank reduces its exposure to the risk of early default.

[3] The bank engages in no loan sales or credit-default swaps in period 0, and sells a fraction $\overline{f}$ of the loan in period 1 ($f_0 = X = 0, f_1 = \overline{f}$). With this strategy, the bank reduces its exposure to the risk of late default.

[4] The bank makes no loan sales and purchases no credit-default swaps ($f_0 = f_1 = X = 0$). It does not reduce its exposure to default in either period.

For each of these four strategies, the bank's expected profit conditioned on p_2 can be calculated as a function of f_0, f_1, X, p_2, and outsiders' expectations of p_2 (which affect S_i). The respective profit expectations are:

$$E(\Pi|f_0=\overline{f},f_1=X=0;p_2) = L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_2)\Big]+ \overline{f}L\Big[w(1-p_1)(p_2-E(p_2|\Omega_0))\Big], \quad (4)$$

$$E(\Pi|f_0=f_1=0;X=\overline{f};p_2) = L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_2)\Big]- B[p_2(1-p_1)], \quad (5)$$

$$E(\Pi|f_0=X=0;f_1=\overline{f};p_2) = L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_2)\Big]+ \overline{f}L\Big[w(1-p_1)(p_2-E(p_2|\Omega_1))\Big]-Bp_1, \quad (6)$$

$$E(\Pi|f_0=f_1=X=0;p_2) = L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_2)\Big]- B\Big[p_1+p_2(1-p_1)\Big]. \quad (7)$$

The first terms on the right-hand-sides of (4), (5), (6), and (7) represent the expected profit from making the loan, which depends on the loan quality p_2. The second terms of (4) and (6) represent the profit (or loss) associated with asymmetric information. If the loan's actual probability of default is greater (less) than what outsiders believe, the bank profits (loses) by selling part of the loan to outsiders. The third term of (6) and the second terms of (5) and (7) represent the expected deadweight cost of the bank's financial distress owing to the failure of the loan.

3.5. The solution with only loan sales

To establish a baseline with which to examine the effect of credit derivatives, we first assume that credit derivatives do not exist. Loan risk-sharing can only be accomplished through loan sales; banks cannot choose a nonzero X. This rules out the second risk-sharing strategy described in Section 3.4. 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 $E(p_2|\Omega_i)$ is bounded above by p_l. From (4), the expected bank profit given the loan sale strategy ($f_0 = \overline{f}, f_1 = 0$) is decreasing in $E(p_2|\Omega_0)$,

hence, given $p_2 = p_l$, it is bounded below by $L[R+(1-p_1)R-w(p_1+(1-p_1)p_l)]$. This lower bound exceeds the expected bank profit given the no-loan-sale strategy in (7). 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, $E(p_2|\Omega_0) = E(p_2|\Omega_1)$, the bank will not choose the strategy $(f_0 = 0, f_1 = \overline{f})$, regardless of the realization of p_2.

Proof. From (4) and (6), if $E(p_2|\Omega_0) = E(p_2|\Omega_1)$, 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 (4) and the expected profit in (6). Subtracting (6) from (4) produces

$$\overline{f}L\Big[w(1-p_1)(E(p_2|\Omega_1) - E(p_2|\Omega_0))\Big] + Bp_1. \tag{8}$$

The expression in (8) 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 $E(p_2|\Omega_0) = E(p_2|\Omega_1) = (p_h + p_l)/2$. The pooling equilibrium can exist if

$$B > \left(\frac{1}{2}\right) \frac{\overline{f}Lw(1-p_1)(p_l - p_h)}{p_1 + (1-p_1)p_h}. \tag{9}$$

Proof: Assume an equilibrium in which 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

$$E(p_2|\Omega_0) = E(p_2|\Omega_1) = \frac{p_l + p_h}{2}. \tag{10}$$

Because $E(p_2|\Omega_0) = E(p_2|\Omega_1)$, 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 (4) exceeds that in (7), given outsiders' expectations in (10). This inequality holds whenever (9) 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 $E(p_2|\Omega_0) = E(p_2|\Omega_1) = p_l$ if there are loan sales and $E(p_2|\Omega_0) = E(p_2|\Omega_1) = p_h$ if there are no loan sales. The separating equilibrium can exist if

$$B < \frac{\overline{f}Lw(1-p_1)(p_l - p_h)}{p_1 + (1-p_1)p_h}. \tag{11}$$

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

$$E(p_2|\Omega_0) = E(p_2|\Omega_1) = p_l. \tag{12}$$

By (12) 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 (7) exceeds that in (4), given the expectations of (12). This inequality holds whenever (11) holds. **Q.E.D.**

Note that from (9) and (11), 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. We will show in Section 4 that banks are better off with the pooling equilibrium, regardless of the realization of p_2. Therefore we simplify further analysis of this model by assuming that the pooling equilibrium holds in the region characterized by (13). Nothing important is lost with this assumption.

Because there is a region of the parameter space in which only a separating equilibrium is possible, we see that a loan-sale market, even one with an implicit commitment by the selling bank to continue to hold a fraction of the loan, may be of no use to banks in avoiding the risk of their own insolvency. This is not a contradiction of Gorton and Pennacchi (1995); they do not claim that a loan sale market is guaranteed to make bank loans marketable. The point we make here is qualitatively similar to their conclusion that banks sell a smaller proportion of loans for which the loan sale premium is high. In Section 3.6, we go beyond Gorton and Pennacchi to consider an alternative method of transferring loan risks.

3.6. The solution with loan sales and credit derivatives

Here we assume that banks have access to the market for credit-default swaps. The bank is allowed to choose f_0, f_1, and X to maximize its expected profit. 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 (7). **Q.E.D.**

Lemma 4 says that it is never optimal for the bank to retain the entire risk of the loan. The bank is better off by reducing its exposure to the risk of early default.

Lemma 5. If $p_2 = p_l$, the bank will not choose the strategy $(f_0 = f_1 = 0, X = \overline{f})$.

Proof. Identical to the proof of Lemma 1 with references to (7) replaced by references to (5). **Q.E.D.**

Lemma 6. If, in equilibrium, the bank does not choose the 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. By the assumption of this Lemma and by Lemmas 4 and 5, we only need to consider the strategies $(f_0 = \overline{f}, f_1 = X = 0)$ and $(f_0 = X = 0, f_1 = \overline{f})$. The logic of Lemma 3 then implies Lemma 6. **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 is $(f_0 = \overline{f}, f_1 = X = 0)$ regardless of its observation of p_2. Outsiders' expectations of loan quality are given by $E(p_2|\Omega_0) = E(p_2|\Omega_1) = (p_h + p_l)/2$. The pooling equilibrium can exist if

$$B > \left(\frac{1}{2}\right) \frac{\overline{f} L w (1 - p_1)(p_l - p_h)}{(1 - p_1) p_h}. \tag{14}$$

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 $f_0 = \overline{f}, f_1 = X = 0$ 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 $E(p_2|\Omega_0) = E(p_2|\Omega_1) = p_l$ if the bank

follows the first strategy and satisfy $E(p_2|\Omega_0) = E(p_2|\Omega_1) = p_h$ if the bank follows the second strategy.

The separating equilibrium can exist if

$$B < \frac{\overline{f}Lw(1-p_1)(p_l - p_h)}{(1-p_1)p_h}. \tag{15}$$

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

As in Section 3.5, either a pooling or a separating equilibrium is possible, depending on the model's paramters. In the pooling equilibrium, the bank sells $\overline{f}$ of all loans. In the separating equilibrium, it sells $\overline{f}$ of low-quality loans and uses a credit-default swap to reduce its exposure to early default of high-quality loans. From (14) and (15), either equilibrium can be supported in the region

$$\frac{p_l - p_h}{2} < \frac{B(1-p_1)p_h}{\overline{f}Lw(1-p_1)} < p_l - p_h. \tag{16}$$

We show in Section 4 that the bank is better off in this region with the pooling equilibrium, so we assume that the pooling equilibrium holds in the region characterized by (16).

We now informally justify our conjecture that if the bank reduces its exposure to the risk that the loan defaults, it reduces its exposure by the fraction $\overline{f}$. First consider either 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 reduce its exposure by less than $\overline{f}$ but more 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.

The strategies in the separating equilibria are somewhat arbitrary. First consider the separating equilibrium in Theorem 2. The sale of $\overline{f}$ in period 0 when the bank observes

p_l 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] There is another arbitrary feature to the equilibrium in Theorem 4. The bank is indifferent between purchasing $\overline{f}$ in credit-default protection and purchasing any larger amount. Regardless of the amount it buys, it receives a fair price.

There are two important differences between the equilibria described in Theorems 1 and 2 and those described in Theorems 3 and 4. The first difference concerns the nature of the separating equilibria. In the separating equilibrium when credit derivatives are unavailable, the bank does not reduce its exposure to loan default risk at all, but when credit derivatives are available the bank uses a credit derivative to reduce its exposure to the risk of early default.

The second difference is that the region of the parameter space that supports a pooling equilibrium is smaller when the bank is able to purchase credit derivatives. This result is immediate from comparing the region in (9) with that in (14). In the next section we consider whether the net effect of these differences makes banks better off if they have access to the credit-derivatives market.

4. Are banks better off with credit derivatives?

We now consider whether introducing a market for credit-default swaps is beneficial to banks that previously had access to only a market for loan sales. We do so by comparing expected bank profits across the possible equilibria. The bank's unconditional expected

[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.

profit in either pooling equilibria 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

$$\text{Pooling:} \qquad E(\Pi) = L\left[R + (1-p_1)R - w\left(p_1 + (1-p_1)\frac{p_l + p_h}{2}\right)\right]. \tag{17}$$

This expected profit is simply the mean return to a loan. The bank's unconditional expected profit in the separating equilibrium of Theorem 2, where credit derivatives are unavailable, is

$$\begin{aligned}\text{Separating,}\\ \text{no derivatives:}\end{aligned} \qquad \begin{aligned} E(\Pi) = \; & L\left[R + (1-p_1)R - w\left(p_1 + (1-p_1)\frac{p_l + p_h}{2}\right)\right] \\ & - \; B(p_1 + p_h(1-p_1))/2\ . \end{aligned} \tag{18}$$

Eq. (18) has one more term than does (17). 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. The bank's unconditional expected profit in the separating equilibrium of Theorem 4, where credit derivatives are available, is

$$\begin{aligned}\text{Separating,}\\ \text{derivatives:}\end{aligned} \qquad \begin{aligned} E(\Pi) = \; & L\left[R + (1-p_1)R - w\left(p_1 + (1-p_1)\frac{p_l + p_h}{2}\right)\right] \\ & - \; B(p_h(1-p_1))/2. \end{aligned} \tag{19}$$

The profits in (19) exceed those in (18) 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. Armed with these expected profit calculations, we determine whether banks are better off with access to the credit-derivatives market.

Corollary 1. Expected bank profits are *higher* with the credit-derivatives market than without if the model's parameters do not satisfy the inequality in (9).

Proof. If (9) does not hold, a pooling equilibrium is impossible if credit derivatives are unavailable. Because Theorem 3's corresponding condition (14) is not satisfied if (9) is not satisfied, a pooling equilibrium is also impossible when credit derivatives are available. Therefore bank profits without a credit-derivatives market are given by (18) and bank profits with a credit-derivatives market are given by (19). Bank profits are higher in (19). **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

$$Bp_1 > \overline{f}Lw(1-p_1)\frac{(p_l - p_h)}{2} - B(1-p_1)p_h > 0. \tag{20}$$

Proof. Given (20), 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). Unconditional expected bank profits are higher with a pooling equilibrium (given by (17)) than with credit derivatives combined with a separating equilibrium in the loan-sale market (given by (19)). **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 the model's parameters satisfy (11).

Proof. If (11) is satisfied, a pooling equilibrium will exist when credit derivatives are available. Eq. (11) implies (9), thus a pooling equilibrium also exists when credit derivatives are unavailable. Therefore regardless of whether credit derivatives are available, expected bank profits are given by (17). **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, as noted by Stein (1987).

4.1. 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. In a purely formal sense, it is fairly easy to tweak the model to make credit derivatives redundant. For example, the bank can offer one-period loans to the borrower in both periods 0 and 1. 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 long-maturity loans to a sequence of short-maturity loans; e.g., liquidity risk as in Diamond (1991) or tax timing as in 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

[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).

the relationship at risk. Thus, all else equal, the credit derivative 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. Moral hazard and capital allocation issues

5.1. Moral hazard

The model in Section 3 focused 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 that increases the probability of repayment. This monitoring cannot be observed by those outside 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. 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

$$(p_l - p_h)wL > D > (1 - \overline{f})(p_l - p_h)wL. \tag{21}$$

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 (21) 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.

5.2. The solution with only loan sales

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

$$B[p_1 + (1 - p_1)p_h] < (1 - p_1)[(p_l - p_h)wL - D]. \tag{22}$$

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 (22) 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 $(1/2)(1 - p_1)[(p_l - p_h)wL - D]$. We can think of this as the deadweight cost of the equilibrium.

5.3. The solution with loan sales and credit derivatives

Now consider the introduction of credit-default swaps. If (22) 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 $(1/2)p_1B$, 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 (22) 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 (23) holds.

$$\frac{(1-p_1)[(p_l - p_h)wL - D]}{(1-p_1)p_h} > B > \frac{(1-p_1)[(p_l - p_h)wL - D]}{p_1 + (1-p_1)p_h} \tag{23}$$

Note that the second inequality in (23) is simply the reverse of (22). If the parameters satisfy (23), 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. (23) assures that the former is larger than the latter.

The other relevant case is when (24) holds.

$$B > \frac{(1-p_1)[(p_l - p_h)wL - D]}{(1-p_1)p_h} \tag{24}$$

Given (24), 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 as the basic condition for moral hazard, eq. (21), is satisfied, 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.

5.4. Capital allocation and negative NPV loans

In the model of adverse selection presented in Section 3, both low-quality and high-quality loans were positive NPV projects from the bank's perspective. This assumption, if taken literally, trivializes the role of banks in allocating capital. If all potential loans are positive NPV projects, any firm could make a loan (or equivalently, everybody would become a bank) unless there are barriers to entry in the banking industry. In practice, an important part of financial intermediation is knowing which potential borrowers should get loans and which should not. In this subsection we return to the model of adverse selection, but 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

$$R + (1 - p_1)R - w(p_1 + (1 - p_1)p_l) < 0. \tag{25}$$

One possible equilibrium with this setup is that the bank does not make the negative NPV loan and uses loan sales or credit derivatives to share the risk of the high-quality loan with outsiders. (This is the idea behind the model in Section 3.) However, more complicated equilibria are also possible, including the possibility that the bank makes negative NPV loans. The intuition is straightforward. If outsiders believe that the bank will not make any negative NPV loans, they will pay a relatively high price for a share of a loan's payoff. At this high price the bank will profit from making a negative NPV loan if its profit on the loan sale/credit derivative exceeds the loss it expects to incur on the portion of the loan it retains. Outsiders, realizing this, will rationally expect the bank to attempt to sell negative NPV loans. The bank would be better off if it could commit to not making negative NPV loans, but such a commitment is impossible.

Rather than exhaustively examining the various possible equilibria given (25), we provide a flavor of the results by considering one of these more interesting equilibria. We impose certain restrictions on the parameters that allow for a pooling equilibrium to exist in which the bank makes both positive and negative NPV loans and sells a fraction of

these loans in the loan sale market. The mathematical formulation of these restrictions is discussed below.

The first parameter restriction we impose is that the mean potential loan is a positive NPV project. The sum of the positive NPV of high-quality loans and the negative NPV of low-quality loans is positive:

$$R + (1 - p_1)R - w\left[p_1 + (1 - p_1)\left(\frac{p_h + p_l}{2}\right)\right] > 0. \tag{26}$$

Without this assumption, a pooling equilibrium is impossible because outsiders would have no interest in funding the average loan. We now examine the case where 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 (9) holds and if

$$R + (1 - p_1)R - w\left[p_1 + (1 - p_1)\left(\frac{\overline{f}p_h + (2 - \overline{f})p_l}{2}\right)\right] > 0. \tag{27}$$

Proof. Assume a pooling equilibrium, so that $E(p_2|\Omega_0) = (p_l + p_h)/2$. Eq. (9) is the condition from Theorem 1 that the bank will sell $\overline{f}$ of the loan in a pooling equilibrium if the bank observes $p_2 = p_h$. If (9) holds and $p_2 = p_l$, we can also conclude that the bank will sell $\overline{f}$ of the loan in a pooling equilibrium as long as the bank is willing to make the loan at all. Eq. (27) is the condition required for the bank to make the loan if $p_2 = p_l$. It is derived by setting expected profits in (4) greater than zero with $p_2 = p_l$ and $E(p_2|\Omega_0) = (p_l + p_h)/2$. **Q.E.D.**

Note that if $\overline{f} = 1$, (27) reduces to (26). If $\overline{f} = 0$, (27) violates (25). We therefore require that $\overline{f}$ is sufficiently close to one to satisfy (27); 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 (11) holds and if

$$R + (1 - p_1)R - w\left[p_1 + (1 - p_1)\left(\overline{f}p_h + (1 - \overline{f})p_l\right)\right] > 0. \tag{28}$$

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 (11) 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 (28) holds. If outsiders expect the bank to sell $\overline{f}$ of the loan when $p_2 = p_h$, (28) 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 (28) 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.

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 $E(p_2|\Omega_0) = E(p_2|\Omega_1) = (p_h + p_l)/2$. The pooling equilibrium can exist if (14) and (27) 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 (15) and (28) hold.

Proof: A combination of Theorem 2 and Corollary 5, 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 (25) and (26) 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 (25) and (26). 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 are the effects of these assumptions on the conclusion of Corollary 2. Recall that Corollary 2 states that over the parameter region satisfying (20), 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 (20) 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 (20), 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 (25). 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 (29).

$$-L\Big[R+(1-p_1)R-w(p_1+(1-p_1)p_l)\Big] > Bp_h(1-p_1). \tag{29}$$

To summarize, if the model's parameters satisfy (20), (25), and (26), 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 (29) holds, the net effect is positive.

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 an asymmetric-information 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 asymmetric-information 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, when we consider the effects that a credit-derivatives market has on other markets for sharing risks, 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. We find that if the asymmetric-information problem is one of adverse selection, the net effect is to leave the bank worse off, while if the problem is one of moral hazard, the bank is better 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. 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 empirically unresolved issue is examined in 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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