Managing Credit Risk with Credit Derivatives

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Abstract: Credit risk is one of the most important forms of risk faced by national and international banks as financial intermediaries. Managing this kind of risk through selecting and monitoring corporate and sovereign borrowers and through creating a diversified loan portfolio has always been one of the predominant challenges in bank management. The aim of our study is to examine how a risky loan portfolio affects optimal bank behavior in the loan and deposit markets, when derivatives to hedge credit risk are available. In a stochastic continuous-time framework a hedging model is developed where the bank management can use derivatives to hedge credit risk. Optimal loan, deposit and hedging strategies are then studied. It is shown that the magnitude and the direction of hedging are determined by the bank manager' s preferences, the corresponding risk premium and the variance of the loan rate and its hedging instrument respectively.

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Relevance for Practice: Over the last decade, credit securitization has emerged and gained substantial popularity by providing new instruments to mitigate credit risks for banks and other financial institutions. In particular, banks can now rely on credit derivatives to manage the credit risks of their loans on a portfolio basis. Research conducted in this paper examines more closely how a bank's manager should dynamically structure a risky loan portfolio if credit derivatives are available. An analytical solution for a dynamic hedging strategy is presented and implications for optimal loan and deposit policies are deduced and discussed. Apart from the usual mean-variance results our results explicitly account for the bank manager's risk preferences and discuss their impact on hedging. In a period of financial crises, those results are of great potential value to bank managers and practitioners alike.

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1. Introduction

Asset/liability management and especially credit risk management is one, if not the most, important business area of banks and other financial institutions(e.g. Rochet (2003)). Indeed, as documented in Froot et al. (1993), it is ranked by financial managers as one of their primary objectives (see also Bessis (2002), British Bankers' Association (2003)). Accounting for the real world importance of credit risk management, and loan portfolio management respectively, there have been many studies concerning the financial and hedging decisions of risk averse banking firms facing default risk (see e.g. Wong (1997), Briys et al (1990), Briys and Solnik (1992), Loubergé and Schlesinger (2002), Stiglitz and Greenwald (2003), Broll et al. (2004), Wahl and Broll (2005)). However, this field of business has gone through major changes due to globalization, developments of new financial instruments and the reform of the capital adequacy framework by the Basel Committee on Banking Supervision which was implemented in 2006. In addition, the introduction of the euro set aside the need for domestic interest rate markets of the member countries. In this way, credit derivatives enjoy increasing popularity as they provide opportunities to both enhance yields and diversify credit portfolios.

Since the early 1980s, credit derivatives have already been used for the securitisation of bonds. However, at the annual conference of the International Swaps and Derivatives Association (ISDA) in Paris in 1992 they were first presented as over-the-counter (OTC) products (see e.g. Schmid 1998 p.8). With respect to the type of credit reference entity the market saw a further growth in corporate underlyings accounting for 64% of the total market in 2003 as opposed to 60% in 2001. Accordingly, the market share of sovereigns from emerging markets dropped to 7% in 2003 (as opposed to 9% in 2001) while financial institutions were referenced in 22% of all cases.

The reason for the increase is the desire of the financial system to manage credit risk in order to stabilize financial markets.[1] Banks can pool assets with credit risk and can sell parts of the pool. This kind of securitization or creation of asset backed securities has seen considerable growth in recent years. Credit derivatives such as credit default swaps, credit forwards and credit-linked notes have gained importance as instruments to manage credit in situations, where the diversification of loans and credit risks makes it difficult to securitize loans or sell them individually.

What is credit risk and what are credit derivatives? In general credit or default risk is the risk that the borrower does not repay part or the entire financial obligation. Following the International Swaps and Derivatives Association's (ISDA) conventions, credit events are typically defined as one or more of the following: bankruptcy, failure to pay, restructuring, repudiation,

[1]Documented by an increase in corporate and sovereign bankruptcies such as Asian Financial Crises in 1997, Russian Financial Crises 1998, and Argentina Financial Crises in 2001 (Stiglitz and Greenwald (2003)).

moratorium, obligation default, or obligation acceleration. Credit derivatives are financial instruments designed to transfer credit risk from one party to another. The legal ownership of the obligation is usually not transferred. In general, credit derivatives can have the form of forwards, options and swaps which may be embedded in financial assets such as loans and bonds. Credit derivatives allow an investor to reduce or eliminate default risk or to buy credit risk, expecting to benefit from it. There are many ways in which financial managers can utilize credit derivatives. The main applications are hedging, arbitrage and speculation.[2]

Against the background of this recent surge in the use of credit derivatives we ask how the availability of such derivatives affects a bank's decision concerning interest rates or loan and deposit volumes and what can be said about the optimal hedge policy. According to the capital market theory credit risk has both an idiosyncratic and a systematic component (Loubergé and Schlesinger (2002)), i.e. there is risk of creditor default originating from the creditor herself and from factors unrelated to the creditor. Systematic risk of a loan arises, for example, from the business cycle or from the general political instability. According to Wilson (1998) only a small number of macroeconomic factors are sufficient to explain this type of risk which determines most part of all risk related to a loan contract. From the capital market theory we have an understanding that systematic risk can not be diversified but it is tradeable. Unsystematic risk should be eliminated through diversification.

The aim of our study is to examine how a risky loan portfolio affects optimal bank behavior in the loan and deposit markets, when derivatives to hedge credit risk are available. Given credit risk and risk aversion of the owner of the bank, within a dynamic hedging model we derive the bank's optimal risk management, i.e. the optimal hedge position in a credit derivative market. We demonstrate that the loan and deposit policy is optimal if

[2] We are focusing on the value of hedging, i.e. the desire of an investor to reduce risks in order to stabilize the stream of consumption.

marginal costs equal marginal revenue at each instant. In the optimum the marginal utility of consumption equals the marginal indirect utility of wealth at each unit of time.

The basic motivation of our study can be interpreted as follows. Banks are facing corporate and sovereign credit risks. If a banking firm does not hedge, there will be some stochastic variability in the cash flows. Random fluctuations in cash flows due to credit risk result in variability in the amount of the bank's owner consumption due to random wealth. Variability in consumption will generally be undesirable, to the extent that there is risk aversion. Credit derivatives can reduce this variability in cash flows and increase the expected utility of the owner of the bank.

The structure of the paper is as follows. In section 2 we present a continuous-time stochastic model of a competitive commercial banking firm under credit risk. The banking firm can sell or buy derivatives correlated with the risk of the loan portfolio. Section 3 examines optimal loan, deposit and hedging positions of the banking firm. In section 4 we discuss the benefits for the bank's management consumption in the presence of hedging opportunities, and without hedging respectively. Section 5 concludes the paper.

2. The Model

The framework we use for our study is the so called industrial organization approach of banking (see e.g. Morgan et al. (1988), Freixas and Rochet (1997)). The approach is focusing on the bank's role as intermediary, but abstracts from informational aspects of banking, adverse selection and moral hazard. Our objective is to examine how the possibility to sell (or buy) partially or fully a bank's risky loan portfolio at a market price affects the banks' optimal asset and liability management (see e.g. Battermann et al. (2000), Broll et al. (2001)). In the following we will neglect the great variety of credit derivatives and model a simple credit derivative which corresponds to a credit forward. A credit forward is a derivative which generates a payoff based on the differential between the spot and forward credit price or spread (Banks (1997) p. 254). Thus, the derivate can be used to offset or lower credit exposure to a given counterparty by providing the bank with a compensatory forward payment as its counterparty deteriorates or defaults. It should be stated here, that this approach is conservative and accounts for credit exposure based on simple deterioration rather than on default.[3] Thus, simple credit deterioration is sufficient to generate a payment.[4] Furthermore we assume the existence of a market for credit derivatives.

Consider a straightforward model of a competitive banking firm in a continuous-time stochastic framework. The bank is a classical intermediary, taking deposits D and making loans L where the latter is subject to credit risk. [5] Equity capital, K, of the bank is taken as given. The bank faces operational cost $G(L, D)$, which are increasing and convex: $G_L > 0$, $G_{LL} > 0$, $G_D > 0$, $G_{DD} > 0$. To keep the notion as simple as possible, we ignore a voluntary or mandatory holding of reserves on deposits, as we ignore regulatory capital requirements for loans. Therefore the balance sheet constraint of the bank can be written as follows:

$$L + M = K + D \tag{1}$$

where M is the positive or negative balance of capital invested in or financed from an interbank market at a given deterministic interest rate r_M.

The bank faces credit risk in the sense that repayments are uncertain. The evolution of the effective loan rate, r, is assumed to be stochastic. We assume that the effective loan rate r follows a geometric Brownian motion with a fixed drift rate μ_r and a fixed variance parameter σ, which is a measure

[3]In the case of default, implementing a jump argument in the stochastic evolution of r is more appropriate.

[4]In 2003, roughly 52 percent are AAA/AA/A rated while 30 percent of global credit derivatives exposures refer to BBB rated entities. Only a minority of 18 percent belong to below investment grade rated entities (Fitch Rating (2004)). Given these facts, extraordinary credit events can be neglected.

[5]By competitive we mean that the bank is a price taker.

of the diffusion. Mathematically, we write this process as follows:[6]

$$dr/r = \mu_r dt + \sigma_r dz_r \tag{2}$$

where dz is a standard Wiener process.

The banking firm can use the credit derivatives to hedge the default risk. Futures contracts cost nothing to enter but pay off df continuously thereafter due to marking to market. We assume that the time to maturity of the futures contract perfectly matches the investor's hedging horizon and that its dynamics can also be described by a Brownian motion as followed:

$$df/f = \mu_f dt + \sigma_f dz_f. \tag{3}$$

with a drift rate, i.e. the risk premium, μ_f that differs from that of the underlying effective loan rate. It is assumed that dr/r and df/f are correlated and ρ_{rf} represents the degree of correlation.

Now we turn to the risk averse bank owner's wealth accumulation and its utility maximization problem, that is, to the best the bank manager can do in the interest of the shareholder, who cares about consumption. Consider an investor with a fixed planning horizon T, who has total wealth W, from which she has already invested an amount I in a competitive banking firm. The difference, namely $W-I$, is invested at the deterministic market interest rate r_M and generates a cash flow of $r_M(W-I)dt$ per unit of time.

A second cash flow comes from the investment in the banking firm, namely the profits from financial intermediation

$$\Pi dt = (rL + r_M M - r_D D - G(L, D))dt,$$

where r_D is the market determined deposit rate and the term $r_M I dt$ represents the opportunity cost of the investment in the banking firm, i.e. the deterministic interest revenue forgone over time. Thus, M corresponds to

[6]For simplicity, we will abstract from a mean-reverting expression of dr and df respectively. For mean-reverting processes see e.g. Hull (2003)

the net position in the interbank market. We will assume, that M equals $(1-\alpha)D-L$ so the above equation can further be simplified. Here, α denotes the fraction that is not used for cash reserves (see Freixas and Rochet (1997, p. 52)).

The banking firm can use the risk sharing market to hedge the default risk. Credit derivatives pay off df continuously thereafter due to marking to market. The consumption expenditure of the shareholder over time is denoted by Cdt. Since loan portfolio revenues over time are uncertain due to the stochastic evolution of the credit risk, the banking firm is hedging against this risk by taking a position in the credit derivative market. The purpose of hedging is to stabilize the consumption path of the shareholder through a reduction in the variability of the wealth accumulation path. Thus, the banking firm takes a hedge position with contract volume H. Hence, the wealth accumulation equation is given by:

$$dW = [r_M(W-I)+\Pi-C]dt-Hdf \tag{4}$$

As the futures price changes over time, the bank must adjust its margin account. If the futures price rises, $df>0$, she has to pay an amount Hdf. If the futures price falls, she receives cash payments Hdf. With the definition of the hedge ratio with respect to wealth as $h=fH/W$, and substituting the stochastic process for df in (5) gives the wealth accumulation equation:

$$dW = (\Omega+(r_M-h\mu_f)W)dt-hW\sigma f dz_f \tag{5}$$

with $\Omega=\Pi-C-r_MI$ which results to:

$$\Omega=(r-r_m)L-(r_m(1-\alpha)-r_D)D-G(L,D)-C-r_MI. \tag{6}$$

From the expression of dW it is now obvious that the wealth accumulation over time is uncertain and can formally be expressed as a Brownian motion. The investor cares about consumption. We donate $u(C)$ as a von Neumann-Morgenstern utility function which exhibits risk aversion, i.e.

$u'(C) > 0, u''(C) < 0$. The parameter β is a subjective discount rate. The agent's objective is to select consumption, together with the portfolio of assets and liabilities, to maximize the expected value of discounted utility subject to the wealth constraint. Thus, the risk averse bank manager solves the following maximization problem.

$$\max_{C,L,D,h} E \int_0^T u(C)e^{-\beta t}dt, \tag{7}$$

subject to the stochastic wealth flow constraint (6). Now we turn to the optimal asset/liability management, optimal consumption and hedging rules of the banking firm.

3. Asset/Liability Management and Hedging

Solving the maximization problem (7) subject to the wealth constraint (6) leads to the following

Proposition 1: *When credit risks are tradeable on a credit derivative market, the optimal loan and deposit decisions, the optimal hedge ratio and the consumption rule are described by:*

$$u'(C^*) = V_W(W, r, t), \tag{8}$$

$$r - r_M = G_L(L^*, D^*), \tag{9}$$

$$r_M(1-\alpha) - r_D = G_D(L^*, D^*), \tag{10}$$

$$h = \frac{\mu_f}{\sigma_f^2 V_{WW} W / V_W} + \frac{r\sigma_{fr}}{\sigma_f^2 V_{WW} W / V_{Wr}}. \tag{11}$$

Proof: The value function $V(W, r, t)$ is defined as follows:

$$V(W, r, t) = \max_{C,L,D,h} E_t \int_t^T u(C)e^{-\beta\tau}d\tau,$$

subject to the dynamic wealth accumulation equation (6) and some initial and terminal conditions. The Bellman equation is [7]

[7] See, for example, Dixit and Pindyck (1994), Turnovsky (1997).

$$\beta V(W,r,t) = \max_{C,L,D,h} \left\{ u(C) + \frac{E(dV)}{dt} \right\},$$

where

$$dV = V_t dt + V_W(dW) + \frac{1}{2}V_{WW}(dW^2) + V_r(dr) + \frac{1}{2}V_{rr}(dr^2) + V_{Wr}(dW)(dr),$$

and

$$\begin{aligned} E(dr) &= \mu_r r dt, \\ E(dr^2) &= \sigma_r^2 r^2 dt, \\ E(dW) &= (r_M W - (\mu_r - r_M)hWf - r_M I + \Pi - C)dt, \\ E(dW^2) &= h^2 W^2 \sigma_f^2 dt, \\ E[(dr)(dW)] &= -hWfr\sigma_{rf} dt. \end{aligned}$$

Substituting these expressions into the Bellman equation yields:

$$\begin{aligned} \beta V(W,r,t) &= \max_{C,L,D,h} \{V_t + \alpha V_W + \delta W^2 V_{WW} + \mu_r r V_r \\ &+ 1/2\sigma_r^2 r^2 V_{rr} - \epsilon W V_{Wr} + u(C)\} \end{aligned}$$

where $\alpha = (\Omega + (r_m - hf\mu_f), \delta = \frac{1}{2}h^2\sigma_f^2$, and $\epsilon = hr\sigma_{rf}$. Maximization on the right hand side of the equation leads to the optimality conditions in the claim.

3.1 Optimal inter-temporal consumption rule

Equation (8) determines the optimal consumption decision. It is the stochastic version of the Keynes-Ramsey rule for optimal inter-temporal consumption: the marginal utility of consumption $u'(C)$ has to be equal to the marginal utility of wealth $V_W(.)$ where $V(W,r,t)$ can be identified as the indirect utility function of the bank's owner. Due to equation (8) it follows that optimal consumption is also a function of W, r, and t. To see this, we can determine the expression of dV_W by applying Itô's Lemma on dV. Using the relation $V_W = u'$, we can transform the resulting stochastic differential equation into

$$\begin{aligned}\frac{du'(C)}{u'(C)} &= ((\beta - r_M) + h(\mu_f + r\sigma_{rf}V_{Wr}/V_W) - h^2\sigma_f^2 WV_{WW}/V_W)dt \\ &- hWV_{WW}/V_W\sigma_f dz_f + V_{Wr}/V_W\sigma_r r dz_r.\end{aligned}$$

Taking expected values of this equation leads to

$$\frac{E[du'(C)/dt]}{u'(C)} = (\beta - r_M) + h(\mu_f + r\sigma_{rf}V_{Wr}/V_W) - h^2\sigma_f^2 WV_{WW}/V_W,$$

which corresponds to the continuous-time version of the Euler equation if hedging is not considered, i.e. $E[du'(C)/dt]/u'(C) = (\beta - r_M)$.

3.2 Optimal loan and deposit policy

A competitive bank will adjust its volume of loans and deposits such that the intermediation margins, $r - r_M$ and $r_M - r_D$, equal its marginal operation costs. The best the bank management can do is taking deposits and giving loans at each instant of time according to the static optimization rule, which requires that net marginal revenue equals marginal cost, i.e. see (9) and (10). The intermediation margin, $r > r_M > r_D$, is fulfilled. Therefore, an increase in the rate of deposit r_D will lead to a decrease in the bank's demand for deposit. Similarly, an increase in the loan rate will entail an increase in the bank's supply of loans. The cross effect depends on the sign of $\partial^2 G/\partial D\partial L$.

The economic interpretation of the cross effect is related to the notion of economies of scale. When the cross effect is negative, this means, that an increase in D has the consequence of decreasing the marginal cost of loans. This is interpreted as a form of economies of scope. It implies that the bank that offers loans and deposits is more efficient than two separate entities, specialized in loans and deposits respectively. When the cross effect is positive, then there are diseconomies of scope.

3.3 Optimal risk management

Proposition 1 gives the optimal hedge ratio. The first term of the optimal hedge ratio in (11) captures the pure hedging motive, i.e. the desire to stabilize consumption over time. We see that the optimal hedge ratio with respect to this motive depends on preferences. The second term in (11) is the speculative component of the optimal hedge policy. The futures market may turn out to be in a backwardation situation, which means that there is a risk premium on the credit derivative. A risk averse investor will take this into account and deviate from the variance minimizing hedge ratio. As can be seen, the degree of the speculative component depends on the investor's degree of relative risk aversion, which is measured by the expression $-V_{WW}W/V_W$, and the variance of the evolution of the futures price, σ_f^2. The greater the risk aversion or the greater the variance of the evolution of the futures price, the smaller becomes the speculative component.

4. The value of Hedging Credit Risk

As discussed in section 2 and 3 the evolution of the loan rate is uncertain. Assume for the moment, that μ_r and μ_f are zero, i.e. r and f are without any drift and the second term in (11) is zero. It is commonly acknowledged that systematic credit risk is driven primarily by macroeconomic conditions (Wilson (1998)). In the case of a negative shock, i.e. credit deterioration risk for sovereign and individual entities, r drops, which implies that the dynamic stochastic time path continues from a lower level. The whole expected time path of the loan return for the banking firm becomes lower. This means that the expectation of profit is lower, which leads to lower wealth and therefore lower consumption. Here the credit derivative market comes into play. Since spot and futures prices are perfectly correlated and obey the same Wiener process, it follows that a stochastic drop in r lowers f proportionally. Taking a short position in the derivative market therefore creates a positive cash flow, i.e. the hedger gains. Hence, the higher the hedging amount the hig-

her the inter-temporally offsetting effect on wealth. This enables the bank's management to stabilize the consumption of the shareholder over time. We conclude the hedging acts like an insurance against credit deterioration risk for banks and other market participants.
Now we are in a position to demonstrate the benefits of hedging opportunities. The economic purpose of hedging with derivatives is to stabilize the inter-temporal consumption of the bank's owner. The stabilizing effect on optimal consumption can best be seen given that the risk premium μ_f is zero. In this case the change in consumption of time, it follows that:

$$du'(C)/u'(C) = (\beta - r_M)dt$$

This means consumption is fully stabilized. Without hedging consumption is always stochastic which implies a loss in expected utility. As a matter of fact, bank managers will prefer financial hedging (be it with or without basis risk) to none and, therefore, there is a value of hedging to the banking firm.

Corollary 1: *If the risk premium is zero, hedging completely removes the uncertainty over future consumption. With a positive or negative risk premium, consumption is not fully stabilized. Without hedging, consumption is always stochastic, i.e. the higher the credit risk, the more volatile the consumption path becomes.*

Proof: Applying Itô's Lemma to $dV(W, r, t)$, taking the partial derivative of the Bellman equation with respect to wealth by using envelope properties. Substitution in Itô's expansion of dV_W and by applying the optimal hedge ratio will lead to the claim. This gives the stochastic version of the Keynes-Ramsey optimal consumption rule (see Turnovsky (1997), chapter 9). With hedging we get

$$du'(C)/u'(C) = (\beta - r_M)dt - \frac{\mu_f}{\sigma_f}dz_f - \frac{V_{Wr}r\sigma_{fr}}{V_W\sigma_f}dz_f + \frac{rV_{Wr}}{V_W}\sigma_r dz_r. \quad (12)$$

For μ_f being equal to zero r and f have to be perfect correlated. Thus, $\rho_{rf} = \sigma_{rf}/(\sigma_r\sigma_f)$ equals one and equation results in the stabilized consumption expression.

On the other hand, when there are no hedging opportunities with credit derivatives or any other correlated asset traded on financial markets, i.e. $h = 0$ optimal consumption over time is

$$du'(C)/u'(C) = (\beta - r_M)dt + \frac{rV_{Wr}}{V_W}\sigma_r dz_r.$$

This proves the claim.

5. Conclusion

Credit derivatives started trading actively in the mid 1990s. However, they are not a recent financial innovation. Other forms of default protection, e.g. a letter of credit and bond guarantees, have been used for many years in the financial sector and in other parts of the economy (see e.g. Bessis (2002), Marin and Schnitzer (2002)). More recently, new financial instruments and risk sharing markets have been established. The credit derivatives market can be divided in four categories - credit default swaps, total return swaps, credit-spread products and synthetic products. In our study we used the term credit derivatives both for securities originating from loan securitization and for more advanced instruments such as credit futures and options. Our objective is to examine how the opportunity to sell part of a bank's uncertain loan portfolio on a risk sharing market affects bank behavior in loan and deposit markets.

This paper presents a banking firm model of dynamic risk management where the underlying source of the risky wealth is an unanticipated change in the default risk. A position in the credit derivative market is used to hedge, ex ante, the uncertain loan revenues. The purpose of hedging is to stabilize the consumption path through a reduction in the variability of the wealth accumulation path. The magnitude and the direction of hedging are determined by the preferences, the risk premium and the variance.

Credit derivatives are an important financial instrument in which banks and financial intermediaries, without transferring their portfolio or reducing their portfolio concentration, can buy into their risk of each other. The bartering of risks in such bilateral transactions is enforced through marketable contracts. The credit risk inherent in a portfolio can be securitized and sold in the capital market like any other capital market security. The important underlying economic insight hereby is that the concept of credit derivatives and securitization have joined together to make risk a tradeable commodity enhancing the usage of viable hedging strategies.

Our analysis is not limited to credit derivatives. Any tradeable financial asset will do. In particular, a so-called macro derivative could serve as a substitute for a missing credit derivate (see e.g. Wilson (1998) and Broll et al. (2004)). The effectiveness of the financial instrument to hedge against credit risk crucially depends on the correlation structure between credit risk and the hedge instrument.

However, some simplification has been made and it seems worthwhile to address some direction for further research. First, due to the fact that most of the credit derivatives deal with low credit risk profiles of their entities extraordinary default events have been neglected. One possible way to extend the model is to implement jump arguments. Second, while great stress has been laid on credit risk due to deterioration this deterioration is growing in the long run. Consequently, it seems worthwhile to expand the research toward considering advanced term structure models, e.g square-root mean reverting structures of the loan rate.

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