A Structure-Break Option Framework for Bank Margin Valuation When Foreign-Denominated Loans Squeezing a Country

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Abstract: The banking industry is recently experiencing a renewed focus on retail banking, a trend often attributed to the stability and profitability of retail activities (Hirtle and Stiroh, 2007). This paper examines operations management in bank interest margin when foreign-denominated loans are squeezing a country as its currency falters. In a call-option model with fat-tail distribution framework where structural changes from exchange rate depreciated dramatically are the source of uncertainty (we call such changes bad events), exchange rates or bad events have direct effects on the bank's optimal interest margin. A depreciation in the domestic currency results in an increased interest margin. We conclude that retail banking may be a relatively shrinking lending activity but it is a high return one when an observed bad event from the domestic-currency depreciation is becoming worse.

Key-words: Bank Interest Margin, Retail Banking, Exchange Rate, Structural Change.

1 Introduction

The banking industry has undergone considerable changes over the last two decades in response to major deregulation, financial innovation, and technological advance (Hirtle and Stiroh, 2007). From a

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diversification perspective, a major strategic shift in the late 1990s was the move to create more diversified financial service banks that could reap cross-selling and diversification gains in a more deregulated environment. As pointed out by Hirtle and Stiroh (2007), the focus on the diversification operations management, however, was short-lived. A report by Matlack and Scott (2008) illustrates that foreign-currency loans are popular in developing countries because they offer lower interest rates than those in local currencies. In Romania, for instance, foreign currency loans run as low as 8%, vs. 10% or more for loans in lei, the Romanian currency. But a problem is that borrowers' loans are in euros while their incomes are in lei, which is off by 12% against the euro in the past year. Foreign-denominated loans are squeezing a country as its currency falters. Concern about bank loan quality has promoted banks to adopt prudential operations management in retail banking. This paper examines the relationships among exchange rate, structural change (bad event related to domestic currency falter), and the optimal bank interest margin. Since changes in exchange rate and bad event can affect bank margins and thus bank profits and risks, our results address bank operations management in retail activities related to these two issues.

Our primary emphasis is the selection of the bank's optimal interest margin, which is the difference between the rate of interest the bank charges borrowers and the market rate the bank pays to depositors. The literature on the determination of bank interest margin is scarce but important for the return to retail banking (Hirtle and Stiroh, 2007). McShane and Sharpe (1985), and Allen (1988) have developed models of bank interest margins based on the bid-ask spread model of Stoll (1978). Zarruk and Madura (1992), and Wong (1997) have developed models where assume a setting in which the bank is subject to prevailing regulatory parameters and multiple sources of uncertainty, respectively. Unlike previous formulations, the model developed here uses Merton's (1974, 1977) setting in which a bank's equity return can be view as a call option on its risky-asset portfolio value with a strike price equal to the face value of its net obligations, which is the deposit debt net of default-free liquid asset value. The principal advantage of our approach is the explicit treatment of bank interest margin operations management that integrates the risk considerations of the portfolio-theoretic approach with the market conditions and loan rate-setting behavioral mode of the firm-theoretical approach.

More specifically, the purpose of this

paper is to demonstrate that there is a fundamental difference between foreign loans and standard options on domestic loans. The standard option is a break-independent asset because its payoff depends on the underlying asset value only at one-price (domestic price) valuation, and not on the particular two-price (exchange rate) valuation. This means that the value of the standard option remains constant regardless of the rise or decline in foreign price recognized by break dependence within the framework of the option. In contrast, earning-asset portfolio including foreign loans are break-dependent options because their payoffs depend on the particular path followed by the underlying asset in a normal distribute with fat-tail distribution. It there is break dependence, a forced switch to break independence could lead to large inefficiencies.

The proposed conceptual framework can be expressed mathematically in the closed-form, structural-change call valuation model of Merton (1974). The primary feature distinguishing a structure-dependence call option valuation from a structure-independence one is the existence of a foreign-loan lending activity squeezing a domestic loan market which causes the inefficiency of the option valuation. Comparative static results show that the bank's optimal interest margin is an increasing function of the depreciated domestic currency in the retail banking. In addition, a volatility-preserving spread of the distribution of foreign currency loan loss (in the sense of fat tails of asset returns caused by significant exchange rate changes in Hansen (2001)) increases the bank's optimal interest margin.

One immediate application of this paper is to evaluate the plethora of lending operations management as alternatives for future loans in the return to retail banking. The results suggest that decisions on bank interest margins depending on lending operations practices contribute to the bank's success. In particular, one frequent suggestion for the bank's increasing its profits is to hold foreign loans rather than domestic loans when the domestic currency is depreciated (or the foreign currency is appreciated) dramatically. This paper provides explanations why this suggestion should be expected.

This paper is organized as follows. Section 2 develops the basic structure of the model. Section 3 derives the solution of the model and the comparative static analysis. The final section presents the conclusions.

2 The Model

Consider a single-period $t \in [0, 1]$ model of a retail banking firm. The bank's objective is to set its loan rate to maximize the expected value of equity return, which is the residual value of the bank after meeting all obligations:

$$E = \max[0, V + (1+R)B - (1+R_D)D]$$

subject to $L + X + B = D + K$ (1)

The objective setting of equation (1) is explained in details as follows:

First, at $t = 0$, the bank accepts D dollars of deposits. The bank provides depositors with a rate of return equal to the riskless market rate R_D.[1]

Second, equity capital K held by the bank is tied by regulation to be a fixed proportion q of the bank's deposits, $K \geq qD$. The required capital-to-deposits ratio is assumed to be an increasing function of amounts of domestic-currency and foreign-currency loans, L and X, respectively, held by the bank at $t = 0$, $\partial q / \partial L = \partial q / \partial X = q' > 0$. (see Zarruk and Madura, 1992; Lin, Lin, and Jou, 2009a).

Third, the bank makes term loans L and X at $t = 0$ and are paid off at $t = 1$. The interest rate on the domestic currency loans is R_L. We assume that the bank has some market power in domestic currency lending (see Cosimano and McDonald, 1998) which implies that $\partial L(R_L) / \partial R_L < 0$.[2] The assumption of market power is only to limit the scale of domestic currency lending activities. With the foreign currency loans, the initial exchange rate is equal to one and the market interest rate is R_X.[3] At $t = 1$, the borrowers agree to pay $s(1+R_X)X$ in terms of domestic currency at their own exchange rate risk, where s is the expected exchange rate measured as the ratio of domestic currency / foreign currency, for instance, lei / euros. A depreciation in the lei is expressed as $ds > 0$. We further demonstrate the risky-asset portfolio diversification expressed as $\partial X / \partial R_L > 0$. As a result, the bank's risky-loan repayments at $t = 1$ can be expressed as $V = (1+R_L)L + s(1+R_X)X$ in objective (1).

[1] The bank is fully insured and it pays a zero insurance cost. An analysis of the effect of deposit insurance costs on the risk-taking incentives of banks is unimportant for our purposes, so this abstraction is sufficient. For considering the impact on the bank's loan rate from changes in the deposit insurance premium, see Zarruk and Madura (1992).

[2] The assumption of market power is only to limit scale of lending activities, and an assumption, for example, about borrower acceptance issue discussed by Asosheha, Bagherpour, and Yahyapour (2008) is unimportant for our purposes. So this simple reduced-form approach is sufficient.

[3] Relatively speaking, the bank takes the loan rate R_X determined in the foreign loan market since foreign banks find themselves facing stiffer competition facing much stiffer competition from local banks (Damanpour, 1986). Further, for convenience, we follow O'Hara (1990) and set the initial exchange rate equal to one.

Forth, in addition to term loans, the bank can also hold an amount B of liquid assets, for example, central bank reserves or Treasury bills, on its balance sheet during the period horizon. These assets earn the security-market interest rate of R.

Fifth, the balance sheet constraint of equation (1) captures the bank's liquidity management in retail banking since the total assets in the left-hand side are financed by demandable deposits and equity capital in the right-hand side.

As noted by Santomero (1984), the choice of an approach goal in modeling the bank's optimization problem remains a controversial issue. Much of the literature follows Black and Scholes (1973) and Merton (1974) by viewing the market value of bank equity as the standard call option on the underlying assets with exercise price equal to the promised payment of liabilities (for example, see Lin, Chang, and Lin, 2009a, b). In place of the conventional view of bank equity as a standard call option, we apply Lin, Lin, and Jou (2009b) and investigate that the bank's objective is to set R_L to maximize the market value of its equity further with the break-dependence framework.

As mentioned previously, there are three investment opportunities of the bank's earning-asset portfolio: one instantaneously riskless and the remainder risky. The effect of structural break changes is divided into two parts. One is from the effect on the mean of risky-asset portfolio returns; the other part is to affect risky-asset portfolio volalities. When structural breaks are known as foreign-denominated loans squeezing a domestic loan market, this objective can tractably disclose the impact of the event on the contingent claim pricing. Specifically, the vector of instantaneous net returns on the investment opportunities of objective (1) follows dynamics and discontinuity:

$$\begin{pmatrix} dV = (\delta - \alpha(s))Vdt \\ \qquad + (\sigma - \beta(s))dW \\ dZ = \mu Z dW \end{pmatrix} \tag{2}$$

where

$$Z = \frac{(1+R_D)K}{q} - (1+R)[K(\frac{1}{q}+1) - L - X]$$

In vector (2), the drift coefficients $\mu \equiv (\mu_1, \mu_2)^T$ illustrating domestic and foreign-currency loans, respectively, the volatility matrix $\sigma \equiv \{\sigma_{ij}, i = 1, 2; j = 1, 2\}$, and the spread rate $\mu = R - R_D$ might be break dependent. W is a standard Wiener process. $\alpha(s)$ and $\beta(s)$ are the parameter differences between with and without structural changes from exchange rate falter in the mean and volatility of V, respectively. The expectation $(E^{\rho}(\cdot))$

and variance ($Var(\cdot)$) of V under the probability measure are calculated as follows:

$$E^{\rho}(dV/V|\ \alpha(s)=0, \beta(s)=0) = \delta dt$$

$$Var(dV/V|\ \alpha(s)=0, \beta(s)=0) = \sigma^2 dt$$

$$E^{\rho}(dV/V|\ \alpha(s)\neq 0, \beta(s)\neq 0) + \delta$$
$$= \alpha(s)dt$$

$$\sqrt{Var(dV/V|\ \alpha(s)\neq 0, \beta(s)\neq 0)} + \sigma dt$$
$$= \beta(s)dt$$

There are the following cases where vector (2) can be simplied. First, when the structural changes do not happen ($\alpha(s)=0$ and $\beta(s)=0$), V follows a geometric Brownian motion. Second, when the structural changes take place with $\alpha(s)=\delta+1$ and $\beta(s)=\sigma$, V is equal to zero. Third, $0<\alpha(s)<\delta+1$ and $0<\beta(s)<\sigma$ represent the structural changes in the mean and volatility make V be lower, respectively, meaning bad events. Contrary, $\alpha(s)<0$ and $\beta(s)<0$ stand for good events which can enlarge V. It should be noted that while our model in the following section is based on the third case of a bad event of the structural change from the domestic currency depreciated dramatically as mentioned in the Introduction section, we have of $\partial(dV/V)/\partial s<0$. Accordingly, we have $\partial\alpha/\partial s>0$ and $\partial\beta/\partial s>0$.

Given vector (2), the expected equity value of the call option with structural break framework in the risk-neutral state is $\hat{E}=\hat{E}(\max[0, V-Z])$. From the risk-neutral valuation argument, the call option price E is the value of this discounted at the riskless difference rate μ, that is, $E=e^{-\mu}\hat{E}$, where $\ln V \sim \phi(\cdot)$, denoting a normal distribution of fat tails with mean $\ln V+\mu-(\sigma+\beta(s))^2/2$ and standard deviation $\sigma+\beta(s)$.

In light of previous work, the bank's objective can be specified as:

$$\underset{R_L}{Max} \quad E = VN(d_1) - Ze^{-\mu}N(d_2) \qquad (3)$$

where

$$d_1 = \frac{1}{\sigma-\beta(s)}(\ln\frac{V}{Z}+\mu+\frac{1}{2}(\sigma-\beta(s))^2]$$
$$d_2 = d_1 - (\sigma-\beta(s))$$

$N(\cdot)=$ the cumulative density function

3 Solution and Results

Partially differentiating equation (3) with respect to R_L , the first-order condition is given by:

$$\frac{\partial E}{\partial R_L} = \frac{\partial V}{\partial R_L}N(d_1) + V\frac{\partial N(d_1)}{\partial d_1}\frac{\partial d_1}{\partial R_L}$$
$$-\frac{\partial Z}{\partial R_L}e^{-\mu}N(d_2) - Ze^{-\mu}\frac{\partial N(d_2)}{\partial d_2}\frac{\partial d_2}{\partial R_L} = 0$$
$$(4)$$

To simplifying equilibrium condition (4), we have

$$d_2^2 = d_1^2 + (\sigma - \beta(s))^2 - 2d_1(\sigma - \beta(s))$$
$$= d_1^2 - 2(\ln\frac{V}{Z} + \mu)$$

Using Hull (1993), we can have the following approximation:

$$\frac{\partial N(d_2)}{\partial d_2} = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}[d_1^2 - 2(\ln\frac{V}{Z} + \mu)]}$$
$$= \frac{\partial N(d_1)}{\partial d_1} \frac{V}{Ze^{-\mu}} > 0$$

Accordingly,

$$Ze^{-\mu} \frac{\partial N(d_2)}{\partial d_2} \frac{\partial d_2}{\partial R_L} = V \frac{\partial N(d_1)}{\partial d_1} \frac{\partial d_1}{\partial R_L}$$

where

$$\frac{\partial d_2}{\partial R_L} = \frac{\partial d_1}{\partial R_L} \neq 0$$

As a result, equilibrium condition (4) can be restated as:

$$\frac{\partial E}{\partial R_L} = \frac{\partial V}{\partial R_L} N(d_1) - \frac{\partial Z}{\partial R_L} e^{-\mu} N(d_2)$$
$$= 0 \qquad (5)$$

where

$$\frac{\partial V}{\partial R_L} = [L + (1 + R_L)\frac{\partial L}{\partial R_L}] + s(1 + R_X)\frac{\partial X}{\partial R_L}$$

$$\frac{\partial Z}{\partial R_L} = [\frac{(R - R_D)Kq'}{q^2}$$
$$+ (1 + R)](\frac{\partial L}{\partial R_L} + \frac{\partial X}{\partial R_L})$$

To ensure that a unique maximization is obtained, assume that $\partial^2 E / \partial R_L^2 < 0$.

In equation (5), the term associated with $N(d_1)$ represents the bank's risk-adjusted value for marginal risky-asset repayment of loan rate, while the term associated with $N(d_2)$ represents the bank's risk-adjusted value for marginal net-obligation payment. The term $\partial L / \partial R_L < 0$ is in general insufficient to be offset by the term $\partial X / \partial R_L > 0$ because of the risky-asset portfolio diversification characteristics. The marginal net-obligation payment is then negative. The sign of the marginal risky-asset repayment is negative based on the first-order condition. The equilibrium condition demonstrates that the bank maximizes the market value of its equity return anticipating resolution in the loan rate determination.

Consider next the impact on the bank's loan rate (and thus on the bank's margin) from changes in exchange rate. Implicit differentiation of equation (5) with respect to s yields:

$$\frac{\partial R_L}{\partial s} = -\frac{\partial^2 E}{\partial R_L \partial s} / \frac{\partial^2 E}{\partial R_L^2} \qquad (6)$$

where

$$\frac{\partial^2 E}{\partial R_L \partial s} = \frac{\partial^2 V}{\partial R_L \partial s} N(d_1) + \frac{\partial V}{\partial R_L}(1 - \frac{VN(d_1)}{Ze^{-\mu} N(d_2)}) \frac{\partial d_1}{\partial s} - \frac{\partial Z}{\partial R_L} e^{-\mu} \frac{\partial N}{\partial d_2} \frac{\partial \beta}{\partial s}$$

$$\frac{\partial^2 V}{\partial R_L \partial s} = (1 + R_X) \frac{\partial X}{\partial R_L} > 0$$

$$\frac{\partial d_1}{\partial s} = \frac{1}{\sigma - \beta} [\frac{\partial \beta}{\partial s} d_2 + \frac{(1 + R_X)X}{V}] > 0$$

An explanation of the results of equation (6) is possible in terms of $\partial^2 E / \partial R_L \partial s$, the impact on $\partial E / \partial R_L$ from changes in s. The first term of this impact, the term associated with $N(d_1)$, represents the mean profit effect. The sign of this first term is positive. The second term of this impact, the term associated with $\partial d_1 / \partial s$, captures the variance or risk effect. The sign of this second term is positive since we have $\partial V / \partial R_L < 0$ and $\partial d_1 / \partial s > 0$. The third term of this impact, the term associated with $\partial \beta / \partial s$, demonstrates the structural change effect. If the structure change in the volatility makes the bank's risky assets be lower, meaning the bad event, then the sign of this third term is negative since we have $\partial Z / \partial R_L < 0$ and $\partial \beta / \partial s > 0$. Consequently, the sign of the term $\partial^2 E / \partial R_L \partial s$ is positive, and then a depreciation in domestic currency increases the bank's interest margin. Basically, a depreciation in domestic currency relative to foreign currency encourages the bank to shift investments to its foreign currency loans from domestic currency loans. If domestic loan demand is relatively rate-elastic, larger foreign currency loans are possible at an increased margin.

One intriguing case is that d_1 occurs when the ratio of the value of risky assets to net obligations is greater than 1, or its log is positive. The d_1 tells us by how many standard deviations with structural changes from exchange rate falter in the volatility of risk assets the log of this ratio needs to deviate from its spread μ. Notice that the value of the call option in equation (3) does not depend on $\delta - \alpha$ but on $\sigma - \beta$. We further consider the impact on the bank's interest margin from changes in β. Implicit differentiation of equation (5) with respect to β yields:

$$\frac{\partial R_L}{\partial \beta} = -\frac{\partial^2 E}{\partial R_L \partial \beta} / \frac{\partial^2 E}{\partial R_L^2} \qquad (7)$$

where

$$\frac{\partial^2 E}{\partial R_L \partial \beta} = \frac{\partial V}{\partial R_L}(1 - \frac{VN(d_1)}{Ze^{-\delta} N(d_2)}) \frac{\partial d_1}{\partial \beta} - \frac{\partial Z}{\partial R_L} e^{-\delta} \frac{\partial N(d_2)}{\partial d_2}$$

$$\frac{\partial d_1}{\partial \beta} = -\frac{d_2}{\sigma + \beta} < 0$$

The interpretation of equation (7) follows a similar argument as in the case of a change in s. The first term on the right-hand side of $\partial^2 E / \partial R_L \partial \beta$ can be interpreted as the variance effect, while the second term can be interpreted as the structural change effect on $\partial E / \partial R_L$ from changes in β. Both the variance effect and the structural change effect are negative in sign. When the variance effect is less significant than the structural change effect, meaning that the break event is crucial, the term $\partial^2 E / \partial R_L \partial \beta$ is positive in sign. We then can state that the less domestic currency loans and the larger foreign currency loans are possible at an increased loan rate (and thus an increased margin) when the bad event becomes worse. As the bank anticipates the bad event caused by domestic currency depreciated dramatically becoming worse, it must now provide a return to a larger variance based. One way the bank may attempt to augment its total returns is by shifting its investments to its foreign currency loans and away from its domestic currency loans. If domestic loan demand is relatively rate-elastic, a larger foreign currency loans are possible at an increased margin.

4 Conclusion

The results imply that changes in exchange rate and structural changes in a domestic exchange rate falter environment have a direct effect on the bank's optimal interest margin. These results demonstrate the importance for operations management in retail bank lending activities. In particular, when foreign-denominated loans are squeezing countries as their currencies falter, a depreciation in the domestic currency benefits banks but harms borrowers if margin management in bank lending activities is operated properly. Furthermore, if the squeezing situation becomes worse, the results yield as above though banks operate less risky lending activities.

Of course, other factors besides foreign-denominated loans would squeeze countries. Strategic operations management in bank lending may play a very important role, as would more extreme problems of macroeconomic changes. For example, in Turkey, its trade deficit is alarmingly high, and investors have been dumping the lira (Matlack and Scott, 2008). Such concerns are beyond the scope of this paper and so not addressed here. What this paper does demonstrate, however, is the important role played by loan structure in affecting bank profitability and risk management.

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