* **Draft**

Bank Default Risk and Capital Regulation: Evidence from Jamaica

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ABSTRACT

This study extends the economic framework used by Bichsel and Blum (2002) in examining the relationship between bank capital and default risk. An option-based default metric is computed for Jamaican banks using a Merton-type model. This indicator accurately tracks the default experience for Jamaican banks over important periods in the 1996 to 2004 sample. However, the study does not uncover a significant relationship between either bank capital and asset risk or bank capital and the likelihood of default. Additionally, contrary to previous research, it is found that a higher volatility in equity prices is associated with a lower default probability. This may be explained by the fact that, during the sample period, higher bank equity volatility has occurred in instances of an upward trend in bank share prices.

Keywords: market discipline, bank capital, default risk

JEL Classification Numbers: G21, G28

1. Introduction

It is a widely accepted fact that risk-taking behaviour is a requisite feature of banks given the nature of their asset transformation role. Bank leverage, measured by the capital-asset ratio, represents the extent to which the risk in assets is covered. Assuming the bank's asset value is allocated between equity and zero-coupon debt, Merton (1974) proposed that equity and debt could be viewed as European-type options on a bank's asset. Bank equity prices contain useful information about the market's forecast of the bank's asset risk. In particular, a bank's equity has embedded option characteristics, which may be valued using the Black-Scholes (1973) and Merton (1974) option-pricing framework. This framework utilizes equity prices to extract important market information on banks' risk that is not contained in historical balance sheet information. In this study, equity prices for publicly listed Jamaican banks are used to compute an option-based default indicator. It is discovered that the evolution of the indicator accurately reflects the onset of bank fragility during the sample period. This provides support for its use by the Bank of Jamaica to supplement available accounting information in its 'early warning' assessment of banking sector crisis.

Some recent empirical studies concerning banking sector fragility in both developed and developing countries provide evidence that greater capital requirements may have the unintended effect of inducing banks to increase their risk exposure. Since capital is costly, banks may incur higher risks in order to maximize the return on equity. The regulatory intent, however, is that capital regulation will not only be binding, but will result in banks taking on less risk, as opposed to increasing risk levels to maximize profitability. Therefore, a 'buffer stock' effect is desired for regulative purposes. This achieved when the banks incentives to minimize its default risk decreases with the amount of costly capital it risks losing in the event of a default.

Bichsel and Blum (2002) derive the market value of assets for publicly listed Swiss commercial banks and the associated default risk indicator using Merton's option pricing framework. They then estimate a simultaneous equation system using two-stage least squares to examine the impact of capital on the banks' risk-taking behaviour. They measure risk as the volatility per unit of the market value of assets and an option-based measure of the probability of default.

This paper provides an important variation of the Bichsel and Blum (2002) study, which found a positive relationship between bank capital and risk taking for Swiss banks based on data between 1990 and 2002. In particular, this paper strengthens their original economic and empirical framework. A critical drawback of their study is the inclusion of the capital to assets ratio as an exogenous variable, which underpins the assessment of banks' risk-capital relationship, is likely to induce an endogeneity bias in their two-equation system. Kopcke (2001) indicates that this problem is created because the capital ratio is itself a dependent variable in a wider simultaneous equation system and, as a consequence, this variable will be correlated with the errors in the equations. To address the endogeneity of this variable, Kopcke's idea to explicitly model the capital ratio the simultaneous equation system is adopted. The research design of the capital regression reflects factors which theory predicts are significant in the choice of capital. The choice of exogenous variables in this study includes proxies for market discipline such as a deposit insurance dummy variable and the relative deposit exposure to other banks. These variables typically reflect moral hazard in bank regulation. For instance, deposit insurance creates important incentive problems.[1] In particular, Furlong (1988) and others have examined whether the value of a bank is positively related to risk taking and the degree of leverage due to flat-rate deposit insurance.[2] Additionally, a bank will withdraw its deposits from other banks if it perceives an increase in their default risk.

Mullings (2003) provides important findings on banks' responses to leverage (capital to assets) and risk-based capital requirements in Jamaica. The study finds that banks prefer to maintain a high buffer on risk- based capital requirements so as to avoid regulatory costs. This suggests that regulatory capital requirements are binding for banks. In addition there is weak evidence that these regulations generated a credit crunch owing to the comparative attractiveness of default free assets relative to risky assets (loans). However, this finding is biased by the fact that although the high-return Government of Jamaica bonds may contain significant credit risk, it is assigned a zero risk weight by

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[1] Using cross-country evidence on 61 countries, Demirguc-Kunt, Ash and Edward J. Kane (2001) presents findings that deposit insurance is associated with a greater probability of banking crisis.

[2] Using data for the US on 98 publicly trade bank holding companies (BHC) for the period 1975-1986, Furlong (1988) finds evidence to the contrary.

regulators. In the capital to assets requirement, however, the study finds that banks prefer to minimize the capital buffer.

The rest of the paper is organized as follows. The next section describes the empirical framework used to examine the empirical relationship between bank capital and default risk. Section 3 generates indicators of the publicly listed banks' unobserved market value of assets and default risk by modelling the banks' equity as a call option on their assets. Section 4 addresses some important concerns about the Bichsel and Blum (2002) economic framework and provides an explicit empirical variation of their model. This section also outlines the econometric methodology used in this study. The empirical results are presented in section 5. Section 6 provides some concluding remarks.

2. The Empirical Model

The specification used in this paper to model the relationship between bank capital and default risk in Jamaica is a variation of the approach proposed by Bichsel and Blum (2002) and Hovikimian and Kane (2000).

Equation (1) relates changes in the riskiness of bank assets, σ_V , to changes in the capital ratio at time t, c_t, and the volatility of the banks' stock index at time t, σ_{BSI_t}. Equation (2) relates the banks' default risk indicator, z_t, to the same exogenous variables specified in equation (1). However, the fact that the capital ratio itself represents default risk will introduce a bias in the simultaneous equation system.

This paper extends this two-equation system by adding equation (3) to account for the endogeneity of the capital ratio. By modelling the capital ratio explicitly and by estimating the system using an appropriate econometric technique,[3] the correlation between the capital ratios and the regression errors from equations (1) and (2) should be removed.

$$\Delta\sigma_t = \alpha_0 + \alpha_1\Delta c_t + \alpha_2\Delta\sigma_{BSI_t} + \varepsilon_t \quad (1)$$

$$\Delta z_t = \beta_0 + \beta_1\Delta c_t + \beta_1\Delta\sigma_{BSI_t} + \nu_t \quad (2)$$

[3] The three stage least squares (3SLS) estimation technique is used in this paper. 3SLS will be discussed in the section 4.

$$\Delta c_t = \gamma_0 + \gamma_1 \Gamma_t + \psi_t \tag{3}$$

The hypothesis underlying the specification of equation (3) is that banks choose their capital ratio as a function an exogenous vector of macroeconomic and microeconomic factors, Γ, which were chosen from a broad coverage of explanatory factors proposed by Nier and Baumann (2003). As mentioned earlier, the error terms ε_t, v_t and ψ_t are probably not independently and identically distributed. As noted by Kopcke (2001), the errors are likely to follow a mixed distribution with occasional jumps given that the risk of assets and the default risk indicator typically exhibit highly correlated and sudden changes in their levels and variances. Kopcke (2001) suggests that the inclusion of Γ could address these issues.

Positive values for α_1 and β_1 indicate that increases in bank capitalization are correlated with increases in the market's perception of bank risk and the probability of default risk, respectively. The correct estimation of these key coefficients are essential to the conclusions of this study.

3. The Application of Option Pricing Theory

From the perspective of bank capital regulation and bank risk, an important use of option pricing theory lies in the estimation of the market value of assets and its associated asset risk. Importantly, with the values derived from the Black-Scholes formula, a metric known as the distance-to-default can be constructed. This measures the number of standard deviations of the market value of bank assets from the 'default point'. The usefulness of this option theoretic framework in measuring banks risk lies in recognition that equity prices contain additional information on banks outside of balance sheet data.

Merton (1973) proposed the idea that the equity value of a firm can be modelled as a call option on its assets, with the book value of its liabilities being interpreted as the strike price (default point) of the option. Consider a firm with a simple capital structure containing equity, E, and zero coupon debt, X, which promises to pay D dollars at maturity date T. Equity holders have a junior claim on the bank's assets. The firm's market value at any point in time is: [4]

$$V_t = D_t + E_t$$

Option pricing theory may be used to frame the behaviour of investors holding the banks' debt and equity. In essence, bondholders can be viewed as owning the bank's assets and giving shareholders the option to repurchase the assets at maturity. However, the expiration date pay-offs are not without risk as depicted in Chart 1 below.

Chart 1. Payoffs for Equity and Debt Holders

	Case $V \leq X$	Case $V > X$
Debtholders	V	X
Shareholders	0	V – X
Sum of Stakeholders	V + 0 = V	X + V – X = V

When the debt matures at time, t, the value of the firm's assets may either lie above or below the value of its liabilities. The liabilities constitute a claim by debtholders with a maturity date of one year.[5] If the bank is in good standing at maturity, owner's equity will be $V - X$, which will make it profitable for them to exercise their option to purchase the firm. Alternatively, if the bank is insolvent, equity holders will surrender control of the bank to debtholders and incur losses equal to the amount of their investment. This model is described as a contingent claims model because the maturity pay-off is dependent on the solvency of the firm.

More generally, the value of equity on the date of debt maturity is

$$E = \max\ (0,\ V^T - X)$$

The asset value dynamics of firm may be modelled using an Ito process [6]

$$\frac{dV}{V} = \mu_V dt + \sigma_V dZ \tag{4}$$

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[4] The firm does not pay dividends

[5] As in Marcus and Shaked (1984), it is assumed that bank audits are conducted annually and in this way it is reasonable assume a debt maturity of one year.

[6] This model of asset price dynamics is also referred to as a geometric Brownian motion

where μ_V and σ_v are the instantaneous average return and instantaneous volatility of the firm's assets, respectively. The former is a deterministic drift component and the latter is random diffusion component. The change dZ is called a Weiner process with a drift rate of zero and a unit variance. Asset prices are assumed to exhibit a stochastic process, which may be accurately captured by the above stochastic differential equation. With knowledge about the process followed by equities, the stochastic process of any option with the same underlying asset is also known. This link paves the way to computing the market value and market volatility of the bank's assets.

According to the Black and Scholes (1973) and Merton (1974) option pricing theory, the equity call option written by debt holders to shareholders may be valued by solving the following second-order linear partial differential equation (PDE):

$$\frac{\partial E}{\partial t} = rE - rV\frac{\partial E}{\partial V} - \frac{1}{2}\sigma^2 V^2 \frac{\partial^2 E}{\partial V^2}$$

subject to the boundary conditions:

$$E(V_T, T) = Max[V^T - X, 0] \text{ and } E(0,t) = 0\,.$$

The unique solution to this PDE is the celebrated Black-Scholes-Merton option pricing formula:

$$E = VN(d_1) - Xe^{-rT}N(d_2)$$

where

$$d_1 = \frac{\ln(V/X) + (r + \sigma_v^2/2)T}{\sigma_V\sqrt{T}}$$

$$d_2 = \frac{\ln(V/X) + (r - \sigma_v^2/2)T}{\sigma_V\sqrt{T}} = d_1 - \sigma_v\sqrt{T}$$

Assuming a debt maturity of one year ($T = 1$), the Black-Scholes-Merton formula is rewritten as:

$$E = VN(d_1) - XN(d_2) \tag{5}$$

where

$$d_1 = \frac{\ln(V/X) + \sigma_v^2/2}{\sigma_V}$$

$$d_2 = \frac{\ln(V/X) - \sigma_v^2/2}{\sigma_V} = d_1 - \sigma_v$$

Additionally, from equation (4), the value of assets at maturity is lognormally distributed as expressed by the following equation:

$$\ln V^T \sim N[\ln V + (\mu_V - \frac{\sigma_V^2}{2})T,\ \sigma_V \sqrt{T}]$$

where $N(\bullet)$ denotes the cumulative normal probability density function, r ,is the risk free interest rate used to discount the bank's debt and T is the time remaining until maturity of the debt.

One of the assumptions underlying the Black-Scholes-Merton model is that asset returns are constant and invariant over the option's duration. This assumption yields a risk neutral probability measure in the sense that the average return of asset, μ_V, is replaced with riskless rate, r. The principle of risk neutral valuation is a key concept underlying the Black-Scholes-Merton model. It reflects the idea proposed by Merton that a portfolio of stocks and options with a riskless payoff must also earn the risk free rate.[7]

Given the assumption on the continuous time process followed by the equity process, stochastic calculus is applicable to the derivation of the option's properties. By Ito's Lemma, the volatility of the diffusion component of E is:

$$\sigma_E E = \sigma_V V \frac{\partial E}{\partial V} = \sigma_V V N(d_1) \tag{6}$$

Values for V and σ_V, the unobservable parameters for bank's asset value and volatility of assets, respectively, can be found by solving (5) and (6), simultaneously. These values are inputs in the calculation of the probability of default.

Studies, including Boyd and Graham (1986) and Furlong (1988), have derived a default indicator based on the probability that some measure of profitability falls below the capital position of a firm. Since the default indicator is expressed in standard

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[7] This riskless rate, which may be approximated by the yield on Treasury Bills, was also shown to be independent of investors' risk preferences. This synthetic portfolio is a theoretical construct, which uses option contracts to perfectly hedge the risk associated with the price volatility of financial assets.

deviation terms, it provides a measure of the number of standard deviations that the asset returns would have to fall below the default point.[8] As discussed earlier, Gropp *et al* (2001) and Bichsel and Blum (2002) improves on this risk indicator by incorporating the option value of equity. They use equity prices and balance sheet data to compute an option-based bank vulnerability indicator.

By the lognormal assumption, the asset returns dynamics in equation (4) may be rewritten as:

$$\ln V^T = \ln V + (r - \frac{\sigma^2}{2})T + \sigma_V \varepsilon \sqrt{T} \tag{7}$$

where ε represents the uncertainty component and is a random drawing from a standard normal variate, $\phi(0,\ 1)$. In an option theoretic framework, the default point is set equal to the nominal value of total liabilities. At maturity, the distance from the default point is $d = \ln V^T - \ln X$. Using this metric, a bank is considered to have defaulted if the value of its assets falls below the default point. That is:

$$\begin{aligned}
\Pr\left(\ln V^T - \ln X < 0\right) &= \Pr\left(\ln V + (r - \sigma^2/2)T + \sigma_v \varepsilon \sqrt{T} - \ln X < 0\right) \\
&= \Pr\left(\frac{\ln V/X + (r - \sigma^2/2)T}{\sigma_v \sqrt{T}} + \varepsilon \sqrt{T} = z < 0\right) \\
&= \Pr\left(-\frac{\ln V/X + (r - \sigma^2/2)T}{\sigma_v \sqrt{T}} - \varepsilon \sqrt{T} = z < 0\right)
\end{aligned}$$

The risk neutral probability of default is given by $N(-z)$, where z is expressed as:

$$z = -\frac{\ln(V/X) + \sigma^2/2}{\sigma_v} \tag{8}$$

The standard normal variate, z, is the default measure, which indicates the probability that that a variable, defined by the above asset value process, falls below the default point.

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[8] Furlong (1988) improved on the approach of Graham (1986) by using estimates of the market value of standard deviation of equity returns and standard deviation of asset returns in the computation of Z values instead of book values.

4. Data, Estimation Design and Market Based Indicators

4.1 Data

Monthly bank equity prices and balance sheet data were obtained from the Jamaica Stock Exchange and the Bank of Jamaica's Bank Supervisory System (BSS), respectively. The sample is comprised of 10 publicly listed banks over the period January 1996 to March 2004. The banking sector experienced a financial distress during the period 1996 to 1998, with systemic weaknesses enduring into 2001. Observations on three publicly listed banks in default during the sample period permitted an assessment of the usefulness of market-based indicators to signal the onset of banking fragility. Since the sample also includes observations on the merger of failed banks, as well as bank acquisitions, the issue of survivorship bias does not arise. As at March 2004, the sample represented 76 per cent of banking system assets or 7 banks in the population of 17 banks.[9] On the whole, the sample selection is representative of the banking system in Jamaica and permits broad inferences about the risk in banks' portfolios based on equity performance.

Following Bichsel and Blum (2002), the capital positions are measured using both book value and market value data. Book value capital, c_{BV}, is defined as book value capital to total assets. Capital includes capital paid-up and assigned, share premium, reserves, retained earnings and unappropriated profits. Similarly, market value capital, c_{MV}, is computed as the market value of assets minus total liabilities divided by the market value of assets.

The research design for the capital regression reflects key variables chosen from a broad coverage of explanatory factors proposed by Nier and Baumann (2003). Banks' capital choice is also assumed to be influenced by exogenous changes in the market share ($Share$), the six-month Treasury Bill rate ($TBill$), and the capitalized charter values (Q).[10] Market share is defined as a listed bank's asset size divided by total assets of listed

[9] The population of banks includes commercial banks, merchant banks and building societies, but omits credit unions, which constitute a relatively small share of the financial system asset base.

[10] Consistent with the explanation of Nier and Baumann(2003), it is appropriate to treat a banks' market share as being exogenous over a short horizon such as a year since it unlikely to be able to influence its industry position within this period. However, over longer time horizon, banks will be able to exert greater control.

and unlisted commercial banks and merchant banks. The proxy for banks' charter value is given by the market value capital to equity.[11] Based on the hypothesis as originally formulated by Keely (1990), large charter values are derived from banks' market power, which is assumed to be positively related to their capital ratio. In accordance with theory, market discipline effects are presumed to be important in influencing bank behaviour. The presence of an explicit deposit insurance scheme ($DepIns$) and the deposit exposure to other commercial banks ($DepRatio$) represent proxy variables for the strength of market discipline. Market discipline imposed by investors in the inter-bank market is expected be greater, the higher the liability exposure, particularly given the absence of insurance for inter-bank deposits.[12]

4.2 Estimation Design

The estimation steps to estimate the relationship between bank capital and default risk are outlined as follows:

1. First, the following system of two non-linear equations is solved using the Newton-Raphson algorithm to derive the unknown variables consisting of the market based assets value, V, and volatility, σ_V, for the publicly listed banks in the Jamaican banking sector. The minimization problem is expressed as:

$$\begin{aligned} &Min\ (|\lambda_1^2+\lambda_2^2|) \\ &s.t.\ \sigma_V, V \geq 0 \end{aligned} \tag{9}$$

where

$$VN(d_1)-DN(d_2)-E=\lambda_1$$

and

$$\sigma_E E-\sigma_V VN(d_1)=\lambda_2$$

The variable X, E, σ_E, T and r are determined exogenously.

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[11] Keely (1990) assumes that changes in capitalized charter values are reflected in market value changes, but not in book value changes. Thus, larger charter values are expected to be associated with higher market value capital to equity ratios.

[12] See discussion in Nier and Baumann (2003)

2. A three-equation system is then estimated using the appropriate simultaneous equation technique, as well as, V and σ_V from step 1. Noting that the variable $c_{i,t}$ in (10) reflects either book value or market value estimates of the capital ratio in the three-equation system is specified as: [13]

$$\begin{aligned}
&\Delta\sigma_{V_t} = \alpha_0 + \alpha_1 \Delta c_{i,t} + \alpha_2 \Delta\sigma_{BSI_t} + \alpha_3 \Delta TBill_t + \alpha_4 DepRatio + \alpha_5 Q_t + \alpha_6 Share_{i,t} + \alpha_7 DepIns_t + \varepsilon_t \\
&\Delta z_t = \beta_0 + \beta_1 \Delta c_{i,t} + \beta_2 \Delta\sigma_{BSI_t} + \beta_3 \Delta TBill_t + \beta_4 DepRatio + \beta_5 Q_t + \beta_6 Share_t + \beta_7 DepIns_t + \nu_t \\
&\Delta c_{i,t} = \gamma_0 + \gamma_1 \Delta TBill_t + \gamma_2 \Delta DepRatio_t + \gamma_3 \Delta Q_t + \gamma_4 Share_t + \gamma_5 DepIns_t + \psi_t
\end{aligned} \tag{10}$$

The sign and significance of coefficients α_1 and β_1 reflect the influence of the capital ratio on bank default risk.

4.3 Market-Based Indicators

As illustrated in the left panel of Chart 2, the occurrence of a financial sector crisis during the period 1996 to 1998, dominated the movements in the average book value and market value capital ratios for banks in the sample. The market value of capital ratio exhibited significant volatility, fluctuating between positive and negative values, at least one year before the book value ratio became negative. This occurred around the onset of the banking crisis. Further, the market value of the capital ratio remained negative even after substantial capital injection by the Jamaica government to restore the book value capital ratio to positive values to lie within the regulatory requirement. The market value of capital ratio returned to positive value only in 2000, almost a year after the book value capital ratio had returned to positive values.

As exhibited in the right panel of Chart 2, proceeding the period of bank distress, the excess of market value over book value capital ratio change from negative to positive values. This excess steadily rose in the post 2000 period indicating a strengthening of buoyant market perception, especially in relation to the financial sector.

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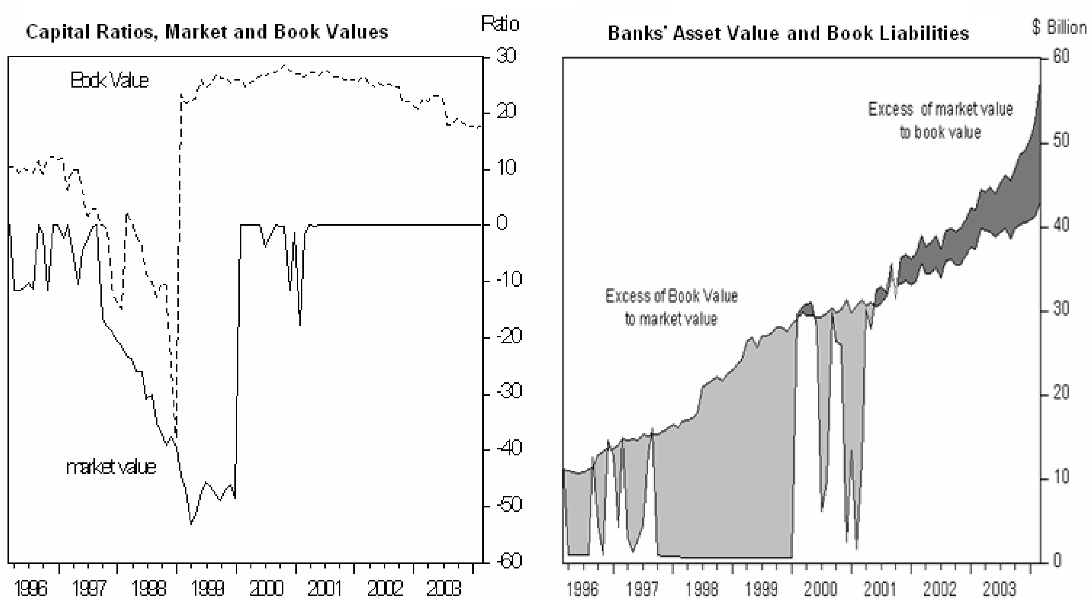
[13] Note that $c_{MV} = \dfrac{V - X}{V}$

Chart 2



The volatility estimates computed from equity prices and Black-Scholes-Merton asset prices are compared with the Jamaica Bank Index in Chart 3. Given that option-pricing theory attributes risk in equity to unobservable risk in assets, a graphical depiction of the relationship is informative. The left panel of Chart 3 reveals that significant equity volatility spikes are associated with upward jumps in bank equity prices.[14] One possible reason is that high volatility has been coupled with large capital gains during the sample period.

In contrast the right panel of Chart 3 reveals that significant option-implied asset volatility spikes appear to be positively correlated with downward jumps in bank equity prices.[15] This finding is consistent with theory because asset volatility spikes, which reflect the market perception, seem to correctly anticipate a build-up of bank risk and the occurrence of failures. This suggests that option implied asset volatility is an ideal proxy for the market assessment of asset default risk.

[14] That is, there is a close correspondence between high volatility in share prices and bank's upside profit potential.
[15] That is, there is a close correspondence between high implied volatility and bank's downside risk.

Chart 3. The Jamaica Bank Index, and Historical and Implied Volatility Estimates

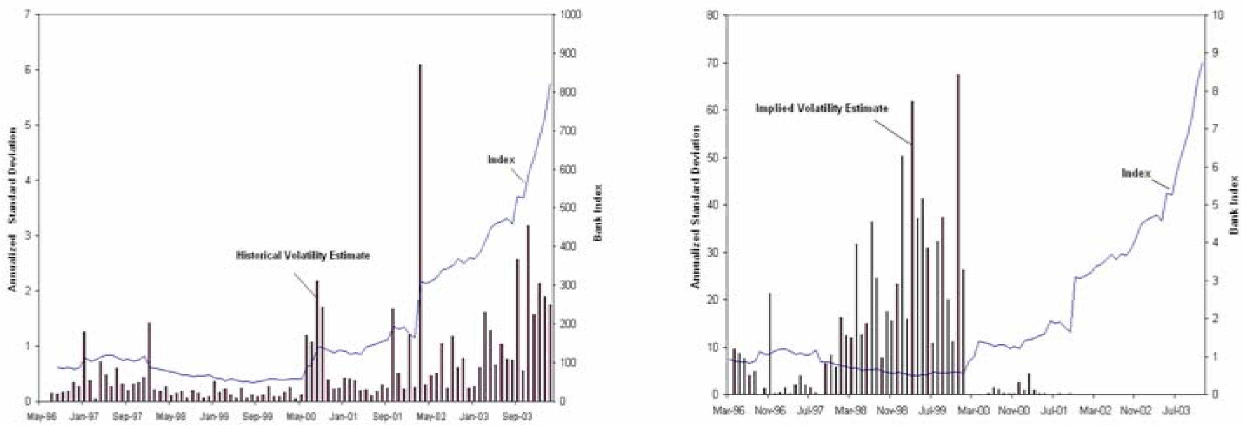


Chart 4. Default Risk Indicator

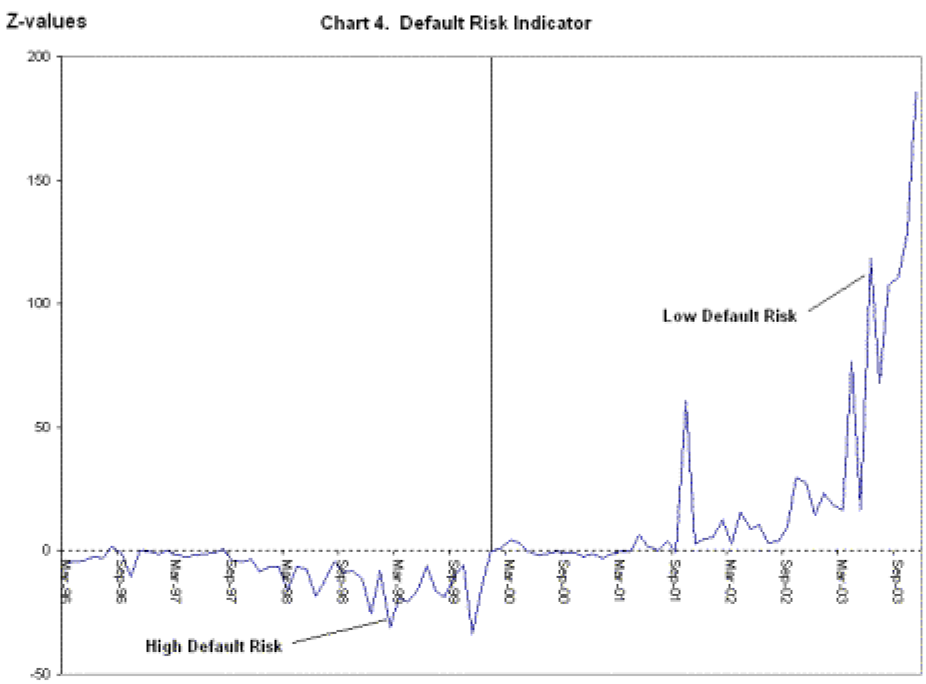
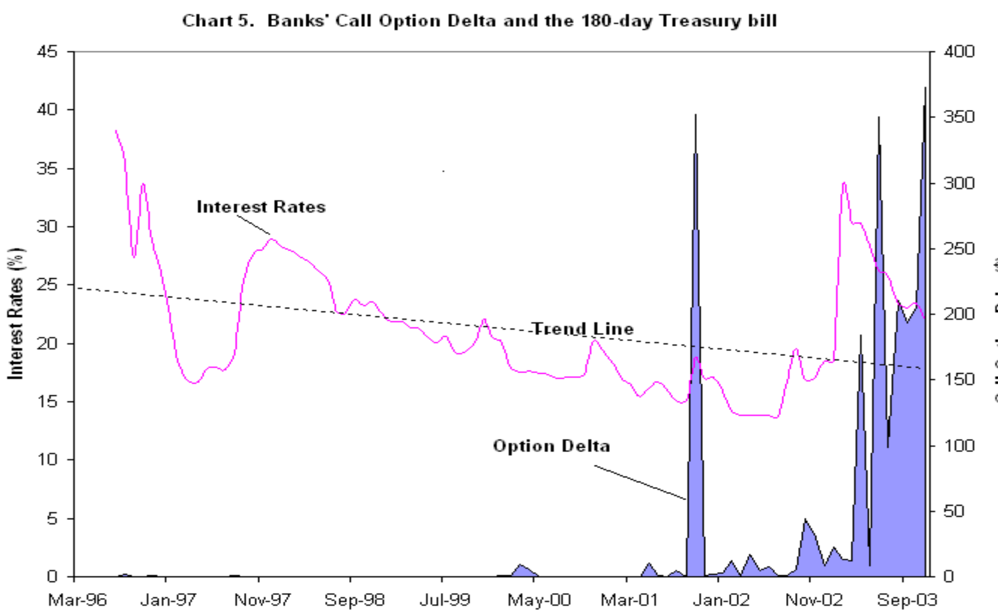


Chart 4 presents the option-based indicator of default. Higher z-values indicate a lower default risk. It is evident from the graph that the z-values correctly depict the highest default risk occurring in the crisis period and the lowest default risk taking place in the region of the recent equity price boom. Keely (1988) argues that the z-values will likely overestimate the risk of default if its computation includes observations on banks with a negative net worth. This caveat applies to the dataset since, in the period when the book value capital ratios for some banks were negative, the z-values were relatively low.[16]



The option delta for the bank index, as well as interest rates are reported in Chart 5. The delta reflects the values for the cumulative normal distribution ($N(d_1) = \partial E / \partial V$).[17] The unequal relationship between the value of the option and the value of banks' assets has

[16] Depositors' interest and confidence in the financial system were important reasons why authorities used the recourse of placing insolvent institutions under temporary management instead the closure option.
[17] Specifically, it is a dollar measure of the sensitivity of the equity call price to a change in the underlying stock price. On the assumption that banks have similar sensitivities for calls, it is possible to extrapolate the results at the bank level.

supported rising deltas.[18] As depicted in Chart 5, due to banks' strong upside profit potential in recent years, options written on banks' equity prices are more valuable to shareholders and this will be reflected in its price prior to the expiration date. The call option values are also a positive function of the rate of interest as shown by the jumps in call deltas coinciding with the upward adjustments in rates.

4.4 Deficiencies of the Framework

The measures of asset risk, the market value of assets and the default metric derived in the paper are based on a Black-Scholes-Merton interpretation of the liabilities of banks. However, this approach may not be entirely appropriate in describing the default risk and market value of banks' assets. Although Bischel and Blum (2002) identify some of these limitations, further discussion is useful.

The key assumptions of the option pricing method of log-normality, debt homogeneity, constant volatility and market efficiency may be flawed. First, the lognormality of assets is not unambiguously supported by empirical evidence. Kopcke (2001) argues that errors in the equation for asset risk and default probability may be characterized by a mixed distribution with occasional jumps. This is because risk in banking may be dominated by structural and unpredictable changes in markets. Second, it is assumed for simplicity that banks have a simple capital structure, characterized by a homogenous debt structure (i.e. zero coupon debt). In reality, the capital structure for banks is far more complex. Third, it is assumed that asset volatility, σ_V, will not change until the debt matures in one year. However, the time series behaviour of asset volatility suggests that it can be highly variable. Gizycki (1999) indicates that in an efficient market the market capitalization reflects the market net worth of firms (i.e. market value of asset less liabilities). If efficiency is an issue, then the estimate of the market's belief about future volatility may depart from its true value. Notwithstanding these caveats, the option-pricing framework is useful because it reflects forward looking information not contained in balance sheet statements.

[18] In contrast, Bichsel and Blum (2002) report that the option's delta is nearly constant for each Swiss bank at each point in time.

5. Estimation Results

Simultaneous equation bias due to misspecification and endogeneity problems are two important empirical concerns in the theoretical framework used by Bischel and Blum (2002). First, if their two-equation system (equation (1) and (2)) were not adequately specified, then estimation using two-step feasible generalized least squares would yield biased estimates. Second, there is an endogeneity bias due to the correlation between the endogenous capital ratios and the error terms of the two equations. In addressing these weaknesses a capital ratio equation was added to the system and the three-stage least squares (3SLS) estimation procedure was employed to account for the endogeneity bias. This addition is important to the results because it is based on a sounder economic framework. The results from the 3SLS estimation were then compared to the Seemingly Unrelated Related (SUR) regression results, which does not tale account of endogeneity problems.

Contemporaneous correlation in the errors may arise in simultaneous equation models due to the problem of misspecification. In the presence of contemporaneous correlation in the residuals, SUR is appropriate if all the regressors are exogenous. However, if any of the exogenously specified variables are, in fact endogenous, the 3SLS is the appropriate estimator. For comparison purposes, the SUR and 3SLS estimates are reported jointly.

5.1 The SUR Estimation Results

As shown in Tables 1 and 2, the SUR parameter estimates indicate statistically significant negative relationship between market asset volatility and both the book value and market capital ratios (see equation (1) in Table). This suggests that improvements in the capital ratio are unambiguously associated with reduced risk. Importantly, there is considerable difference in the magnitudes of the estimated parameters. The estimation using the book value measure of capital, c_{BV}, indicates that, on average, a one unit increase in the capital ratio associated with a 0.4 unit reduction in asset volatility. Using the market value measure, c_{MV}, a one unit increase in the capital ratio is, on average, associated with 57 unit reduction in asset volatility.

Table 1. Estimation Using the Book Value of Capital

Model	Equation 1		Equation 2		Equation 3	
	SUR Estimate	3SLS Estimate	SUR Estimate	3SLS Estimate	SUR Estimate	3SLS Estimate
Constant	0.6717	0.9894	-20.2647	0.7575	-0.0096	-0.0045
	(0.2958)	(0.4040)	(-0.8030)	(0.1692)	(-0.7150)	(-0.2986)
Capital -asset ratio	-57.41661***	-26.9774	-149.9386	-111.4938	-	-
	(-3.4558)	(-0.7032)	(-0.8120)	(-1.5956)		
Volatility of Jamaica Bank Index	-1.0164	-1.1287	-16.5520	-12.8074***	-	-
	(-.08151)	(-0.8715)	(-1.1943)	(-5.4293)		
180-day Treasury Bill Rate	109.207**	107.0469***	-415.9382	203.6679**	0.0456	0.0401
	(2.2741)	(2.1726)	(-0.7793)	(2.2607)	(-0.1644)	-0.1328
Bank Deposit Ratio	-28.8371	-25.6609	103.4689	-32.7956	-0.0946	-0.0985
	(-0.7891)	(-0.6879)	-0.2547	(-0.4809)	(-0.4233)	(-0.4310)
Charter Value	0.0005	0.0003	-0.1192	-0.009704***	0.0000	0.0000
	(0.5108)	(0.2097)	(-10.8170)	(0.8312)	(-0.4054)	(-0.6260)
Market Share	352.6466	295.0707	-1137.1510***	508.7076	1.6295	1.3687
	(1.0845)	(0.8815)	(-0.3147)	(-0.4300)	(0.8182)	-0.6743
Explicit Deposit Insurance Dummy	-0.8297	-1.2615	56.7725*	-2.4400	0.0151	0.0086
	(-0.3004)	(-0.4064)	-1.8493	(0.4299)	(0.9222)	-0.4596

Table 2. Estimation Using the Market Value of Capital

Model	Equation 1		Equation 2		Equation 3	
	SUR Estimate	3SLS Estimate	SUR Estimate	3SLS Estimate	SUR Estimate	3SLS Estimate
Constant	1.0283	1.3226	-16.3453	0.3066	-0.9137	-0.3791
	(0.4373)	(0.5431)	(-0.6568)	(0.1198)	(-0.7483)	(-0.3019)
Capital -asset ratio	-0.4022**	0.1913	3.5396*	0.0087	-	-
	(-2.0962)	(0.36860	(1.7431)	(0.159)		
Volatility of Jamaica Bank Index	-1.121935	-1.3192	-19.7105	-13.4550***	-	-
	(-0.8666)	(-0.9692)	(-1.4385)	(-9.3197)		
180-day Treasury Bill Rate	89.03784*	120.1420**	-248.9851	87.8196	-55.9375**	-45.1685*
	(1.75790	(2.0817)	(-0.4645)	(1.4458)	(-2.2291)	(-1.6694)
Bank Deposit Ratio	-31.6560	-19.6104	193.0827	-4.2438	-17.7896	-20.8099
	(-0.8312)	(-0.4840)	(0.4790)	(-0.0996)	(-0.8798)	(-1.0279)
Charter Value	0.0008	0.0000	-0.1183	-0.0020	0.0003	0.0017**
	(0.7783)	(0.0138)	(-10.9115)	(-1.0347)	(0.7975)	(2.1030)
Market Share	163.3242	298.6470	-609.9694	270.4906	-230.1522	-224.0404
	(0.4824)	(0.8223)	(-0.1702)	(0.7083)	(-1.2768)	(-1.2489)
Explicit Deposit Insurance Dummy	-1.4670	-1.7518	50.9849	-2.2156	1.0490	0.1940
	(-0.5139)	(0.5847)	(1.6875)	(-0.7038)	(0.7069)	(0.1262)

Notes:

***,**,* Indicates Statistical Signficance at the 1 percent, 5 per cent and 10 per cent levels, respectively

Equation1:

$\Delta \sigma_{V,i,t} = \alpha_{0,i} + \alpha_1 \Delta c_{mv,i,t} + \alpha_2 \Delta \sigma_{bi,t} + \alpha_3 \Delta tbill_t + \alpha_4 depratio + \alpha_5 q_{i,t} + \alpha_6 mktshare_{i,t} + \alpha_7 Depin_t + \varepsilon_{i,t}$

Equation 2:

$\Delta z_{i,t} = \beta_{0,i} + \beta_1 \Delta c_{mv,i,t} + \beta_2 \Delta \sigma_{bi,t} + \beta_3 \Delta tbill_t + \beta_4 depratio + \beta_5 q_{i,t} + \beta_6 mktshare_{i,t} + \beta_7 Depin_t + \nu_{i,t}$

Equation 3:

$\Delta c_{mv,i,t} = \gamma_{0,i} + \gamma_1 \Delta tbill_{i,t} + \beta_2 \Delta depratio_{i,t} + \gamma_3 \Delta q_{i,t} + \gamma_4 mktshare_{i,t} + \beta_5 Depin_t + \psi_{i,t}$

There appears to be no statistically significant relationship between the amount of capital held and the odds of default when the using c_{BV} (equation (2)). However, the relationship is significant at the 10 per cent level when c_{MV} is used. Further the sign of the coefficient suggests that an unintended consequence of a higher capital requirement is associated with a higher probability of default.

While the estimation of the capital ratio regression did not reveal a significant relationship with any of the explanatory variables using c_{BV}, the six-month Treasury bill rate is significant and negative when c_{MV} was used. The Treasury bill rate is statistically significant and positive in the equation for asset volatility, when both c_{BV} and c_{MV} are used. The rate is also statistically significant and positive in the default risk case (equation (2)) when c_{MV} is used. These results suggest a prominent role for policy in encouraging capital market development as increases in the Treasury bill rate leads to a decline in the market value of capital ratio, greater market perception of default risk, as well as an increased likelihood of default.

5.2 The 3SLS Estimation Results

In the case of the asset volatility and default risk equations (equations (1) and (2)), the parameters estimates for the capital ratios become statistically insignificant, in the case of both c_{BV} and c_{MV}.[19] This suggests that there exists no explicit relationship between either risk and capital or the likelihood of default and capital.

Using the book value measure of capital, c_{BV}, the 3SLS estimate of the impact of the Treasury bill rate on the asset volatility (equation (1)) has a statistically significant and positive impact, similar to that obtained in the SUR results. Additionally, for the equation estimating the odds of default (equation (2)), the coefficient on the Treasury bill rate is positive and significant (whereas it was insignificant for the corresponding SUR estimate). The result implies that upward adjustments to interest rates have the effect of increasing the likelihood of default. However, this relationship does not hold when c_{MV} is used.

[19] These results are also robust to changes in the specification of the model.

The statistical significance of 'charter value' (market power) emerges for the default probability and capital ratio equations (equations (2) and (3)) in the cases of c_{BV} and c_{MV}, respectively. The results suggest that banks with greater influence or market power have a lower probability of book value default and hold greater share of market value capital.

A curious finding, however, is the statistically significant, negative coefficient on the volatility of the Jamaica bank stock index, σ_{BSI}, in the estimation of probability of default using both c_{BV} and c_{MV}. The relationship is robust to changes in specification and the inclusion of lagged values of the default indicator. The explanation for this anomalous result was discussed earlier in the description of Chart 3. In particular, if in the market's assessment, high equity volatility is associated with the possibility of high capital gains, then contrary to the findings in similar studies (at least over the sample period), increased volatility should be correlated with a lower probability of default.

5. Concluding Remarks

The paper finds no explicit empirical relationship between risk and capital. The significance of the Treasury bill rate in the 3SLS estimation lends support to the negative influence of the high interest rates on bank risk. The sign on this variable is significant and positive in the equations for asset volatility and the probability of default when market value capital is used. Additionally, high interest rates related to the Central Bank's attempt to control high inflation in the early 1990s might have influenced a flight to the bond market and the tightening of the liquidity in the system. The confluence of these factors would work against the regulatory intent of controlling the balance between risk and capital and, hence, the probability of default. An important recommendation from this finding is that the use of interest rates to alleviate foreign exchange market pressures should be tempered against the possibility of negative effects on bank default risk.

The evolution of the default indicator is sensitive to the historical weaknesses in fragility and systemic instability. The Merton-type model, based on the excess of market value of assets over the book value liabilities in the sample, identifies the post 2000 period as an important benchmark for Jamaican banks. This period marked a significant improvement in the assessment of default risk. In particular, the default risk for banks is relatively low for the last three years of current history. The success of this measure of default widens the pool of available tools to conduct ‘early warning’ analyses of bank distress.

References

Bank for International Settlements (1999), "Capital Requirements and Bank Behaviour: The Impact of the Basle Accord", Basel Committee on Banking Supervision Working Papers.

Bichsel, Robert and Jurg Blum (2002): "The Relationship between Risk and Capital in Swiss Commercial Banks: A Panel Study", Swiss National Bank, Working Paper 02/04.

Furlong, Frederick F. (1998): "Changes in Bank Risk Taking", Federal Reserve Bank of San Franciso, *Economic Review*.

Gizycki, Marinne and Brenton Goldworthy (1999), " Australian Banking Risk: The Stock Market's Assessment and the Relationship Between Capital and Asset Volatility", Reserve Bank of Australia, Working Paper

Gropp, Reint , Jukka Vesala, Giuseppe Vulpes: " Equity and Bond Market Signals as Leading Indicators of Bank Fragility.", European Central Bank, Working Paper

Hull, John (1989), Options, Futures, and Other Derivative Securities. Prentice Hall

Keely, Michael C. (1990), "Deposit Insurance, Risk and Market Power in Banking", The *American Economic Review*, Volume 80, Number 5.

Keely, Micheal C. (1988), " Bank Capital Regulation in the 1980s: Effective or Ineffective", Federal Bank of San Francisco, *Economic Review*, No. 1

Kim, Daesik and Anthony Santomero (1988), "Risk in Banking and Capital Regulation", *Journal of Finance,* 43, 1219-1233.

Kopcke, Richard W. (2001), "Comment on 'The Relationship between Risk and Capital in Swiss Commercial Banks: A Panel Study'", Workshop on Applied Banking Research, Oslo, Norwat, 12-13 June 2001, Norges Bank.

KMV Corporation (1999): Modelling Credit Risk. San Francisco

Lewis, Jide (2004), " A Measure of Banking Sector Fragility in the Post-bank Distress Period from 1997-2004: A Banking Risk Index for Commercial Banks, Merchant Banks, and Building Societies", Bank of Jamaica, Working Paper.

Merton, Robert (1974): " On Pricing of Corporate Liabilities: The Risk Structure of Commercial Banks". *Journal of Finance*, 29(2), 449-470.

Nier, Erlend and Ursel Baumann (2002), "Market Discipline, Disclosure and Moral Hazard in Banking", Bank of England, Working Paper.

Wall, Larry D. and Pamela P. Peterson (1996), " Banks' Response to Binding Regulatory Capital Requirements", Federal Reserve Bank of Atlanta, *Economic Review*, Volume 81, No. 2.

Demirguc-Kunt and Edward J, Kane (2001), " Deposit Insurance Around the Globe: Where Does it Work", Working Paper.