# AUSTRALIAN BANKING RISK: THE STOCK MARKET'S ASSESSMENT AND THE RELATIONSHIP BETWEEN CAPITAL AND ASSET VOLATILITY

Marianne Gizycki* and Brenton Goldsworthy**

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*System Stability Department, Reserve Bank of Australia
**Research and Financial Studies, Australian Prudential Regulation Authority

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## Abstract

The likelihood of a bank failing, within a given period of time, is a function of the variability in its income and its ability to withstand losses. These determinants depend, in turn, on the volatility of the return on bank assets and the bank's level of capital. Although accounting measures of the volatility of the rate of return on bank assets and bank capital-asset ratios are published on a regular basis, market prices provide alternative risk measures. This paper uses share prices to estimate these risk measures for 15 Australian banks that were listed on the Australian Stock Exchange for all, or part of, the period 1983 to 1998. Option prices are also used to generate alternative estimates of these risk measures, the results of which corroborate those obtained from share prices. We find that the market's assessment of the capital-asset ratio for the Australian banking sector has risen considerably over the sample period. There has also been a slight upward trend in the volatility of asset returns. These two trends have opposite effects on the market's assessment of total bank risk: rising capital-asset ratios reduce bank risk, but rising asset volatility increases it. To uncover which trend has dominated, we examine a couple of measures of total bank risk, which summarise the net impact of movements in both the capital-asset ratio and asset volatility. These additional risk measures suggest that the riskiness of the sector has declined. In investigating the relationship between banks' capital-asset ratio and asset volatility over time, we find that increases in the growth of the capital-asset ratio precede increases in asset volatility which, in turn, cause a slowdown in capital growth.

JEL Classification Numbers: G13, G21

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## 1. Introduction

The stability of the banking sector has long been a concern of public policy. Recent events in Asia, and elsewhere, have emphasised the importance of the two-way interaction between the soundness of the banking sector and the health of the macro economy. The potential public-sector liability that may arise if a bank fails is also of concern. The nature of the public-sector liability is most transparent in countries with explicit deposit insurance or deposit-guarantee structures in place. However, Kane and Kaufman (1992) argue that even in Australia, where no deposit insurance is provided, the possibility of claims on the government is a legitimate concern of public policy.

Estimates of the probability of failure of an individual bank are useful both for individual-bank supervision and in forming an assessment of the overall stability of the financial system. If an institution fails, depositors in that institution may lose funds, and in particular circumstances, the failure could cause difficulties for other financial institutions or turmoil in financial markets. The likelihood of a bank becoming insolvent, within a given period of time, is a function of the variability in its income and its ability to withstand losses in the short run. These two determinants depend, in turn, on the volatility of the rate of return on bank assets and the bank's level of capital, respectively. Estimates of asset volatility and capital ratios can be computed from banks' annual reports. However, the backward-looking nature of accounting measures means that these figures are unlikely to correspond to the relevant economic concepts (i.e. discounted future flows of economic earnings). In principle, one way of overcoming this problem is to use market values as proxies for economic values. Unfortunately in this case, this solution is not available because most bank assets and liabilities are not regularly traded and, therefore, lack an observable market price.

However, for many Australian banks one piece of market-based information is available and readily observable: the value of shareholder equity. In an efficient share market, the market capitalisation of a firm reflects the difference between the economic (or market) value of its assets and liabilities. Thus, a model of the relationship between the market capitalisation of the firm and its economic assets and liabilities can be used to infer those economic values. Similarly, the volatility of the market capitalisation reflects the unobservable volatility of the bank's economic assets and liabilities, again suggesting the possibility of inferring one from the other. These measures need to be viewed with caution since they depend on the assumption of market efficiency. If the share market is inefficient then the firm valuation and risk measures based on this valuation will be inaccurate.

Gizycki and Levonian (1993) used such a model to calculate the economic values of asset volatility and capital ratios for 11 Australian banks between 1983 and 1993. They found that the estimated capital ratio for the banking sector rose over this period, while there was no noticeable increase in the asset volatility of banks. They also concluded that banks with more volatile assets tend to maintain higher capital ratios and that there is a positive relationship between the two variables over time.

Since 1993, a number of developments that have occurred in the Australian banking sector suggest that an update of the Gizycki and Levonian (1993) study is warranted. Firstly, five more banks have listed on the Australian Stock Exchange. Secondly, the regulatory requirements applied to banks since the late 1980s have changed considerably. Any effect these changes have had on the relationship between banks' capital ratios and their asset volatility will be made clearer over the longer sample period. Thirdly, risk-management techniques have become more sophisticated, giving rise to the possibility that the interaction between banks' leverage and asset volatility may have changed. When the sample is extended, we find that both banks' asset volatility and capitalisation grew strongly during the 1990s. We also find that the net effect of the growth in these two variables has been a decline in the overall riskiness of Australian banks and, thus, a more stable financial system.

In addition to updating the results of Gizycki and Levonian (1993), this paper contains three key extensions. Firstly, call options on banks' shares are used to generate alternative estimates of the risk measures. Secondly, the probability that each bank will close (based on our estimated model) is used as a further measure of risk. Thirdly, an attempt is made to unearth the direction of any causation between a bank's asset volatility and its capital ratio. The introduction of the 1988 Capital Accord marked a movement from flat rate to risk-based capital adequacy requirements. Beyond any shift in the overall level of capital, this change in the regulatory regime altered the incentives facing banks. We, therefore, consider the impact of the 1988 Capital Accord on the capital-risk relationship and test for asymmetry in that relationship.

The paper proceeds as follows. Section 2 outlines the contingent-claim model that is used to estimate each bank's capital ratio and volatility of assets, the probability that each bank will close and the expected creditor losses in the event of bank closure. In Section 3, the data, assumptions and the estimation technique used are outlined. The results of the analysis are then presented in Section 4. In addition to presenting average levels of capital ratios, asset volatility and probability of failure we consider the probability distribution of the likelihood of losing a giving share of the banking system, which is taken to be an indicator of overall system stability. Section 5 provides a theoretical and empirical discussion of the relationship between asset volatility and capital. Section 6 concludes.

## 2. Methodology

In this section we present the contingent-claim model used to derive four measures of bank risk, namely: (1) the volatility of the return on economic assets; (2) the economic capital ratio; (3) the probability of closure; and (4) the value of the potential public liability.[1] Initially, we outline a contingent-claim model that can be applied to all leveraged firms. This model is then modified to accommodate bank-specific factors. We then explain how the model is estimated and discuss how the model is used to infer the aforementioned measures of risk.

[1] The application of this technique to leveraged firms was pioneered by Merton (1974), the central framework of which has been employed in a number of subsequent papers (see, for example, Markus and Shaked (1984) and Cordell and King (1992)).

## 2.1 A Contingent-claim Model of a Bank

Consider a firm that has assets with an economic value of $A_T$ and liabilities with an economic value of $B_T$ due at date $T$. If assets exceed liabilities at maturity of the debt, the firm will continue operating, with the value of equity being the difference between assets and liabilities.[2] If, on the other hand, assets are less than liabilities, equity holders will relinquish control of the firm and draw on their position of limited liability; as a result, the value of equity has a lower bound of zero. Thus, the value of equity at date $T$ is:

$$E_T = \begin{cases} A_T - B_T & \text{if} \quad A_T \geq B_T \\ 0 & \text{if} \quad A_T < B_T \end{cases} \tag{1}$$

Equity is described as a contingent claim since a positive payoff to equity is contingent upon the bank being solvent at date $T$. At any time prior to $T$, the total market value of a bank's equity can be calculated using the same valuation techniques used to price other contingent claims, such as options. Equity holders are often viewed as having a long call option on the assets of the firm, where the strike price is equal to the face value of liabilities, because the payoff from such a position at maturity of the option is characterised by Equation (1).

Following Levonian (1991a), this basic model is augmented to capture factors that relate specifically to banks. The first adjustment to the model is to incorporate a bank 'licence value'. This licence value captures the intangible asset value in a firm. Financial institutions that are granted a banking licence benefit from being called a 'bank'. Specifically, the fact that banks are *perceived* to have some form of public-sector backing generally enables them to pay a rate of interest on deposits that is approximately equal to the risk-free rate, since depositors anticipate little risk of default.[3] Furthermore, some customers are willing to pay an added premium to transact with banks since banks are viewed as being a superior source of both credit and debit services. It should be noted that these benefits of a banking licence

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2 The value of a firm's *economic* liabilities (including equity) is equal to the value of a firm's *economic* assets, since the former represents a complete set of claims on the cash flows that accrue from the assets.

3 Of course, protected deposits are still risky in the sense that the real return on deposits can fluctuate unexpectedly.

are partially offset by compliance costs, since banks must abide by portfolio-constraining directives issued by the Australian Prudential Regulation Authority (APRA) (such as limits on the concentration of exposures to counterparties). Beyond these regulatory concerns, a large part of a bank's licence value will be due to its franchise value (value of its brand name or goodwill). Since such branding distinguishes each bank from the others, competitive forces do not necessarily drive the franchise value down to zero. In our model, the licence value is modelled as a constant fraction ($\varphi$) of liabilities and is received by equity holders at date $T$ only if the bank remains open.[4]

As in Cordell and King (1992), a second adjustment is made to account for the impact of dividends on the value of equity. The payment of dividends reduces assets and, hence, the value of the contingent claim, but it also transfers value directly to shareholders. In our model, it is assumed that dividends, $\gamma A_T$ are paid at date $T$.

The third modification allows for the fact that regulators have some discretion over whether a bank continues to operate – the so-called closure threshold need not be the point of actual insolvency, as was the case in Equation (1). In our model, regulators are assumed to monitor banks at discrete intervals with a view to deciding whether to close the bank (the present date is taken to be $t$=0 and the next

4 The main motivation for assuming that the licence value is proportional to liabilities is technical modelling convenience. It is likely that the value is positively related to bank size. As will be discussed later, assets in the model are assumed to be stochastic; thus, if the licence value was related to assets in the model rather than liabilities, then its value would also be stochastic. This would introduce an additional element of random fluctuation into the value of shares, thereby complicating the theoretical development of the model without substantially adding to the analysis. The assumption is appropriate to the extent that the value of the licence reflects the opportunity to use deposits as a low cost source of funds.

monitoring date $t$=$T$ ).[5] It is further assumed that regulators will close a bank if that bank's capital ratio, $k_T$, is less than $c$, where $k_T$ is defined as:[6]

$$k_T \equiv \frac{(1-\gamma)A_T - B_T}{(1-\gamma)A_T} \tag{2}$$

If the bank's capital ratio is above the closure threshold, equity holders receive the full value of the bank as a going concern. If a bank remains open at date $T$, shareholders receive the dividend-adjusted difference between assets and liabilities $((1-\gamma)A_T - B_T)$, a lump sum equal to the rents conferred by a banking licence ($\varphi B_T$) and a dividend payment ( $\gamma A_T$ ).[7] This is the case regardless of whether the closure threshold is positive or negative.

If the bank is closed, it is assumed that equity holders manage to appropriate one final dividend payment from the firm. This assumption is made for algebraic convenience and, since dividend payments are small relative to total assets, does not materially affect our results. The full payout for equity holders, however, depends upon whether the closure threshold is positive or negative. If regulators only close banks with negative capital then, at closure the equity holders will only receive the final dividend ( $\gamma A_T$). If, however, regulators apply a positive closure threshold, then at time $T$, equity holders would receive the net tangible assets of the bank $((1-\gamma)A_T - B_T + \gamma A_T)$ – once the bank is closed the licence value falls to zero.

A number of countries (including the US and Japan) have introduced prompt corrective action schemes whereby troubled banks must be closed before book-value equity falls below zero. Nevertheless, the slippages that have been seen

5 In this formulation, debt holders are assumed to play a passive role in the decision of whether the bank will be closed. One rationale for this assumption is that the operations of the bank are sufficiently opaque to prevent debt holders from observing the market value of the bank's assets. In this environment, debt holders are reliant on the supervisor to act in their best interests.

6 The capital-asset ratio is defined exclusive of the licence value. It, therefore, captures only the tangible assets of the bank. For this reason, the firm can still be solvent with a capital-asset ratio less than zero. This is discussed further in Section 3.3.

7 In a multi-period setting, $\varphi B$ and $\gamma A$ would reflect the discounted value of the future stream of rents and dividends respectively.

in the implementation of prompt corrective action schemes (see for example Benston and Kaufman (1998)), and the past experience of resolving troubled financial institutions in Australia, suggest that it can be difficult for regulators to close a bank at positive economic capital ratios.[8] As a result, we exclude the possibility of closure at positive capital ratios from the model.

Reflecting adjustments for licence value, dividend payments and regulatory closure, the value of equity at the monitoring date, *T*, can be stated as:

$$E_T = \begin{cases} (1-\gamma)A_T - B_T + \varphi B_T + \gamma A_T & \text{if } k_T \geq c \\ \gamma A_T & \text{if } k_T < c \end{cases} \tag{3}$$

where $c$ is less than or equal to zero.

To obtain estimates of the value of equity prior to the monitoring date, it is necessary to make some assumptions regarding the stochastic processes followed by assets and liabilities. As in most contingent-claim models, assets are assumed to follow Geometric Brownian Motion. The change in assets, $d_A$, can be expressed as:

$$d_A = \mu_A(\gamma)A(t)dt + \sigma_A A(t)dz \tag{4}$$

where $t$ is a time index, $\mu_A$ is the expected instantaneous rate of return on assets per unit of time, $\sigma_A$ is the instantaneous standard deviation of the rate of return on assets and $dz$ is the differential of a Wiener process.[9] Put simply, the first term on the right-hand side describes the drift of assets (or the average rate of return) over time while the second term can be regarded as adding noise or variability to the path followed by assets. For simplicity, the market value of liabilities is assumed to be constant. Provided that liabilities are repriced frequently, any move in interest rates will be offset by changes in future cash flows, leaving the present value of liabilities roughly constant. Any risk that does arise from liabilities (for example,

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8 Supporting this claim, the final annual report of the State Bank of Victoria gives a capital-asset ratio of about -0.06 when considering the State Bank group as a whole in the absence of government assistance.

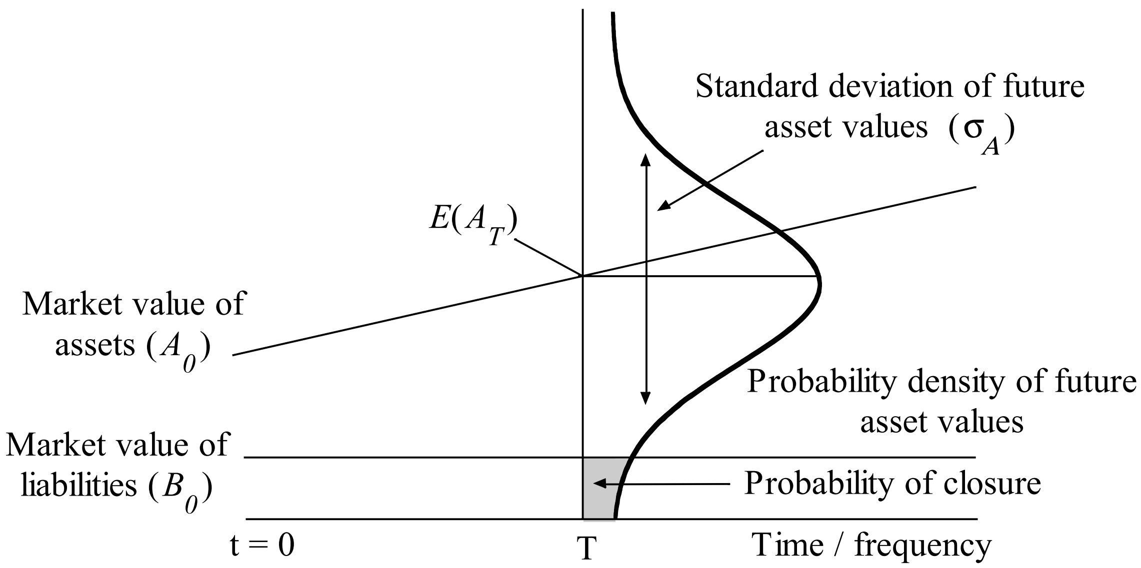
9 This assumption implies that assets have a log-normal distribution and, hence, the returns on assets have a normal distribution.

from those with fixed payments) will appear in our estimate of the volatility of the return on assets.

An important determinant of the value of equity is the probability that the bank will close. The relationship between the key determinants of closure is delineated in Figure 1. For illustrative purposes, the figure is presented in the context of the basic model outlined in Equation (1).

Knowledge of the current market value of assets and the stochastic process followed by assets makes it possible to estimate the distribution of asset values at the monitoring date. As Figure 1 shows, the probability that assets will be less than liabilities at the monitoring date depends on: (1) the expected value of assets at the monitoring date, $E(A_T)$ (i.e. the first moment of the distribution); (2) the variability of assets (i.e. the second moment of the distribution); and (3) the level of liabilities. The shaded area of the distribution in Figure 1 represents this probability.

**Figure 1: Contingent–claim Model**




The Black-Scholes option-pricing formula incorporates all the factors described above in estimating the value of a contingent claim. Using this formula, the value of equity at date $t$=0 is:

$$E = (1-\gamma)AN(x) - BN\left(x - \sigma_A\sqrt{T}\right) + \varphi BN\left(x - \sigma_A\sqrt{T}\right) + \gamma A \tag{5}$$

where

$$\chi = \frac{\ln\left(\frac{(1-c)(1-\gamma)A}{B}\right) + \frac{\sigma_A^2 T}{2}}{\sigma_{A\sqrt{T}}} \tag{6}$$

$N(\bullet)$ is the cumulative standard-normal distribution function and variables without subscripts denote present values.[10] As discussed previously, equity holders can be viewed as having a long European call option position in the value of the firm; equity holders have the option of either paying out the debt holders and acquiring the firm (receiving $(1-\gamma)A+\varphi B+\gamma A$) or letting their claims to the firm expire (still receiving $\gamma A$).[11] The probability that this option will be exercised (i.e. the probability that the bank will remain open) is represented in Equation (5) by $N\left(x-\sigma_A\sqrt{T}\right)$. As mentioned earlier, the probability that the option is not exercised is illustrated by the shaded area of the distribution in Figure 1.

Given values for the market capitalisation of the firm ($E$), bank liabilities ($B$), the regulatory monitoring interval ($T$), the capital-ratio closure threshold ($c$), the licence value ratio ($\varphi$), and the rate of dividend payments relative to assets ($\gamma$), the two remaining unknowns in Equation (5) are the value of assets ($A$), and the volatility of assets $(\sigma_A)$.[12] Clearly, to compute the two unknowns a second independent equation is needed.

Marcus and Shaked (1984) suggest applying Ito's Lemma to the expression for the value of equity, to yield a second equation involving the volatility of equity and the volatility of assets. They follow Merton (1974) in deriving the relationship:

$$\sigma_E = \sigma_A \frac{\partial E}{\partial A}\frac{A}{E} \tag{7}$$

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10 Note that, for simplicity, we have assumed that the expected periodic rate of return on assets, $\mu_A$, is equal to zero.

11 Using standard option terminology: assets are the underlying security; liabilities are the strike price of the option; and the value of equity is the price, or premium, of the option.

12 The values of $E$, $B$, $T$, $C$, $\varphi$ and $\gamma$ used in the estimation are discussed in Section 3.

The basic idea of Equation (7) is that the volatility of a bank's equity is a magnified version of the volatility of a bank's assets, where the magnification factor depends on leverage and how changes in assets are divided between liabilities and equity (that is, the elasticity of equity to assets).[13]

Differentiating Equation (5) with respect to $A$ yields:

$$\frac{\partial E}{\partial A} = (1-\gamma)N(x) + \frac{\theta BN'\left(x-\sigma_A\sqrt{T}\right)}{A_{\sigma A}\sqrt{T}} + \gamma \tag{8}$$

where $N'(\bullet)$ is the standard-normal density function and $\theta=1/(1-c)-(1-\varphi)$.[14] Using Equation (8), the relationship defined by Equation (7) can be expressed as:

$$\sigma_E = \frac{(1-\gamma)AN(x)\sigma_A\sqrt{T} + \theta BN'\left(x-\sigma_A\sqrt{T}\right) + \gamma A\sigma_A\sqrt{T}}{E\sqrt{T}} \tag{9}$$

If $\sigma_E$ is observable, this equation also has $A$ and $\sigma_A$ as the only unknowns; hence, Equation (5) and Equation (9) can be solved simultaneously for values of these two variables. Thus, under the assumption that the value of bank equity is determined as in Equation (5), the market capitalisation of a bank can be used to infer the market value of assets and asset volatility.

## 2.2 Measures of Banking Risk

Given this theoretical framework, the central issue of this paper can be posed more explicitly. The key measure of the riskiness of a bank is the probability of closure. This overall risk measure can then be broken down into two components – 'financial risk' and 'operating risk'. (The term 'operating risk' is used in the literature. It should not be confused with *operational* risk, which is the risk of earnings volatility not caused by market or credit factors.)

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[13] A substantial change in the market value of assets will influence the bank's probability of default and, therefore, the market value of liabilities.

[14] The partial derivative $\frac{\partial E}{\partial A}$ is the delta of the option with respect to the underlying asset.

Financial risk is aligned with the bank's leverage. Regardless of the proclivity of banks to take risks, exogenous events can result in banks incurring large losses. A bank's ability to withstand such large losses will depend on its level of capital. In terms of Figure 1, financial risk is inversely related to the difference between the economic assets and liabilities of the firm (that is, the mean of the distribution relative to $B_0$). The second component of overall risk, which is denoted operating risk, increases if the volatility of assets increases. If a bank takes on a portfolio of assets characterised by a more uncertain income stream then, *ceteris paribus*, the chance of it incurring crippling losses increases. In Figure 1, this risk shows up in the shape of the distribution; specifically, closure is more likely, the more volatile the assets.

In addition to the probability of closure, we present an alternative measure of overall risk, the expected losses borne by banks' creditors. We include this measure for purposes of comparison as this measure is widely used in the literature. This measure originated in those countries where the repayment of deposits is guaranteed. For these countries (including France, Germany, Japan, United Kingdom and the United States), the losses borne by creditors are transferred to the deposit insurer. The expected creditor losses can, therefore, be thought of as the value of the deposit guarantee, or the expected amount that the guarantor will have to pay depositors at the monitoring date. In Australia, the system of depositor protection is quite different. While the *Banking Act 1959* places a duty on APRA to exercise its powers and functions to protect depositors, the repayment of deposits is *not* guaranteed.[15] Despite the absence of explicit depositor protection, market participants may hold the view that depositors are protected from financial loss, whether as a result of pre-emptive action by the supervisor, or due to compensation payments. Regardless of whether any liability is borne by a government authority or the debt holders themselves, the size of this contingent liability can be estimated in a similar way to how we estimate the value of equity.

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15 The Act provides APRA with a range of powers designed to protect depositors. In particular, where a bank is likely to become unable to meet its obligations, the Act confers power on APRA to investigate the bank's affairs and assume control of the bank for the benefit of its depositors. The Act also provides that the assets of the bank in Australia shall be available to meet its deposit liabilities in Australia in priority to all other liabilities. For a more extensive discussion of APRA's powers and objectives see Goldsworthy, Lewis and Shuetrim (1999).

For simplicity, it is assumed that all creditors of a failed bank will be protected from financial loss *if* a government authority steps in whenever equity holders do not exercise their option. This assumption enables us to treat the claims covered by any deposit guarantee as the total value of liabilities, $B$. If a bank fails, the payout under the guarantee may take the form of direct restitution to depositors. In this situation, the guarantor will liquidate the assets of the bank and will pay depositors the amount they are owed. When liquidating the assets on behalf of depositors, the guarantor is only able to sell the bank's tangible assets. Therefore, to compute the contingent liability under this scenario it is important to distinguish between the tangible assets of the bank, $A$, and the intangible assets, $\varphi B$. An alternative approach which the guarantor could follow is to locate a purchaser for the failed bank; the acquirer would receive all assets of the bank – both tangible and intangible – and would assume all of the liabilities. If the assumed liabilities exceed the combined value of the tangible assets and the licence, the deposit guarantor makes up the difference.

The size of the contingent liability depends on which action the regulator is likely to choose. Clearly, the liability will be lower under the second scenario since the licence value is being used to reduce the payout to depositors following the bank's failure. As with the other risk measures, we are more interested in movements of the contingent liability rather than the level. Thus, given our assumption that the licence value is constant through time, our conclusions will not be affected by what action we assume the guarantor will take following a bank's failure. Since it seems likely that the guarantor would take the action that limits its liability wherever possible, we assume that the guarantor will find a purchaser for the failed bank. In this situation, the payout by the guarantor at the monitoring date, $V_T$, is:

$$V_T = \begin{cases} (1-\varphi)B_T - (1-\gamma)A_T & \text{if } B_T > (1-\gamma)A_T + \varphi B_T \\ 0 & \text{if } B_T \le (1-\gamma)A_T + \varphi B_T \end{cases} \tag{10}$$

The guarantor has sold a put option to equity holders that has the same characteristics as the long call option held by equity holders (i.e. same strike price, etc).[16] If the value of the firm falls below liabilities, equity holders will exercise

[16] In actual fact, the long call option position, discussed in Section 2.1, is equivalent to equity holders owning the assets of the firm and having a long put option in those assets.

their put option and will force the guarantor to pay the debt holders the shortfall (of course, if the government does not step in, debt holders will suffer the loss – they can be viewed as having a short put option position). Using the Black-Scholes formula once again, the value of the contingent payout in Equation (10) is:

$$V_T = (1-\varphi)BN\left(\gamma + \sigma_A\sqrt{T}\right) - (1-\gamma)AN(y) \tag{11}$$

where

$$y = \frac{\ln\left(\dfrac{(1-\varphi)B}{(1-\gamma)A}\right) - \dfrac{\sigma_A^2}{2}}{\sigma_A\sqrt{T}} \tag{12}$$

Therefore, once values for $A$ and $\sigma_A$ have been obtained it is straightforward to calculate the deposit-guarantee liability. *Ceteris paribus*, bank risk has increased if the size of this deposit guarantee has increased.

## 3. Data, Assumptions and Methods

To derive estimates of the four risk measures, it is necessary to specify values for the following variables and parameters: $\sigma_E$, $\varphi$, $c$, $E$, $B$, $\gamma$, and $T$. This section focuses on these inputs to the model.

### 3.1 Estimates of the Volatility of Equity Returns

In our model we use both an historical, or backward-looking, estimate and a forward-looking estimate of the standard deviation of the rate of return on equity, $\sigma_E$.

#### *3.1.1 Historical estimate*

Traditionally, historical estimates have been used. In this paper, each month the historical estimate of $\sigma_E$ is calculated as the annualised standard deviation of daily returns over the 50 days preceding the last day of the month. Our sample is comprised of 15 banks that were listed on the Australian Stock Exchange between January 1983 and April 1998. As at December 1998, these banks accounted for over 93 per cent of all Australian banks' assets. For the full list of banks see Appendix A.

### *3.1.2 Forward-looking estimate*

Theoretically, the appropriate measure of volatility is the expected volatility of the return on equity over the life of the option (i.e. $t$=0 to $t$=$T$). Underlying the use of the historical measure is the assumption that expectations at each point in time are formed adaptively. Specifically, the historical measure used in this paper assumes that market participants base their expected level of volatility over the next year on the previous 50 days' realised returns. To the extent that market participants use additional information when forming their expectations of $\sigma_E$, the historical measure may be a poor proxy.

A more conceptually appealing alternative is to infer volatility estimates from the price of options written over individual bank share prices. The price of an option depends on the:

- price of the underlying asset;
- strike price;
- term to maturity;
- risk-free rate of return; and
- expected volatility of the underlying asset over the life of the option.

Given values for the first four determinants and the price of the option itself, numerical techniques can be used to calculate the expected, or implied, volatility. This implied volatility is then used as the estimate of $\sigma_E$.

Unfortunately, there are two principal drawbacks to using implied volatility estimates. Firstly, from a theoretical standpoint, we are interested in the expected volatility of the return on equity. However, options trade on individual shares and, therefore, only provide us with the expected volatility of the share price, $\sigma_P$. Provided that we are willing to accept the assumption that the number of shares on issue is constant, over the life of the option, then this is not a problem – $\sigma_P$ will equal $\sigma_E$. Secondly, from a practical standpoint, the sample size is reduced substantially, since only six banks (Advance Bank, ANZ, Commonwealth Bank of Australia, National Australia Bank, St. George Bank and Westpac) have had options traded on their shares. As a consequence, the results may not fully reflect the riskiness of the banking sector as a whole. However, these six banks accounted for 89 per cent of all banks' assets (at December 1998) and thus, while being a more restricted sample than that employing share-price data, can be regarded as representative of the Australian banking market.

Day and Lewis (1988) point out two additional sources of potential bias in the use of option prices. Firstly, to correctly calculate the implied volatility, it is necessary to use contemporaneous share and option prices. However, in reality, the last option trade may not coincide with the last observed share price. Secondly, trades may occur at anywhere between bid and ask prices making it impossible to obtain a precise estimate. To mitigate the extent of these potential biases, we adopt Day and Lewis' suggestion of using estimates of implied volatility from a number of different options on the same stock. Specifically, we select those options that are either at- or near-the-money. This rule, which is similar to that adopted by Levonian (1991b), was chosen on the basis that trading volume is concentrated in these options: as trading volume increases, the problem of nonsynchronous trading will diminish, and the spread between the bid and ask prices will be reduced.

Ideally, options from which the volatility of equity is inferred should have a term to maturity of one year, this being the assumed length of the regulatory monitoring interval. However, this is not practical given the paucity of trading in options of this length. For reasons already given, we selected the more actively traded short-term options. Provided that volatility is not expected to change significantly in the period between the expiration of the option and the monitoring date, the implied volatility from these options should provide a reasonable estimate. However, Day and Lewis also point out that technical factors relating to the unwinding of hedged positions may distort option prices, and hence, volatility estimates, for those options near expiry. Following Levonian, we omit from our sample options with a term to expiry of less than approximately two months.

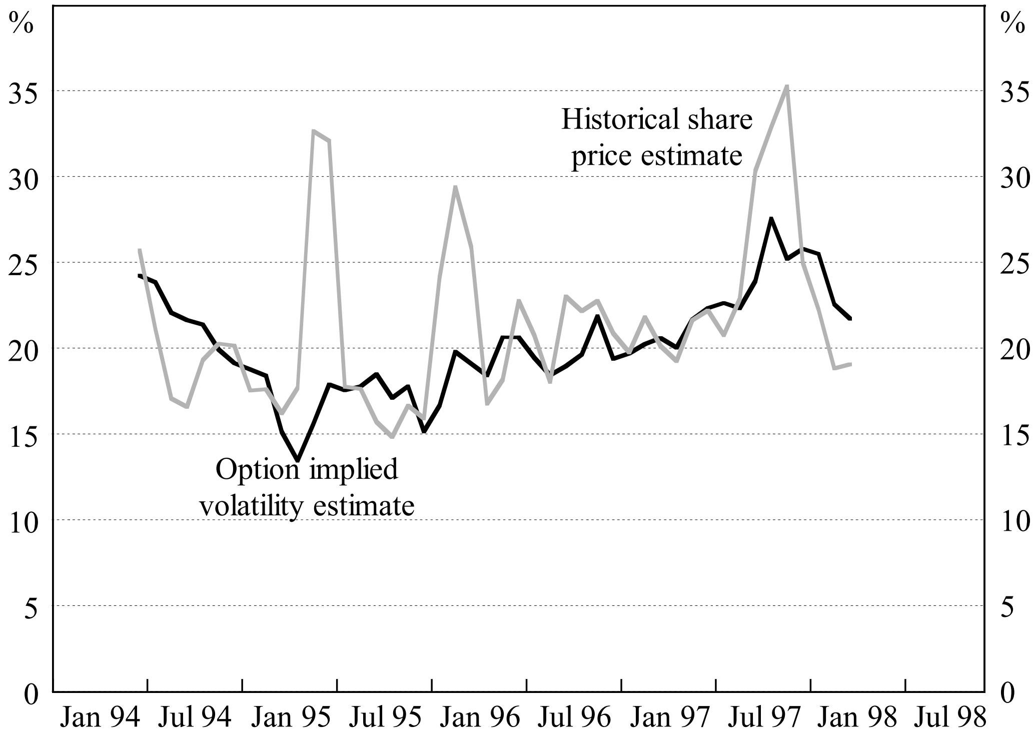
Implied volatility estimates were collected from the *Australian Financial Review* for every Wednesday over the period July 1995 to April 1998.[17] Monthly averages of the weekly estimates were then used for $\sigma_E$.

### *3.1.3 A comparison of equity volatility estimates*

Figure 2 shows both the historical and implied volatility estimates used in this paper. Both measures are calculated by taking the simple average of the annualised volatility estimates for the six banks included in the options sample.

**Figure 2: Historical and Implied Volatility Estimates**

(Annual standard deviation)




[17] The implied volatility estimates provided by the Australian Stock Exchange Options Market were used rather than taking option prices and inferring volatilities ourselves.

Whilst the long-term movements in the two series are comparable, the historical measure is considerably more variable. This reflects two facets of the estimates. Firstly, as mentioned earlier, the implied estimate assumes that the number of shares on issue is constant. Thus, a significant change in the number of shares on issue will only surface in the historical estimate. This helps to explain the large divergence between the two series in 1995. Specifically, the two measures reacted in contrasting ways to the capital raising undertaken by Advance Bank. The implied estimate reacted to the capital raising only to the extent that it contained information regarding the future volatility of the share price. The historical measure, on the other hand, reflected both the realised change in share price and the issue of additional shares. Secondly, the historical estimate places equal weight on all share-price movements in the preceding 50 days, regardless of the information content contained in them. The implied volatility estimate, on the other hand, reacts only to that information deemed relevant in formulating expectations on the future volatility of bank shares.

### 3.2 The Value of a Banking Licence

The value of a banking licence is likely to be revealed in interest rate spreads. On the liability side, the licence may enable banks to set a rate on their deposits which is less than the rate on government securities. Similarly, on the asset side, the licence may allow banks to earn a rate of return on their loans in excess of the rate required on the open market for securities of commensurate risk. Conceptually, we can use loan and deposit spreads to obtain a rough estimate of the licence value.

Levonian (1991b) demonstrates that the licence value can be approximated by

$$\varphi = \frac{\Delta}{1-k} + (r_f - r_d) \qquad (13)$$

where $\Delta$ is the loan spread – the rate of return on loans held by the bank minus the required rate of return for assets with the same level of risk, $r_f - r_d$ is the deposit spread – the rate on government securities minus the average cost of banks' liabilities, and $k$ denotes the capital ratio. The difficulty in obtaining good measures of these spreads prevents us from generating accurate estimates of the licence value in Australia. A cursory look at some interest rate spreads suggests that the bank licence value is somewhere between 4 and 7 per cent of liabilities, depending on the capital ratio employed. Since substantial approximation error is likely, these estimates should only be regarded as a rough guide to the true licence value. In Section 4 we discuss the impact that the size of the bank licence has on the results.

Given the differences in size, geographical location and business strategies across the banks in our sample, it is likely that there are inter-bank differences in $\varphi$. However, the aggregated nature of the data available necessitates assuming that the licence-value ratio is identical across banks. We also assume that the licence value is constant over time.

### 3.3 The Closure Threshold

As discussed in Section 2, the basic contingent-claim model is augmented to reflect the fact that bank closures may not necessarily occur at the point of insolvency. Instead, we argue that regulators will close a bank if that bank's capital ratio falls below a pre-specified, negative, closure threshold. In searching for solutions to our systems of equations, we therefore assume that the closure threshold has an upper bound of zero. However, solutions for the system of equations could not be obtained for some banks at closure thresholds above -0.02. This suggests that the market views bank closures as being extremely unlikely at small negative values of capital. For this reason, we consider -0.02 to be a maximum value for the assumed closure threshold.

The capital ratio can become negative since it is defined exclusive from the licence value. We estimate the market value of assets and separate those assets that are intangible – the value of the banking licence – from those that are tangible, $A_T$. In calculating the capital ratio we use tangible assets. Because we make this distinction, a bank can still be solvent at the monitoring date when $A_T < B_T$. There is, however, a limit on how low assets and, hence, the capital ratio can go. Specifically, the bank will become insolvent if liabilities are greater than the sum of tangible assets and the licence value. Because of this, we can place a lower bound on the closure threshold as a function of the licence value: the solvency condition, $A + \varphi B - B \geq 0$, implies that $c \geq -\varphi/(1-\varphi)$

### 3.4 Parameter Assumptions

Given the uncertainty surrounding the size of the licence-value ratio and the closure threshold, four different scenarios are considered in this paper.

**Table 1: Licence Value and Closure Threshold**

| | Early closure | Late closure |
|---|---|---|
| Licence value relatively low | Case I | Case II |
| | $c$ = -0.02, $\varphi$ = 0.04 | $c$ = -0.04, $\varphi$ = 0.04 |
| Licence value relatively high | Case III | Case IV |
| | $c$ = -0.02, $\varphi$ = 0.06 | $c$ = -0.06, $\varphi$ = 0.06 |

Early closure describes the situation where banks are closed when the value of tangible assets is judged by the market to be lower than the value of liabilities, but the bank's intangible assets have not been exhausted (i.e. $A_T < B_T$ but $A_T - B_T + \varphi B_T \geq 0$). This highlights the differences between solvency judged on accounting, market-value and cash-flow bases. It is possible for a bank to be solvent when assessed against accounting measures of the value of assets and liabilities, but to be insolvent in market-value terms. It is also possible that a firm may be insolvent in either accounting or market-value terms but still have sufficient cash flow to remain in business for sometime. Late closure, on the other hand, occurs when banks are closed at the point at which the market value of tangible assets falls below liabilities by an amount equal to the value of the banking licence; that is, the licence value is fully exhausted. The robustness of the results to the different scenarios in Table 1 is analysed in Section 4.5.

### 3.5 Equity, Liabilities, Dividend Payments, Monitoring Intervals and Estimation Techniques

The final step before the risk measures can be estimated is to assign monthly values for equity, liabilities, the rate of dividend payments relative to the value of assets and the monitoring interval. Equity is simply the monthly average of the bank's market capitalisation. The nature of a bank's liabilities enables us to assume that the book value of liabilities is equal to their economic value. Final and interim dividends paid by each bank are used to compute the dividend rate; hence, it is assumed that market participants perfectly forecast future dividends. Lastly, the monitoring interval is set equal to one year. This is consistent with APRA's practice of conducting an on-site review and a prudential consultation with each bank once per year (on average).[18]

The system of equations was solved using the GAUSS 1.49B procedure for solving non-linear equations. The algorithm employed is a modification of Broyden's secant method (Eldefsen and Jones (1986), Dennis and Schnabel (1983)), which combines Broyden's method with Newton's method, Newton's method being used when Broyden's approximation does not move towards the system's solutions.

# 4. Results

## 4.1 Financial Risk

A market estimate of the weighted-average capital-asset ratio is constructed to combine the individual bank results each month, with each bank weighted by its share of the total market value of assets. Weighted averages for each of the four cases considered, derived using historical estimates of equity volatility, are presented in Figure 3. In this figure the capital-asset ratio is defined to include the bank licence value $[k = (A + \varphi B - B)/(A + \varphi B)]$ and thus captures both the tangible and intangible assets of the bank.

As found in Gizycki and Levonian, the estimated capital-asset ratio rose sharply in the late 1980s, after being at quite low levels in the preceding years.[19] Interestingly, this coincided with the introduction of the Basel risk-based capital adequacy standards. Following this dramatic increase, the capital-asset ratio fell during the years 1989–1991 before regaining its upward momentum. The estimates continued to trend upwards, rising particularly quickly over the periods 1991–1992 and 1993–1994. The capital-asset ratio ended the sample period at a level

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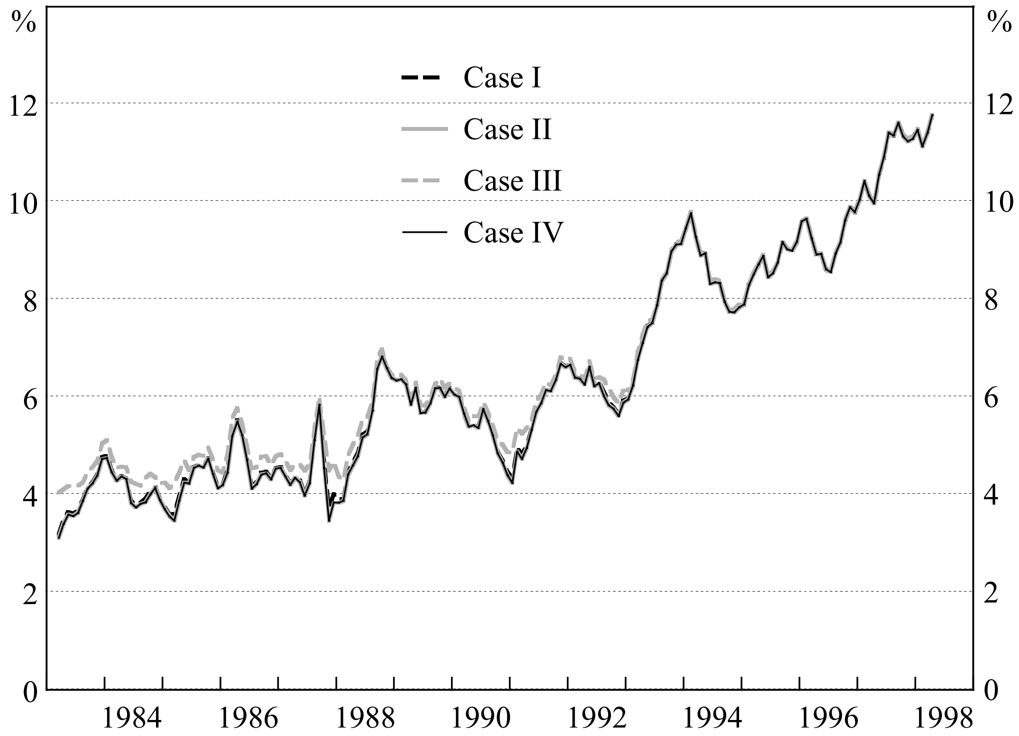
[18] It is possible that regulators might vary the closure threshold and, in particular, the monitoring interval according to the condition of each bank. The volatility of asset returns and the market capital-asset ratio are both increasing functions of the monitoring interval.

[19] Note that Gizycki and Levonian (1993) do not include the licence value in the capital-asset ratio calculation.

considerably higher than was observed in the early 1980s, suggesting that stock market participants are of the view that the financial risk of banks has decreased over this period.

**Figure 3: Weighted-average Market Capital-asset Ratio**




The observed behaviour of this stock market based measure of financial risk differs considerably from that implied by the regulatory capital-asset ratio. The regulatory risk-weighted ratio (considered as an asset-weighted average across the banks in our sample) declined over the first half of the 1990s from around 11 per cent to a low of 8.3 per cent. From the second half of 1995 the ratio steadily increased to a level of 10.4 per cent by March 1998. The main source of difference in the two ratios follows from the differing treatment of capital. Our model estimate of capital (and in turn the capital-asset ratio) is strongly affected by the market capitalisation of each bank. In most years of the 1990s growth in Australian banks' market capitalisation was considerably stronger than the growth in book value equity (which is the basis for the regulatory ratio).

The secular pattern of the weighted-average capital-asset ratio is most heavily influenced by the four largest banks.[20] Individual bank results vary considerably, with some banks' capital-asset ratios rising significantly over the sample period and others remaining static or falling slightly.

## 4.2 Operating Risk

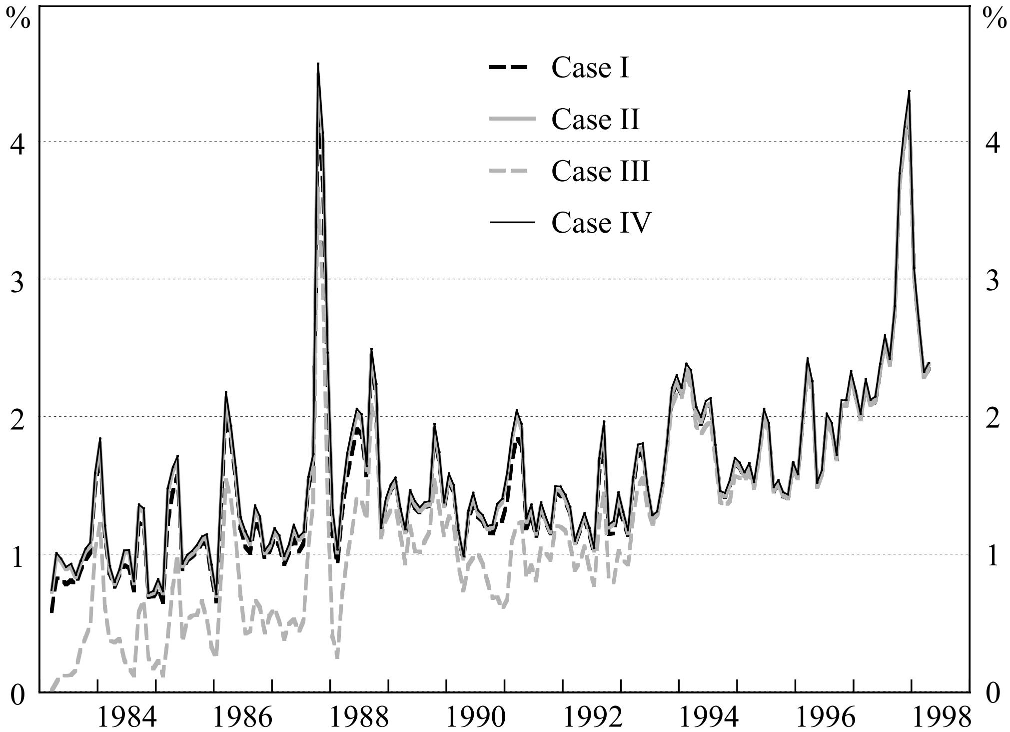
Figure 4 illustrates the weighted-average asset volatility, derived once again using historical estimates of equity volatility. The model's estimate of asset volatility is itself highly variable through time. The market's assessment of individual firms can change rapidly and frequently. The quality of the model's risk estimates is greatly dependent on the stock market's efficiency. Any tendency for price bubbles to develop that push share values away from economic fundamentals will undermine the model's accuracy. In particular, instances of market-wide movements driven by speculative dynamics may swamp assessment of the riskiness of individual firms. In this regard, the spikes in volatility surrounding the stock market corrections in 1987 and 1997 clearly greatly overstate the riskiness of banks' assets.

The slight upward trend in asset volatility during the 1980s, detected by Gizycki and Levonian, gathered momentum in the following decade. This finding contrasts strongly with the declines in banks' impaired assets and charges to profit and loss for bad and doubtful debts since the early 1990s, which suggest that the banks' primary risk exposure – credit risk – has fallen (see, for example, Ulmer (1997)). The patterns for the individual banks differ to some degree, although in no case is there substantial disagreement.

[20] The four largest banks are ANZ, Commonwealth Bank of Australia, National Australia Bank and Westpac.

**Figure 4: Weighted-average Asset Volatility**

Annual standard deviation




These results suggest that the stock market based measure of operating risk has increased over the sample period, mitigating to some extent the positive effect of increased capital on insolvency risk. The evolution of the probability of closure should give us a feel for which effect dominated.

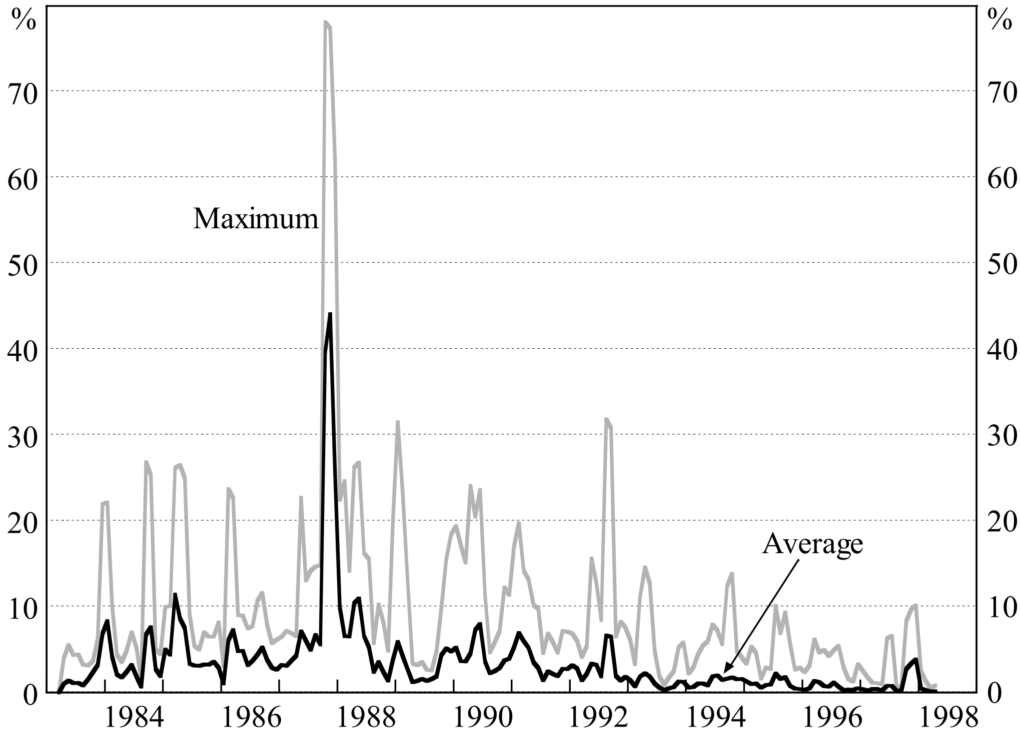
## 4.3 Total Bank Risk

### *4.3.1 Probability of closure*

The model's implied probability of bank closure is expressed as $1-N\left(x-\sigma_A\sqrt{T}\right)$.

Figure 5 presents the average probability of closure across the 15 banks, when applying the Case III (high licence value and early closure) parameterisation of the model. To give an idea of the dispersion across the banks, the largest individual-bank estimate for each month is also shown.

**Figure 5: Probability of Closure Over the Next 12 Months**



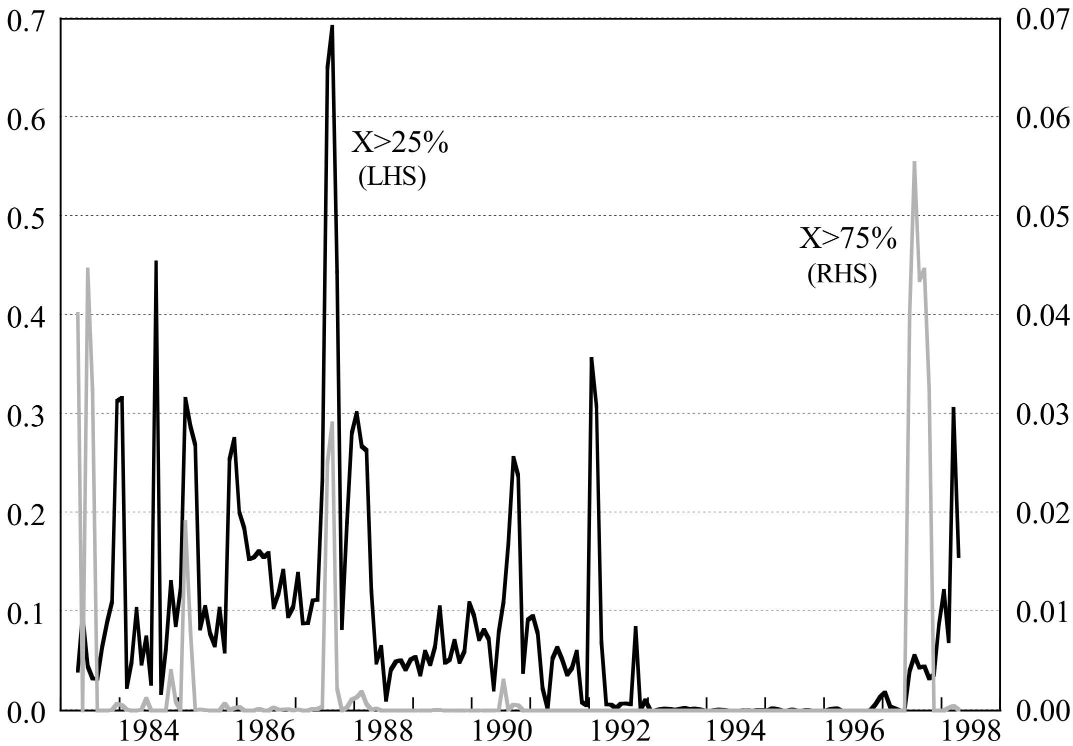

Not surprisingly, the effect of the 1987 stock market crash dominates the series. The sharp decline in share prices, coupled with extreme volatility around this time, combined to produce the aberrant result. The model assumes that such extreme volatility reflects a change in the markets' valuation of individual firms. However, market-wide speculative dynamics would seem to have dominated in this episode. Other notable features are the sensitivity of the results to the underlying data and the gradual decline in the series since 1990. The only blip in recent times has been the spike towards the end of 1997, reflecting the sudden fall in stock markets.

Despite the steady rise in the volatility of assets, observed in Figure 4, the market's assessment of the average probability of closure has declined over the years. It appears, therefore, that in the market's view the increase in operating risk has been more than offset by decreases in financial risk.

It seems reasonable to argue that the macroeconomic impact of an individual institution's failure depends on the proportion of the financial system that the institution accounts for (see, for example, Kent and Debelle (1998)). Given each bank's estimated default probability, it is possible to obtain the probability distribution of losing a given share of the banking system (as measured by the market value of assets). To do this we make the simplifying assumption that each bank's default probability is independent of all other banks.

Figure 6 shows the probability of losing more than a quarter and more than three-quarters of banking assets in the year ahead. Once again, the period around the 1987 stock market crash dominates the results and, for the reasons discussed above, can be discounted as overstating true risk. For most of the 1990s the market's assessment of the probability of loss has been very low. The increases in the likelihood of loss seen from mid 1997 reflect recent spikes in sharemarket volatility.

**Figure 6: Probability of Losing a Given Share of the Banking System Over the Next 12 Months**



### *4.3.2 Expected creditor losses*

Annual averages of the sum, across banks, of the expected losses borne by creditors are presented in Table 2.[21] The assumptions employed in deriving these estimates (e.g. all liabilities, not just deposits, are insured) mean that whilst we can

**Table 2: Annual Averages of the Expected Creditor Losses**

$ million

| Year | Case I (low licence value and early closure) | Case II (low licence value and late closure) | Case III (high licence value and early closure) | Case IV (high licence value and late closure) |
|---|---|---|---|---|
| 1983 | 0.82 | 1.37 | 0.07 | 1.35 |
| 1984 | 3.22 | 6.20 | 0.18 | 6.09 |
| 1985 | 3.89 | 8.59 | 0.21 | 8.42 |
| 1986 | 2.47 | 4.64 | 0.26 | 4.57 |
| 1987 | 181.00 | 208.75 | 137.11 | 206.24 |
| 1988 | 4.42 | 6.79 | 1.36 | 6.69 |
| 1989 | 2.66 | 2.99 | 1.78 | 2.96 |
| 1990 | 1.06 | 1.47 | 0.44 | 1.45 |
| 1991 | 4.08 | 6.81 | 0.76 | 6.70 |
| 1992 | 22.74 | 35.50 | 3.85 | 35.02 |
| 1993 | 0.55 | 1.19 | 0.03 | 1.17 |
| 1994 | 0.68 | 0.90 | 0.17 | 0.88 |
| 1995 | 40.83 | 42.38 | 36.21 | 41.92 |
| 1996 | 0.51 | 0.57 | 0.27 | 0.56 |
| 1997 | 10.65 | 11.23 | 8.39 | 11.04 |
| 1998 | 0.57 | 0.61 | 0.32 | 0.60 |

Notes: In some years, the annual average of the total contingent payout is materially affected by one or two outliers. For example:

(a) In 1992, Westpac raised capital through a rights issue. The sudden increase in the market value of WBC was reflected in the volatility of equity which, in turn, generated a large contingent payout in the months affected. If these months are excluded from the calculation, the annual average of the total contingent payout falls to $0.94 million (Case I); and

(b) Similarly, if the months affected by the capital raising undertaken by Advance Bank in 1995 are excluded from the calculation, the annual average of the total contingent payout falls to $0.39 million (Case I).

[21] If the public sector were to guarantee deposits, then Table 2 could be interpreted as the deposit guarantee liability.

draw conclusions from movements in the series with a degree of confidence, not too much emphasis should be placed on their level.

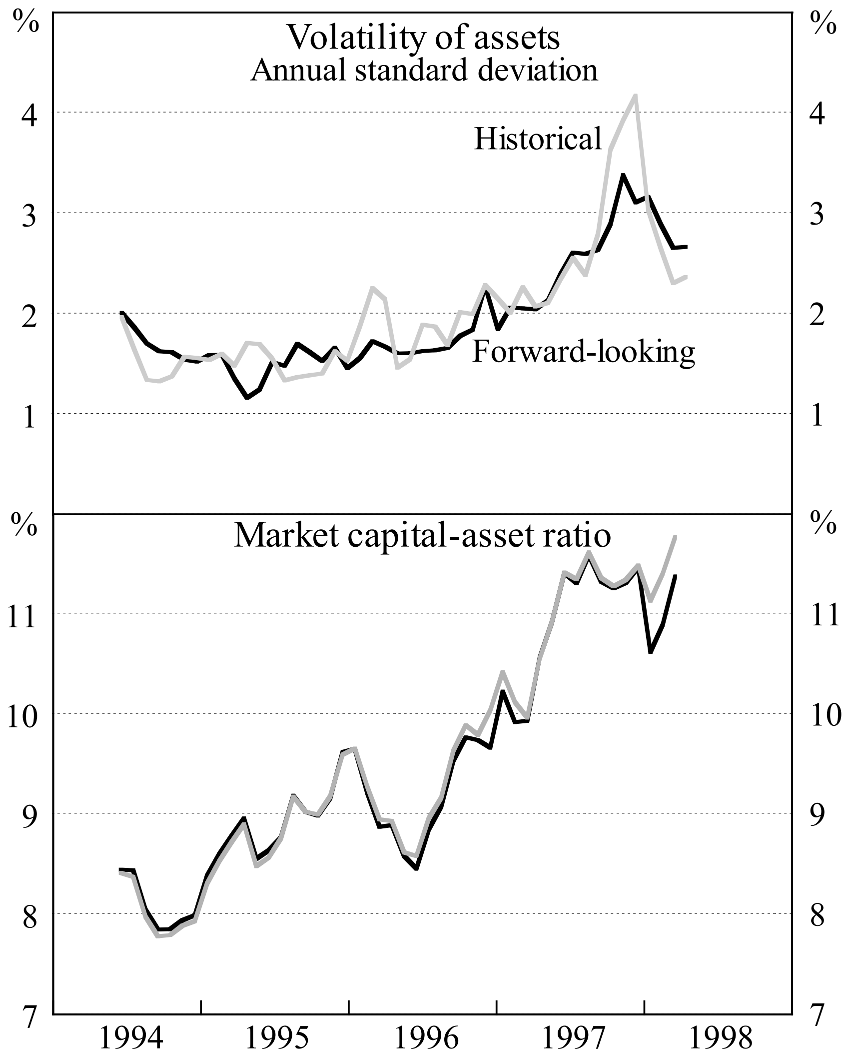
Expected losses are negligible in most years. Notable exceptions are the large values recorded in 1987 and, to a lesser extent, in 1997 – both are the result of volatility in the stock market. Overall, the movements corroborate the conclusions reached from the analysis of the probability of closure.

### 4.4 Impact on Results of the Different Proxies for the Volatility of Equity

Figure 7 illustrates the impact on the results of using the forward-looking estimate of $\sigma_E$, obtained from options, when applying the Case III parameterisation of the model.

The market capital-asset ratio is not significantly affected by the choice of estimate. The volatility of assets, on the other hand, is dependent on the estimate employed; whilst the long-term movements are comparable, the series is more variable when the historical estimate is used. This is not entirely surprising given that the historical measure is itself more variable than the forward-looking measure (Figure 2 and Equation (7)). Although not shown, this difference is manifested in estimates of both the probability of closure and the deposit-guarantee liability; specifically, the estimated series have fewer spikes when the forward-looking measure of equity volatility is used.

**Figure 7: Effect of Different Estimates of the Volatility of Equity on the Results**




## 4.5 Sensitivity of Results to Assumed Closure Threshold and Licence Value

The sensitivity of the results to the assumed closure threshold and licence value can be investigated by comparing the results for the four cases described in Table 1. Specifically, the sensitivity to a change in the closure threshold can be determined by comparing Case I with Case II and Case III with Case IV, while the impact of movements in licence value are borne out by contrasting Case I with Case III.

Figure 3 shows that the market capital-asset ratio is unaffected by variations in either the assumed closure threshold or the licence value. The licence value has no influence on the capital-asset ratio by construction. As stated earlier, the capital-asset ratio presented in Figure 3 incorporates both the tangible and intangible assets of the bank. For a given value of equity, any increase in intangible assets (i.e. a higher $\varphi$) will lead to a commensurate fall in tangible assets leaving total assets and, hence, the capital-asset ratio unchanged.

From Figure 4, a clear relationship between the volatility of assets and the calibrated parameters cannot be discerned. Before the early 1990s, it appears that the volatility of assets was influenced by the difference between the closure threshold and the licence value, rather than the level of either one of them. Since then, changes in the level of, and the difference between, the closure threshold and the licence value do not appear to have had any impact.

Turning our attention to Table 2, it can be seen that a higher closure threshold (i.e. the bank is closed earlier) reduces the contingent liability. This is to be expected since the closure threshold places a cap on losses. Increasing the licence value also reduces the public-sector liability. The sensitivity of the contingent liability to assumptions about $c$ and $\varphi$ make it inappropriate to attach much weight to the specific dollar amounts of the liability. The general pattern over time is, however, reasonably consistent across the four cases. There are analogous relationships between the calibrated parameters and the probability of closure.

## 5. The Relationship Between a Bank's Operating and Financial Risk

The contingent-claim model used to derive asset volatility assumes that the market value of assets follows the Geometric Brownian Motion process set out in Equation (4). In particular, it assumes that, over the regulatory monitoring period, the volatility of assets is constant and that the level of assets (and hence, the capital-asset ratio) is independent of asset volatility (that is, $\mu_A$ is not a function of $\sigma_A$).[22] Since it is not possible to obtain analytical expressions for $\sigma_A$ and $A$ from Equations (5) and (9), it is difficult to determine those values of the model parameters that will generate a positive or negative relation between $\sigma_A$ and $A$ (and

[22] The results of our analysis suggest that this assumption is not a good one, with estimated asset volatility itself being quite variable.

thus $k$). Moreover, the evolution of $\sigma_A$ and $A$ will reflect the dynamic behaviour of $\sigma_E$, $\gamma$, $E$ and $B$, since we use updated estimates of these variables when solving for new values of $\sigma_A$ and $A$. In this section we present a number of arguments which suggest that movements in a bank's capital-asset ratio and asset volatility will be related. We then go on to examine the empirical significance of that relationship and investigate its dynamics.

Whilst the theoretical relationship between a bank's operating risk and its capital has been the focus of numerous studies over the years, the literature has generated differing conclusions about how risk taking and capital are related. This section begins by reviewing the more popular hypotheses with the aim of establishing a framework within which the empirical results can be understood.

### 5.1 Risk-based Capital Adequacy Standards

The Basel risk-based capital adequacy standards explicitly link the amount of capital that banks are required to hold with the riskiness of their assets. Under the initial standards, adopted by the Reserve Bank of Australia in 1988, the appropriate level of capital was deemed to be 8 per cent of risk-weighted assets. The risk weights were designed to measure the relative degree of credit risk attached to various groups of assets. An elaboration of the 1988 guidelines, which came into effect in 1998, means that banks are now required to hold capital against their market-risk exposures in addition to that held to support credit risk.

Although the risk-based capital arrangements are by no means perfect (the risk weights are rough rules of thumb; for example, all non-government corporate enterprises are given a 100 per cent risk weighting), we would expect that those banks engaging in riskier activities would be required to hold a larger amount of capital. That is, despite the standards' simplicity, as long as higher-weighted assets tend to have higher risk then a positive relation between capital and risk will prevail, if the regulatory requirements are binding.

To expand its business or to take on additional risk, a bank would need to raise capital concurrently or beforehand to meet prudential requirements if it is currently constrained by them, or if it expects business expansion to absorb capital held above the regulatory minimum. Causation may run in the opposite direction, and be asymmetric, if regulators force banks to raise capital in response to increases in asset risk but do not require reductions in capital if asset risk falls.

To the extent that the regulatory risk weights reflect the true risks arising from banks' assets, a positive relationship between banks' asset volatility and capital-asset ratios is expected. However, changes in regulations concerning required capital may induce changes in the composition of portfolios, creating second-round effects on asset volatility – hence, the overall impact may be uncertain.

Kim and Santomero (1988) demonstrate, using a mean-variance utility maximisation framework, that an increase in *flat-rate* capital requirements may cause banks to choose higher-risk portfolios. Capital requirements restrict the opportunity set available to banks, prohibiting them from selecting certain asset portfolios on their efficient frontier. Although an increase in capital requirements limits choice even further, banks may still choose a higher-risk portfolio as they maximise utility along the new frontier. Whether this is the case depends on the bank's attitude towards risk; the stronger is the bank's appetite for risk, the more likely it becomes.

In the presence of a flat-rate capital regime, it is argued that, among banks that operate at or near the regulatory minimum capital levels, a positive relationship between capital and asset risk will result. In other words, banks which experience a regulatory induced increase in capital may substitute asset risk for leverage and, in doing so, circumvent the intent of the regulation. Basing capital standards on true asset risk mitigates the likelihood of this happening. Kim and Santomero derive optimal risk weights and show that their model places an upper bound on insolvency risk.

Keeley and Furlong (1990) object to using the mean-variance utility maximisation framework because it misrepresents the banks' efficient frontier by assuming that changes in the probability of bank failure do not affect the cost of deposits. They argue that, even for insured banks, borrowing costs are not impervious to changes in insolvency risk and, therefore, leverage. The reason is that, as explained in Section 2, a fixed-rate deposit insurance guarantee represents an option to the bank to sell its assets to the insuring agency at a strike price equal to the maturity value of its liabilities. The value of this option (per dollar of deposits) is an increasing function of both leverage and asset risk.[23] This relationship, in effect, lowers the expected marginal cost of deposits in the face of an increase in the probability of failure. Thus, Keeley and Furlong argue that, for the constant borrowing cost assumption to hold, the probability of failure must be zero; this, of course, contradicts the finding that an increase in capital requirements may increase insolvency risk. Keeley and Furlong conclude that once this oversight is corrected the results generated from such models no longer stand. Furlong and Keeley (1989) show, using both state-preference and options models, that an increase in required capital will not, by itself, cause a value-maximising bank to increase asset risk.

Before risk-based standards were introduced in 1988, established Australian banks were required to maintain a capital-asset ratio (not adjusted for risk) of 6.5 per cent.[24] Overall, Australian banks were well capitalised relative to the minimum regulatory requirements in the years surrounding the implementation of the new standards. Thus, it is arguable that regulatory capital requirements were not a strong force driving bank behaviour.

## 5.2 Agency Theory

Agency theories of the firm highlight the potential for conflicts of interest between equity holders and debt holders, and between equity holders and managers. The impact that this has on the capital structure decision is discussed in Jensen and Meckling (1976). Differences in motives between the various parties may also affect the relationship between risk and capital.

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[23] The option is valuable to shareholders because without it, they could be forced to raise the funds required to satisfy the debt holders.

[24] New entrants, primarily building societies converting to bank status and foreign banks taking up a banking licence in Australia, were required to adhere to a higher ratio.

### *5.2.1 The asymmetry between debt and equity*

#### *(a) Debt market discipline*

Higher levels of debt may encourage equity holders to demand riskier operations and investments. This can be best understood by viewing equity holders as having an option over the value of the firm (Equations (5) and (6)). The value of the option is a positive function of the volatility of the return on assets; because the option has a payoff structure with a lower bound of zero, as the return on assets becomes more variable, the expected payoff of the option at maturity also increases. Put more simply, if a risky investment proves successful the residual benefits will flow to equity holders, but if the investment fails, debt holders will fully absorb the losses. Knowing this, the debt holders (including depositors) demand higher compensating returns and/or restrictions on the activities of the firm (for example, covenants), thereby imposing agency costs on equity holders. One way for firms to reduce agency costs is to operate with lower leverage. Agency costs may, therefore, drive a positive relationship between risk and capital; if, for example, a bank takes on more risk, it may also decide to raise capital so as to appease debt holders who would otherwise impose additional agency costs on the bank.

In an environment where information asymmetries lead firms to use leverage as a signalling device, capitalisation and asset volatility may be complements rather than substitutes. For example, Leland and Pyle (1977) argue that a higher-quality firm (that is, one with low asset volatility) may signal that quality by increasing the capital-asset ratio. Since financial capital constitutes the bank's own stake in its risk management, it conveys a credible signal to debt holders of the resources allocated to ensuring the continued survival of the firm and thus the safety of depositors' claims. Signalling theory, therefore, predicts a negative cross-sectional correlation between the capital-asset ratio and asset volatility.

#### *(b) Moral hazard*

As discussed previously, many countries explicitly guarantee or insure bank deposits. Deposit insurance schemes have the common effect of making deposits risk-free in nominal terms. Deposit insurance, as a result, excludes depositors from the set of individuals who have a vested interest in the riskiness of the insured institution. Market signals may not, therefore, provide the necessary risk-reducing discipline to managers. It is argued that this gives banks an incentive to take on riskier activities without being adequately capitalised (see, for instance, Gennotte and Pyle (1991)).

Incentives for such risk taking are magnified in weak institutions by the policy of limited shareholder liability. Losses to equity holders are limited to the amount invested while there is no limit to earnings of equity holders if the project should prove successful. This leads to behaviour known as 'betting the bank', wherein the managers of the bank adopt a high-risk strategy which lowers the expected value of the bank, but which has a chance of yielding high profits. This behaviour is expected to be most prevalent amongst banks having negligible opportunities for profitable growth over time. A decline in a bank's capital-asset ratio is liable to increase the likelihood of moral hazard driven behaviour; thus, a negative relation between capital and asset risk is predicted by the moral-hazard theory.

However, even with extensive deposit guarantees, banks do not hold zero capital and take on infinite asset risk. One reason for this is that the bank's ability to raise funds from uninsured sources will continue to be influenced by its probability of failure. Whether there is a positive or negative relation between asset risk and capital depends on the marginal benefits and costs of asset risk and leverage.

### *5.2.2 Managerial risk aversion*

The relationship between shareholders and the manager of a bank can also be affected by agency problems. Managers may have an incentive to decrease risk below the level desired by shareholders, since they have more to lose if the bank fails – managers have firm- and industry-specific human capital whereas shareholders generally have a smaller proportion of their wealth invested in the bank. Hence, risk-averse managers may seek to offset increases in asset risk with higher levels of capital, providing a further rationale for a positive relationship between asset risk and capital.

Regulatory capital constraints excepted, the theories outlined above do not make any predictions concerning the temporal ordering of movements in leverage and asset volatility. Transaction costs and variations in the degree of information asymmetry, between bank insiders and outsiders, dictate that capital issues are usually made in relatively large discrete steps. This leads us to expect that increases in capital would precede increases in asset risk. Reductions in capital, however, may more closely approximate a continuous process. In such a case, the relationship between the capital-asset ratio and asset volatility may be asymmetric: increases in capital preceding increases in asset volatility, and decreases in capital lagging or coinciding with asset-volatility declines.

Having outlined the theoretical framework within which we can consider the relationship between risk and capital, the following section presents the results of our analysis.

### 5.3 The Empirical Relationship Between Asset Volatility and Capital

The contingent-claim model assumes that the stock market is always efficient, but there are grounds for considering the crash to be an anomalous event that should be excluded from the analysis. Therefore, the months affected by the 1987 stock market crash are excluded from the empirical work presented in this section.

Statistical analysis of the data suggests that while asset volatility is stationary, for around half of the banks, the capital-asset ratio is integrated of order one.[25] The implications of this are two-fold. Firstly, our modelling needs to consider the relationship between the level of asset volatility and both the level of and month-to-month changes in the capital-asset ratio.[26] Secondly, the inferences drawn from our modelling are confined to the short-run dynamics of the relation rather than any longer-run behaviour.

[25] The order of integration of the capital ratio is a difficult statistical issue. Over the long run, theory would suggest that the capital-asset ratio is bounded since the risk of insolvency places a lower bound on the ratio and the need to provide shareholders with a competitive return caps the ratio. Over the 15 years included in our sample, however, the capital-asset ratio does not show any signs of reverting to some permanent or equilibrium level.

[26] Ordinarily, any relationship found from regressing an I(0) process on an I(1) process would be labelled spurious. However, because of the low power of these tests, we still report the results of regressions involving the level of the capital-asset ratio.

### *5.3.1 Simple regression analysis*

We first consider the contemporaneous correlation between the capital-asset ratio and asset volatility. Table 3 presents the correlation of asset volatility with the level and changes in the capital-asset ratio calculated across time for each bank. Asset volatility is found to have a strong positive relationship with the capital-asset ratio (the apparent non-stationarity of the capital-asset ratio places a strong *caveat* on this result). For all banks the correlation coefficient is positive, and for 12 out of the 15 banks the coefficient is significant at the 1 per cent level. When changes in the capital-asset ratio are considered a positive relation is found for most banks; the correlation, however, is significant for only four of the banks.

**Table 3: Contemporaneous Correlation Between the Capital-asset Ratio and Asset Volatility**

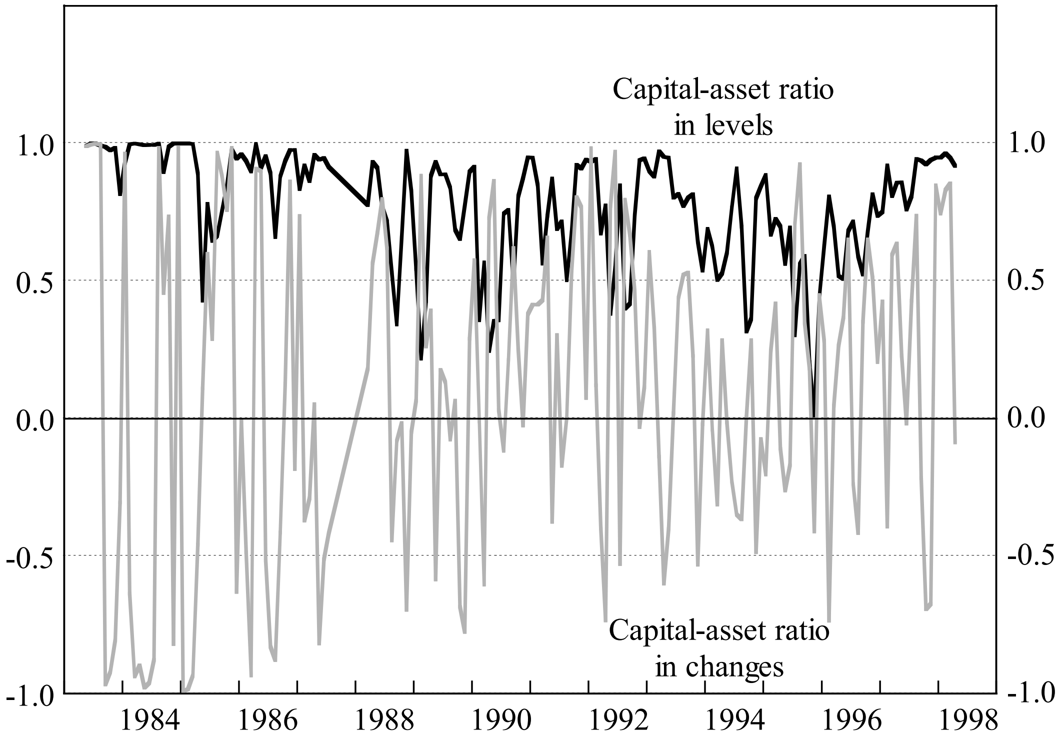
Monthly; March 1983 – April 1998 (excluding October – December 1987)

| Bank | Correlation between $k_t$ and $\sigma_{At}$ | Correlation between $\Delta k_t$ and $\sigma_{At}$ |
|---|---|---|
| A | 0.875*** | 0.284*** |
| B | 0.664*** | 0.098 |
| C | 0.854*** | -0.160 |
| D | 0.828*** | 0.098 |
| E | 0.172 | 0.273*** |
| F | 0.447*** | -0.143 |
| G | 0.497*** | 0.541*** |
| H | 0.813*** | 0.086 |
| I | 0.402*** | 0.229 |
| J | 0.134* | 0.108 |
| K | 0.597*** | 0.353*** |
| L | 0.092 | -0.152 |
| M | 0.917*** | 0.217* |
| N | 0.476*** | 0.146 |
| O | 0.546*** | 0.166 |

Notes: ***, * denote significance at the 1 and 10 per cent levels respectively.
$\Delta k_t$ is the month-to-month change in the capital-asset ratio.
$k_t$ and $\sigma_{At}$ are obtained from the Case III paramaterisation of the model using historical estimates of $\sigma_E$.

Figure 8 summarises the results of cross-sectional correlations for each month between March 1983 and April 1998. The black line shows the correlation between asset volatility and the level of the capital-asset ratio, while the grey line shows the correlation coefficient when the change in the capital-asset ratio is used. The small number of banks in this study (15) suggests a degree of caution in interpreting the results. Keeping this in mind, there is a consistently positive correlation between the capital-asset ratio and asset volatility (this correlation is significant about 75 per cent of the time). The cross-sectional correlation between the change in the capital-asset ratio and asset volatility tends to be close to zero, being significantly positive on only one fifth of occasions.

**Figure 8: Correlation Across Banks Between the Capital-asset Ratio and Asset Volatility**




Our finding of positive correlation conflicts with models of moral hazard, which predict that as the capital-asset ratio falls banks are likely to take on riskier assets. Our results also contrast with the majority of studies in the US (see, for example, Benston and Kaufman (1998)). Australian banks' behaviour seems to more strongly reflect regulatory requirements, debt-market discipline and agency cost considerations.

### *5.3.2 Granger-causality tests*

Since we have a panel of cross-sectional data with many more observations through time than across banks, our first step was to consider a seemingly unrelated regressions model. However, we failed to find evidence of significant contemporaneous correlation between disturbances from equations estimated separately for each bank. Hence, the results presented here are based on applying ordinary least squares to each bank's equation separately. These results are presented in Tables 4 and 5. Where significant, a trend or a broken trend (split between March 1983 – December 1991 and January 1992 – April 1998) is included in the model of asset volatility. In each equation, lags of the change in capital and the level of volatility are included as explanatory variables. Tables 4 and 5 present the number of lags included in each equation (chosen by eliminating insignificant lagged coefficients), the sum of the coefficients on the lagged variables and, in parentheses, the significance from testing whether all lagged variables can be excluded from the equation. The final two columns of Table 5 summarise impulse response functions for the two estimated equations considered together. The change in capital growth observed six months after a one standard deviation, one period, shock to asset volatility is shown for each bank. Similarly, the response of asset volatility to a temporary shock to capital growth is presented.

While there is variation across banks in the relation between asset volatility and capital, overall it can be seen that *there is a significant two-way feedback relationship between the two variables*. For most banks, increases in the growth of the capital-asset ratio precede an increase in asset volatility; banks build up their stock of capital in anticipation of expanding their risk exposures. The corollary to this is that reductions in the capital-asset ratio (for example, through capital buy-backs) presage a reduction in risk exposures (this is investigated further in Section 5.3.4). This finding is consistent with banks having to build up capital to avoid breaching regulatory requirements.

**Table 4: Granger-causality Test**

Dependent variable: change in capital ($\Delta\kappa$)

Monthly; March 1983 – April 1998 (excluding October – December 1987)

| Bank | Constant | Change in capital | | Asset volatility | |
|---|---|---|---|---|---|
| | | No. of lags | Sum of coefficients | No. of lags | Sum of coefficients |
| A | 0.000 | 1 | 0.153 | 1 | 0.015 |
| | (0.332) | | (0.154) | | (0.742) |
| B | 0.006 | 6 | 0.394 | 1 | -0.391 |
| | (0.004) *** | | (0.009)*** | | (0.016)** |
| C | 0.011 | 1 | 0.347 | 1 | -0.377 |
| | (0.069)* | | (0.022)** | | (0.070)* |
| D | 0.001 | 1 | 0.176 | 1 | -0.047 |
| | (0.021)** | | (0.004)*** | | (0.187) |
| E | 0.002 | 1 | 0.028 | 1 | -0.095 |
| | (0.246) | | (0.814) | | (0.206) |
| G | -0.001 | 1 | 0.083 | 7 | -0.016 |
| | (0.330) | | (0.414) | | (0.000)*** |
| H | 0.001 | 1 | 0.183 | 1 | -0.015 |
| | (0.420) | | (0.044)** | | (0.786) |
| I | 0.000 | 4 | -0.479 | 5 | 0.007 |
| | (0.975) | | (0.001)*** | | (0.040)** |
| J | 0.000 | 1 | 0.093 | 1 | -0.014 |
| | (0.998) | | (0.225) | | (0.738) |
| K | 0.006 | 3 | 0.386 | 9 | -0.275 |
| | (0.002)*** | | (0.001)*** | | (0.025)** |
| L | 0.001 | 1 | 0.054 | 2 | 0.128 |
| | (0.019)** | | (0.698) | | (0.003)*** |
| M | 0.000 | 1 | 0.310 | 1 | -0.067 |
| | (0.751) | | (0.000)*** | | (0.104)** |
| N | 0.007 | 9 | 0.039 | 2 | -0.337 |
| | (0.048)** | | (0.088)* | | (0.101) |
| O | -0.004 | 1 | 0.037 | 9 | -0.184 |
| | (0.098)* | | (0.795) | | (0.000)*** |

Notes: The numbers in parentheses show the significance level from testing whether all lagged variables can be excluded from the regression.

***, **, * denote significance at the 1, 5 and 10 per cent levels respectively.

$\Delta k_t$ is the month-to-month change in the capital-asset ratio.

$k_t$ and $\sigma_{At}$ are obtained from the Case III paramaterisation of the model using historical estimates of $\sigma_E$.

## Table 5: Granger-causality Test

Dependent variable: volatility of assets, in levels ($\sigma_A$)

Monthly; March 1983 – April 1998 (excluding October – December 1987)

| Bank | Constant | Trend | Trend 1 | Trend 2 | Change in capital | | Volatility | | Impulse response | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | No. of lags | Sum of Coefficients | No. of lags | Sum of Coefficients | Change in capital (percentage points) | Asset volatility (percentage points) |
| A | 0.000 | 0.00004 | | | 2 | -0.028 | 1 | 0.730 | 0.003 | -0.008 |
| | (0.929) | (0.006)*** | | | | (0.089)* | | (0.000)*** | | |
| B | 0.003 | | | | 5 | 0.554 | 6 | 0.794 | -0.005 | 0.188 |
| | (0.046)** | | | | | (0.008)*** | | (0.000)*** | | |
| C | 0.035 | 0.00026 | | | 9 | 0.315 | 2 | 0.440 | 0.175 | 0.111 |
| | (0.001)*** | (0.006)*** | | | | (0.004)*** | | (0.000)*** | | |
| D | 0.001 | 0.00004 | | | 1 | 0.166 | 1 | 0.709 | -0.009 | 0.016 |
| | (0.105) | (0.007)*** | | | | (0.016)** | | (0.000)*** | | |
| E | 0.008 | | | | 1 | 0.156 | 1 | 0.575 | -0.003 | 0.005 |
| | (0.001)*** | | | | | (0.035)** | | (0.000)*** | | |
| G | 0.006 | | | | 1 | 0.023 | 2 | 0.000 | -0.300 | -0.001 |
| | (0.000)*** | | | | | (0.908) | | (0.604) | | |
| H | -0.006 | 0.00008 | | | 1 | 0.207 | 1 | 0.588 | -0.001 | 0.007 |
| | (0.020)** | (0.004)*** | | | | (0.017)** | | (0.000)*** | | |
| I | -0.036 | 0.00034 | | | 4 | 0.667 | 1 | 0.089 | -0.176 | -0.056 |
| | (0.005)*** | (0.000)*** | | | | (0.003)*** | | (0.614) | | |
| J | 0.026 | -0.00006 | | | 3 | 0.495 | 2 | 0.361 | 0.002 | -0.050 |
| | (0.000)*** | (0.003)*** | | | | (0.018)** | | (0.000)*** | | |
| K | 0.018 | | -0.00010 | 0.00003 | 7 | 0.890 | 2 | 0.313 | 0.057 | 0.133 |
| | (0.001)*** | | (0.049)** | (0.389) | | (0.001)*** | | (0.000)*** | | |
| L | 0.008 | | | | 1 | -0.062 | 1 | 0.568 | -0.004 | -0.002 |
| | (0.001)*** | | | | | (0.672) | | (0.000)*** | | |
| M | 0.000 | | | | 4 | 0.807 | 6 | 0.965 | -0.012 | 0.131 |
| | (0.407) | | | | | (0.028)** | | (0.000)*** | | |
| N | 0.002 | | | | 4 | 0.344 | 6 | 0.929 | -0.048 | 0.029 |
| | (0.353) | | | | | (0.156) | | (0.000)*** | | |
| O | -0.030 | 0.00029 | | | 10 | 0.694 | 4 | 0.139 | 0.305 | 0.034 |
| | (0.043)** | (0.005)*** | | | | (0.001)*** | | (0.000)*** | | |

Notes: The numbers in parentheses show the significance level from testing whether all lagged variables can be excluded from the regression.
***, **, * denote significance at the 1, 5 and 10 per cent levels respectively.
$\Delta k_t$ is the month-to-month change in the capital-asset ratio.
$k_t$ and $\sigma_{At}$ are obtained from the Case III paramaterisation of the model using historical estimates of $\sigma_E$.
'Trend' is a full sample trend while 'Trend 1' runs from March 1983 to December 1991 and 'Trend 2' runs from January 1992 to April 1998.
The impulse response shows the change in the variable (after six months) as a result of a one standard deviation, one period, shock to the other variable.

The results also suggest that an increase in asset volatility usually leads to a slowdown in the growth of the capital-asset ratio. To understand why this may occur requires us to add another layer of detail to the model presented in Section 2. Referring to Figure 1, each point on the distribution of assets represents the present value of a set of cash flows that may accrue from the assets. The moments of this distribution reflect those of the distributions pertaining to each cash flow. More specifically, the volatility of assets (i.e. the width of the distribution) reflects the uncertainty surrounding the cash flows, while the expected value of assets (i.e. the mean of the distribution) is equal to the present value of the expected cash flows. If the cash flows expected to accrue from the assets become more uncertain then the discount rate that is applied to the cash flows increases, causing their present value to fall – that is, the expected value of assets decreases. A further, and more obvious, effect is that the uncertainty surrounding the expected value of assets also increases. In terms of Figure 1, we can think of this as both a widening and a downward displacement of the distribution of assets. However, this displacement of the distribution is somewhat inconsistent with the model from which the results are derived. Recall that assets were assumed to follow Geometric Brownian Motion, which can be described by:

$$d_A = \mu_A(\gamma)A(t)dt + \sigma_A A(t)dz \tag{14}$$

Our results suggest that an increase in the volatility of assets will reduce the market value of a bank's assets. For this displacement to occur, the drift term in Equation (14), $\mu_A$, needs to be a function of $\sigma_A$; this is inconsistent with our assumption, made earlier, that the drift term is equal to zero. To some extent, this discrepancy can be rationalised by realising that we are assuming a zero drift over a short time horizon (one year), whereas the relationship detected by the Granger-causality tests is based on a much longer time period.

Thus, banks raise capital prior to expanding their risk positions, after which, some of that capital is effectively consumed by the risk exposures. The adjustment within this feedback system is quite quick. Scrutiny of the impulse response functions show that by six months the response in capital growth rates to a temporary shock in asset volatility has fully played out. The adjustment of asset volatility following a shock to capital growth is slower, taking around twelve months. The impulse response function results show that on average, across all banks, a one standard deviation, one period, increase in asset volatility leads to a slowdown in capital growth of 0.001 percentage points after six months, while an equivalent shock to capital growth yields a 0.04 percentage point increase in asset volatilities. That said, there is considerable variation across banks around these average responses.

### *5.3.3 The impact of the 1988 Capital Accord*

For those banks with sufficient observations before and after 1988, we consider the extent to which the relationship between the capital-asset ratio and asset volatility may have altered following the introduction of the risk-based capital adequacy arrangements. We extend the models presented in Tables 4 and 5 by estimating separate coefficients on the inter-relationship for the periods March 1983 – December 1988 and January 1989 – April 1998. These results are presented in Appendix C.

The results support the notion that prior period increases in the level of asset volatility lead to a slow down in the growth of the capital-asset ratio. For most banks, there is a significant difference in the size of this effect following the introduction of the Capital Accord, with the magnitude of the impact of asset volatility on capital growth falling in most cases.

For most banks the magnitude of the effect that prior period changes in the capital-asset ratio have on the volatility of assets does not change significantly following the introduction of the Capital Accord. Whilst insignificant, the size of the effect does appear to have increased slightly. This could be interpreted as providing some weak evidence that the introduction of the Capital Accord strengthened the linkages between banks' risk taking and capital.

### *5.3.4 Is the relationship between capital and asset volatility asymmetric?*

If regulators require banks to increase capital in response to increases in asset risk, but do not force reductions in capital if asset risk falls, then it is possible that the relation between capital and asset risk is asymmetric. The discrete nature of capital issues may also result in such asymmetry. Thus, the second modification that we make to our model is to differentiate between periods of growth and decline in the capital-asset ratio. The results are presented in Appendix C.

The impact of prior period volatility on growth in the capital-asset ratio is largely unaffected by whether capital growth was accelerating or slowing. As with the full sample results, increased prior period volatility tends to lead a slowdown in capital growth.

For half of the banks in our sample there is a significant difference in the effect of changes in the capital-asset ratio on volatility according to whether growth in the capital-asset ratio is positive or negative. Consistent with the full sample analysis, when the capital ratio is increasing there is a strong positive relation between previous growth in the capital-asset ratio and asset volatility. In contrast, when capital is declining the sign of the relationship is indeterminate (being positive for half of the banks and negative for the other half). Moreover, for most banks the relationship between the capital-asset ratio and asset volatility is weaker when capital growth is slowing. There does not seem to be any consistent relation between either the size of the bank or the bank's average capital-asset ratio and the size (and sign) of the coefficient.

These results are consistent with some asymmetry in supervisors' and markets' treatment of banks: while banks increase capital in advance of taking on risk exposures, falls in capital do not necessarily trigger reductions in asset volatility.

## 6. Conclusion

This paper has presented a contingent-claim model that translates the market capitalisation of a bank into measures of bank risk. The risk measures obtained from this model provide an alternative to the more readily available measures published in banks' annual reports. If the share market is efficient, with share prices being based on assessment of each firm's fundamental value, the market-based risk measures will more closely approximate the appropriate economic concepts. The accuracy of the risk measures does, however, rely on efficient, well-informed share markets. It is clear that, at times, the market may overreact to developments in the underlying riskiness of individual firms.

Moreover, the volatility in market prices means that short-term movements in these risk measures should be viewed with caution.

We find that the market's assessment of banks' capital-asset ratios has risen markedly over the 1990s, after oscillating around a comparatively low level during the 1980s. Against this, the market's assessment of the riskiness of banks' assets also grew quite strongly over the 1990s. When these two offsetting trends are drawn together to derive a model-based estimate of the probability of closure, it is found that the growth in capital outweighs the increase in asset volatility – that is, the estimated average probability of bank closure has fallen in the 1990s relative to its level over most of the 1980s.

Closer investigation of the relationship between each bank's capital-asset ratio and asset volatility suggests that banks increase capital in anticipation of taking on more risk exposures. Such behaviour is consistent with banks being concerned about breaching regulatory capital-adequacy requirements, debt-market discipline and managerial risk aversion. We do not find much support for the notion that moral-hazard considerations are driving banks' behaviour. Our evidence does not suggest that the introduction of the Basel Capital Accord greatly affected the relationship between the capital-asset ratio and asset volatility. Our results do suggest that the relation between capital and asset risk is asymmetric. When the capital-asset ratio is increasing, the relationship between the capital-asset ratio and asset volatility is strongly positive, whereas when the capital-asset ratio is falling the relation between the two variables is weak.

## Appendix A: Banking Groups

Several banking groups consisted of both a trading and savings bank – these groups have been consolidated. Where necessary, subsidiary banks have been added to their parent. The banking groups, and the period for which risk measures are obtained, are:

**Table A1: Banking Groups**

| | |
|---|---|
| Adelaide Bank (ADL)<br>*January 94 – present* | Adelaide Bank |
| Advance Bank (ADV) [(a)]*<br>*June 85 – January 97* | Advance Bank Australia<br>Civic Advance Bank<br>Canberra Advance Bank |
| Australia and New Zealand Banking Group (ANZ)*<br>*March 83 – present* | Australia and New Zealand Banking Group<br>Australia and New Zealand Savings Bank<br>National Mutual Royal Savings Bank<br>Town and Country Bank<br>ANZ Grindlays Bank Limited |
| Bendigo Bank (BBL)<br>*July 95 – present* | Bendigo Bank |
| Bank of Melbourne (BML)<br>*July 89 – October 97* | Bank of Melbourne |
| Bank of Queensland (BQL)<br>*March 83 – present* | Bank of Queensland<br>Bank of Queensland Savings Bank |
| Bank of Western Australia (BWA)<br>*February 96 – present* | Bank of Western Australia |
| Commonwealth Bank of Australia (CBA)*<br>*September 91 – present* | Commonwealth Bank of Australia<br>Commonwealth Savings Bank<br>Australian Bank<br>Commonwealth Development Bank<br>State Bank of Victoria |
| Challenge Bank (CBL)<br>*May 87 – December 95* | Challenge Bank |
| Macquarie Bank (MBL)<br>*July 96 – present* | Macquarie Bank |

Notes: Only those banks marked with a * are included in the options sample.
(a) In June 1995, ADV raised a substantial amount of capital through a rights issue. The dramatic rise in the market value of ADV caused the two risk measures to move markedly away from their 'true' value in the months affected (June – August 1995). For this reason, these months are excluded from the regression analysis presented in Section 5.

**Table A1: Banking Groups (*continued*)**

| | |
|---|---|
| Suncorp-Metway (MET)<br>*July 88 – present* | Metway Bank |
| National Australia Bank (NAB)*<br>*March 83 – present* | National Australia Bank<br>National Australia Savings Bank<br>Australian Resources Development Bank<br>Bank of New Zealand<br>Bank of New Zealand Savings Bank |
| Standard Chartered Bank (SCB)<br>*May 86 – April 91* | Standard Chartered Bank |
| St. George Bank (STG) (b)*<br>*July 92 – present* | St. George Bank<br>St. George Partnership Banking Ltd<br>Advance Bank (from 15 January 1997) |
| Westpac Bank (WBC)*<br>*January 83 – present* | Westpac Banking Corporation<br>Westpac Savings Bank<br>Challenge Bank (from 9 December 1995)<br>Bank of Melbourne (from 10 October 1997) |

Notes: Only those banks marked with a * are included in the options sample.
(b) In January 1997, STG took-over ADV. The sudden increase in the market value of STG caused the two risk measures to behave abnormally in the months affected (January–March 1997). For this reason, these months are excluded from the regression analysis presented in Section 5.

## Appendix B: Data

The data used in Gizycki and Levonian (1993) were employed for the period 1983–1992. In the ensuing years, the data were constructed from the following sources.

**Interest rates**

Small business loan – Reserve Bank of Australia *Bulletin*, Table F.4.

180-day bank accepted bill – Reserve Bank of Australia *Bulletin*, Table F.1.

26 week Treasury notes – Reserve Bank of Australia *Bulletin*, Table F.1.

Weighted cost of funds – calculated using internal Reserve Bank of Australia data.

**Equity**

Share prices – Australian Stock Exchange.

Number of shares – series for each bank was constructed using information from banks' annual and interim reports, and Australian Stock Exchange Company Files. Partly paid shares are included in the total number of shares weighted according to the proportion paid up.

**Bank financial data**

Total liabilities – total liabilities were obtained from reporting forms submitted by each bank to the RBA. The data reported only includes liabilities within Australia. ANZ, Commonwealth Bank, National Australia Bank and Westpac each hold a significant proportion of their liabilities outside of Australia. Data on foreign assets as a proportion of total assets are contained in the banks' annual and interim reports. The asset data reported to the RBA were scaled up by those proportions, with linear interpolation used to calculate the proportions between reporting dates.

# Appendix C: Capital and Risk Relationship

Impact of the 1988 Capital Accord

**Table C1: Impact of Risk-based Capital Adequacy Standards**

Regression: $\Delta k_t = \alpha + t + \sum_{i=1}^{l} \beta_i \Delta k_{t-i} + \sum_{i=1}^{m} \varphi_i \delta_1 \sigma_{At-i} + \sum_{i=1}^{q} \gamma_i (1-\delta) \sigma_{At-i} + \varepsilon_t$

where $\delta$= 1 if $t \leq$ December 1988 and 0 otherwise

Monthly; March 1983 – April 1998 (excluding October – December 1987)

| Bank | Constant | Lags of change in capital | | Lags of asset volatility (pre-Accord) | | Lags of asset volatility (post-Accord) | | Significance of testing $H_0 : \sum_{i=1}^{m} \varphi_i = \sum_{i=1}^{q} \gamma_1$ |
|---|---|---|---|---|---|---|---|---|
| | | No. of lags | Sum of coefficients | No. of lags | Sum of coefficients | No. of lags | Sum of coefficients | |
| A | 0.001 | 1 | 0.136 | 6 | -0.136 | 1 | 0.009 | 0.049** |
| | (0.143) | | (0.243) | | (0.000)*** | | (0.831) | |
| D | 0.004 | 1 | 0.134 | 12 | -0.543 | 11 | -0.179 | 0.012** |
| | (0.001)*** | | (0.071)* | | (0.080)* | | (0.004)*** | |
| E | 0.002 | 1 | 0.025 | 5 | 0.175 | 1 | -0.089 | 0.000*** |
| | (0.281) | | (0.835) | | (0.000)*** | | (0.238) | |
| G | 0.001 | 1 | 0.157 | 5 | -0.081 | 4 | -0.033 | 0.645 |
| | (0.169) | | (0.062)* | | (0.000)*** | | (0.000)*** | |
| J | 0.001 | 1 | 0.071 | 3 | -0.073 | 1 | -0.043 | 0.502 |
| | (0.267) | | (0.377) | | (0.146) | | (0.249) | |
| M | 0.001 | 1 | 0.439 | 1 | -0.269 | 10 | -0.063 | 0.000*** |
| | (0.014)** | | (0.000)*** | | (0.002)*** | | (0.005)*** | |
| N | 0.005 | 4 | 0.159 | 5 | 0.198 | 9 | -0.256 | 0.422 |
| | (0.092)* | | (0.024)** | | (0.000)** | | (0.010)*** | |

Notes: The numbers in parentheses show the significance level from testing whether all lagged variables can be excluded from the regression.

***, **, * denote significance at the 1, 5 and 10 per cent levels respectively.

$\Delta k_t$ is the month-to-month change in the capital-asset ratio.

$k_t$ and $\sigma_{At}$ are obtained from the Case III paramaterisation of the model using historical estimates of $\sigma_E$.

## Table C2: Impact of Risk-based Capital Adequacy Standards

Regression: $\sigma_{At} = \alpha + t + \sum_{i=1}^{l} \beta_i \sigma_{At-i} + \sum_{i=1}^{m} \varphi_i \delta \Delta k_{t-1} + \sum_{i=1}^{q} \gamma_i (1-\delta) \Delta k_{t-i} + \varepsilon_t$

where $\delta$= 1 if $t \leq$ December 1988 and 0 otherwise

Monthly; March 1983 – April 1998 (excluding October – December 1987)

| Bank | Constant | Trend 1 | Trend 2 | Lags of change in capital (pre-Accord) | | Lags of change in capital (post-Accord) | | Lags of volatility | | Significance of testing $H_0: \sum_{i=1}^{m} \varphi_i = \sum_{i=1}^{q} \gamma_1$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No. of lags | Sum of coefficients | No. of lags | Sum of coefficients | No. of lags | Sum of coefficients | |
| A | -0.001 | 0.00008 | 0.00005 | 1 | 0.358 | 10 | 0.733 | 1 | 0.647 | 0.445 |
| | (0.248) | (0.003)*** | (0.001)*** | | (0.046)** | | (0.020)** | | (0.000)*** | |
| D | 0.001 | 0.00005 | 0.00004 | 1 | 0.369 | 2 | 0.218 | 1 | 0.675 | 0.320 |
| | (0.471) | (0.144) | (0.003)*** | | (0.004)*** | | (0.016)** | | (0.000)*** | |
| E | 0.008 | | | 3 | -0.872 | 1 | 0.151 | 1 | 0.583 | 0.032 |
| | (0.001)*** | | | | (0.000)*** | | (0.041)** | | (0.000)*** | |
| G | 0.005 | | | 1 | 0.628 | 1 | 0.121 | 1 | 0.682 | 0.728 |
| | (0.015)** | | | | (0.657) | | (0.579) | | (0.000)*** | |
| J | 0.018 | | | 1 | 0.148 | 1 | 0.165 | 4 | 0.425 | 0.930 |
| | (0.000)*** | | | | (0.131) | | (0.330) | | (0.058)* | |
| M | 0.001 | | | 1 | 0.392 | 5 | 1.197 | 6 | 0.943 | 0.001 |
| | (0.231) | | | | (0.000)*** | | (0.001)*** | | (0.006)*** | |
| N | 0.002 | | | 1 | -0.242 | 1 | 0.138 | 6 | 0.927 | 0.072 |
| | (0.348) | | | | (0.062)* | | (0.342) | | (0.001)*** | |

Notes: The numbers in parentheses show the significance level from testing whether all lagged variables can be excluded from the regression.
***, **, * denote significance at the 1, 5 and 10 per cent levels respectively.
$\Delta k_t$ is the month-to-month change in the capital-asset ratio.
$k_t$ and $\sigma_{At}$ are obtained from the Case III paramaterisation of the model using historical estimates of $\sigma_E$.
'Trend 1' runs from March 1983 to December 1988 and 'Trend 2' runs from January 1989 to April 1998.

## Table C3: Impulse Response

| Bank | Pre-Accord | | Post-Accord | |
|---|---|---|---|---|
| | Change in capital (percentage points) | Asset volatility (percentage points) | Change in capital (percentage points) | Asset volatility (percentage points) |
| A | -0.144 | 0.012 | 0.001 | 0.117 |
| D | -0.021 | -0.003 | 0.103 | 0.022 |
| E | -0.286 | -0.524 | -0.003 | 0.005 |
| G | 0.025 | -0.032 | -0.113 | 0.013 |
| J | -0.018 | -0.019 | 0.010 | -0.018 |
| M | -0.047 | 0.030 | -0.007 | 0.237 |
| N | 0.132 | -0.074 | -0.089 | 0.010 |

Note: Each column shows the change in the variable (after six months) as a result of a one standard deviation, one period, shock to the other variable.

## Table C4: Test for Asymmetry

Regression: $\Delta k_t = \alpha + t + \sum_{i=1}^{l} \beta_i \Delta k_{t-1} + \sum_{i=1}^{m} \varphi_i \theta \sigma_{At-i} + \sum_{i=1}^{q} \gamma_i (1-\theta) \sigma_{At-i} + \varepsilon_t$

where $\theta = 1$ if $\Delta k_t < 0$ and 0 otherwise

Monthly; March 1983 – April 1998 (excluding October – December 1987)

| Bank | Constant | Lags of change in capital | | Asset volatility (capital increasing) | | Asset volatility (capital decreasing) | | Significance of testing: $\sum_{i=1}^{m} \varphi_i = \sum_{i=1}^{q} \gamma_i$ |
|---|---|---|---|---|---|---|---|---|
| | | No. of lags | Sum of coefficients | No. of lags | Sum of coefficients | No. of lags | Sum of coefficients | |
| A | 0.000 | 1 | 0.365 | 1 | -0.041 | 1 | 0.102 | 0.093* |
| | (0.397) | | (0.024)** | | (0.507) | | (0.087)* | |
| B | 0.006 | 1 | -0.115 | 1 | -0.294 | 1 | -0.480 | 0.165 |
| | (0.011)** | | (0.445) | | (0.047)** | | (0.022)** | |
| C | 0.009 | 5 | -0.379 | 6 | -0.184 | 3 | -0.570 | 0.099* |
| | (0.000)*** | | (0.000)*** | | (0.008)*** | | (0.007)*** | |
| D | 0.001 | 1 | 0.234 | 1 | -0.070 | 1 | -0.030 | 0.542 |
| | (0.020)* | | (0.031)** | | (0.255) | | (0.378) | |
| E | 0.002 | 1 | -0.022 | 5 | -0.136 | 1 | -0.077 | 0.321 |
| | (0.256) | | (0.869) | | (0.118) | | (0.378) | |
| G | 0.000 | 1 | 0.036 | 1 | 0.112 | 1 | 0.005 | 0.209 |
| | (0.663) | | (0.786) | | (0.091)* | | (0.949) | |
| H | 0.001 | 1 | 0.326 | 1 | -0.065 | 1 | 0.023 | 0.145 |
| | (0.364) | | (0.017)** | | (0.385) | | (0.647) | |
| I | -0.002 | 3 | -0.090 | 3 | 0.115 | 1 | 0.066 | 0.760 |
| | (0.464) | | (0.000)*** | | (0.000)*** | | (0.564) | |
| J | 0.000 | 1 | -0.044 | 1 | 0.020 | 1 | -0.080 | 0.038** |
| | (0.767) | | (0.726) | | (0.650) | | (0.034)** | |
| K | 0.003 | 3 | 0.380 | 1 | -0.119 | 1 | -0.139 | 0.781 |
| | (0.038)** | | (0.007)*** | | (0.157) | | (0.100) | |
| L | -0.002 | 1 | 0.149 | 2 | 0.098 | 2 | 0.075 | 0.807 |
| | (0.571) | | (0.540) | | (0.055)* | | (0.077)* | |
| M | 0.001 | 1 | 0.252 | 1 | -0.044 | 1 | -0.092 | 0.526 |
| | (0.033)** | | (0.034)** | | (0.513) | | (0.021)** | |
| N | 0.006 | 10 | 0.347 | 10 | -0.433 | 1 | -0.164 | 0.162 |
| | (0.006)*** | | (0.047)* | | (0.048)* | | (0.280) | |
| O | -0.001 | 1 | 0.218 | 1 | 0.008 | 2 | 0.045 | 0.618 |
| | (0.724) | | (0.258) | | (0.912) | | (0.582) | |

Notes: The numbers in parentheses show the significance level from testing whether all lagged variables can be excluded from the regression.

***, **, * denote significance at the 1, 5 and 10 per cent levels respectively.

$\Delta k_t$ is the month-to-month change in the capital-asset ratio.

$k_t$ and $\sigma_{At}$ are obtained from the Case III paramaterisation of the model using historical estimates of $\sigma_E$.

## Table C5: Test for Asymmetry

Regression: $\sigma_{At} = \alpha + t + \sum_{i=1}^{l} \beta_i \sigma_{At-i} + \sum_{i=1}^{m} \varphi_i \theta \Delta k_{t-i} + \sum_{i=1}^{q} \gamma_i (1-\theta) \Delta k_{t-i} + \varepsilon_t$

where $\theta = 1$ if $\Delta k_t < 0$ and 0 otherwise

Monthly; March 1983 – April 1998 (excluding October – December 1987)

| Bank | Constant | Trend | Trend 1 | Trend 2 | Lags of change in capital (capital increasing) | | Lags of change in capital (capital decreasing) | | Lags of asset volatility | | Significance of testing $\sum_{i=1}^{m} \varphi_i = \sum_{i=1}^{q} \gamma_i$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | No. of lags | Sum of coefficients | No. of lags | Sum of coefficients | No. of lags | Sum of coefficients | |
| A | 0.000 | | 0.00003 | 0.00004 | 1 | 0.461 | 1 | -0.227 | 1 | 0.621 | 0.034** |
| | (0.698) | | (0.036)** | (0.002)*** | | (0.002)*** | | (0.304) | | (0.000)*** | |
| B | 0.005 | | | | 1 | -0.120 | 1 | 0.249 | 1 | 0.754 | 0.133 |
| | (0.008)*** | | | | | (0.552) | | (0.012)** | | (0.000)*** | |
| C | 0.031 | -0.00025 | | | 1 | 0.377 | 1 | 0.104 | 2 | 0.458 | 0.195 |
| | (0.00)*** | (0.000)*** | | | | (0.052)* | | (0.148) | | (0.000)*** | |
| D | 0.001 | 0.00004 | | | 1 | 0.367 | 1 | -0.122 | 1 | 0.684 | 0.033** |
| | (0.421) | (0.004)*** | | | | (0.011)** | | (0.314) | | (0.000)*** | |
| E | 0.009 | | | | 1 | 0.210 | 1 | -0.032 | 2 | 0.462 | 0.267 |
| | (0.000)*** | | | | | (0.277) | | (0.648) | | (0.000)*** | |
| G | 0.004 | | | | 3 | 0.285 | 1 | -0.971 | 2 | 0.642 | 0.052* |
| | (0.001)*** | | | | | (0.000)*** | | (0.037)** | | (0.000)*** | |
| H | -0.014 | 0.00014 | | | 7 | 2.125 | 10 | -1.129 | 2 | 0.261 | 0.002*** |
| | (0.000)*** | (0.000)*** | | | | (0.000)*** | | (0.003)*** | | (0.000)*** | |
| I | -0.032 | 0.00031 | | | 1 | 0.225 | 4 | 0.610 | 1 | 0.155 | 0.451 |
| | (0.000)*** | (0.000)*** | | | | (0.199) | | (0.012)** | | (0.389) | |
| J | 0.026 | -0.00006 | | | 1 | 0.367 | 1 | 0.113 | 2 | 0.364 | 0.436 |
| | (0.000)*** | (0.004)*** | | | | (0.129) | | (0.402) | | (0.000)*** | |
| K | 0.020 | | 0.00010 | 0.00002 | 3 | 0.605 | 1 | -0.463 | 9 | 0.050 | 0.046** |
| | (0.001)*** | | (0.039)** | (0.614) | | (0.002)*** | | (0.122) | | (0.000)*** | |
| L | 0.033 | | | | 4 | -2.297 | 6 | 1.746 | 4 | -0.386 | 0.000*** |
| | (0.000)*** | | | | | (0.000)*** | | (0.000)*** | | (0.000)*** | |
| M | 0.001 | | | | 1 | 0.222 | 12 | 0.475 | 5 | 0.958 | 0.435 |
| | (0.211)** | | | | | (0.048)** | | (0.103) | | (0.000)*** | |
| N | 0.002 | | | | 1 | 0.575 | 12 | 0.114 | 6 | 0.845 | 0.291 |
| | (0.243) | | | | | (0.012)*** | | (0.000)*** | | (0.000)*** | |
| O | 0.001 | | | | 3 | 1.885 | 3 | -0.835 | 1 | 0.700 | 0.010*** |
| | (0.705) | | | | | (0.072)* | | (0.057)* | | (0.000)*** | |

Notes: The numbers in parentheses show the significance level from testing whether all lagged variables can be excluded from the regression.

***, **, * denote significance at the 1, 5 and 10 per cent levels respectively.

$\Delta k_t$ is the month-to-month change in the capital-asset ratio.

$k_t$ and $\sigma_{At}$ are obtained from the Case III paramaterisation of the model using historical estimates of $\sigma_E$.

'Trend' is a full sample trend while 'Trend 1' runs from March 1983 to December 1991 and 'Trend 2' runs from January 1992 to April 1998.

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