The Fluctuating Default Risk of Australian Banks

By

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ABSTRACT

Australian banks are widely considered to have fared far better during the Global Financial Crisis (GFC) than their global counterparts, continuing to display solid earnings, good capitalisation and strong credit ratings. Nonetheless, Australian banks experienced significant deterioration in the market values of assets. We use the KMV/Merton structural methodology, which incorporates market asset values, to examine default probabilities of Australian banks. We also modify the model to incorporate conditional probability of default which measures extreme credit risk. We find that, during the GFC, based on extreme asset value fluctuations, Australian bank default probabilities fare only slightly better than their global counterparts.
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Keywords: Financial crisis; Credit risk; Banks; Default; Capital adequacy

1. Introduction

The question addressed by this paper is how the Global Financial Crisis (GFC) impacted on the probability of default (PD) of Australian banks, using a methodology which includes changes in the market value of assets, as opposed to static measures such as external ratings. This methodology includes the structural credit model of Merton (1974) and KMV (Crosbie & Bohn, 2003), and our own conditional probability of default (CPD) model which measures extreme fluctuations in the market value of assets. The study also considers the implications of fluctuating asset values for capital adequacy.

There is generally considered to be strong evidence to demonstrate the resilience of Australian banks during the extreme conditions of the GFC. The 5 largest banks in Australia showed net profit of approximately $8billion over the second half year in 2008. In contrast the 5 largest US banks showed losses of nearly $50 billion over the 2008 year, and the 5 largest banks in the UK reported losses of approximately £20 billion before extraordinary items (Reserve Bank of Australia, 2009c). The ratings of the 4 major Australian banks were raised from AA- to AA in 2007 on the back of "progressive structural strengthening of financial profiles, as well as continued development of their risk-management capabilities". These ratings were confirmed in July 2009 with Standard & Poor's (2009a) citing a key underpinning reason for this being adoption of a more traditional retail and commercial model, with little reliance on volatile market related trading income. This was supported by the rater's expectations of continued satisfactory earnings, well controlled credit losses, adequate capitalisation, well-managed funding and liquidity, and conservative risk appetite. The above provides an extremely rosy picture of Australian banks, which should surely be reflected in bank equity prices and reduced PD measures as compared to international experience. However, in reality, Australia is not isolated from global markets, with uncertainty leading to pressures on the cost and availability of global funding (Reserve Bank of Australia, 2009c). As discussed in Section 3, there was also a sharp rise in impaired assets and loss provisions of Australian banks, albeit at a lower level than their global counterparts. As happened globally, these events had a sharply negative effect on share prices and bank asset values. The S&P/ASX200

Bank Index, which includes the six largest Australian banks, plunged 58% from a peak in October 2007 to a trough in January 2009. In line with global government intervention, the Australian government introduced stimulus packages to boost the Australian economy, and guarantees on deposits and wholesale funding to shore up confidence in the banking industry.

The AA ratings of Australian banks, which remained unchanged (static) during the GFC have an associated probability of default (PD) of 0.38% according to Standard and Poor's (2008) default matrix. As will be shown, this is well below the default probabilities indicated by the modelling undertaken by this study over the GFC period. It should be noted that rating agents such as Standard and Poor's and Moody's stress that ratings are not absolute measures of default, but rather a relative ranking of one entity to another. Standard and Poor's maintain that "Ratings opinions are not intended as guarantees of credit quality or as exact measures of the probability that a particular debt issue will default. Instead, ratings express relative opinions about the creditworthiness of an issuer or credit quality of an individual debt issue, from strongest to weakest, within a universe of credit risk." Although credit ratings are meant to be relative risk ratings and not absolute measures of default, they are nonetheless used by banks for measuring default probabilities and credit VaR, including of course the credit risk of borrowing banks. For example, CreditMetrics, which is the benchmark RiskMetrics credit equivalent for calculating credit VaR, is based on the transition and default probabilities provided by issuers such as Standard and Poor's. In addition, external credit ratings are used by banks under the standardised Basel approach for allocating capital. If the ratings themselves do not fluctuate with market conditions, then neither does the capital allocated.

Contrary to these static indicators, the funding squeeze, impaired asset increase, and necessity for government intervention do not indicate that credit risk of Australian banks remained the same as prior to the financial crisis. Had global and Australian governments not intervened in the market, the situation could potentially have been far worse, both globally and locally.

Unlike static ratings, the Merton/KMV methodology does incorporate asset value fluctuations. The model is widely used, with Moody's KMV (2010) reporting use of their products by more than 2,000 leading financial institutions in over 80 countries, including most of the 100 largest financial institutions in the world. The model measures changes to default probabilities based on the distance to default of a firm which is a combination of asset values, debt, and the standard deviation of asset value fluctuations, from which PDs can be calculated as detailed in Section 5. The point of default is considered to be where debt exceeds assets, and the greater the volatility of the assets, the closer the entity moves to default. Although, under Basel, capital required for credit risk is a function of the PDs of the borrowers of a bank, rather than the PDs of banks themselves, a link can be drawn between the PDs of banks themselves and capital adequacy, as illustrated by the Bank of England (BOE, 2008b). BOE report that in 2008 UK banks had equity ratios of around 3.3%, and assuming volatility in market value of assets of 1.5%, this gives a PD of around 1%. If volatility doubles, then PD increases substantially to 15%. As bank PDs increase with deteriorating market conditions, so too does the chance of the assets needing to be liquidated at market prices. Therefore as PDs rose during the GFC, market participants changed the way they assessed underlying bank assets, placing a greater weight on mark to market asset values, implying lower asset values and higher potential capital needs for banks. Thus BOE sees the mark to market approach of a bank's assets as providing a measure of how much capital needs to be raised to restore market confidence in the bank's capitalisation.

Other literature on default probabilities includes an evaluation of static models such as accounting models, and an assessment of point in time (PIT) as compared to Through the Cycle (TTC) models. Accounting models have been critiqued by Vassalou and Xing (2004) as being backward looking as opposed to the Merton model which uses market prices reflecting investor expectations of future performance. Vassalou and Xing also make the point that accounting models imply that firms with similar financial ratios will have similar default probabilities, whereas firms with similar debt and equity levels might have very different default probabilities if the volatility of their assets differ. Most of the literature on cyclicality of capital requirements (for example, Catarineu-Rabell, Jackson, & Tsomocos, 2003; Drumond, 2009; Gordy & Howells, 2006; Kashyap & Stein, 2003; Lowe, 2002; Pederzoli & Toricelli, 2005; Rosch & Scheule, 2010) deals with an investigation into the pro-cyclicality of rating approaches and a comparison of the relative benefits of TTC and PIT capital adequacy methods. PIT means that banks hold capital based on the current rating of a borrower, causing banks to have to increase capital in bad times and reduce it in good times. TTC means that banks hold one level of capital at all times, based on an assessment of 'average' or 'median' risk over a period of time. The TTC approach smooths the potential volatility of PD estimates and hence the capital requirements. The European Central Bank (ECB, 2009) calls the TTC approach into question, stating that the recent financial crisis shows the limits of using TTC ratings. The ECB states that for banks to maintain credibility, they need to maintain strong capital during downturns and that during these times, even banks using the TTC approach may be forced to raise additional capital to align themselves with the capital adequacy of PIT based approaches. In summary, the literature uncovers a number of shortfalls with current capital adequacy approaches. Firstly, external ratings are only designed to be a measure of relative risk between entities, and capital based on this measure will not respond timeously to changes in the business cycle. Secondly, TTC is based on an average or median approach. This capital therefore corresponds to 'normal' conditions which means that insufficient capital is held in downturn times when it is most needed, such as during the GFC. Thirdly, PIT ratings mean that banks have to continuously increase or decrease capital according to changing circumstances. None of the methods (external ratings, PIT, TTC) focus on extreme risk, meaning that in each case banks could be left scrambling for capital, precisely when it is most difficult to obtain it, such as during the GFC with many global banks needing government bailout to address their capital shortages. Our CPD model, in contrast, does focus on extreme risk. Measuring and holding capital based on extreme risk measurements has the downside that banks have to bear the cost of 'buffer' capital in upside times. However, the key point of capital adequacy is that buffers are available to absorb risk when required. The IMF (Caruana & Narain, 2008) maintains that the need for banks to have a robust capital regime adequate to the risks they face, including business cycle risk, is borne out by the problems banks faced over the GFC, and that "as the experiences of some large international banks in the current turmoil have shown, the benefits of being able to access capital rapidly in bad times may outweigh the costs of having to hold capital buffers through the cycle". Basel II, in fact, emphasizes that volatility should be addressed in capital allocation and that strategic plans should take into account capital needs especially in a stressful economic environment (Caruana & Narain, 2008). Indeed, proposed amendments to Basel II (i.e. Basel III) include "Introducing a series of measures to promote the build-up of capital buffers in good times that can be drawn upon in periods of stress. A countercyclical capital framework will contribute to a more stable banking system, which will help dampen, instead of amplify, economic and financial shocks" (Basel Committee on Banking Supervision, 2008).

The Merton/KMV model, which does take asset volatilities into account, is primarily used to measure default probability (PD) of bank customers. In contrast, (similar to the BOE approach discussed above, whereby increasing bank PD's are an indicator of what additional capital is required to restore confidence in capital adequacy), we use this methodology to measure default risk of the banks themselves, both prior to and during the financial crisis. The model however, does not measure extreme risk within each period as it is based on the standard deviation of all daily asset returns over a specific period. To address this, we have developed a model to measure Conditional Probability of Default (CPD), which is based on extreme fluctuations.

Market asset value fluctuations, which form a key component of these methodologies, are in turn influenced by share price fluctuations (as the KMV/Merton model methodology in Section 5 will show). Therefore, whilst default probability is the primary focus of this paper, it is also important to understand the banks' equity fluctuations, and thus measurement of this risk forms a supporting secondary focus of this paper. We will use Value at Risk (VaR), which is a primary measure of market risk, together with CVaR which measures extreme risk to measure changes in equity market risk prior to and during the financial crisis.

It is necessary to take into account that Australian banks have a high reliance on funding from international markets, and thus shocks to international markets can impact on bank equity markets while underlying asset risk remains unchanged. Therefore, we use a range of other evidence to support the findings of the Merton model. This includes examining the changes in bad debts and impaired assets of Australian banks, as well as fluctuations in credit default swap (CDS) spreads. As the Merton model typically produces a wider spread of default probabilities than KMV, who modify their estimated default frequency (EDF) based on observations of actual probabilities from their extensive worldwide database, we sensitise the Merton outcomes through calibration to KMV EDF. We also compare the relative change in Bank default risk to other Australian industries.

The default modelling techniques used in this study show how the market value of assets and the capital of Australian banks have been eroded, substantially increasing default probabilities. These findings are supported by deterioration in other indicators such as impaired assets and credit default swap spreads. The importance of using CVaR and CPD is that not only is risk measured in the extreme circumstances of the GFC, it is also measured at the extreme tail of asset fluctuations, precisely where default is most likely to occur.

Whilst our focus is on Australian banks, in examining the default risk of these banks, we will make comparisons with other global banks, specifically US, European and Canadian banks. We have selected US and European markets due to their prominence in global banking, and Canadian banks because (as discussed in Section 3) they are considered to have had similar experiences to Australian banks during the GFC.

The remaining paper is organised as follows. Section 2 summarises the key contributions and benefits of the study. Section 3 provides background on the Australian banking industry. Section 4 covers VaR and CVaR, followed by a discussion about PD and structural methodology in Section 5. Data and methodology are discussed in Section 6. The results are presented in Section 7. Finally, Section 8 provides conclusions and implications.

The study does not make representations about the PD of individual banks. Default probabilities calculated using the structural methodology are based on available balance sheet and equity price information, and do not take into account external options available to banks for reducing PD, such as additional capital raising or government intervention.

2. Contribution and Benefits of the Study

The study provides key insights into changes in default risk of Australian banks since the onset of the GFC. The study shows how default risk increases dramatically over this period, as compared to the default ratings indicated by the external credit ratings. The study can benefit regulators and banks by providing insight into the differences in PD estimates using models based on asset value fluctuations as compared to external credit ratings. As per the discussion by BOE in Section 1, the mark to market approach on bank capital can provide a measure of what additional capital is required to restore market confidence in bank capitalisation.

In addition, the study incorporates conditional probability of default (CPD) techniques into structural models, which is a unique metric developed by the authors designed to measure the asset value fluctuations under the most extreme circumstances, which is when default is most likely to occur.

3. The Australian Banking Industry

As background to our study of Australian banks, this section examines the industry structure as well as key growth and risk indicators, with comparisons provided to the US, Europe and Canada.

The Australian Prudential Regulation Authority (APRA) regulates all Authorised Deposit Taking Institutions (ADI's). As per statistics from APRA (2009) and the RBA (2009e), ADI's comprise 58 banks, 11 building societies, and 129 credit unions. Of the 58 banks, 13 are Australian owned (comprising 88% of total bank assets), the remainder are subsidiaries or branches of foreign banks (comprising 12% of total bank assets). The industry is dominated by the four major banks, which comprise approximately 75% of

ADI's total assets. These banks include Westpac, the Australia and New Zealand Banking Corporation (ANZ), the National Australia Bank (NAB), and the Commonwealth Bank of Australia (CBA). These figures include the assets of St. George Bank and the Bank of Western Australia (Bankwest) who have recently merged with Westpac and CBA respectively. The Central Bank is the Reserve Bank of Australia (RBA) whose primary responsibilities are monetary policy, financial system stability, and the payments system.

In comparison, as per figures obtained from Office of the Canadian Superintendant of Financial Institutions (2009), Canada has a total of 78 banks with assets totalling USD $3 trillion. 22 of these are domestic banks, with the others being primarily branches of foreign banks. Of the 22 domestic banks, 9 are public companies listed on the Toronto Stock Exchange. The 'Big 5' banks (Royal Bank of Canada, Toronto-Dominion Bank, Bank of Nova Scotia, Bank of Montreal, and Canadian Imperial Bank) have total assets of USD $2.4 trillion, approximately 80% of the total Canadian domestic banking market.

In the US, FDIC (Federal Deposit Insurance Corporation, 2009) shows just over eight thousand banks with total assets of USD $12 trillion. Only 52 of these banks are listed on the New York Stock Exchange (NYSE). These 52 banks represent approximately 65% of total US bank assets. The remaining entities are smaller commercial banks, mutual savings banks or branches / offices of foreign banks. The 5 dominant banks are JP Morgan, Bank of America, Citigroup, Wells Fargo, and US Bancorp, with Total Assets of $5.8 Trillion representing close to half of the total US banking market.

Europe (including the UK) has extremely large banks with several European banks featuring among the world's largest 15 banks (including Barclays, BNP Paribas, Credit Agricole, Credit Suisse, DeutscheBank, ING, Royal Bank of Scotland, Santander, Societe Generale, Unicredit and UBS). 15 of the world's largest 25 Banks are European, with these banks having Total Assets of $30 trillion, nearly double the combined assets of all the banks in the 3 other regions (US, Australia and Canada) compared in this study.

Table 1. *Key Growth and Risk Indicators for Australian Banks*

	Total assets ($bn)	Impaired assets (%)	Provisions for bad & doubtful debts (%)	Tier 1 capital ratio (%)	Total capital ratio (%)	Total Risk Weighted assets ($bn)	Equity Ratio (%)
Mar-2000	958	0.61	0.73	7.38	9.88	671	7.09%
Mar-2001	1,139	0.59	0.65	6.88	9.77	790	6.77%
Mar-2002	1,118	0.69	0.71	7.85	10.50	763	7.16%
Mar-2003	1,178	0.58	0.61	7.69	10.00	819	6.95%
Mar-2004	1,352	0.41	0.54	7.55	10.06	928	6.90%
Mar-2005	1,489	0.27	0.48	7.87	10.88	1,013	7.41%
Mar-2006	1,709	0.21	0.43	7.68	10.52	1,133	6.97%
Mar-2007	1,953	0.19	0.38	7.56	10.38	1,277	6.78%
Mar-2008	2,387	0.34	0.39	7.31	10.49	1,337	5.88%
Mar-2009	2,610	0.95	0.69	8.42	11.44	1,406	6.16%

Figures are calculated from RBA Statistics (2009f) for all banks operating in Australia (58 banks per paragraph 2 of Section 3). Other ADI's (Building Societies and Credit Unions) are not included. Impaired assets refer to non-accrual (income may no longer be accrued ahead of its receipt because there is doubt about the ultimate collectability of principal and/or interest) and restructured assets (modified to provide for concessions of interest or principal exposures), both on- and off-balance sheet, plus any assets acquired through the enforcement of security conditions. Provisions include specific and collective provisions. Tier 1 and Total capital ratios are as per Basel requirements. A minimum of 8% is required for total capital of which at least half must be Tier 1. Risk weighted assets are also as per Basel requirements, where different assets have different risk weightings for the purpose of calculating capital. The equity ratio is total shareholder equity to total assets (no risk-weighting applied). Amounts are all in Australian dollars.

The figures in Table 1 show that Australian banks continue to grow total assets, although the growth to March 2009 slowed to 9% as compared to 22% the previous year. APRA (2008) reports that growth is driven predominantly by housing loans which account for 52.1% of total bank assets.

Total assets have doubled over the past 5 years, and have continued to increase over the past year. A significant increase is shown in impaired assets. However, this is off a very low base of 0.19%, and the peak of 0.95% is very low in comparison to international standards. Provisions for doubtful debts have not quite doubled over the past year, and are at slightly lower levels than in the early 2000's.

Summary comparative asset growth and impaired asset figures are provided in Table 2 for selected global regions. All regions show continued asset growth during the GFC period.

Table 2. *Key Growth and Risk Indicators for Global Banks*

	US		UK		Canada	
	Total assets ($bn)	Impaired assets (%)	Total assets ($bn)	Impaired assets (%)	Total assets ($bn)	Impaired assets (%)
Mar-2000	5,725	1.9	4,613	2.0	1,431	1.1
Mar-2001	6,226	2.1	5,702	1.9	1,577	1.4
Mar-2002	6,391	1.9	5,496	2.0	1,651	1.6
Mar-2003	7,087	1.6	6,639	1.8	1,703	1.6
Mar-2004	7,620	1.4	7,373	1.6	1,754	1.1
Mar-2005	8,308	1.4	8,330	1.9	1,877	0.6
Mar-2006	9,125	1.5	9,993	2.0	2,083	0.5
Mar-2007	9,872	2.4	11,365	2.1	2,375	0.4
Mar-2008	11,117	4.8	12,364	2.6	2,727	0.5
Mar-2009	12,127	8.8	12,869	6.6	3,021	0.9

US figures include commercial banks as classified by the Federal Reserve Bank (FRB), and all figures are obtained from FRB (2009) statistical reports. The US impaired asset column shows loans classified as delinquent, which are loans past thirty days or more and still accruing interest as well as those in non-accrual status, measured as a percentage of end-of period loans. Total UK bank Assets are obtained from Bankstats (Bank of England, 2009a) and include banks only (excludes building societies and other monetary institutions). UK impaired assets are loans for the 5 major banks classified as impaired assets from 2005 and as non-performing loans prior to this date. Figures subsequent to 2005 are obtained from the Bank of England (2009b) and KPMG (2009), and prior to 2005 from the annual reports of the banks themselves. Impaired assets for both the UK and Canada are calculated as impaired loans and advances (as presented in the financial statements) compared to total loans and advances (as presented on the face of the balance sheet). Impaired assets for Canada and the UK follow a similar definition to those for Australia as defined in Table 1. Canadian total assets and impaired assets are for all banks classified domestic as obtained from the Office of the Superintendant of Financial Institutions Canada (2009). Figures were either taken at the quarterly reporting date shown in column 1 or the closest reporting date to it. Amounts are all in USD.

The US shows delinquency rates increasing approximately five-fold in the 3 years to the second quarter of 2009, and doubling over the past year. In their 2009 2nd Quarterly Banking Profile Report, FDIC (Federal Deposit Insurance Corporation, 2009) shows continued aggregate bank losses for the industry, reducing total bank assets, increasing charge off rates and continued rises in loan loss reserves to 2.77%. The UK shows a trebling of impaired assets in the year to March 2008. The BOE Credit Conditions Survey (2008a) reports rising default rates, widening spreads, and reduced credit availability to households and businesses due to economic outlook concerns as well as the cost and availability of funds. The survey shows an expectation that these circumstances will continue going forward. The Financial Stability Report (Bank of England, 2009c) shows mortgage arrears nearly trebling from the first quarter 2008 to first quarter 2009. Canadian banks' impaired assets show the lowest increase of all the regions during the GFC, and at March 2009 are just under double the prior year, at very similar levels to Australian banks. Indeed, Canada's impaired assets, whilst increasing during the GFC, are at lower levels to those experienced in the early 2000's following the bursting of the technology bubble and the terrorist attacks in the US.

Parallels have been drawn between the Australian and Canadian financial sectors (Stevens, 2009). The major banks in both countries reported similar returns on equity (Canada 14.5% and Australia 17%), which in both cases was down on the preceding two years. Banks in both countries had low holdings of complex securities in comparison to international standards, and both had conservative lending standards. Whilst both countries show increases in mortgage arrears, households in these countries seem to having less trouble servicing debt than those in the US and UK.

Tier 1 and total capital in Table 1 for Australian banks are showing an increasing trend, both ratios well above the regulatory requirements of 4% and 8% respectively. The total equity ratio (shareholders funds to total assets) is just over half of the total capital ratio, showing that assets, on average, are being discounted at nearly 50% to obtain risk weighted assets. This is in line with the high housing loan component of the Australian banks, which attract a lower risk weighting than commercial borrowers. Table 3 provides a comparison to other global areas.

Table 3. *Comparison of Capital Ratios 2008*

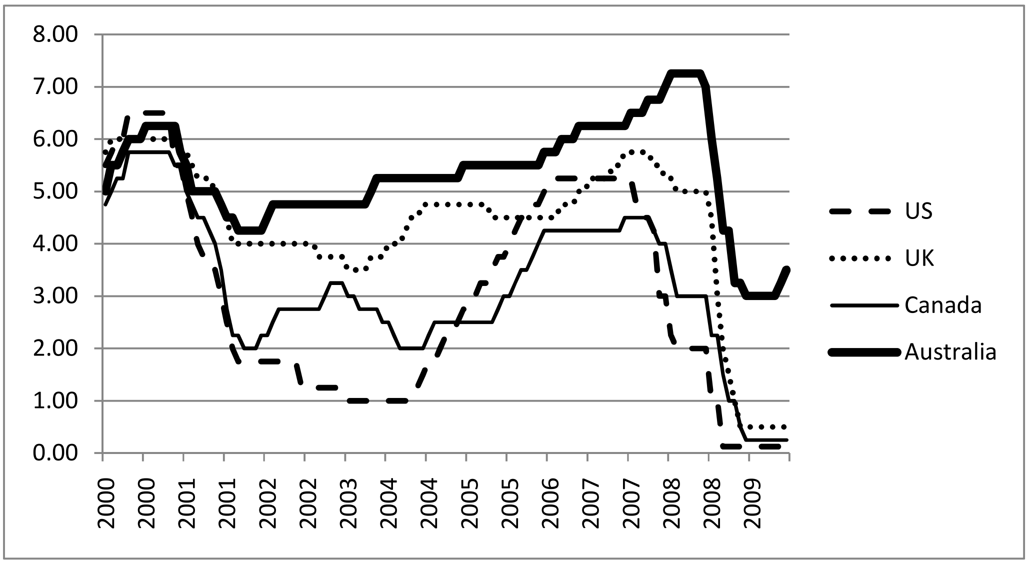
	Tier 1 Capital ratio (%)	Total Capital ratio (%)	Equity Ratio (%)
Australia	8.4	11.4	6.2
Canada	11.8	14.5	5.2
UK	8.1	12.1	3.9
Other Europe	8.9	11.6	3.2
US	10.4	13.1	7.1

Figures for all regions are taken at quarterly reporting date March 2009, or closest reporting date to it. Tier 1 and Total Capital figures are as reported by the banks in accordance with Basel requirements. Equity ratio in all cases is calculated as total shareholder equity / total assets. Figures for Australian banks are as per table 1. All figures for Canada obtained from Office of the Superintendant of Financial Institutions Canada (2009) for all domestic banks. All figures for UK are from the KPMG (2009) average for the 5 major UK banks. Tier 1 and Tier 2 ratios for Other Europe include Euro Area large and complex banking groups as reported by the European Central Bank (2009). Equity ratios are calculated from DataStream shareholder equity and total asset figures for the US and non-UK European banks used in this study as described in Section 6. US Tier 1 and Tier 2 figures are obtained from Federal Reserve Bank Statistics for Commercial Banks.

The equity ratio of just over 6% for Australian banks is higher than most European banks, slightly higher than Canadian banks, but somewhat lower than in the US. The differential between risk weighted and absolute capital ratios is not as marked for Australia as for UK and other European banks. Discrepancies among banks between the Basel risk weighted approach and absolute ratios have led to many parties, for example the Swiss National Bank (Blum, 2007; Hildebrand, 2008) and Bank of England (2008b), calling for the introduction of minimum leverage ratios to run in parallel with the existing regulatory approach. Indeed The Swiss Financial Market Supervisory Authority (FINMA) has already introduced such a measure for the two major Swiss banks. In Australia, APRA has generally taken a conservative approach to the risk weighting of assets, introducing a higher risk weighting to apply to higher risk non-standard home loans, and in 2003 undertook stress testing on home loans. Subject to the limitations of the stress testing methodology, the aggregate results reported by APRA (Esho, Coleman, Sellathura, & Thavabalan, 2005) indicated that Australian ADIs were well capitalised, with good Loan to Value (LVR) ratios and well placed to withstand a housing market shock that is far more severe than any nationwide experience in Australian history. Over 90 per cent of ADIs were deemed able to survive the stress event, without breaching minimum regulatory capital requirements. Indeed, confidence in the robustness of Australian home loan portfolios had previously led APRA (2001) to make recommendations to the Basel Committee on Banking Supervision for a reduced risk weighting (from 50% to 20%) to apply to home loans. The stress test findings would appear to have since been vindicated by the performance of Australian banks through the GFC.

Interest rates in Australia have not experienced the same volatility levels as some of their global counterparts. Figure 1 compares cash rates between Australia, US, UK, and Canada. The Australian cash rate moved from a low of 4.25% in Dec 2001, peaking at 7.25% in March 2008 (an increase of 1.7x), and falling to 3% in April 2009. In contrast, the US Fed funds rate rose from 1% in June 2003 to 5.25% (an increase of 5.25x) in June 2006, and down to 0% in Dec 2008. Rates in the UK and Canada have also fallen to much lower levels than in Australia. Due to strong economic data, the RBA has commenced interest rate increases, whereas rates in all 3 other regions have not increased.

Figure 1. *Comparison of Central Bank Interest Rates.*



Figures are obtained from RBA (2009b) statistics for official interest rates of Central Banks. Included in the graph are the Australian target cash rate, the Canada target rate, the United Kingdom official bank rate, and the United States federal funds target rate.

Australia had a housing boom in the early 2000's. For some regions, such as Western Australia which experienced a commodities led boom, this continued through to 2007. House prices in most Australian areas softened over the past few years, but have fared better than many countries. House prices reduced by about 4% in Australia over 12 months to March 2009, compared to reductions of between 10-25% in areas of US and Europe. Nonetheless, housing loan arrears increased from 0.32% in 2007 to 0.48% in 2008, associated with the general downturn in the economy, and associated unemployment.

Overall, this section has shown that there has been a substantial increase in Australian bank risk indicators such as impaired assets and provisions. However these are modest in comparison to US and European banks, and are at similar levels to the Canadian banks.

4. VaR and CVaR

The prior section has highlighted some of the key trends taking place in the banking industry. This included the extreme volatility in bank share prices. This is an important component in the measurement of market asset value fluctuations and in turn impacts on PD (as covered in Section 5). VaR is a widely used method for measuring market risk, with CVaR providing a measurement for extreme risk. Thus prior to examining default probabilities using the Merton model, this study examines share price VaR and CVaR prior to and during the GFC, with this section explaining these metrics.

VaR's use in the banking industry escalated since being adopted by Basel as the primary measure for calculating market risk capital requirements. The metric measures potential losses over a specific time period at a given level of confidence for a specific time period. Internationally, there is extensive literature coverage about VaR. Examples include RiskMetricsTM (1996) who introduced and popularised VaR, Jorion (1996), and comprehensive discussion of VaR by more than seventy recognised authors in the VaR Modeling Handbook and the VaR Implementation Handbook (2009a, 2009b). In summary, there are 3 methods applied for calculating VaR. The Variance-Covariance (parametric) method estimates VaR on the assumption of a normal distribution. The Historical method groups historical losses in categories from best to worst and calculates VaR on the assumption of history repeating itself. Monte Carlo Simulation simulates multiple random scenarios. In order to exclude the possibility of distortion of results due to sensitivity to the method chosen, we use all 3 methods.

As the parametric method assumes returns are normally distributed, to obtain VaR for a single asset X, all that needs to be calculated is the mean and standard deviation (σ). Using standard distribution tables, and given the normal curve assumption, we automatically know where the worst 1% and 5% lie on the curve:

95% confidence = -1.645 x σ_x

99% confidence = -2.330 x σ_x

When calculating VaR, it is usual practice (and is the method used by RiskMetrics) to not use actual asset figures, but the logarithm of the ratio of price relatives, i.e. the logarithm of the ratio between today's price and the previous price, obtained by using the following calculation:

$$\ln\left(\frac{P_t}{P_{t-1}}\right) \qquad (1)$$

For the historical method, daily returns for assets are calculated in the same way as for the parametric method as per equation 1. Instead of assuming a normal distribution, the actual 5th percentile value is taken as VaR at the 95% confidence level. Because historical weightings in a portfolio can change, thus distorting VaR for the current portfolio, it is usual practice to use historical simulation for this method whereby the value of the portfolio is calculated assuming constant weightings (based on the current portfolio weightings, for which we use market capitalisation) for each day in the period.

Monte Carlo analysis generates future simulated prices, assuming a random walk. Using closing prices, mean and standard deviation of returns, thousands of random variables are generated (we use 20,000) which are then used to calculate VaR, with the 95th lowest value in the simulation being VaR at the 95% confidence level.

A key criticism of VaR is that it says nothing of risk beyond VaR. Critics have included Standard and Poor's analysts (Samanta, Azarchs, & Hill, 2005) due to inconsistency of VaR application across institutions and lack of tail risk assessment. Artzner, Delbaen, Eber, & Heath (1999; 1997) found VaR to have undesirable mathematical properties; such as lack of sub-additivity. Criticism of VaR has mounted since the onset of the GFC with VaR being perceived as having a focus on historical risk and not measuring extreme tail risk.

In addition to VaR, this paper examines CVaR which considers losses beyond VaR. If VaR is calculated at 95%, then CVaR is the average of the 5% extreme returns. Pflug (2000), showed CVaR to be a coherent measure, which does not contain the undesirable properties of VaR. CVaR has been used to measure tail risk in an Australian setting by Allen and

Powell (2007), who find significant correlation between VaR and CVaR in ranking risk among Australian sectors (customers of banks as opposed to banks which are examined in this study) prior to the GFC and Powell and Allen (2009) who use CVaR to show how relative risk has changed among sectors since the onset of the GFC.

5. Structural Models and PD

The prior section has explained VaR and CVaR which will be used to measure market risk, a key component of asset price fluctuations. These in turn, are important to measuring distance to default (DD) and probability of default (PD) using the Merton structural methodology, which is explained in this section. The model is based on the option pricing methodology of Black & Scholes (1973). The model uses fluctuations in market asset values combined with asset and debt levels of a firm to measure DD (measured by number of standard deviations). The firm defaults when asset values fall below debt levels.

In the Merton model, equity and the market value of the firm's assets are related as follows:

$$E = V\mathrm{N}(d_1) - e^{-rT} FN(d_2) \qquad (2)$$

E = market value of firm's equity
V = market value of firm's assets
F = face value of firm's debt
r = instantaneous risk free rate
N = cumulative standard normal distribution function
T = selected time horizon

$$d_1 = \frac{\ln(V/F) + r(+0.5\sigma_v^2)}{\sigma_v\sqrt{T}} \qquad (3)$$

$$d_2 = d_1 - \sigma_v\sqrt{T} \qquad (4)$$

σ_v is the standard deviation of asset returns. Volatility and equity are related under the Merton model as follows:

$$\sigma_E = \left(\frac{V}{E}\right) N(d_1)\sigma_v \tag{5}$$

DD is calculated as:

$$DD = \frac{\ln(V/F) + (\quad - 0.5\sigma_v^2)T}{\sigma_v\sqrt{T}} \tag{6}$$

μ = an estimate of the annual return (drift) of the firm's assets, which can be calculated as the mean of the change in lnV (Vassalou & Xing, 2004).

Probability of Default (PD) can be determined using the normal distribution. For example, if DD = 2 standard deviations, we know there is a 95% probability that assets will vary between 1 and two standard deviations. There is a 2.5% probability that they will fall by more than 2 standard deviations. Using *N* as the cumulative standard normal distribution function, PD is measured as:

$$PD = N(-DD) \tag{7}$$

Moody's KMV (Crosbie & Bohn, 2003) is a popular model used by banks to measure PD. KMV calculates DD based on the Merton approach, but instead of using a normal distribution to calculate PD, KMV use their own worldwide database to determine PD associated with each default level. In KMV, debt is taken as the value of all short-term liabilities (one year and under) plus half the book value of all long term debt outstanding. T is usually set as 1 year. The approach to calculating σ_V, as per KMV and Bharath and Shumway (2008) and (Vassalou & Xing, 2004) involves first estimating σ of equity from historical data (as we have done in section 4), and then applying an iterative procedure. An initial asset value can be estimated as

$$\sigma_V = \sigma_E\left(\frac{E}{E+F}\right) \tag{8}$$

For each trading day, *V* is computed by applying σ_E to equation 5. Thus we obtain daily values for *V* every day. The daily log return is calculated and σ of asset returns calculated, which is then used as V for the next iteration to estimate new asset values. This process is repeated until asset returns converge to 10E-3. Once we obtain the converged value of σ_V, we back out V through equation 2.

We use the same definition as KMV for debt and also set T to 1 year. We also use same iterative process as described above for estimating σ_V. In line with Vassalou and Xing (2004), we calculate μ as the annual mean of change in lnV. The risk free rate used is the annual average 1 year indicative mid rate for selected Commonwealth Government securities as provided by the Reserve Bank of Australia (2009d).

We have modified the Merton model to incorporate a CVaR approach due to the fact that firms are most likely to default under extreme circumstances. Instead of using the standard deviation of all asset returns, we use the standard deviation of the worst 5% of returns (which we label CStdev) to calculate conditional distance to default (CDD) and conditional probability of default CPD (default conditional upon asset values fluctuating at the extreme 5% level):

$$CDD = \frac{\ln(V/F) + (\quad -0.5\sigma_v^2)T}{CStdev_v \sqrt{T}} \tag{9}$$

and

$$CPD = N(-CDD) \tag{10}$$

Other studies which use the Merton model in an Australian context include Sy (2007, 2008) who focuses on home loans and proposes a revised causal framework for estimating default which incorporates serviceability; Powell and Allen (2009) who rank default risk of industries (bank customers); Gharghori, Chan and Faff (2007) who compare the performance of option-based and accounting-based models, Chan, Faff and Koffman (2008) who examine the role of default risk in asset pricing using microcap stocks; and Tanthanongsakkun and Treepongkaruna (2008) who examine how the Merton model combined with size and book-to-market ratios effectively explain credit ratings when compared to accounting ratios. No other studies are located which apply the Merton model specifically to bank credit risk in an Australian setting, and the CPD concept is unique to the authors.

6. Data and Methodology

Having explained the VaR, CVaR, DD and PCD metrics, this section now proceeds to explain our data selection, and how these metrics will be used in this study.

6.1 Data

All data is obtained from DataStream. As per Section 1, although there are 58 banks in Australia, there are only 13 Australian owned banks according to APRA (with assets of AUD $2.3 trillion totalling 88% of all banking assets in Australia), the rest (totalling only 12%) being branches of foreign banks. At 2008, the ASX showed 12 listed banks. Macquarie was classified as ‘Diversified Financials” on the ASX, but we have included Macquarie in our analysis due to being classified as a bank by APRA, giving 13 entities in total. St. George is now wholly owned by Commonwealth Bank, but we have included this separately, as it was a separately listed bank to end 2008. These 13 entities include the 4 major banks and 9 smaller / regional banks. A complete list of these entities is shown in our results section in table 4.

As discussed in Section 1, for comparative purposes we include US, European and Canadian banks. Section 3 shows that although there are over 8,000 banks in the US, there are only 52 US owned listed banks, with assets of USD 7.8 trillion representing about 65% of total bank assets in the US. The remainder are smaller unlisted banks, mutually owned savings banks or branches of foreign banks. We include all 52 banks in our analysis. Due to the large number of European countries and banks, we use only the 15 largest European banks by total assets (aggregate equivalent to USD 30 trillion), with representation from the UK, France, Switzerland, Belgium, Spain, Italy and the Netherlands. These European banks are all among listings (BankersAlmanac, 2009; The Banker, 2009) of the world’s largest 25 banks. Section 3 shows that there are 22 domestic Canadian banks, 9 of them being public companies listed on the Toronto Stock exchange. We include all 9 listed banks (including the 'big 5' and 4 smaller banks) with total assets of USD 2.5 trillion, representing approximately 80% of total bank assets in Canada.

We obtain 10 years of daily equity prices for each bank. Only trading days are used (approximately 250 days per annum), thus excluding all weekends and holidays. We also obtain the required balance sheet data from Datastream for calculating VaR, CVaR, DD and PD as described in Sections 4, 5, 6.2 and 6.3. This includes daily market capitalisation (used in calculation of daily asset values and for weighting banks to calculate VaR and CVaR); annual total liabilities, current liabilities and long term liabilities (used in calculation of DD). In line with KMV, we compute liabilities as the sum of current liabilities and one half of long term debt.

We compare trends for each of the 10 years (1 year / 250 day windows). In addition, we divide the data into a pre-GFC period and a GFC period. The GFC period is two years from 2007-2008 (500 day window), and the pre-GFC period is the 7 year period from 2000 – 2006 (7 years aligns with the Basel Accord Advanced requirements for measuring credit risk). We use an F test to compare share price volatility and market asset volatility between the two periods, testing for significance at both the 95% and 99% levels.

6.2 VaR and CVaR Methodology

We use all 3 VaR methodologies (parametric, historical and Monte Carlo simulation) as described in Section 4. We calculate the returns using the logarithm of price relatives every day for each bank for the past 10 years. For total bank portfolios, we use an undiversified approach, whereby total VaR is the weighted average of the individual bank VaRs. As we are examining VaR and CVaR of equities, we weight each bank according to market capitalisation. Correlation (diversification) among assets in the portfolio is not calculated as we are not calculating VaR for investment purposes, and do not need to show the effect of portfolio diversification, and our total bank figures are based on a weighted average of the underlying bank VaRs (for example the 95% daily VaR for the S&P/ASX200 Bank index which contains the largest 6 banks is 0.0302 during the GFC period compared to a weighted average for the same banks of 0.0337, the difference being that the index is based on a diversified portfolio of 6 banks as opposed to a weighted average of VaRs). The weighted average is a more meaningful figure to compare individual banks against. VaR is usually measured at high levels of confidence, either 95% or 99%, with CVaR measured as the returns beyond VaR (5% or 1%). As the GFC period relates to only 2 years with 250 daily returns each year, for a confidence level of 99%, CVaR would only encompass 2.5 returns for each of the 2 years, giving 5 returns in total for each bank. We have thus chosen CVaR at 5% (VaR 95%), which provides analysis of a reasonable number of extreme returns.

For the parametric method, based on a normal distribution, we multiply the standard deviation by 1.645 to obtain VaR at the 95% confidence level. For the historical method, we calculate VaR as being the lowest 95^{th} value over the period. For Monte Carlo we generate 20,000 random scenarios for the pre-GFC period (based on the pre-GFC distribution) and 20,000 for the post-GFC period (based on the post-GFC distribution), and then calculate VaR as the lowest 95^{th} value for each period. For each of the 3 methods used, CVaR is calculated as the average of the returns beyond the VaR measure (the worst 5%).

6.3 Structural Methodology

We apply the Merton methodology discussed in Section 5. Using the equity returns obtained in Section 6.2, and the relationship between equity and assets as described in section 5, we estimate an initial asset return. The daily log return is calculated and new asset values estimated. This is applied every day. Following KMV, this process is repeated until asset returns converge.

CVaR methodology is incorporated into the structural model to obtain CDD and CPD as per Section 5.

7. Results and Discussion

This section presents and discusses the results obtained using the methodology and data described in Sections 4 – 6. We commence with the VaR and CVaR results (summarised in

Tables 4 and 5), followed by the outcomes for DD and PD (summarised in Table 6). Trends are compared to the US, Europe and Canada.

7.1 VaR and CVaR Results

Table 4. *VaR and CVaR Results for Australian Banks*

Pre-GFC	Parametric VaR	Historical VaR	Monte Carlo VaR	Parametric CVaR	Historical CVaR	Monte Carlo CVaR
ANZ	0.0192	0.0250	0.0268	0.0261	0.0303	0.0338
BANK OF QUEENSLAND	0.0208	0.0293	0.0292	0.0291	0.0350	0.0366
BENDIGO & ADELAIDE	0.0218	0.0308	0.0270	0.0308	0.0360	0.0301
COMMONWEALTH	0.0181	0.0246	0.0254	0.0253	0.0287	0.0315
HOMELOANS	0.0457	0.0700	0.0641	0.0700	0.0859	0.0807
MACQUARIE	0.0244	0.0352	0.0343	0.0352	0.0418	0.0432
MORTGAGE CHOICE	0.0365	0.0483	0.0514	0.0505	0.0561	0.0645
NATIONAL AUSTRALIA	0.0205	0.0277	0.0291	0.0296	0.0319	0.0366
ROCK	0.0216	0.0359	0.0305	0.0323	0.0432	0.0383
ST. GEORGE	0.0173	0.0227	0.0244	0.0243	0.0265	0.0308
SUNCORP-METWAY	0.0209	0.0299	0.0296	0.0300	0.0356	0.0373
WESTPAC	0.0186	0.0242	0.0244	0.0252	0.0285	0.0331
WIDE BAY	0.0226	0.0357	0.0264	0.0348	0.0437	0.0398
ALL BANKS	0.0198	0.0232	0.0266	0.0286	0.0326	0.0339
Correlation with parametric method		0.9788	0.9890		0.9890	0.9823
p		<0.0001	<0.0001		<0.0001	<0.0001
Significance		**	**		**	**

GFC	Parametric VaR	Historical VaR	Monte Carlo VaR	Parametric CVaR	Historical CVaR	Monte Carlo CVaR
ANZ	0.0351	0.0434	0.0490	0.0630	0.0740	0.0682
BANK OF QUEENSLAND	0.0353	0.0445	0.0502	0.0592	0.0711	0.0697
BENDIGO & ADELAIDE	0.0408	0.0455	0.0581	0.0677	0.0792	0.0801
COMMONWEALTH	0.0308	0.0411	0.0438	0.0516	0.0624	0.0607
HOMELOANS	0.0519	0.0574	0.0733	0.1059	0.1260	0.1025
MACQUARIE	0.0561	0.0698	0.0744	0.1007	0.1204	0.1107
MORTGAGE CHOICE	0.0392	0.0413	0.0562	0.0729	0.0778	0.0780
NATIONAL AUSTRALIA	0.0361	0.0429	0.0513	0.0587	0.0715	0.0714
ROCK	0.0316	0.0380	0.0446	0.0614	0.0710	0.0623
ST. GEORGE	0.0375	0.0446	0.0524	0.0630	0.0739	0.0726
SUNCORP-METWAY	0.0382	0.0470	0.0542	0.0669	0.0775	0.0750
WESTPAC	0.0327	0.0400	0.0460	0.0537	0.0650	0.0638
WIDE BAY	0.0229	0.0297	0.0322	0.0414	0.0480	0.0448
ALL BANKS	0.0347	0.0428	0.0488	0.0585	0.0702	0.0679
Correlation with parametric method		0.9592	0.9947		0.9921	0.9653
p		<0.0001	<0.0001		<0.0001	<0.0001
Significance		**	**		**	**

VaR and CVaR calculations are as per Section 6.2. In summary, parametric VaR multiplies the standard deviation of daily returns by 1.645 (being 95% confidence level based on a normal distribution), Historical VaR is based on the actual historical 95th worst return, and Monte Carlo generates 20,000 simulations and then identifies the worst 95th simulated return. Annual VaR can be obtained for each method by multiplying daily VaR by the square root of 250. Figures are undiversified and represent the weighted average of the individual banks. CVaR is calculated as the average of the worst 5% of actual returns (those beyond the 95% VaR) for each of the 3 methods. The pre-GFC category calculates daily VaR for the 7 year period from 2000-2006. The GFC category calculates daily VaR for the 2 year window from 2007-2008.

There is a very strong correlation between the outcomes of the 3 different modelling techniques, significant at the 99.9% level. A key reason for this is the large number of historical observations, as well as the large number of forward simulations (20,000) used in our analysis. A high VaR or CVaR for a bank using any one of the models, corresponds with a high VaR or CVaR for that bank using any of the other two models. What is somewhat different is the actual VaR and CVaR levels between the models. The historical and Monte Carlo methods provide very closely matched outcomes, but both of these are slightly higher than the parametric outcomes, which means the parametric model is slightly underestimating the tail risk. For each bank, there is an increase in both VaR and CVaR from pre-GFC to GFC. Table 5 shows yearly VaR and CVaR figures. To avoid excessively detailed output, we have only shown the parametric method here, however as per our discussion on the outcomes for table 4, the other models show the same trend, just at slightly higher levels.

Table 5. *Pre-GFC / GFC Comparison of VaR and CVaR Results for Australian Banks*

	VaR	**CVaR**		**VaR**	**CVaR**
Year:			*Pre-GFC / GFC Summary:*		
1999	0.0178	0.0328	1.Pre-GFC	0.0198	0.0286
2000	0.0229	0.0320	2.GFC	0.0347	0.0585
2001	0.0227	0.0317			
2002	0.0222	0.0310	*Statistical testing:*		
2003	0.0200	0.0280	σ_1	*0.0120*	*0.0174*
2004	0.0151	0.0211	σ_2	*0.0211*	*0.0355*
2005	0.0141	0.0197	σ^2_1	*0.0001*	*0.0003*
2006	0.0154	0.0216	σ^2_2	*0.0004*	*0.0013*
2007	0.0170	0.0301	*F*	*3.0750*	*4.1767*
2008	0.0511	0.0868	*p*	*<.0001*	*<.0001*
			Significance	**	**

The left section of the table shows Daily VaR and CVaR for each year (12 month windows). VaR is calculated on a parametric basis as described in Section 6.2, whereby the standard deviation of daily returns is multiplied by 1.645 (being 95% confidence level based on a normal distribution). CVaR is calculated as the average of the worst 5% of actual returns (those beyond the 95% VaR). The top right section of the table groups VaR and CVaR into pre-GFC (up to 2006) and GFC (2007 - 2008) categories. The third section of the table undertakes F testing to test for variance in volatility between the pre-GFC and GFC categories. σ_1 is the standard deviation of daily returns for the pre-GFC period and σ_2 for the GFC period. F is σ^2_1 / σ^2_2, whereby a value of 1 shows no difference between the samples and a value of 3 shows variance of 3x higher in the GFC period than the pre-GFC period. * denotes significance at the 95% level and ** at the 99% level.

The table shows both VaR and CVaR reducing during the mid 2000's and increasing sharply over the GFC period. CVaR shows a similar trend at a higher level. The higher VaR during the early 2000's is attributable to several factors. Firstly, global share markets entered a much anticipated cool-off following a period of very high growth during the 1990s. Secondly, the Federal Reserve Bank and many other Central Banks made several interest rate increases to cool spending and inflation. Thirdly, the dot-com bubble burst in March 2000, sending high tech stocks tumbling. Fourthly, the terrorist attacks of September 11, 2001 caused markets to further decline. It was only after 2003 that markets entered a period of sustained growth, which continued up until the start of the GFC. This period of growth and stability is reflected in lower VaR and CVaR in the mid 2000's. Similar patterns were experienced in Canada (which is highly reliant on the US economy), the European Union, and other world markets. Canada, in particular, experienced problems such as high unemployment and high volatility in the telecommunications and technology sectors in the early 2000's.

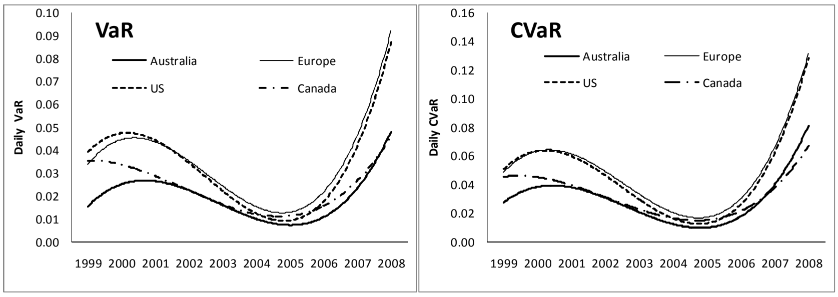
Despite the rosy picture painted at the start of this paper, whereby Australian banks show good profitability and improved credit rating in 2007 which have been maintained during the GFC, the share price has been very volatile. The annualised VaR in 2008 is approximately 80%. F values show that the GFC period variance is three times higher than pre-GFC. CVaR variance is four times higher, showing a greater spread between VaR and CVaR during the GFC. This volatility difference is significant at the 99% level.

Table 5 shows banks' VaR increasing from 0.0154 for 2006 to 0.0511 for 2008 (an increase of 3.3 times). In order to benchmark the bank results, we also calculated VaR and CVaR for the market as a whole, using the All Ordinaries (All Ords) index which includes the largest 500 Australian listed shares by market capitalisation and accounts for approximately 95% of the values of all shares traded on the ASX. All Ords daily VaR increased from 0.0249 to 0.0441 over the same period, an increase of 1.8x. Deducting the market increase from the bank increase, shows the market adjusted bank VaR increase to be 1.5x. The same process was applied to CVaR, with an increase of 4.0x for banks and 2.9x for the market, giving banks a market adjusted bank VaR increase of 1.1x. Thus, while clearly the overall market risk showed a large increase (and hence bank customers as they are drawn from these industries), the bank specific risk was over and above this.

There are several factors which could explain why banks show a higher increase in VaR and CVaR than other industries. The fallout in global financial markets, particularly in the US and Europe, and the failure of major banks such as Lehman Bros. and Northern Rock, sparked fears of contagion to all global markets. Additionally, the wholesale and securitisation markets dried up, making it extremely difficult for banks to obtain funding. Australian banks obtain 48% of funding from wholesale sources of which 54% is sourced from offshore financial markets (Australian Bankers Association, 2009). This was exacerbated by market conditions being very poor for raising capital, and by market fears of rising unemployment and increasing corporate failures affecting loan repayments. All these factors were coupled with sharply rising impaired assets and provisions as shown in section 3.

As shown by the comparative trends in Figure 2, both the US and European portfolios show higher volatility than the Australian banks. Nonetheless, all 3 regions show substantial increases in VaR and CVaR from 2007. Bank stock indices in the US and Europe plunged by up to 85% over the GFC period compared to the 58% drop in Australia. Canada starts off with VaR at levels similar to US and Europe, but during the GFC, these are at similar levels to Australia, and CVaR is below Australia, showing less extreme fluctuations.

Figure 2. *VaR and CVaR Comparison between Bank Portfolios.*



The figure compares the yearly VaR and CVaR Australian figures in Table 5 to the other 3 regions using 3 point polynomial trend lines. Daily data for the European and US banks is obtained from Datastream, and Daily VaR and CVaR for each year is calculated in exactly the same manner as for Australia in table 5, using the same 12 month windows.

So far, we have only discussed results relating to share price volatility. These have a key impact on asset volatility, and the next step is to explore default probabilities based on the Merton model, which are a function of asset volatility and leverage. Based on balance sheet shareholder equity to total assets, as per table 3, Australian banks have equity of 6.2%, Canadian banks 5.2%, US banks 7.1%, and European banks 3.2%. Table 6 shows DD, CDD, PD and CPD.

7.2` Default Risk Results

Table 6. *DD, CDD, PD and CPD Results.*

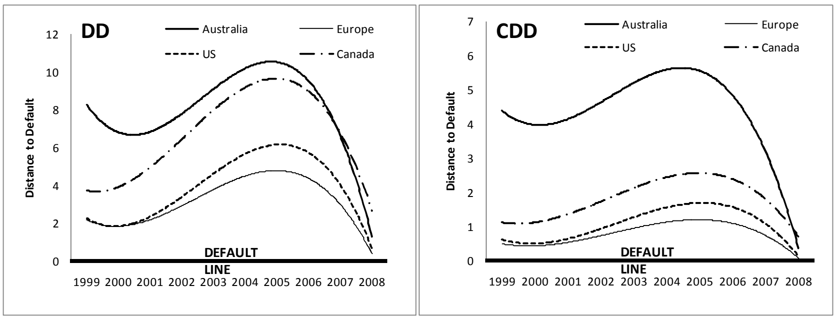
	DD	CDD	PD	CPD
Annual figures:				
1999	7.8385	4.0918	<0.1%	<0.1%
2000	7.5752	4.4523	<0.1%	<0.1%
2001	6.9326	4.2122	<0.1%	<0.1%
2002	7.7138	4.5711	<0.1%	<0.1%
2003	8.2710	4.8397	<0.1%	<0.1%
2004	9.8635	5.3818	<0.1%	<0.1%
2005	11.3099	5.7639	<0.1%	<0.1%
2006	10.1931	5.1948	<0.1%	<0.1%
2007	1.8069	0.5653	3.5%	28.6%
2008	0.5993	0.1962	27.4%	42.2%
Pre GFC / GFC Summary:				
1.Pre-GFC	8.2566	5.1948	<0.1%	<0.1%
2.GFC	1.1821	0.3927	11.9%	34.7%
Statistical testing:				
σ_1	*0.0018*	*0.0062*		
σ_2	*0.0031*	*0.0128*		
σ^2_1	*0.000003*	*0.000038*		
σ^2_2	*0.000010*	*0.000164*		
F	*3.1380*	*4.2622*		
p_1	*<.0001*	*<.0001*		
Significance	**	**		

The top section of the table shows DD, PD, CPD and CDD figures for each year. Figures are computed from daily market value of asset returns using Merton / KMV methodology per Sections 5 and 6.3, with all data obtained from Datastream. CDD and CPD are based on the worst 5% of actual asset returns. The second section of the table groups data into pre-GFC and GFC categories. The GFC category includes the 2 year window from 2007 to 2008. The pre-GFC category includes the 7 years from 2000-2006. The third section of the table undertakes F tests for variance in volatility of market asset values (as opposed to share price values in table 5) to assess the impact of the GFC. σ_1 is the standard deviation of daily asset returns for the pre-GFC period and σ_2 for the GFC period. F is σ^2_1 / σ^2_2, whereby a value of 1 shows no difference between samples and a value of 3 shows volatility of 3 x higher in the GFC period than pre-GFC. * denotes significance at the 95% level and ** at the 99% level.

DD increases in the mid-2000's and then dramatically reduces in 2007 and 2008. Associated PD is extremely small up to 2006, increasing to 27% in 2008. Using our own

CPD model, CPD is 42% during the extreme 5% of asset value fluctuations in 2008. Comparing the 2 year GFC period to the 7 year pre-GFC period, PD leaps from almost negligible values to 12% PD and 35% CPD. The F statistic shows that variance in market asset value fluctuations has increased more than 3 times (4X on the most extreme values), with a 99% confidence level. Clearly, default risk has not stayed static as indicated by the external ratings of the banks.

Figure 3. *DD and CDD Comparison.*



The figure compares the yearly DD and CPD Australian figures in Table 6 to the other 3 regions using 3 point polynomial trend lines. Daily data for the European and US banks is obtained from Datastream, and DD and CDD for each year is calculated in exactly the same manner as for Australia in table 6, using the same 12 month windows.

The lower volatility levels of the Australian banks result in higher DD levels as compared to Europe and the US. The combination of high volatility and low equity means European banks fare the worst. Canada lies between the US/Europe and Australia in the earlier years but has a higher DD during the GFC, which is line with Canada's higher bad debt experience following the technology bubble burst and US terrorist attacks in the early 2000's as shown in Table 2, and lower bad debt experience during the GFC. All regions show a dramatic shift towards the default line in 2007 and 2008, brought about the huge drop in equity values in all 4 regions. Australia fares slightly better than Europe and US due to the lower drop in equities, but nonetheless shows a huge leap towards the default line, with all regions except Canada dropping well below DD of 1σ and CPD of 0.5σ, with associated CPDs (calculated as per equation 10) all exceeding 40%. Canada's CPD is 25%.

One could argue that the credit risk of all industries based on fluctuations in market asset values deteriorated during the GFC, so how are banks different? Table 7 shows DD rankings for all sectors forming part of the Australian All Ords Index (which contains the 500 largest listed firms by market capitalisation, including all Australian banks) pre-GFC as compared to during the GFC. Pre-GFC Banks were ranked 14th out of 20 industries (with 1 being the least risky) based on DD, which moved to 18^{th} during the GFC. On a CDD basis, Banks moved from 8^{th} to 18^{th}. Only Diversified Financials and Automobiles & Components were riskier during the GFC. This shows that Banks have shown a marked deterioration in credit risk relative to other industries as a whole.

Table 7. *Industry Comparison.*

	Values				Ranking			
	DD Pre GFC	DD GFC	CDD Pre GFC	CDD GFC	DD Pre GFC	DD GFC	CDD Pre GFC	CDD GFC
Automobiles & Components	5.80	1.09	3.26	0.27	18	19	20	19
Banks	8.26	1.18	5.19	0.39	14	18	8	18
Capital Goods	8.49	3.10	4.99	0.83	12	16	13	16
Commercial Services & Supplies	7.80	5.34	4.53	1.51	15	9	15	11
Consumer Durables & Apparel	9.27	5.33	5.16	1.64	9	10	10	9
Diversified Financials	11.65	0.59	5.17	0.16	2	20	9	20
Energy	9.52	6.43	5.36	1.81	6	6	6	6
Food & Staples Retailing	10.06	6.05	5.33	1.80	4	7	7	7
Food Beverage & Tobacco	9.44	8.54	5.06	2.73	7	3	11	2
Healthcare Equipment & Services	8.86	10.71	5.86	3.13	10	1	4	1
Insurance	3.70	2.13	3.38	0.60	20	17	19	17
Media	9.97	5.53	5.00	1.75	5	8	12	8
Metals & Mining	8.50	3.88	5.86	1.11	11	14	5	14
Pharmaceuticals & Biotechnology	7.64	6.65	4.54	2.14	16	5	14	4
Real Estate	11.54	3.40	6.26	0.94	3	15	2	15
Retailing	7.12	4.46	4.35	1.46	17	13	16	12
Technology	5.64	5.21	3.84	1.58	19	11	18	10
Telecommunication Services	9.40	7.07	6.59	2.13	8	4	1	5
Transportation	8.31	4.85	4.31	1.43	13	12	17	13
Utilities	13.93	8.61	6.17	2.61	1	2	3	3
	8.54	4.33	4.95	0.54				

DD and CD figures are calculated for each industry in the same manner as they are calculated for Banks in Table 6, and industries are then ranked from 1 (lowest risk) to 20 (highest risk). A higher ranking in the GFC column as compared to the pre-GFC column means the industry has been affected worse by the GFC than other industries as a whole. A lower ranking in the GFC column as compared to the pre-GFC column does not mean the industry has improved over the GFC, but that the industry has been affected less by the GFC than other industries as a whole.

Similarly to our benchmarking in the VaR section, we can benchmark bank DD to industry DD using table 7. DD for banks reduced from 8.26 pre-GFC to 1.18 during the GFC (reduction of 7 times), which was a far larger reduction than the total industry DD reduction from 8.54 to 4.33 (2 times) over the same period. This gives a market adjusted DD reduction of 5 times. The DD of other industries represents risk that banks would be taking by lending to corporate customers in those industries. We therefore see that the riskiness of bank customers generally has increased substantially, and that there is also a large bank specific risk over and above this. DD is a combination of movement in market values, and equity levels. The reason the increase in bank DD is so much higher than the market is a combination of the high movement in market values, as noted in our discussion on VaR, and the very low equity levels of banks as compared to the other industries. Table 3 shows equity levels of Australian banks of just over 6%. In comparison the average equity levels of all the companies in our All Ords sample is 46%.

As previously mentioned, the PD values obtained from the Merton model are considered by KMV to be too low. Thus KMV use their worldwide database to calculate an empirically obtained EDF value for each DD value. KMV EDF values are not readily available for each DD, however KMV do provide EDF factors for each external rating. Using these EDF values, and the external ratings of each entity (Moody's Investor Services, 2009; Standard & Poor's, 2009b), we are able to obtain estimated EDF's for our All Ords portfolio (and their associated DD's) using the inverse of the formula $PD = N(-DD)$. We are then able to calibrate our bank DD's obtained using the Merton model to an estimated EDF as follows:

$$CalibratedDD = \overline{DD}_{eP} + \frac{DD_B - \overline{DD}_p}{\sigma_P}\sigma_{eP} \tag{11}$$

Where

$\overline{DD}_{eP}$ and σ_{ep} = estimated weighted average DD and standard deviation for the entire All Ords portfolio based on the external ratings of all entities,

$\overline{DD}_p$ and σ_p = actual weighted average DD for the entire All Ords portfolio using the Merton model, and

DD_B = DD for Banks using the Merton model.

We have obtained estimated EDFs (from Lopez, 2004) at the year 2000, the commencement of our data sample. These EDFs range from 0.02% for AAA loans up to 18.5% for the lowest rated (C) non-defaulting loans. We note that not only are the Merton values lower at the least risky end of the scale, but we see from Table 6 that Merton PD's can go much higher at the other end of the scale as compared to the KMV ceiling of 18.5%. Thus the range of KMV default probabilities is narrower than obtained from the Merton model. By calibrating our Merton PD's to KMV EDF at the start of our sample in 2002, then allowing the calibrated PD to fluctuate each year relative to our calculated change in asset values per section 67.2 and mapped to the EDF distribution, we can calculate calibrated PD (and DD) for each year. Similarly we can calculate calibrated CDD and CPD based on the worst 5% of asset value fluctuations. The outcomes for 7 years are shown in table 8. These show the same trend as for the uncalibrated values, but provide a narrower range of more meaningful PD values.

Table 8. *Calibrated Default Probabilities.*

	Calibrated DD	Calibrated PD	Calibrated CDD	Calibrated CPD	CDS Spread Australia	CDS Spread US	CDS Spread Europe
2002	2.6	0.54%	1.8	3.44%	15	42	28
2003	2.6	0.45%	1.9	3.15%	12	18	13
2004	2.8	0.26%	1.9	2.65%	10	18	10
2005	3.0	0.16%	2.0	2.38%	9	16	9
2006	2.8	0.22%	1.9	2.79%	7	9	8
2007	2.0	2.31%	1.3	9.85%	48	76	52
2008	1.5	6.58%	1.0	16.26%	145	180	158
r	-0.930	0.999	-0.932	0.973			
p	0.0024	<0.001	0.0022	0.0002			
Significance	**	**	**	**			

The DD, PD, CDD and CPD values have all been calibrated to EDF values as per the discussion preceding the table. The CDS spreads are for terms of 5 years on non-subordinated debt as reported by the Reserve Bank of Australia (RBA 2008; 2009a) and defined by the RBA as being the average spreads of Australian commercial banks and their US and European equivalents. Comparative Canadian bank spreads are not available. Correlation between each column and Australian CDS spreads is shown at the bottom of the table. * denotes significance at the 95% level and ** at the 99% level.

We compare this to Credit Default Swap (CDS) spreads for Australian and US banks in the last 2 columns of Table 8. CDS spreads are premia payable for protection against the default of an underlying contract. These can be traded without any ownership of the underlying debt, with increases in spreads representing an increase in default probability. As seen in the table, US bank CDS contracts typically trade at a higher spread than Australian banks. We have correlated our DD, PD, CDD and CPD values with the Australian bank spreads. These correlations all show exceedingly high significance (>99% confidence). Thus, while all the indicators in this paper (bad debts, loss provisions, PD, CPD, Calibrated PD, Calibrated CPD, and CDS) show different levels of default according to different methodologies used, they all have one thing in common – a significant increase in risk in default risk levels is indicated from pre-GFC to GFC.

7.3 Cross-Sectional Analysis

To ascertain if there are size / region / individual bank differences in our measurements, Appendix 1 splits the banks for all the regions into 'major' and 'other' banks and provides figures on VaR, CVaR, Stdev (asset value fluctuations) and CStdev (worst 5% of asset value fluctuations). We have used $40 billion market capitalisation as the cut-off point for defining a major bank, as this point ensures all Australian major banks are included as major banks, and also that all of our regions have at least 3 banks included in the comparison. Given the high number of banks (over 4 countries / regions) only the major bank figures have been shown at individual level, with the 'other' bank figures showing the weighted average for those banks. Also, to avoid extensively detailed tables, we have only included parametric method for measuring VaR and CVaR in the tables. In summary, the figures show major banks in Australia to have lower VaR, CVaR, Stdev, and CStdev figures than 'other' Australian Banks. Both groups have significantly worse figures for all these 4 indicators during the GFC as compared to pre-GFC (significant difference at 99% confidence level using an F test), however the extent of the increase in tail risk was actually larger for the majors (2.14x for CVaR and 1.80x for CStdev) than for 'other' (1.66x for CVaR and 1.54x for CStdev). The significance of the differential between CStdev for the major banks and the 'other' banks falls from the 99% level pre-GFC to the 95% level during the GFC period. The following paragraphs elaborate on, and provide reasons for these trends.

Table 4 shows that the 5 largest banks (the four majors and St. George) have the 5 lowest volatility levels, with St George having the lowest, followed by Westpac, Commonwealth, ANZ, then National Australia Bank. The aggregate VaR for the pre GFC majors is 0.0191 (CVaR 0.0265) as compared to VaR 0.0249 (CVaR 0.0432) for the 'other' banks.

Increase in risk indicators is particularly high for ANZ with a 2.41x increase in CVaR and a 2.12x increase in CStdev. Whilst both NAB ($3.5 bn) and ANZ ($2.47 bn), had higher credit impairment charges over 2007 and 2008 than the other major banks, NAB already had higher VaR and CVaR figures than the other major banks due to high rogue-trading losses and multi-billion dollar write-offs related to their US Homeside business in the pre-GFC period, and thus ANZ had further to fall than NAB when the GFC problems hit. Although the 'other' banks have higher overall volatility than the majors (the notable exception being St. George), the aggregate VaR and CVaR for all banks is not much higher than that for the major banks, due the much greater size of the majors. In particular, smaller entities such as Homeloans and Mortgage Choice show much higher volatility levels. Macquarie also shows particularly high CVaR levels during the GFC, having a high reliance on wholesale and corporate markets, as well as market reaction to news that Macquarie's investments included exposure to sub-prime mortgages, although this was assessed by Standard & Poor's (2007) to be "less than significant relative to the bank's asset book and earnings". KPMG (2008) shows bad debts increasing by 64% in 2008 for the Regional banks (for whom they include St. George, Bendigo-Adelaide-Rural Bank, Suncorp Metway, and Bank of Queensland), and a low increase in profits of 4.8%. There was very low growth in non-interest income particularly due to decrease from wealth management operations (in which the regional banks have significant activity) and significant falls in global stock market operations. Losses for Australian banks were generally higher for corporate exposures than in consumer markets, and the Regional Banks were not as exposed as the majors to the corporate sector. The exception here is Suncorp, who although showed VaR and CVAR figures in table 4 for 2007-2008 which were not very different to the 'other' banks, they suffered significant credit losses in 2009 due to greater exposure to corporates. A 600% increase in credit impairment losses was shown by Regional banks in 2008/2009, which is much higher than the increase in impaired assets for all Australian banks shown in Table 1. However, excluding Suncorp, the increase for Regional banks was 191%, which is line with the increase for all Australian banks.

The Australian government financial claims scheme guaranteed deposits of $1 million and below for all Australian owned banks, building societies, and credit unions which helped improve confidence in the banking sector for major and 'other' banks. Deposits over $1 million were subject to a fee, which varied according to the deposit institution's credit rating. This somewhat disadvantaged the smaller banks whose lower credit rating meant a higher fee. AA- (and above) rated banks paid a fee of 70 basis points per annum, A+ to A- 100 basis points and BBB+ and below 150 basis points. Most funds raised under the scheme were by the four majors who have AA ratings and other banks who fall in the A+ to A- category such as Macquarie and Suncorp. The remaining 'other' banks fall in the BBB+ and below category. However, this advantage of the higher rated banks only had a short term impact (which in turn would have included only a short term impact on our VaR, CVaR and Asset Value measures), with the RBA (2010) reporting that take up was at the highest just after introduction of the scheme and as concerns about the global system eased, ADIs were less willing to absorb the fee and customers were less willing to pay for additional security over what was already perceived to be a relatively low risk investment. The wholesale guarantee scheme was predominantly used to guarantee long-term liabilities, and after the initial take-up the AA rated banks continued to issue unguaranteed bonds rather than issuing guaranteed and paying the extra fee. The RBA reports that whilst there continues to be little unguaranteed bond issuance for lower rated deposit institutions, these entities have not traditionally been large players in this market.

In all 3 of the comparison regions (Canada, Europe, US), there is also a significant increase in all risk measures shown in Appendix 1 from pre-GFC to GFC. Among the majors, Barclays, UBS, Unicredit, Bank of America, Citigroup and Wells Fargo stand out as having high VaR, CVAR and asset value fluctuations during the GFC. These are all entities which featured prominently in the GFC among those banks which suffered problems such as large losses, capital shortages, and substantial writedowns of investments in subprime mortgages. Overall, there is no clear pattern emerging as to differences in the risk measurements between major and 'other' banks. In Canada 'other' banks have lower asset value fluctuations than major banks both pre and during the GFC, but there is no significant difference in VaR and CVaR. In Europe 'other' banks are more risky than majors on all measures with this differential increasing during the GFC. In the US, the increase in all measures was fairly similar for majors and 'other' banks, with GFC asset value fluctuations being similar across both groups. It should be noted of course, that as we are looking at asset value fluctuations, our study only includes listed groups, and (with the notable exception of Lehman Brothers) the large number of financial institution failures are predominantly smaller unlisted entities. If we consider all 4 regions as a whole, the large increases in our risk measurements are widespread (but to a lesser degree in Canada and Australia), across all categories of banks in our study. Larger banks experienced significant difficulties such as access to wholesale funding (all regions), writedown of investments in sub-prime mortgages (mainly US and Europe), and exposure to corporate loan losses (all regions). Many smaller entities also had problems accessing funding. These entities generally also had relatively large exposures to the home loan market which was impacted by rising unemployment and falling house prices, particularly in the US and Europe. Many of the smaller banks also had large exposures to a falling commercial property market. Thus all categories of banks, small and large, experienced problems during the GFC.

7.4 Implications for Capital Adequacy.

As discussed in Section 1, the Basel Committee on Banking Supervision sees it as important that adequate capital buffers are held in good times that can be drawn upon in periods of stress, and are looking to introduce buffer requirements in Basel III. It was also discussed in Section 1 how a mark to market approach of a bank's assets can provide a measure of how much capital needs to be raised to restore confidence in a bank's capitalisation. Let us take the take the BOE example, whereby UK banks held capital (total balance sheet equity to total assets) of 3.3% prior to the GFC. We see in Appendix 1 that European banks experienced an approximate doubling in asset volatility during the GFC.

Let us also assume that this capital position position held by the banks provided a DD which was acceptable to regulators in pre-GFC circumstances. Given that volatility in assets is the denominator of the DD equation, in order to restore UK DD to the pre-GFC position, capital needs to be doubled in line with the volatility increase. This means a capital buffer of 3.3% (resulting in a total ratio of 6.6%). Applying the same rationale to Australian banks, they would require a much lesser increase, as their capital ratio is already 6.2%. Thus, provided a benchmark DD (and hence PD) is provided by regulators (or banks themselves), and increases in asset volatility are modelled during downturns, the extent of the capital buffer required can be determined.

8. Conclusions and Implications

Despite the lower volatility of Australian banks in comparison with their US and European peers, Australian bank default risk still increases dramatically during the GFC when we include market asset value fluctuations as compared to the static external ratings. On a CPD basis, Australian banks fare only slightly better than the US and UK during the GFC, with all 3 of these regions showing extremely high default probabilities. Banks typically have much lower equity levels than other industries, and the combination of this and market asset value fluctuations leads to increased default probabilities.

This paper has provided a range of evidence to show that the risk of Australian banks deteriorated during the GFC, in contrast to the static external ratings. Firstly, although impaired assets are much lower than those of global peers, they nonetheless increased five-fold. Secondly, share prices have been extremely volatile, dropping 58% over the GFC period, with highly significant increases in VaR and CVaR. Thirdly, banks show highly significant increases in default probabilities on both DD and CDD measures. Fourthly, sensitisation of the Merton DD and CDD measures, through calibration to EDF, still results in extremely high default probabilities during the GFC. Fifthly, the relative default rankings of Australian banks in relation to other industries has deteriorated. Finally, CDS spreads have shown a strong increase.

This reduction in bank equity values, increase in impaired assets and provisions for bad debts, increasing credit default swap spreads, and the shift in relative default rankings of banks as compared to other industries, all support the findings of significantly increased risk based on market values. In conclusion, contrary to the low static default probabilities indicated by external credit ratings, there has been a significant increase in Australian bank default probabilities during the GFC when taking into account market asset value fluctuations.

These findings have implications for lenders to banks in assessing default probabilities and regulators in determining capital adequacy. The Basel standardised capital approach is based on external credit ratings, which sees capital requirements in respect of loans to these banks remaining static during the GFC as compared to pre-GFC. This is not consistent with the increased default probabilities shown in this paper. The findings support including an assessment of fluctuating asset values in lending and capital adequacy buffer decisions.

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Appendix 1

Table 9. *Global Bank Fluctuations*

Australian Banks		Pre-GFC		GFC		VaR/ CVaR increase (times)		Asset Value Fluctuation increase (times)	
	Market Cap USD $m	Daily VaR	Daily CVaR	Daily VaR	Daily CVaR	Daily VaR	Daily CVaR	Daily Stdev	Daily Cstdev
ANZ	54,366	0.0192	0.0261	0.0351	0.0630	1.83	2.41	2.25	2.12
COMMONWEALTH	52,468	0.0181	0.0253	0.0308	0.0516	1.71	2.03	1.69	1.47
NATIONAL AUSTRALIA	56,071	0.0205	0.0296	0.0361	0.0587	1.76	1.98	2.07	1.77
WESTPAC	68,424	0.0186	0.0252	0.0327	0.0537	1.76	2.13	2.32	1.85
SUBTOTAL MAJOR BANKS	231,330	0.0191	0.0265	0.0337	0.0566	1.76	2.14	2.10	1.80
OTHER BANKS (10)	33,097	0.0249	0.0432	0.0420	0.0717	1.69	1.66	2.16	1.54
TOTAL	264,427	0.0198	0.0286	0.0347	0.0585	1.75	2.05	2.10	1.76

Volatiliy Significance Testing: F Test:

	GFC / Pre GFC - Major Banks				Other Banks / Major Banks - Pre GFC			
	VaR	CVaR	Asset Stdev	Asset Cstdev	VaR	CVaR	Asset Stdev	Asset Cstdev
F	3.1150	4.5588	4.3903	3.2566	1.7079	2.6517	1.2873	1.6077
p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Significance	**	**	**	**	**	**	**	**

	GFC / Pre GFC - Other Banks				Other Banks / Major Banks - GFC			
	VaR	CVaR	Asset Stdev	Asset Cstdev	VaR	CVaR	Asset Stdev	Asset Cstdev
F	2.8431	2.7578	4.6680	2.3638	1.5588	1.6041	1.3687	1.1669
p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0425
Significance	**	**	**	**	**	**	**	*

Canadian Banks		Pre-GFC		GFC		VaR/ CVaR increase (times)		Asset Value Fluctuation increase (times)	
	Market Cap USD $m	Daily VaR	Daily CVaR	Daily VaR	Daily CVaR	Daily VaR	Daily CVaR	Daily Stdev	Daily Cstdev
BANK OF NOVA SCOTIA	44,523	0.0225	0.0323	0.0366	0.0561	1.63	1.74	1.92	2.26
ROYAL BANK CANADA	74,466	0.0214	0.0317	0.0380	0.0602	1.77	1.90	1.99	2.43
TORONTO-DOMINION	50,852	0.0234	0.0336	0.0362	0.0572	1.54	1.70	1.69	2.10
SUBTOTAL MAJOR BANKS	169,841	0.0223	0.0324	0.0371	0.0582	1.66	1.80	1.87	2.28
OTHER BANKS (6)	60,969	0.0228	0.0330	0.0406	0.0625	1.79	1.90	2.13	2.41
TOTAL	230,810	0.0224	0.0326	0.0380	0.0594	1.70	1.82	1.92	2.30

Volatiliy Significance Testing: F Test:

	GFC / Pre GFC - Major Banks				Other Banks / Major Banks - Pre GFC			
	VaR	CVaR	Asset Stdev	Asset Cstdev	VaR	CVaR	Asset Stdev	Asset Cstdev
F	2.7614	3.2253	3.4958	5.1972	1.0409	1.0336	2.6102	2.6706
p	<0.0001	<0.0001	<0.0001	<0.0001	0.2012	0.2448	<0.0001	<0.0001
Significance	**	**	**	**	-	-	**	**

	GFC / Pre GFC - Other Banks				Other Banks / Major Banks - GFC			
	VaR	CVaR	Asset Stdev	Asset Cstdev	VaR	CVaR	Asset Stdev	Asset Cstdev
F	3.1899	3.5935	4.5301	5.8226	1.2024	1.1516	2.0143	2.3838
p	<0.0001	<0.0001	<0.0001	<0.0001	0.0199	0.0576	<0.0001	<0.0001
Significance	**	**	**	**	*	-	**	**

Appendix 1 (continued)

European Banks

		Pre-GFC		GFC		VaR/ CVaR increase (times)		Asset Value Fluctuation increase (times)	
	Market Cap USD $m	Daily VaR	Daily CVaR	Daily VaR	Daily CVaR	Daily VaR	Daily CVaR	Daily Stdev	Daily Cstdev
BANCO SANTANDER	121,617	0.0335	0.0482	0.0430	0.0699	1.28	1.45	1.52	1.64
BARCLAYS	48,519	0.0322	0.0473	0.0651	0.1018	2.02	2.15	3.84	4.17
BNP PARIBAS	84,755	0.0313	0.0476	0.0503	0.0812	1.61	1.70	2.68	2.92
CREDIT SUISSE	76,650	0.0393	0.0620	0.0607	0.1006	1.54	1.62	2.08	2.16
HSBC	192,500	0.0241	0.0369	0.0354	0.0588	1.47	1.60	1.68	1.90
LLOYDS TSB	50,130	0.0310	0.0455	0.0617	0.0985	1.99	2.16	3.00	2.93
SOCIETE GENERALE	45,040	0.0350	0.0511	0.0575	0.0873	1.64	1.71	2.49	2.52
UBS	72,326	0.0291	0.0435	0.0658	0.1072	2.26	2.46	3.36	3.64
UNICREDIT	50,240	0.0267	0.0411	0.0544	0.0933	2.03	2.27	3.35	3.88
SUBTOTAL MAJOR BANKS	741,777	0.0303	0.0456	0.0503	0.0818	1.66	1.79	2.05	2.22
OTHER BANKS (7)	153,969	0.0340	0.0523	0.0653	0.1118	1.92	2.14	3.61	3.92
TOTAL	895,746	0.0310	0.0468	0.0529	0.0869	1.71	1.86	2.15	2.34

Volatiliy Significance Testing: F Test:

	GFC / Pre GFC - Major Banks				Other Banks / Major Banks - Pre GFC			
	VaR	CVaR	Asset Stdev	Asset Cstdev	VaR	CVaR	Asset Stdev	Asset Cstdev
F	2.7459	3.2146	4.2014	4.9261	1.2582	1.3162	8.5943	7.0611
p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Significance	**	**	**	**	**	**	**	**

	GFC / Pre GFC - Other Banks				Other Banks / Major Banks - GFC			
	VaR	CVaR	Asset Stdev	Asset Cstdev	VaR	CVaR	Asset Stdev	Asset Cstdev
F	3.6873	4.5682	13.0506	15.3323	1.6896	1.8705	2.7668	2.2686
p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Significance	**	**	**	**	**	**	**	**

US Banks

		Pre-GFC		GFC		VaR/ CVaR increase (times)		Asset Value Fluctuation increase (times)	
	Market Cap USD $m	Daily VaR	Daily CVaR	Daily VaR	Daily CVaR	Daily VaR	Daily CVaR	Daily Stdev	Daily Cstdev
BANK OF AMERICA	130,273	0.0268	0.0407	0.0778	0.1326	2.91	3.26	6.04	8.34
CITIGROUP	94,280	0.0306	0.0462	0.0895	0.1566	2.92	3.39	6.04	7.64
JP MORGAN	154,621	0.0361	0.0549	0.0666	0.1075	1.84	1.96	2.09	2.33
US BANCORP	43,062	0.0294	0.0460	0.0479	0.0756	1.63	1.64	1.95	2.09
WELLS FARGO	139,771	0.0213	0.0316	0.0648	0.1019	3.05	3.22	3.28	4.02
SUBTOTAL MAJOR BANKS	562,006	0.0288	0.0437	0.0711	0.1177	2.47	2.69	3.22	3.93
OTHER BANKS (46)	125,900	0.0241	0.0361	0.0638	0.1024	2.65	2.84	3.06	3.59
TOTAL	687,906	0.0279	0.0423	0.0698	0.1149	2.50	2.72	3.19	3.86

Volatiliy Significance Testing: F Test:

	GFC / Pre GFC - Major Banks				Other Banks / Major Banks - Pre GFC			
	VaR	CVaR	Asset Stdev	Asset Cstdev	VaR	CVaR	Asset Stdev	Asset Cstdev
F	6.0948	7.2621	10.3795	15.4100	1.4353	1.4624	1.3362	1.1596
p	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0010
Significance	**	**	**	**	**	**	**	**

	GFC / Pre GFC - Other Banks				Other Banks / Major Banks - GFC			
	VaR	CVaR	Asset Stdev	Asset Cstdev	VaR	CVaR	Asset Stdev	Asset Cstdev
F	7.0377	8.0475	9.3722	12.8910	1.2430	1.3197	1.2066	1.0308
p	<0.0001	<0.0001	<0.0001	<0.0001	0.0076	0.0010	0.0181	0.3673
Significance	**	**	**	**	**	**	*	-

VaR is calculated on a parametric basis, whereby the standard deviation of daily returns is multiplied by 1.645 (being 95% confidence level based on a normal distribution). Annual VaR can be obtained by multiplying Daily VaR by the square root of 250. Figures are undiversified and represent the weighted average of the individual bank VaRs. CVaR is calculated as the average of the worst 5% of actual returns (those beyond the 95% VaR). The pre-GFC category calculates daily VaR for the 2 year window including data from 2007 and 2008. The GFC category calculates daily VaR for the 7 year period from 2000-2006. Major banks for the purposes of this table are defined as all banks with market capitalization exceeding USD $40billion. The four columns on the right of the table show the increases (GFC as compared to pre-GFC) in VaR, CVaR Asset Stdev and Asset CStdev. Market asset value of returns is (Stdev) calculated as the standard deviation of all asset returns for the period, whereas CStdev is based on the worst 5% of asset returns. F testing is undertaken to test for variance in volatility. F is $\sigma21/ \sigma22$, where $\sigma1$ and $\sigma2$ are the standard deviations of returns for the two samples being compared. An F value of 1 shows no difference between the samples and a value of 3 shows variance of 3x higher in the one sample as compared to the other. * denotes significance at the 95% level and ** at the 99% level.