



Queensland University of Technology

**DISCUSSION PAPERS IN ECONOMICS, FINANCE AND  
INTERNATIONAL COMPETITIVENESS**

**Time-Varying Market, Interest Rate and Exchange Rate  
Risk in Australian Bank Portfolio Stock Returns:  
A Garch-M Approach**

**Susan Ryan and Andrew C. Worthington**

***Discussion Paper No. 112, June 2002***

**Series edited by  
Dr Andrew Worthington**

ISSN 1324-5910

**All correspondence to:**

Dr Andrew Worthington  
Editor, *Discussion Papers in Economic, Finance and International  
Competitiveness*  
School of Economics and Finance  
Queensland University of Technology  
GPO Box 2434, BRISBANE QLD 4001, [Australia](#)

Telephone: 61 7 3864 2658  
Facsimilie: 61 7 3864 1500  
Email: [a.worthington@qut.edu.au](mailto:a.worthington@qut.edu.au)

---

**School of Economics and Finance**

# TIME-VARYING MARKET, INTEREST RATE AND EXCHANGE RATE RISK IN AUSTRALIAN BANK PORTFOLIO STOCK RETURNS: A GARCH-M APPROACH

Suzanne K. Ryan & Andrew C. Worthington

*School of Economics and Finance, Queensland University of Technology*

---

## ABSTRACT

This study employs an extended version of the Generalised Autoregressive Conditional Heteroskedasticity in Mean (GARCH-M) model to consider the time-series sensitivity of Australian bank stock returns to market, interest rate and foreign exchange rate risks. Daily Australian bank portfolio returns, a market wide accumulation index, short, medium and long-term interest rates, and a trade-weighted foreign exchange index are used to model these risks over the period 1996 to 2001. The results suggest that market risk is an important determinant of bank stock returns, along with short and medium term interest rate levels and their volatility. However, long-term interest rates and the foreign exchange rate do not appear to be significant to the Australian bank return generating process over the period considered.

*JEL classification:* C32; C52; G12; G21

*Keywords:* Bank stock returns; GARCH; market risk; interest rate risk; foreign exchange risk

---

## 1. INTRODUCTION

Once the institutional core of a national financial system, the Australian banking sector now lies enmeshed in the evolutionary process shaping the Australian, and more generally, global financial system (Hoenig, 2000). With stringent regulation in the immediate post-WWII era, Australian bank activity primarily revolved around a 'traditional' product mix of domestic borrowing and lending and was generally viewed as a 'low-risk proposition' with minimal credit, interest rate and foreign exchange rate risks (Edey and Gray, 1996; Faff and Howard, 1999). However, financial deregulation in the 1980s saw the removal of restrictive controls on banks' loan and deposit portfolios, interest rates and investment activities alongside the broader program of microeconomic reform and the introduction of flexible exchange rates. In response, banking in Australia has fundamentally changed as banks have sought to manage changes in the level and volatility of the core market, interest rate and foreign exchange rate risks. Duration gaps have shortened, loans securitised, off-balance sheet activities increased and derivative positions expanded as banks have expanded their range and pricing of financial products, both domestically and internationally, during a period of unprecedented global financial activity.

Unfortunately, and despite the clear importance of an understanding of operational risk in the banking sector, very little empirical evidence is found concerning the Australian institutional milieu. Indeed, most existing literature has an overwhelming North American focus. A comparison with international studies highlights this deficiency. Madura and Zarruk (1995), Adjaoud and Rahman (1996), Prasad and Rajan (1995), Choi, *et al.* (1998) and Chamberlain, *et al.* (1997), for example, have examined the joint interaction of market, interest rate and foreign exchange rate risks in US financial institutions. No comparable Australian study exists. Similarly, despite the proliferation of international work concerning interest rate risk in banks [see, for instance, Kane and Unal (1988), Akella and Chen (1990), Brewer and Lee (1990), Kwan (1991), Madura and Zarruk (1995), Adjaoud and Rahman (1996), Flannery, *et al.* (1997) and Elyasiani and Mansur (1998)] a single study by Faff and Howard (1999) constitutes Australian endeavours in this area.

Just as importantly, the foreign exchange rate risk of Australian banks is, as yet, unquantified, and while market risk in banking has already attracted some attention in the Australian context [see, for instance, Brooks and Faff (1995, 1997); Brooks, *et al.* (1997b, 1998); Lie, *et al.* (2000)] most of these studies are concerned with the

period before the mid-1990s. Finally, most of the existing research on the nature of Australian banking risk ignores the sizeable advances made in the autoregressive conditional heteroskedastic (ARCH) family of techniques to model the effect of these three risks and their volatility on the bank stock return generation process. Though these frameworks discard the restrictive assumptions of linearity, independence, and constant conditional variance they are nonetheless frequently overlooked in the banking literature. Accordingly, the purpose of the present paper is to jointly quantify market, interest rate and foreign exchange rate risks in Australian banking using advanced time-series techniques.

The paper itself is divided into five main areas. The first section briefly surveys the empirical literature concerning market, interest rate and foreign exchange rate risk in banking. The second section explains the methodology employed in the analysis and the requisite data is discussed in the third section. The results are dealt with in the fourth section. The paper ends with some brief concluding remarks.

## 2. LITERATURE REVIEW

### 2.1 Market risk

A not inconsiderable amount of work has already focused on CAPM's empirical counterpart in the form of the 'market model'. The market model hypothesizes that the return on any asset (including banking stocks) is determined by the systematic risk of that asset relative to the market, and that to the extent that bank stock returns move relative to the market, some indication of market risk may be obtained. Most early work using single and dual-index models (primarily market and interest rate factors) and an assumption of constant variance error terms concluded that while market risk did not explain all variation in bank returns [see, for example, Rosenberg and Perry (1981) and Unal (1989)] it nonetheless explained a higher proportion of returns even when other risk factors were considered [see, for instance, Lyngne and Zumwalt (1980) and Song (1994)]. Subsequent work in a variety of institutional milieus, including Australia, has confirmed the positive association between bank (or other financial institution) stock returns and the return on the market [see, for instance, work in Australia by Hogan and Sharpe (1984); Brooks and Faff (1995); Brooks, *et al.* (1997b)].

At the same time, an increasing part of this broader literature has addressed the impact of deregulation on financial institution risk over time (Hoenig, 2000). In the United States this includes studies by Izan (1985), Aharony, *et al.* (1986, 1988), Allen and Wilhelm (1988), Unal (1989) and Bundt, *et al.* (1992). These and other studies have generally tested for structural shifts in the data associated with regulation, and then considered the magnitude of market risk (as measured by beta) to determine whether bank risk relative to the market had increased or decreased. Results have been mixed. For example, Aharony, *et al.* (1988) found that systematic risk in banking declined as a result of deregulation, whilst Bundt, *et al.* (1992) concluded otherwise. More recently, the models used for testing stability in bank market risk have increased in complexity. In particular, recent work has centered on the time-varying properties of banks' responsiveness to market risks by allowing beta to change continuously over time (Brooks, *et al.*, 1997a) [see also Brooks, *et al.*, (2000) and McKenzie, *et al.* (2000b)].

Within the Australian banking sector work by Hogan and Sharpe (1984) and Harper and Scheit (1992) found an inverse relationship between the severity of regulatory controls and systematic risk; that is, bank sensitivity to market risk increased with deregulation. Similarly to US studies at the time, Hogan and Sharpe's (1984) and Harper and Scheit's (1992) use of the conventional market model assumed that bank responsiveness to market returns did not fluctuate continuously over time. With increasing evidence concerning continuous time stock variation drawn from literature outside the financial sector, Brooks and Faff (1995) first considered bank instability in market risk within a continuous parameter variation approach. Surmising that deregulation may have caused the relative risk of the banking sector to alter, Brooks and Faff (1995: 5) highlighted "[the] effect of beta being time varying on the market model is to alter the properties of the disturbance term" and argued that if market risk is time dependent, the conventional least squares market model may not efficiently estimate systematic risk. Sampling the period 1974-1992 and using adjusted monthly continuously compounded returns on three individual banks and a bank portfolio, Brooks and Faff (1995) found that deregulation did not add to overall bank risk. On the contrary, Brooks and Faff (1995) concluded that deregulation appeared to produce a degree of stability in bank betas that had not previously existed in the regulated environment. Brooks and Faff (1997) arrived at a similar inference.

A later Australian study by Brooks, *et al.* (1997b) extended this work through application of the multivariate Generalised Autoregressive Conditional Heteroskedasticity (MGARCH) model first introduced by Bollerslev (1990). Upon estimation of the time-varying conditional betas for individual banks and the industry comparison was made with the beta estimates from the market model in order to show that the later discarded important information about the variability of bank betas that conditional betas captured. Brooks, *et al.* (1997b: 89) found that whilst "...the two estimation techniques provide similar parameterizations of risk" the conditional beta estimates indicated that there was considerable variability in market risk within the sample period chosen. Brooks, *et al.* (1997b: 85) concluded, "...where one is willing to make the assumption that market based risk is constant through time, the market model can be applied. In contrast, if a researcher believes that beta risk is truly time-varying, there is a need to estimate the time-varying conditional beta".

Taking as given the time-varying properties of market risk in the banking sector, Brooks, *et al.* (1998) completed the first Australian comparison between the chief modelling techniques used to estimate conditional market risk betas. These included the MGARCH technique, the Kalman filter approach and the Schwert and Seguin (1990) model. Brooks, *et al.* (1998) found that from 1974 to 1996 the conditional time dependant market betas of Australian banking portfolios were most accurately modelled using a Kalman filter approach, although the MGARCH model also performed reasonably well. Several Australian studies followed. To start with, Lie, *et al.* (2000) extended Brooks, *et al.* (1997b) by considering a wider range of Australian financial sector stocks, using daily as opposed to monthly data, and incorporating both a GARCH and Kalman filter approach. Lie, *et al.* (2000) preferred the Kalman filter approach. This conclusion was consistent with the findings of Brooks, *et al.* (1998), as was the finding of time-dependence up until 1998. On the other hand, McKenzie, *et al.* (2000a) extended the literature by considering whether the time-varying betas of Australian stocks ought to be estimated using a national or world market index. McKenzie, *et al.* (2000a) found that a domestic index was preferred for all industries, not the least the banking sector.

## 2.2 Interest rate risk

Following the inability of the simple market model to fully explain bank stock returns, early work by King (1966) and Stone (1974), amongst others, proposed an extension whereby the return on the asset would be determined by both the systematic risk of the market portfolio and a bond portfolio. Put differently, interest rate risk was assumed to be an additional and pertinent explanatory factor in explaining bank stock returns. Though Merton's (1973) Intertemporal CAPM and Ross's (1976) Arbitrage Pricing Theory also included an interest rate factor, most succeeding work on bank interest rate sensitivity has adhered to Stone's (1974) two-factor model of returns [see, for instance, Kane and Unal (1988), Song (1994), Choi, *et al.* (1992), Neuberger (1991), Elyasiani and Mansur (1998)]

The first study to find evidence in favour of Stone (1974) was Lloyd and Shick (1977). Focusing on sixty commercial banks, Lloyd and Shick (1977) concluded that unadjusted monthly individual bank returns were negatively related to long-term interest rates from 1969 to 1972. However, Lloyd and Shick (1977) themselves, and later Chance (1979) and Gultekin and Rogalski (1979) argued that deficiencies concerning their [Lloyd and Shick's (1977)] data, statistical tests, and interpretation of the results left open the veracity of these findings. At the same time, Martin and Keown (1977: 189) found a common group factor that impacted particularly on financial institution returns, which "...possibly related to interest rate sensitivity" (emphasis added). Lyngne and Zumwalt (1980) subsequently specified Stone's (1974) model with both short and long-term interest rates. Lyngne and Zumwalt (1980) found that irrespective of the bond index used, the interest rate sensitivity of banks was greater than that measured by Lloyd and Shick (1977). On this basis, Lyngne and Zumwalt (1980) concluded that the two different interest rate maturities considered had independent affects on the bank return generating process and thus, as suggested by Stone (1974) the bond index actually represented a wide spectrum of bond maturities. One additional finding by Lyngne and Zumwalt (1980) was that interest rate sensitivity in the period 1969-1975 had increased relative to the original period 1969 to 1972 and that bank sensitivity to movements in the long-term interest rate had a magnitude of 74 percent whilst responsiveness to the short-term interest rate was 61 percent. Both these figures were markedly higher than the 26 percent found by Lloyd and Shick (1977) over the shorter sample period and were attributed to the highly volatile interest rate environment after 1972 (Lyngne and Zumwalt, 1980).

A similar approach considering the period from 1972 to 1976 was used by Chance and Lane (1980), though with adjusted equity returns, a larger sample and short, intermediate and long term interest rate changes. Unlike Lyngne and Zumwalt (1980) Chance and Lane (1980) found that bank monthly returns were not significantly sensitive to interest rates. Moreover, bank stocks were found to exhibit less interest rate sensitivity than the market as a whole. A feature of the work by Chance and Lane (1980) was the use of an unbiased estimator for

interest rate sensitivity by eliminating the correlation between the bond and equity indices through orthogonalisation. In performing orthogonalisation the estimates for the bond and equity index resulted in an unbiased coefficient for the interest rate risk, as compared with the orthogonalising ‘misspecification’ inherent in the procedure utilised by Lyngne and Zumwalt (1980) (Giliberto, 1985; Booth and Officer, 1985). Unfortunately, the procedure potentially introduced a misspecification that biased some, but not all, of the coefficient estimates (Giliberto, 1985; Kane and Unal, 1988).

A later Australian study by Booth and Officer (1985) concluded that bank returns did indeed respond to interest rates over an equivalent sample period. Booth and Officer (1985) also found that sensitivity has also increased over the more volatile interest rate period from 1972 to 1976. Booth and Officer (1985) concluded for their sample of sixty-six banks that the monthly returns were sensitive to short-term interest rate changes from 1966 to 1980. However, and in marked contrast to Chance and Lane (1980), Booth and Officer (1985) also concluded that bank returns were more sensitive than the market as a whole to changes in interest rates.

Further indirect support for the notion that bank equity values respond to interest rate movements derived from the work of Flannery and James (1982, 1984a, 1984b). Flannery and James (1982, 1984a, 1984b) provided the first empirical evidence that maturity mismatch between banks’ nominal assets and liabilities explained cross-sectional variation in bank interest rate sensitivity, and therefore that, the nominal contracting hypothesis was applicable in the banking context. This conclusion is consistent with subsequent work by Akella and Greenbaum (1992) on duration mismatch. More importantly, in the process of verifying the nominal contracting hypothesis, Flannery and James (1982, 1984a, 1984b) provided evidence that from 1976 to 1981 the adjusted weekly returns for 67 US commercial banks and saving and loan (S&L) associations were sensitive to unanticipated interest rates, where the unanticipated component of interest rates was proxied by the residuals from an autoregressive model of the interest rate series. Interestingly, Flannery and James’s (1982, 1984a, 1984b) conclusion was robust irrespective of whether the interest rate index was proxied by holding period returns on short-term interest rates, or with the percentage changes on long-term interest rates. Although Flannery and James (1982, 1984a, 1984b) utilised Lyngne and Zumwalt’s (1980) orthogonalising misspecification, later tests by Scott and Petersen (1986) suggested that use of Chance and Lane’s (1980) ‘unbiased estimator’ technique actually produced similar results [see also Mitchell (1989)].

Work by Unal and Kane (1988) further examined the issue of interest rate risk. Using the period from 1975 to 1985, Unal and Kane (1988) found that portfolio returns on large, medium and small commercial banks and saving and loan associations were significantly related to long-term interest rates, though not to short-term rates. They concluded that these results were robust “...irrespective of whether interest rates [were] proxied by errors from autoregressive forecasts or by components orthogonal to [the market index]” (Kane and Unal, 1988: 209). Unal and Kane (1988) also concluded that interest rate sensitivity varied across time. Building on this work, Kane and Unal (1988) used a slight variation in banking class classification (money centre, super regional and regional), to show that the results of earlier studies differed due to the different sample periods examined. Kane and Unal (1988) also corrected one of the arguable limitations of Unal and Kane (1988) such that interest rate sensitivities were assumed to vary in continuous time, not just at structural break points. Using Goldfeld and Quandt’s (1972, 1973, 1976) Switching Regression Method (GQSRM) to identify this nonstationarity or time-varying property interest rate sensitivity was found to be significant only during volatile interest rate periods. Thus, interest rate sensitivity was found to vary across both time and across different types and sizes of banks.

In a similar manner, Akella and Chen (1990) adopted a dummy variable approach to investigate temporal change in interest rate sensitivity of US banks from 1974 to 1984. Similar findings to Unal and Kane (1988) resulted, with quarterly bank returns sensitive to long term interest rates and innovations in interest rates irrespective of the orthogonalising procedure adopted. The results were found to be sample period dependent and declining through time and Akella and Chen (1990) concluded that the magnitude of results were also dependent on model specification. Concurrently, Brewer and Lee (1990) found that daily bank returns from 1978 to 1984 were sensitive to unanticipated, unorthogonalised changes on medium term interest rate yields. Neuberger (1991) also provided evidence of declining interest rate sensitivity over the 1979 to 1990 period, with complete statistical insignificance found for the 1988 to 1990 sub-period, a lack of substantial differences or error in results from either type of orthogonalising procedure and differing results based on bank size (with minimal sensitivity recorded for small banks across all periods). A large body of work confirmed these early findings that financial institution returns are generally more sensitive to interest rates with longer maturities, that interest rate sensitivity has declined over time and that ignoring the time-varying data properties of bank returns may result in biased or inefficient estimates of interest rate sensitivity [see, for example, Saunders and Yourougou (1990) and Yourougou (1990), Kwan (1991), Choi *et al.* (1992), Hirtle (1997), Flannery, *et al.* (1997)].

In an attempt to improve the 'ad hoc' nature of the time-varying models used by Kane and Unal (1988) and others, Song (1994) provided the first application of Autoregressive Conditional Heteroskedasticity (ARCH) type modelling to bank stock returns. Using comparable data to Kane and Unal (1988), Song (1994) classified banks into money centre and regional portfolios along with savings and loan (S&L) associations. Song (1994) concluded that during the period 1976-1987 banks were found to be sensitive to holding period returns on long-term interest rates and that both categories of banks and the S&Ls displayed similar interest rate risks, though these were generally less volatile than overall market risk. Bearing in mind the similarity in results to that obtained by Kane and Unal (1988), Song (1994: 325) suggested that while a comparison between his approach and that employed in Kane and Unal (1988) was difficult, the ARCH technique was superior as it allowed the identification of "...the dynamic pattern of the market and interest rate risks" with graphical plots giving "...visual evidence of changing risks in the banking industry".

Elyasiani and Mansur (1998) also used ARCH methodology to aid their investigation into interest rate risk in banking in the form of Engle's *et al.* (1987) Generalised ARCH in the Mean (GARCH-M) model. Elyasiani and Mansur (1998) pointed out that the fundamental attraction of the 'in mean' extension is its ability to capture the dynamic pattern of changing risk premium over time, whilst portraying the trade-off between expected return and volatility and therefore is arguably a better *ex post* statistical approximation of the orthodox *ex ante* asset pricing theories. Extending earlier work suggestive of the pertinent role that interest rate volatility played in the bank return generating process [see for example, Lyngne and Zumwalt (1980); Booth and Officer (1985); Kane and Unal (1988); Flannery, *et al.* (1997)], Elyasiani and Mansur (1998) considered both the effects of long term interest rates and its volatility on monthly US bank stock returns, compiled into three distinct portfolios (money centre, large and regional banks) over the period from 1970 to 1992. Consistent with the earlier empirical literature, Elyasiani and Mansur (1998) found that long-term interest rates had a significantly negative impact on bank returns. Further, interest rate volatility, as measured by the conditional variance of the long term interest rate was similarly found to be an important determinant of both bank return volatility and bank risk premium for money centre and large banks, though not the regional bank portfolio.

Only recently has the analysis of bank interest rate attracted empirical attention outside the United States. For example, Madura and Zarruk (1995) compared banks in Canada, Germany, Japan, the United Kingdom and the United States, and found evidence that non-US banks have greater interest rate sensitivity than their US counterparts. Later work by Adjaoud and Rahman (1996) and Dinienis and Staikouras (1998) provided complementary evidence of interest rate sensitivity in the Canadian and UK markets, respectively. In Australia, Faff and Howard (1999) focused on the period 1978-1992 to examine interest rate risk in four broad categories; namely, an aggregate banking and finance industry portfolio, large banks portfolio, small banks portfolio, and a finance companies portfolio. The sample period was divided into a pre-deregulation, deregulation and post-deregulation period, in the face of Kane and Unal's (1988) warning about arbitrary assignment of sub-periods. In line with findings in the United States, large banks, and less importantly finance companies, were found to be sensitive to interest rates, with responsiveness varying across sub-periods and particularly for long-term interest rates. Interestingly no sensitivity was recorded for the post-deregulation period. Faff and Howard (1999: 99) suggested that this declining interest rate sensitivity is attributable to the development of "...better systems for measuring and managing interest rate risk".

### 2.3 Foreign exchange rate risk

The emergence of flexible exchange rate systems along with internationalisation of banking activities has seen the sensitivity of financial institution stock returns to foreign exchange rates risk also attract some empirical attention (Choi, *et al.*, 1992; Chamberlain, *et al.*, 1997). As with the early work on interest rate risk, approaches in this area have concentrated on augmenting the simple market model with a second factor for exchange rate risk. Aharony, *et al.* (1985) and Grammatikos, *et al.* (1986) were among the first to explore this possibility, encompassing their respective studies of bank returns within the broader question of corporate foreign exchange exposure [see also Adler and Dumas (1984), Flood and Lessard (1986), Choi (1986) and Eun and Resnick (1988)]. Aharony, *et al.* (1985) and Grammatikos, *et al.* (1986) concluded that movements in the foreign exchange rate had a statistically significant impact on banks' return generating process.

More recently, Choi, *et al.* (1992) considered the joint interaction of market, interest rate and foreign exchange rates on US bank stock returns. Using a multi-factor model with the inclusion of a third variable proxying foreign exchange risk, Choi, *et al.* (1992) found that the monthly return on 48 US banks was sensitive to the percentage change on a short-term interest rate index and a trade-weighted multilateral foreign exchange index during the period 1975-1987. Choi *et al.* (1992) found that there were some differences in foreign exchange rate sensitivity through time and across bank type, and that foreign exchange rate exposure is tied to unhedged

foreign loan exposure. Wetmore and Brick (1994) later used a similar model to extend Choi's, *et al.* (1992) work by providing the first evidence that foreign exchange exposure was indeed tied to unhedged foreign loan exposure. They concluded that foreign exchange rate risk was positively and significantly related to foreign or less developed country loan exposure and negatively and significantly related to off-balance sheet exposure.

Additional findings from Wetmore and Brick (1994) resulted from their consideration of three distinct sample periods. While little foreign exchange rate sensitivity was recorded pre-crash, after October 1987 Wetmore and Brick (1994) found that changes in the foreign exchange rate had a significant impact on bank stock returns, although the magnitude of the effect was not large until the end of 1989. With respect to the interest rates considered, pre-October 1987 interest rate sensitivity was significant regardless of the index used, however after this period no interest rate sensitivity was recorded. Wetmore and Brick (1994) thus found that estimates of risk differ across bank type and period and as interest rate risk declined, foreign exchange risk appeared to be increase. On this basis, Wetmore and Brick (1994: 594) concluded, "...the market continues to reflect changes in the economic and regulatory situation of commercial banks in the pricing of bank stocks". In related work, Chaudhry, *et al.* (2000) provided indirect support for bank interest and foreign exchange rate sensitivity in their attempt to link market-based risk measures of risk to the foreign currency contingency claims activities of commercial banks.

More recent empirical work in the US literature has attempted to incorporate the time-varying properties of foreign exchange rate risk. Tai (2000), for example, applied three different econometric techniques to the consideration of whether foreign exchange rate risk is priced in the US market. From the nonlinear seemingly unrelated regression (SUR), multivariate GARCH in mean (MGARCH-M), and 'price kernel' approaches used, the MGARCH-M model produced "...strong evidence of time-varying interest rate risk and exchange rate risk" (Tai, 2000: 397). Recent empirical attention has also extended to a consideration of foreign exchange risk, in the absence of interest rate risk, outside the US market. Prasad and Rajan (1995) found that foreign exchange risk is priced in the US, Japanese and UK stock markets and Choi, *et al.* (1998) concluded that foreign exchange risk is priced in the Japanese stock market on the basis of a conditional multi-factor asset pricing model. Chamberlain, *et al.* (1997) also considered the exchange rate sensitivity of the equity returns of US and Japanese banks. They found that a significant fraction of US banks in the sample were foreign exchange rate sensitive, unlike the Japanese banks. These differences in US and Japanese bank responsiveness to foreign exchange rate movements highlighted the fact that potential differences in the foreign exchange rate sensitivity existed across countries.

### 3. MODEL SPECIFICATION

Most research into market, interest rate and foreign exchange rate risk in banking has been undertaken using single or multi-factor least squares regression whereby the parameter estimates provide an indication of risk sensitivity. Examples of two-factor models, largely concerned with market and interest rate risk, include Chance and Lane (1980), Lyngne and Zumwalt (1980), Flannery and James (1982, 1984a, 1984b), Booth and Officer (1985), Kane and Unal (1988), Unal and Kane (1988), Chen and Chan (1989), Akella and Chen (1990), Brewer and Lee (1990), Madura and Zurruck (1995), and Adjaoud and Rahman (1996). Alternatively, Choi, *et al.* (1992) and Wetmore and Brick (1994) have employed a three-factor approach to model market, interest rate and foreign exchange rate risk simultaneously.

However, recent empirical evidence suggests that bank sensitivities to market, interest rate and foreign exchange rate risk are time varying. For example, Unal and Kane (1988), Kane and Unal (1988), Akella and Chen (1990), Brewer and Lee (1990), Neuberger (1991) and Kwan (1991) have established the time varying properties of interest rate risk. Likewise, Choi, *et al.* (1992), Wetmore and Brick (1994), and Tai (2000) have found that financial institution responsiveness to foreign exchange rates is also time-dependent. And Song (1994), Brooks, *et al.* (1997a, 1998), Brooks, *et al.* (2000), McKenzie, *et al.* (2000b), Brooks and Faff (1995) document the time-varying sensitivities of market returns in banking stocks. Accordingly, if the bank returns generating process is time-dependent use of least squares techniques may result in biased and inconsistent parameters.

To address the problem of time-varying parameters, some of the more recent empirical work on interest rate risk uses dummy variables to indicate structural shifts in the data [see, for example, Akella and Chen (1990); Brewer and Lee (1990); Neuberger (1991)]. However because the potential break points are somewhat arbitrarily assigned, this approach has been criticised [see, for instance, Kane and Unal (1988)]. As an alternative, Kane and Unal (1988) adopt Goldfeld and Quandt's (1972, 1973, 1976) Switching Regression Method (GQSRM) to statistically assign possible structural break points, while Kwan (1991) uses the Random Coefficient Framework. However, both Kane and Unal's (1988) and Kwan's (1991) choice of model has also been described as *ad hoc* due to the lack of an appropriate theoretical or empirical basis (Song, 1994). As a result of these criticisms,

Engle's (1982) Autoregressive Conditional Heteroskedasticity (ARCH) technique and its various permutations have recently and more collectively found favour in the literature. For example, Song (1994) applies a univariate two-factor ARCH model to the question of bank sensitivity to market and interest rate risk. Similarly, Elyasiani and Mansur (1998) adopt an extension of Bollerslev's (1986) Generalised Autoregressive Conditional Heteroskedasticity (GARCH) in mean model (GARCH-M) to consider the affects of interest rate levels and volatility on bank shares.

The GARCH-M model used in this paper is considered appropriate for several reasons. First, a univariate model is preferred over the multivariate case for reasons of simplicity and the fact that the multivariate specification models volatility feedback from the dependent variable to the independent variables, in addition to volatility interactions between individual exogenous variables and from these to the dependent variable. It could be argued that while the volatility in the bank portfolio may arguably feedback into the market portfolio if the banks in the index are sufficiently represented in the market index, there appears to be no adequate rationale for why bank portfolio volatility may feedback into foreign exchange rate volatility or even interest rate volatility. Thus, the additional modelling inherent in the multivariate models is deemed unnecessary and inappropriate in this case where there is a definite hypothesises as to the order of the affect between bank returns and the selected variables, that is, bank returns are determined by market, interest and foreign exchange risk, without any feedback from the bank index to these variables.

Second, there is a preference in the literature for GARCH over ARCH techniques for reasons of parsimony. That is, analogous to the infinite order autoregressive process approximating the first order moving average process and thus the MA(1) specification being the most parsimonious, higher order ARCH processes may be more parsimoniously represented by GARCH(1,1) models (McKenzie and Brooks, 2000). Third, the 'in mean' extension of the GARCH model allows the effect of bank volatility to be incorporated as a determinant of bank return. For example, Elyasiani and Mansur (1998: 542) argue that return volatility "...is especially important in banking because in this industry the high leverage ratio and the prevalence of the contagion effect makes investors more sensitive to changes in volatility than in the case for non-financial firms". Lastly, the GARCH-M model is also favoured over a simple GARCH model because the GARCH-M model is a generalisation of the GARCH, ARCH and constant variance specifications. That is, it nests these models as special cases and allows a test of their validity, rather than arbitrarily assuming that they are invalid (Elyasiani and Mansur, 1998: 542).

The general form of the GARCH( $p,q$ )-M model is described by the following system of equations:

$$y_t = \mathbf{f}x_t + \mathbf{g}h_t + \mathbf{e}_t \quad (1)$$

$$h_t = \mathbf{a}_0 + \sum_{i=1}^p \mathbf{a}_i \mathbf{e}_{t-i}^2 + \sum_{i=1}^q \mathbf{b}_i h_{t-i} \quad (2)$$

$$\mathbf{e}_t | \Omega_{t-1} \sim N(0, h_t) \quad (3)$$

where the mean equation, (1), shows that the excess return or risk premium at time  $t$  ( $y_t$ ) is a function of an exogenous vector of variables at time  $t$  ( $x_t$ ), the conditional variance of  $y_t$  at time  $t$  ( $h_t$ ) and some random error ( $\mathbf{e}_t$ ) distributed as indicated in (3) with zero mean and conditional variance of  $h_t$ , with the parameter  $\mathbf{f}$  representing the sensitivity of excess returns ( $y_t$ ) to the independent variable(s) ( $x_t$ ) and parameter  $\mathbf{g}$  indicating the sensitivity of  $y_t$  to its own conditional variance, or risk ( $h_t$ ). The variance equation in (2) shows that the conditional variance ( $h_t$ ) is linearly dependent on the past behaviour of the squared error terms ( $\mathbf{e}_{t-i}^2$ ) and a moving average of its own past conditional variance ( $h_{t-i}$ ), where  $\mathbf{a}_0$  is a parameter representing the time-invariant component of the risk or variance, and  $\mathbf{a}_i$  and  $\mathbf{b}_i$  are the time-dependent components of risk, generally termed the ARCH and GARCH parameters, respectively. The ARCH parameter ( $\mathbf{a}_i$ ) represents the sensitivity of the conditional variance to the past values of the squared error whilst the GARCH parameter ( $\mathbf{b}_i$ ) measures variance responsiveness to its own past behaviour. Importantly, use of the squared error term in ARCH models implies that if innovations have been large in absolute value, they are also likely to be large in the future (Elyasiani and Mansur, 1998). To ensure a well-defined process, all parameters in the variance equation, (2) must be non-negative such that  $\mathbf{a}_0, \mathbf{a}_i$  and  $\mathbf{b}_i > 0$ , whilst the sum of time-dependent components of risk,  $\mathbf{a}_i$  and  $\mathbf{b}_i$ , must be less than 1 such that  $\mathbf{a}_i + \mathbf{b}_i < 1$ .

As indicated, one of the advantages of the GARCH-M specification is that it allows a test of the more restrictive models of GARCH, ARCH-M, ARCH and constant variance specifications. Specifically, in the event that  $\gamma$  in

(1) is zero, that is, volatility does not significantly affect the excess return, the model reduces to the general GARCH form. Where the past variance in (2)  $\beta_i$  is zero the model reduces to an ARCH-M specification, whilst statistical insignificance from zero for both the volatility ( $\gamma$ ) and past variance ( $\beta_i$ ) means that the model collapses to an ARCH model. Lastly, in the event that volatility ( $\gamma$ ), and both time-dependent components of risk ( $\alpha_i$  and  $\beta_i$ ) are zero the model converts to the usual constant variance case, where the return generating process is time-invariant.

It becomes apparent that the common feature of ARCH and GARCH techniques is that the conditional variance ( $h_t$ ) is specified as a function of the past shocks thus allowing volatility to evolve over time and permitting volatility shocks to persist. That is, ARCH techniques allow for a non-constant error variance where shocks in that variance may persist and have a continuing effect on the return generating process. Put differently, ARCH techniques allow for non-stationarity in the relationship between the dependent and independent variables as this manifests in a non-constant error variance. The distinction between ARCH and GARCH techniques more specifically lies in the fact that ARCH techniques allow for a limited number of lags in deriving the conditional variance, and as such they are considered to be short term memory models. On the other hand, GARCH models allow all lags to exert an influence and thereby constitute long term memory models. Subsequently, specification of a form of GARCH model in this study means that shocks to volatility are expected to continue to impact bank returns for a relatively long period, as compared with the short-term ARCH case.

In order to incorporate the various hypotheses under consideration in the present study and consistent with the work of Elyasiani and Mansur (1998), a modified version of the GARCH( $p,q$ )-M model is used. The form of the modified GARCH(1,1)-M model adopted extends the work of Elyasiani and Mansur (1998) and can be described by a system of three equations:

$$R_{j,t} = b_0 + \sum_{i=1}^n b_1 R_{j,t-i} + b_m R_{m,t-1} + b_r R_{r,t-1} + b_e R_{e,t-1} + \log(\mathbf{g}h_{it}) + \mathbf{e}_{j,t} \quad (4)$$

$$h_{it} = \mathbf{a}_0 + \mathbf{a}_1 \mathbf{e}_{i,t-1}^2 + \mathbf{b}h_{i,t-1} + \mathbf{d}CV_{t-1} \quad (5)$$

$$\mathbf{e}_{i,t-1} | \Omega_{t-1} \sim N(0, h_t) \quad (6)$$

where the variables in the mean equation, (4), are as follows:  $R_{j,t}$  is the return on the bank stock portfolio  $j$  at time  $t$ ,  $R_{m,t-1}$  is the return on the market at time  $t-1$ ,  $R_{r,t-1}$  is the return at time  $t-1$  on the interest rate index,  $R_{e,t-1}$  is the return on the foreign exchange rate index at  $t-1$ ,  $h_t$  measures the stock return volatility or risk of bank portfolio  $j$  at time  $t$ , and  $\mathbf{e}_{j,t}$  is the error term which is normally distributed with zero mean and a variance of  $h_t$ , as described by Equation (6). The sensitivity of bank portfolio  $j$  at  $t$  to the market return, interest rates and the foreign exchange rate at time  $t-1$  are measured by the parameters  $b_m$ ,  $b_r$  and  $b_e$ , respectively, responsiveness to volatility at  $t-1$  is measure by parameter  $\gamma$ , and  $b_0$  is the usual constant term. The conditional variance  $h_t$  follows the process described in (5) and is determined by the past squared error terms ( $\mathbf{e}_{t-1}^2$ ) and past behaviour of the variance ( $h_{t-1}$ ), or the usual GARCH process, in addition to conditional interest rate volatility at  $t-1$  ( $CV_{t-1}$ ),  $\mathbf{a}_0$  is the time-invariant component of risk,  $\mathbf{a}_1$  is the ARCH parameter,  $\mathbf{b}$  is the GARCH parameters and the parameter  $\mathbf{d}$  represents sensitivity to the conditional variance of the interest rate index,  $R_r$ . As in the general ( $p,q$ )-M case, robustness of the model depends on the non-negativity of the variance parameters,  $\mathbf{a}_0$ ,  $\mathbf{a}_1$  and  $\mathbf{b}$ , and the sum of the ARCH and GARCH parameters being less than unity ( $\mathbf{a}_1 + \mathbf{b} < 1$ ).

With respect to the mean equation in (4) several points are noted. First, unlike the general GARCH-M model outlined earlier, excess bank returns have not been used. This decision derives from the fact that in the context of work relating to the market model it has been argued that in the absence of an intention to simultaneously test the *ex ante* CAPM, there is no real reason to depart from the use of raw returns, in favour of excess returns, particularly when "[in] Australia, there is difficulty in obtaining a suitable proxy" for the risk-free rate (Brailsford, *et al.*, 2000: 10). Moreover, the literature on the time-varying bank market return sensitivity largely adheres to the use of raw returns.

Second, bank returns are specified as a function of the return on the market ( $R_m$ ), interest rate ( $R_r$ ) and foreign exchange rate ( $R_e$ ). However, in addition to the specification outlined in (1), bank returns are also estimated as a function of an autoregressive process  $\left( \sum_{i=1}^n b_1 R_{j,t-i} \right)$  and bank return volatility or risk ( $\log(\mathbf{g}h_{it})$ ). Estimation of the mean equation in this form extends Elyasiani and Mansur's (1998) work through the inclusion of the return on the market and foreign exchange rate. Also following Elyasiani and Mansur (1998) the formulation

includes the volatility variable ( $h_t$ ) in the mean equation. In accordance with the finding of Engle *et al.* (1987) that  $\log(h_t)$  is a better representation of risk than either standard deviation or variance this variable is specified in logarithmic form (Elyasiani and Mansur, 1998).

Third, the exogenous variables,  $R_m$ ,  $R_r$  and  $R_e$  along with the conditional interest rate volatility variable CV in (5) are lagged one period. This follows Elyasiani and Mansur (1998) and is intended to avoid the error in variable problem and consequent estimator inconsistency that may result from contemporaneous correlation of the shocks to the financial markets (the error term) and the innovations in the independent variables.

Lastly, in relation to the mean equation, there is the potential that the ‘exogenous’ variables considered might, in fact, be highly correlated. In order to eliminate the potential for such multicollinearity many of the earlier studies on bank sensitivity to interest rates and the market return orthogonalised the variables. That is, the interest rate series was regressed on the market returns, or vice versa, and the residuals from this regression were then used in the two-index model. However, Giliberto (1985) and Kane and Unal (1988), amongst others have pointed out the potential bias in this procedure whilst other studies have suggested that differences in the results from orthogonalising or not, are statistically insignificant [see, for example, Neuberger (1991)]. Accordingly, unorthogonalised variables are specified (Faff and Howard, 1999).

As with the mean equation, there are several points worthy of note in relation to the variance equation in (5). First, a GARCH(1,1)-M is chosen. This means that only the previous period’s squared past error terms ( $\varepsilon_{t-1}^2$ ) have an impact on the variance and similarly, only the previous period’s conditional variance ( $h_{t-1}$ ) determine the current period’s variance. Use of a one period lag for both the ARCH and GARCH parameters follows Elyasiani and Mansur (1998) who argue, “...the GARCH (1,1)-M specification achieves parsimony while simultaneously allowing for long memory in the volatility process”. Second, consistent with Elyasiani and Mansur (1998) the usual GARCH-M case is extended by modelling the conditional variance as a function of the conditional interest rate volatility ( $CV_{t-1}$ ) in addition to the lagged squared error terms and lagged conditional variance. The parameter  $d$  determines the significance of this variable. In the event that  $d = 0$  conditional variance collapses to the usual case. Inclusion of conditional interest rate volatility as a determinant of bank return volatility is arguably “...important because this variable conveys critical information about the overall volatility of the financial markets and it influences the volatility of the bank stock returns also at the micro level” (Elyasiani and Mansur, 1998: 545). Market volatility could also be arguably included in the variance equation on this basis. However, given the potential for severe multicollinearity between the market and interest rate volatility measures, market volatility is excluded (Elyasiani and Mansur, 1998).

## 4. DATA DESCRIPTION

In order to estimate the GARCH-M model outlined above, data on Australian bank stock returns, the market return, interest rate levels, interest rate volatility and the foreign exchange rate are required. The following outlines the type and source of data collected for estimation in the main model, the frequency of the data collected and the sample period over which the GARCH-M model is estimated. All values are nominal, as opposed to real, given the absence of a theoretical justification to convert given beta inflation ‘neutrality’ (Brailsford, *et al.*, 2000).

### 4.1 Bank stock return specification

The sample consists of nine Australian commercial bank stocks listed on the Australian Stock Exchange (ASX) collected and compiled by Datastream International into a value-weighted Australian Bank Index adjusted for capitalisation changes. The index used is a ‘total return’ or accumulation index in the sense that it shows the theoretical growth in the value of the shareholding over a specified period. Given the assumption of normality underling the GARCH-M model outlined above, continuously compounded returns are to be preferred over discrete returns. This is due to the fact that continuously compounded returns result in a lower value (except for zero returns), thus implying that the effect of any outliers or data errors is reduced, as this series is more likely to follow a normal distribution as compared with a discrete series. Further, continuously compounded returns are more consistent with return generation through calendar rather than trading time, and they also remove some of the increasing variability in the series as the price level increases (Brailsford, *et al.*, 2000). This choice differs from the work of Faff and Howard (1999) who use discrete returns.

For consistency the market, interest rate and foreign exchange rate variables discussed below are also converted assuming continuous compounding. Flannery and James (1984b), Kane and Unal (1988), Akella and Chen (1990), Song (1994), Wetmore and Brick (1994) and Faff and Howard (1999), amongst others, point out the need for consistent expression of all terms. The decision to use an index or portfolio of returns, rather than

individual bank data, is considered advantageous because it is an “...efficient way to condense a substantial amount of information about bank stock return behaviour...” whilst smoothing out the noise in the data due to transitory shocks to individual banks which might otherwise distort the results (Elyasiani and Mansur, 1998: 539). Of course, one disadvantage is that variation among individual banks may be masked (Elyasiani and Mansur, 1998). One potential remedy followed in the US literature is the further division of the sample into classifications based on bank practise and size. For example, banks in the US are often categorised into money centre, large and regional banks. Unfortunately, due to the relative small number of institutions in the Australian banking sector as compared with their overseas counterparts arbitrarily dividing the sample may introduce misspecification bias.

#### 4.2 Market index specification

The value-weighted ASX All Ordinaries Index (AOI) is obtained from Datastream International proxies the market index. Consistent with the specification of the bank index, the market index is a total return or accumulation index and is adjusted for capitalisation changes. As with the bank stock returns the index is converted to a continuously compounded return series. The market index used comprises approximately the top 300 stocks ranked by market capitalisation in Australia (Brailsford, *et al.*, 2000). Although indices other than the AOI may better represent the market portfolio, Brailsford, *et al.* (2000) suggest that using a broader index, such as the Australian Graduate School of Management’s (AGSM) index which comprises all traded equities, introduces further problems. Therefore, following the bulk of the empirical literature the most common domestic index for Australia is used, despite the recognition that “...composition and weighting of the index can affect the individual betas and might affect the conclusions drawn” (Brailsford, *et al.*, 2000: 12).

#### 4.3 Interest rate index specification

Yields on 10 year and 5 year Treasury Bonds and 90 day Bank Accepted Bills are obtained from the Reserve Bank of Australia (RBA) and after conversion to continuously compounded holding period returns proxy the long, medium and short-term interest rates, respectively. In light of the prediction of the efficient market hypothesis that bank stock returns should only be related to unanticipated changes in interest rates with the expected component already reflected in the return, some studies estimate the ‘innovation’ rather than use actual or unadjusted interest rates. For example, the forecast errors from autoregressive models (Flannery and James, 1984b; Yourougou, 1990), the difference between the spot rate at time  $t$  and forward rate at  $t-1$  (Brewer and Lee, 1990), and the change in yield on the given maturity of a long-term bond (Scott and Peterson, 1986; Sweeney and Warga, 1986; Elyasiani and Mansur, 1998) have all been used to proxy the unanticipated component of interest rates. However, much evidence exists in the literature supporting interest rate sensitivity irrespective of whether interest rates are proxied by raw returns or otherwise (Song, 1994). These include studies by Flannery and James (1984b), Unal and Kane (1987), Bae (1990), Choi, *et al.* (1992) and Faff and Howard (1999).

#### 4.4 Interest rate volatility specification

Following Elyasiani and Mansur (1998), interest rate volatility is measured by the conditional variance of the interest rate index that is generated using an ARCH technique. Elyasiani and Mansur (1998) find that the optimal specification for their long term interest rate series is to model the mean equation as an autoregressive process with 12 lags and the variance of the error term following an ARCH(1) specification. In the present study the optimal specification for the long and medium term interest rates is determined to be a simple naïve (no change) mean equation with the error term variance modeled as a GARCH(1,1) process. The short term interest rate, on the other hand, is found to be more optimally described by an autoregressive process with one lag and an ARCH(1) variance specification. After each interest rate series is modelled, the conditional variance estimated is then used in the GARCH-M model as a proxy for the conditional interest rate volatility variable (CV).

#### 4.5 Foreign exchange rate specification

The requisite foreign exchange rate data is collected from the Reserve Bank of Australia. Following Prasad and Rajan (1995), Choi, *et al.* (1992) and Wetmore and Brick (1994), the foreign exchange rate index is defined as the Australian currency value of one unit of foreign currency, where foreign currency is defined as the trade-weighted basket with current weights as set out in the Reserve Bank Bulletin. For consistency with the other variables included in the study and the empirical literature, for instance Prasad and Rajan (1995) and Choi, *et al.* (1992), the foreign exchange index is converted to a continuously compounded holding period return. Also for

reasons of consistency with the interest rate variables, actual foreign exchange rate data rather than the 'innovations' in such are used.

#### 4.6 Sampling frequency

Following McKenzie and Brooks' (2000) general work on ARCH and GARCH techniques, daily data excluding national holidays is specified. This data selection choice is also consistent with the work of Brewer and Lee (1990) and Adjaoud and Rahman (1996) in the context of interest rate sensitivity in bank stock returns. Lie's, *et al.* (2000) work on market returns and the foreign exchange rate study of Chamberlain, *et al.* (1997) also use daily data. Despite this, a substantial amount of the empirical work in this area employs monthly data, with a few studies such as those by Flannery and James (1984b), Wetmore and Brick (1994) and Dinenis and Staikouras (1998) preferring weekly sampling periods. Nevertheless, daily data is preferred for the following reasons. First, the use of monthly data has arguably been a result of historic phenomena whereby it has more widely available than either weekly or daily data (Brailsford, *et al.*, 2000). Second, given the well-documented decline in ARCH effects for some assets "...as the periodicity of the sampling frequency decreases" statistical support for the use of daily over weekly sampling is also found (McKenzie and Brooks, 2000: 59) [see also Diebold (1988), Baille and Bollerslev (1989) and Andersen and Bollerslev (1997)]. However, one potential limitation for this study arising out of the use of a daily sampling frequency is there may be too much noise in the data and 'day of the week' effects may represent a problem.

#### 4.7 Sample period

A 5-year sample period from 1 March 1996 to 28 February 2001 is specified. The justification for this particular sample period is as follows. First, with most studies on interest rate sensitivity considering periods prior and around the deregulation of the financial system, a study focusing on a more recent period should throw light on the nature of bank risk in the post-deregulation period. Second, this length of time results in 1263 observations, thereby satisfying the claim that for statistically reliable ARCH regression estimates at least 300 observations are required (McClain, *et al.*, 1996). Similarly, the suggestion that the significance of ARCH coefficients may change as the sample size is reduced does not present a problem with this number of observations (McKenzie, 1998). Moreover, whilst persistence in ARCH models has been related to sample size (McClain, *et al.*, 1996), it is thought that this sample is not large enough to evoke the problem whereby "the sum of the alpha and beta coefficients asymptotes toward unity" as the sample size increases (McKenzie and Brooks, 2000: 59). Lastly, this period ensures that the banks included in the bank index were continuously listed on the stock exchange throughout the sample period.

### 5. EMPIRICAL RESULTS

Table 1 presents descriptive statistics for the continuously compounded returns included in the analysis of market, interest rate and foreign exchange rate risk; namely, bank portfolio returns, market returns, short, medium and long-term interest rate returns and the foreign exchange rate returns. During the sample period 1996-2001 the mean continuously compounded return is highest in the bank portfolio index and lowest in medium-term interest rates, while volatility is highest in medium-term interest rates and lowest in the foreign exchange rate. The sample skewness for all six variables is generally close to zero, but the sample kurtosis for all variables with the exception of short-term interest rates exceeds the normal value of three. Verification that the unit root has been removed from each series by the calculation of continuously compounded returns is indicated by the insignificant Augmented Dickey-Fuller (ADF) and Phillips-Perron statistics.

As the independent variables used to explain bank returns are hypothesised to be time-dependent, it follows that the bank return series must also be time dependent. From graphical displays (not shown here) it is readily apparent that the bank portfolio returns exhibit an upward trend. More formal support for the presence of non-stationarity in the bank portfolio is found through inspection of the autocorrelation function (also not shown) that indicates that Australian bank returns exhibit correlation at lag 1. This provides support for the inclusion of the autoregressive lag of one in the mean equation. Likewise, the autocorrelation from the squared observations of the bank portfolio also suggests there is substantial correlation in the squared values of the bank index. This is usually a good indication that the potential time-dependence of the relationship between market, interest rates and foreign exchange rates will be adequately modelled by a GARCH technique. Combined together, these results suggest that ARCH type modelling is the most appropriate framework for analysing banks stock returns and risk.

One particular issue in this analysis is the specification of bank portfolio returns as against individual bank returns, with the suggestion that portfolio returns may obscure unique individual bank responses to market, interest and foreign exchange rate risks. Summary statistics of the bank portfolio and its constituent individual banks (not shown here) show that the mean daily return of the Australian bank portfolio is approximately  $3.9 \times 10^{-4}$  with a variance of around  $2 \times 10^{-5}$ . The bank portfolio is also not normally distributed, as evidenced by non-zero skewness (-0.24828), kurtosis above three (4.83438), and more formally, a significant Jarque-Bera statistic (190.055). Comparing these figures with those for each individual bank, we find that most of the larger and medium-sized banks conform approximately well to the portfolio statistics. This is expected given that they comprise the largest weighting in calculation of the value-weighted index. However, some of the smaller banks diverge somewhat from the portfolio with returns and volatility less than the industry as a whole. Accordingly, the results of this analysis may not accurately describe the return generating process in these institutions.

Another potential concern arising out of the methodology is the degree of multicollinearity between the 'independent' variables. To address this correlations between each exogenous variable are calculated. Aside from the lagged bank index and the market return, which have a correlation of 0.7614, the remaining variables have correlation coefficients of less than 0.25. Brooks, *et al.* (1997b) indicate that a correlation coefficient between 0.637 and 0.771 may indicate a significant relationship. A more general rule of thumb is that if the pairwise or zero-order correlation coefficient between two regressors is, say, in excess of 0.8, then multicollinearity is a serious problem. The correlation coefficients indicate that while multicollinearity is present it is not too serious a problem.

The final point to note relates to the sensitivity of the bank return generating process to long, medium or short-term interest rates, especially given that the bulk of empirical evidence has generally found that bank returns are more sensitive to longer-term rates. Correlation coefficients (not shown here) indicate a high degree of correlation (0.9396) between the 10-year and 5-year bond indices. Faff and Howard (1999) made a similar observation with regard to Australian interest rates over the period 1978 to 1992. However, unlike Faff and Howard (1999) who find that the correlation between either the long term or medium term interest rate and the short term rate is less than 0.5 in either case, here, there is evidence of a relatively high degree of correlation between the medium and short term indices (0.6170), though not between the long and short term (0.4875). Given these differences with Faff and Howard's (1999) prior Australian study, there appears ample reason to reconsider all three interest rates.

Table 1  
Descriptive statistics of the continuously compounded variables in the mean equation

Statistic	Bank index at $t-1$	Market	Interest Rates			Foreign Exchange
			Long Term	Medium Term	Short Term	
Mean	3.920	1.910	-1.710	-1.780	-1.080	0.396
Median	5.380	3.340	0.000	0.000	0.000	0.000
Maximum	2.510	2.570	2.360	2.290	3.980	1.410
Minimum	-2.410	-3.030	-1.890	-2.510	-3.320	-1.080
Standard Deviation	4.760	3.850	5.050	5.150	3.440	2.700
Skewness	-0.243	-0.558	0.144	-0.060	-1.040	0.217
Kurtosis	4.820	9.190	4.350	4.950	0.361	4.880
Jarque-Bera	1.869	20.843	1.003	2.000	579.984	1.963
Jarque-Bera p-value	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***	0.000 ***
Aug. Dickey-Fuller	-16.446	-16.870	-16.670	-16.498	-16.358	-15.970
Phillips-Perron	-32.174	-35.634	-37.515	-36.483	-31.099	-39.908
Observations	1263	1263	1263	1263	1263	1263

Notes: Asterisks represent significance at the \* - .10, \*\* - .05 and \*\*\* - .01 level. Statistics for mean and median are  $\times 10^{-4}$ , maximum, minimum, JB and ADF are  $\times 10^{-2}$  and standard deviation is  $\times 10^{-3}$ .

Table 2 presents various robustness checks associated with the GARCH-M model as it is generally necessary to consider the adequacy of the chosen GARCH-M model in order to be confident that the estimates in Table 3 are reliable. The sufficiency of the model is addressed on two levels. First, the general model performance is considered. Second, the added parameters resulting from the GARCH-M model are interpreted. To start with, the general adequacy of the model rests on whether it has captured all ARCH effects present in the data and

whether the standardised residuals conform to the assumption that they are independent and identically distributed; that is, they are white noise and follow a normal distribution with zero mean and variance of one [i.i.d.  $\sim N(0,1)$ ]. With respect to the elimination of the remaining ARCH effects, the insignificant Ljung-Box (Q) statistic on the squared standardized residuals indicates an absence of remaining GARCH effects, as does the insignificant Lagrange Multiplier statistic. These conclusions are robust irrespective of the interest rate specification.

However, the significant Jarque-Bera statistics in Table 2 indicate that the assumption of normality is violated, though the Shapiro-Wilk tests of normality indicate that the null hypothesis that the residuals are normally distributed cannot be rejected at any conventional level. Brooks, *et al.* (1997b: 89) argue that provided standard deviation is close to one, a mean that is statistically different from zero will not disrupt the assumption of a robust model fit. Similar findings of non-normality have been found in the most relevant literature. For example, Elyasiani and Mansur (1998) similarly find that the normality assumption for each of the three portfolios considered is rejected. They attribute much of this non-normality to the failure of the models to account for the leptokurtic disturbances of market excess returns [see also McKenzie and Brooks (2000)]. Finally, the insignificant Ljung-Box (Q) statistic for the standardized residuals indicates that there is no serial correlation in the disturbances. On the basis of these statistics, the GARCH-M model appears to perform reasonably well.

Table 2.  
General performance statistics

Statistic	Interest Rate Maturity		
	Long term	Medium term	Short term
Jarque-Bera (JB)	36.25	35.72	41.73
JB $p$ -value ( $\times 10^{-8}$ )	(1.341) ***	(1.75) ***	(0.08664) ***
Shapiro-Wilk (SW)	0.9878	0.9874	0.9871
	(0.6212)	(0.5376)	(0.4763)
Ljung-Box (Q) statistic for standardised residuals	8.742	8.526	8.685
	(0.7248)	(0.7428)	(0.7296)
Ljung-Box (Q) statistic for squared standardised residuals	10.03	8.307	10.22
	(0.6136)	(0.7607)	(0.5971)
Lagrange Multiplier (LM)	10.27	8.477	10.31
	(0.5924)	(0.7469)	(0.5887)

Notes: Values in parentheses are  $p$ -values. Asterisks \*, \*\* and \*\*\* represent significance at the .10, .05 and .01 levels, respectively.

The second issue with respect to the adequacy of the chosen GARCH-M model is the additional parameters that are estimated. First, with respect to the inclusion of an autoregressive process, it is clear from Table 3 that the bank return in the previous period is a determinant of its return in the current period. That is, the autoregressive lag parameter ( $b_1$ ) is significant (at the .01 level) irrespective of the interest rate variable under consideration. The robustness checks in Table 4 also reject at the .01 level the null hypothesis that the autoregressive variable has no effect on bank returns ( $b_1 = 0$ ). Second, the GARCH-M technique used also includes the conditional variance or volatility of the bank index, represented by  $\gamma$ , as a determinant of bank returns. Inclusion of this variable in the mean equation is premised on the notion that risk-averse agents require compensation for holding risky assets. Subsequently, the return on the bank index is expected to increase with a corresponding increase in the volatility of its returns. Surprisingly, Table 3 shows that for all three interest rate maturities (long, medium and short term) the coefficient,  $\gamma$ , is statistically insignificant. Table 4 also confirms that the likelihood ratio test of the null hypothesis that volatility does not affect bank returns ( $\gamma = 0$ ) is also statistically insignificant for all interest rate maturities ( $\chi^2 = 0.24; 0.08; 0.77$ ). This differs from Elyasiani and Mansur (1998) who found a statistically significant volatility effect across the three bank portfolios considered [Money centre -0.00131, large -0.00142 and regional -0.001 at the .01, .01 and .10 levels, respectively]. However, Baillie and DeGennaro (1990) find  $\gamma$  to be insignificant in seven out of their eight specifications, indicating the lack of a trade-off (Elyasiani and Mansur, 1998).

The main implication is that the volatility risk premia is absent during the period analysed. One potential explanation for this finding is that over the period of the late 1990s, the bank portfolio return was significantly less volatile than in the immediate post-deregulation period in the 1980s and early 1990s. This is confirmed by

examining the continuously compounded returns for the Australian bank index since the early 1970s (not shown here). A lower level of volatility in bank returns is also found when compared with comparable international studies. For instance, Elyasiani and Mansur (1998) calculate portfolio variances ranging from 0.003 to 0.005 for the three bank portfolios considered. This may be a product of both the different time periods studied along with institutional differences between the Australian and the US banking sectors.

Another point to note with respect to the volatility parameter ( $\gamma$ ) is that it is negative: clearly contrary to the theoretical prediction that higher risk results in higher returns. Elyasiani and Mansur (1998: 551) make a similar finding and suggest, “[since] volatility is a measure of total risk, rather than the non-diversifiable systematic risk, the increase in it need not always be accompanied by an increase in the risk premium. Indeed, if fluctuations in volatility are mostly due to shocks to the unsystematic risk, the trade-off coefficient  $\gamma$  can have any sign” [see also Fama and Schwert (1977), Campbell (1987) and Glosten, *et al.* (1993)]. As an alternative, Glosten, *et al.* (1993) suggest that a negative risk-return trade-off may result from riskier periods coinciding with periods when investors are better able to bear risk or the fact that if investors want to save more during riskier times, and all assets are risky, competition can raise asset prices and lower the risk premium. More relevant in the present context is the suggestion that “...if banks are affected less strongly by random shocks than other sectors, investors will switch to bank stocks in response to the shocks, in order to avoid the sectors more strongly affected. This substitution process will result in a lower bank stock premium” (Elyasiani and Mansur, 1998: 551).

In terms of the remaining parameter estimates in Table 3, three points are considered. First, the time-dependence of the return generating process; that is, the significance of the ARCH and GARCH parameters. Second, whether the chosen functional form for describing the variance equation, or the time-dependence of bank returns, is appropriate. More particularly, this question relates to whether a GARCH-M model is more useful as compared to either an ARCH, ARCH-M or GARCH model. Finally, whether the constraints implied by use of a modified ARCH technique have been satisfied.

Table 3.  
Maximum likelihood estimates of GARCH(1, 1)-M models

		Interest Rate Maturity					
		Long term		Medium term		Short term	
Mean equation parameters	$b_0$	-0.0023	-0.5100	-0.0014	-0.3285	-0.0028	-0.6583
	$b_1$	0.2298 ***	5.3735	0.2242 ***	5.2559	0.2940 ***	5.5687
	$b_m$	-0.2082 ***	-4.1803	-0.2114 ***	-4.2335	-0.2091 ***	-4.3425
	$b_r$	-0.0312	-1.1976	-0.0622 ***	-2.3845	-0.1150 ***	-3.7612
	$b_e$	0.0209	0.4505	0.0238	0.5085	0.0277	0.6102
	$\mathbf{g}$	-0.0002	-0.6024	-0.0001	-0.4168	-0.0002	-0.7582
Variance equation parameters	$\mathbf{a}_0$	0.0001 ***	2.4199	0.0001 *	1.5695	0.0001 ***	4.1897
	$\mathbf{a}_1$	0.1319 ***	5.2313	0.1329 ***	5.0367	0.1279 ***	5.7492
	$\mathbf{b}$	0.6822 ***	10.1403	0.6645 ***	9.6590	0.7616 ***	17.6051
	$\mathbf{d}$	0.0759 *	1.6241	0.1129 **	2.1899	-0.0157 ***	-2.8166
Statistics	$\alpha_1 + \mathbf{b}$	0.8141		0.7974		0.8895	
	AIC	-10045.80		-10054.00		-10055.81	
	BIC	-9994.39		-10002.59		-10004.40	

The GARCH(1,1)-M models are estimated as follows:

$$R_{j,t} = b_0 + \sum_{i=1}^n b_i R_{j,t-i} + b_m R_{m,t-1} + b_r R_{r,t-1} + b_e R_{e,t-1} + \log(\mathbf{g}h_{it}) + \mathbf{e}_{j,t}$$

$$h_{it} = \mathbf{a}_0 + \mathbf{a}_1 \mathbf{e}_{i,t-1}^2 + \mathbf{b}h_{i,t-1} + \mathbf{d}CV_{i,t-1}$$

$$\mathbf{e}_{i,t-1} | \Omega_{t-1} \sim N(0, h_{it})$$

where  $R_{jt}$  is the return on the bank portfolio at time  $t$ ,  $R_{j,t-1}$  is the lagged return on the portfolio,  $R_m$  and  $R_e$  are the return on the market and foreign exchange rate respectively,  $R_r$  is the return on the long, medium and short term interest rate index respectively,  $\mathbf{e}_{j,t}$  denotes the error term which is dependent on the information set  $\Omega_{t-1}$ ,  $h_{it}$  is the conditional variance of return at time  $t$ . The optimal lag was determined to be 1.  $CV$  is the conditional variance on the long, medium and short term index respectively. Values in parentheses are t-statistics. Asterisks \*, \*\* and \*\*\* represent significance at the .10, .05 and .01 levels, respectively.

First, the figures in Table 3 suggest that there is a significant time-invariant component in the bank return generating process since the constant in the variance equation ( $\alpha_0$ ) is significant [ $\alpha_0 = 1.955 \times 10^{-6}$  (.01 level);  $1.382 \times 10^{-6}$  (.10 level);  $2.605 \times 10^{-6}$  (.01 level)]. Neuberger (1994) also found a zero intercept term in the volatility equation, though Elyasiani and Mansur's (1998) estimated insignificant time-invariant parameters for all banks save the regional banking portfolio. However estimates in Table 3 also suggest that the Australian bank return generating process has a significant time dependent component. In particular, the ARCH ( $\alpha_1$ ) and GARCH ( $\beta$ ) parameters are highly significant at the .01 level irrespective of the interest rate maturity under consideration ( $\alpha_1 = 0.1319$ ;  $0.1329$ ;  $0.1279$  and  $\beta = 0.6822$ ;  $0.6645$ ;  $0.7616$ ). Further, the likelihood ratio test statistics in Table 4, also reject the hypotheses of time invariability in return volatility ( $\alpha_1 = \beta = \delta = 0$ ), irrespective of the interest rate index at any traditional level of significance ( $\chi^2 = 103.60$ ;  $109.90$ ;  $104.51$ ). Subsequently, despite a significant time-independent component of bank returns, a time-invariant model of banking returns is inappropriate due to the substantial time-dependent component.

Second, attention turns to the functional form chosen to describe the time-dependent component of bank returns in the form a GARCH model with the addition of a variable for interest rate volatility. To start with, the hypothesis that the return generating process follows an ARCH specification ( $\beta = \delta = \gamma = 0$ ) is rejected at the .01 level ( $\chi^2 = 35.46$ ;  $42.46$ ;  $39.23$ ) in all three models, as is the hypothesis that the return generating process follows

an ARCH-M specification ( $\chi^2 = 35.48; 42.36; 39.03$ ). However, the null hypothesis that the return generating process follows a GARCH specification is only rejected when medium term interest rates are under consideration [ $\chi^2 = 3.20; 8.12; 3.83$ ]. This indicates that when considering the long and short-term interest rates, the volatility parameter ( $\gamma$ ) and the interest rate volatility variable ( $\delta$ ) are not significantly different from zero. However, upon consideration of whether the return generating process for banks follows a pure GARCH-M specification ( $\delta = 0$ ), the null is rejected for both short and medium term interest rates ( $\chi^2 = 2.46; 7.26; 3.01$ ). It is therefore suggested that the appropriate model is the modified GARCH-M specification used in the analysis. In relation to this point, Elyasiani and Mansur (1998: 552) conclude, "...the rejection of a hypothesis is a sufficient condition for the rejection of any other hypothesis which is more restrictive in nature, namely one that imposes more constraints than implied by the former". Therefore, the rejection of the null hypotheses that the return generating process follows an ARCH, ARCH-M and GARCH process provides support for the suggestion that the more restrictive constant variance specification must also be rejected.

Third, in terms of the constraints imposed by the use of a modified ARCH technique the constant ( $\alpha_0$ ), ARCH ( $\alpha_1$ ) and GARCH ( $\beta$ ) parameters are all non-negative. The magnitude of the ARCH parameter ( $\alpha_1 = 0.1319; 0.1329; 0.1279$ ) is smaller than that of the GARCH parameter ( $\beta = 0.6822; 0.6645; 0.7616$ ). Thus, the effect of last period's shock ( $e_{t-1}^2$ ) on bank volatility is smaller than the effect of the previous surprises ( $h_{t-1}$ ). This finding is consistent with that of Elyasiani and Mansur (1998) and indicates that the market has a memory longer than one period and that volatility is more sensitive to its own lagged values than it is to new surprises in the market place.

Table 4.  
The  $\chi^2$  statistics for various hypotheses tests

Hypotheses	Interest Rate Maturity		
	Long term	Medium term	Short term
There is no autoregressive process: $b_1=0$	28.40 ***	26.96 ***	28.43 ***
There is no market effect: $b_m=0$	16.48 ***	16.58 ***	16.63 ***
There is no interest rate level effect: $b_r=0$	1.38	5.56 **	10.69 ***
There is no foreign exchange effect: $b_e=0$	0.22	0.26	0.29
Volatility is not a significant factor: $\gamma=0$	0.24	0.08	0.77
Return volatility is time invariant: $\alpha_1=\beta=\delta=0$	103.60 ***	109.90 ***	104.51 ***
Return generating process follows an ARCH specification: $\beta=\delta=\gamma=0$	35.46 ***	42.46 ***	39.23 ***
Return generating process follows an ARCH-M specification: $\beta=\delta=0$	35.48 ***	42.36 ***	39.03 ***
Return generating process follows a GARCH specification: $\gamma=\delta=0$	3.20	8.12 **	3.83
Interest rate volatility has no effect on bank risk and return: $\delta=0$	2.46	7.26 ***	3.01 *
There is no interest rate effect: $\delta=b_3=0$	3.40	11.60 ***	13.41 ***

Asterisks \*, \*\* and \*\*\* represent significance at the .10, .05 and .01 levels, respectively. Figures are  $\chi^2$  values

The second constraint that must be complied with is that the sum of the ARCH and GARCH parameters ( $\mathbf{a}_l + \mathbf{b}$ ) as a measure of volatility persistence should be less than unity. From Table 3 the sum of  $\mathbf{a}_l + \mathbf{b}$  is less than one, indicating that the model is second order stationary, irrespective of whether short, medium or long term interest rates are used ( $\mathbf{a}_l + \mathbf{b} = 0.8141; 0.7974; 0.8895$ ). The relatively high value of the persistence measure provides evidence that shocks to the banking sector have highly persistent effects and that the response function of volatility decays at a relatively slow pace. For example, when long term rates are specified, the persistence measure ( $\mathbf{a}_l + \mathbf{b}$ ) is 0.8141 thereby indicating that the proportion of the initial shock to the bank portfolio remaining after a 5-day period is  $(0.8141)^5$  or 36 percent, and after two weeks 13 percent of the initial shocks persist. Generally the persistence documented here for the Australian bank portfolio is lower than Elyasiani and Mansur's (1998) findings for US banks over their sample period. This indicates that, at least for the sample chosen in this study, Australian banks are relatively more capable of absorbing shocks than their US counterparts. Alternatively, this observation may merely be a consequence of the less volatile bank environment in the late 1990s.

The major concern in this study is of course whether Australian bank stock returns are sensitive to market, interest rate and foreign exchange rate risk. The estimated coefficients in Table 3 and the chi-square statistics in Table 4 represent the associated hypothesis tests. First, and not surprisingly, the coefficients in Table 3 indicate that bank returns are highly sensitive to the return on the market as represented by the coefficient  $b_m$ . This result is invariant to the specification of the interest rate. The coefficient for market risk has a value of -0.2082, -0.2114 and -0.2091 for the model with long, medium and short-term interest rates, respectively. These results are supported by rejection at the .01 confidence interval of the null hypothesis of no market risk ( $b_m = 0$ ) in Table 4 ( $\chi^2 = 16.48, 16.58$  and  $16.63$ ). The magnitude of this coefficient suggests that the Australian banking industry has relatively low systematic risk. This is comparable to previous Australian estimates of bank sensitivity to market risk (estimated coefficients in brackets), including Brooks and Faff (1995) (0.6222–1.2517), Brooks, *et al.* (1997b) (0.7867–0.8458), and Brooks, *et al.* (1998) (0.838–0.881).

The second hypothesis of interest is the magnitude of market risk as compared with the remaining variables. Noticeably the market return is found to explain a greater proportion of bank returns, that is  $b_m$  is larger in absolute magnitude, than interest rates irrespective of the maturity under consideration ( $b_r = -0.03127; -0.06219; -0.115$  for long, medium and short term interest rates respectively). Similarly, the market index explains more than the foreign exchange rate, even ignoring the finding of foreign exchange insignificance discussed below ( $b_e = 0.0209; 0.02385; 0.02779$ ). These findings are consistent with the results of Song (1994), amongst others.

The last hypothesis of interest in relation to the effect of market returns on Australian bank stocks is related to the time dependence of bank sensitivity to market returns. Preliminary evidence presented earlier suggested that market effects were time varying. As noted, in the event that market returns are time-dependent, a least squares regression is generally inappropriate for determining the relationship between these variables and bank returns. Thus, a GARCH-M model was specified to take into account this time-varying sensitivity. The significance of the variance equation parameters  $\alpha$  and  $\beta$  in Table 3 and the rejection of the null hypothesis that returns are time invariant ( $\alpha = \beta = \delta = 0$ ) in Table 4 indicates that the return process is indeed time-varying.

A second group of hypotheses addressed in this study concerns interest rate risk. First, in terms of the magnitude and direction of influence of interest rates on Australian bank returns, as indicated by the sign and significance of the interest rate coefficient  $b_r$ , Table 3 shows that the short and medium term interest rates are significant at the .01 level with coefficients of -0.115 and -0.06219 respectively. The importance of short and medium term rates to the bank return generating process is verified by the rejection of the null hypothesis of no interest rate level effect ( $b_r = 0$ ) in Table 4. The finding of a significant negative relationship between short term interest rates and bank returns accords with findings by Booth and Officer (1985), Choi, *et al.* (1992), Bae (1990), and Faff and Howard (1999), amongst others. Conversely, Unal and Kane (1988) and Akella and Chen (1990) failed to find a significant short term interest rate effect. In relation to the negative sensitivity to medium term rates, Brewer and Lee (1990) and Bae (1990) have made similar findings.

More surprising however is the insignificance of the long-term interest rate. From Table 3 the coefficient on the long-term rate is 0.03127 lacks statistical significance at any usual level. This is consistent with the failure to reject the null hypothesis of no long-term interest rate level effect ( $b_r = 0$ ) in Table 4 ( $\chi^2 = 1.38$ ). This result is inconsistent with much existing work in this area, including Elyasiani and Mansur (1998), Unal and Kane (1988), Kane and Unal (1988), and Akella and Chen (1990). A potential reason for this unexpected finding lies in the period considered such that while previous studies have focussed on the deregulation era this study considers the post-deregulation era exclusively. Given the move towards regulatory focus on internal management of bank's risks in recent years, as evidenced by adoption of the Basle Accord, the banks' ability to manage long term interest rate exposure has increased. This may be compared with the situation immediately post-deregulation because "...deregulation was associated with increases in risks faced by banks which were not well prepared to manage higher risk" (Faff and Howard, 1999: 99). This also accords with the documented decline in longer-term interest rate sensitivity, especially Faff and Howard (1999) as the only other Australian study concerned with interest rate sensitivity.

The second hypothesis is that bank returns are likely to be more sensitive to longer-term interest rates than either medium or short term. Clearly, upon consideration of the interest rate coefficients ( $b_r$ ) for long, medium and short term rates (-0.03127, -0.06219 and -0.115) the converse are true. That is, from early 1996 through to the beginning of 2001 Australian bank returns are more sensitive to short term interest rates, than either medium or long term, with long term rates providing the least explanatory power. The Akaike Information Criterion (AIC) and Schwartz Bayesian (BIC) model selection criterion presented in Table 3 support this conclusion whereby the most parsimonious specification for Australian bank returns, as indicated by the lowest AIC/BIC value, is the

model including short term interest rates [AIC = -10055.81, BIC = -10004.4]. This is contrary to the results of Lyngne and Zumwalt (1980), Unal and Kane (1988), Bae (1990) and Faff and Howard (1999), amongst others.

One possibility is as follows. Historically Australian banks have had a substantial exposure to long-term interest rate risk as a result of the maturities mismatch between the major components of the banks' balance sheet in the form of deposits and loans. More recently, as the importance of the traditional bank product mix has declined and the banking sector's balance sheet has embraced shorter-term market-linked securities, the maturity length of the interest rate risk that is of relevance or concern to the banking sector has also declined. The process of this transformation in the typical bank balance sheet would therefore explain the documented decline in long-term interest rate sensitivity found in the literature to date. For example, Faff and Howard (1999) find that in the Australian context, long-term interest rate risk is insignificant in the latest sub sample considered. This explanation may validate the finding of no long-term interest rate risk in this study and also the finding that short-term interest rate risk is of greater import than either medium or long-term interest rates. Alternatively, another explanation for the lack of long term interest rate sensitivity is that the banks are better placed to hedge this exposure as compared to shorter term interest rate risk. Perhaps banks are more risk adverse to this length of interest rate risk and therefore undertake more rigorous hedging action for this maturity.

The third hypothesis concerning the effect of interest rates on bank returns that interest rate sensitivity is time-varying has already been supported. The significance of the variance equation parameters  $\alpha$  and  $\beta$  in Table 3 and the rejection of the null hypothesis that returns are time invariant ( $\alpha = \beta = \delta = 0$ ) in Table 4 indicate that the return process is time dependent. Lastly, interest rate volatility was also hypothesised as being an important determinant of bank returns in Australia. In terms of the model specified interest rate volatility is included as a determinant of bank return volatility, which is in turn a determinant of bank mean return. Considering the effect of interest rate volatility on bank return volatility the long term interest rate volatility has a value of 0.07595 and is significant at the .10 level, medium term interest rate volatility has a magnitude of 0.1129 and is significant at the .05 confidence interval, whilst short term interest rate volatility is significant at the .01 level and has a value of -0.01572. Similarly, the null hypothesis of no long term interest rate volatility effect in Table 4 ( $\delta=0$ ) cannot be rejected. Coupled with the marginal significance of the long term interest rate volatility coefficient in the main model estimation (Table 3) this indicates that long term interest rate volatility is not a particularly important determinant of bank return volatility. While this conflicts with Elyasiani and Mansur's (1998) findings for money centre and large bank portfolios, it is in accordance with their results for regional banks. Elyasiani and Mansur (1998: 556) suggest that an insignificant interest rate volatility parameter "...may indicate insignificant exposure to interest rate risk due to stronger risk aversion and hedging action".

Second, whilst the null hypothesis of no medium term interest rate volatility effect is rejected at the .01 level, the hypothesis for short term interest rate volatility is only rejected at the .10 level. A potential reason for this is that since the 5-year medium term rate now represents the longest time horizon over which Australian banks deem relevant, the volatility in this rate is more important to banks than fluctuations in shorter-term rates. Lastly, in relation to the findings on the effect of interest rate volatility on bank volatility, the long and medium term interest volatility coefficients are positive whilst the short-term volatility has a negative relationship with bank return volatility. The negative coefficient for short-term volatility indicates that if interest rates become more volatile, bank stock returns will stabilise in the following period (i.e. the next day).

One possible explanation for the decline in stock return volatility in response to short term interest rates is that when short term interest rate volatility increases, banks seek shelter from short term interest rate risk and are capable of doing so within one day, for example by holding derivatives and matching the duration of assets and liabilities. This, in turn, results in lower bank stock volatility in the following period (the next day). This finding does not preclude (contemporaneous) movements of in bank variance ( $h_t$ ) and conditional interest rate volatility ( $CV_{t-1}$ ) in the same direction. Indeed, if  $CV$  is negatively autocorrelated (and  $\delta$  is negative) the two variables will move together. By way of contrast, if long or medium term rates become more volatile, bank stock returns also become more volatile in the following period (Elyasiani and Mansur, 1998). The reason for the different responses between short and both medium and long term rates is that banks may have a slower response time to movements in the long and medium term interest rate volatility as compared with short term. Banks also appear to have a stronger reaction to short term interest rate volatility than either long or medium term. Again this is posited to be a result of shifting balance sheet exposures.

The final hypothesis concerning Australian bank returns is their sensitivity to foreign exchange rate risk. From the estimated coefficients in Table 3 it would appear that foreign exchange rate risk is not significant determinant of Australian bank stock returns, regardless of the interest rate maturity under consideration ( $b_e = 0.02090$ ; 0.02385; 0.02779). This conclusion is supported by the failure to reject the null hypothesis of no foreign

exchange rate effect ( $b_e = 0$ ) in Table 4 ( $\chi^2 = 0.25, 0.28, 0.30$  for long, medium and short term interest rates, respectively). This is contrary to the US findings of Choi, *et al.*, (1992), Wetmore and Brick (1994) and Tai (2000).

A number of potential explanations for this unexpected finding exist. First, and foremost, is that Australian banks simply are not exposed to significant foreign exchange rate risk over the sample period. However, in line with the globalisation of banking and increased offshore activities in the banking sector, at least some (major) Australian banks do have significant on-balance sheet foreign currency exposure. It is therefore inappropriate to assume that lack of balance sheet exposure to fluctuations in the foreign exchange rate is the reason for a failure to find that foreign exchange risk is significant to the Australian bank return generating process. Second, while exposed to adverse fluctuations in the foreign exchange rate, Australian banks may simply have adequately hedged their foreign exchange rate exposure throughout the sample period. Support for this argument is found in several different sources. Gizycki and Lowe (2000: 189), for example, found that while "...around 70 per cent of foreign borrowing by financial institutions is denominated in foreign currency, these institutions do not have large foreign currency risks, with the currency risk typically hedged through the swaps market. One indicator that the banks' foreign exchange risk is small is that the aggregate regulatory capital charge for the Australian banks' market risk (which includes foreign exchange risk) accounts for just 1 per cent of the total capital requirement, compared to over 5 per cent for the large Canadian and German banks, and over 10 per cent for the large Swiss banks". Similarly, Bank for International Settlements (BIS) statistics suggest that while net foreign currency liabilities currently represent around 13 percent of Australian banking assets, exposure to foreign exchange movements is arguably negligible due to the vast bulk of this exposure being hedged, "...in the derivatives markets, predominately using such instruments as cross-currency swaps and foreign exchange forwards. These hedges are off-balance sheet items and therefore generally are only recorded "...when they acquire some value (either positive or negative)" or they are not recorded at all (RBA, 2000c: 47).

A third possibility is that while foreign exchange rate exposure is an important factor in the return generation process, the effect has already been incorporated within the market risk parameter. Unfortunately, this argument is somewhat lessened by the minimal correlation (0.019) between the foreign exchange rate and market indices correlations. A fourth possibility is that the proxy used for foreign exchange rate risk may not accurately reflect the true portfolio of foreign exchange risk to which Australian banks are exposed. That is, the weights of the currencies used to formulate the trade-weighted index may not be representative of the banks' actual investments (Benson and Faff, 2000). Finally, use of a bank portfolio rather than individual bank returns may obscure aspects of individual foreign exchange exposure. For example, while the major Australian banks have significant foreign currency exposure, the exposure of the smaller banks is much less.

## 6. CONCLUDING REMARKS

This study employs an extended version of the Generalised Autoregressive Conditional Heteroskedasticity in Mean (GARCM) model to consider the time-series sensitivity of Australian bank stock returns to market, interest rate and foreign exchange rate risks. Daily Australian bank portfolio returns, a market wide accumulation index, short, medium and long-term interest rates, and a trade-weighted foreign exchange index are used to model these risks over the period 1996 to 2001. The results suggest that market risk is an important determinant of bank stock returns, along with short and medium term interest rate levels and their volatility. However, long-term interest rates and the foreign exchange rate do not appear to be significant to the Australian bank return generating process over the period considered.

The study extends previous work in this area in two ways. First and foremost, the study represents the first attempt to simultaneously model market, interest rate and foreign exchange rate risk in the Australian banking sector. Second, the study employs a GARCM methodology to undertake this modelling exercise, and thereby allows for volatility to vary with time. Nonetheless, the study does suffer from a number of limitations, all of which suggest future directions for research. First, by specifying a portfolio of bank returns rather than individual bank stock returns the analysis may have obscured interesting differences in market, interest rate and foreign exchange rate risks among individual banks. Future work in this area should attempt to highlight the differences between Australian banks in much the same way as the US literature draws comparisons between, say, money centre, large and regional banks. Second, while this study has much to say about risks in the bank return generation process in the post-deregulation era, it does not provide an indication of how this compares with risk in the pre-deregulation and deregulation periods. A new dimension could then include a longer sample period to throw light on these changes.

## REFERENCES

- Adjaoud, F. and Rahman, A. (1996) 'A Note on Temporal Variability of Canadian Financial Services Stock Returns', *Journal of Banking and Finance*, Vol. 20, pp. 165–177.
- Adler, M. and Dumas, B. (1984) 'Exposure to Currency Risk: Definition and Measurement', *Financial Management*, Vol. 13, Summer, pp. 41–50.
- Aharony, J., Saunders, A. and Swary, I. (1985) 'The Effects of the International Banking Act on Domestic Bank Profitability and Risk', *Journal of Money, Credit, and Banking*, Vol. 17, No. 4, November, pp. 493–506.
- Aharony, J., Saunders, A. and Swary, I. (1988) 'The Effects of DIDMCA on Bank Stock-holders' Return and Risk', *Journal of Banking and Finance*, Vol. 12, No. 3, pp. 317–331.
- Akella, S.R. and Chen, S.J. (1990) 'Interest Rate Sensitivity of Bank Stock Returns: Specification Effects and Structural Changes', *Journal of Financial Research*, Vol. 13, No. 2, Summer, pp. 147–154.
- Akella, S.R. and Greenbaum, S.I. (1992) 'Innovations in Interest Rates, Duration Transformation, and Bank Stock Returns', *Journal of Money, Credit, and Banking*, Vol. 24, No. 1, February, pp. 27–42.
- Allen, P.R. and Wilhelm, W.J. (1988) 'The Impact of the 1980 Depository Institutions Deregulation and Monetary Control Act on Market Value and Risk: Evidence from the Capital Markets', *Journal of Money, Credit and Banking*, Vol. 20, No. 3, pp. 364–373.
- Andersen, T.G. and Bollerslev, T. (1997) 'Heterogenous Information Arrivals and Return Volatility Dynamics: Uncovering the Long-Run in High Frequency Returns', *Journal of Finance*, Vol. 52, pp. 975–1005.
- Bae, S.C. (1990) 'Interest Rate Changes and Common Stock Returns of Financial Institutions: Revisited', *Journal of Financial Research*, Vol. 13, No. 1, Spring, pp. 71–79.
- Baille, R.T. and Bollerslev, T. (1989) 'The Message in Daily Exchange Rates: A Conditional-Variance Tale', *Journal of Business and Economic Statistics*, Vol. 7, pp. 297–305.
- Bollerslev, T. (1986) 'Generalised Autoregressive Conditional Heteroscedasticity', *Journal of Econometrics*, Vol. 31, pp. 307–28.
- Bollerslev, T. (1990) 'Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalised ARCH Model', *Review of Economics and Statistics*, Vol. 72, pp. 498–505.
- Booth, J.R. and Officer, D.T. (1985) 'Expectations, Interest Rates, and Commercial Bank Stocks', *Journal of Financial Research*, Vol. 8, No. 1, Spring, pp. 51–58.
- Brailsford, T.J., Faff, R.W. and Oliver, B.R. (2000) *Volume 1: Research Design Issues in the Estimation of Beta*, Brailsford, T.J. and Faff, R.W. (eds.), Sydney: McGraw-Hill.
- Brewer, E. and Lee, C.F. (1990) 'An Intracyclical Analysis of the Risk Sensitivity of Bank Stock Returns', *Quarterly Journal of Business and Economics*, Vol. 29, No. 4, Autumn, pp. 125–144.
- Brooks, R.D. and Faff, R.W. (1995) 'Financial Market Deregulation and Bank Risk: Testing for Beta Instability', *Australian Economic Papers*, Vol. 34, pp. 180–199.
- Brooks, R.D. and Faff, R.W. (1997) 'Financial Deregulation and Relative Risk of Australian Industry', *Australian Economic Papers*, Vol. 36, December, pp. 308–320.
- Brooks, R.D., Faff, R.W. and Ho, Y.K. (1997a) 'A New Test of the Relationship between Regulatory Change in Financial Markets and the Stability of Beta Risk of Depository Institutions', *Journal of Banking and Finance*, Vol. 21, pp. 197–219.
- Brooks, R.D., Faff, R.W. and McKenzie, M.D. (1997b) 'Bivariate GARCH Estimation of Beta Risk in the Australian Banking Industry', *Accountability and Performance*, Vol. 3, No. 3, pp. 81–101.
- Brooks, R.D., Faff, R.W. and McKenzie, M.D. (1998) 'Time-Varying Beta Risk of Australian Industry Portfolios: A Comparison of Modelling Techniques', *Australian Journal of Management*, Vol. 23, No. 1, June, pp. 1–22.
- Brooks, R.D., Faff, R.W., McKenzie, M.D. and Ho, Y.K. (2000) 'U.S. Banking Sector Risk in an Era of Regulatory Change: A Bivariate GARCH Approach', *Review of Quantitative Finance and Accounting*, Vol. 14, pp. 17–43.
- Bundt, T.P., Cosimano, T.F. and Halloran, J.A. (1992) 'DIDMCA and Bank Market Risk: Theory and Evidence', *Journal of Banking and Finance*, Vol. 16, No. 6, pp. ??.
- Chamberlain, S., Howe, J.S. and Popper, H. (1997) 'The Exchange Rate Exposure of U.S. and Japanese Banking Institutions', *Journal of Banking and Finance*, Vol. 21, pp. 871–892.
- Chance, D.M. (1979) 'Comment: A Test of Stone's Two-Index Model of Returns', *Journal of Financial and Quantitative Analysis*, Vol. 14, No. 3, September, pp. 641–644.

- Chance, D.M. and Lane, W.R. (1980) 'A Re-Examination of Interest Rate Sensitivity in the Common Stocks of Financial Institutions', *Journal of Financial Research*, Vol. 3, No. 1, Spring, pp. 49–56.
- Choi, J.J. (1986) 'A Model of Firm Valuation with Exchange Exposure', *Journal of International Business Studies*, Vol. 17, Summer, pp. 153–160.
- Choi, J.J., Elyasiani, E. and Kopecky, K.J. (1992) 'The Sensitivity of Bank Stock Returns to Market, Interest and Exchange Rate Risks', *Journal of Banking and Finance*, Vol. 16, pp. 983–1004.
- Choi, J.J., Hiraki, T. and Takezawa, N. (1998) 'Is Foreign Exchange Risk Priced in the Japanese Stock Market', *Journal of Financial and Quantitative Analysis*, Vol. 33, No. 3, pp. 361–382.
- Diebold, F.X. (1988) *Empirical Modelling of Exchange Rate Dynamics*, New York: Springer Verlag.
- Edey, M. and Gray, B. (1996) 'The Evolving Structure of the Australian Financial System', Conference Proceedings of The Future of the Financial System, Reserve Bank of Australia, Research Discussion Paper 9605, <http://www.rba.gov.au/PublicationsAndResearch/>.
- Elyasiani, E. and Mansur, I. (1998) 'Sensitivity of the Bank Stock Returns Distribution to Changes in the Level and Volatility of Interest Rates: A GARCH-M Model', *Journal of Banking and Finance*, Vol. 22, pp. 535–563.
- Eun, C.S. and Resnick, B. (1988) 'Exchange Rate Uncertainty, Forward Contracts, and International Portfolio Selection', *Journal of Finance*, Vol. 43, pp. 197–215.
- Faff, R.W. and Howard, P.F. (1999) 'Interest Rate Risk of Australian Financial Sector Companies in a Period of Regulatory Change', *Pacific-Basin Finance Journal*, Vol. 7, pp. 83–101.
- Flannery, M.J. and James, C.M. (1982) 'The Impact of Market Interest Rates on Intermediary Stock Prices', *Proceedings of a Conference on Bank Structure and Competition*, Chicago, pp. 520–538.
- Flannery, M.J. and James, C.M. (1984a) 'Market Evidence on the Effective Maturity of Bank Assets and Liabilities', *Journal of Money, Credit, and Banking*, Vol. 16, No. 4, November, pp. 435–445.
- Flannery, M.J. and James, C.M. (1984b) 'The Effect of Interest Rate Changes on the Common Stock Returns of Financial Institutions', *Journal of Finance*, Vol. 39, No. 4, September, pp. 1141–1153.
- Flannery, M.J., Hameed, A.S. and Harjes, R.H. (1997) 'Asset Pricing, Time-varying Risk Premia and Interest Rate Risk', *Journal of Banking and Finance*, Vol. 21, pp. 315–335.
- Flood, E. and Lessard, D.R. (1986) 'On the Measurement of Operating Exposure to Exchange Rates: A Conceptual Approach', *Financial Management*, Vol. 15, Spring, pp. 25–36.
- Giliberto, M. (1985) 'Interest Rate Sensitivity in the Common Stocks of Financial Intermediaries: A Methodological Note', *Journal of Financial and Quantitative Analysis*, Vol. 20, No. 1, March, pp. 123–126.
- Goldfeld, S.M. and Quandt, R.E. (1972) *Nonlinear Methods in Econometrics*, Amsterdam: North-Holland Publishing Co.
- Goldfeld, S.M. and Quandt, R.E. (1973) 'The Estimation of Structural Shifts by Switching Regressions', *Annals of Economics and Social Management*, Vol. 2, pp. 475–485.
- Goldfeld, S.M. and Quandt, R.E. (1976) 'Techniques for Estimating Switching Regressions' in Goldfeld, S.M., and Quandt, R.E. (ed.) *Studies in Nonlinear Estimation*, Cambridge, MA: Ballinger Publishers.
- Grammatikos, T., Saunders, A. and Swary, I. (1986) 'Returns and Risks of U.S. Bank Foreign Currency Activities', *Journal of Finance*, Vol. 41, No. 3, July, pp. 671–683.
- Gultekin, N.B. and Rogalski, R.J. (1979) 'A Test of Stone's Two-Index Model of Returns', *Journal of Financial and Quantitative Analysis*, Vol. 14, No. 3, September, pp. 455–461.
- Harper, I.R. and Scheit, T. (1992) 'The Effects of Financial Market Deregulation on Bank Risk and Profitability', *Australian Economic Papers*, Vol. 31, No. 59, pp. 260–290.
- Hirtle, B.J. (1997) 'Derivatives, Portfolio Composition, and Bank Holding Company Interest Rate Risk Exposure', *Journal of Financial Services Research*, Vol. 12, No. 2/3, pp. 243–266.
- Hoenig, T.M. (2000) 'Discussion of The Australian Financial System in the 1990s', Conference on the Australian Economy in the 1990s, Reserve Bank of Australia, July, <http://www.rba.gov.au/publ/>.
- Hogan, W.P. and Sharpe, I.G. (1984) 'Regulation, Risk and the Pricing of Australian Bank Shares, 1957-1976', *Economic Record*, Vol. 60, No. 168, pp. 34–44.
- Izan, H.Y. (1985) 'Testing for Changes in Relative Risk', *Australian Journal of Management*, Vol. 10, No. 1, pp. 39–48.
- Kane, E.J. and Unal, H. (1988) 'Change in Market Assessments of Deposit-Institution Riskiness', *Journal of Financial Services Research*, Vol. 1, pp. 207–229.

- King, B.F. (1966) 'Market and Industry Factors in Stock Price Behaviour', *Journal of Business*, January, pp. 139–189.
- Kwan, S.H. (1991) 'Re-examination of Interest Rate Sensitivity of Commercial Bank Stock Returns Using a Random Coefficient Model', *Journal of Financial Services Research*, Vol. 5, pp. 61–76.
- Lie, F., Brooks, R. and Faff, R. (2000) 'Modelling the Equity Beta Risk of Australian Financial Sector Companies', *Australian Economic Papers*, Vol. 39, No. 3, September, pp. 301–311.
- Lloyd, W.P. and Shick, R.A. (1977) 'A Test of Stone's Two-Index Model of Returns', *Journal of Financial and Quantitative Analysis*, Vol. 12, September, pp. 363–376.
- Lynge, M.J. and Zumwalt, J.K. (1980) 'An Empirical Study of the Interest Rate Sensitivity of Commercial Bank Returns: A Multi-Index Approach', *Journal of Financial and Quantitative Analysis*, Vol. 15, No. 3, September, pp. 731–742.
- Madura, J. and Zarruk, E.R. (1995) 'Bank Exposure to Interest Rate Risk: A Global Perspective', *Journal of Financial Research*, Vol. 18, March, pp. 1–13.
- Martin, J.D. and Keown, A.J. (1977) 'Interest Rate Sensitivity and Portfolio Risk', *Journal of Financial and Quantitative Analysis*, Vol. 12, June, pp. 181–191.
- McClain, K.T., Humphreys, H.B. and Boscan, A. (1996) 'Measuring Risk in the Mining Sector with ARCH Models with Important Observations on Sample Size', *Journal of Empirical Finance*, Vol. 3, pp. 369–391.
- McKenzie, M.D. (1998) 'The Impact of Exchange Rate Volatility on Australian Trade Flows', *Journal of International Financial Markets, Institutions and Money*, Vol. 8, pp. 21–38.
- McKenzie, M.D. and Brooks, R.D. (2000) *Volume 2: Research Design Issues in Time-Series Modelling of Financial Market Volatility*, Brailsford, T.J. and Faff, R.W. (eds.), Sydney: McGraw-Hill.
- McKenzie, M.D., Brooks, R.D. and Faff, R.W. (2000a) 'The Use of Domestic and World Market Indexes in the Estimation of Time-Varying Betas', *Journal of Multinational Financial Management*, Vol. 10, pp. 91–106.
- McKenzie, M.D., Brooks, R.D., Faff, R.W. and Ho, Y.K. (2000b) 'Exploring the Economic Rationale of Extremes in GARCH Generated Betas: The Case of U.S. Banks', *Quarterly Review of Economics and Finance*, Vol. 40, pp. 85–106.
- Merton, R.C. (1973) 'An Intertemporal Capital Asset Pricing Model', *Econometrica*, Vol. 41, No. 5, September, pp. 867–887.
- Mitchell, K. (1989) 'Interest Rate Risk at Commercial Banks: An Empirical Investigation', *Financial Review*, Vol. 24, No. 3, August, pp. 431–455.
- Neuberger, J.A. (1994) 'Interest Rate Risk at US Commercial Banks', Working Paper, Federal Reserve Bank of San Francisco.
- Prasad, A.M. and Rajan, M. (1995) 'The Role of Exchange and Interest Risk in Equity Valuation: A Comparative Study of International Stock Markets', *Journal of Economics and Business*, Vol. 47, pp. 457–472.
- Rosenberg, B. and Perry, P.R. (1981) 'The Fundamental Determinants of Risk in Banking', in Maisel, S.J. (ed.) *Risk and Capital Adequacy in Commercial Banks*, Chicago, University of Chicago Press, pp. 367–423.
- Ross, S. (1976) 'The Arbitrage Theory of Capital Asset Pricing', *Journal of Economic Theory*, Vol. 13, pp. 341–360.
- Saunders, A. and Yourougou, P. (1990) 'Are Banks Special? The Separation of Banking from Commerce and Interest Rate Risk', *Journal of Economics and Business*, Vol. 42, pp. 171–182.
- Schwert, G.W. and Seguin, P.J. (1990) 'Heteroscedasticity in Stock Returns', *Journal of Finance*, Vol. 4, pp. 1129–1155.
- Scott, W.L. and Peterson, R.L. (1986) 'Interest Rate Risk and Equity Values of Hedged and Unhedged Financial Intermediaries', *Journal of Financial Research*, Vol. 9, No. 4, Winter, pp. 325–329.
- Song, F.M. (1994) 'A Two-Factor ARCH Model for Deposit-Institution Stock Returns', *Journal of Money, Credit, and Banking*, Vol. 26, No. 2, May, pp. 323–340.
- Stone, B.K. (1974) 'Systematic Interest-Rate Risk in a Two-Index Model of Returns', *Journal of Financial and Quantitative Analysis*, November, pp. 709–721.
- Sweeney, R.J. and Warga, A.D. (1986) 'The Pricing of Interest-Rate Risk: Evidence From the Stock Market', *Journal of Finance*, Vol. 41, No. 2, June, pp. 393–410.
- Tai, C.S. (2000) 'Time-varying Market, Interest Rate, and Exchange Rate Risk Premia in the US Commercial Bank Stock Returns', *Journal of Multinational Financial Management*, Vol. 10, pp. 397–420.

- Unal, H. (1989) 'Impact of Deposit-Rate Ceiling Changes on Bank Stock Returns', *Journal of Money, Credit, and Banking*, Vol. 21, No.2, May, pp. 206–220.
- Wetmore, J.L. and Brick, J.R. (1994) 'Commercial Bank Risk: Market, Interest Rate, and Foreign Exchange', *Journal of Financial Research*, Vol. 17, No. 4, Winter, pp. 585–596.
- Yourougou, P. (1990) 'Interest-Rate Risk and the Pricing of Depository Financial Intermediary Common Stock: Empirical Evidence', *Journal of Banking and Finance*, Vol. 14, pp. 803–820.