AN EMPIRICAL ANALYSIS OF THE TRANSMISSION OF MARKET MOVEMENTS: LINKAGES BETWEEN EQUITY MARKETS IN THE ASIA PACIFIC REGION

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ARIE DEKKER

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Abstract

This study provides an empirical analysis of the transmission of market movements to examine the linkages between markets, and the efficiency with which innovations between markets are transmitted in the Asia Pacific region. Vector autoregression (VAR) analysis has been carried out on daily data for the period, January 1, 1987 to May 29, 1998, for ten markets in the Asia Pacific region: Australia, Hong Kong, Japan, Malaysia, New Zealand, the Philippines, Singapore, Taiwan, Thailand and the United States. This is the first study, that the author is aware of, to consider the generalised approach to forecast error variance decomposition and impulse response analysis in favour of the traditional orthogonalised approach for studying the linkages between equity markets. The generalised approach is invariant to the order of the variables in the VAR model. Forecast error variance decomposition and impulse response analysis has been used to study the nature of the linkages between markets in the region, and the efficiency with which innovations are transmitted between the markets in the region. The Asia Pacific region is characterised by a number of markets with strong linkages. The dominant influence of the U.S. market in the region is also apparent from the results. The impulse response functions are consistent with the notion of informationally efficient equity markets in the Asia Pacific region. The analysis has been carried out on exchange rate adjusted data as well as local currency data so that the effect of exchange rate risk can be taken into account.

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Introduction

Although Markowitz' (1952) portfolio theory was firmly established in the finance literature by the end of the 1950's, it was not until Grubel (1968) that consideration of the issues relating to diversification outside the domestic market became prominent in the finance literature. Since then, the literature looking at international diversification issues has developed to the extent that it now occupies an important area of continuing research in the finance literature. The fundamental tenet of portfolio theory states that investors can realise gains from portfolio diversification by combining assets with returns that are less than perfectly positively correlated. Because there are a number of factors that will tend to impact on all financial assets, it is obviously very difficult to find assets that are negatively correlated. Assets with low positive correlation coefficients still provide a great deal of benefit for investors. Traditionally investors combined such assets by diversifying in the domestic market.

Grubel (1968) was the first to make the point that investors who simply confine their portfolio choice to the domestic market ignore an obvious and potentially rewarding source of low correlation – assets denominated in equity markets outside the domestic country. Because the returns on assets in foreign markets are derived from unique factors operating in those countries, foreign assets were seen as an attractive choice for investors wanting to diversify away non-systematic risk. The idea was that investors had a better chance of combining assets with low correlation coefficients, if they broadened their investment horizon to include assets from outside the domestic market. The early literature in the area of international portfolio diversification tended to focus on how the unique characteristics of individual markets made portfolio diversification outside the domestic market attractive.

The results from the early empirical analysis looking at investment opportunities for investors wanting to diversify outside their domestic market generally confirmed the idea of partially isolated world equity markets. These studies revealed that there were gains available for investors seeking investment opportunities in foreign markets. The findings generally confirmed the notion that markets were largely independent of each other due to the unique economic and monetary policies operating in foreign markets. At the time, international trade was a lot less prevalent than it is today, especially between geographically isolated markets, resulting in further independence between markets. By the end of the 1970's, however, evidence started to point to stronger linkages between world equity markets. The gradual removal of trade barriers, floating exchange rate regimes, and technological advancement, have all contributed to the increasing integration of world financial markets. The integration of markets continued to strengthen in the 1980's and 1990's.

The increasing integration of world financial markets would obviously have a large impact on the potential benefits from diversifying in foreign markets. As integration increases, the advantage of foreign assets over domestic assets is obviously reduced. This reduces the attractiveness of diversifying outside the domestic market, particularly given the generally higher costs involved in investing overseas. Clearly the integration of financial markets would tend to be emphasised by a worldwide financial crisis. The October 1987 stock market crash, with its impact on equity markets around the world, emphasised for many investors just how integrated financial markets around the world had become. The October 1987 stock market crash renewed interest in the finance literature looking at the comovements between markets. The focus of the literature after 1987, moved away from examining the benefits that might accrue for investors from diversifying outside the domestic market. The focus also turned away from studying the relative degrees of integration between financial markets. Instead, the literature began to more formally consider the nature of the linkages between equity markets and the transmission of market movements between equity markets.

Not surprisingly, the early literature after the 1987 stock market crash examined the association between volatility and comovement between markets. A strong relationship between comovement in equity markets and high levels of volatility was found. The evidence from the 1987 crash also sparked interest in the efficiency with which innovations in a particular market are transmitted through equity markets around the world. The role of volatility and the transmission of volatility between markets has become increasingly prominent in the literature since the crash. If markets exhibit greater co-dependency, volatility in one market, particularly a major market, is likely to filter through and be felt in other markets. There was evidence of this phenomenon in October 1987, which has been reinforced by the 1997 'Asian crisis'. Worldwide financial crises themselves tend to lead to greater comovement between markets. This is, at least in part, "because only larger price changes pierce the transaction cost barriers between markets, associations between markets will appear to be stronger in periods of unusually large price volatility." (Neumark, Tinsley & Tosini, 1991, p. 160).

Given the general consensus that markets are neither fully segmented nor fully integrated, but instead partially integrated, the research now focuses on testing the linkages between markets and the efficiency with which markets respond to shocks in different markets. The comovement between markets itself, has become less of a focus in the literature. Instead of simply using pairwise correlation coefficients to examine the comovement between markets, multivariate techniques are used to study the underlying linkages between markets and the efficiency with which markets respond to shocks in other markets. After the early tests established the association between volatility and comovement, more sophisticated techniques were employed to look at the linkages between markets and the transmission of market movements. Because it is so well suited to exploring the linkages between markets and the transmission of market movements, vector autoregression (VAR) analysis is the primary tool used in this study.

The data set for this study focuses on ten markets in the Asia Pacific region using daily data for the period from January 1, 1987 to May 29, 1998. The markets studied are Australia, Hong Kong, Japan, Malaysia, New Zealand, the Philippines, Singapore, Taiwan, Thailand and the United States. Four of these markets have been classified as emerging markets: Malaysia, the Philippines, Taiwan and Thailand. The remaining markets are considered developed markets. Because of their strong growth, emerging markets are often seen as an attractive investment opportunity for international investors who can take advantage of the lower comovements that they have with more developed markets. The strong growth that characterised many of the Asia Pacific markets in this study, and the emerging markets in particular, during the 1980's and for much of the 1990's resulted in a great deal of interest from international investors in these markets. More recently, the finance literature has also begun to examine these markets.

The VAR technique used in this study produces two important outcomes: forecast error variance decomposition and impulse response analysis. Forecast error variance decomposition allows the researcher to see how much of the variance in one market is explained by innovations in the other markets and vice versa, while impulse response analysis is useful for determining how markets react to shocks in other markets. VAR analysis has been used to answer the two central questions in this study:

1. To what extent are markets in the Asia Pacific region linked and what are the key linkages between these markets?
2. How efficiently are innovations in one market transmitted to the other markets in the region?

Multivariate cointegration has also been used to complement the VAR analysis and test whether a stable long-run relationship between the markets exists.

It is important to emphasise that this study focuses on the linkages between markets in the Asia Pacific region. The purpose of this study is not look at portfolio selection issues as they arise in the Asia Pacific region. In fact, this study makes no attempt at all to suggest how investors might go about combining stocks from the Asia Pacific region given the comovement and linkages that exist between the markets. While some general comments are made about the implications for investment in the region arising from the study's findings, these comments are general rather than specific. Apart from anything else, there is a quite practical explanation for leaving out portfolio selection issues. This arises from a limitation in studies of this kind which use stock exchange indices to proxy investment opportunities available in different equity markets. Clearly, indices do not properly reflect the investment opportunities available to investors. Investors tend to choose from among individual stocks rather than market indices. Ripley (1973) does suggest, however, that "a stock price index, while not accurately reflecting the variation of any one stock price does present a good description of general market movement." (p. 357). The following point is also pertinent. Investors can make better bets against the market, once they understand the broader relationship between the markets.

The empirical analysis in this study has also been carried out on exchange rate adjusted data. Using local currency stock index data ignores an important potential source of risk to investors investing in foreign equity markets - exchange rate risk. Using local currency stock index data assumes that investors have hedged their exposure to currency risk. This assumption is not necessarily valid given the expense involved in hedging. Because of this the empirical analysis in this study was also conducted on stock index data, expressed in U.S. dollars. Using U.S. dollar index data insures that exchange rate risk is also factored into the linkage structure between markets. The choice of the U.S. dollar was not arbitrary, nor was it made with the intention of making the study from a U.S. investor's perspective. The choice reflects the dominant role of the U.S. dollar in international trade and investment.

In relation to the two central questions posed in this study, the results from the empirical testing have provided strong conclusions. The results from the exploratory analysis, cointegration analysis and vector autoregression analysis have all complemented each other and provide consistent evidence of linkages between markets in the region. The VAR analysis has also provided a very strong indication of the efficiency with which information is transmitted between markets. There are a number of markets in the Asia Pacific region that have very strong linkages. The strongest linkages are between markets with strong economic ties and close geographic proximity like Singapore, Malaysia and Hong Kong, and Australia and New Zealand. These markets are also the most endogenous in the region. The emerging markets of the Philippines, Taiwan and Thailand have the weakest linkages with other markets in the Asia Pacific region. This result is consistent with the unique influences which characterise emerging markets and tend to isolate them from developed markets.

The U.S. market is clearly the most dominant market in the region. The U.S. market has a strong influence on almost all of the markets in the region, yet is itself not influenced by any of the other markets. The Japanese market, the only market comparable to the U.S. in capitalisation size, has very little impact on the other markets in the region. Even when the U.S. market is excluded from the system, it does not exert itself. More consistent with its size, the Japanese market is not influenced by movements in the other markets. The Hong Kong market appears to be the most interactive market in the region. Innovations in the Hong Kong market influence a number of the other markets in the region, especially the Asian markets. The Hong Kong market is also very endogenous, influenced by innovations in a number of the markets in the region.

The results from the impulse response analysis confirm the linkages between markets found in the forecast error variance decomposition. Not surprisingly, markets that have strong linkages also show large responses to shocks in the markets with which they are linked. More importantly, the impulse response analysis shows that the reactions of markets to innovations in other markets is very quick. The transmission of information between markets is very efficient. This suggests that there is very little opportunity for investors to profit on the lag between a shock in one market, and the response in the other markets. The emerging markets of the Philippines, Taiwan and Thailand do not respond quite as efficiently as the other markets in the region. Even for these markets there are no significant delayed responses.

In terms of investment opportunities for diversification, the generally strong nature of the linkages between markets in the region tends to suggest that the gains from portfolio diversification might not be as great as suggested in the early literature. The emerging markets of the Philippines, Taiwan and Thailand may provide some opportunity for risk reduction through portfolio diversification because of the weaker linkages between these markets and the developed markets. The efficiency with which innovations are transmitted between markets also suggest that there is little to be gained by trying to profit on the lag between innovations in one market and the response of another. Again the emerging markets of the Philippines, Taiwan and Thailand present some opportunity, although the weaker linkages of these markets means that the responses to shocks tend to be very small anyway.

The rest of this study has been separated into three parts. An extensive review of the literature relating to issues of global investment and the linkages between world equity markets is provided in Part one. Chapter 1 follows the early development of the literature relating to portfolio diversification in an international setting. The necessary and sufficient conditions for such investment are established. Chapter 2 looks at volatility and the transmission of volatility between markets. Chapter 3 presents the literature that has explored the linkages between markets and the transmission of market movements. Part two presents the data and methodologies used in this study. The data is described in Chapter 4. Chapter 5 presents the methodology used for testing for stationarity in the variables and cointegration amongst the variables, while Chapter 6 provides a comprehensive description of the VAR methodology. Part three provides the results and analysis. The exploratory analysis is presented in Chapter 7. Chapter 8 presents the results from tests of stationarity and cointegration, while the VAR results are discussed in Chapter 9. The conclusions from the empirical analysis carried out in Part three are presented in Chapter 10, which summarises the study's major findings.

PART ONE

LITERATURE REVIEW

An extensive review of the literature relating to international equity market issues is provided in Part one. Linkages between equity markets and the transmission of market movements in the Asia Pacific region is the focus of this thesis. The literature review creates the context within which this area of the finance literature has developed. The literature in this area, particularly the early literature cannot be separated from issues relating to portfolio diversification in an international setting. Although the principles behind portfolio diversification were firmly established in the finance literature in the 1950s, diversification in an international context was not formally considered until Grubel (1968). Chapter 1 reviews the early literature relating to portfolio diversification in an international setting. The early literature established the necessary and sufficient conditions for the realisation of gains from diversification outside the domestic market. Chapter 2 considers the increasingly important area of volatility in equity markets and its effect on the comovement of equity markets around the world. The literature in this area flourished after the stock market crash of October 1987, which had a significant worldwide impact. Chapter 3 considers issues relating to market efficiency in world equity markets and the linkages that bind equity markets from different countries. The increasing integration of financial markets and the effect of volatility in world markets has led to increasing interest in this area.

Chapter 1: International Portfolio Diversification - A Review Of The Early Literature

The issue of portfolio diversification in equity markets around the world came into prominence with the seminal article of Grubel (1968). Chapter 1 reviews some of the most important articles to appear in the early literature. A review of the early literature establishes the context within which the area of international equity market linkages has developed. Chapter 1 looks at the establishment of the necessary and sufficient conditions for the realisation of gains from portfolio diversification in an international setting. Lead and lag relationships between world equity markets are also introduced. While issues of portfolio diversification outside the domestic market may be the focus of the articles in this chapter, it is important to note that implicitly, these articles provide the early consideration of the extent to which world equity markets are linked, and the reasons for these linkages.

1.1 Comovement Between World Equity Markets

In this section the necessary condition for the realisation of gains from portfolio diversification in an international setting is considered. The necessary condition is that the correlation coefficients between world equity markets must be lower than those found between domestic assets - otherwise one can obtain the risk-reduction benefits of portfolio diversification by simply investing in the domestic market. Grubel (1968) laid the theoretical foundations for portfolio diversification in an international setting. Although Markowitz (1952) and Sharpe (1964) had clearly established the tenets of portfolio theory and developed selection techniques for portfolio optimisation, it was not until Grubel that portfolios diversified in assets, from outside the domestic market, were formally considered in the literature. Grubel pointed out that investors who did not consider foreign assets were ignoring a potentially important source of low correlation.

Grubel used the special case of a two-country two-asset investment model, where as long as less than perfect correlation exists between the two countries, diversification of investment will benefit investors. Grubel's revelation offered nothing particularly new in terms of portfolio optimisation except that it highlighted the importance of considering international assets. Further, the outcome of the special case is unlikely to hold where more than one domestic asset exists and internally diversified portfolios are an option. Grubel's (1968) empirical study examined the range of potential gains to United States (U.S.) investors from international diversification which Grubel found to be potentially large. Grubel's investigation of portfolio diversification provided a descriptive explanation of why international capital flows exist and as such remains important in highlighting a previously neglected area in the literature.

Subsequent authors starting with Levy and Sarnat (1970) looked at international portfolio diversification from a normative stance. Levy and Sarnat used efficient frontiers and the market equilibrium model developed by Lintner (1965) and Sharpe (1964) to determine the proportion of investment in each of the various markets in their sample, at different interest rates. Levy and Sarnat were able to clearly demonstrate the benefits of diversifying outside the domestic market, for the U.S. investor. They did point out, however, that the benefits were only marginal for moving from a U.S. stocks only portfolio to one containing stocks from high income, common market or Western European countries. It was only when the American investor diversified to include countries such as Japan and South Africa and the developing countries of South America and Asia that a significant improvement in the efficient frontier resulted. These countries tend to have lower correlations with the U.S. market, and hence are able provide the benefits of diversification to the investor.

Grubel and Fadner (1971) highlighted two important influences not encountered by U.S. assets which might result in lower inter-country correlation coefficients and make foreign assets attractive to U.S. portfolio holders. First, returns on foreign assets are influenced by business cycles, natural and man-made catastrophes and government policies whose effects are limited to or felt most strongly in the economies of the affected countries. Second, the capital value changes of assets due to exchange rate variation influence the variance of returns on foreign assets. Grubel and Fadner attempted to measure the strength of those two factors by considering the *ex post* variance-covariance matrices of returns for industry subindices from U.S., U.K, and West German stock indices. They found that the pairwise inter-country correlation coefficients were low positive and certainly lower than intra-country coefficients. Solnik (1974) also suggested that inter-country differences in business cycles provide a means to benefit from international portfolio diversification. Solnik demonstrated the level of risk reduction as more and more stocks are included in a portfolio. For portfolios diversified in assets from outside the domestic market, the reduction was clearly greater than for domestic stock only portfolios. Even after allowing for exchange rate fluctuations, the risk was still less for portfolios diversified in foreign assets.

An assumption implicit in these early studies, is the hypothesis that international diversification will result in larger gains than ordinary 'pure diversification' gains arising from increasing the universe of available securities within a single country. The early studies can also be characterised by their focus on the gains for foreign market diversification from a U.S. investor perspective. Lessard (1974) characterises the early tests well:

> "The early tests of Grubel (1968) and Levy and Sarnat (1970) relied on low correlations between the various national markets and the performances of *ex post* efficient internationally diversified portfolios to establish these greater gains. However, the low correlations among markets may or may not indicate large potential gains relative to domestic diversification depending on the correlations among groups of stocks in each market and the *ex post* efficient portfolios are, at best, indicative of gains." (p. 379).

Research by Agmon (1972) and Lessard (1976) considered the concept of segmented versus integrated capital markets. Lessard (1973, 1974) highlighted the difference between gains from domestic versus inter-country portfolio diversification alluded to above. These two areas took a fresh approach to portfolio diversification in an international setting and were important in developing this area of the literature. They are considered below.

Agmon (1972) pointed out that the literature up until that point had approached national capital markets based on a segmented markets approach where national capital markets are separate entities, hardly related to each other, as in Grubel's (1968) two-country, two-asset model. For this reason, one might naturally assume low correlation coefficients between markets. Agmon notes that "different currency areas, separated political organisations and trade barriers have been given as *a priori* evidence for the segmentation of the international capital market." (p. 839). Agmon argues that the alternative hypothesis, that prices of capital assets in the global capital market behave as if there is one multinational perfect capital market should also be considered and that an examination of the behaviour of capital asset prices reveals that the price behaviour is consistent with the one market hypothesis.

In terms of Grubel's (1968) two-country, two-asset framework, Agmon (1972) argues that, while still important, the more interesting question relates to how the opening of economic relations between the two countries affects the composition of investment portfolios, an issue that could not be addressed by Grubel since the full risk-return profile for each of the markets is not captured by the market index used in Grubel's study. Agmon points out that while it is correct in terms of

Grubel's theoretical two-country, two-asset world to look at portfolio diversification in terms of correlation, the empirical analysis conducted by Grubel was based on market indices which are composed of many shares and are only close approximations to diversified portfolios. When comparing two portfolios, domestic and foreign, the relevant measure is a function of the covariance between the return of any given asset and the return on the investor's portfolio. It may be that, even in situations like the one presented by Grubel, that investors cannot benefit from diversification between countries.

Agmon could not accept Grubel's assumption that, given equity markets are segmented, correlation coefficients substantially less than unity between any index of non-U.S. equity markets and the U.S. market index would give U.S. investors potential welfare gains from international diversification, the benefits accruing once the barriers among equity markets were removed. Because composite market indices do not capture all the possibilities for diversification within a local market, the fact that two indices are weakly correlated does not necessarily imply the superiority of international diversification over internal diversification. Because of this, one cannot be sure that internal diversification would not give the same (or better) efficient sets. The one market hypothesis may have an advantage here since it implies that all the potential gains from inter-country and internal diversification are already reflected in the current prices of capital assets traded on the world market. Using individual stock returns from four countries, Agmon presented a framework of a single equity market and showed that price behaviour in these countries was consistent with the single market hypothesis. Despite the barriers that exist in multinational equity markets, a strong relationship among the four equity markets was present. In particular, Agmon notes that the price movement in the majority of German shares was indistinguishable from U.S. shares. Agmon highlights the importance of not simply accepting the segmented markets hypothesis.

McDonald (1973) also highlighted the need for caution in interpreting the studies of Grubel (1968) and Levy and Sarnat (1970).

> "In the context of portfolio choice these results must be interpreted with caution, as one cannot demonstrate with *ex post* returns on market indices alone the extent to which international diversification is desirable. The important question is whether efficient (*ex ante*) multinational portfolios of individual securities dominate efficient portfolios constructed from stocks in a single country, and on this issue the evidence is limited." (pp. 1161-1162).

McDonald notes that the issue also rests on the effective degree of integration of the world's equity markets. McDonald suggests that due to impediments in multinational investment, reality lies somewhere between two hypotheses discussed by Agmon (1972): the fully-integrated one-market hypothesis; and the fully-segmented market hypothesis. In the former, the CAPM model of capital market equilibrium would include portfolios of domestic common stocks from a number of nations lying along a common capital market line; for the latter, one would expect a unique capital market line in each national market. "In fully-integrated markets, a portfolio which purchased common stocks in a second country would gain only the 'pure diversification' advantage of access to a larger part of the total universe of securities. The segmented-market hypothesis implies potential advantages from international investment beyond those associated with pure diversification, as more favourable ratios of expected return to non-diversifiable risk may be available in foreign markets." (McDonald, 1973, p. 1162). McDonald measured the investment performance of French mutual funds as examples of portfolios diversified outside the domestic market and found that the funds generally produced superior risk-adjusted returns than funds invested only in domestic assets.

Lessard (1976) also considered the debate relating to segmented versus integrated markets. The following passage captures the importance of segmented versus integrated markets in establishing the theory of portfolio diversification in an international context.

> The low correlations between the country factors represent the key to gains from international diversification. The magnitude of these gains will depend, however, on whether markets are segmented or integrated internationally. In the former case, assuming the validity of the capital asset pricing model, prices and expected returns are determined by the undiversifiable risk of each security in the context of the appropriate national portfolio. In the latter, prices and expected returns are determined by the undiversifiable risk of each security in the context of the world portfolio. With fully integrated markets, the advantage to international diversification is a pure diversification effect, a reduction in the non-systematic risk of the portfolio. With fully segmented markets gains might be even greater, since prices would adjust to reflect the fact that some previously undiversifiable risk was becoming diversifiable." (Lessard, 1976, p. 34).

Unfortunately it is very difficult to actually determine which of the two conflicting theories most accurately describes portfolio diversification in an international setting. The most likely answer, and the one that will have to suffice, is that reality lies somewhere between the two extremes.

Lessard (1973) looked at the communality among returns within individual countries relative to the communality across countries. Using an Investment Union (IU) approach for four Latin American countries, multivariate analysis of the return structure for individual stocks was used to examine the possibility of greater gains for inter-country diversification over domestic diversification. For gains from inter-country diversification to be greater, two important conditions must be met. Firstly, returns within each country need to share a strong common element of variance, and secondly, the common elements for each country must be largely independent of those from the other countries. Using principal component analysis, Lessard found "...that even though the principal components for each country are not absolutely independent, it is possible to explain an average of 93 per cent as much variance for each country as is explained by the principal components with four completely *independent* factors." (p. 625). This demonstrates that the conditions for substantial gains from an IU exist among this group of countries.

This is an important finding since it again highlights the benefit of inter-country diversification over domestic diversification. It shows that while the benefits of domestic diversification are limited due to the common trend in stock returns, potential benefits are much greater by diversifying outside the domestic market because common trends are much more difficult to find between countries. Lessard attributes this to different levels of economic activity at different times and the different monetary and fiscal policies of different governments. Although different methodologies were applied, Lessard's findings are consistent with what McDonald (1973) found for French mutual funds.

Lessard (1974) continues to examine the benefits of diversifying outside the domestic market relative to domestic diversification by considering the stochastic process generating returns. Lessard notes that in previous studies which have used a CAPM market model, national markets have been found to be characterised by a strong market factor consistent with a single-factor stochastic process. Because of the linkages between national markets, one might expect some relationship between market factors in different countries. However, Lessard finds that only a small part of these factors can be explained in terms of a common world factor. In finding that only a small proportion of the variance of national portfolios is common in an international context, Lessard demonstrated the considerable risk reduction available through portfolio diversification in an international setting.

The literature reviewed in this section was important in establishing portfolio diversification in an international setting to the finance literature. Grubel (1968), Levy and Sarnat (1970), Grubel and Fadner (1971) and Solnik (1974) all highlighted that lower correlation coefficients between national equity markets meant that additional benefits were available to investors who diversified outside the domestic market. Agmon (1972), McDonald (1973) and Lessard (1976) looked at the segmented versus integrated market hypotheses, providing a context in which the early studies of portfolio diversification in an international context should be viewed. They showed that it was important to consider the assumptions being made in testing the benefits of portfolio diversification in an international setting. Lessard (1973, 1974) provided further evidence to support the notion of additional benefits offered by portfolios diversified outside the domestic market, over portfolios with domestic assets only.

1.2 Inter-temporal Stability In The Comovement Between World Equity Markets

In the previous section the necessary condition for the realisation of gains from portfolio diversification in an international setting was considered. While correlation coefficients between world equity markets lower than those between domestic assets may provide the necessary condition for the realisation of gains from portfolio diversification in an international setting, the sufficient condition must also be met. The sufficient condition requires that it must be possible for the investor to predict the future relationship among the price movements of two or more world equity markets. In other words the *ex post* correlation structure must be stable so that it can be used for *ex ante* investment decisions.

"In practice, this [sufficient] condition will be met if *either* the relationships among the various stock markets and their price movements (and variances in price movement) are stable over time so that a diversified portfolio can be selected strictly on past performance, *or* if the investor has information about the relationships among the various stock markets in order to be able to make diversified portfolio decisions on the basis of some leading indicator." (Makridakis and Wheelwright, 1974, p. 197). Given the general consensus accorded to weak form market efficiency, tests of stability in the inter-temporal relationships between markets have become an important topic in the literature relating to portfolio diversification in an international setting. This is because the "… inter-temporal instability of the correlation structure implies that the efficient frontier is continuously changing so that the selection of an *optimal ex ante* investment strategy would be extremely difficult for the investor to identify." (Maldonado and Saunders, 1981, p. 55).

Makridakis and Wheelwright (1974) provide one of the first tests for inter-temporal stability in the relationship between markets. Ripley (1973) had already provided a structurally-oriented paper, which used factor analysis to identify four factors that accounted for more than half of the common movement among 19 major world equity markets. Ripley, however, did not offer any evidence of the stability or otherwise of this relationship. Makridakis and Wheelwright used principal component analysis for three subperiods between January 1968 and September 1970 to analyse the daily stock indices of fourteen national markets. They tested whether the interrelationship between markets was stable or whether future relationships could be forecast. Makridakis and Wheelwright found that the interrelationship between the major stock exchanges were unstable over time. They also found that, at least up until that point, no way had been found to predict the form of these possible interrelationships before the fact.

Makridakis and Wheelwright's results had major implications for portfolio diversification in an international setting - it meant that the realisation of gains from such diversification might be difficult to achieve. Makridakis and Wheelwright demonstrated that their results were totally consistent with what one would find if they compared the correlation coefficients for returns found by Grubel (1968) and Levy and Sarnat (1970) for the same countries using different time periods. Correlation coefficients between the U.S. and other countries differed substantially between the two studies. While the technique used by Makridakis and Wheelwright was fairly naïve, their study was important in signaling a new direction for the literature on portfolio diversification outside the domestic market.

Panton, Lessig, and Joy (1976) provided another of the early tests for inter-temporal stability. They also noted "... that in an examination of comovement structure a measure of structural stability is equally as important as the characterisation of the structure over a specific time period." (p. 415). They used cluster analysis on the correlation matrix which allowed them to identify groups and subgroups of countries having highly similar or dissimilar comovement characteristics. They used a much wider time period than Makridakis and Wheelwright (1974) used and looked at 12 countries for a ten-year period between 1963 and 1972. Two important questions were considered by Panton, et al. The first related to whether there is a discernible comovement structure in national equity markets; the second considered whether this structure had changed over time? Panton, et al. look for structural stability using ten one-year periods where the stability of adjacent one-year period pairs is investigated. The stability of eight overlapping three-year periods and two five-year periods is also tested. There is, of course, some repetition in this analysis but it is employed since it is not possible to specify *a priori* what the appropriate time frame for structural analysis is.

Because dendrograms provide only a visual indication of the level of stability, a technique called cophenetic correlation was used as an indicator of similarity among the structures. The results of the cophenetic correlations are produced in Table 1.1. The three-year time periods provide the best support for stability in the comovement patterns of national markets with each of the five cophenetic correlations significantly positive at the 0.01 level. The results also show that stationarity is more apparent over a longer time period than one year. The five-year results indicate some degree of comovement pattern stability (significant at the 0.10 level) but not as much as in the one-year and three-year results. Looking at the results in aggregate, the evidence points to short-run stability in the comovement of national equity markets, but does not support stability in the longer-run. This suggests that the use of *ex-post* correlations coefficients for *ex-ante* portfolio selection techniques is likely to be most useful for reasonably short-run horizons. For investors with investment horizons longer than one to three years the result is not particularly encouraging.

Table 1.1

COPHENETIC CORRELATIONS OF OBSERVED STRUCTURES IN CONTIGUOUS TIME PERIODS

(a) One-Year Periods		(b) Three-Year Periods		(c) Five-Year Periods	
Years	Cophenetic Correlations	Years	Cophenetic Correlations	Years	Cophenetic Correlations
63-64	.179*	[63,64,65]–[66,67,68]	.328***	[63-67]-[68-72]	.179*
64-65	.427***	[64,65,66]–[67,68,69]	.338***		
65-66	.406***	[65,66,67]–[68,69,70]	.289***		
66-67	.243**	[66,67,68]–[69,67,71]	.406***		
67-68	.223**	[67,68,69]–[70,71,72]	.489***		
68-69	.370***				
69-70	.481***				
70-71	.450***				
71-72	.173*				

* Significant at the .10 level. ** Significant at the .05 level. *** Significant at the .01 level.
Reproduced from Panton, et al. (1976, p. 424).

Panton, et al. go on to investigate the structural features, producing one-year, three-year and five-year dendrograms. A dendrogram for the complete ten-year period was also produced. The structural properties of the ten-year dendrogram were found to be remarkably similar to those of the shorter periods. Dendrograms reveal groupings that have highly similar comovement characteristics and Panton, et al. uncover some interesting structural features. There seemed to be a core of national markets that have higher degrees of similarity that differentiate them from the other markets. These markets (the U.S., Canada, the Netherlands, Switzerland, West Germany and to a lesser extent, Belgium) can generally be described as relatively well developed and open to international capital flows which might explain why they are similar.

Watson (1980) examined the stationarity of the correlation coefficients between the monthly returns of the share market indices from eight industrial countries between January 1970 and December 1977. The inter-country correlation coefficients were calculated over one-year, two-year and four-year sub-periods. Consistent with earlier studies, Watson found results consistent with the necessary condition for the realisation of gains from portfolio diversification with inter-country correlation coefficients substantially less than positive one (an average of approximately 0.45). Two tests of stationarity were used. Firstly, the inter-country correlation coefficients were tested to see whether they changed significantly, either from one two-year sub-period to the next, or between the two four-year sub-periods. Watson found that the inter-country correlation coefficients did not generally change significantly from one sub-period to the next over the eight year period of the study. In the second test, the annual inter-country correlation coefficients were regressed over the eight-year period of the study to determine whether they varied significantly with time. The results of this test also found in favour of stationarity, with none of the inter-country correlation coefficients significantly time dependent at the five per cent level.

The three studies considered so far have produced inconsistent results. Maldonado and Saunders (1981) highlight one of the major downfalls in the early tests on inter-temporal stability.

> "The usual approach with respect to the sample period has been to divide the sample in two, with the division normally associated with a test of some specific hypothesis, such as the effects of a change in exchange rate systems on the correlation matrix. While a division along these lines may be a useful test of the effects of a change in exchange rate regimes, it is a poor test of inter-temporal stability, because only two sample observations are drawn from the whole possible distribution of correlation coefficients." (p. 54).

Maldonado and Saunders studied a large 22 year sample period from 1957 to 1978 and considered the correlation of returns for the U.S. and four foreign stock market indices (Japan, Germany, Canada, and the United Kingdom). The study takes the point of view of U.S. investors over different time horizons. Their *a priori* assumption is interesting and worth noting.

> "... we expected *a priori* that there would be international factors present (see Lessard (1974)) that would produce a degree of stability in the correlation structure between their stock markets over time. Following Lessard (1974) and Solnik (1974) we can view a country's stock returns as being generated by some (common-to-all) world factor and some national factor(s). The more integrated the economies of the world, the greater the importance of this world factor, and the more similar the return-generating functions for each country will be. Consequently, in this case, as the world factor changes, inter-country returns will tend to move together (in the same direction) over time, generating high and relatively stable inter-country correlations." (p. 55).

Based on their empirical evidence, Maldonado and Saunders findings largely reject such a view.

To start with, Maldonado and Saunders tested to see whether the correlation time series was inter-temporally random by testing whether it followed a random walk. If it does then *ex ante* planning of optimal international portfolio investments is rendered extremely hazardous. If the annual correlations are generated by the first-order process described in Equation (1.1) below:

$$\rho_{ijt} = \beta\rho_{ijt-1} + e_t \qquad (1.1)$$

where

$E(e_t) = 0$;

$Cov(e_t, e_{t-1}) = 0$; and

$E(e_t, e_{t-1}) = \sigma^2$,

then randomness requires β to be insignificantly different from zero. For each of the four correlations with the U.S., Maldonado and Saunders found values of β insignificantly different from zero at the 1% level, and the D.W. statistics indicate the absence of first-order autocorrelation in the residuals. Therefore, the hypothesis that these annual correlations have followed a random walk, *ex post*, cannot be rejected.

While the random walk model assumes a rather simple first-order generating process, there may be a more complex generating process, which if identifiable could be used to provide important informational content to the investor diversifying outside their domestic market. Maldonado and Saunders used Box-Jenkins techniques to see if higher-order lag relationships could be identified but found no autocorrelation coefficient significant at the 5% level. Even after using a more complex Box-Jenkins generating process, no empirical evidence in support of a stable underlying correlation structure between the stock indices could be found. Finally, a non-parametric runs test was conducted to look for serial dependence. Again, randomness could not be rejected with the Z-statistic indicating randomness in three out of the four cases at the 5% level of confidence. The exception was the correlation between the U.S. and Germany where randomness could not be rejected at the 1% level.

Maldonado and Saunders employed the same tests for quarterly and biennial correlation coefficients. The collective results revealed that in the very short-term (up to two quarters), there is a relatively predictable relationship between inter-country correlations, which is good news for an investor with a very short-term strategy. Beyond two quarters, inter-country correlations were found to be generally unstable. Maldonado and Saunders therefore find that the 'practical' use of mean-variance models as devices for determining *ex ante* optimal globally diversified portfolios has very limited use beyond short run investment horizons. The result is surprising in view of two widely held beliefs: (1) that there are important international factors present in national stock market returns; and (2) that these factors have been strengthened over time through international trade and investment.

Philippatos, Christofi and Christofi (1983) also noted the inconsistency in tests of inter-temporal stability in world equity market comovement patterns. Their view was that the early tests confounded the central issue of stationarity by employing different methodologies, separate sample countries, dissimilar sample periods, and variable differencing intervals. They acknowledged that the study by Maldonado and Saunders (1981) had added to the pool of knowledge concerning inter-temporal stability, but highlighted five problems with that and other early studies. The problems are summarised below:

1. The presence of different exchange rate regimes needs to be recognised.
2. Utilisation of the full-covariance model requires that the entire correlations matrix be analysed rather than only the part relating the U.S. to other countries.[1]
3. The investment horizons tested must be extended beyond one-to-two years, as many investors will have horizons greater than such a period.
4. The analysis of stationarity patterns requires that the full sample of fourteen industrial countries be examined rather than the smaller sample of countries used in most studies.
5. One must recognise that the proper utilisation of Box-Jenkins techniques to identify possible patterns among correlations requires that the minimum sample size be much larger than that employed in studies such as Maldonado and Saunders.

Philippatos, et al. attempted to rectify these problems by considering fourteen industrial countries between 1959 and 1978. Using Principal Component Analysis, they found strongly in favour of stability in the inter-temporal relationships for intermediate-term investment horizons. For shorter-term structural stability, Philippatos, et al. found mixed results in contrast to the conclusive evidence against stability found by Maldonado and Saunders. They suggest that the analysis of a small part of the correlation matrix coupled with the small sample of five countries is apparently not representative of market behaviour in the industrialised world. Further, the utilisation of Box-Jenkins techniques was not warranted with the few observations available in Maldonado and Saunders (1981). Finally, the inclusion of 1957 and 1958 – a period when most European countries moved toward full currency convertibility – simply compounded the difficulties of interpretation by obscuring the nature of the relationships during the subsequent years.

In contrast to the findings in the previous section regarding the necessary condition for international portfolio diversification, it is quite clear from the evidence presented in this section that the issue of inter-temporal stability in the relationship between world equity markets was not conclusively solved in the early literature. More work is clearly required in this area if *ex-post* data is going to be used in mean-variance analysis to find optimally diversified portfolios in an international setting.

[1] Maldonado and Saunders' (1981) analysis should have been carried out on $(N^2-N)/2 = 10$ correlations rather than the four correlations they used.

1.3 Lead-lag Relationships Between World Equity Markets

Lead-lag relationships and the linkages between world equity markets were considered by a small number of authors in the early literature. The most notable studies were by Granger and Morgenstern (1970), Agmon (1974), and Hilliard (1979). Granger and Morgenstern who used spectral analysis on weekly data for stock indices in eight countries concluded that "contrary to widespread beliefs, there is little or no interrelationship between different stock market exchanges around the world." (p. 234). The only relationship Granger and Morgenstern were able to detect was a small relationship between Amsterdam and New York, and Amsterdam and Germany. They did, however suggest that markets would be less likely to be independent if a worldwide financial crisis occurred or a war began. Agmon (1974) did not find any significant leads or lags either. Agmon used monthly stock data from the common stocks of Germany, Japan, the United Kingdom, and the United States. The findings by Granger and Morgenstern and Agmon are consistent with those in the first section where low comovement between world equity markets was found.

Hilliard (1979) provided one of the first papers to specifically examine the structure of world equity markets during a worldwide financial crisis, thereby providing a test of Granger and Morgenstern's contention that during a worldwide financial crisis, markets were more likely to be related. Hilliard examined the period from July 7, 1973 to April 30, 1974 – a period that included an event of significant world wide impact, the OPEC Embargo, announced on October 18, 1973. Daily data for the major industrial indices on 10 world exchanges was used. The assumption is that the embargo should have operated as a common external variable, introducing comovement into world equity markets. "*A priori,* our expectations were two-fold. First, we expected significant coupling (comovement) among world equity indices. Second, in keeping with efficient markets, we expected that if coupling exists between markets, there should be no lag in real time reactions among the indices." (Hilliard, 1979, p. 104).

Not surprisingly, Hilliard's results were in contrast with those of Granger and Morgenstern (1970) and Agmon (1974). They were, however, consistent with what Granger and Morgenstern predicted would happen in the case of a financial crisis. Hilliard found some very close relationships among market indices around the world. Hilliard found that intra-continental prices moved simultaneously while for inter-continental prices, most did not seem to be closely related (with the notable exception of New York-Amsterdam). Hilliard's article is very important in establishing the link between financial market crises and stronger market linkages. Chapter 2 will deal more extensively with the literature related to financial crises, looking at the literature that followed the October 1987 world stock market crash. Lead-lag relationships will be considered more closely in Chapter 3 which looks at the issue of world equity market linkages and efficiency.

1.4 Conclusions

The study of linkages between world equity markets came into prominence and followed the development of the area of portfolio diversification in an international setting. Grubel's (1968) seminal article firmly introduced the idea that investors should consider investment opportunities outside their domestic market. Building on the work by Grubel, Chapter 1 follows the path of the early literature in the area of portfolios, diversified outside the domestic market. In the first section, the necessary condition for the realisation of gains from portfolios diversified outside the domestic market was considered. Clearly investors will only invest outside the domestic market if the correlation coefficients between assets in world equity markets is less than what could be achieved between domestic assets. Studies by Levy (1970), Grubel and Fadner (1971) and Solnik (1974) established the existence of the necessary condition. Agmon (1972) suggested that low correlation coefficient between world equity markets should be considered in the context of the assumptions made about segmented or integrated markets. MacDonald (1973) and Lessard (1976) showed that markets are likely to fall somewhere between the extremes of fully segmented or fully integrated markets. Lessard (1973, 1974) provided further evidence that diversifying outside the domestic market provided greater gains than portfolios diversified solely within the domestic market.

Establishing the existence of the sufficient condition for the realisation of gains from portfolios diversified outside the domestic market has been much more difficult. If inter-temporal stability does not exist then using *ex post* correlation matrices to determine *ex ante* optimal portfolios can not be achieved using mean-variance portfolio theory. The evidence from the testing in this area is mixed: Makridakis and Wheelwright (1974) and Panton, et al. (1976) found against inter-temporal stability while Watson (1980) found in favor of it. Further testing by Maldonado and Saunders (1981) found the relationship between the return patterns of world equity markets to be generally stable only in the very short-term, and unstable in the longer-term, while Philippatos, et al. (1983) found strongly in favor of inter-temporal stability in the medium-term.

The efficiency of world equity markets in an international setting received little attention in the early literature. Some of the articles to considers this were reviewed in the third section of this chapter. Granger and Morgenstern (1970) found little in the way of a lead lag relationship between markets. Hilliard (1979) considered the OPEC embargo - a period of financial crisis around the world. This period was characterised by a much stronger relationship between world equity markets. Hilliard highlighted the tendency for markets to exhibit greater comovement in a financial crisis.

Chapter 2: Volatility And Comovement In World Equity Markets

The October 1987 stock market crash highlighted for many, the extent to which world equity markets had become increasingly integrated, and how strong the comovement between markets were in response to an international shock. The combination of increasingly integrated equity markets and financial shocks has serious implications for the necessary condition for the realisation of gains from portfolio diversification in an international setting. In Chapter 1 articles by Granger and Morgenstern (1970) and Hilliard (1979) were reviewed. Granger and Morgenstern found little relationship between international markets, but recognised that comovement would be more likely during a worldwide financial crisis, something Hilliard confirmed in his study of the 1973-74 OPEC oil crisis. In Chapter 2 some of voluminous literature that sprung up as a result of the 1987 stock market crash is reviewed. The focus in the first section will be on the worldwide impact of the crash with only a brief discussion of the possible causes of the crash. The second section considers the interaction among world equity markets, as characterised by the volatility of prices in different markets, and their transmission from one market to another.

2.1 The October 1987 Stock Market Crash[1]

The October 1987 stock market crash attracted a lot of interest not only in the academic literature, but from regulatory authorities who commissioned a number of reports.[2] Roll (1989) made the following point regarding these reports, "specifically excluded from my survey of empirical papers will be reports provided by various 'commissions.' Some of these reports contain fine empirical work, but they are not really scientific studies in the sense of having been subjected to a thorough review by peers before publication." (Roll, 1989, p. 211). These reports will not be reviewed here

[1] The structure of this section has benefited greatly from a thorough review of the literature by Roll (1989).
[2] The Commissioned reports include those by the Presidential Task Force on Market Mechanisms, and the International Stock Exchange of London. See Kamphuis, et al. (1989) for a review of the commissioned reports.

either. It is not feasible to review all of the literature relating to the 1987 stock market crash, but some of the most important articles will be reviewed, particularly those which focus on the association between volatility and comovement.

Table 2.1

STOCK PRICE INDEX PERCENTAGE CHANGES IN MAJOR MARKETS:

CALENDER YEAR 1987 AND OCTOBER 1987

	Local Currency Units		U.S. Dollars	
	1987	October	1987	October
Australia	-3.6	-41.8	4.70	-44.9
Austria	-17.6	-11.4	0.70	-5.8
Belgium	-15.5	-23.2	3.1	-18.9
Canada	4.0	-22.5	10.4	-22.9
Denmark	-4.5	-12.5	15.5	-7.3
France	-27.8	-22.9	-13.9	-19.5
Germany	-36.8	-22.3	-22.7	-17.1
Hong Kong	-11.3	-45.8	-11.0	-45.8
Ireland	-12.3	-29.1	4.7	-25.4
Italy	-32.4	-16.3	-22.3	-12.9
Japan	8.5	-12.8	41.4	-7.7
Malaysia	6.9	-39.8	11.7	-39.3
Mexico	158.9	-35.0	5.5	-37.6
Netherlands	-18.9	-23.3	0.3	-18.1
New Zealand	-38.7	-29.3	-23.8	-36.0
Norway	-14.0	-30.5	1.7	-28.8
Singapore	-10.6	-42.2	-2.7	-41.6
South Africa	-8.8	-23.9	33.5	-29.0
Spain	8.2	-27.7	32.6	-23.1
Sweden	-15.1	-21.8	-0.9	-18.6
Switzerland	-34.0	-26.1	-16.5	-20.8
United Kingdom	4.6	-26.4	32.5	-22.1
United States	0.5	-21.6	0.5	-21.6

Reproduced from Kamphuis, et al. (1989, p. 37).

Given the ramifications of increasing volatility in world equity markets on international portfolio diversification, it is not surprising that the October 1987 stock market crash led to a great deal of interest in volatility and comovement of equity markets. One of the most striking features of the October 1987 share market collapse was its worldwide scope. The findings in the early literature had focused on low comovement between world equity markets. The 1987 crash raised the obvious question of whether world equity markets had become more integrated? Table 2.1 shows that prices in October 1987 dropped all around the world – the only month in 1980s where all markets shown in Table 2.1 moved in the same direction. Roll (1989) shows that day-to-day volatility around the crash period of October 1987 also reached very high levels. Table 2.1 also reveals a wide level of disparity during the entire calendar year of 1987. The speed with which volatility and comovement return to pre-crash levels is an important issue. If volatility returns quickly to normal levels then the ramifications for diversifying portfolios outside the domestic market will also be less severe if comovement returns to pre-crash levels quickly too.

As would be expected, various authors have expended much effort in explaining what might have caused the crash. "Among the most popular explanations are those related to the U.S. market's institutional structure and practices; e.g., computer-assisted trading, portfolio insurance, the organised exchange specialists, concurrent trading in stock index futures, margin rules, and the absence of 'circuit breakers' such as trading suspensions and limitations of price movements." (Roll, 1988, p. 35). Because the crash was felt around the world, the increasing globalisation of financial activities has also been attributed to causing the crash. This increasing globalisation was highlighted as a possible cause by the Presidential Task Force on Market Mechanisms (1988) which suggested that, "investors made comparisons of valuations in different countries, often using higher valuations in other countries as justification for investing in lower valued markets. Consequently, a process of ratcheting up among worldwide stock markets began to develop." (p. 10). The Commission goes on to report that while the crash may have appear to have had its origins on Wall Street, it was more likely to have been the result of the cumulative impact of several developments occurring simultaneously in other financial centres. As will be pointed out in this section, the evidence does not tend to back up this claim. Further, while the globalisation of financial markets is likely to have been a reason for the spread of the crash around the world, it is less likely to have been the catalyst of the crash itself.

Roll (1989) notes that empiricists have found it difficult to confirm any of the contentions that journalists and politicians have made about the causes of the crash. Journalists and politicians attribute the crash to sources ranging from portfolio insurance to inadequate computer systems. The absence of an obvious or fully persuasive triggering event, led to the fairly popular notion of a speculative 'bubble' prior to the crash. The evidence for the existence of a bubble is based, in the main, on the existence of positive serial correlation in price changes before the crash. Evidence for the speculative 'bubble' is also mixed. Wadhwani (1989) makes clear his thoughts regarding the likelihood of speculative 'bubbles', "...there are several reasons for believing that the existence of a speculative bubble is implausible. There is the difficulty of explaining why Frankfurt fell even though it hardly rose through 1987.... In the same vein, if there were a market with a bubble before the crash, then Tokyo, with its sky-high price-earnings ratios would surely be it. Yet Japan declined less than other major markets, and also recovered more quickly." (p. 255). Roll concludes that further empirical work is required to sort out the appropriate conclusion with respect to the cause of the crash but it seems highly probable that a number of causes were responsible.

Factors including the improvement in electronic coordination across world markets and less regulation of international capital flows suggest that markets have become more integrated and that the opportunities found in Chapter 1, might no longer be available to investors. Dwyer and Hafer (1988) examined the short-term relationship among four big markets (Germany, Japan, the United States, and the United Kingdom) around the October 1987 crash. They found no evidence of increased correlation, except for the period immediately around the crash. Further, they found only a slight increase in correlation in the longer term from the fixed exchange rate period (January 1957 through April 1973) to the flexible rate period (after April 1973). Bennett and Kelleher (1988) document the same increase in international comovement from the 1970s to the 1980s but also note that this increase is only small in magnitude. These results should provide investors with some comfort that the increased comovement is only effective in the period immediately around such events.

Neumark, Tinsley and Tosini (1991) took an interesting approach to the study of comovement between equity markets in a study that considered U.S. stocks dual listed in Tokyo and London. Their results suggest that the increased comovement between markets in volatile periods is not due to the increased integration of markets but rather because arbitrage is more viable in such periods. Neumark, et al. remove the issue of the disparate composition of the price indices of national exchanges by examining the prices of a set of multiple-listed stocks as they are valued in successive trading on the three aforementioned national equity markets. The previous price change in either Tokyo or London was used to predict the New York change. If markets are informationally efficient, the slope coefficient should be unity in the prediction equation, i.e., the price change in Tokyo should be an unbiased predictor of the price change in New York since the previous close, the prediction error reflecting any news between Tokyo's close and the next New York close. Neumark, et al. summarise their results as follows:

> "The empirical results in this paper indicate that in the immediate aftermath of the October 1987 stock market collapse, prices of U.S. stocks with listings on the Tokyo and London exchanges were tightly linked across international capital markets.... This is the expected result if international capital markets are efficient, or not segmented. This behaviour was not observed, however, in stock price data collected for trading days further removed from the collapse. In intervals of more typical price volatility, transmission from after-hours foreign price movements to opening New York prices was significantly weaker or entirely absent, whereas foreign prices continued to fully reflect the New York trading day news. Both the asymmetry of cross-market responses and the time variation in New York responses

appear to be due to the impact of transaction costs on the profitability of responding to after-hours news. Transaction costs provide a barrier to international transmissions of small (but not large) price signals." (pp. 175-176).

Bertero and Mayer (1990) take a different approach again, to the study of the correlation of returns between equity markets around the crash. They look at regional indices for the Pacific Basin, Europe and North America, weighted according to market value. They find that return correlations across geographical regions increase dramatically during the period around the crash (October 1987 to May 1988) compared to the coefficients for the earlier period of January 1981 to September 1987. For example, the correlation between the Pacific Basin and North America increases from 0.3601 to 0.6583. Likewise, the correlation between the Pacific Basin and Europe increases from 0.4524 to 0.7212; and for Europe and North America, increases from 0.5387 to 0.9752.

Bertero and Mayer break down the analysis further by splitting the period from January 1987 to May 1988 into seven subperiods. Their results show a sharp increase in correlations between all regions during the crash. Further, they argue that these findings support the idea that correlations remain higher for an appreciable period after the crash. This would appear to be a fairly bold statement, given that it is unlikely that the period to May 1988 represents an 'appreciable period'. The regional approach taken by Bertero and Mayer may also result in the persistently high levels of correlation found. Other studies have looked at individual market indices and found much less persistence in the size of correlation coefficients after the crash. When Bertero and Mayer plot the standard deviation of return for each of the three regions, their findings are more consistent with similar studies. They show that the standard deviation increased by a factor of about ten times in all three regions, but that by February 1988, the standard deviations had returned to their previous levels.

Bennett and Kelleher (1988) studied the transmission of international price changes around the October 1987 crash for Germany, Japan, the United States and the United Kingdom. In the pre-crash period they found that daily return volatility within a given month tended to be significantly positively related across countries. They also found that higher volatility was associated with a larger degree of inter-country correlation. Bennett and Kelleher conclude that, "if huge price movements were again to occur in one of the world's major stock markets, the disruptions would be likely to spread worldwide." (p. 26). They suggest that this coupled with some evidence of small increases in the comovement between markets in the 1980s would suggest that an increased level of international regulatory coordination would be necessary to complement domestic measures in lessening the chances of another market collapse.

The empirical literature considering the October 1987 stock market crash, provides evidence of significant international linkages among national equity markets in periods of extreme volatility like that experienced around the October 1987 crash. Most of the evidence suggests that the level of volatility and correlation returns to pre-crash levels reasonably quickly. Apart from the period immediately around the crash, there is only minor support for international linkages having increased. Given that volatility returns to pre-crash levels quickly, it will require more periods of volatility for the necessary condition for the realisation of gains from portfolio diversification in an international setting to be threatened. It is important to note, however, that while the studies reviewed in this section provide interesting information about the association between volatility and comovement, they are only exploratory in nature. In the next section, and in Chapter 3 studies which more formally consider the linkages between equity markets are reviewed.

2.2 Returns, Volatility And The Transmission Of Price Changes Between World Equity Markets

The interaction among world equity markets can be characterised by assessing the volatility of prices in different markets and the transmission of that volatility from one market to another. This approach has received increasing attention in the recent literature. The 1987 stock market provided an ideal sample period for the study of such transmission, and work in this area gained momentum after the crash. According to Brailsford (1996), "the study of volatility inter-dependence provides useful insights into how information is transmitted and disseminated across markets. Research results in this area have implications for international diversification and market efficiency." (p. 13). The literature on 'volatility spillovers', the term coined for the transmission of volatility across markets, can be categorised into two groups. The first group focuses on return series and the errors from modelling return series. The second category of papers directly examine volatility.

The first group includes studies by Eun and Shim (1989) and Jeon and Von Furstenberg (1990) who use the Vector Autoregression (VAR) methodology to study long-term linkages between markets. The second group of papers look directly at volatility and utilises the ARCH family of models developed by Engle (1982) and generalised by Bollerslev (1986). The literature in this second category has so far looked at high frequency data for reasonably short time horizons, focusing on a small number of international stock markets - usually London, New York and Tokyo. The multivariate GARCH techniques that are generally needed to apply these techniques are fairly difficult to run. While this thesis focuses on long-term linkages between markets using the VAR approach, a review of the literature in this area is still important and is considered in this section. In Chapter 3, the literature looking at the long-term linkages between markets is considered.

King and Wadhwani (1990) provide what is certainly one of the most interesting and innovative papers to look at international linkages. Their paper is simply concerned with the question - why, in October 1987, did almost all stock markets fall together despite widely differing economic circumstances? King and Wadhwani developed a 'contagion' model of international volatility transmission. The idea underlying the model is that rational traders in one country should use price movements in another country to deduce changes in underlying economic fundamentals, even in the absence of any public news. This implies that a price 'mistake' in one country will be transmitted to others almost as if it were an infectious disease. King and Wadhwani note that while there may well be weak evidence of contagion during periods where markets are 'normal,' this does not preclude contagion from being rampant in volatile periods. This is consistent with Neumark, et al. (1991) who suggested that volatile periods provided the opportunity to arbitrage between markets and trade on the information revealed by another market. King and Wadhwani were motivated by the puzzling uniformity of the crash across countries.

> "... it is difficult to come up with a credible story that links 'fundamentals' to the crash; ... moreover, it is extremely hard to imagine that any such explanation would be consistent with the uniform decline in equity prices in different countries. In a non-fully revealing equilibrium, price changes in one market will ... in a real sense depend on price changes in other countries through structural contagion coefficients. Mistakes or idiosyncratic changes in one market may be transmitted to other markets, thus increasing volatility. It is this feature that appeals to us as an alternative to 'news' as an explanation of the contemporaneous fall in all major stock markets in October, 1987." (King and Wadhwani, 1990, pp. 6-7).

The central tenet of King and Wadhwani's contagion theory states that contagion increases with volatility. If this is true, a contagion-based model is consistent with the generally low cross-country dependencies exhibited in 'normal' times and with a much greater degree of dependence in periods of major disruption. While increased correlation around the crash period has been observed, King and Wadhwani present a more refined empirical study of the phenomenon. In the previous section it was noted that the Presidential Task Force on Market Mechanisms found that annual covariances were not stable and did not exhibit any clear trend. They interpreted this as evidence of the insignificance of international transmission of price volatility during the 1987 crash. The task force used monthly data. Using high-frequency data, King and Wadhwani demonstrate that covariances are related to volatility in a way that is consistent with the contagion model and with the observed low-frequency correlations. "An implication of this result is that an increase in volatility could be self-reinforcing and persist for longer than would otherwise be the case. We conjecture that this might be one reason for the uniform fall in stock markets during October 1987, despite their varying experience both before and after that date. As volatility declines, market links become weaker, and price changes are less closely tied together." (King and Wadhwani, 1990, p. 8).

In their study, King and Wadhwani used high-frequency data for London, New York, and Tokyo for an eight-month period around the crash, July 1987 to February 1988. One of the distinguishing features of their model is the price jumps that occur in all markets whenever one market reopens. Using half-hourly returns at 15-minute intervals, King and Wadhwani find that the New York opening is associated with unusually high volatility in London, although the response is more diffused than would be predicted by their theoretical model. To identify the contagion coefficients, King and Wadhwani estimate the model on hourly data for stock price changes in New York, Tokyo, and London for the period, September to November 1987. The hypothesis they pay particular attention to is that the contagion coefficients increase during and immediately after the crash in response to the rise in volatility but then decline as volatility decreases.

King and Wadhwani's results are consistent with the notion that the contagion model is a suitable explanation of the October 1987 crash. The evidence of price jumps with time zone trading supports the contagion model and merits further research with data from other markets. Also the evidence that volatility in London was lower when the New York market was closed on some Wednesdays in 1968 provides further support for the contagion model. King and Wadhwani found that the empirical evidence suggests that an increase in volatility leads in turn to an increase in the size of the contagion effects. The rise in the correlation between markets just after the crash is evidence of this. These results, should they prove robust, have the important implication, that volatility can in part, be self-sustaining. The role of contagion should not be dismissed on the grounds that there has been no historical trend increase in correlations between markets. King and Wadhwani's argument does not rely on this, rather it is the volatility-related increase in contagion effects that is the feature of the transmission mechanism. Brailsford (1996) summarises the conclusion from the King and Wadhwani paper well:

> "... in an investigation of the Crash of October 1987 [King and Wadhwani] report evidence which supports the transmission of price information across markets through volatility innovations, even when the information is market specific. They argue that there is a 'contagion' effect across markets whereby markets overreact to the events of another market, irrespective of the economic value of the information." (p. 15).

Having concluded that stock prices in one country might be affected by changes in other countries beyond what is conceivable through economic fundamentals alone, it is not surprising that King and

Wadhwani's study sparked a fair amount of controversy in the academic literature. Roll (1989) questioned whether contagion as measured by King and Wadhwani is really inconsistent with fundamental news.

> "Imagine, for instance, that many different and important news items happened to arrive at random intervals during the crash period, some arriving when London was open and New York and Tokyo were closed, and vice versa in all combinations. Then, to the extent that these news items had importance for all markets, a price change in, say, New York would indeed be highly related to the next opening price change from the previous close in Tokyo, and so on. And to the extent, that there were more important news events around the crash than in a quieter period, the King/Wadhwani contagion coefficients would be larger. The coefficients are clearly a positive function of the number of news items arriving per unit of calendar time and of the international significance of the news relative to the background news idiosyncratically concentrated in each local country." (Roll, 1989, p. 226).

In his review of the King and Wadhwani article, Poterba (1990) raises some interesting points. While acknowledging that the higher volatility of the London stock market at the time the NYSE opens may support contagion theory, he suggests that these findings raise two basic questions about the comovements between national equity markets. The first is whether there is any reason to expect the correlations across markets to be stable through time. King and Wadhwani find that returns on the London, New York, and Tokyo markets were more highly correlated around the market break down of October 1987 than in other periods. Volatility is the result of shocks to many different factors that affect equity values, some of which are country-specific and others which affect all markets together. Poterba suggests that because there is no reason to expect the relative importance of different shocks, for example, news about world resource prices versus domestic political events, to remain constant through time, instability in the cross-correlation of market returns should be expected. King and Wadhwani's results confirm this prediction and hence raise the question as to whether the sufficient condition for the realisation of gains from diversifying outside the domestic market can be met.

Poterba also finds it difficult to interpret the finding that markets in one country are more volatile when markets in other countries are open. He suggests that this may be evidence for the model where traders in one country attempt to extract signals about price fundamentals from the price changes in other markets. These findings could also indicate, however, that price changes in one market directly affect the price fundamentals in other markets. This alternative explanation warrants further exploration. One of the central tenets of the King and Wadhwani paper, that traders look to prices for information about the fundamental value of securities, has profound implications for the transmission of volatility across markets. If a relatively small proportion of investors make their own calculations of fundamental values and the majority of traders are 'informational freeloaders' who presume the accuracy of markets prices, shocks to one market or one set of prices might have far-reaching consequences. Poterba suggests that further work should be directed at disentangling the competing explanations for international volatility linkages.

Around the same time as King and Wadhwani's innovative paper, Hamao, Masulis and Ng (1990) presented the seminal article to look at equity market linkages using multivariate generalised autoregressive conditional heteroscedasticity (GARCH) developed by Engle (1982) and Bollerslev (1986). Their paper examined the dynamics of cross correlations, focusing on high-frequency dependence in returns and the conditional volatility of returns, commonly referred to as 'spillovers.' Earlier studies such as Hilliard (1979), Eun and Shim (1989), Jeon and Von Furstenberg (1990), and Koch and Koch (1991) "... all focused on the contemporaneous and lagged correlation in daily closing-price changes across major stock markets. These studies ignore, however, the changing conditional volatility of stock price changes and, more importantly, the international spillovers of these price-change volatilities that might be occurring at the same time." (Karolyi, 1995, p. 12). Hamao, et al. used autoregressive conditionally heteroscedastic models to demonstrate the different dynamics for spillover effects in price changes and volatilities between markets. Because, the analysis of two or more countries requires the use of multivariate GARCH based models, the methodology used in these studies is fairly complex.

By investigating the extent to which volatility might spillover across markets, the work of Hamao, et al. can be thought of as extending on, or at least being related to King and Wadhwani's (1990) study. Hamao, et al. note that although the extent of international financial integration has received much attention in recent years, there has been a lack of attention to the empirical implications for the functioning of individual capital markets. Hamao, et al. consider the short-term relations among security prices across three major stock markets: Tokyo, London, and New York over the three-year period, April 1, 1985, to March 31, 1988. They are interested in (1) the extent to which security price changes in one market influence the opening prices in the next market to trade and (2) whether changes in price volatility in one market are positively related to changes in price volatility in the next market to trade. They examine the transmission mechanisms of the conditional first and second moments in common stock prices across national stock markets and allow for changing conditional variances as well as conditional mean returns.

Whereas studies like Eun and Shim (1989) use close-to-close returns to estimate spillover effects, Hamao, et al. divide daily close-to-close returns into their close-to-open and open-to-close components. This represents an improvement since straight close-to-close returns tend to confuse several alternative causes of correlation in return processes across markets since the time interval represented by these returns overlap. Hamao, et al. also offer a good explanation of the virtues of ARCH based models over other techniques such as VAR, based on the characteristics that have been found in stock returns.

> "Prior statistical analysis of common stock daily returns has documented mild serial correlation over very short periods of time. Previous analyses of daily and monthly U.S. common stock returns have found that "large price changes tend to be followed by large changes - of either sign - and small changes tend to be followed by small changes..." [see Mandelbrot (1963, p. 418); also see Fama (1965, pp. 85-87)]. There is also evidence that percentage changes in stock prices and indices exhibit fatter tails than that predicted by a stationary normal distribution. The autoregressive conditional heteroskedastic (ARCH) model recognises the temporal dependence in the second moment of stock returns and exhibits a leptokurtic distribution for the unconditional errors from the stock returns generating process." (Hamao, et al., 1990, p. 283).

The generalised autoregressive conditional heteroskedastic-in-mean (GARCH-M) used by Hamao, et al. to examine the spillover effects on close-to-open returns between markets was found by French, Schwert and Stambaugh (1987) to be a good representation of daily stock-return behaviour in the United States, successfully capturing the effects of time-varying volatility on a stock's expected return.

For all three markets Hamao, et al. find clear evidence that the most recent open-to-close returns of the two foreign markets consistently have positive influences on the opening price in the next market to trade with at least one of these two foreign markets exhibiting statistical significance. Unexpected changes in foreign market indices are associated with significant spillover effects on the conditional mean of the domestic market for both open-to-close and close-to-open returns. The effect on the open-to-close returns suggests some informational inefficiencies in these markets. For the close-to-open returns, this effect on the conditional mean is consistent with international financial integration. The mean spillover result suggests a degree of relationship between the markets over the entire period, which is similar for the pre-crash period also.

The magnitude of volatility spillover is generally much less than is the case for mean spillover between markets. Roll (1989) quotes the following section from Hamao, et al. (1989), the working paper version of their 1990 article which sums up well the conclusions with respect to volatility spillover found by Hamao, et al.:

> "If the impact of a foreign market is completely absorbed in the subsequent foreign market to open trading, then there should be no significant effect from adding the spillover ... from the foreign market which trades earlier. [Nonetheless] ... for the full sample period [which includes the crash], all three markets are affected by the volatility surprises of the two previously open foreign markets, with the exception that Tokyo has no significant influence on New York. ... The spillover ... from New York is

> larger than the effect from the other ... markets. [Excluding the crash] there is no significant spillover onto the London and New York markets, but there is an equally significant spillover effect from London and New York onto the Tokyo stock market. The Japanese market is most influenced by spillovers from foreign markets, but the other two major stock markets are only moderately affected, if at all, by volatility spillovers from foreign stock markets." (Hamao, et al., 1989, p. 17 in Roll, 1989, p. 222).

The October 1987 crash has obviously had an influence on the level of volatility spillover across markets, with the spillover between markets generally higher for higher volatility. However, the volatility spillover between markets has been shown by Hamao, et al. to be relatively short lived. Mean spillover on the other hand is shown to be fairly stable over the entire period studied. Whether the results from the three large equity markets studied suggest that equity markets in general are related and financially integrated is another matter. The inability to generalise the results of studies by the likes of Hamao, et al. represents a limitation to studies of this type. Because they require high frequency data they have tended to study only short periods of time and include only small samples of equity markets from around the world.

In a follow up to the study by Hamao, et al., Lin, Engle and Ito (1994) present a study that is very similar in methodology and data to Hamao, et al. but finds that volatility spillover effects are much more balanced across markets than previously believed. Their paper demonstrates that the early evidence was overly sensitive to the measurement of the opening quotes. The selection of an appropriate proxy for opening quotes allows Lin, et al. to improve on earlier studies. Stoll and Whaley (1990) found that it takes an average of 5 minutes for large stocks and 67.4 minutes for small stocks on the New York Stock Exchange for the first transaction to occur after the market opens. Because of the delay in trading, the measured opening price index does not accurately reflect the true underlying price value.

Lin, et al. investigate how returns and volatilities of stock indices are correlated between the Tokyo and New York markets. When the New York market opens, many things that happened overnight must be incorporated in the stock prices. One relevant piece of information is how the Tokyo stock market did earlier in the day. The same is true at the Tokyo open. The two economies of the two largest equity markets are related through trade and investment, so that any news about economic fundamentals in one country most likely has implications for the other country, suggesting that the stock returns of international equity markets will be correlated. Lin, et al. suggest that the contagion model of King and Wadhwani (1990) is simply an alternative explanation for international correlation of stock price changes. Lin, et al. suggest that the New York market incorporates what happened in Tokyo earlier in the day when it opens. They do note, however, that the survey results of Shiller, Kon-Ya and Tsutsui (1991) found that Tokyo participants are generally influenced by what happens in New York (but not vice versa).

Lin, et al. look to incorporate a number of empirical regularities that have been found in the literature on the international transmission of stock returns and volatility. The regularities reported by Lin, et al. are: "(i) the volatility of stock prices is time-varying; (ii) when volatility is high, the price changes in major markets tend to become highly correlated; (iii) correlations in volatility and prices appear to be causal from the United States to other countries; and (iv) lagged spillovers of price changes and price volatility are found between major markets.[3]" (pp. 508-509). As well as using a more accurate opening proxy, Lin, et al. improve on earlier studies by decomposing returns into daytime and overnight returns. Because the Tokyo and New York stock markets do not have any overlapping trading hours (unlike New York and London), Lin, et al. decompose daily price changes (return and volatility) into daytime (open-to-close) and overnight (close-to-open) returns, where the daytime segment in one market is a subset of the overnight segment of the other market in real time. This along with the inclusion of time-varying volatility in the signal extraction model improves on the study of King and Wadhwani (1990) who used a simple signal extraction model. Solving the 'nonsynchronous trading problem' which tends to induce spurious lagged spillovers and a more complicated signal extraction model than that of the GARCH-in-mean model used by Hamao, et al. (1990) represents another improvement. Lin, et al. study the period, 28 September, 1985 to 31 December, 1989.

Lin, et al. (1994) summarise their main results as follows:

> "First, the foreign daytime returns can significantly influence the domestic overnight returns. It has often been suggested in the literature that New York stock returns influence Tokyo, but not vice versa. Contrary to this belief, we find that cross-market interdependence in returns and volatilities is generally bi-directional between the New York and Tokyo markets. Second, we find weak evidence that the signal-extraction model characterises Tokyo traders' behaviour better than the other models in terms of the Schwarz criterion. While our empirical results are consistent with the contagion-effect hypothesis of King and Wadhwani (1990), we extend their model by incorporating the time-varying volatility to characterise volatility clustering and the time-varying extraction coefficient. Third, we find little evidence of the lagged return spillovers from New York daytime to Tokyo daytime or vice versa. In contrast to Hamao, Masulis, and Ng (1990), our results show little evidence against the hypothesis that the domestic market efficiently adjusts to foreign information." (p. 536).

The difference between their results and those of Hamao, et al. (1990) can be attributed to the nonsynchronous trading problem in Hamao, et al. referred to above. Lin, et al. are able to

[3] Lagged spillovers are defined as correlations between the foreign daytime return (volatility) and the subsequent domestic daytime return (volatility), without any overlapping trading hours.

demonstrate that spillover effects were much more balanced across markets than previously believed and showed that the early evidence was sensitive to measurement of opening quotes. Their results suggest that markets are less likely to be integrated and that the comovement between markets is weaker than suggested by Hamao, et al.. Whether the results for the relationship between the New York and Tokyo markets can be generalised for other markets remains a problem.

By including the Canadian and German markets with the markets of the U.S., Japan and the U.K., in a study looking at the transmission mechanism of stock market returns and volatility shocks, Theodossiou and Lee (1995) improve on the small number of markets included in previous studies. On the negative side, Theodossiou and Lee use weekly data to look at the extent to which conditional volatility in these markets affects expected returns. Statistically significant mean spillovers exist from the stock markets of the U.S. to the U.K., Canada, and Germany, and from Japan to Germany. It is, however, important to note that these spillover relations explain less than 6% of the total variation of returns in each market and do not extend beyond one week. Such low explanatory power raises a serious question as to whether investors can employ them to predict the future course of stock prices for speculative purposes.

Theodossiou and Lee found that significant own-volatility spillovers[4] are present only in the stock markets of the U.S., Japan, and Germany. Statistically significant cross-volatility spillovers exist from the U.S. to all four stock markets, from the U.K. to Canada, and from Germany to Japan. Volatility spillover effects from the U.S. market to the German market and from the German market to the Japanese market are weak. This suggests that the German market is the least integrated of the five markets. The absence of own-volatility spillovers in the U.K. and Canadian stock markets supports the view that conditional volatility of returns in these markets is 'imported' from abroad, mainly from the U.S. Theodossiou and Lee's results provide only mixed evidence of comovement between markets, but do show that the U.S. market is the most influential market.

The research reviewed in this section generally supports the existence of interdependence in returns and volatility between equity markets. While common international factors that influence the volatility of different markets may be the reason for a causal relationship between markets, the evidence summarised in this section suggest that this is unlikely. An alternative explanation may be that a causal relationship exists such that the volatility in one market induces volatility in another market, through a lead-lag relationship. Certainly, the tests reviewed have found some evidence that

[4] Own-volatility spillovers indicate a one-way causal relationship between past volatility shocks and current volatility in the same market, while cross-volatility spillovers represent the same one-way causal relationship in another market.

shocks in one stock market can influence other markets in subsequent trading sessions. It is, however, difficult to make conclusions regarding the efficiency of equity markets around the world from these studies. This is largely due to the nature of the tests which rely on high frequency data, and only test for short-term horizons for a small sample of countries. Longer-term tests of the linkages and efficiency between world equity markets are reviewed in more detail in Chapter 3. The methodologies employed in this testing are able to incorporate a larger number of markets and longer time periods.

2.3 Conclusions

The studies reviewed in this chapter, grew largely in response to the issues raised by the October 1987 stock market crash. These studies deal with a number of different topics in relation to market interrelatedness but tend to stress the following points about the crash: "... (1) compared to pre-crash data, stronger cross-exchange index covariation is found immediately before and after the crash; (2) 'psychological contagion' between markets and the bursting of a global rational speculative bubble, rather than a change in fundamentals, appears responsible for the simultaneity of market responses; and (3) information channels are such that a single 'shock' can be internationally transmitted to other exchanges much more quickly than previously realised." (Brocato, 1994, p. 645). In the first section we saw that in the period around the October 1987 stock market crash, markets around the world exhibited a strong degree of comovement, much stronger than in normal periods. A relationship between volatility and the comovement of world equity markets was demonstrated. Because the tendency for volatility and greater comovement were reasonably short lived, the results suggested that the necessary condition for successful portfolio diversification in an international context was unlikely to be very severe.

In the second section, papers which use volatility to study the transmission mechanism between markets were reviewed. An interesting paper by King and Wadhwani (1990) suggested that a 'contagion' variable drives volatility in markets which affects the comovement between equity markets. Their theory suggests that markets follow each other but that this comovement is not necessarily the result of any fundamental news. Studies by Hamao, et al. (1990) and Lin, et al. (1994) have looked at the mean and volatility spillover between markets. These studies have generally confirmed the efficient transmission of mean spillover between markets. Of much greater interest is the transmission of volatility between markets. If volatility spills over between markets so that markets are efficient in their transmission of volatility then there is likely to be greater comovement between markets in periods of volatility which suggests less incentives for portfolio diversification in an international setting. The results of these tests are mixed, but where volatility spillover was found, it was generally short-lived. Certainly the nature of these tests, which rely on high frequency data and therefore only include a small number of equity markets, means that it would be difficult to generalise the results of these tests for other markets. The results from this section are not able to seriously undermine the potential benefits for investors from diversifying outside the domestic market.

Evidence from the articles reviewed in both sections of this chapter suggest that linkages between markets do exist. In particular, the evidence presented in the first section suggested that such linkages were short-lived and that the linkages returned to pre-crash levels quickly after October 1987. It is important to note, however, that the studies reviewed in this chapter tend to consider linkages only over short-time horizons and do not provide conclusive evidence on the linkages that exist in the longer-term. Further, the tests in the second section are limited to only a small number of large equity markets which makes it difficult to generalise the results from these studies across other markets. Chapter 3 looks at studies that focus on long-term linkages between world equity markets.

Chapter 3: Linkages Between World Equity Markets

If the linkages between world equity markets are strong then we might expect shocks in one market to be felt in other markets around the world. Strong linkages between equity markets suggests that it will be more difficult for investors to benefit from diversifying outside the domestic market. It might, however, be possible for investors to profit on the lag between the leading market and those markets it leads. If the relationship between equity markets is efficient, it should not be possible to earn unusual profits by investing in a particular equity market based on the observed developments in other markets. The lag should be short, reflecting the efficiency with which information is transmitted between markets. In Chapter 2 studies that used the volatility of returns to look at the transmission mechanism between stock markets were reviewed. While these studies test inter-market efficiency and the linkages or interrelationships between markets, the nature of the tests is such that it is difficult to draw conclusions regarding market efficiency around the world from them.

In Chapter 3 methodologies better suited to the study of a greater sample of markets for longer time periods are considered so that the question of long-term market linkages can be analysed. Studying the linkages between markets cannot be separated from issues relating to the integration and the globalisation of financial markets around the world. Trends toward greater integration between financial markets provide the setting in which issues relating to portfolio diversification in an international setting are discussed. Chapter 3 begins by reviewing some of the recent literature to look at the segmentation/integration issue. In the second section the literature that uses the Vector Autoregression (VAR) methodology to test for market linkages is reviewed. Finally, studies that have used cointegration analysis to test for the linkages between markets and the collective efficiency of markets are considered.

3.1 Integration Of World Equity Markets

The degree to which financial markets around the world are segmented or integrated has been debated since the early literature looking at portfolio diversification in an international setting. Some of the early articles to consider this issue were reviewed in Chapter 1. It was established in those early studies that markets are neither fully integrated nor fully segmented and instead sit at some point on a continuum between these two extremes. Because markets have becoming increasingly open during the 1980's and 1990's, an integrated markets hypothesis may well describe the relationship between markets better than it did in the 1970's. Of course, it is unlikely, even now, that markets could be classified as fully integrated. The classification of markets as segmented versus integrated is important for investors who are only able to benefit from diversification outside the domestic market if markets are partially integrated. By definition, a fully segmented market does not allow for foreign investment. If, however, markets are almost entirely integrated, assets in different markets have the same risk-return characteristics, and investors cannot profit from diversification either. This section reviews a recent article that has tested the degree of segmentation/integration in a sample of world equity markets.

If world capital markets are partially segmented/integrated then it should be possible to detect the presence of an international factor in an international market model regression of the form:

$$r_i = \alpha_i + \beta_i r_m + \varepsilon_i. \tag{3.1}$$

Equation (3.1) asserts that the rate of return r_i, on an individual security i, can be divided into two components: α_i which is independent of the rate of return on the overall market, and $\beta_i r_m$, which depends on the market movements. The parameter β_i is the beta coefficient and ε_i is a random disturbance term. The beta coefficient represents the sensitivity of the security with respect to a common world factor, and can be regarded as the international market risk of the security. The return on a world stock index is used as a proxy for the international factor, and thus the return and risk performance of the various countries is consistently compared. The market model in Equation (3.1) is applied in an international investment framework by Shawky, Kuenzel and Mikhail (1997) in a study that looks at cross-market efficiency between Austria, Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, the U.K., and the U.S. between January 1990 and December 1995.

The coefficient of variation, R^2, indicates the percentage of the variation in the dependent variable that can be explained by the independent variable. Shawky, et al. find that the R^2 value ranges between 18 percent and 49 percent, for the full sample period, indicating that a fairly influential world factor exists. These findings are consistent with partially integrated markets, implying that investors should be able to benefit from international diversification[1]. The full period was split into two subperiods of 1990-1992 and 1993-1995, with R^2's ranging from 8% to 54%. The beta estimates for the subperiods 1990-1992 and 1993-1995 are relatively unstable.

Eun and Resnick (1994) have shown that investors can potentially increase their gains from international diversification by hedging foreign exchange risk. To examine this possibility, Shawky, et al. estimated an extended market model regression described by the following equation:

$$r_i = \alpha_i + \beta_i r_m + \gamma_i s_i + \varepsilon_i. \qquad (3.2)$$

Equation (3.2) posits that the rate of return, r_i, on an individual security, i, can be broken into three components: α_i which is particular to the security, a component $\beta_i r_m$ which depends on the world factor, r_m, and a component $\gamma_i s_i$ which depends on changes in the exchange rate, s_i. Again, ε_i is a random disturbance. The parameter γ_i, represents the sensitivity of the security returns to changes in the exchange rate, and is expected to incorporate the foreign exchange risk factor into the pricing model. Using this model, Shawky, et al. estimate the regression equation for the French, German and British market indices for the period January 1990 to December 1995. The exchange rates of these respective countries with the United States as base country are used.

Using the extended market model in equation (3.2), the value of the adjusted R^2 coefficient increases only slightly. This suggests that fluctuations to the exchange rate explain only a small additional portion of the variance of the market indices. The contribution of exchange risk to the total risk of international investments seems to be fairly small. Shawky, et al. also find the size of the exchange rate coefficient, γ_i, to be positive at the 1% level for all market indices, with its magnitude ranging between one and two thirds of the size of the world market factor. This means that the size of the exchange rate influence on the rate of return is itself fairly large, but that the level of exchange rate risk is much smaller. This is an interesting finding and indicates that although exchanges might fluctuate, over a five year period the overall risk effect seems to still be fairly small with the fluctuations balancing out.

[1] It should be noted that these results are based on the correlation and the variance/covariance behaviour between markets and are independent of the unit of currency used in the analysis. These results are also applicable to investors in any country including the U.S.

3.2 Examining The Linkages Between World Equity Markets – A Vector Autoregression Approach

With the lifting of restrictions on foreign investment and modern technology allowing investors to buy and sell securities all over the world almost instantaneously, and at lower cost, it is conceivable that the trend toward greater globalisation in financial markets has caused stronger comovement among markets, thereby reducing the traditional benefits of diversifying the portfolio outside the domestic market. In chapter 2, studies that looked at the short-term linkages between markets were reviewed. In this section the long-term linkages between equity markets are examined using the Vector Autoregression (VAR) technique. It will be interesting to see to what extent globalisation has impacted on the linkages between equity markets. If strong linkages between markets are found then the rationale for diversifying outside the domestic market to benefit from risk reduction through portfolio diversification becomes more questionable.

As well as studying the linkages between equity markets, the VAR technique allows the speed with which information is transmitted between markets to be analysed. If substantial lags exist between an innovation in one market and the response of another market, investors may be able to profit on the lag between markets by taking advantage of developments in the leading market. Profiting from such lags indicates that the transmission mechanism between markets is inefficient. Eun and Shim (1989) were the first to utilise the VAR methodology to investigate the international transmission mechanism of stock market movements. Because the VAR is the primary tool used in this thesis to study the linkages between Asia Pacific equity markets, Eun and Shim's study will be reviewed in some detail so that the capabilities of the VAR technique in examining stock market linkages and efficiency in an international setting can be demonstrated.

The VAR technique is well suited to examining the interdependence structure of world equity markets and the international transmission mechanism of stock market movements as it allows long-term linkages between equity markets to be examined. VAR systems treat all variables as jointly endogenous. The VAR model provides a multivariate framework where changes in a particular market index are related to changes in its own lags and to changes in other market indices and imposes no restrictions on the structural relationships, if any, between the markets being analysed. Each variable is allowed to depend on its past realisations and on the past realisations of all other variables in the system. Once a VAR system is estimated, the dynamic responses of each of the markets to innovations in a particular market can be traced out using the simulated responses of the estimated VAR system. It also allows the relative importance of an individual market in generating variations in its own returns and in the returns of other markets to be assessed.

Eun and Shim (1989) noted that much of the literature to come before them on international portfolio diversification had focused on showing how the interdependence of share price movements is much less pronounced among countries than within a country. They noted that little attention had been given to the structure of the interdependence among world equity markets. Eun and Shim's study was motivated by the empirical observations that suggest a substantial degree of interdependence among world equity markets. Although unexpected developments in one stock market seem to have become important 'news' events that influence domestic stock markets around the world, Eun and Shim pointed to a lack of in-depth analysis in the interdependence structure of world equity markets. By emphasising the international transmission mechanism of stock market movements, Eun and Shim aimed to develop a greater understanding of the interdependence structure of world equity markets.

Eun and Shim used the VAR methodology to address the following issues:

(i) How much of the movements in one stock market can be explained by innovations in other markets?

(ii) Does the U.S. stock market indeed influence other markets? Are there any markets whose movements are causally prior to those of other markets?

(iii) How rapidly are the price movements in one market transmitted to other markets.

Daily data for the stock indices of Australia, Canada, France, Germany, Hong Kong, Japan, Switzerland, the United Kingdom, and the United States for the period January 1980 through December 1985 was used in the study. Because equity markets operate in diverse time zones, making return observations non-synchronous, the structure of time differences was carefully examined and the implications explicitly incorporated into the interpretation of empirical results.

The vector autoregression technique allows for the accounting of national stock market innovations. Table 3.1 presents a useful summary that identifies the main channels of influence in the nine-market dynamic system, providing a decomposition of 5-day, 10-day, and 20-day ahead forecasts of stock market returns into fractions that are accounted for by the innovations of different markets.[2] Table 3.1 shows that no national stock market is exogenous in that a market's own innovations fully

[2] The variables are ordered as follows: the U.S., the U.K., Switzerland, Japan, Hong Kong, Germany, France, Canada, and Australia. When the different innovations are correlated, the error variance decomposition could be sensitive to the order to variables for orthogonalisation. When Eun and Shim changed the order of variables, the U.S. still emerged as the dominant market.

account for its variance. Further, the Granger (1969) exogeneity test for the hypothesis that the U.S. or any single market is exogenous to other markets, is strongly rejected at the 5-percent significance level. The hypothesis that the U.S. and Canada, as a block are exogenous, is also rejected at the 5-percent significance level. The results clearly detect the presence of a substantial amount of interaction among world equity markets. At the horizon of 15 days, the percentage of error variance of a national stock market attributable to collective innovations in foreign stock markets range from 6.84 percent for the U.S. to 50.08 percent for Canada.

Table 3.1 confirms the U.S. market as the most influential in the world. While no single foreign market can explain more than 2 percent of the U.S. error variance, the U.S. explains between 6.43 percent (for Hong Kong) through to 42.03 percent (for Canada) of the foreign market error variances, with an average of 16.78 percent. U.S. innovations account for about 89 percent of its own variance with no other market nearly as exogenous. Patterns between Australia, Canada, Hong Kong, and the U.K. reveal that a British Commonwealth factor may be present with innovations in the Canadian, Hong Kong, and U.K. markets collectively accounting for nearly 10 percent of the Australian variance while nearly 6 percent of the Canadian variance is explained by innovations in Australia, Hong Kong, and the U.K. The Japanese market is the only market comparable to the U.S. stock market in terms of capitalisation value, yet it clearly acts like a follower in international stock markets. Innovations in the Japanese market fail to explain any substantial part of the error variances of other markets. On the other hand, the U.S. as well as the European markets, especially Switzerland and the U.K., exert substantial influence on the Japanese market.

Additional insight into the mechanism of international transmission of stock market movements can be gained by simulating the dynamic responses of each of the markets to innovations in a particular market. Eun and Shim concentrated on the responses of each of the nine markets to a shock in the U.S. market and found that innovations in the U.S. stock market were rapidly transmitted to all the other markets. All of the European and Asia-Pacific markets respond to the U.S. shock most dramatically on day 1, with the responses rapidly tapering off after the first day. Since these foreign markets are either closed or about to be closed when the U.S. market opens, they are expected to react to a U.S. shock with a one-day lag. The impulse response of the Canadian market to a U.S. shock is 0.67 on day 0, followed by 0.21 on day 1, and 0.04 on day 2. This implies that, unlike other markets, the Canadian market responds most strongly to the U.S. shock on day 0 when the U.S. shock occurs, with most adjustments completed by day 1. The result is consistent with a high degree of economic and financial integration and the free flow of information between the two countries, as well as the two markets being open at the same time. The U.K. market also reacts somewhat to the U.S. shock without lag because the two markets operate together for half an hour a day. Unlike the other markets, the U.K. seems to overreact to the U.S. shock on days 0 and 1, which is subsequently corrected by a negative reaction on day 2.

Table 3.1

ACCOUNTING NATIONAL STOCK MARKET INNOVATIONS[1]

Market Explained	Horizon (days)	By Innovations in AUS	CAN	FRA	GER	HK	JAP	SWI	UK	US	FM[2]
Australia	5	73.89	2.80	1.16	0.31	1.17	1.13	0.60	3.50	15.44	26.11
	10	72.07	3.24	1.24	0.45	1.64	1.43	0.68	3.94	15.31	27.93
	20	70.05	3.49	1.70	0.82	2.06	1.46	1.48	4.03	14.89	29.95
Canada	5	0.24	51.74	0.06	0.24	0.39	0.30	0.57	0.85	45.59	48.26
	10	1.03	49.92	0.29	0.28	1.13	0.49	1.40	1.43	44.04	50.08
	20	1.94	47.98	0.71	0.74	1.60	0.85	2.09	2.05	42.03	52.08
France	5	0.15	0.44	82.38	0.33	0.97	1.11	1.07	0.66	12.89	17.62
	10	0.47	0.53	80.02	0.44	1.64	1.24	1.72	1.11	12.83	19.98
	20	0.97	0.79	77.81	0.77	1.97	1.36	2.04	1.57	12.72	22.19
Germany	5	0.48	0.41	0.11	75.64	0.78	0.85	5.89	1.59	14.25	24.36
	10	0.74	0.59	0.57	73.41	0.89	1.39	6.79	1.81	13.80	26.59
	20	0.83	0.88	0.81	71.98	1.17	1.65	6.80	2.01	13.88	28.02
Hong Kong	5	0.16	0.40	0.31	0.57	90.36	0.55	0.31	1.05	6.28	9.64
	10	0.34	1.20	0.38	0.88	87.38	0.96	0.93	1.70	6.23	12.62
	20	0.84	1.43	0.67	1.07	84.49	1.46	1.31	2.30	6.43	15.51
Japan	5	0.70	0.43	0.24	0.31	0.82	81.15	3.14	2.54	10.68	18.85
	10	0.88	0.57	0.71	0.70	1.22	78.88	3.55	2.57	10.92	21.12
	20	1.36	0.93	1.26	1.03	1.67	76.22	3.62	2.87	11.04	23.78
Switzerland	5	0.27	0.58	0.47	0.62	0.47	0.27	76.23	1.14	19.93	23.77
	10	0.45	0.63	1.40	0.78	0.69	0.74	73.89	1.35	20.07	26.11
	20	0.97	1.65	1.83	1.28	1.02	1.24	71.13	1.38	19.49	28.87
U.K.	5	0.39	1.01	0.16	0.11	0.44	0.22	0.57	82.70	14.40	17.30
	10	0.51	1.25	0.75	0.26	0.98	0.81	0.94	80.45	14.06	19.55
	20	0.88	1.66	1.45	0.66	1.20	1.38	1.08	77.94	13.76	22.06
U.S.	5	0.59	1.19	0.18	0.15	0.84	0.37	0.34	0.07	96.27	3.373
	10	0.71	1.70	0.26	0.38	1.06	0.68	1.49	0.56	93.16	6.84
	20	1.30	2.24	1.00	0.76	1.32	1.28	2.09	1.02	88.98	11.02

[1] Each entry in the table denotes the percentage of forecast error variance of the left-hand side market explained by the market at the top.
[2] Each entry in the last column, FM, of the table denotes the percentage of forecast error variance of the left-hand side market explained collectively by the 'foreign' markets.
Reproduced from Eun and Shim (1989, p. 249).

Reactions to a shock in the U.S. market also reveal interesting regional patterns. The three continental European markets of France, Germany, and Switzerland, respond to a U.S. shock in an almost identical fashion. They accommodate most of the U.S. shock on day 1 which shows that they are highly efficient in processing international news. In contrast to this are the Asian-Pacific markets, especially Australia and Japan, which process the information more slowly. These markets continue to react noticeably through day 2. Because both the Australian and Japanese markets are influenced by the U.K. as well as U.S. market, these slow responses may reflect the reactions of these markets to the (unpredicted) U.K. reaction to the U.S. shock, rather than market inefficiency per se. With these 'reactions to reactions' lasting for a few days following the original shock, market efficiency would require that much of the responses to a shock be completed within a few days. Eun and Shim examined the patterns of Australian and Japanese reactions to a U.K. shock and the evidence supports the view. Both the Australian and Japanese markets essentially complete their reactions to a U.K. shock by day 1, with no further noticeable responses. Given the time zone differences between these two countries and the U.K., the observed response patterns are fully consistent with the market efficiency.

Eun and Shim's results appear to be generally consistent with the notion of efficiency between world equity markets with most of the responses completed within two days of a shock. This efficiency suggests that while there are some large responses to shocks, in the U.S. market in particular, it would be difficult for investors to profit from developments in leading markets due to the short duration of the lag. Most of the response is felt immediately. Eun and Shim's results certainly confirm the existence of significant linkages between markets in their study. The benefits of diversifying outside the domestic market are much reduced when an investor can simply invest according to the effect of a leading market like the U.S. when its shocks are quickly transmitted to other markets. Eun and Shim's results confirm increasing comovement between world equity markets. Their results confirm the U.S. as the leader market. Espitia and Santamaria (1994) define a market as leader, "… if price movements in this market affect other markets, and it is not itself affected by price movements in the other markets in the earlier periods. This will result in the forecast errors of this market being determined by its own innovations, without being significantly affected by innovations produced in other markets." (p. 2).

Jeon and Von Furstenberg (1990) explain that increasing comovement between equity markets might be the result of one of two things. It may be due to the decreasing regulation of world financial markets and the resultant increase in integration which has led to an increase in the efficiency with which capital is allocated and news is processed worldwide. Alternatively, world equity markets may just be reacting increasingly to each other even if there are no news developments of global economic significance that would account for such comovement. The latter description is fairly similar to the contagion effect put forward by King and Wadhwani (1990). Regardless of the explanation, if markets are indeed prone to greater comovement, then the benefit of diversifying outside the domestic market are reduced. Jeon and Von Furstenberg examined changes in price relations among the world's major stock markets that might have been precipitated by the crash of October 1987.

Using the VAR technique, Jeon and Von Furstenberg focused on the correlation of daily price movements from 1986 to 1988 for the New York, Tokyo, London and Frankfurt stock markets. The 35-month period is divided into two subperiods (January 6/7, 1986 to October 13/14, 1987, and October 21/22, 1987, to November 24/25, 1988) to examine whether there have been changes in interrelationships among stock prices in the major world equity markets since the stock market crash of October 1987. While their study focuses on a short time period and a small number of countries, their findings are worth noting. They found that the degree of international comovement in stock price indices has increased significantly since the crash of October 1987. Since the crash there has been an increase in the role of the immediately preceding market in determining prices. The results are of course consistent with both of the explanations put forward by the authors for explaining faster and stronger transmission of innovations. Jeon and Von Furstenberg's results also indicate that the leadership of the New York Stock Exchange has been reduced, especially against the Tokyo market.

Espitia and Santamaria (1994) also used the VAR technique to study the linkages between world equity markets. Using daily data during the period of 1987 to 1992, their sample included indices for the stock exchanges of Japan, Spain, Italy, Germany, France, U.K., and the U.S., thus overlapping a large part of Eun and Shim's sample. The early studies of Grubel (1968) and others argued that diversification reduces risk without sacrificing expected return but Espitia and Santamaria pointed out that a prerequisite to justify this argument is that capital markets must be independent in the formation of their prices. If the markets move in parallel, then the opportunities for diversification are removed. The transmission of shocks in one market to other markets means that linkages between markets exist which might reduce the benefits of portfolio diversification.

The tests conducted by Espitia and Santamaria are similar to those used by Eun and Shim, except that they look at the effect of unit impulses for all of the markets, not only the U.S. Espitia and Santamaria found a high level of correlation between the daily return time series for all the markets studied. Like, Eun and Shim they find that the U.S. market is the most influential and the least influenced with Japan and Germany the most sensitive to shocks in the U.S. market, followed by the U.K., Spain and France. The impulse analysis revealed that the other markets were not nearly as influential as the U.S. market. When Espitia and Sanatamaria expressed the returns data in a common currency (Swiss francs) they found that their results were very similar. The strength of the relationships decreased only slightly. The analysis was also carried out without the U.S. market in the system. Even after excluding the influence of the U.S. market, the European markets proved to have very little influence on each other.

Espitia and Santamaria concluded from their results that diversification outside the domestic market does not appear to have an excessive economic rationale. Only if diversification is implemented by choosing stocks whose differential characteristics give them a specific behaviour with respect to the local stock market on which they are quoted will there be some use in such diversification. They believe that it makes more sense to take advantage of the information transmitted through the U.S. market, taking stock positions before this information is incorporated into the price of the stock. They also note that the effects of a shock to the New York market last longer in the period from 1987 to 1992 (up to four days) than in the 1980 to 1985 period (two days). Like Jeon and Von Furstenberg, this result suggests that the comovements of the markets have increased. In light of their results and those of Eun and Shim (1989), Espitia and Santamaria suggest, perhaps somewhat boldly on the weight of their evidence, that:

> "The growing internationalisation of economic activity has brought about a reduction of 'domestic' factors which have an effect only at national level. This has caused the parallel effect of a greater correlation among markets, although these are shown to be more independent in the discounting of strictly 'domestic' information, given that the amount of information that can be classified as such is becoming less and less." (p. 10).

Janakiramanan and Lamba (1997) studied the linkages between Pacific-Basin stock exchanges. Since the economies of these countries have been relatively isolated from outside influences and their foreign exchange markets only recently opened up and exchange rates floated, they make for an interesting sample. Also, restrictions on foreign ownership and capital flows continue to remain in place in some countries. With all the markets open simultaneously during the same day, the market linkages can be studied in a more dynamic setting where shocks in the system are expected to be transmitted between markets quickly. The developed markets of Australia, Hong Kong, Japan, New Zealand, Singapore, and the U.S. and the developing markets of Indonesia, Malaysia, and Thailand are examined, using daily data for the period, 1988-1996.

Results show that the U.S. market influences all markets, excluding the Indonesian market. The U.S. market accounts for between 6 and 22 percent of the forecast error variance of the Pacific Basin markets, excluding Indonesia where only 1 percent of the forecast error variance is explained. The U.S. market influences Australia the most, followed by New Zealand, Singapore, Malaysia, Hong Kong, Thailand and Japan. No market has any significant influence on the U.S. market. Consistent with the results of previous authors, the U.S. market is clearly the leading market in the Pacific Basin. Malaysia is the most 'endogenous' market with around 50% of its forecast error variance explained by all foreign markets combined followed by Australia, Singapore, Hong Kong, Thailand, and New Zealand. Like Eun and Shim (1989), Japan is found to be the least influenced among developed markets. Geographically and economically close countries like Australia and New Zealand, and Singapore and Malaysia exert significant influence over each other, based on their market opening times. For example, New Zealand, which opens before Australia, accounts for around 12% of the forecast error variance in Australia, while Australia only accounts for less than 3% of the forecast error variance of the New Zealand market.

When the VAR model was re-estimated without the U.S. market, no market leader was found. With the U.S. market excluded, the total foreign forecast error variance decreases substantially for Australia and New Zealand. On the other hand, there is only a marginal reduction in the total foreign error variance results for Hong Kong, Japan, Singapore, Malaysia and Thailand. This suggests that most of the foreign influence on New Zealand is from the U.S. market, while for all other markets opening later in the day, except Australia, the U.S. influence is filtered through the markets opening earlier in the day. The hypothesis that investor groups and the multiple listing of securities cause linkages with the larger market influencing the smaller market is supported by evidence from the linkage between Singapore and Malaysia. It cannot, however, be conclusively shown in the case of Australia and New Zealand, since New Zealand influences Australia more than Australia influences New Zealand. Of course, here the result is confounded due to the indirect influence, through New Zealand, of the U.S. market[3].

When Janakiramanan and Lamba test the impulse responses of the Pacific Basin markets to a one standard deviation unit shock in the U.S. market, they find, as would be expected in internationally efficient markets, that innovations in the U.S. market are rapidly transmitted to all other markets by day 1, except for Indonesia which does not react to innovations in any market. Malaysia and

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[3] The result is also confounded by the order of the variables in the VAR system, using the orthogonalised approach. The results presented in this study use the generalised approach which is invariant to the ordering of the variables in the VAR model. The results in Chapter 9 show that the Australian market actually has a greater influence on the New Zealand market, a finding that more accurately reflects the reality of the relationship between these markets.

Thailand's responses are relatively slow, with some reaction to a U.S. market shock after day 1. The impulse responses in the Australasian markets of New Zealand, Australia, Singapore, and Hong Kong on all other Australasian markets, excluding Indonesia, are also calculated. With the U.S. market excluded, impulse responses increase for shocks in these markets. The indirect influence of the U.S. market is made apparent since markets opening earlier in the day affect markets opening later in the day (and not vice versa).

Geographically and economically close markets such as Australia/New Zealand and Singapore/Malaysia are again shown to significantly affect each other with the earlier opening market exerting greater influence. For example, Australia's impulse response coefficient to a unit shock in New Zealand is 0.39 on day 0, while New Zealand's impulse response to a unit shock in Australia is 0 on day 0 and 0.14 on day 1. Finally, the VAR model was re-estimated over two subperiods, 1988-1991 and 1992-1996, so that the stability of the various market relationships observed could be considered and any major shifts in market linkages highlighted. The results generally indicate the absence of major shifts in the linkages between the markets analysed. They do however show that the percentage forecast error variance explained by the U.S. market drops in the 1992-1996 period for Hong Kong, Japan, New Zealand, Singapore, and Malaysia, while the percentage forecast error variance explained by all other foreign markets, excluding the U.S. market, increases.

The VAR tests reviewed in this section have provided largely consistent results. The U.S. market is certainly the dominant market, although some studies suggest that this dominance may be declining. Overall, there appears to be a high degree of linkage between markets, and the speed with which innovations are transmitted between markets suggests that the relationship between markets is highly efficient. The high level of comovement, implicit in the strong linkages found, mean that the benefits for international portfolio diversification may be less than suggested in the early literature. Greater comovement between markets, higher levels of market integration and the resulting linkages between markets, can all be seen as contributing to a reduction in the rationale to diversify outside the domestic market.

The benefits of the VAR technique in analysing international market efficiency should be clear. For one thing the consistency of the results should be encouraging. It is worth noting that the VAR methodology is not without criticism. Karolyi (1995) points out that studies like Eun and Shim (1989) and Jeon and Von Furstenberg (1990), which have focused on the contemporaneous and lagged correlation in daily closing-price changes across major stock markets, have ignored the changing conditional volatility of stock price changes and, more importantly, the international spillovers of these price-change volatilities that may be occurring at the same time. These volatility spillovers can be taken into account by using autoregressive conditionally heteroscedastic models to demonstrate the different dynamics for spillover effects in price changes and volatilities between the countries. Studies such as that by Hamao, et al. (1990) have already been reviewed in Chapter 2. Considerable attention has already been given to the problems that these alternative methods posses. The ability of the VAR technique to be employed to examine long-term linkages between a number of markets is the VAR technique's major advantage.

3.3 Using Cointegration Analysis To Examine The Linkages Between World Equity Markets

The VAR methodology is not the only technique that has been employed to test the relationship that exists between world equity markets. In this section the literature that has used cointegration analysis to test for stable long-run relationships between markets is considered. Arshanapalli and Doukas (1993) noted that the levels of national stock price indices for several of the countries Eun and Shim (1989) studied were non-stationary. Because the stationarity assumption is a requirement for models that test the effectiveness of international portfolio diversification or models which examine the efficiency of international stock markets, it is usual for these tests to take first differences of the series. The problem with first differencing is that it imposes too many unit roots, filtering out potentially important information regarding long-run common trends among non-stationary stock indices. Arshanapalli and Doukas used recent developments in the theory of cointegration by Engle and Granger (1987) to test international equity market linkages.

Cointegration among a set of variables implies that even if they are non-stationary, they never drift far apart. In contrast the lack of cointegration suggests that such variables have no long-run link. This methodology was used to study how different stock markets around the world are related. Engle and Granger showed that if two variables are cointegrated, then the variables follow a well specified error-correction model, where by 'well specified' it is meant that coefficient estimates, as well as the standard errors for the coefficients of the estimated equation(s) are consistent. The error-correction equation provides a means of testing the dynamic interaction of national stock price movements. Cointegration results have two important ramifications for investors. Firstly, diversifying outside the domestic market may not be as effective if those markets have comovements, i.e., they are cointegrated. If the markets are cointegrated they share a stable long-run relationship which implies comovement, although a VAR is needed to actually shed light on the nature of those linkages. Secondly, if two markets are cointegrated they may not be collectively efficient since it may be possible to use one stock market index to forecast the other. If the markets are collectively inefficient, the investor may be able to profit on the lag between markets. If one market leads another then investors have the opportunity to profit on the lag between markets if the lag is large enough to exploit. The important point is that this lag must be economically as well as statistically significant. Again, the VAR technique is needed to further examine the nature of the lags between markets.

Arshanapalli and Doukas study the linkages among stock prices in Germany, U.K., France, Japan and U.S., using daily closing data from January 1980 through May 1990. The relationships between stock market indices before and after the October crash are also considered, as is the impact of stock price movements in one market on another. Before testing for cointegration, the order of integration of the national indices needs to be determined. Tests for unit roots are performed using the augmented Dickey-Fuller (ADF) tests. The results of the unit root tests based on local currency units show the presence of a unit root in the levels of all indices. There is however, no evidence to support the presence of a unit root in first differences of the stock price indices. These results are consistent with the hypothesis that the national stock index series are individually integrated of order one, I(1). The results are similar when the period is split into pre-crash and post-crash subperiods. "Because stock price series are almost invariably found to be I(1), tests for cointegration have frequently been used to address questions about the nature of the long-run relationship between the stock prices of different companies or the overall market indices of different countries." (Richards, 1995, p. 637).

With the U.S. market as the base index, OLS estimation of cointegrating regressions were performed to test for stationarity in the residuals. Stationary residuals imply cointegration. Testing the entire sample revealed that the stock markets of France, Japan and the U.K. appear to be cointegrated with the U.S. stock market. The null hypothesis of no cointegration between the U.S. and German markets cannot be rejected. For the pre-crash period none of the stock markets appear to be cointegrated with the U.S. stock market at the 5 percent level, indicating that the link among stock prices in the five major stock exchanges was very weak for the period, January 1980 to September 1987. This result is in contrast to Eun and Shim (1989) who found a substantial amount of interdependence among national stock markets for the 1980 to 1985 period. For the post-crash period, the French, German and U.K. stock markets were found to be cointegrated with the U.S. stock market, but not the Japanese market. This result suggests that the link between the Tokyo and New York markets has reduced since the October 1987 crash with the linkage found between the markets for the entire period, attributable to the strong cointegrating influence of the month of October 1987. The interdependence between the U.S. stock market and the markets of France, Germany and the U.K. since October 1987 is consistent with the notion of cross-border market efficiency, with these markets not drifting far apart. When the tests were performed using dollar-denominated stock market indices the results were very similar.

The cointegration test was also conducted without the U.S. index, using the Japanese index as the base index for the OLS estimation of the cointegrating regressions. No cointegration between Japan and the stock markets in France, Germany and U.K. were found using the entire 1980-1989 period. For the pre-crash and post-crash periods no cointegration is found either. These results, together with those found in the previous test, indicate that the Japanese market offers an appealing choice for international portfolio diversification since it is not cointegrated with any of the four markets. Having established France, Germany and the U.K. as cointegrated with the U.S. in the post-crash period, Arshanapalli and Doukas proceed to examine the interactions among these markets by estimating the error-correction equations using data from the post-crash period. The error-correction term represents the degree to which stock markets deviate from a long-run alignment.

The first pair of stock markets (U.S. and France) were found to be tied together with a long-run relationship, which implies that the equilibrium error cannot be used to predict next period's stock market price changes in either stock exchange and that the two stock markets are efficient. This result means that even though the two markets are cointegrated, U.S. stock market innovations can still be exogenous. Results for the second pair of markets indicate that innovations in the U.S. stock market may affect the German stock market, consistent with the view that the two markets are efficient in the sense that the error correction cannot be used to help predict stock market changes. Similar results were obtained from the final pair of the U.S. and U.K. markets for the post-October 1987 period, although as was the case with France, the U.S. stock market changes appear to be exogenous. The results show substantial cross-exchange efficiency between the U.S. market and the three major European markets in the post-October 1987 period. Error-correction analysis also provides information about the short-run influence of a change in one market on the performance of another. The U.S. stock price index variable exerts a substantial amount of influence on all three European markets but European short-run stock market changes do not appear to have any significant influence on the U.S. stock market. This result is consistent with the results in the previous section where the VAR technique was used.

The problem with the cointegration analysis employed by Arshanapalli and Doukas is that it only provides pairwise comparisons and is not conducted in a multivariate framework where the interaction of all of the variables, together, are considered. This may account for some of the inconsistencies with the VAR tests reviewed in the previous section. Johansen (1988, 1991) extended the Engle and Granger (1987) cointegration methodology into a multivariate framework. In terms of world equity markets, the Johansen test has the advantage of not being restricted to only pairwise comparisons and is capable of examining the interdependence among several equity markets. This is much more realistic for assessing the linkages between world equity markets. While two countries may not be pairwise cointegrated, consideration of a third country might well result in a cointegrating relationships between the markets. Two recent studies have employed the Johansen multivariate cointegration technique to test for long-term relationships between world equity markets. The existence of such relationships reduce the benefit of diversifying outside the domestic market.

Hung and Cheung (1995) studied five Asian markets, Hong Kong, Korea, Malaysia, Singapore and Taiwan, using weekly data between January, 1981 to December 1991. The data was also split into two subperiods, 1981-1987 and 1987-1991. Using the Johansen multivariate cointegration technique they found no evidence that the markets were cointegrated where domestic currency was used. Exchange rate risk is also an important consideration for international investors. When the returns were translated into US dollar returns, the results revealed that the markets were cointegrated during the second subperiod of 1987-1991. This relationship can be attributed to the depreciation of the US dollar during the late 1980s. The evidence reflects coherence among the Asian currency responses against the US dollar in the second subperiod. When the same techniques were applied to examining the exchange rate, the five Asian currencies and the US dollar were found to be cointegrated in the second subperiod. By taking exchange rate risk into account, the results suggest that the benefits of diversifying outside the domestic market may be limited.

Chan, Gup and Pan (1997) used monthly price indices of stock markets for 18 countries which were separated into seven regional groupings. Unit root tests were carried out on the individual equity markets which were all found to follow a random walk, meaning that the markets are individually weak-form efficient. Johansen multivariate cointegration testing showed that in most of the cases, there was no significant cointegration for the full sample period, or for the 1960s, the 1970s or after 1988. There was one cointegrating vector found in the 1960s subperiod in the Asian group of countries. Chan, et al., concluded that "... common economic and geographic ties do not necessarily lead national stock markets to follow the same stochastic trend. The lack of significant cointegration in the overall sample and various sub-samples seems not to support this hypothesis... our results show no increase in the number of significant cointegration after the October 1987 stock market crash, indicating that the contagion effect is not very strong either." (p. 809). Although multivariate cointegration analysis can give us some indication about the level of comovement between markets, VAR analysis is much better suited to studying the linkages between markets.

3.4 Conclusions

If world equity markets are at least partially integrated, there will be at least some incentive for investors to diversify outside the domestic market, depending on the comovement between assets in the domestic market. The increasing integration of world equity markets would tend to result in reduced incentives to diversify outside the domestic market. In the first section, the finding in the early literature that markets are partially integrated was confirmed. Shawky, et al. (1997) found markets to be partially integrated. This means that the opportunity to realise gains from diversification outside the domestic market exists. Shawky, et al. also considered foreign exchange risk and found exchange rate risk to have very little impact on the risk of diversifying outside the domestic market. The problem with the methodology employed by Shawky, et al. is that it does not properly consider market linkages or the extent to which markets are linked.

The vector autoregression (VAR) methodology is well suited to testing the transmission mechanism between equity markets and gauging the linkages and efficiency between markets. Studies that have employed the VAR technique were reviewed in the second section. The results of these studies have generally found significant linkages between equity markets which suggest that the comovement between these markets is greater than that suggested in the early literature. The increasing integration of equity markets might explain this. The U.S. market was found to be the only market to exert significant influence on the other markets. Shocks to prices in the U.S. are quickly reflected in other markets suggesting a high degree of efficiency between markets. This efficiency suggests that investing on the lag between markets is unlikely to be profitable, especially when transaction costs mean that the size of the shock needs to be large for the transaction to be economic. The evidence from the testing in this section questions the rationale for investing outside the domestic market to reduce risk in the portfolio, although more isolated markets may still provide some opportunities.

Cointegration analysis has also been used to examine the linkages between markets. Arshanapalli and Doukas (1993) used pairwise cointegration testing and were able to confirm the dominant position of the United States in world equity markets. Although some signs of stable long-run linkages between equity markets were found, the influence of the October 1987 stock market crash was large on these results. Prior to the crash, the relationships were generally weak. When the United States was excluded from the tests, no significant linkages could be found between the other markets. The problem with the pairwise approach to cointegration testing is that the multivariate relationship between the markets which make up an investor's investment universe are not properly reflected. Multivariate cointegration tests consider more than two countries and give a better indication of the relationship between equity markets. Hung and Cheung (1995) and Chan, et al. (1997) used the Johansen cointegration technique to study the long-run relationship between markets and found little evidence of cointegration between markets. Hung and Cheung also considered exchange rate risk and when the returns data was expressed in U.S. dollars they found cointegration between the markets. The VAR technique appears to be much better suited to examining the linkages between markets than cointegration analysis is.

PART TWO

DATA & METHODOLOGY

Part two provides both a description of the data and the methodologies to be used in the empirical analysis in this study. Chapter 4 describes the stock index and exchange rate data used for the ten Asia Pacific markets in the study. The different time zones in which the markets trade are presented and the implications of non-synchronous trading discussed. The markets are also classified as 'emerging' or 'developed' to aide in the analysis of the results in Part three. Chapter 5 looks at the need to test for stationarity in the stock index data used for the empirical testing. The development of the unit root methodology for testing whether variables are stationary is presented. Chapter 5 also presents the methodology for multivariate cointegration testing which looks for linear combinations of the variables that are stationary, where the underlying variables are not individually stationary in their levels. Chapter 6 outlines the methodology of vector autoregression analysis. Special attention is given to a newly developed technique which results in impulse response analysis and variance decomposition outcomes that are invariant to the ordering of the variables in the model. The newly developed generalised approach is contrasted with the traditional orthogonalised approach. Chapter 6 also discusses the relative benefits of an unrestricted vector autoregression versus the vector error correction model (cointegrating vector autoregression).

Chapter 4: Data Description

In Chapter 4 the data set used for the empirical testing in this study is introduced. The stock market indices for the countries included in the study will be introduced and the exchange rate data used to transform the index data into United States dollar indices will also be described. Because the markets in this study do not all open and close simultaneously, consideration needs to be given to the non-synchronous nature of the stock market data. For this reason the open and closing times of each of the markets is presented in common Greenwich Mean Time (GMT). Establishing the order in which markets trade, enhances the understanding of the results in the empirical analysis. The ten Asia Pacific region markets included in this study can be classified as either 'emerging' or 'developed' markets. Classifying the markets aides the understanding of the results from this study. Finally, it is common with stock index data to take the natural logarithm of the levels data and to take first differences also. The rationale for this transformation is briefly discussed.

4.1 Raw Data

This study focuses on markets in the Asia Pacific region and looks at the linkages between the markets in this region. The large growth experienced by Asian markets during the 1980's, and for much of the 1990's, resulted in a great deal of foreign investment in these markets. The interest in this region has been reflected recently in a number of studies focusing on markets in this region. Janakiramanan and Lamba (1997) studied the linkages between nine Asia Pacific markets. The markets included in this study are similar to those studied by Janakiramanan and Lamba with three differences. The Indonesian market has been left out of this study. It was felt that the unstable nature of the Indonesian market might bias the results. For example, Syarif (1996) notes that in 1988 the number of listed companies on the Jakarta Stock Exchange was 24, a number which increased to 124 by 1990. The evidence in Janakiramanan and Lamba support this concern. The isolation of the Indonesian market actually resulted in Janakiramanan and Lamba excluding

Indonesia from some of their tests. The Philippines and Taiwan which were not included in the study by Janakiramanan and Lamba are included in this study.

Table 4.1 shows the ten markets and market indices chosen for empirical testing in this study. Because this study looks at the linkages between markets in the Asia Pacific region it was deemed important that the sample form a good representation of Asia Pacific markets. The ten markets included in this study represent a large proportion of the total capitalisation of Asia Pacific markets. The United States and Japan which are the two largest markets in the region, are included in the study. Stock exchange indices have been used as a proxy for the investment opportunities available in each country. In terms of applying the results to portfolio selection problems, this obviously represents a limitation. It should, however, be noted that "a stock price index, while not accurately reflecting the variation of any one stock price does present a good description of general market movement." (Ripley, 1973, p. 357). The following point is also pertinent. Investors can take better bets against the market, once they understand the broader relationship between the markets.

Table 4.1

ASIA PACIFIC STOCK MARKET INDICES DATA

Country	Index
Australia	Australia SE All Ordinary - Price Index
Hong Kong	Hang Seng - Price Index
Japan	Nikkei 225 Stock Average - Price Index
Malaysia	Kuala Lumpur Composite - Price Index
New Zealand[1]	New Zealand SE Capital 40 - Price Index
Philippines	Philippines SE Composite - Price Index
Singapore	Singapore Straits Times Industrial - Price Index
Taiwan	Taiwan SE Weighted - Price Index
Thailand	Bangkok Book Club - Price Index
United States	S&P 500 Composite - Price Index

[1] The Barclays Index was used for the period, 01/01/87 to 27/09/91. From 30/09/91, the NZSE Capital 40 Index replaced the Barclays index. Despite the change in index name, data was obtained to ensure continuity in the series so that it is useful for testing purposes.

The market indices were chosen according to two criteria. Firstly, they represent a substantial proportion of the total capitalisation of the market they proxy. As a consequence of this, they tend to meet the second criterion as well - that they be well recognised and quoted. The indices are much the same as those used in similar studies of Asia Pacific markets. The main difference is that other studies often use the Dow Jones Industrial Average of 30 stocks for the United States market proxy.

While this index is quoted as the most recognised United States index, the Standard & Poors 500, which is also well quoted, was chosen as it represents a greater cross-section of United States stocks.

The time period chosen for the study is January 1, 1987 through to May 29, 1998. Weekends are not included in the sample which results in 260 quoted trading days' in each non-leap year. It is standard practice in studies using stock market indices to use the 260 trading days. While this inevitably leads to non-trading days such as holidays being included in the sample, the standard practice (and that employed here) is to simply assume the same value of the last trading day for non-trading day holidays. The data set incorporates 2977 daily observations. This sample period was chosen for a number of reasons. The aim was to incorporate data as recently as possible so that the recent volatility that has occurred in world markets, and particularly Asian markets, could be captured. The October 1987 stock market crash was also included so that two periods of significant volatility common to all markets could be compared. January 1, 1987 was chosen as the start of the period because of a limitation with the statistics package, *Microfit* version 4.0 for Windows used for the empirical testing. The package allows for a maximum of 3000 observations. Certainly the 2977 observations used in this study will not result in any small sample threat to the integrity of the results.

An important risk facing investors seeking to diversify outside the domestic market is exchange rate risk. If an investor in foreign securities does not protect themselves against exchange rate fluctuations, they are effectively speculating on currency fluctuations. By using local currency data, the exchange rate risk for investors is effectively being ignored. If investors hedge their currency exposure, local currency data is sufficient. Given that the expense of hedging may rule it out for many investors, exchange rate adjusted data is also considered. The empirical testing is conducted twice - once on local currency data and also on exchange rate adjusted data which is transformed into United States dollars so that exchange rate risk is also considered. The United States dollar was chosen because of its dominant position in international trade and investment. The availability of U.S. dollar exchange rate data over the entire period was also an advantage. Daily exchange rates for each of the nine remaining Asia Pacific markets against the United States dollar, were used to transform the stock market indices into a common currency.

Table 4.2 shows the exchange rate data that was used in this study. Figure 4.1 plots each of the stock market indices, in levels, both in local currency and in expressed in U.S. dollars. The levels data is plotted in their natural logarithm form, to aid in the presentation of the graphs. Without such transformation it would be difficult to plot some of the local currency and U.S. dollar market indices effectively on the same graph. The graphs in Figure 4.1 were plotted so that the rationale for using exchange rate adjusted data could be considered and to provide a greater understanding of the data used throughout the study.

Table 4.2

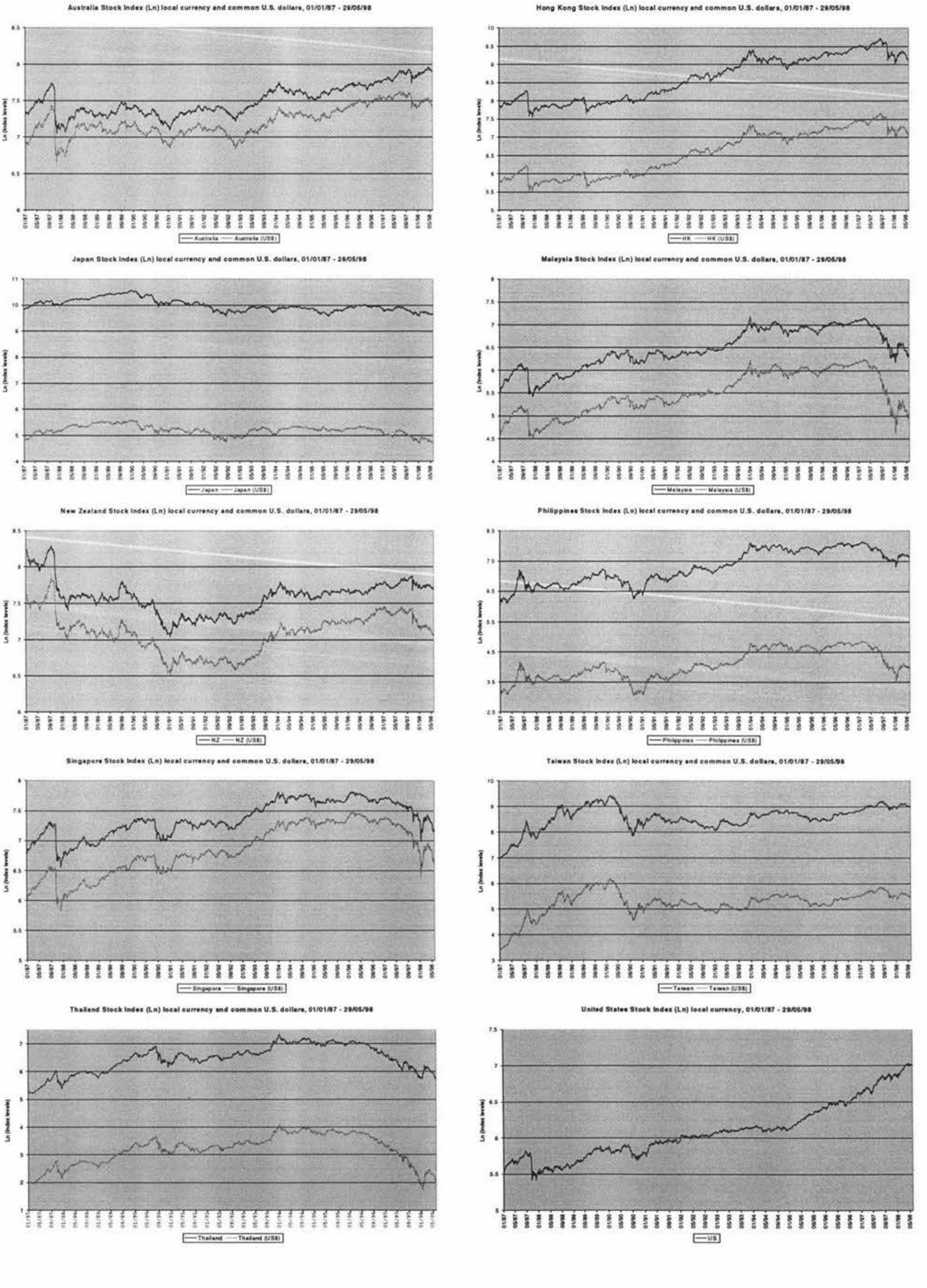
ASIA PACIFIC EXCHANGE RATE DATA

Country	Exchange Rate
Australia	US $ to Australian $
Hong Kong	US $ to Hong Kong $
Japan	US $ to Japanese Yen
Malaysia	US $ to Malaysian Ringgit
New Zealand	US $ to New Zealand $
Philippines	US $ to Philippine Peso
Singapore	US $ to Singapore $
Taiwan	US $ to Taiwan New $
Thailand	US $ to Thai Baht

Figure 4.1 shows that the correlation between the local currency and U.S. dollar stock market indices is generally high. There are, however, a number of differences which suggest that the analysis in this study will benefit from the consideration of exchange rate risk. Certainly the difference between the two data series is most notable in the case of Japan and least notable in the case of Hong Kong (whose currency has been fixed to the U.S. dollar during the entire period). For some of the other markets however, it is fairly apparent that the crisis in 1997 was like a two edged sword with investors suffering both a falling stock market and a falling currency to the U.S. dollar. Figure 4.1 makes it very clear that there are two periods of significant volatility, common to all ten markets, during the sample period. They are the October 1987 stock market crash and the 1997 'Asian crisis'. The U.S. market also stands out amongst the other markets. The U.S. market appears to have been reasonably free of significant volatility during the sample period and has continued to grow steadily throughout the period.

Figure 4.1

STOCK INDEX LEVELS (LN) FOR ASIA PACIFIC MARKETS - LOCAL CURRENCY AND U.S. DOLLARS, 01/01/87 – 29/05/98



4.2 Market Opening And Closing Times

Table 4.3 presents the market opening and closing times in local time and in Greenwich Mean Time (GMT). Because the Asia Pacific countries included in this study are in different time zones and do not all have the same trading hours, the markets do not simultaneously open and close. Non-synchronous trading can cause problems in some of the empirical testing carried out in this study. The empirical analysis is generally aided by establishing the order in which markets close so that it can be taken into account where necessary. Following Janakiramanan and Lamba (1998), the markets are ordered by closing time since close-to-close returns data is being used. Table 4.3 shows that the first market to trade (and close) in each new calendar day is the New Zealand market while the United States is the last market to close at the end of each calendar day.

Table 4.3

MARKET OPENING AND CLOSING TIMES[1]

Country	Index	Local Time	Greenwich Mean Time
New Zealand	New Zealand SE Capital 40	10:00 – 16:00	22:00[2] – 04:00
Taiwan	Taiwan SE Weighted	09:00 – 12:00	01:00 – 0.400
Philippines	Philippines SE Composite	09:30 – 12:00	01:30 – 0.400
Australia	Australia SE All Ordinary	10:00 – 16:00	00:00 – 06:00
Japan	Nikkei 225 Stock Average	09:00 – 11:00	00:00 – 02:00
		12:30 – 15:00	03:30 – 06:00
Hong Kong	Hang Seng	10:00 – 12:30	02:00 – 04:30
		14:30 – 15:30	06:30 – 07:30
Singapore	Singapore Straits Times Industrial	09:00 – 12:30	01:00 – 04:30
		14:00 – 16:00	06:00 – 08:00
Malaysia	Kuala Lumpur Composite	10:00 – 12:30	02:00 – 04:30
		14:30 – 16:00	06:30 – 08:00
Thailand	Bangkok Book Club	10:00 – 12:30	03:00 – 05:30
		14:30 – 16:00	07:30 – 09:00
United States	S&P 500 Composite	09:30 – 16:00	14:30 – 21:00[2]

[1] Ordered according to closing time (GMT).
[2] Times correspond to the previous day.

Evidence from the empirical testing in the literature revealed that the United States is considered the market leader in equity markets around the world. Certainly, market practitioners tend to look to the

U.S. market for guidance. Because of this the U.S. is often the first market to enter a system of equations with the other markets following in the order with which they close on the next calendar day. It is also common when correlation coefficients are being calculated between markets using daily data, a one day lagged value is used for the U.S. to reflect its influence and the fact that it is the first market to close (but that it closes on the prior calendar day). There are only two periods during each 24-hour day when no market in the study is open. One of these periods is between the time when Thailand closes at GMT 09:00 and the U.S. market opens at GMT 14:30. The other is between the U.S. market close of GMT 21:00 and the New Zealand open of GMT 22:00. It should be noted that daylight savings which operates in a number of the countries in the sample is likely to mean that there will be periods where these open and closing times in GMT will be slightly different to those reported in Table 4.3.

4.3 Emerging And Developed Markets

There are several countries in the Asia Pacific region that can be classified as an 'emerging' markets while other markets are clearly 'developed' markets. The classification of markets as being either 'emerging' or 'developed' can aide in the interpretation of the results from the empirical testing. For this reason, the ten markets in this study have been assigned as either 'emerging' or 'developed'. It should be noted that emerging markets tend to be less correlated with the rest of the world because of the high growth rates that characterise them. This adds to their attraction for international investors. It will be interesting to see if the linkages between the Asia Pacific equity markets reflect what has been observed of emerging markets. Richards (1996) used the International Finance Corporation's (IFC) classification criterion to determine emerging and developed markets. The IFC includes as emerging markets those stock markets in countries or territories with income levels that are classified by the World Bank as low or middle income.

For the ten Asia Pacific markets in this study, the Philippines, Malaysia, Taiwan and Thailand are regarded as emerging markets by the IFC while Singapore, New Zealand, Australia, Japan, the United States and Hong Kong are regarded as mature or developed markets. The IFC classification will be used in this study. The only respect with which this classification differs to those used in some other studies is the inclusion of Singapore and Hong Kong as developed nations. Because of their natural association with Asian emerging markets a number of studies have tended to categorise these markets as emerging. As the World Bank classification on income levels suggest, these markets are not emerging and are in fact developed nations. If Singapore and Hong Kong were to be classified as emerging, then one might naturally question the classification of the New Zealand market as developed.

4.4 Data Transformation

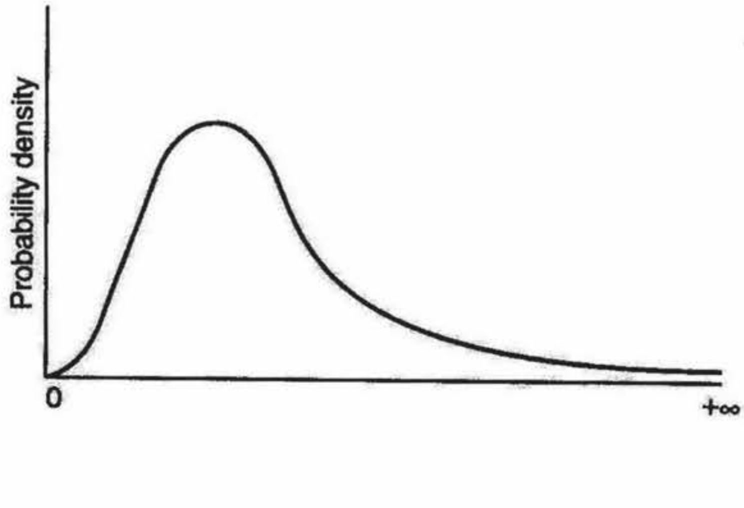
Following the convention used in much of the empirical testing of stock market data, the stock index levels will be transformed by taking the natural logarithm of the raw data. Further, stock return relatives will be taken as the first differences of the transformed data, calculated using the formula in Equation (4.1).

$$R_{j,t} = [Ln(I_{j,t}) - Ln(I_{j,t-1})] * 100$$
$$= Ln\,(I_{j,t} / I_{j,t-1}) * 100, \qquad (4.1)$$

where $I_{j,t}$ is the value of the index on day t for stock market j and $I_{j,t-1}$ is the value of the index on day t-1 for stock market j. The natural logarithm of a stock index data series is used as shown in equation (4.1). The natural logarithm is used in empirical testing where the assumption of normality in the data is a requirement for the test. "A variable is said to be lognormally distributed if the natural logarithm of the variable is normally distributed. This is an intuitively appealing model of the distribution of security price relatives because, if the price rises the price relative will be greater than one, whereas if the price falls, the price relative will be less than one, but it cannot be negative." (Watsham & Parramore, 1997, p. 140).

Figure 4.2

LOGNORMAL PROBABILITY DENSITY FUNCTION



The lognormal probability density function in Figure 4.2 shows that the lognormal distribution is skewed to the right but has no negative numbers. This is compatible with the possible distribution of security price relatives because they cannot fall below zero but a few observed values could be very high. It is also worth noting "that the natural logarithm of the security price relative, Ln $(I_{j,t} / I_{j,t-1})$, is the continuously compounded rate of return to holding security j over the time period t – (t – 1). If security prices relatives are lognormally distributed, the continuously compounded rate of return, Ln $(I_{j,t} / I_{j,t-1})$ * 100, will be normally distributed. Skewness and kurtosis are two problems that often occur in stock price returns and cause the distribution to be non-normal.

Chapter 5: Testing For Stationarity And Cointegration

Testing for stationarity in variables to be used in time series analysis came into prominence in the late 1970's as a result of a growing body of evidence, most notably including Granger and Newbold (1974) that showed non-stationary variables resulted in spurious regression results. In this chapter the methodology to test market index variables for stationarity is presented. The weight of empirical evidence suggests that stock index data is not stationary in its levels but is stationary in its first differences. The first section concentrates on unit root testing, highlighting the development of unit root testing and presenting the methodology to be used in this study. Following, Perron (1989), the effect of structural change is considered in testing for the presence of a unit root. A dummy variable for the 1987 stock market crash is included in the unit root regressions. In the second section, cointegration analysis is introduced and the multivariate cointegration methodology explained. Testing for cointegration in a set of variables amounts to checking for a linear combination of the variables which is stationary. If the variables are not individually stationary in their levels, there may be a combination of the variables that is. The results from the cointegration analysis are important both, in establishing whether an error-correction term should be considered in the vector autoregression analysis, and in establishing whether a stable long-run relationship between the variables exists.

5.1 Testing For The Presence Of A Unit Root[1]

A time series is said to be stationary if it has a constant mean, a constant variance and a covariance, which depends only on the time between lagged observations. The mean of a stock price series will naturally depend on the level of the index. The magnitude of the variance is also a function of the levels of the data used in the calculations, while the covariance is similarly influenced by the levels

[1] This section benefited greatly from Chapter 4: Testing for Trends and Unit Roots, in Enders, W. *Applied Econometric Time Series*. (New York: John Wiley & Sons, 1995).

of the data being analysed. This tends to suggest that stock index data is generally non-stationary in its levels. Stock market returns, or first differences, however, are more likely to be stationary. This is because the returns required by investors should be dependent only on the uncertainty surrounding the investment and independent of the level of the index. Returns data is more likely to have a constant mean and variance, and a covariance between observations that depends only on the number of lags between those observations. For this reason, stock index data in their first differences is often used in empirical testing in finance. If a variable is stationary in its levels it is said to be integrated of order zero, or an I(0) process. If a variable is stationary in its first differences then it is said to be integrated of order one, or an I(1) process. Unit root tests also have an economic interpretation. Weak form efficiency asserts that stock index data should not be stationary in their levels, but that a stock index should follow a random walk. An I(0) process does not follow a random walk, but an I(1) process does. A number of approaches to testing for the presence of a unit root have been devised. The development of unit root testing is presented in this section.

The unit root issue arises naturally in the context of a standard regression model, the type which forms the basis of the vector autoregression analysis in this study. Consider the regression equation:

$$y_t = a_0 + a_1 z_t + e_t \tag{5.1}$$

The assumptions of the classical regression model necessitate that both the $\{y_t\}$ and $\{z_t\}$ sequences be stationary and the errors have a zero mean and finite variance. In the presence of non-stationary variables, there might be what Granger and Newbold (1974) referred to as a spurious regression. A spurious regression has a high R^2, t-statistics that appear significant, but results that are without any economic meaning. If the researcher wants to ensure that their empirical testing has results with economic meaning, it is important that the variables used are stationary.

Fortunately, Dickey and Fuller (1979, 1981) devised a procedure to formally test for the presence of a unit root. Dickey and Fuller considered three different regression equations that can be used to test for the presence of a unit root:

$$\Delta y_t = \gamma y_{t-1} + \varepsilon_t \tag{5.2}$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \varepsilon_t \tag{5.3}$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \varepsilon_t \tag{5.4}$$

The difference between the three regression equations relates to the presence of the deterministic elements, a_0 and a_2t. The first is a pure random walk model, the second adds an intercept or drift term, and the third includes both a drift and a linear time trend. The parameter of interest in the regression equations is γ; if $\gamma = 0$, the $\{y_t\}$ sequence contains a unit root. The test involves estimating one (or more) of the equations above using OLS in order to obtain the estimated value of γ and the associated standard error. Comparing the resulting *t*-statistic with the appropriate value reported in the Dickey-Fuller tables allows the researcher to determine whether to accept or reject the null hypothesis, $\gamma = 0$. Regardless of which of the three forms of the equations is estimated, the methodology is the same. The critical values of the *t*-statistics do, however, depend on whether an intercept and/or time trend is included in the regression equation.

Not all time series processes can be well represented by the first-order autoregressive process, $\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \varepsilon_t$. It is possible to use the Dickey-Fuller tests in higher order equations such as (5.5), (5.6), and (5.7). These tests are known as augmented Dickey-Fuller tests.

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+a} + \varepsilon_t \tag{5.5}$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+a} + \varepsilon_t \tag{5.6}$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+a} + \varepsilon_t \tag{5.7}$$

The parameter of interest remains γ, and the critical values for (5.2), (5.3) and (5.4) apply for (5.5), (5.6), and (5.7) respectively. While the standard Dickey-Fuller test is robust against reasonable degrees of heteroscedasticity, serial correlation is often found in the residuals of the standard regressions. Serial correlation can cause problems which results in incorrect conclusions from unit root testing. The problem of testing for stationarity when there is serial correlation in the residuals can be solved by using the augmented Dickey-Fuller test. This approach incorporates lagged values of the dependent variable in the regression equation, with the number of lags chosen to remove serial correlation from the residuals.

Just what constitutes the appropriate lag length has puzzled researchers for some time. Because serial correlation in the residuals leads to spurious regression results which cannot necessarily be relied on, the lag length adopted should to a large extent, be chosen to ensure the absence of serial correlation in the residuals. It is not possible to properly estimate γ and its standard error unless all the autoregressive terms are included in the estimating equation and it is important to include the appropriate number of lags. Including too many lags reduces the power of the test to reject the null of a unit root since the increased number of lags necessitates the estimation of additional parameters and a loss of degrees of freedom. To few lags will not appropriately capture the actual error process so that γ and its standard error will not be well estimated.

A number of pre-procedure tests for selecting the appropriate lag length exist, such as the Schwarz Bayesian criterion (SBC) recommended by Enders (1995). The SBC trades off a reduction in the sum of squares of the residuals for a more parsimonious model and is calculated as in equation (5.8).

$$SBC = T \ln(\text{residual sum of squares}) + 2n, \quad (5.8)$$

where n is the number of parameters estimated and T is the number of usable observations. In the empirical testing in this study, the SBC is calculated in *Microfit* to give an indication of what lag length might be appropriate. The SBC provides an initial lag length to use, but further consideration should be given to the choice of lag length after the regression is run, by checking the residuals for serial correlation. There are two useful statistics for checking residuals for serial correlation. In the case where no lags of the dependent variable were included amongst the regressors, the Durbin Watson statistic can be used to check for serial correlation. A Durbin Watson statistic, *d*, of two means that there is no serial correlation present in the residuals. Ott (1993) suggests values of *d* less than approximately 1.5 (or greater than approximately 2.5) lead one to suspect positive (or negative) serial correlation. To err a little more on the side of caution, it was decided to accept an absence of serial correlation for values of d between 1.7 and 2.3.

Where lags of the dependent variable are included amongst the regressors, the Lagrange Multiplier (LM) test developed by Godfrey (1978 a,b) was used to check for the presence of serial correlation in the residuals. The LM test for residual serial correlation is applicable to testing the hypothesis that the residuals are serially uncorrelated against the alternative hypothesis that they are autocorrelated of order p (either as autoregressive or moving average processes). The order p is set equal to 1 for the tests conducted on daily data using *Microfit*. While the Durbin Watson statistic and LM test for residual serial correlation were used, further consideration to serial correlation was given by examining how the coefficient of interest, γ, was affected by changing the number of lags. If the coefficient is stable for changing lag lengths, one can be more confident that serial correlation is not causing spurious regressions.

Another important consideration in unit root testing is which of the models, (5.5), (5.6) and (5.7) is most appropriate. Unless the researcher knows the actual data-generating process, some choice as regards which model to use needs to be made. It might seem reasonable to use the most general of the models. If the true process is a random walk process, this regression should find $\gamma = 0$. The important point, however, is that a regression equation that mimics the actual data-generating process should be used. If we inappropriately omit the intercept or time trend, the power of the test can go to zero. For example, if as in equation (5.7) the data generating process includes a trend, omitting a_2t imparts an upward bias in the estimated value of γ. On the other hand, extra regressors increase the absolute value of the critical values so that you may fail to reject the null of a unit root. Suppose that the time series $\{y_t\}$ is assumed to be generated by the random walk plus drift process:

$$y_t = a_0 + a_1 y_{t-1} + \varepsilon_t, \qquad a_0 \neq 0 \text{ and } a_1 = 1.$$

If there is no drift, it is inappropriate to include the intercept term since the power of the Dickey-Fuller test is reduced. When the drift is actually in the data generating process, omitting a_0 from the estimating equation also reduces the power of the test in finite samples. How do you know whether to include a drift or time trend in performing the tests? "The key problem is that the tests for unit roots are conditional on the presence of the deterministic regressors and tests for the presence of the deterministic regressors are conditional on the presence of a unit root." (Enders, 1995, p. 255).

Dolado, Jenkinson, and Sosvilla-Rivero (1990) suggest a fairly straight forward procedure to test for a unit root when the form of the data-generating process is unknown. Where other considerations such as structural change described below do not take precedence, the procedure of Dolado, et al. (1990) will be adopted in the unit root tests. The first regression run will include both the drift and trend terms in the equation. Because unit root tests have low power to reject the null hypothesis with more terms included, there is no need to proceed if the null is rejected. If the null cannot be rejected then the significance of the drift and trend terms should be examined. If they are significant then they should be included and we must conclude that there is a unit root present. If they are not significant, one or both should be removed and the regression run again to test for the presence of a unit root.

The distribution theory supporting the Dickey-Fuller tests assumes that the errors are statistically independent and have a constant variance. In using this methodology, care must be taken to ensure that the error terms are uncorrelated and have constant variance. Phillips and Perron (1988) developed a generalisation of the Dickey-Fuller procedure that allows for fairly mild assumptions concerning the distribution of the errors. Enders (1995) briefly explains the procedure by considering the following regression equations:

$$y_t = a_0^* + a_1^* y_{t-1} + \mu_t \tag{5.9}$$

and

$$y_t = \tilde{a}_0 + \tilde{a}_1 y_{t-1} + \tilde{a}_2 (t - T/2) + \mu_t \tag{5.10}$$

where T = number of observations and the disturbance term μ_t is such that $E\mu_t = 0$, but there is no requirement that the disturbance term is serially uncorrelated or homogeneous. Instead of the Dickey-Fuller assumptions of independence and homogeneity, the Phillips-Perron test allows the disturbances to be weakly dependent and heterogeneously distributed.

Phillips and Perron characterise the distributions and derive test statistics that can be used to test hypotheses about the coefficients a_i^* and $\tilde{a}_i$ under the null hypothesis that the data are generated by the process, $y_t = y_{t-1} + \mu_t$. The Phillips-Perron test statistics are modifications of the Dickey-Fuller *t*-statistics that take into account the less restrictive nature of the error process. The critical values for the Phillips-Perron statistics are the same as those used for Dickey-Fuller tests. The Phillips-Perron test is a semi-parametric test that takes into account the possibility of time-dependent heteroskedasticity of errors. In this study, the Dickey-Fuller and augmented Dickey-Fuller tests will be used. This is essentially because the Dickey-Fuller tests can be more easily modified to take into account the possibility of structural change as highlighted by Perron (1989).

In performing unit root tests, special care must be taken if it is suspected that structural change has occurred. When there are structural breaks, Dickey-Fuller and Phillips-Perron tests are biased toward the non-rejection of a unit root. In terms of stock market data, it is not difficult to think of a situation where this might occur. In the sample period used in this study, there were two periods where a shock common to all ten markets occurred. The first was the October 1987 stock market crash. The second was the more recent October 1997 correction. Where a one-time shock occurs in an otherwise largely stationary time series, that shock may well result in the non-rejection of a unit root where, had the shock not occurred, the existence of a unit root would have otherwise been rejected. Because the critical values in Perron (1989) were calculated for only one structural break, a dummy variable for 1987 is considered in this study.

Perron (1989) used his analysis of structural change to challenge the findings of Nelson and Plosser (1982) who had found most macroeconomic variables to be non-stationary. Perron found that most macroeconomic variables were *not* characterised by unit root processes. Instead, Perron found these processes to be trend stationary with structural breaks. In particular, the stock market crash of 1929 and the dramatic oil price increase of 1973 were exogenous shocks having permanent effects on the mean of most macroeconomic variables. To take account of the effect of structural change and one-time shocks to time series data, Perron included a dummy variable in the Dickey-Fuller regression equations to take into account the effect of structural change.

Perron described three different models: one that permits exogenous change in the level of the series (a "crash"), one that permits an exogenous change in the rate of growth, and one that allows both changes. The first of these three models, Perron's 'Model (A),' is suitable for one-time shocks like the 1987 crash. The inclusion of a dummy variable for structural change is suitable when testing the levels for stationarity. If it is not possible to reject the null hypothesis of a unit root in the levels, even after having taken into account the effect of the 1987 crash, then the first differences will be tested. A dummy variable is not included in the regression equation for testing for a unit root in the first differences. Where the variable is tested in its first differences for stationarity, the standard Dickey-Fuller regressions described above will be used. Testing for the presence of a unit root in the levels data using Perron's method is now described.

Equation (5.11) shows Perron's 'Model (A)' for testing for the presence of a unit root while considering structural change by including the dummy variable, $D(TB)_t$ in the original Dickey-Fuller regression in (5.6).

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+a} + dD(TB)_t + \varepsilon_t, \tag{5.11}$$

where $D(TB)_t = 1$ if $t = TB + 1$,that is the time of the structural break, and 0 otherwise. Perron (1989) conducted 5000 replications, using Monte Carlo simulations to determine the critical values for the parameter of interest, γ. These critical values are calculated for different values of the parameter, λ, the ratio of pre-break sample size to total sample size. The critical values are identical to the Dickey-Fuller critical values if $\lambda = 0,1$. The values for λ are given in increments of 0.1 from 0.1 to 0.9 inclusive. The value of λ in this study, is 0.07 reflecting the relatively close proximity of the 1987 crash to the start of the period, January 1987 to May 1998. The values of γ calculated from equation (5.11) will be compared to the critical values for $\lambda = 0.1$, as provided by Perron (1989).

There is, however, one problem in considering structural change in the unit root testing in this study. That is, critical values have only been calculated for the model (5.11) which includes an intercept term. As we know, there are two other models, one with an intercept and trend, and a standard model with neither intercept nor trend that can explain the data generating process of a variable. While it may be no problem where a variable's true data-generating process is reflected by the model (5.11), there may be problems, for example, where the intercept is not significant. The approach taken in this study will be to consider with care any situation that arises where (5.11) does not appear to adequately explain the data generating process of the variable in question. Using what we know about the relationship between the Perron critical values and the Dickey-Fuller critical values, it is possible to make an informed decision, even in the absence of the actual critical values. This process will be discussed in more detail in Chapter 8.

Enders (1995) warns that care must be taken in adopting Perron's procedure since it assumes that the date of the structural break is known. Care was taken in the case of the 1987 crash, although it was fairly apparent in surveying the daily returns data where the structural break occurred. It is also important to recognise that Perron's approach assumes that the structural break, in this case the 1987 stock market crash, is exogenous and not a realisation of the underlying data-generating mechanism of the particular series. While it might be difficult to consider the 1987 crash as truly exogenous, one can still justify the assumption by the undue significance that this one date places on the result for the entire series. At least to some extent, the 1987 crash was the result of overreaction by market participants which did not properly reflect the underlying data-generating mechanism of the stock index series. Also, it is true that such crashes which are reasonably few and far between, do not constitute 'normal' trading conditions in the market. It may not be altogether appropriate to let an incident which does not reflect 'normal' trading conditions to impact on the results of empirical testing on the market so greatly.

5.2 Johansen Multivariate Cointegration Methodology[2]

The concept of cointegration was developed in Engle and Granger (1987). Cointegration is a property possessed by some non-stationary time series. If two non-stationary time series are cointegrated then a linear relationship exists between the two series which is stationary. Cointegration testing is suitable for time series which are integrated of the same order and is often used to test for stationarity in a combination of I(1) variables. The results from cointegration testing are important for two reasons. Firstly, they have an economic interpretation which indicates whether a stable long-run relationship between the variables exists. Secondly, where variables are cointegrated, an error-correction model exists which should be considered in any further testing such as vector autoregressions (VARs). Variables that are cointegrated mean that a cointegrating vector autoregression which specifies the error-correction term in the vector autoregression may be more appropriate than the traditional unrestricted VAR. The issue of whether to use an unrestricted VAR or a cointegrating VAR will be taken up in the next chapter. In this section a brief methodology for testing for the existence of multivariate cointegration in non-stationary variables is

[2] This section has been adapted from an excellent description of the methodology of Johansen multivariate cointegration in Chan, Gup, and Pan (1997).

presented. Many of the principles that apply in tests of multivariate cointegration, apply in VARs and will be presented in more detail in the following chapter.

Cointegration allows for the departure from equilibrium in the short-run but not in the long-run. The description of the multivariate cointegration methodology is probably aided by considering pairwise cointegration first. Consider the stock prices in countries, i and j (S^i_t and S^j_t), and let P_t be the vector that consists of S^i_t and S^j_t. Engle and Granger (1987) found that a variable, say S^i_t, is said to be integrated of order d, denoted as $S^i_t \sim I(d)$, if the dth difference of S^i_t is stationary. The vector P_t is said to be cointegrated of d, b, denoted as $P_t \sim CI(d, b)$, if (1) each component of P_t is integrated of order d, and (2) there exists a non-zero vector γ such that $\gamma' P_t$ is integrated of order $d - b$, for $b > 0$. If both S^i_t and S^j_t are $I(1)$ and $P_t \sim CI(1, 1)$ (i.e. $\gamma' P_t \sim I(0)$), error-correction equations like equation (5.12) exist for countries i and j.

$$\Delta S^i_t = a_1[S^i_{t-1} - \gamma_1 S^j_{t-1}] + \text{lagged } (\Delta S^i_t \text{ and } \Delta S^j_t) + e^i_t,$$

$$\Delta S^j_t = a_1[S^j_{t-1} - \gamma_1 S^i_{t-1}] + \text{lagged } (\Delta S^i_t \text{ and } \Delta S^j_t) + e^j_t, \qquad (5.12)$$

where a's are non-zero coefficients and e_t's are stationary, possibly autocorrelated error terms.

Granger (1986) and MacDonald and Taylor (1988, 1989) showed that the asset prices from two efficient markets cannot be cointegrated. The implication from the error-correction equations is that stock price changes in country i and j are predictable by $[S^i_t - \gamma_1 S^j_t]([S^j_t - \gamma_1 S^i_t])$ if stock prices in countries i and j are cointegrated. On the other hand, if stock prices in countries i and j are not cointegrated, then the stock price in country i has already incorporated all available information into the pricing process and the historical prices of country j contain no useful information for forecasting the stock price changes of country i. The idea behind the error-correction terms is "... simply that a proportion of the disequilibrium from one period is corrected in the next period." (Engle and Granger, 1987, p. 255). By incorporating this into a VAR which includes non-stationary I(1) variables, long-run stability can be enhanced.

Johansen (1988, 1991) extended Engle and Granger's (1987) cointegration tests into a multivariate framework. The Johansen test has the advantage of not being restricted to pairwise comparisons of variables and can be used to examine interdependence among several variables. While two variables may be pairwise cointegrated, the inclusion of a third variable may result in the absence of cointegration and vice versa. When evaluating a number of variables for interdependence, pairwise cointegration tests are limiting. The null hypothesis for the multivariate cointegration is that there is no cointegration among the stock prices. Johansen considers a fairly general unrestricted error-correction model in the form in equation (5.13).

$$\Delta S_t = \Gamma_1 \Delta S_{t-1} + \ldots + \Gamma_{k-1}\Delta S_{t-k+1} + rS_{t-k} + \mu + \varepsilon_t, \quad (5.13)$$

where S_t = (ρ * 1) vector of stock prices at time t;

r = (ρ * ρ) parameter matrix;

μ = (ρ * 1) intercept term.

Equation (5.13) may also include a trend term and dummy variables for structural change. Dummy variables for the 1987 crash will be included in (5.13), as will an intercept and trend term. *Microfit* computes log-likelihood ratio statistics to test whether these variables are jointly significant or whether they can be deleted from the model. The methodology for this test can be found in Chapter 6 which explains tests for the significance of deterministic/exogenous variables in the context of vector autoregressions. For multivariate cointegration, explicit modelling of intercept and trends is required. Pesaran and Pesaran (1997) recommend using a cointegration model with restricted intercepts and no trends for most macroeconomic data. Chan, Gup and Pan (1997) used both the model with an intercept and no trend, and a model with an intercept and trend. The sensitivity of the results, in terms of the number of cointegrating relationships found, to the model specified is checked in this study. Three models will be tested to ensure robust results: a model with a restricted intercept, no trend; a model with an unrestricted intercept, a restricted trend; and a model with no intercept or trend.

Microfit also provides a pre-procedure test for the selection of the lag order to be used in the cointegration. The methodology for this procedure is also provided in Chapter 6. The individual regression equations were checked for the absence of serial correlation from the residuals to ensure that the lag length specified was sufficient to prevent spurious regression results. The Lagrange Multiplier (LM) approach was used since lags of the dependent variables were included amongst the regressors. The methodology for checking for serial correlation in the residuals has already been considered in the previous section.

The parameter matrix r in (5.13), indicates whether the (ρ * 1) vector of stock prices has long-run dynamic relationship or not. The rank of r equals the number of cointegrating vectors. If the rank of r is zero, equation (5.13) reduces to a standard vector autoregression model. If r has full rank, then all the stock price series are stationary in levels. Cointegration is suggested if the rank of r is between zero and the number of stock index series. Two commonly used statistics have been developed to test the null hypothesis of r cointegrating relationships and they are used in this study. These two statistics are the maximum eigenvalue statistic and the trace statistic. "*Trace* statistics are obtained by the likelihood ratio test results of there being at most r cointegrating factors in a set of p

variables. λmax is the maximum eigenvalue statistics obtained by the likelihood ratio test for testing that there are r cointegrating vectors as opposed to $r + 1$." (Hung and Cheung, 1995, p. 287). The problem with the use of these statistics is that they often lead to conflicting results. When this is the case, subjective judgement is called for. The results of the cointegration analysis will be presented and discussed in Chapter 8.

Chapter 6: Vector Autoregression Methodology

Vector autoregression (VAR) analysis is an important technique in time series research and is particularly useful in examining issues surrounding the efficiency and transmission of information between world equity markets. The VAR technique was developed by Sims (1980). The first section presents the methodology of Sims' unrestricted VAR. The methodology for testing the VAR order selection, testing for the deletion of deterministic and exogenous variables, impulse response analysis and forecast error variance decompositions are all described. Of particular interest in this section is the description and discussion surrounding a new innovation in both impulse response analysis and forecast error variance. This new technique takes a generalised rather than an orthogonalised approach to the impulse response analysis and variance decomposition. The application of this new technique should offer new insights into the linkages between markets using the VAR methodology, as it is invariant to the ordering of the variables in the VAR model. Because the generalised approach has only recently been developed, this study is the first, that the author is aware of, to use the generalised approach in examining the linkages between national equity markets. In Chapter 5, the methodologies for testing for stationarity and cointegration were examined. In the second section of this chapter the issues surrounding stationary and cointegration, and their significance to VAR analysis is discussed. The second section discusses whether levels or first differenced data is more appropriate in conducting VARs. It also looks at the issue of cointegration and whether a vector error correction model (cointegrated VAR) or an unrestricted VAR is more appropriate for short-run horizon impulse response analysis and variance decomposition, where some or all of the variables are cointegrated.

6.1 Unrestricted Vector Autoregression Methodology

There are a number of reasons why the vector autoregression technique is well suited to examining the interdependence structure of world equity markets and the international transmission mechanism of stock market movements. In particular, once the VAR system has been estimated, the dynamic responses of each of the markets to innovations in a particular market can be traced out using the simulated responses of the estimated VAR system. The relative importance of an individual market in generating variations in its own returns and in the returns of other markets can also be assessed. The VAR model provides a multivariate framework where the changes in a particular market index are related to the changes in its own lags and to the changes in other market indices. The model imposes no restrictions on the structural relationships, if any, between the markets being analysed. All of the variables (markets) in the VAR model are treated as endogenous.

The unrestricted vector autoregression technique was developed by Sims (1980). The VAR technique was developed to account for problems with intervention and transfer function analysis, two multivariate techniques that were developed to generalise the univariate methodology by allowing the time path of a dependent variable to be influenced by the time path of an independent variable. If it is known that there is no feedback, then intervention and transfer function analysis are very effective tools for forecasting and hypothesis testing. Many economic systems do, however, exhibit feedback. It is not always known if the time path of a series designated to be the independent variable has been unaffected by the time path of the so-called dependent variable. Clearly, in the case of world equity markets, we might expect markets to have at least some influence on each other. VARs treat all variables as jointly endogenous. Each variable is allowed to depend on its past realisations and the past realisations of all other variables in the system. The VAR specification has attracted widespread use for its flexibility and computational ease. This section provides both a theoretical and descriptive explanation of the VAR methodology.[1]

Equation (6.1) describes the basic augmented vector autoregressive model (VAR), used as a starting point in describing the vector autoregression methodology.

$$z_t = a_0 + a_1 t + \sum_{i=1}^{p} \Phi z_{t-i} + \Psi w_t + u_t, \qquad t = 1, 2, \ldots, n$$

$$= A' g_t + u_t \qquad (6.1)$$

where z_t is a $m * 1$ vector of jointly determined dependent variables and w_t is a $q * 1$ vector of deterministic or exogenous variables. w_t will include intercept and trend terms as well as dummy variables for structural shocks. In the analysis of trend-stationary VAR models, without any loss of generality, the intercept and the trend terms, i_n and t_n can be subsumed in w_t. The $m * 1$ vector of

[1] The theoretical explanation of the VAR methodology outlined in this section is adapted from Pesaran and Pesaran (1997). This section also benefits from an excellent description of the VAR methodology, as it relates to the study of linkages between world equity markets, from Janakiramanan and Lamba (1997).

disturbances satisfy the following assumptions, which are simply multivariate generalisations of those underlying the univariate classical linear regression model on which the VAR model is based:

1. Zero mean assumption - the $m \times 1$ vector of disturbances, u_t, has zero means:

   $E(u_t) = 0$, for $t = 1,2, \ldots,$ n

2. Homoscedasticity Assumption - the $m \times 1$ vector of disturbances, u_t, has a time-invariant conditional variance matrix:

   $E(u_t u`_t \mid z_{t-1}, z_{t-2}, \ldots, w_t, w_{t-1}, \ldots) = \Sigma,$

   where $\Sigma = (\sigma_{i,j})$ is an a $m \times m$ symmetric positive definite matrix.

3. Non-autocorrelated Error Assumption - the $m \times 1$ vector of disturbances, u_t, is serially uncorrelated:

   $E(u_t u`_s) = 0$ for all $t \neq s$.

   By choosing p (the order of the VAR) high enough, the residual serial correlation problem can be avoided.

4. Orthogonality Assumption - the $m \times 1$ vector of disturbances, u_t, and the regressors, w_t, are uncorrelated:

   $E(u_t \mid w_t) = 0$ for all t

5. Stability Assumption - the augmented VAR(p) model (6.1) is stable. That is, all the roots of the following detrimental equation fall outside the unit circle.

   $$\left| I_m - \Phi_1 \lambda - \Phi_2 \lambda^2 - \ldots - \Phi_p \lambda^p \right| = 0 \qquad (6.2)$$

6. Normality Assumption - the $m \times 1$ vector of disturbances has a multivariate normal distribution. This assumption is required for the use of a maximum likelihood function.

7. The observations $g_t = (1, t, z_{t-1}, z_{t-2}, \ldots, z_{t-p}, w_t)$, for all $t = 1,2, .., n$ are not perfectly collinear.

Thus, the innovations u_t, are serially uncorrelated but can be contemporaneously correlated.
The VAR model treats all the variables in a system as endogenous. It estimates the parameters in a dynamic system without imposing any *a priori* restrictions on the presence of variables in the equation. However, since it expresses the dependent variables in terms of only predetermined lagged variables, the VAR model is a reduced form model. This is worth noting, since the reduced form nature of the model is what makes the VAR model so easy to work with and so appealing. Because the VAR is not in the form of simultaneous equations, it can simply be solved by using one-by-one ordinary least squares (OLS) regressions. This section is now broken down under a number of headings which follow the procedures that need to be used to conduct the VARs in the empirical analysis in Chapter 9.

Lag Order of the VAR

An important consideration when using the VAR model is the determination of the appropriate lag structure in the system. The lag structure chosen should be such that the estimated model exhibits no significant serial correlation. The choice of the appropriate lag structure can be guided by the desire to specify a parsimonious model, using model selection criteria, such as the Akaike information criterion (AIC) or the Schwarz Bayesian criterion (SBC). The values of the AIC and SBC for (6.1) are given by equations (6.3) and (6.4) respectively.

$$AIC_p = \frac{-nm}{2}(1+\log 2\pi) - \frac{n}{2}\log\left|\tilde{\Sigma}_p\right| - ms \tag{6.3}$$

and

$$SBC_p = \frac{-nm}{2}(1+\log 2\pi) - \frac{n}{2}\log\left|\tilde{\Sigma}_p\right| - \frac{ms}{2}\log(n) \tag{6.4}$$

where $s = mp + q + 2$. *Microfit* reports AIC_p and SBC_p for values of $p = 0, 1, 2, \ldots, P$, where P is the maximum order of the *VAR* model chosen. It is important that the order chosen, includes enough lags so that the optimal model can be selected. It is usual for the SBC to choose a lower order VAR compared to the AIC. Sawa (1978) is amongst those who have argued that the AIC tends to choose models of higher order than the true model. If serial correlation remains in the residuals of the individual regression equations, then extra lags will be added to the optimal amount according to the SBC criterion.

Testing for the deletion of deterministic/exogenous variables in the VAR

Log-likelihood ratio statistics can be computed for testing the deletion of the deterministic and exogenous variables in the VAR. The intercept i_n, the trend t_n, and the dummy variables w_t, or a subset of these variables can be tested for their significance in the VAR(p) model (6.1). For notational convenience from here onwards until notice to the contrary we shall be subsuming the intercept and the trend terms, i_n and t_n under w_t. Let

$$\underset{q*1}{w_t} = \begin{pmatrix} w_{1t}, & q_1*1 \\ w_{2t}, & q_2*1 \end{pmatrix} \text{ and } \underset{m*q}{\Psi} = \begin{pmatrix} \Psi_1, & \Psi_2 \\ m*q_1 & m*q_2 \end{pmatrix} \tag{6.5}$$

where $q = q_1 + q_2$. The log-likelihood ratio statistic for testing the null hypothesis

$H_0 : \Psi_1 = 0$, against $H_1 : \Psi_1 \neq 0$

is computed as

$$LR(\Psi_1 = 0) = 2\{LL_U - LL(\Psi_1 = 0)\} \tag{6.6}$$

where LL_U is the unrestricted maximised value of the log-likelihood function and $LL(\Psi_1 = 0)$ is the maximised value of the log-likelihood function obtained under $\Psi_1 = 0$. Asymptotically $LR(\Psi_1 = 0)$ is distributed as a chi-squared variate with mq_1 degrees of freedom.

Impulse Response Analysis

To analyse the dynamics of the system, the VAR model in (6.1) is typically transformed into its moving-average representation expressed in equation (6.7).

$$z_t = \sum_{j=0}^{\infty} A_j u_{t-j} + \sum_{j=0}^{\infty} B_j w_{t-j} \tag{6.7}$$

where the matrices, A_j, are computed using the recursive relations

$$A_j = \Phi_1 A_{j-1} + \Phi_2 A_{j-2} + ... + \Phi_p A_{j-p}, \qquad j = 1,2, ... \tag{6.8}$$

with $A_0 = I_m$, and $A_j = 0$, for $j < 0$, and $B_j = A_j \Psi$, for $j = 1, 2, ...$

Two alternative approaches have been developed to carry out impulse response analysis using the VAR(p) model (6.1). *Microfit* can be used for both methods.

1. The orthogonalised impulse response (IR) function advanced by Sims (1980, 1981).
2. The generalised IR function recently proposed by Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998).

The methodologies for both of these methods is explained below. The generalised impulse response function is a relatively new innovation, and this is the first paper examining linkages between world equity markets that the author is aware of, to use the generalised approach. Because of this, some attention is paid to the difference between the two approaches and the problems with the orthogonalised approach and other approaches that led to the development of the generalised approach. The orthogonalised impulse response function will be described first.

Sims' (1980, 1981) approach employs the following Cholesky decomposition of Σ (i.e. the covariance matrix of the shocks, u_t):

$$\Sigma = \mathrm{TT}' \tag{6.9}$$

where T is a lower triangular matrix. Sims then rewrites the moving average representation (6.7) as

$$\begin{aligned} z_t &= \sum_{j=0}^{\infty} (A_j T)(T^{-1} u_{t-j}) + \sum_{j=0}^{\infty} B_j w_{t-j} \\ &= \sum_{j=0}^{\infty} A_j \varepsilon_{t-j} + \sum_{j=0}^{\infty} B_j w_{t-j} \end{aligned} \tag{6.10}$$

where

$$A^*_j = A_j \mathrm{T}, \text{ and } \varepsilon_t = \mathrm{T}^{-1} u_t.$$

It should now be apparent that

$$E(\varepsilon_t \varepsilon'_t) = \mathrm{T}^{-1} E(u_t u'_t) \mathrm{T}'^{-1} = \mathrm{T}^{-1} \Sigma \mathrm{T}'^{-1} = \mathrm{I}_m,$$

and the new errors ε_t obtained using the transformation matrix T are now contemporaneously uncorrelated and have unit standard errors. In other words, the shocks $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t} \dots \varepsilon_{mt})$ are orthogonal to each other. The 'orthogonalised IR' function of a 'unit shock' (equal to one standard error) at time t to the ith orthogonalised error, namely ε_{it}, on the jth variable at time $t + N$ is given by the jth element of

$$\text{Orthogonalised IR function to the } i\text{th variable (equation)} = A_N^* e_i = A_N T e_i \tag{6.11}$$

where e_i is the m * 1 selection vector,

$$e_i = (0, 0, \dots 0, 1, 0, \dots 0)' \tag{6.12}$$

↑ ith element

The essential point is that the innovations are orthogonalised using a Chelosky decomposition so that the resulting covariance matrix is diagonal. This basically amounts to assuming that the first variable (stock market, in the case of this study) in a prespecified ordering has an immediate impact on all other variables in the VAR system. A shock in the second variable in the system has an immediate impact on all variables, excluding the first variable, and so on. The prespecified ordering of markets is an important factor that can dramatically alter the dynamics of the VAR system. These orthogonalised impulse responses are not unique and generally depend on the particular ordering of the variables in the VAR. The orthogonalised responses are invariant to the ordering of the variables in only two cases. The first is when Σ is diagonal (or almost diagonal) and there is little, if any, reason to suspect that it is. The second case is for the impulse response analysis of the first variable in the VAR.

According to Pesaran and Smith (1998) there are two problems with orthogonalised impulse response functions and variance decomposition (described later). The impulse responses obtained refer to the effects on the endogenous variables of a unit displacement (measured by one standard error) in the orthogonalised error, and not in the structural or even the reduced form errors. The other problem is, of course, that the choice of the results is only made unique by the ordering of the variables in the VAR. In fact, the particular ordering of the variables in the VAR and the Cholesky decomposition procedure used constitute an implicit identification assumption. It was quickly recognised, e.g. Cooley and LeRoy (1985), that orthogonalised impulse response functions actually employed traditional identification assumptions. These assumptions were based on the order of the variables in the VAR model, something with no particular economic rationale.

Because of the inherent problem with Sims' unrestricted VAR model, the structural VAR approach was developed in the mid-1980's by Bernanke (1986), Blanchard and Watson (1986), Sims (1986), Shapiro and Watson (1988) and Blanchard and Quah (1989). The structural VAR methodology attempts to identify the impulse responses by imposing *a priori* restrictions on the covariance matrix of the structural errors and the contemporaneous and/or long-run impulse responses themselves. "However, this latter methodology possess its own problems, both in terms of the validity of the estimation procedure and the interpretation of the results." (Sarte, 1997, p. 49). The main problem with the structural VAR relates to the *a priori* restrictions placed on the covariance matrix of structural errors. Two problems are highlighted by Pesaran and Smith (1998). The first relates to the typical assumption with structural VARs that the structural (or economic) errors are uncorrelated. This assumption is not reasonable in many macroeconometric applications of the structural VAR methodology. Also, while this approach can be used in very small systems, the number of restrictions required grows very rapidly with the number of endogenous variables in the system, making it non-feasible in larger systems.

When plausible *a priori* information to identify the effects of structural shocks is not available, it would still be of some interest to examine the effect of shocks to the reduced form errors. "The generalised impulse response function provides a natural way to do this since it measures the effect on the endogenous variables of a typical shock to the system, based on the estimated covariance between the reduced form shocks in the estimation period." (Pesaran and Smith, 1998, p. 9). The structural VAR methodology has not been employed in studies examining linkages between world equity markets because of the difficulty in imposing *a priori* assumptions on the relationships between world equity markets. Studies up until now, have therefore, made do with an orthogonalised approach to both impulse response analysis and variance decomposition. Despite the care taken in ordering the variables in the VAR model, the main criticism with this approach remains that the ordering of the variables in the VAR, affects the results of the impulse response functions and variance decomposition.

The generalised approach was developed because of the problems with both the structural VAR and orthogonalised impulse response analysis and variance decomposition. The main idea behind the generalised impulse response function was to circumvent the problem of the dependence of the orthogonalised impulse responses on the ordering of the variables in the VAR. The concept was advanced in Koop, et al. (1996) for non-linear dynamic systems and applied to linear systems by Pesaran and Shim (1998). The generalised impulse response function measures the effect on the endogenous variables of a typical shock to the system, based on the estimated covariance between the reduced form shocks in the estimation period. These impulse responses can be uniquely estimated from the parameters of the reduced form and unlike the orthogonalised impulse responses are invariant to the ordering of the variables in the VAR. A comparable forecast error decomposition can also be constructed.

There are only two situations in which the results of the orthogonalised and generalised approaches to impulse response analysis and forecast variance decomposition are the same. For the first variable in the VAR, the impulse response analysis will be the same, whether the orthogonalised or generalised approach is used. The second case is when Σ is diagonal, where Σ is the covariance matrix of the shocks to the VAR model. The estimated system covariance matrix of errors will be analysed in Chapter 9 to see if the off-diagonal values are zero. If there is reason to believe that at least, some of the off-diagonal values are non-zero, then the generalised approach to impulse response analysis and forecast variance decomposition should be used. Pesaran and Shin (1998) summarise the difference between the two approaches as follows.

> "There are many alternative reparameterisations that could be employed to compute orthogonalised impulse responses, and there is no clear guidance as to which one of these possible parameterisations should be used. In contrast, the generalised impulse responses are unique and fully take account of the historical patterns of correlations observed amongst the different shocks." (p. 20).

Generalised impulse response analysis deals explicitly with the three main issues that arise in impulse response analysis:

1. How was the dynamic system hit by shocks at time *t*? Was it hit by a variable-specific shock or system-wide shocks?
2. What was the state of the system at time $t-1$, before the system was hit by shock(s)? Was the trajectory of the system in an upward or in a downward phase?
3. How would one expect the system to be shocked in the future, specifically, in the interim period from $t+1$ to $t+N$?

The way the generalised approach deals with the second issue is in contrast to the orthogonalised approach which simply starts at time t = 0, and does not consider the state of the system before the shock hits.

In the context of the VAR model (6.1), the generalised impulse response function for a system-wide shock, u_t^0, is defined by

$$GI_z(N, u_t^0, \Omega_{t-1}^0) = E(z_{t+N} \mid u_t = u_t^0, \Omega_{t-1}^0) - E(z_{t+N} \mid \Omega_{t-1}^0) \tag{6.13}$$

where $E(\cdot \mid \cdot)$ is the conditional mathematical expectation taken with respect to the VAR model (6.1), and Ω^0_{t-1} is a particular historical realisation of the process at time $t-1$. In the case of the VAR model having the infinite moving-average representation (6.7), we have

$$GI_z(N,\ u_t^0\ ,\Omega^0_{t-1}) = A_N u_t^0, \tag{6.14}$$

which is independent of the 'history' of the process.

If we consider the effect of a variable-specific shock on the evolution of $z_{t+1}, z_{t+2}, \ldots, z_{t+N}$, and suppose that for a given w_t, the VAR model is perturbed by a shock of size $\delta_i = \sqrt{\sigma_{ii}}$ to its ith equation at time t. By the definition of the generalized IR we have

$$GI_z(N,\ \delta_i,\ \Omega^0_{t-1}) \ = \ E(z_t \mid u_{it} = \delta_i,\ \Omega^0_{t-1}) \ - \ E(z_t \mid \Omega^0_{t-1}) \tag{6.15}$$

Putting this into an infinite moving average process as shown in equation (6.7), we obtain,

$$GI_z(N,\ \delta_i,\ \Omega^0_{t-1}) \ \sim \ A_N\, E(u_t \mid \ u_{it} = \delta_i) \tag{6.16}$$

which is history invariant. That is, it does not depend on Ω^0_{t-1}. The computation of the conditional expectations, $E(u_t \mid u_{it} = \delta_i)$, depends on the nature of the multivariate distribution assumed for the disturbances, u_t. In the case where $u_t \sim N(0,\Sigma)$, we have

$$E(u_t \mid \ u_{it} = \delta_i) = \begin{pmatrix} \sigma_{1i}/\sigma_{ii} \\ \sigma_{2i}/\sigma_{ii} \\ \vdots \\ \sigma_{mi}/\sigma_{ii} \end{pmatrix} \delta_i \tag{6.17}$$

where as before $(\Sigma = \sigma_{ij})$. Hence for a 'unit shock' defined by $\delta_i = \sqrt{\sigma_{ii}}$ we have:

$$GI_z(N,\ \delta_i = \sqrt{\sigma_{ii}}\ ,\ \Omega^0_{t-1}) = \frac{A_N \sum e_i}{\sqrt{\sigma_{ii}}},\ \ i,j, = 1,2,\ \ldots\ ,m \tag{6.18}$$

where e_i is a selection vector given by (6.12). The generalised impulse response function of a unit shock to the i^{th} equation in the VAR model (6.1), on the j^{th} variable at horizon N is given by the j^{th} element of (6.18) , or expressed more compactly as

$$GI_{ij,N} \ = \ \frac{e_j' A_N \sum e_i}{\sqrt{\sigma_{ii}}},\ \ i,j, = 1,2,\ \ldots,\ m \tag{6.19}$$

Unlike the orthogonalised impulse responses in (6.11), the generalized impulse responses in (6.18) are invariant to the ordering of the variables in the VAR.

Forecast Error Variance Decompositions

Another feature of VARs is that they provide a forecast error variance decomposition which provides a decomposition of the variance of the forecast errors of the variables in the VAR at different horizons. The forecast error variance decomposition details the proportion of the movements in a sequence due to its 'own' shocks versus shocks to the other variable. If ε_{zt} shocks explain none of the forecast error variance of $\{y_t\}$ at all forecast horizons, we can say that the $\{y_t\}$ sequence is exogenous. In such a circumstance, the $\{y_t\}$ sequence would evolve independently of the ε_{zt} shocks and $\{z_t\}$ sequence. We might expect markets to explain most of their forecast error variance at short horizons and smaller proportions at longer horizons. Further, we might expect one market to be particularly influential, in that it explains a high proportion of the movements in its own sequence as well as a high proportion of the movements in the sequences of the other markets. Such a market would be considered the market leader.

The variance decomposition contains the same problem inherent in impulse response function analysis where the orthogonalised forecast error variance decomposition method is used. The generalised forecast error variance decomposition method has been developed so that the order of the variables in the VAR does not influence the results. These two methodologies are outlined below. In the context of the orthogonalised moving-average representation of the VAR model given by (6.10), the forecast error variance decomposition for the ith variable in the VAR is given by

$$\theta_{ij,N} = \frac{\sum_{l=0}^{N} (e_i' A_l T e_j)^2}{\sum_{l=0}^{N} e_i' A_l \Sigma A_l' e_i}, \qquad i,j = 1, 2, \ldots, m \tag{6.20}$$

where T is defined by the Cholesky decomposition of Σ, (6.9); e_i is the selection vector defined by (6.12); and A_l, $l = 0, 1, 2, \ldots$ are the coefficient matrices in the moving average representation (6.7). $\theta_{ij,N}$ measures the proportion of the N-step ahead forecast error variance of variable i, which is accounted for by the orthogonalised innovations in variable j. As with the orthogonalised impulse response function, the orthogonalised forecast error variance decompositions in (6.20) are not invariant to the ordering of the variables in the VAR. While the structural VAR overcomes this problem, it has its own problems as regards the *a priori* restrictions that need to be established.

An alternative procedure to the orthogonalised forecast error variance decomposition would be to consider the proportion of the variance of the N-step forecast errors of z_t which is explained by conditioning on the non-orthogonalised shocks, $u_{it}, u_{i,t+1}, \ldots, u_{i,t+N}$, but explicitly to allow for the contemporaneous correlations between these shocks and the shocks to the other equations in the system. Using the MA representation (6.7), the forecast error of predicting the z_{t+N} conditional on the information at time t-1 is given by

$$\underset{m\times 1}{\xi_t(N)} = \sum_{l=0}^{N} A_l u_{t+N-l} \tag{6.21}$$

with the total forecast error covariance matrix

$$\text{Cov}(\xi_t(N)) = \sum_{l=0}^{N} A_l \Sigma A_l^{'} \tag{6.22}$$

Consider now the forecast error covariance matrix of predicting z_{t+N} conditional on the information at time $t-1$, and the given values of the shocks to the i^{th} equation, $u_{it}, u_{i,t+1}, \ldots, u_{i,t+N}$. Using equation (6.7), we have

$$\underset{m\times 1}{\xi_t^{(i)}(N)} = \sum_{l=0}^{N} A_l \left(u_{t+N-l} - E\left(u_{t+N-l} \mid u_{i,t+N-l}\right) \right) \tag{6.23}$$

As in the case of the generalised IR functions, assuming $u_t \sim N(0,\Sigma)$, we have

$$E(u_{t+N-l} \mid u_{i,t+N-l}) = (\sigma_{ii}^{-1}\Sigma e_i) u_{i,t+N-l} \qquad \text{for} \quad l = 0,1,2,\ldots,N$$

$$i = 1,2,\ldots,m$$

Substituting this result back into (6.23)

$$\xi_t^{(i)} = \sum_{l=0}^{N} A_l \left(u_{t+N-l} - \sigma_{ii}^{-1}\Sigma e_i u_{i,t+N-l} \right)$$

and taking unconditional expectations, yields

$$Cov(\xi_t^{(i)}(N)) = \sum_{l=0}^{N} A_l \Sigma A_l^{'} - \sigma_{ii}^{-1}\left(\sum_{l=0}^{N} A_l \Sigma e_i e_i^{'} \Sigma A_l^{'} \right) \tag{6.24}$$

Therefore, using (6.22) and (6.24), it follows that the decline in the N-step forecast error variance of z_t obtained as a result of conditioning on the future shocks to the i^{th} equation is given by

$$\begin{aligned} \Delta_{iN} &= Cov[\xi_t(N)] - Cov[\xi_t^{(i)}(N)] \\ &= \sigma_{ii}^{-1} \sum_{l=0}^{N} A_l \Sigma e_i e_i^{'} \Sigma A_l^{'} \end{aligned} \tag{6.25}$$

Scaling the j^{th} diagonal element of Δ_{iN}, namely $e_j^{'}\Delta_{iN}e_j$, by the N-step ahead forecast error variance of the i^{th} variable in z_t, we have the following generalised forecast error variance decomposition:

$$\Psi_{ij,N} = \frac{\sigma_{ii}^{-1}\sum_{l=0}^{N}\left(e_j^{'} A_l \Sigma e_i\right)^2}{\sum_{l=0}^{N} e_j^{'} A_l \Sigma A_l^{'} e_i} \tag{6.26}$$

Note that the denominator of this measure is the ith diagonal element of the total forecast error variance and is the same as the denominator of the orthogonalised forecast error variance decomposition (6.20). Also, $\theta_{ij,N} = \Psi_{ij,N}$ when z_{it} is the first variable in the VAR, and/or Σ is diagonal. However, in general the two decompositions differ, resulting in different results depending on the approach used.

6.2 The Order Of Integration, Cointegration And VARs

If the variables to be analysed in the VAR are all stationary in their levels, that is, I(0) processes, then the choice of an unrestricted VAR to analyse these variables is easy. If however, some or all of the variables are I(1), that is, stationary in their first differences, the choice of VAR becomes more difficult, particularly if the I(1) variables are cointegrated. We have already presented Johansen's methodology for multivariate cointegration in the previous chapter. This section discusses two important considerations in VAR analysis. The first relates to whether stationary variables are required for the VAR and whether levels or first differences are more appropriate in VAR analysis. Secondly, this section considers whether, in the presence of cointegrated variables, a cointegrated VAR should be used in preference to an unrestricted VAR.

The issue of whether the variables in a VAR need to be stationary is substantial. Sims (1980) and Doan (1992) recommend against taking first differences even if the data is an I(1) process and the levels data contain a unit root. They argue that the goal of VAR analysis is to determine the interrelationships among the variables and that differencing eliminates information concerning the comovements in the data, including the possibility of cointegrating relationships. The majority view, however is that the data should be stationary to prevent the potential problems with non-stationary data, highlighted by Granger and Newbold (1974) and Phillips (1986) who found that non-stationary data led to spurious regressions. More recent research has shown that the conventional asymptotic theory is, in general, not applicable to hypothesis testing in levels VAR's if the variables are integrated. "If economic variables were known to be, say I(1) (integrated of order 1) with no cointegration, then one could estimate a VAR in first-order differences of the variables so that the conventional asymptotic theory is valid for hypothesis testing in the VAR." (Toda and Yamamoto, 1995, p. 226).

In this study, the VAR will be conducted in levels, only if all of the variables are I(0) processes. In this case there will be no loss in information due to differencing and there will be no problem of spurious regression results, attributable to non-stationary data. In the case where some or all of the variables are I(1) processes, the VAR will be conducted in first differences. While some information may be sacrificed in taking first differences, it is felt that it is more important to ensure that the data is stationary and that the regression results are not spurious.

An area that has received considerable attention in the recent literature looking at issues in vector autoregressions methodology, relates to vector error correction models (VECM) or cointegrating VARs. Sims, Stock and Watson (1990) argue that if variables are cointegrated then an error correction model (ECM) should be specified. Where variables are cointegrated, a vector autoregression in levels can be fitted by estimating each equation individually (usually by OLS). "With cointegration this may be interpreted as estimating a vector of error correction equations. The cointegrating vector(s) is (are) presumed to bind the long run behaviour of the variables together." (Naka and Tufte, 1997, p. 1593). In so far as the cointegrating vectors bind the long run behaviour of the variables, the VECM is expected to produce results in the impulse response analysis and variance decomposition that more accurately reflect the relationship between the variables than the standard unrestricted VAR. Although this may well be true for long-run horizons in both impulse response analysis and variance decomposition, it has been argued that over short-run horizons unrestricted VARs may in fact perform better than a cointegrating VAR.

Despite even the long-run advantages of using a constrained vector error correction model, Naka and Tufte (1997) highlight five reasons why practitioners may still want to estimate the unrestricted vector autoregression.

> "First, estimating a vector autoregression is simpler than a vector error correction model. Secondly, recent entries in the literature have increasingly advocated vector autoregression techniques due to their unrestricted nature (e.g. Toda and Yamamoto, 1995). Third, obtaining impulse response functions and variance decompositions from a vector error correction model is not straightforward in most computer packages.[2] Fourth, it is not clear that imposing the cointegrating vector improves performance at all horizons. In fact, Engle and Yoo (1987), Clements and Hendry (1995), and Hoffman and Rasche (1996) show that an unrestricted vector autoregression is superior (in terms of forecast variance) to a restricted vector error correction model at short horizons when the restriction is true. Lastly, imposing the cointegrating restriction may not be wise since cointegration is a point hypothesis that may have low power against close alternatives (e.g. fractionally integrated and cointegrated series)." (p. 1594).

These reasons raise serious doubts about the usefulness of using a vector error correction model. While the under performance of VECMs has been highlighted in previous research for variance decomposition over short-run horizons, Naka and Tufte studied the performance of VECMs and unrestricted VARs for impulse response analysis over the short-run. They found that, "... at short horizons, the performance of the two methods is nearly identical. This suggests that abandoning vector autoregressions for short horizon work is premature. Their low computational burden appears to outweigh any problems presented by cointegration at short horizons." (p. 1602). While the evidence, in terms of both impulse response analysis and variance decomposition tends to suggest that cointegrating relations should be imposed as a constraint on the system for analysis at long-run horizons, the evidence suggests that the problems with the cointegration relationship at short-run horizons means that the unrestricted VAR still has a place in the study of world equity market linkages, especially when one considers the other problems with the VECM.

Previous studies that have examined the linkages between equity markets have all used the unrestricted vector autoregression technique. None of those studies reviewed have used the VECM to take into account any cointegration between variables. Although this may have been largely due to a lack of theoretical development in the technique at the time, the evidence presented in this chapter suggests that the choice of the unrestricted model has been correct. Examining the efficiency of the transmission mechanism between markets only requires impulse response analysis and variance decomposition to be calculated over short-run horizons. The evidence indicates that the unrestricted VAR is a better choice for short-run horizon analysis. The unrestricted VAR will be used in this study for the impulse response analysis and variance decomposition.

[2] Anecdotal evidence suggests that this is not a trivial concern.

PART THREE

RESULTS & ANALYSIS

The results from the empirical testing that has been conducted in this study are presented in Part three. The exploratory analysis is presented in Chapter 7. By illustrating the general characteristics of the data sets being used, the exploratory analysis was conducted to aide in the interpretation of the results in Chapters 8 and 9. Chapter 7 includes summary statistics, correlation coefficients between Asia Pacific equity markets, and tests for the association between volatility and comovement in the Asia Pacific region. The results from vector autoregression (VAR) analysis in Chapter 9 are generally enhanced by using stationary variables. The results from the unit root tests for stationarity are presented in Chapter 8. Multivariate cointegration analysis was also conducted to test for a linear combination of non-stationary variables that is stable in the long-run. When cointegration is found, a stable long-run relationship between the variables exists. The cointegration results are presented, and the implications of the results discussed in Chapter 8. The results from the VAR analysis are presented in Chapter 9. Of particular interest, are the results from the forecast error variance decomposition which highlights the structure of the linkages between markets in the Asia Pacific region. The results from the impulse response analysis are also important. The impulse response analysis indicates how strongly markets react to a one standard error shock in a particular market. The impulse response analysis also provides a measure of the efficiency with which new information is transmitted between markets. Chapter 10 provides the conclusions from the results of the empirical testing in this study. In particular, the major findings relating to the transmission of market movements and the linkages between equity markets in the Asia Pacific region are presented.

Chapter 7: Exploratory Data Analysis

The results from exploratory analysis are presented in Chapter 7 so that the general characteristics of the data set to be used in further testing in Chapters 8 and 9 can be better understood. The exploratory analysis is carried out largely, on the local currency stock exchange indices although some of the testing was also carried out on the data, expressed in U.S. dollars so that the effect of exchange rate risk could also be considered. In Chapter 4, the local currency and U.S. dollar denominated stock exchange indices were plotted in Figure 4.1 which revealed that there was very little difference between the two data sets. This will be explored further in this chapter, and also in the empirical testing in Chapters 8 and 9. The exploratory analysis in this chapter considers the first four moments of each of the country's return distribution first. The coefficient of variation is also presented. In the second section, correlation matrices are produced to check for comovement in the return patterns of Asia Pacific markets. Consideration of the correlation matrices provide the first indication of the linkages between markets that we might expect to find in Chapters 8 and 9. Volatility and particularly the association between volatility and comovement in the Asia Pacific region is investigated in the third section. The 1987 stock market crash and the 1997 'Asian correction' are used to investigate the association. The time it takes for volatility to return to pre-crash levels is also studied. The final section concludes.

7.1 Summary Statistics

Table 7.1 presents the first four moments of the return distributions, calculated using daily, weekly, and monthly frequencies. Regardless of the time frequency used, Taiwan has the highest mean daily return value and consistent with the risk-return tradeoff also experiences the highest measure of standard deviation. The Philippines has the next highest returns followed by Hong Kong, the United States, Malaysia, and Thailand. The returns from the Australian and Singapore markets are more moderate but still well above those of Japan while New Zealand is the only country with a negative mean return. As well as having one of the better mean returns, the United States has the lowest standard deviation indicating the attractiveness of that market for investment in a purely isolated mean variance framework. The benefits of combining assets from various markets into a diversified portfolio will be examined in the next section where correlation between Asia Pacific markets is considered.

Table 7.1

FIRST FOUR MOMENTS OF THE RETURN DISTRIBUTIONS OF ASIA PACIFIC MARKETS

	Sing	Phil	Mal	Taiw	Thai	NZ	Aus	Jap	US	HK
Daily Return Data[1]										
Mean	0.0200	0.0699	0.0377	0.0913	0.0316	-0.0121	0.0260	0.0035	0.0554	0.0579
Std. Devn	1.2940	1.8811	1.5690	2.1518	1.7433	1.1273	1.0169	1.3918	0.9742	1.7501
Skewness	-1.5828	0.2811	0.5173	0.0504	0.1409	-1.1370	-5.6429	0.1081	-3.3556	-2.9043
Kurtosis	39.51	10.67	29.92	2.65	6.97	21.48	129.23	10.38	72.74	62.51
Weekly Return Data[2]										
Mean	0.1097	0.3734	0.1938	0.4907	0.1833	-0.0596	0.1297	0.0093	0.2688	0.2840
Std Devn	3.1301	4.7207	3.5981	5.4771	4.4980	2.5485	2.2999	2.8299	1.9152	3.7100
Skewness	-2.0504	-0.0371	-0.3612	0.1931	-0.2555	-0.7724	-3.8863	0.0118	-0.7285	-1.7232
Kurtosis	24.65	3.51	11.41	2.90	5.70	6.45	46.91	2.46	4.07	13.25
Monthly Return Data[3]										
Mean	0.5452	1.7151	0.9228	2.4779	0.8935	-0.1790	0.6323	0.0886	1.1931	1.3288
Std Devn	7.38	10.99	8.49	14.22	10.36	6.62	5.64	6.66	4.16	8.80
Skewness	-1.2538	0.8343	-0.3357	0.3339	0.0716	-0.1037	-3.1186	-0.0793	-1.1543	-0.9311
Kurtosis	7.92	4.13	2.99	1.37	0.82	4.59	23.29	0.51	6.09	5.30

[1] Daily data for the full sample period, 01/01/87 to 29/05/98.
[2] Weekly data for the period, 02/01/87 to 29/05/98.
[3] Monthly data for the full sample period, 01/01/87 to 29/05/98.

Negative skewness is quite visible in the return distributions of Singapore, New Zealand, Australia, the United States and Hong Kong. The magnitude of this negative skewness is most significant where daily return data is used. Skewness in stock market returns is much more likely to be found in daily data since this data is more prone to outlier values than weekly or monthly data. When the weekly and monthly return data is examined, the presence of skewness is much less apparent, except for Australia. Positive skewness is not found to any significant degree in any of the markets. As would be expected, this indicates that high volatility tends to exert itself in a falling market. The difference between the results generated using daily, weekly or monthly data is even more apparent in the kurtosis statistic. Using return data of a daily frequency, Australia, the United States, Hong Kong, Singapore, Malaysia and New Zealand all have high positive kurtosis indicating peaked distributions for these markets. The level of kurtosis reduces markedly where weekly and monthly return data is used although even in the case of monthly return data, Australia can again be singled out with higher than normal levels of kurtosis. The return distribution of Australia would appear to least exhibit the characteristics of normality. The summary statistics in Table 7.1 highlight why the natural logarithmic transformations of the index data described in Chapter 4 are taken. It is fairly apparent from some of the skewness and kurtosis statistics that not all markets are normally distributed as highlighted as early as Fama (1965).

The coefficient of variation measures the level of volatility per unit of return and therefore more accurately measures the attractiveness of a market. One problem with the coefficient as a measure of volatility arises in the way the coefficient is calculated, that is standard deviation divided by mean. It can be difficult to compare absolute levels of the coefficient because where the mean is small and close to zero, the coefficient becomes very large. Table 7.2 ranks the countries (from highest to lowest) by standard deviation and by coefficient of variation. Panel a in Table 7.2 measures volatility in local currency terms while panel b provides the same measures for U.S. dollar adjusted data. The problem with the coefficient as a measure of volatility is well highlighted by the size of Japan's coefficient in panel a. It is not accurate to portray the Japanese market as five times more volatile than New Zealand and nearly 40 times more volatile than the United States on an equal return basis!

Considering panel a first, the United States presents itself as an attractive market for investment with the lowest coefficient of variation. Although Taiwan has the highest standard deviation, its high return compensates investors and makes Taiwan an attractive market. At the other end of the scale, Japan and New Zealand (with its low negative mean return) are the least attractive markets for investors. Although Japan does not have the highest standard deviation in the Asia Pacific region, the size of its return means that investors are not being appropriately rewarded for what risk they do take - at least in terms of what other markets in the Asia Pacific region offer. The coefficient of variation is an absolute measure and does not take into account the negative mean return of New Zealand. Because New Zealand's return is low negative it still scores a high coefficient which it should given the negative return. There is a lot less variation in the level of the coefficient of variation for the other markets. These markets provide a reasonable level of return to compensate for the risk taken. It should be emphasised that these comments relate only to the time period considered in this study.

Table 7.2

MEASURES OF VOLATILITY FOR ASIA PACIFIC MARKETS - LOCAL CURRENCY AND U.S. DOLLARS[1]

Country	Standard Deviation	Country	Coefficient of Variation
Panel a Local Currency			
Taiwan	5.4771	Japan	305.5100
Philippines	4.7207	New Zealand	42.7245
Thailand	4.4980	Singapore	28.5419
Hong Kong	3.7100	Thailand	24.5442
Malaysia	3.5981	Malaysia	18.5636
Singapore	3.1301	Australia	17.7365
Japan	2.8299	Hong Kong	13.0642
New Zealand	2.5485	Philippines	12.6423
Australia	2.2999	Taiwan	11.1616
United States	1.9152	United States	7.1259
Panel b U.S. dollars data			
Taiwan	5.6434	Japan	65.8680
Philippines	5.0007	New Zealand	60.8468
Thailand	4.8133	Thailand	38.2134
Malaysia	4.2217	Malaysia	28.0378
Hong Kong	3.7113	Singapore	21.0390
Singapore	3.3203	Australia	20.5234
Japan	3.3163	Philippines	17.8682
New Zealand	2.8788	Hong Kong	12.9883
Australia	2.7111	Taiwan	11.0232
United States	1.9152	United States	7.1259

[1] Weekly data, 02/01/87 to 29/05/98.

Examination of panel b reveals that the standard deviation of return increases for all of the markets except the United States and Hong Kong. Because the returns are measured in U.S. dollars we would not expect the level to change for the U.S or for Hong Kong which has its exchange rate fixed to the U.S. dollar. The higher standard deviation in the other markets reflects the extra risk associated with exchange rates. It is important to consider the effect of exchange rate risk given that investors who diversify outside their domestic market must themselves consider this risk. The only change in the ranking of countries by standard deviation is the change in ranking by the Philippines and Thailand, with the Philippines' risk higher when exchange rate risk is included. There are only three minor changes in the ranking of countries by coefficient of variation. The coefficient of variation of Japan decreases significantly although the Japan remains the country with the highest coefficient. Singapore and Taiwan's coefficients also decrease slightly. The Philippines, Malaysia, Thailand, New Zealand and Australia's coefficients all increase with New Zealand and Thailand increasing in particular.

The 'emerging markets' of Malaysia, the Philippines, Taiwan and Thailand, are not surprisingly, amongst the most volatile, as measured by the standard deviation. The higher volatility is evident in both the local currency and U.S. dollar data. The high growth that characterises emerging markets results in strong returns that compensates investors for this risk, as measured by the coefficient of variation. The Philippines and Taiwanese markets, in particular have low coefficients of variation although the coefficients of Malaysia and Thailand are not exceptionally high either, at least for local currency data. When U.S. dollars data is used, the coefficient of variation for Thailand appears to increase slightly. Malaysia's coefficient is higher also but remains at a more reasonable level.

7.2 Comovement Of Asia Pacific Equity Markets

"Low international correlation across markets is at the root of global portfolio diversification. Diversifying across national markets with low correlation of returns allows investors to reduce their total portfolio risk, presumably without sacrificing return." (Solnik, Boucrelle, & Le Fur, 1996, p. 17). The correlation coefficient between two markets gives a basic measure of the degree of comovement in the returns of those two markets. Correlation matrices are used in this section to look at the comovement between Asia Pacific markets. An important note of caution with correlation matrices is made by Solnik, et al. (1996) who point out that: "... the time differences in market openings introduce a well-known downward bias in daily data. Using longer-frequency data reduces this bias. Weekly correlation also tend to be slightly lower than monthly correlation because of the time difference in international market opening hours." (p. 34). The correlation coefficients calculated for the Asia Pacific region reflect this observation.

Table 7.3

ASIA PACIFIC STOCK MARKET CORRELATION MATRICES - LOCAL CURRENCY AND U.S. DOLLARS[1]

Panel a Local Currency

	Sing	Phil	Mal	Taiw	Thai	NZ	Aus	Jap	US	HK
Sing	1.0000	.47868	.80368	.37742	.54578	.45258	.61451	.39629	.60906	.75386
Phil		1.0000	.52461	.10198	.39327	.15720	.23236	.18200	.33759	.46605
Mal			1.0000	.33019	.59924	.34860	.50706	.32632	.48904	.73145
Taiw				1.0000	.37142	.19227	.36479	.31653	.20799	.31100
Thai					1.0000	.28795	.38647	.30603	.40260	.52579
NZ						1.0000	.74472	.27363	.41615	.44082
Aus							1.0000	.35462	.58048	.58963
Jap								1.0000	.36594	.27500
US									1.0000	.57015
HK										1.0000

Panel b U.S. dollars data

	Sing	Phil	Mal	Taiw	Thai	NZ	Aus	Jap	US	HK
Sing	1.0000	.50278	.81662	.38605	.65207	.46493	.52454	.34515	.57539	.74355
Phil		1.0000	.53887	.13975	.46058	.14436	.18243	.15974	.31459	.46562
Mal			1.0000	.34532	.68834	.34689	.41461	.28481	.45764	.70495
Taiw				1.0000	.38883	.22345	.31383	.23100	.20688	.32770
Thai					1.0000	.33223	.39367	.23688	.39639	.58281
NZ						1.0000	.75725	.27889	.38028	.48295
Aus							1.0000	.32937	.49224	.55250
Jap								1.0000	.26787	.22438
US									1.0000	.56975
HK										1.0000

[1] Monthly data for the full sample period, 01/01/87 to 29/05/98.

Table 7.3 presents the correlation matrices for Asia Pacific countries using monthly return data, both in local currency and in U.S. dollars. The coefficients calculated using daily and weekly return data are not presented but were as suggested by Solnik, et al. much lower than in the case where monthly data was used. Looking at the general levels of the correlation coefficients first, it is fairly apparent that in both panel a and b the majority of the correlation coefficients are below 0.50. The average correlation coefficient in panel a where the returns are measured in local currency is 0.42317. The idea behind modern mean-variance portfolio theory, developed by Markowitz (1952), is the combination of assets with correlation coefficients below unity, resulting a in a reduction in risk for a given level of return. Certainly coefficients around 0.42 suggest that there might be potential rewards from diversifying outside the domestic market. The average correlation coefficient in panel b where returns were measured in U.S. dollars was only slightly lower at 0.41397. Taking into account exchange rate risk appears to have little effect on the comovement between markets.

The correlation coefficients in Table 7.3 reveal that some pairs of markets exhibit much greater comovement than others. The correlation coefficients between Singapore and Malaysia, Singapore and Hong Kong, New Zealand and Australia, and Malaysia and Hong Kong are particularly high reflecting the close economic and geographic ties between these countries. A portfolio that diversified only in these markets is likely to offer less benefits than a portfolio diversified in a broader range of markets where the coefficients are not so high. The evidence in Table 7.3 certainly points to possibilities for international diversification. The correlation coefficients in Table 7.3 are pairwise. A better understanding of the linkages between equity markets in the Asia Pacific region will be gained in Chapters 8 and 9 where multivariate techniques are used.

One of the major shortfalls in the data used in this study makes itself apparent in the correlation coefficients presented in Table 7.3. Upward bias in the correlation coefficients of markets which include a number of dual listed stocks is likely. This is certainly the case for Malaysia and Singapore. While these countries are geographically and economically close, their correlation coefficient is undoubtedly biased upwards because of the large number of dual listed stocks on the Singapore and Kuala Lumpur stock exchanges prior to January 1, 1990. This dual listing ceased on December 31, 1989 when both markets de-listed those stocks from the other country listed on their exchange. Prior to the de-listing, 182 of the 317 companies quoted in Singapore were incorporated in Malaysia. In fact, the move to de-list Malaysian stocks traded on the Singapore market halved the S$112 billion capitalisation of the Singapore market. Correlation coefficients for Singapore and Malaysia were calculated (using local currency data) for the period prior to, and after the de-listing, 01/01/87 - 31/12/89 and 01/01/90 - 29/05/98, respectively. In the first period the coefficient was 0.8498. This reduced significantly to 0.5635 in the second period. New Zealand and Australia also have dual listed stocks, but the proportion is much less than was the case for Malaysia and Singapore.

Meric and Meric (1989) produced what they termed a 'dependency index,' by calculating the average correlation coefficient for one country and all the other countries in their sample. They used this index to show the most dependent through to the most independent market. Dependency indices were calculated from the correlation matrices using both the local currency and U.S. dollar returns. The results are presented in Table 7.4. Singapore, Malaysia and Hong Kong appear to be the most open markets in the sample of Asia Pacific markets offering the least, in terms of benefits from diversification although with average correlation coefficients only marginally higher than 0.50 these markets are still significantly less than unity. By and large the values of the average correlation coefficients change only marginally when U.S. dollar returns are used and the rankings also change only marginally. Australia, New Zealand, Thailand and the United States are the next most dependent. Taiwan, the Philippines and Japan are the least dependent markets. Meric and Meric's dependency index are useful in presenting in one statistic, a means by which to reaffirm the existence of the necessary condition for the realisation of gains from portfolio diversification in the Asia Pacific region. Again, the multivariate techniques used in Chapters 8 and 9 to consider the linkages between markets should provide a better description of the structures underlying the linkages between markets in the Asia Pacific region. Despite this the results provided in this section do provide an exploratory view of the linkages between markets in the Asia Pacific region.

Table 7.4

DEPENDENCY INDICES OF ASIA PACIFIC STOCK MARKETS - LOCAL CURRENCY AND U.S. DOLLARS[1]

Local Currency		U.S. Dollars Data	
Country	Average correlation	Country	Average correlation
Singapore	.55910	Singapore	.55679
Malaysia	.51780	Hong Kong	.51713
Hong Kong	.51819	Malaysia	.51089
Australia	.48607	Thailand	.45909
United States	.44211	Australia	.44005
Thailand	.42488	United States	.40678
New Zealand	.36821	New Zealand	.37903
Taiwan	.34332	Philippines	.32319
Philippines	.31930	Taiwan	.28476
Japan	.31071	Japan	.26201

[1] Monthly data for the full sample period, 01/01/87 to 29/05/98.

7.3 Volatility And Worldwide Stock Market Crashes

The time period used for this study incorporates two periods of significant volatility, common to all ten of the Asia Pacific markets in the study. The first is the October 1987 stock market crash while the second occurs in October 1997. The volatility in 1997 is probably more appropriately referred to as a major correction, spurred on by the Asian crisis. These two periods will be used to explore volatility more closely and to test the association between volatility and comovement in Asia Pacific stock markets. In the literature review, discussion by Granger and Morgenstern (1970) and testing by Hilliard (1979), in relation to what might happen in a worldwide financial crisis, was reviewed. These studies suggested and proved that in the case of a worldwide financial crisis, world equity markets would tend to exhibit stronger comovement with other markets. In this section the magnitude of the 1987 and 1997 market crashes will be examined. The extent to which the correlation coefficients between Asia Pacific markets were affected in these periods is also investigated. Finally, the speed with which volatility returns to pre-crash levels will be examined. The testing in this section considers local currency data only.

Table 7.5

STOCK MARKET RETURNS IN OCTOBER 1987 AND OCTOBER 1997

	October 1987	October 1997
Singapore	- 40.88%	- 18.86%
Philippines	- 0.30%	- 11.63%
Malaysia	- 34.88%	- 18.40%
Taiwan	- 38.95%	- 16.02%
Thailand	- 29.18%	- 18.82%
New Zealand	- 31.48%	- 7.86%
Australia	- 42.45%	- 10.92%
Japan	- 12.48%	- 7.99%
United States	- 21.76%	- 3.45%
Hong Kong	- 43.20%	- 29.41%

Out of 125 monthly returns from January 1987 to May 1998, there were only eight months where all ten of the Asia Pacific markets had a negative monthly return. Of these eight months there were two months where the magnitude of the volatility was particularly high across virtually all of the ten markets. The first was October 1987 where negative returns of the greatest magnitude were found - seven out of the ten markets fell by more than 25% in that month. The month with the next most severe negative returns across all ten markets was October 1997, although the size of the fall in this case was affected for a number of markets, by the large amounts in which they fell in August 1997. Table 7.5 compares the stock market returns for October 1987 and October 1997 and shows that the magnitude of negative returns were much larger in October 1987 than in October 1997. The October 1987 crash was clearly much worse across the board. The Philippines stands alone in the sample of Asia Pacific countries in this study, for the small size of its fall in October 1987. Although the markets in New Zealand, Australia and the United States also fell considerably, the 1997 correction was much more of an Asian phenomenon.

To look at the effect of severe volatility on the comovement between markets in the Asia Pacific region, correlation matrices were produced for three periods, with the coefficients compared in Table 7.6. The first correlation matrix was calculated using weekly return data around the October 1987 crash period, 02/10/87 to 27/05/88. The second correlation matrix was calculated using weekly data between the two crashes - 03/06/88 to 26/09/97. The third correlation matrix measures the comovement for the period around the October 1997 Asian correction - 03/10/97 to 29/05/98. If markets do, as hypothesised by Granger and Morgenstern (1970) exhibit a greater degree of comovement in a worldwide financial crisis then we would expect the correlation coefficients in the first and third periods to be higher than the second period coefficients[1]. Examination of Table 7.6 shows that for 33 out of 45 cells in the correlation matrix, the coefficients exhibit the pattern that would be expected. Further, in none of the remaining 12 cases is the correlation coefficient between the two volatile periods greater than, both of the volatile period coefficients. These results indicate that markets do indeed exhibit greater comovement during financial crises. The result is important for investors as it signals a reduction in the benefits of portfolio diversification in volatile periods.

To check the validity of the conclusions reached from Table 7.6, it is important to verify that volatility was indeed, higher during the crash periods. Table 7.7 shows the volatility in each of the ten markets for the three periods used to calculate the correlation matrices in Table 7.6. For eight out of the ten markets, the standard deviation is higher in the two crash periods than in the period between crashes. This reaffirms the relationship between volatility and correlation. Australia and Taiwan are the two exceptions although in both cases, the standard deviation around the October 1987 crash was higher than for the period in between crashes – their volatility was however lower during the less severe 1997 correction than for the periods between for these two markets. Of the

[1] The correlation coefficients around the two crash periods have been calculated using less observations than those in the second period. Although the test is only exploratory in nature, it is worth noting that this may result in an upward bias in the size of these correlation coefficients in Table 7.6. With this caution noted, the results in Table 7.6 are still useful in presenting an exploratory view of the relationship between volatility and comovement.

remaining eight countries, only Malaysia's and Japan's volatility was higher around the 1997 crash than it was around the 1987 crash.

Table 7.6

CORRELATION MATRIX OF WEEKLY RETURN DATA FOR ASIA PACIFIC STOCK MARKETS[1]

	Sing	Phil	Mal	Taiw	Thai	NZ	Aus	Jap	US	HK
		.24151	.95065	.36002	.74071	.75676	.88215	.74536	.57122	.71618
Sing	1.0000	.36401	.72787	.22598	.49436	.31989	.35122	.32402	.27275	.49745
		.72147	.82830	.50537	.47262	.34117	.27467	.22255	.55460	.78227
			.24405	.07311	.50856	.32625	.15290	.08408	-.008	.43084
Phil		1.0000	.38188	.17330	.27268	.21644	.23705	.02979	.17111	.28434
			.62147	.45924	.34543	.38700	.41249	.23403	.62138	.71989
				.32498	.69215	.74533	.85046	.71235	.54709	.68808
Mal			1.0000	.18108	.49627	.27102	.28796	.28603	.20723	.46820
				.49969	.59593	.43461	.33552	.13658	.43326	.65529
					.27311	.38744	.28223	.53199	.40228	.24034
Taiw				1.0000	.22780	.19755	.17435	.19049	.03939	.13685
					.35179	.48923	.37170	.31282	.47584	.49349
						.55478	.60474	.54313	.25616	.74213
Thai					1.0000	.20461	.22165	.14945	.14306	.31349
						.39681	.33769	.21303	.26354	.33643
							.83322	.62506	.42211	.56263
NZ						1.0000	.58217	.30126	.31836	.27882
							.63499	.08815	.43993	.41169
								.63726	.48345	.66440
Aus							1.0000	.28434	.29949	.35248
								.10785	.50594	.54227
									.53772	.38355
Jap								1.0000	.30477	.19795
									.29682	.36546
										.29875
US									1.0000	.20418
										.64768
HK										1.0000

[1] The first coefficient in each cell is the correlation between the pair of markets between 02/10/87 and 27/05/88; the second coefficient in each cell is the correlation between the pair of markets between 03/06/88 and 26/09/97; and the third coefficient in each cell is the correlation between the pair of markets between 03/10/97 and 29/05/98.

Table 7.7

STANDARD DEVIATION FOR WEEKLY RETURN DATA FOR ASIA PACIFIC STOCK MARKETS

	02/10/87 - 27/05/88	03/06/88 - 26/09/97	03/10/97 - 29/05/98
Singapore	6.7293	2.2259	6.5641
Philippines	6.2944	4.0841	5.7254
Malaysia	5.9767	2.7614	8.0486
Taiwan	6.6652	5.3901	3.5695
Thailand	7.7169	4.1142	6.1504
New Zealand	4.9140	2.2464	2.3752
Australia	6.2973	1.7256	1.6853
Japan	2.8934	2.8115	3.7077
United States	3.8047	1.6666	2.0989
Hong Kong	7.0894	3.1264	6.2831

The tendency for shocks felt around the Asia Pacific region to result in greater comovement between markets than in periods where markets are relatively stable has potentially serious ramifications for the potential gains from portfolio diversification in the Asia Pacific region. If volatility is short-lived, returning quickly to pre-crash levels the implications are likely to be less severe. Tables 7.8 and 7.9 examine the level of volatility around the two markets crashes and how quickly volatility returned to pre-crash levels. To look at the volatility and in particular the persistence of volatility around the two volatile periods, the standard deviation of daily return data was measured around each of the financial crises. The October 1987 crash is analysed first. The United States market crashed on Monday 19, October 1987 with the other markets responding on Tuesday 20, October.[2] The standard deviation is calculated for the 15 trading days between 12/10/87 and 30/10/87 to capture the major period of volatility. The standard deviation is also measured on daily return data for the 25 trading day periods around the crash with the results presented in Table 7.8.

Keeping in mind the results in Table 7.1 which give an indication of what constitutes a 'normal' level of daily volatility, the results in Table 7.8 are interesting. The Philippines and Taiwan are the only markets which appear to have unusually high volatility prior to the crash. Apart from Taiwan, the standard deviation for the crash period is the period of highest volatility. For all markets, volatility reduces significantly in the period immediately after the crash period. For most markets,

[2] Both the Philippines and Hong Kong markets fell heavily on Monday 19, October, before the United States opened. The Philippines suffered another large fall on Tuesday 20, October in response to the United States fall. While Hong Kong was closed until Monday 26, October, it suffered another large fall when it reopened.

volatility returns to pre-crash, or in the case of Taiwan and the Philippines to normal levels by the period, 15/02/88-18/03/88. New Zealand is a possible exception to this with its volatility taking a little longer to return to pre-crash levels. It is clearly apparent that volatility remains high for only a relatively short time period and by May 1998 it has fallen to its to pre-crash or normal levels. This tends to suggest that volatility is relatively short-lived. This is encouraging for investors given the association between volatility and comovement.

Table 7.8

STANDARD DEVIATION FOR DAILY RETURN DATA FOR ASIA PACIFIC STOCK MARKETS AROUND THE OCTOBER 1987 STOCK MARKET CRASH

	29/06/87-31/07/87	03/08/87-04/09/87	07/09/87-09/10/87	**12/10/87-30/10/87**	02/11/87-04/12/87	07/12/87-08/01/88	11/01/88-12/02/88	15/02/88-18/03/88	21/03/88-22/04/88	25/04/88-27/05/88
Sing	1.2299	1.5972	1.0912	**7.7084**	2.3427	2.2226	1.9190	0.7462	1.0258	0.5263
Phil	5.8590	3.6915	6.2727	**6.3263**	2.5205	1.9289	1.9033	1.4638	1.4315	1.0635
Mal	1.0415	1.84098	1.3725	**7.8325**	1.9770	2.0422	2.1083	0.9093	1.2157	0.6352
Taiw	1.9104	2.3073	3.6049	**3.4574**	2.4543	2.0218	2.0663	1.7383	2.0361	2.0411
Thai	1.7054	1.0797	1.4125	**3.9872**	2.7186	2.8643	2.5150	1.0296	1.9031	0.7159
NZ	0.9649	0.8530	0.8379	**4.3242**	3.0979	0.9414	1.2879	1.8473	1.6945	0.7594
Aus	0.6821	0.7709	0.8103	**7.2239**	2.8161	1.0867	1.2234	0.9058	1.2198	0.8667
Jap	1.4802	0.7008	1.0049	**5.1966**	1.7585	1.5282	0.7906	0.4391	0.6252	0.6688
US	0.6227	0.9834	1.1721	**6.9350**	1.7845	2.1613	1.2642	0.8333	1.3258	0.7892
HK	0.8582	0.9934	1.1020	**9.2343**	3.1194	2.4111	1.7374	0.7837	1.3382	0.8951

The volatility around the October 1987 crash can be compared with volatility around the October 1997 correction. The United States market fell heavily on Monday 27, October 1997 with the other markets responding on Tuesday 28, October. The standard deviation of daily return data is calculated for the 15 trading days between 20/10/97 and 07/11/97 and then for 25 trading day periods around that crash period and the results are reported in Table 7.9. Table 7.9 reveals that volatility was less centered around the one vocal point, like it was in 1987. Apart from Hong Kong which was the most volatile market around the 1997 correction, the magnitude of volatility in the crash period was much lower than it was in October 1987. The generally lower volatility suggests that the crash in October 1997 was more of a worldwide 'correction', than a crash as such. For a number of markets, however, volatility did not return to pre-correction levels as immediately as in 1987, although this too is consistent with the notion of a correction which is more gradual than a crash. The effect on volatility around the 1997 crash is much less uniform among countries in 1997 than it was in 1987 where, by and large, all markets experienced a sudden shock and all returned to pre-crash levels in similar time.

Table 7.9

STANDARD DEVIATION FOR DAILY RETURN DATA FOR ASIA PACIFIC STOCK MARKETS AROUND THE OCTOBER 1997 STOCK MARKET CORRECTION

	07/07/97-08/08/97	11/08/97-12/09/97	15/09/97-17/10/97	**20/10/97-07/11/97**	10/11/97-12/12/97	15/12/97-16/01/98	19/01/98-20/02/98	23/02/98-27/03/98	30/03/98-01/05/98	04/05/98-29/05/98
Sing	0.6439	1.6270	1.0526	**3.4245**	1.3284	3.8015	3.6404	1.2568	1.0504	1.6700
Phil	2.1973	2.8922	1.7709	**2.7447**	2.0254	2.8497	3.5224	1.4475	0.9123	1.5804
Mal	1.3485	3.8547	1.7928	**3.3709**	4.8614	3.0288	5.4462	1.7167	1.3344	2.1882
Taiw	1.2655	1.5921	1.4553	**3.4697**	1.9729	1.5967	1.1242	1.2512	1.0630	1.1358
Thai	2.9479	2.5870	1.5923	**2.8715**	2.3292	2.0389	4.7153	1.6181	1.2144	1.7195
NZ	0.6771	0.7942	0.5129	**4.6629**	1.1236	1.1362	0.7401	0.7900	0.8286	0.6451
Aus	0.7097	0.9008	0.7166	**3.0017**	0.9239	1.1731	0.7276	0.6210	0.7603	0.6267
Jap	1.0365	1.5174	1.1376	**2.2938**	2.9159	2.4004	1.1864	1.4899	1.5625	0.9232
US	0.9381	1.1789	0.8786	**2.6079**	1.0539	1.1186	0.7638	0.7023	0.8466	0.6703
HK	0.9721	2.8004	1.5308	**7.8236**	2.6813	3.7282	3.5860	1.6910	1.2459	1.7321

Table 7.9 reveals that the Australian market appears to have only been affected in the correction period of 20/10/97 to 07/11/97, returning to pre-crash levels immediately. This was also the case for New Zealand and the United States with Taiwan taking only marginally longer to recover. In fact for these markets, volatility returned to pre-correction levels more quickly than was the case in 1987. The remaining six markets took longer to return to pre-crash levels. Australia, New Zealand, the United States, Taiwan and Hong Kong had their volatility peak in the "crash" period as defined in Table 7.9. The other five markets experienced what can be considered as a second wave of high volatility after the initial correction period. Australia, New Zealand, the United States and Taiwan also experienced little in the way of higher than usual volatility in the period prior to the crash period. This tends to reinforce the idea noted earlier that the 1997 correction was more of an Asian specific phenomenon, although the non-Asian markets did also suffer higher volatility in this period.

For Singapore, the Philippines, Malaysia, Thailand, Japan and Hong Kong, volatility did not return to its pre-correction or normal levels until February/March 1998 with a second wave of volatility similar in magnitude to the first occurring in the periods, 15/12/97 to 16/01/98 and in 19/01/98 to 20/02/98. The second wave of volatility in these markets is an important difference between the volatility in 1987 and 1997. While volatility did not return immediately to its pre-crash levels after October 1987, it did steadily decrease and did not rise again after the initial period. In 1997, the magnitude of volatility in the initial correction period might not have been so great, but for a number of markets, a second wave of volatility was experienced. While there are a number of differences between the activity of volatility around the 1987 crash and 1997 correction, the most important point is that in both cases, volatility returned quickly to pre-crash levels. In both cases, volatility returned to pre-crash levels for all markets within six months of the initial volatility - for some markets even sooner. Given that volatility is reasonably short-lived, the implications for portfolio diversification in the Asia Pacific region of higher volatility and the resulting higher comovement between markets is likely to be of little concern.

7.4 Conclusions

In the first section, the summary statistics for the ten Asia Pacific markets were presented. It was fairly apparent in the daily data, in particular, that the stock market distributions were not normal. The Australian market exhibited particularly high degrees of skewness and kurtosis even in the weekly and the monthly data. The importance of taking a logarithmic transformation of the data for empirical testing was noted. The first two moments showed that the Taiwanese market produced both the highest mean returns and highest standard deviation while New Zealand was the only market with a negative mean return. The United States had the lowest standard deviation. The standard deviation of returns increased for all countries (except the United States and Hong Kong, which is fixed to the U.S. dollar) when the data was transformed into U.S. dollars. The coefficient of variations revealed that while the emerging markets of the Philippines, Malaysia, Thailand and Taiwan are high in risk, they also reward investors with high returns. Japan and New Zealand had the highest coefficient of variations while the United States and Taiwan had the lowest.

In the second section the level of comovement between Asia Pacific equity markets was investigated. The results should be generally encouraging for investors wishing to diversify outside the domestic market, in that the coefficients are well below unity. The average correlation coefficient using both local currency and U.S. dollar returns is about 0.42 which is less than correlation coefficients generally found between domestic classes of assets. The exchange rate adjusted data produced coefficients only slightly lower than the local currency coefficients. Singapore, Malaysia and Hong Kong have the highest average levels of correlation while Taiwan, the Philippines and Japan have the lowest. Using the 1987 stock market crash and 1997 Asian correction, the relationship between volatility and comovement between markets was examined. There was very strong evidence to indicate that in periods of severe volatility, the comovement between markets in the Asia Pacific increased. The high levels of volatility around these two periods was also shown to quickly return to pre-crash levels. This would tend to indicate that the implications of greater comovement in volatile periods is unlikely to severely impact on the realisation of the necessary condition for gains from portfolio diversification in the Asia Pacific region.

Chapter 8: Results And Analysis - Stationarity And Cointegration

Establishing whether the variables to be used in vector autoregression (VAR) analysis, and in many other empirical applications in finance are stationary is important. Non-stationary variables can lead to spurious results which make interpretation difficult. Unit root tests were developed to check for stationarity in variables. The methodology for the unit root testing used in this chapter was discussed in Chapter 5. The first section presents the results for the unit root testing conducted in this study. Both the local currency and U.S. dollar variables were tested for stationarity. The effect of structural change on the variables has been taken into account in the unit root tests conducted. The results in this study may differ from those in previous studies because of the consideration of structural change. The reasons for any departure in the results in this study are discussed at the end of the first section. The methodology for multivariate cointegration analysis was also presented in Chapter 5. The variables that were found to be I(1) processes in the first section were tested for cointegration to see if a linear combination of these variables results in a stable long-run relationship. The cointegration results are presented in the second section. Two tests of multivariate cointegration will be conducted, the first on the local currency variables, and the second on the variables expressed in U.S. dollars. The implications of cointegration on the linkages between markets is also considered. The final section concludes.

8.1 Unit Root Test Results

Table 8.1 presents the results of the unit root tests for each of the ten Asia Pacific stock indices for the period 01/01/87 to 29/05/98. Five different regression equations were used, depending on whether it was levels or first differences that were being tested, and whether the model included an intercept, an intercept and a trend, or neither. In the case of the levels data, either equation (8.1) or (8.2) was used. Equation (8.1) was run if the intercept term was significant and (8.2) if the intercept term was not significant. Equations (8.3), (8.4) and (8.5) were used in testing the first differences and do not include the dummy variable for the 1987 stock market crash. Equation (8.3) was used if neither the intercept nor trend term was significant and amounts to the standard Dickey-Fuller regression. Equation (8.4) was used if the intercept was significant but the trend was not, and (8.5) was used if both the intercept and trend terms were significant. Chapter 5 explains the differences between these models in more detail.

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+a} + dD(TB)_t + \varepsilon_t \tag{8.1}$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+a} + \varepsilon_t \tag{8.2}$$

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+a} + \varepsilon_t \tag{8.3}$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+a} + \varepsilon_t \tag{8.4}$$

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+a} + \varepsilon_t \tag{8.5}$$

The results from unit root tests on local currency data are presented in Table 8.1. The critical values used to assess the t-ratios in Table 8.1 depend on the equation being used. The critical values for equations (8.1), (8.3), (8.4) and (8.5) are presented in a footnote to Table 8.1. Unfortunately, Perron (1989) did not calculate critical values for model (8.2) which includes the structural break dummy variable, but is without an intercept term. This problem obviously makes the inclusion of a dummy variable for structural change in the presence of an insignificant intercept term difficult. Rather than fall back on the Dickey-Fuller technique, the following procedure was used so that structural change could still be incorporated in the unit root testing. In the absence of a critical value for (8.2), a decision regarding the presence of a unit root, or otherwise was made under careful consideration justified below. In the case where the variables had significant intercept terms there was no problem and (8.1) was adopted successfully. In the case of the United States, Australia and Japan in Table 8.1 which all have insignificant intercept terms, (8.2) was used. Perron's critical values for models with structural change are more restrictive than the Dickey-Fuller critical values. Given that the t-ratios for the United States, Australian and Japanese markets are not even significant using the Dickey-Fuller critical values, there is no reason to believe they would be significant had Perron calculated critical values for (8.2). As a result it is safe to assume that neither the United States, Australia or Japan are I(0) processes, even in the absence of the appropriate critical values.

Table 8.1

UNIT ROOT TESTS OF DAILY STOCK INDEX DATA – LOCAL CURRENCY, 01/01/87 – 29/05/98

Country	Levels or First Differences	Model	t-ratio for γ[1]	Lag Length[2]
United States	Levels	(8.2)	3.5298	0
	First Differences	(8.4)	- 53.4435 *	0
New Zealand	Levels	(8.1)	- 2.2727	0
	First Differences	(8.5)	- 42.2128 *	0
Australia	Levels	(8.2)	1.7886	0
	First Differences	(8.3)	- 18.2243 *	6
Japan	Levels	(8.2)	- 0.058674	0
	First Differences	(8.3)	- 42.1353 *	0
Singapore	Levels	(8.1)	- 2.5061	1
	First Differences	(8.3)	- 44.2502 *	0
Taiwan	Levels	(8.1)	- 3.5339 ***	3
	First Differences	(8.3)	-49.7210 *	0
Philippines	Levels	(8.1)	- 2.2981	1
	First Differences	(8.3)	- 46.2173 *	0
Hong Kong	Levels	(8.1)	- 1.6254	0
	First Differences	(8.3)	-55.7599 *	0
Malaysia	Levels	(8.1)	- 2.6125	0
	First Differences	(8.3)	-46.7752 *	0
Thailand	Levels	(8.1)	-2.1946	1
	First Differences	(8.5)	-46.5086 *	0

[1] * Significant at the 1% level. ** Significant at the 5% level. *** Significant at the 10% level.
Critical values for γ in (8.1) and for a value of $\lambda = 0.1$, from Perron (1989) are –4.30 (1% level), -3.93 (2.5% level), -3.68 (5% level), and –3.40 (10% level).
Dickey-Fuller critical values for γ in (8.3): -2.58 (1% level) and –1.95 (5% level).
Dickey-Fuller critical values for γ in (8.4): -3.43 (1% level) and –2.86 (5% level).
Dickey-Fuller critical values for γ in (8.5): -3.96 (1% level) and –3.41 (5% level).
[2] The lag length was chosen so to insure the absence of serial correlation in the residuals of (8.1). Chapter 5 discusses the issues considered in eliminating serial correlation.

Despite the inclusion of the dummy variable for the 1987 crash, the results presented in Table 8.1 are generally consistent with what other studies have found for stock index data which is almost invariably found to be I(1). There is marginal evidence to say that Taiwan index data is an I(0) process at the 10% significance level. Given that there is only marginal evidence with which to reject the null hypothesis, it is probably more appropriate to err on the side of caution and not classify Taiwan as an I(0) process. There is not significant evidence at the 5% level to reject the null hypothesis of a unit root for any of the ten Asia Pacific markets using levels data. It is interesting to note that in the case of Taiwan, had a Dickey-Fuller test been used and the effect of structural change ignored, there would not have even been marginal evidence to reject the null hypothesis of a unit root. This reinforces the importance of considering the dummy variable for structural change. Further, the dummy variable was significant at the 1% level in all ten regressions. While the variables are not stationary in their levels, Table 8.1 clearly indicates that the ten stock market indices are I(1) processes. The null hypothesis of a unit root is rejected at the 1% level for all ten markets. This means that all ten markets follow a random walk which means that they are individually efficient in the weak-form sense. The New Zealand and Thailand first differences are stationary around an intercept and a linear trend. The United States is stationary around an intercept. The remaining seven markets are stationary using the standard Dickey-Fuller model, conforming to the traditional notion of a random walk, without drift or trend.

The unit root tests were also conducted on exchange rate adjusted stock index data and the results are presented in Table 8.2. The results are fairly consistent with those reported in Table 8.1, which tends to indicate the small impact exchange rate adjusted data appears to have on testing for stationarity. The notable exception is Taiwan which was a borderline case in Table 8.1. When Taiwan's exchange rate levels are expressed in U.S. dollar denominated currency, they are stationary at the 1% level. This means that, adjusted for exchange rate, Taiwan is an I(0) process and does not follow a random walk. The figures reported for the United States are obviously the same as those reported in Table 8.1. In the case of exchange rate adjusted data, the intercept for New Zealand and Thailand were insignificant in (8.1) so that the levels were tested using equation (8.2). Following the explanation for the United States, Australia and Japan in Table 8.1 above, there is no reason to suggest, even in the absence of critical values, that the t-ratios for New Zealand and Thailand would provide significant evidence to reject the null hypothesis of a unit root in the levels data. All ten dummy variables were again highly significant, but apart from Taiwan, their inclusion did not result in findings different to previous studies.

There is overwhelming evidence in Table 8.2 to indicate that the remaining nine Asia Pacific markets are I(1) processes. The null hypothesis of a unit root in the first differences is rejected at the 1% level in each of the nine cases. Adjusted for exchange rate risk, these stock indices follow a random walk and are individually efficient in the weak-form sense. Thailand, Malaysia and Singapore are stationary around an intercept and a linear trend. The United States is stationary around an intercept. New Zealand, Australia, Japan, the Philippines and Hong Kong are all stationary using the standard Dickey-Fuller model.

Table 8.2

UNIT ROOT TESTS OF DAILY STOCK INDEX DATA – EXPRESSED IN U.S. DOLLARS, 01/01/87 – 29/05/98

Country	Levels or First Differences	Model	t-ratio for γ[1]	Lag Length[2]
United States	Levels	(8.2)	3.5298	0
	First Differences	(8.4)	- 53.4435 *	0
New Zealand	Levels	(8.2)	- .61542	0
	First Differences	(8.3)	- 52.2153 *	0
Australia	Levels	(8.2)	- 1.8398	0
	First Differences	(8.3)	- 49.9382 *	0
Japan	Levels	(8.2)	- 2.1986	0
	First Differences	(8.3)	- 54.9456 *	0
Singapore	Levels	(8.2)	- 2.5628	1
	First Differences	(8.5)	- 43.9952 *	0
Taiwan	Levels	(8.2)	- 4.4907 *	0
	First Differences	n/a	n/a	n/a
Philippines	Levels	(8.2)	- 2.2765	1
	First Differences	(8.3)	- 46.1235 *	0
Hong Kong	Levels	(8.2)	- 1.6248	0
	First Differences	(8.3)	- 55.8174 *	0
Malaysia	Levels	(8.2)	- 2.0985	1
	First Differences	(8.5)	- 46.0002 *	0
Thailand	Levels	(8.2)	- .040221	2
	First Differences	(8.5)	- 46.4299 *	0

[1] * Significant at the 1% level. ** Significant at the 5% level. *** Significant at the 10% level. Critical values for γ in (8.1) and for a value of $\lambda = 0.1$, from Perron (1989) are –4.30 (1% level), -3.93 (2.5% level), -3.68 (5% level), and –3.40 (10% level).
Dickey-Fuller critical values for γ in (8.3): -2.58 (1% level) and –1.95 (5% level).
Dickey-Fuller critical values for γ in (8.4): -3.43 (1% level) and –2.86 (5% level).
Dickey-Fuller critical values for γ in (8.5): -3.96 (1% level) and –3.41 (5% level).
[2] The lag length was chosen so to insure the absence of serial correlation in the residuals of (8.1). Chapter 5 discusses the issues considered in eliminating serial correlation.

The findings in Tables 8.1 and 8.2 are largely consistent with what previous studies have found when considering stock index data. One major departure is the finding that Taiwan stock index levels expressed in U.S. dollars are stationary. The reason for this departure can not be attributed to the inclusion of the dummy variable for the 1987 stock market crash since the null hypothesis was rejected, even without the dummy variable, using the standard Dickey-Fuller tests. What factors might explain this unique result? The sample time period used in this study may be one of the contributing factors to the different result. Another important factor is likely to be the generally poor methodologies employed in previous studies, some of which simply assume the variables being tested are I(1) processes. By failing to even conduct unit root tests on the levels data, they forego the opportunity to find stationarity in the levels data. The finding that the Taiwan stock index data does not conform to a random walk and is, therefore not weak-form efficient, should not be a cause for great concern. A substantial body of literature has developed in the finance literature which suggests that stock prices have a mean reverting tendency which may in part, explain the deviation of Taiwan from a random walk .

Poterba and Summers (1988) were one of the first to observe and document a mean reverting tendency in stock price series. They found that stock prices were positively serially correlated in the short-term and negatively serially correlated over longer time horizons, contravening the traditional random walk hypothesis which assume serial independence. Mean reversion in stock price data clearly contravenes the traditional notion of a random walk hypothesis. By including a mean reverting term in the random walk model, one can reconcile the random walk hypothesis with mean reversion. Such a model suggests that although stock prices are generally random, prices do include a mean reverting tendency over a longer period of time which cannot be specified. Mean reversion can be used to help explain the unit root test result for Taiwan, whose innovation sequence may simply exhibit mean reversion.

The results in this section are important as unit root testing is an important part of time series analysis. To avoid spurious regressions, variables need to be stationary. If variables are found to be stationary in their levels, then the vector autoregression analysis in Chapter 9 can be conducted on the levels of the stock index data. If any of the variables are I(1) processes, stationary in their first differences, then the vector autoregression should be conducted in first differences. The findings in this section indicate that the vector autoregressions in the next chapter should be conducted in first differences. Unit root testing also has an economic interpretation. Markets which are I(1) processes can be thought of as following a random walk which confirms weak form efficiency in that market. All of the markets, with the exception of the exchange rate data for Taiwan, are individually weak-form efficient. In the next section we test to see if the markets are collectively efficient using cointegration analysis.

8.2 Multivariate Cointegration Results

It is common to test I(1) processes for cointegration to see if a linear combination of the variables exists that is stationary. The existence of a stable long-run relationship between the stock markets needs to be investigated for two reasons. Firstly, the existence or otherwise of a cointegrating relationship between the markets has an important economic interpretation that will be discussed later in this section. Secondly, if the variables are cointegrated then an unrestricted vector autoregression (VAR) may not be the best model to use to examine the linkages between markets and the transmission of market movements. It may be more appropriate to use a vector error correction model (cointegrating VAR). The results for two tests of multivariate cointegration are presented in this chapter. The first considers the ten markets, using local currency data. The second considers the nine markets, expressed in U.S. dollars. Taiwan is excluded from the second test since it is stationary in its levels, and cointegration is only appropriate for variables integrated of the same order. Johansen's (1990, 1991) multivariate cointegration technique is used to conduct the cointegration analysis. The methodology for this technique was presented in Chapter 5. A cointegrating relationship ensures that the markets can never drift far away from a stable long-run relationship. The cointegration testing includes the use of dummy variables for structural change so that the results accurately reflect the 'normal' relationship between markets.

Table 8.3 and Table 8.4 show the results of the Johansen cointegration tests for the Asia Pacific markets, using local currency and U.S. dollar data, respectively. The results are presented for a lag length of two which was selected using the Schwartz Bayesian Criterion (SBC), in a pre-procedure test for lag length. In both tests, a lag length of two resulted in very little sign of serial correlation in the residuals of the individual equations. While New Zealand, Australia and Taiwan showed some signs of serial correlation, the other markets did not. The results of the cointegration analysis were tested for their sensitivity to lag length used. The tests were also conducted for lag lengths of three and four. In the case of the U.S. dollar data, the tests provided consistent results for longer lag lengths. For the local currency data, the results differed slightly according to the lag length specified although the lag length used did not change the finding of at least one cointegrating relationship between the Asia Pacific markets. The deterministic intercept and trend, and the exogenous dummy variables for the 1987 stock market crash were tested for their significance to the model using the log-likelihood ratio statistic. The log-likelihood ratio statistic tests whether deterministic and exogenous variables are significant in the model being tested. In both tests the intercept, trend and dummy variables were significant at the 1% level.

Table 8.3

JOHANSEN TESTS FOR COINTEGRATION AMONG TEN ASIA PACIFIC MARKETS USING DAILY STOCK INDEX DATA – LOCAL CURRENCY, 01/01/87 – 29/05/98[1]

Lag length: 2			95% Critical	90% Critical
Null	Alternative	Statistic	Value	Value
Maximum Eigenvalue Statistic:				
$r = 0$	$r = 1$	103.5120	67.0500	63.0000
$r \leq 1$	$r = 2$	53.3781	61.2700	58.0900
$r \leq 2$	$r = 3$	50.4440	55.1400	52.0800
$r \leq 3$	$r = 4$	36.2517	49.3200	46.5400
$r \leq 4$	$r = 5$	25.2076	43.6100	40.7600
$r \leq 5$	$r = 6$	17.9078	37.8600	35.0400
$r \leq 6$	$r = 7$	16.2654	31.7900	29.1300
$r \leq 7$	$r = 8$	12.6967	25.4200	23.1000
$r \leq 8$	$r = 9$	7.2766	19.2200	17.1800
$r \leq 9$	$r = 10$	6.0251	12.3900	10.5500
Trace Statistic:				
$r = 0$	$r = 1$	328.9649	265.7700	258.0100
$r \leq 1$	$r = 2$	225.4530	222.6200	215.8700
$r \leq 2$	$r = 3$	172.0749	182.9900	176.9200
$r \leq 3$	$r = 4$	121.6309	147.2700	141.8200
$r \leq 4$	$r = 5$	85.3792	115.8500	110.6000
$r \leq 5$	$r = 6$	60.1716	87.1700	82.8800
$r \leq 6$	$r = 7$	42.2638	63.0000	59.1600
$r \leq 7$	$r = 8$	25.9984	42.3400	39.3400
$r \leq 8$	$r = 9$	13.3017	25.7700	23.0800
$r \leq 9$	$r = 10$	6.0251	12.3900	10.5500

[1] The results are reported from a cointegrating vector model specified with an unrestricted intercept, restricted trend.

Johansen's multivariate cointegration technique requires the explicit modelling of the intercept and trend terms. Tables 8.3 and 8.4 report the results for a cointegration model with an unrestricted intercept and restricted trend, given the significance of both the intercept and trend terms in the tests for the deletion of deterministic and exogenous variables. The reported results were tested for their sensitivity to the model specified, with two alternative models, one with restricted intercept, no trend, and the other with no intercept or trend, also conducted. Although the number of cointegrating relationships found differed slightly depending on the model used, the conclusion of at least one cointegrating relationship was consistently found in all tests.

Table 8.4

JOHANSEN TESTS FOR COINTEGRATION AMONG NINE ASIA PACIFIC MARKETS USING DAILY STOCK INDEX DATA – EXPRESSED IN U.S. DOLLARS, 01/01/87 – 29/05/98

Lag length: 2			95% Critical	90% Critical
Null	Alternative	Statistic	Value	Value
Maximum Eigenvalue Statistic:				
r = 0	r = 1	80.2964	61.2700	58.0900
r ≤ 1	r = 2	50.5056	55.1400	52.0800
r ≤ 2	r = 3	38.5684	49.3200	46.5400
r ≤ 3	r = 4	23.3611	43.6100	40.7600
r ≤ 4	r = 5	19.2664	37.8600	35.0400
r ≤ 5	r = 6	16.9943	31.7900	29.1300
r ≤ 6	r = 7	10.3383	25.4200	23.1000
r ≤ 7	r = 8	9.2540	19.2200	17.1800
r ≤ 8	r = 9	3.2316	12.3900	10.5500
Trace Statistic:				
r = 0	r = 1	251.8162	222.6200	215.8700
r ≤ 1	r = 2	171.5198	182.9900	176.9200
r ≤ 2	r = 3	121.0142	147.2700	141.8200
r ≤ 3	r = 4	82.4458	115.8500	110.6000
r ≤ 4	r = 5	59.0847	87.1700	82.8800
r ≤ 5	r = 6	39.8183	63.0000	59.1600
r ≤ 6	r = 7	22.8239	42.3400	39.3400
r ≤ 7	r = 8	12.4856	25.7700	23.0800
r ≤ 8	r = 9	3.2316	12.3900	10.5500

[1] The results are reported from a cointegrating vector model specified with an unrestricted intercept, restricted trend.

Table 8.3 shows significant evidence at the 5% level to suggest that r = 2, using the trace statistic, and significant evidence at the 5% level to suggest that r = 1 using the maximum eigenvalue statistic. The conflicting results between the two statistics is not uncommon in multivariate cointegration analysis. In macroeconomic time series analysis, economic theory is often used to make *a priori* assumptions of the relationships one would expect between the variables, and use this to help determine which interpretation of the results should be given more weight. *A priori* assertions on the relationships between world equity markets are much more difficult to make, let alone substantiate. Because of this, and because it will suffice so long as an unrestricted VAR is used rather than a vector error correction model in the testing in Chapter 9, we will simply state that there is at least one cointegrating relationship amongst the variables[1]. We can qualify this statement by adding that the trace statistic suggests two cointegrating relationships. In terms of the economic interpretation of the cointegration analysis, it will suffice to say that there is a cointegrating relationship, the number is not so important. The results in Table 8.3 confirm the existence of at least one cointegrating relationship between the ten local currency stock indices which ties them together and provides a stable long-run relationship between them. Table 8.4 provides significant evidence at the 5% level of one cointegrating relationship between the nine U.S. dollar stock indices. The trace and maximum eigenvalue statistics produce consistent results. This result means that a stable long-run relationship between the nine stock market indices, expressed in U.S. dollars, also exists.

The existence of a stable long-run relationship between the markets found in Tables 8.3 and 8.4 has two important implications for investors wishing to invest outside their domestic market. Firstly such a relationship means that these markets have comovements which tends to reduce the ability for investors to diversify away risk. Chan, Gup, and Pan (1997) give a good example of the ramifications of such relationships:

> "... suppose an investor plans to diversify into two cointegrated stock markets, say the United Kingdom and the United States. If stock prices in the U.S. declined steadily over a long period of time, and stock prices in the U.K. followed the decline closely since the two markets are cointegrated, the diversification would not be effective because the systematic (country) risk cannot be diversified away. Thus, it is not in the best interest of investors who want diversified portfolios to invest in cointegrated markets." (p. 804).

The second implication relates to the opportunities that the stable long-run relationship between markets provides the investor. A stable long-run relationship between a group of markets means that there is comovement between the markets, which implies that either one or both markets may

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[1] Evidence was presented in Chapter 6 that suggested that there was little to be gained from using a vector error correction model instead of an unrestricted VAR for the short-run impulse response analysis and forecast error variance

be inefficient since one stock market index might be able to be used to forecast the other. Collective inefficiency between the markets provides the opportunity to profit on the lag between markets. If one market leads another, then investors can profit on the lag between the markets by investing in the lagging market based on movements in the lead market. The problem with the cointegration analysis is that it does not provide enough information on the linkages between the markets or on the nature of the lags between markets. For the nine and ten markets tested above, we do not know which markets lead and which markets lag. Further, we do not know if the length of the lag is long enough, or if the size of the response in the lagging market to a shock in the lead market is large enough, to profit from. This tends to suggest that cointegration analysis is only so useful in describing the linkages between equity markets and the transmission of market movements. The VAR analysis conducted in Chapter 9 is much better suited to explaining the linkages between markets and the opportunities for investors to profit by following the developments that happen in lead markets.

8.3 Conclusions

Unit root testing is important in time series analysis. To avoid spurious regressions, variables should be stationary. Consistent with earlier studies, all ten of Asia Pacific markets were found to be stationary in their first differences, that is I(1) processes, for the local currency data. This indicates that these markets follow the traditional random walk and are individually weak-form efficient. In the case of the exchange rate adjusted data, nine of the ten markets are I(1) processes. The Taiwanese market was found to be stationary in its levels. The results in this section are important. If the vector autoregression analysis in Chapter 9 is to be conducted on stationary data, then the analysis should be conducted on the first differences in both the case of local currency and U.S. dollar data.

Multivariate cointegration analysis was conducted on the ten markets in local currency and on the nine markets, expressed in U.S. dollars which were I(1) processes. For the local currency data, at least one and possibly two cointegrating relationships were found, while in the case of the U.S. dollar data, one cointegrating relationship was found. This means that while the world equity markets are individually weak-form efficient, they may not be collectively efficient since a stable long-run relationship exists that ties the markets together. The comovements between markets that this implies, suggests that the benefits of diversifying outside the domestic market for risk reduction

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decomposition used in this study.

reasons might be lower than indicated in the earlier literature. It does, however, imply that there is the potential for investors to profit from the lag between markets. Vector autoregression analysis needs to be carried out so that the linkages between the markets and the transmission of market movements between markets can be further considered. This will be presented in Chapter 9.

Chapter 9: Results And Analysis - Vector Autoregressions

The results from the vector autoregression (VAR) analysis conducted on the ten Asia Pacific markets is considered in this chapter. The VAR testing was conducted, both on the local currency data and on data expressed in U.S. dollars. The first section of this chapter describes the four VAR models that have been used in this chapter and the specifications used in conducting the VARs. Consideration of things such as the lag length, and the presence of deterministic/exogenous variables are discussed. The results from the VAR analysis are very important for determining the linkages between markets in the Asia Pacific region. Of particular interest are the results from the forecast error variance decomposition and the impulse response analysis. Before the results from these techniques are presented, the error covariance matrix will be examined in the second section. If the off-diagonal values of this matrix are non-zero then the ordering of variables in the VAR model will impact on the results which adds weight to the argument of using the generalised approach, rather than the orthogonalised approach to variance decomposition and impulse response analysis. The third section presents the results from the forecast error variance decomposition. The impulse response analysis is presented in the fourth section, while the final section concludes.

9.1 Vector Autoregression Model Specifications

There are effectively four VAR systems that have been estimated to produce the results for this chapter. The first is VAR analysis of local currency data for all ten markets. The second, also analyses the local currency data but excludes the U.S. market from the system. The third is VAR analysis of data expressed in U.S. dollars for all ten markets and the fourth considers the U.S. dollar data with the U.S. market excluded again. A lag order of nine was used to conduct each of these four tests. The Akaike Information Criterion (AIC) and Schwarz Bayesian Criterion (SBC) discussed in Chapter 5 were used in pre-procedure testing to determine the optimal lag-length. For each of the four models, the AIC selected either three or four lags while the SBC selected either zero or one lag. The individual regression equations were tested on two lags for the presence of serial correlation using the Lagrange multiplier (LM) test discussed in Chapter 5.[1] There was only marginal evidence of serial correlation in the residuals of the individual regressions equations at two lags. In the VARs that included all ten Asia Pacific markets, only Hong Kong and the United States exhibited evidence of serial correlation. Where the U.S. market was excluded from the VAR, only the residuals of Hong Kong showed signs of serial correlation. Given that there is very little serial correlation with two lags, the use of nine lags may seem excessive.

The choice of nine lags was not without reason. If only two or three lags are used, there is no scope for any delayed adjustment in the responses of one or more markets to movements in the other markets, or in its own market. Although markets are generally expected to react to movements in other markets within a week, usually much less, it is important to allow for the possibility of delayed reactions. By specifying nine lags, markets can show a delayed response to innovations in other markets and its own market of up to nine days. The choice of nine lags reflects the maximum number that *Microfit* allows for the number of variables in the VAR systems used in this study. The choice of a higher number of lags than is implied by the pre-procedure tests is consistent with earlier studies such and Eun and Shim (1989) and Janakiramanan and Lamba (1997) who used 15 lags. Because daily data comprising of almost 3,000 observations was used in this study, the choice of nine lags is not expected to pose any degrees of freedom problems.

In each of the four VAR models, both an intercept and trend term were included, as were dummy variables for the 1987 stock market crash. The inclusion of these variables is consistent with the reasoning for their inclusion in the unit root testing and cointegration testing discussed in Chapter 5. *Microfit* allows for these variables to be tested for their joint significance to the VAR. The methodology for this test is discussed in Chapter 6. In each of the four models, all of the deterministic and exogenous variables were highly significant at the 1% level. Because of this, the variables were all included in the VAR models tested.

9.2 Estimated System Covariance Matrix Of Errors

In Chapter 6 the difference between the orthogonalised and generalised approaches to variance decomposition and impulse response analysis were discussed in detail. It was noted that unless the

[1] Unfortunately, *Microfit* is limited in the number of variables that can be included in a regression equation. It was not possible to compute the individual regression equations for more than two lags.

VARs covariance matrix of errors Σ, is diagonal, the orthogonalised approach varies according to the ordering of variables in the VAR and produces different results to the generalised approach which is invariant to the ordering of the variables in the model. Σ is diagonal if the off-diagonal values of the covariance matrix of errors are zero. Table 9.1 presents the estimated system covariance matrix of errors for the ten Asia Pacific markets. Panel a presents the results when local currency data was used and panel b presents the results for the U.S. dollar data.

Table 9.1

ESTIMATED SYSTEM COVARIANCE MATRIX OF ERRORS - LOCAL CURRENCY AND U.S. DOLLARS, 01/01/87 – 29/05/98

Panel a Local Currency

	Aus	HK	Jap	Mal	NZ	Phil	Sing	Taiw	Thai	US
Aus	.5664	.2980	.1905	.1806	.2723	.1472	.2138	.1558	.1131	.0276
HK		2.3485	.4153	.7468	.2359	.4769	.6979	.2987	.4096	.1451
Jap			1.7024	.3008	.1580	.0564	.2799	.3023	.1831	.1192
Mal				1.9277	.1546	.3535	.8752	.2713	.5047	.0956
NZ					.92810	.1367	.1565	.1674	.0825	.0028
Phil						3.0942	.4187	.2086	.3470	.0446
Sing							1.1610	.27196	.4011	.0935
Taiw								4.4323	.3158	.0537
Thai									2.6173	.0829
US										.7237

Panel b U.S. dollars data

	Aus	HK	Jap	Mal	NZ	Phil	Sing	Taiw	Thai	US
Aus	.9675	.3240	.2438	.2269	.4596	.1786	.2244	.1862	.1204	.0047
HK		2.4539	.4223	.8220	.2350	.5451	.7223	.3631	.4990	.1263
Jap			2.2743	.3710	.2468	.0766	.3156	.3284	.2417	.0731
Mal				2.5798	.2045	.5522	1.0771	.3376	.8135	.1139
NZ					1.2343	.1584	.1753	.1788	.1153	-.0062
Phil						3.5173	.4636	.2909	.5049	.0260
Sing							1.2940	.3116	.5317	.1064
Taiw								4.7921	.3699	.0340
Thai									3.1371	.0716
US										.7274

The results in Table 9.1 show that the covariance matrix of errors is clearly not diagonal. The majority of the off-diagonal values are clearly non-zero with values as high as 0.8752 for Singapore and Malaysia in panel a and 1.0771 between Singapore and Malaysia, again, in panel b. The order of the variables in the VAR will clearly have an impact on the forecast variance decomposition and impulse response analysis using the orthogonalised approach. This means that it will be well worth considering the generalised approach. Although the results are not presented here, the estimated system covariance matrix of errors was not diagonal for the two VAR models tested without the United States market.

The results in Table 9.1 also have an economic interpretation, describing an important aspect of the international transmission of market shocks. They show the extent to which shocks in different market equations are contemporaneously correlated. The coefficients in panel b are generally higher than those in panel a, although not necessarily a lot higher. The higher level does suggest that innovations are transmitted more quickly and to a greater extent between markets when currency risk is an explicit consideration for investors. Such a phenomenon is quite reasonable. Firstly, the inclusion of exchange rate risk results in two factors that investors must consider and react to – price risk in the underlying investment and exchange rate risk in the currency in which the investment is purchased. Further, it is reasonable to suggest that when an investor is exposed to currency risk as well as price risk in the underlying investment, they will be more sensitive to shocks in the price of the investment. Although the results are not reported here, the findings in Table 9.1 are similar to those when the U.S. market is excluded, with the coefficients again slightly higher in the case where the data is expressed in U.S. dollars.

The contemporaneous correlation coefficients between the individual market equations show that markets that are geographically and economically close, such as Singapore, Malaysia and Hong Kong have higher coefficients than more isolated markets. This suggests that the reaction of these markets to a shock in the U.S. market, for example, will be very similar. We would expect these markets to have stronger linkages than markets like Japan and Taiwan which appear to be more isolated in the responses of their equations to shocks in other markets. Table 9.1 reveals very low coefficients between the different markets and the United States. The reason for this can, to a large extent, be explained by the one day lag between the time when shocks occur in the U.S. market, and they are felt in foreign markets. Because the U.S. market does not open until all of the other markets are closed, correlation coefficients are generally biased downwards for the U.S. market when daily data is used. The tests presented in Table 9.1 were conducted again with a one day lag used for the U.S. market. In results not reported here, the coefficients between the U.S. equations and the other markets equations were higher than those reported in Table 9.1. The size of the coefficients were not as high as they were for markets like Singapore and Malaysia but did not suggest that the U.S. market is as isolated as the results in Table 9.1 do.

9.3 Forecast Error Variance Decomposition

The forecast error variance decomposition allows the relative importance of each market in generating unexpected variations of returns in a particular market to be measured. A causal ordering among the equity markets is established, reflecting the extent to which an individual market generates variations in its own returns and in other market returns. By decomposing the forecast error variance, the effect that each market in the system has on itself and each other markets over different time horizons can be measured. The tables in this section provide the 5-, 10- and 15-day ahead forecast error variances of stock market returns into fractions that are accounted for by the innovations of different markets. These tables provide a summary that is useful in identifying the main channels of influence in Asia Pacific markets. For each of the four VAR models specified in this chapter, the forecast error variance decomposition were produced twice – using the orthogonalised and generalised approaches. In the interests of brevity, the orthogonalised and generalised output will be compared only once. Tables 9.2 and 9.3 present the orthogonalised and generalised approaches to forecast error variance decomposition for the ten Asia Pacific markets using local currency data.

Before attention is turned to examining the linkages between markets in the Asia Pacific region, consideration is given to whether the orthogonalised or generalised approach better reflects the relationship between the markets, using Tables 9.2 and 9.3. The covariance matrix of errors in the previous section was not diagonal which means that, by definition, the ordering of the variables will affect the outcome of the orthogonalised approach to forecast error variance decomposition. This is the first study looking at the linkages between world equity markets, that the author is aware of, to consider the generalised approach. It is, therefore, worth considering whether the generalised approach leads to a material improvement in the results, given that previous studies such as Eun and Shim (1989) and Janakiramanan and Lamba (1998) have tried to reduce the effect of the orthogonalised approach by ordering the variables by opening or closing time.

Table 9.2

ORTHOGONALISED DECOMPOSITION OF FORECAST ERROR VARIANCES FOR DAILY MARKET RETURNS FOR TEN ASIA PACIFIC MARKETS – LOCAL CURRENCY, 01/01/87 – 29/05/98[1,2]

Market Explained	Horizon (Days)	By innovations in Aus	HK	Jap	Mal	NZ	Phil	Sing	Taiw	Thai	U.S.	[3]All foreign
Australia	5	62.63	0.8753	0.2840	0.4221	10.89	0.7102	0.2354	0.4290	0.1555	23.37	37.37
	10	61.90	1.2367	0.4060	0.7690	10.71	0.9851	0.3424	0.5036	0.1670	22.98	38.10
	15	61.86	1.2434	0.4190	0.7736	10.70	0.9937	0.3472	0.5105	0.1912	22.95	38.14
Hong Kong	5	3.5598	78.36	2.2029	0.2519	2.5692	2.4062	0.0651	0.6219	0.3329	9.6288	21.64
	10	3.7723	76.87	2.1996	0.5221	2.5555	2.4620	0.4567	0.6621	0.6521	9.8488	23.13
	15	3.7954	76.76	2.2084	0.5356	2.5652	2.4665	0.4848	0.6669	0.6602	9.8596	23.24
Japan	5	2.3982	0.1029	87.52	0.0171	1.7181	0.3156	0.2587	0.9192	0.1202	6.6309	12.48
	10	2.3874	0.3157	86.44	0.1325	1.9035	0.3707	0.4784	1.0558	0.2164	6.6948	13.56
	15	2.4033	0.3245	86.38	0.1338	1.9109	0.3719	0.4858	1.0619	0.2365	6.6953	13.62
Malaysia	5	1.5136	8.0495	1.5566	56.10	1.3881	1.7586	19.14	0.8568	0.3038	9.3314	43.90
	10	1.4796	8.0835	1.6668	54.62	1.6152	1.8111	19.21	0.9926	0.7770	9.7397	45.38
	15	1.4956	8.0847	1.6725	54.56	1.6234	1.8302	19.20	0.9947	0.7882	9.7527	45.44
New Zealand	5	1.9910	0.8561	0.4956	0.2461	79.69	0.0942	0.2380	0.2676	0.1449	15.98	20.31
	10	2.4281	1.0430	0.5815	0.4251	78.01	0.4387	0.6471	0.3052	0.1989	15.92	21.99
	15	2.4478	1.0501	0.5868	0.4381	77.92	0.4402	0.6593	0.3093	0.2064	15.94	22.08
Philippines	5	0.1894	0.6448	0.4063	0.8606	0.7168	91.58	0.4596	0.7548	0.2607	4.1278	8.42
	10	0.2486	0.7432	0.6028	1.2585	0.8150	90.01	0.4819	0.9411	0.7012	4.2016	9.99
	15	0.2580	0.7532	0.6074	1.2595	0.8184	89.93	0.4930	0.9431	0.7328	4.2023	10.07
Singapore	5	3.6585	9.7645	1.5106	0.2887	2.0743	3.6264	62.25	1.1071	0.3747	15.34	37.75
	10	3.9041	9.8897	1.5297	0.9941	2.1945	3.6772	60.81	1.1374	0.6496	15.22	39.19
	15	3.9231	9.8790	1.5353	1.0009	2.1997	3.6799	60.75	1.1406	0.6726	15.22	39.25
Taiwan	5	0.3317	0.2143	0.0405	0.0319	0.7655	0.1986	0.3898	95.71	0.1461	2.1685	4.29
	10	0.6362	0.2932	0.1496	0.1397	0.8543	0.2899	0.4545	94.50	0.3760	2.3111	5.50
	15	0.6490	0.3131	0.1535	0.1467	0.8570	0.2967	0.4565	94.41	0.3786	2.3381	5.59
Thailand	5	0.5227	2.3923	0.4555	1.5883	0.7392	1.9363	3.7411	0.9677	81.75	5.9079	18.25
	10	0.7317	2.7814	0.7178	1.6456	0.7673	2.1746	3.9597	1.1198	80.23	5.8744	19.77
	15	0.7661	2.7976	0.7318	1.6507	0.7751	2.1737	3.9772	1.1219	80.13	5.8802	19.87
United States	5	0.6539	0.3676	0.1821	0.2106	0.1284	0.2826	0.3080	0.2135	0.4801	97.17	2.83
	10	0.8771	0.6391	0.2367	0.2777	0.3737	0.5835	0.4654	0.3014	0.6204	95.63	4.37
	15	0.8925	0.6491	0.2373	0.2788	0.3792	0.5864	0.4700	0.3024	0.6313	95.57	4.43

[1]Market ordering: United States, New Zealand, Taiwan, Philippines, Australia, Japan, Hong Kong, Singapore, Malaysia, Thailand.

[2]Entries in each cell are the percentage forecast error variance of the market in the first column explained by the market in the first row.

[3] Entries in the 'All foreign' column denote the total percentage forecast error variance of the market in the first column explained by all foreign markets.

Table 9.3

GENERALISED DECOMPOSITION OF FORECAST ERROR VARIANCES FOR DAILY MARKET RETURNS FOR TEN ASIA PACIFIC MARKETS – LOCAL CURRENCY, 01/01/87 – 29/05/98[1,2]

Market Explained	Horizon (Days)	By innovations in Aus	HK	Jap	Mal	NZ	Phil	Sing	Taiw	Thai	U.S.	[3]All foreign
Australia	5	57.02	5.2872	2.6821	2.0848	8.4135	0.9162	4.2665	0.6668	0.6528	18.01	42.98
	10	56.48	5.5950	2.7158	2.1178	8.3094	1.1262	4.5093	0.7135	0.6447	17.79	43.52
	15	56.45	5.6008	2.7171	2.1190	8.3087	1.1327	4.5123	0.7183	0.6586	17.78	43.55
Hong	5	4.1925	61.60	2.7564	7.5889	1.7768	2.0506	10.91	0.5866	1.8779	6.6537	38.40
Kong	10	4.3470	60.91	2.7551	7.6331	1.7827	2.0966	11.00	0.6086	1.9969	6.8634	39.09
	15	4.3553	60.87	2.7598	7.6287	1.7912	2.1004	11.01	0.6114	2.0003	6.8775	39.13
Japan	5	3.2347	3.4133	78.89	2.2175	1.4661	0.2634	3.2376	0.9857	0.6590	5.6342	21.11
	10	3.2396	3.5819	78.02	2.3550	1.6257	0.3179	3.3924	1.0846	0.6879	5.6951	21.98
	15	3.2464	3.5870	77.98	2.3550	1.6324	0.3189	3.3952	1.0899	0.7011	5.6973	22.03
Malaysia	5	1.9369	8.2467	1.8440	55.79	0.8869	1.3777	20.21	0.6395	3.1344	5.9386	44.21
	10	1.9202	8.2477	1.8869	55.04	1.0418	1.4081	20.19	0.7337	3.2659	6.2663	44.96
	15	1.9241	8.2482	1.8899	55.01	1.0477	1.4208	20.18	0.7355	3.2695	6.2784	44.99
New	5	11.36	3.3298	2.2880	1.0986	64.78	0.5771	2.4643	0.6570	0.4567	12.99	35.22
Zealand	10	11.43	3.5106	2.3317	1.1614	63.86	0.8532	2.6259	0.6837	0.5187	13.03	36.14
	15	11.43	3.5109	2.3341	1.1643	63.81	0.8537	2.6339	0.6866	0.5234	13.05	36.19
Philippines	5	1.1703	3.6928	0.7336	3.7131	0.6126	78.74	5.3749	0.7352	1.7245	3.5046	21.26
	10	1.1812	3.8250	0.9318	3.9301	0.6986	77.69	5.3330	0.8787	1.9463	3.5813	22.31
	15	1.1852	3.8328	0.9343	3.9294	0.7017	77.66	5.3348	0.8805	1.9679	3.5829	22.35
Singapore	5	3.6933	10.40	2.1172	17.55	1.2493	2.6054	49.59	0.7990	2.8050	9.1798	50.41
	10	3.7697	10.43	2.1092	17.71	1.3389	2.6493	49.04	0.8312	2.8922	9.2288	50.96
	15	3.7789	10.43	2.1103	17.71	1.3428	2.6520	49.01	0.8338	2.9020	9.2371	50.98
Taiwan	5	1.3314	1.2004	1.2411	1.1884	0.7077	0.4748	2.0741	88.85	0.9357	1.9952	11.15
	10	1.5403	1.2758	1.2878	1.2409	0.7906	0.5789	2.0968	87.89	1.1639	2.1303	12.11
	15	1.5537	1.3017	1.2884	1.2419	0.7931	0.5862	2.1089	87.80	1.1669	2.1549	12.20
Thailand	5	1.0154	4.0416	0.8289	6.1596	0.6041	1.9257	7.2937	0.9233	72.44	4.7646	27.56
	10	1.0906	4.3073	0.9995	6.1838	0.6286	2.1179	7.5420	1.0399	71.34	4.7508	28.66
	15	1.1120	4.3221	1.0063	6.1836	0.6352	2.1180	7.5476	1.0419	71.28	4.7574	28.72
United	5	0.6984	1.7035	1.3032	0.7952	0.1233	0.3523	1.2239	0.2783	0.8102	92.71	7.2884
States	10	0.7980	1.9274	1.3817	0.8437	0.3597	0.5843	1.2708	0.3730	0.9345	91.53	8.4732
	15	0.8076	1.9336	1.3817	0.8446	0.3651	0.5874	1.2743	0.3742	0.9412	91.49	8.5097

[1] Entries in each cell are the percentage forecast error variance of the market in the first column explained by the market in the first row.

[2] The generalised forecast error variance decompositions have been standardised for each of the explained markets so that the total error variance sums to 100 percent.

[3] Entries in the 'All foreign' column denote the total percentage forecast error variance of the market in the first column explained by all foreign markets.

The markets in the orthogonalised forecast error variance decomposition in Table 9.2 are ordered according to closing time, starting with the United States because it can be regarded, *a priori,* as the most exogenous market in the system. The markets are then ordered by closing time, with the New Zealand market the first to close after the U.S., but on the following day to the U.S. market. The results were tested and found to be insensitive to the ordering of Australia and Japan, and Singapore and Malaysia, each of which close at the same time. Consistent with the findings in the previous section, examination of the results in Tables 9.2 and 9.3 reveal some quite important differences in the percentage of forecast error variance explained by the respective markets, depending on whether the orthogonalised or generalised approach is used. The role of the United States as the dominant market is unaltered by the approach used, but some of the other linkages are quite noticeably affected.

Because New Zealand is ordered before Australia in Table 9.2, innovations in the New Zealand market explain a far greater proportion of the variance in the Australian market (10.70% at 15 days) than innovations in the Australian market explain variance in the New Zealand market (1.99% at 15 days). This is consistent with the findings in Janakiramanan and Lamba (1997) and reflect the impact of shocks in the U.S. market filtering through the New Zealand market before being felt in markets that (open and) close after the New Zealand market such as Australia. The nature of the linkage between these two markets is not, however, consistent with what we know about them. The New Zealand market is much smaller and less influential than its close neighbour, Australia, yet the results do not reflect this. In Table 9.3, the linkage between Australia and New Zealand is very different and more accurately reflects the underlying relationship between the markets. Innovations in the New Zealand market now account for a smaller proportion of the variance in the Australian market (8.31% at 15 days) than innovations in Australia do in the New Zealand market (11.43% at 15 days). This finding clearly illustrates the benefit of the generalised approach over the orthogonalised approach in more accurately reflecting the nature of the linkages between markets.

The difference between the two approach is also very apparent in the case of two other closely linked geographic and economic locations – Singapore and Malaysia. Singapore is ordered prior to Malaysia in the VAR in Table 9.2, and as a result, innovations in the Singapore market explain a much greater proportion of the error variance in the Malaysian market (19.20% at 15 days) than the innovations in the Malaysian market explain of the Singapore market (1.00% at 15 days). This changes dramatically when the generalised approach is used with innovations in the Singapore market (20.18% at 15 days) having a very similar impact on the Malaysian market as innovations in the Malaysian market (17.71% at 15 days) have on the Singapore market. The results in Table 9.2

are misleading since they suggest that the linkage between Singapore and Malaysia is uni-directional when it is in fact a bi-directional relationship. The results in Table 9.3 also reveal that the Singapore market is actually more endogenous than the Malaysian market is. Although generally less dramatic, there are similar differences in the relationships between other pairs of markets in Tables 9.2 and 9.3.

When the generalised approach is used, innovations in a particular market explain less of their own forecast error variance, or looking at it from the opposite angle, all foreign markets explain a greater percentage of the forecast error variance of a particular market where the generalised approach is used. Although the U.S. market remains dominant, the influence of innovations in the U.S. market on the other nine Asia Pacific markets is reduced when the generalised approach is used, reflecting the extra dominance that the U.S. market exerts when its place as first in the model has an influence on the results. Both of the factors contribute to generally stronger linkages between the other markets when the generalised approach is used. While the increases are generally small, some significant differences do stand out as highlighted above. As well as the dominance of the U.S. market, the isolation of the Taiwanese market is unaffected by the approach used. The ordering of the markets too, from most exogenous to most endogenous is generally unaffected by the approach used.

The differences in the output for the generalised and orthogonalised approaches to forecast error variance decomposition, outlined above, are found in the other VAR models used in this study. There are some minor differences. For example, the VAR model that excludes the U.S. market results in an even greater difference in the linkage between the Australian and New Zealand markets when the generalised approach is used, than was the case in Tables 9.2 and 9.3 above. This tends to suggest that much of the forecast error variance the N.Z. market explains, is as a result of the changes in the U.S. market that are filtered through the N.Z. market. When the U.S. market is excluded, New Zealand is not nearly as influential. Because the generalised approach is clearly favoured for forecast error variance decomposition, a comparison of the two approaches for these other models is not necessary.

Attention turns now, solely, to establishing the linkages that exist between the markets in the Asia Pacific region, using the generalised forecast error variance decomposition. We start with the forecast error variance decomposition of the ten Asia Pacific region markets using local currency data. The results in Table 9.3 reveal that the U.S. market is the most influential in the Asia Pacific region. No market explains more than 2% of the U.S. forecast error variance while the U.S. market influences the majority of the Asia Pacific markets. The exceptions are Taiwan and to a lesser extent the Philippines and Thailand, which the U.S. market appears to have very little influence on, explaining only 2% of the forecast error variance of Taiwan, and less than 5% for the Philippines and Thailand. This result is consistent with the notion that these emerging markets are reasonably isolated from the developed markets. The U.S. market has a strong influence on the more developed markets of Australia (18%), New Zealand (13%) and Singapore (9%). More surprising is the reasonably small influence of the U.S. market on the Japanese market (5.5%). The results Table 9.3 are fairly consistent with those found by Janakiramanan and Lamba (1998) who studied a similar set of markets. They noted that the lack of influence on the U.S. by Asian markets was interesting in light of the recent turmoil in Asia and its effect on world financial markets. It is worth noting, however, that the results in Table 9.3 examine long-term linkages between markets and not short-term linkages.

The results in Table 9.3 indicate that no Asia Pacific equity market is exogenous in that a market's own innovations fully account for its variance. In fact, there is significant interaction between many of the markets. At the 15-day horizon, the percentage of error variance of a equity market explained by the collective innovations in all foreign equity markets ranges between 8.51% for the United States to 50.98% for Singapore. With almost 51% of its variance explained by all foreign markets combined, Singapore is clearly the most endogenous market. After Singapore, the markets are ranked from most endogenous to most exogenous as follows: Malaysia, Australia, Hong Kong, New Zealand, Thailand, Philippines, Japan, Taiwan and the United States. The strong linkage between the Singapore and Malaysian markets obviously contributes to the endogenous nature of these markets. Although Malaysia was classified as an emerging market in Chapter 4, its strong linkages with Singapore, in particular, tend to suggest that its financial markets, at least, are open rather than isolated. The other emerging markets, the Philippines, Taiwan and Thailand are much more isolated. They are hardly influenced by foreign markets, and themselves exert little if any influence on the other markets. The results for these three markets are more consistent with the notion of high growth phases in emerging markets, that tend to isolate them from developed markets.

The results in Table 9.3 confirm that markets with strong economic ties and close geographic proximity like Australia and New Zealand, and Singapore and Malaysia exert significant influence over each other. Unlike earlier studies, however, the influence is shown to be exerted both ways rather than the dominant influence being exerted from the market that closes earlier in the day. Shocks in Australia and New Zealand explain 11% and 8%, respectively, of the forecast error variance in each market. Shocks in Singapore and Malaysia explain 20% and 17.5% respectively, of the forecast error variance in each market. The strong linkages between these markets is consistent with the findings in Chapter 7 where these markets had higher correlation coefficients than some of the other markets. The Hong Kong market appears to be the most interactive market in the system. As well as being one of the more endogenous markets, innovations in the Hong Kong market are felt in many of the other markets. Only the U.S. market appears to exert more influence on the other markets, in general, than Hong Kong does. Innovations in Hong Kong explain 5.5% of the forecast error variance in Australia, 8% in Malaysia, 10.5% in Singapore and 4% of Thailand. Consistent with earlier studies, Japan, the only market comparable with the United States in size, has very little influence on the other markets in the Asia Pacific region. More consistent with its dominant size, apart from the U.S. market, the Japanese market is the least influenced of the developed markets.

The VAR model in Table 9.3 was re-estimated without the U.S. market to see if there are any significant linkages between markets in the absence of the U.S. market. The results of the generalised forecast error variance decomposition on the nine Asia Pacific markets are presented in Table 9.4. The results in Table 9.4 indicate that, in the absence of the U.S. market, no market takes a dominant role in the Asia Pacific region. While there is no dominant market in the absence of the U.S. market, the strong linkages found between some of the markets in Table 9.3, remain in Table 9.4. Further, in the absence of the U.S. market, the linkages between markets in the Asia Pacific region appear to be generally stronger. For example, all nine markets explain a smaller proportion (between 2% and 6% less) of their own forecast error variance when the U.S. market is excluded. Also without exception, the off-diagonal cells in Table 9.4 are greater than those in Table 9.3 which means that innovations in the nine remaining markets explain a greater proportion of the forecast error variance in the other markets left in the system. The increase ranges between 0.5% and 6%. The percentage of forecast error variance explained by foreign markets increases when the U.S. market is excluded.

Apart from a few small differences between Tables 9.3 and 9.4, outlined above, the linkages are generally very similar. The emerging markets of the Philippines, Taiwan and Thailand continue to have very little influence on the other markets, and are themselves largely isolated from the influence of foreign markets. For its size, and in the absence of the dominant role of the U.S., the Japanese market continues to have a very weak influence on the other Asia Pacific markets. Singapore, Malaysia, Australia and Hong Kong remain the most endogenous markets. The strong linkages between Australia and New Zealand, and Singapore and Malaysia remain, and are in fact strengthened a little in the absence of the U.S. market from the system. The influence of innovations in the Hong Kong market on Australia, Malaysia, New Zealand and Singapore are strengthened slightly when the U.S. market is excluded.

Table 9.4

GENERALISED DECOMPOSITION OF FORECAST ERROR VARIANCES FOR DAILY MARKET RETURNS FOR NINE ASIA PACIFIC MARKETS – LOCAL CURRENCY, 01/01/87 – 29/05/98[1,2]

		By innovations in									
Market Explained	Horizon (Days)	Aus	HK	Jap	Mal	NZ	Phil	Sing	Taiw	Thai	[3]All foreign
Australia	5	54.7864	8.2992	4.6890	4.6232	13.8518	1.9959	8.7883	1.2403	1.7260	45.2136
	10	54.4682	8.4603	4.6941	4.5969	13.7013	2.1807	8.9058	1.2819	1.7107	45.5318
	15	54.4586	8.4684	4.6917	4.5967	13.6914	2.1857	8.9065	1.2870	1.7141	45.5414
Hong Kong	5	7.3446	55.8454	3.9823	9.3327	3.8833	2.8185	13.1912	0.9409	2.6612	44.1546
	10	7.3699	55.5178	3.9895	9.3812	3.8611	2.8558	13.3019	0.9640	2.7588	44.4822
	15	7.3873	55.4814	3.9898	9.3771	3.8654	2.8601	13.3107	0.9665	2.7616	44.5186
Japan	5	5.9496	5.1866	73.2323	3.7444	3.3065	0.4950	5.4162	1.3984	1.2711	26.7677
	10	5.9430	5.2959	72.7453	3.8231	3.4194	0.5431	5.4573	1.4709	1.3022	27.2547
	15	5.9478	5.2982	72.7160	3.8228	3.4245	0.5444	5.4596	1.4745	1.3121	27.2840
Malaysia	5	4.5461	9.9672	2.9248	51.6526	2.7038	1.9998	21.3649	0.9844	3.8563	48.3474
	10	4.6255	9.8692	3.0378	51.1018	2.8963	2.0176	21.4313	1.0639	3.9567	48.8982
	15	4.6290	9.8701	3.0385	51.0804	2.9026	2.0237	21.4294	1.0662	3.9600	48.9196
New Zealand	5	16.6529	5.5871	3.5700	3.1525	61.7952	1.4140	5.5227	1.1905	1.1152	38.2048
	10	16.7220	5.6436	3.5889	3.1556	61.3665	1.6208	5.5423	1.2042	1.1563	38.6335
	15	16.7339	5.6438	3.5922	3.1546	61.3334	1.6208	5.5539	1.2074	1.1601	38.6666
Philippines	5	2.8553	4.9885	1.0738	4.6608	1.6450	74.6493	6.9558	0.9381	2.2336	25.3507
	10	2.8689	5.1170	1.2473	4.7900	1.6684	73.8844	6.9095	1.0826	2.4321	26.1156
	15	2.8758	5.1276	1.2490	4.7920	1.6694	73.8411	6.9126	1.0838	2.4486	26.1589
Singapore	5	7.5680	12.3860	3.4600	18.5868	3.6800	3.5051	45.9058	1.2293	3.6790	54.0942
	10	7.5876	12.3666	3.4576	18.6940	3.7297	3.5372	45.6158	1.2550	3.7564	54.3842
	15	7.6005	12.3648	3.4562	18.6913	3.7342	3.5372	45.5980	1.2562	3.7616	54.4020
Taiwan	5	2.4062	1.9419	1.8273	1.9216	1.5321	0.6812	3.0874	85.2939	1.3086	14.7061
	10	2.4822	1.9758	1.9060	1.9522	1.5686	0.7538	3.1237	84.7263	1.5113	15.2737
	15	2.4937	1.9919	1.9062	1.9525	1.5722	0.7622	3.1351	84.6737	1.5125	15.3263
Thailand	5	2.9518	5.7574	1.5828	7.4949	1.7486	2.6008	9.1719	1.2220	67.4697	32.5303
	10	2.9519	5.9710	1.7228	7.5058	1.7580	2.7713	9.3732	1.3397	66.6063	33.3937
	15	2.9732	5.9781	1.7272	7.5084	1.7613	2.7707	9.3792	1.3402	66.5617	33.4383

[1] Entries in each cell are the percentage forecast error variance of the market in the first column explained by the market in the first row.
[2] The generalised forecast error variance decompositions have been standardised for each of the explained so that the total error variance sums to 100 percent.
[3] Entries in the 'All foreign' column denote the total percentage forecast error variance of the market in the first column explained by all foreign markets.

The generalised forecast error variance decompositions were also conducted using the data expressed in U.S. dollars, for all ten Asia Pacific markets and with the U.S. market excluded. The similarity of these results with those presented where local currency was used, in Tables 9.3 and 9.4, means that in the interests of brevity, the results will not be presented. The only noticeable difference in the results when exchange rate adjusted data was used, was the across the board reduction in the influence of innovations in the U.S. market on the other markets. This means that in the absence of exchange rate risk (local currency data), the linkages between the U.S. market and other markets is generally stronger. While the change is generally small, the effect on the relationship between the U.S. and Australian is particularly strong. When local currency data is used, innovations in the U.S. market explain 18% of the forecast error variance. This decreases to 11% when U.S. dollar data is used. While this is a relatively isolated difference between the two data sets' effect on variance decomposition, the result is interesting and does make some sense. It tends to suggest that investors are more likely to respond to shocks in the U.S. market when there is no exchange rate risk. When exchange rate risk is a consideration in investment decisions, investors are less likely to react to shocks in a dominant market like the U.S. because of the added foreign exchange risk. This results in weaker linkages between the dominant U.S. market and the smaller markets.

9.4 Impulse Response Analysis

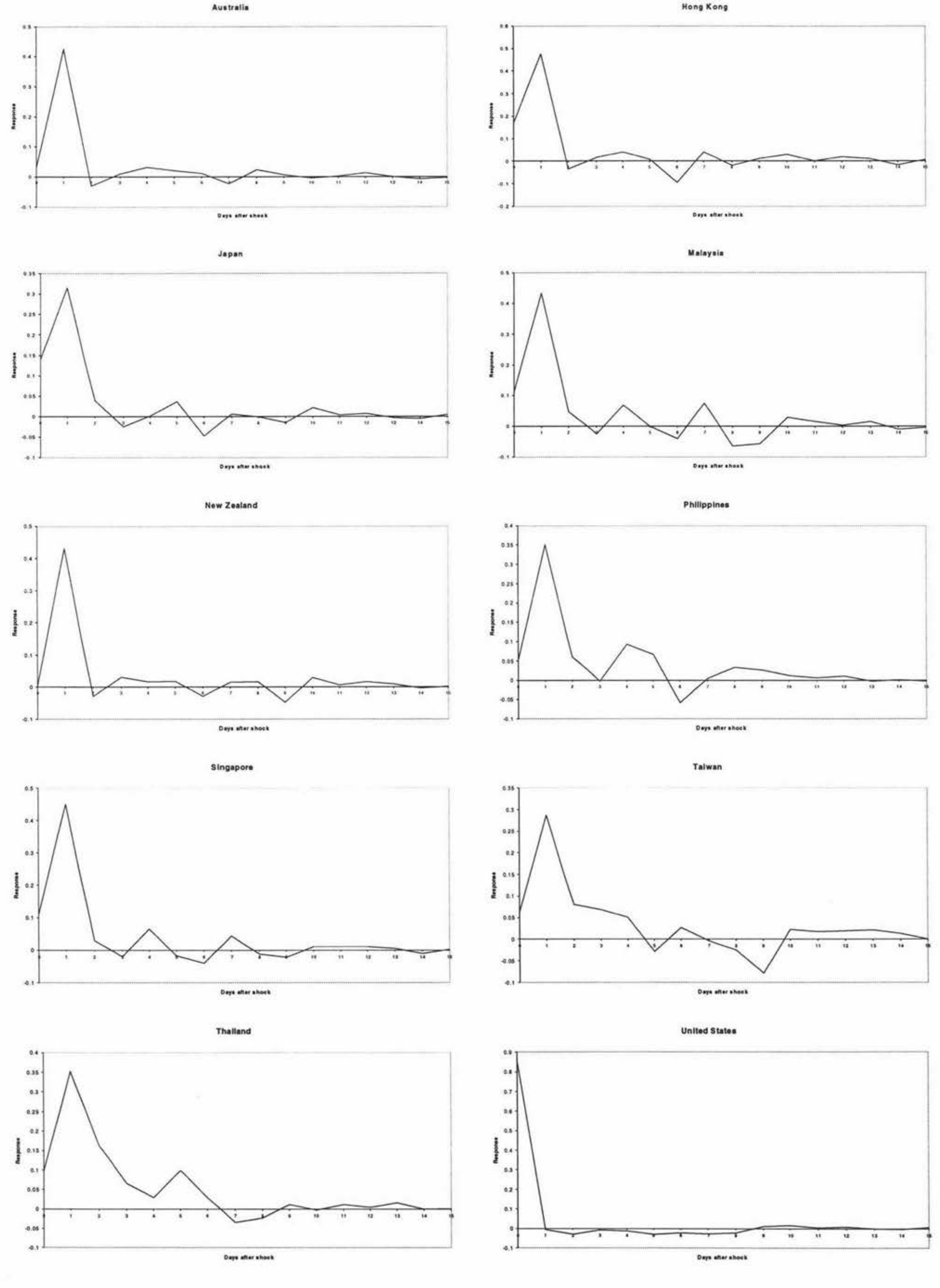
Once the VAR system is estimated, the dynamic responses of each of the markets in the system to innovations in a particular market can be traced out over a defined time horizon using the simulated responses of the VAR system. This practice is referred to as impulse response analysis and enables the researcher to gain additional insight into the mechanism of the international transmission of stock market movements. In this section the impulse responses of the markets in the model to a typical shock (one standard error) in a particular market are analysed. The speed with which innovations in a particular market are transmitted in the other markets provides the researcher with an indication of the responsiveness of markets and the efficiency with which new information, or innovations, are transmitted between markets. Further, the size of a market's response to shocks in other markets indicates how influenced that market is by other markets. While the forecast error variance decomposition reveals how strongly markets are linked, the impulse response analysis can be used to further examine these linkages and the efficiency with which innovations are transmitted between markets.

To determine whether the generalised approach to impulse response analysis is better than the orthogonalised approach, impulse response analysis was carried out for a shock to the Hong Kong market, using both approaches. The output for these tests is presented in Figures 9.7 and 9.8 at the end of this chapter, for the orthogonalised and generalised approaches, respectively. The generalised approach has very little impact on the impulse responses of Singapore, Malaysia and Thailand, which close after Hong Kong. Because these markets enter the model after Hong Kong they can respond on day 0, using both approaches. Because of the way in which the orthogonalised approach is calculated, the other variables, by definition, cannot respond to a shock in the Hong Kong market on day 0. The impulse responses of Australia, Japan, New Zealand, the Philippines, Taiwan and the United States are much improved using the generalised approach, more accurately reflecting the responses we would expect for these markets. These markets at least share some common opening time with the Hong Kong market, except for the U.S. market which actually opens after the Hong Kong market closes. It makes sense, then, that these markets should have some reaction on day 0 to a shock in the Hong Kong market. The generalised approach which is independent of the ordering of the variables in the model, is able to trace out the dynamic responses of the markets to shocks in the other markets better. Because of this, the generalised approach to impulse response analysis will be used.

We can use the information from the forecast error variance decomposition in the previous section to help determine which markets to analyse the effect of a shock on. There is little to be gained from studying the impact of shocks in a market that exerts no, or little influence on the other markets in the system. Markets like the United States, which is the most dominant market in the Asia Pacific region, are well suited to impulse response analysis. Figure 9.1 plots the responses of each of the ten Asia Pacific markets to a one standard error shock in the U.S. market, using local currency data. The plots in Figure 9.1 show that innovations in the U.S. stock market are rapidly transmitted in all other markets. All of the Asia Pacific markets respond to the U.S. shock most dramatically one day after the shock with the responses quickly tapering off to zero after day 1. Only Thailand has a response larger (or smaller) than plus (or minus) 0.1 after day 1. A one day lag is expected and does not reflect any inefficiency in the transmission of innovations between markets. Because the markets all close before the U.S. market opens, the earliest they can respond to a shock in the U.S. market is on day 1.

Figure 9.1

TIME PATHS OF GENERALISED IMPULSE RESPONSES TO A ONE STANDARD ERROR SHOCK IN THE U.S MARKET – LOCAL CURRENCY, 01/01/87 – 29/05/98



The speed with which the responses taper off to zero after the initial shock is felt on day 1, and the speed with which the initial shock is felt mean that there is little, if any, delayed reaction to the unit shock in the U.S. market. This indicates that the market is efficient in transmitting innovations in the U.S. market to the other markets. There is effectively, no lag between a shock in the U.S. market and the responses of the other markets. The efficiency in the responses to a shock in the U.S. market is also reflected in the accuracy of the initial response, to the shock on day 1. If the markets over-reacted in their initial response to the shock then we would expect to see an adjustment in the form of a large negative response after day 1. Although all of the markets exhibit some small negative response after day 1, the small size of these responses indicates that any over-reaction in the initial response is only minor.

The size of the responses to a shock in the U.S. market are quite large (between 0.29 and 0.48, on day 1), reflecting the influence the U.S. market has on the other markets in the Asia Pacific region. Clearly markets like Singapore and Malaysia are likely to exert influence on each other that results in larger responses than 0.50. It is unlikely, however, that any other market in the region would have as great an influence on all of the Asia Pacific markets as the U.S. market does. Inspection of the plots in Figure 9.1 reveals that a clear distinction can be made between the responses of Japan and the emerging markets of the Philippines, Taiwan and Thailand, and the other markets in the system. The forecast error variance decompositions made a similar distinction between these groups of markets. The Philippines, Taiwan, Thailand and Japan again prove to be relatively isolated in the Asia Pacific region. The size of the impulse responses to a U.S. shock on day 1 is greater than 0.40 for the Australian, Hong Kong, Malaysian, New Zealand and Singapore markets. This contrasts with responses between 0.29 and 0.35 on day 1 for the more isolated markets. The isolation of these markets is consistent with what we found in the previous section.

The efficiency with which markets respond to innovations in the U.S. market also distinguishes the developing markets from the more isolated emerging markets. In terms of efficiency, the Japanese market behaves much more in line with the developed markets, which means that while it is not very strongly influenced by innovations in foreign markets, it does behave efficiently in its responses. The responses from the impulse analysis in Figure 9.1 has been tabulated in Table 9.5 to help illustrate the efficiency with which the different markets respond to a shock in the U.S. market. The impulse responses for the Australian, Hong Kong, Japanese, Malaysian, New Zealand, and Singapore markets all taper off to zero very quickly after their initial response on day 1. This is in contrast to the responses for the Philippines, Taiwan and Thailand which react more slowly. The most noticeable case is Thailand which has a response of 0.16 on day 2, 0.07 on day 3, 0.03 on day

4 and 0.10 on day 5. It is important to note, however, that the slower reacting markets still have their largest response to the U.S. shock on day 1, and it would be incorrect to imply that these markets are highly inefficient. The size of these late reactions are, after all, fairly small in magnitude. The most appropriate comment would be that these markets are less efficient than the developing markets in responding to new information. This again, reflects the more isolated nature of these markets. The impulse responses to a shock in the U.S. market, presented in Figure 9.1 and Table 9.5 show that the Asia Pacific markets are efficient in the transmission of information from the U.S. market. The results also tend to confirm that the U.S. market is dominant in the region, with a one standard error shock in the U.S. market felt throughout the Asia Pacific region.

Table 9.5

IMPULSE RESPONSES TO A ONE STANDARD ERROR SHOCK IN THE U.S MARKET USING DAILY DATA FOR TEN ASIA PACIFIC MARKETS – LOCAL CURRENCY, 01/01/87 – 29/05/98

*i*th Day	Impulse Responses in									
after Shock	Aus	HK	Jap	Mal	NZ	Phil	Sing	Taiw	Thai	US
0	0.03	0.17	0.14	0.11	0.00	0.05	0.11	0.06	0.10	0.85
1	0.42	0.48	0.31	0.43	0.43	0.35	0.45	0.29	0.35	-0.01
2	-0.03	-0.03	0.04	0.05	-0.03	0.06	0.03	0.08	0.16	-0.03
3	0.01	0.01	-0.02	-0.03	0.03	0.00	-0.02	0.07	0.07	-0.01
4	0.03	0.04	0.00	0.07	0.02	0.09	0.06	0.05	0.03	-0.01
5	0.02	0.01	0.04	0.00	0.02	0.07	-0.02	-0.03	0.10	-0.03
6	0.01	-0.10	-0.05	-0.04	-0.03	-0.06	-0.04	0.03	0.03	-0.02
7	-0.02	0.04	0.01	0.07	0.02	0.00	0.04	0.00	-0.03	-0.03
8	0.02	-0.02	0.00	-0.06	0.02	0.03	-0.01	-0.03	-0.02	-0.02
9	0.01	0.01	-0.02	-0.06	-0.05	0.03	-0.02	-0.08	0.01	0.01
10	0.00	0.03	0.02	0.03	0.03	0.01	0.01	0.02	0.00	0.02
11	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.02	0.01	0.00
12	0.01	0.02	0.01	0.00	0.02	0.01	0.01	0.02	0.00	0.01
13	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.02	0.02	0.00
14	-0.01	-0.02	-0.01	-0.01	0.00	0.00	-0.01	0.01	0.00	0.00
15	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01

Figures 9.2 through 9.6 present the generalised impulse response functions for shocks to the Australian, New Zealand, Singapore, Malaysian and Hong Kong markets, using local currency data.[2] The forecast error variance decomposition in the previous section revealed that the Japanese

[2] Janakiramanan and Lamba (1997) excluded the U.S. market from the VAR model when they examined the impact of shocks in some of the other markets in their system. The U.S. market is not excluded in this case. While it is not

market and the emerging markets of the Philippines, Taiwan and Thailand exerted very little influence on the other Asia Pacific markets. Accordingly, impulse response analysis is not presented for shocks in these markets.[3] The results from the impulse response analysis in Figures 9.2 through 9.6 are considered briefly. In particular we are interested in how efficiently the innovations are transmitted between markets, if any general patterns emerge in these figures and whether any of linkages found in the previous section can be confirmed.

The most striking observation in the impulse response functions in Figures 9.2 through 9.6 is that the U.S. market is not influenced by shocks in any of these markets. The largest response from the U.S. market is to a shock in the Hong Kong market and this is not even 0.10 on day 0. This is consistent with the results in the previous section where it was shown that innovations in no market explained more than 2% of the forecast error variance of the U.S. market. The efficiency with which the markets respond to the shocks in the five markets in Figures 9.2 through 9.6 is generally very high as was the case in the responses to the U.S. market shock in Figure 9.1. Because all of the markets that experience shocks in Figures 9.2 through 9.6 are open, at least for a short time with the other markets (except for the U.S. market which opens after these markets close), markets would be perfectly efficient in reacting to new innovations if the entire response was on day 0. The responses in Figures 9.2 through 9.6 clearly reflect a high level of efficiency. Almost without exception, the largest response for the various markets is on day 0. Any responses after day 0 are generally very small, although as was the case for the U.S. shock, the responses in some of the more isolated markets carry over on to day 1.

Once again there is little, if any, evidence of over-reaction in the initial response or any significant delayed reaction to the shock with the impulse responses fluctuating within a band of plus or minus 0.1, after day 0 for all of the developed markets. The more isolated emerging markets of the Philippines, Taiwan and Thailand are again slower in their reaction to shocks, with delayed responses in these markets to shocks fairly apparent. For example, the Philippines and Thailand both react to a shock in the Malaysian market quite strongly on day 1 as well as day 0. Whether this lag is long enough (or the response large enough) for investors to profit on is questionable. Relative

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expected that any of these markets will influence the U.S. market, the U.S. market should be included in the system. If it is excluded then the impact of shocks in the markets we look at, may simply be reflecting the impact of the absent U.S. market. The inclusion of the U.S. market more accurately reflects what is reality in the markets being studied.

[3] Impulse response analysis was conducted, but is not presented, for the Japanese, Philippines, Taiwan and Thailand markets. Reactions to shocks in these markets were generally very small, consistent with what would be expected given the forecast error variance decomposition. The only responses greater than 0.20 for one standard error shocks in these markets were in the Hong Kong, Malaysian, and Singapore markets reflecting the endogenous nature of these markets and the closer economic and geographic ties they have with these Asian emerging markets. The responses from the other markets to shocks in these markets were much smaller – usually less than 0.1 and no greater than 0.15.

to the other markets in the Asia Pacific region, however, these markets do appear to be less efficient. Figures 9.2 through 9.6 also reveal that markets with stronger economic ties and closer geographic proximity like Singapore and Malaysia respond in a similar fashion to shocks in the other markets. This is consistent with the high contemporaneous correlation coefficient for the equations of these two markets found in the first section. In fact, the Singapore, Malaysian, New Zealand, Australian, Japanese and Hong Kong markets all respond similarly to shocks in the various markets, although not quite to the extent that the Singapore and Malaysian markets respond together. While the magnitude of the responses for the different markets differ, depending on the market experiencing the shock, the pattern is much the same - a sharp response on day 0, falling rapidly to zero on day 1 or 2, and then fluctuating mildly around zero until around day 10, at which point the responses effectively become zero.

The results in Tables 9.2 through 9.6 are generally consistent with the results that have already been presented in this chapter. As would be expected, a shock in the Australian market is felt most strongly in New Zealand and vice versa. A shock in the Australian market has a greater impact on New Zealand than the New Zealand market has on Australia, reflecting Australia's larger size and influence. The Hong Kong market which is the most interactive market also reacts strongly to a shock in the Australian market. Shocks to the Australian market are also felt in Japan, Singapore and Malaysia, while New Zealand's impact on these markets is much more marginal. Shocks in Australia and New Zealand only have a small impact in the emerging markets of Philippines, Taiwan and Thailand, although again, the Australian market is more influential.

As would be expected, the largest response to a shock in the Singapore market is from Malaysia and vice versa. In fact the responses of these two markets to shocks in the other, are the strongest found in the Asia Pacific region. A shock in the Singapore market results in a response of 0.80 in Malaysia, while a shock in Malaysia results in a response of 0.61 in Singapore. Hong Kong also responds strongly to shocks in these markets, 0.65 and 0.53 for Singapore and Malaysia, respectively. Shocks in Singapore and Malaysia result in moderate responses from the Australian, New Zealand and Japanese markets, and even result in fairly strong responses from the Philippines and Thailand. The response from Taiwan, however is small. Singapore and Malaysia clearly have very strong links with the Asia markets, in particular. The developing markets are again, the most responsive to shocks on day 0, reflecting the high level of efficiency with which these markets respond to new information in other markets, while the emerging markets react more slowly, consistent with the relative isolation of these markets.

Figure 9.2

TIME PATHS OF GENERALISED IMPULSE RESPONSES TO A ONE STANDARD ERROR SHOCK IN THE AUSTRALIAN MARKET – LOCAL CURRENCY, 01/01/87 – 29/05/98

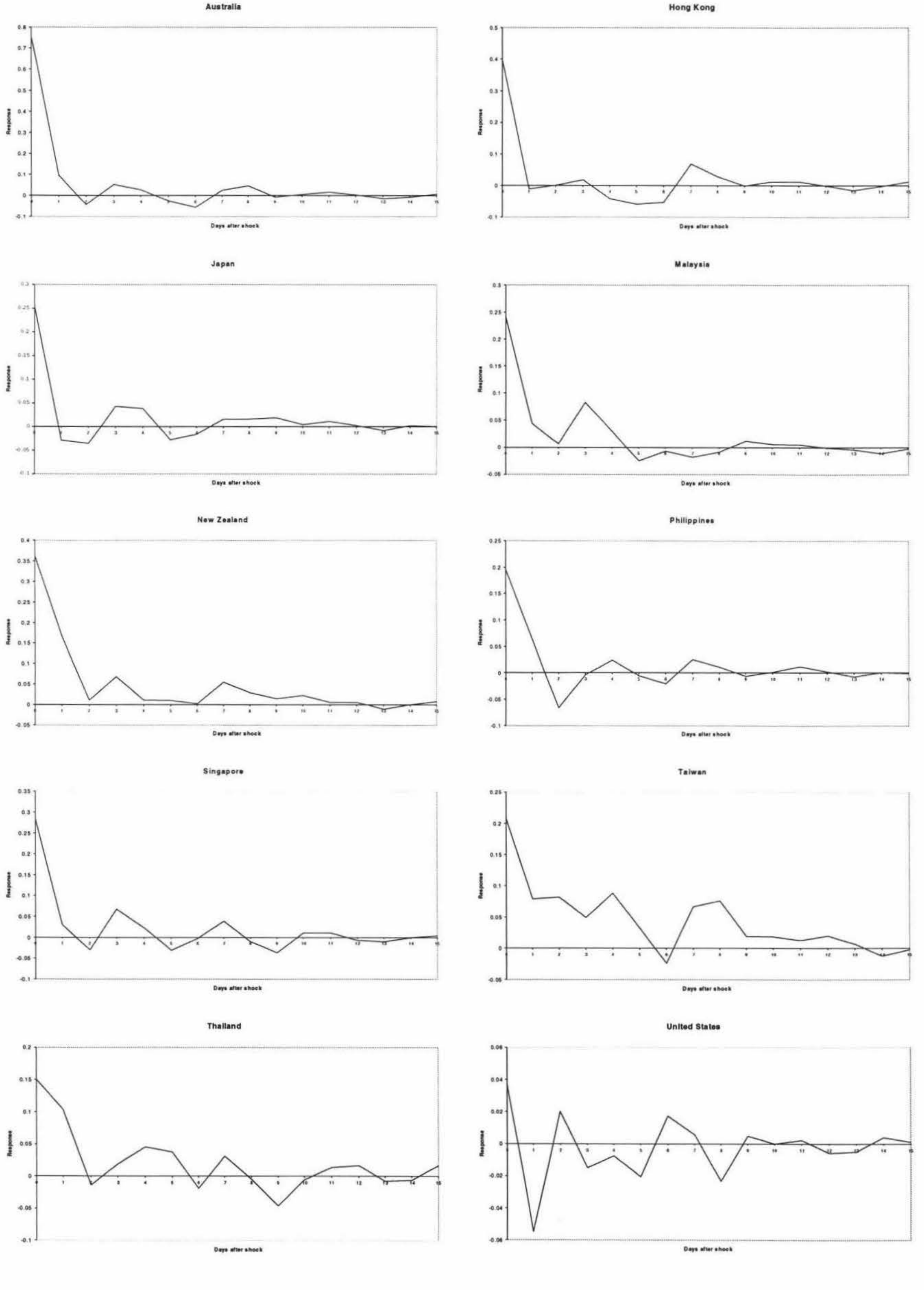


Figure 9.3

TIME PATHS OF GENERALISED IMPULSE RESPONSES TO A ONE STANDARD ERROR SHOCK IN THE NEW ZEALAND MARKET – LOCAL CURRENCY, 01/01/87 – 29/05/98

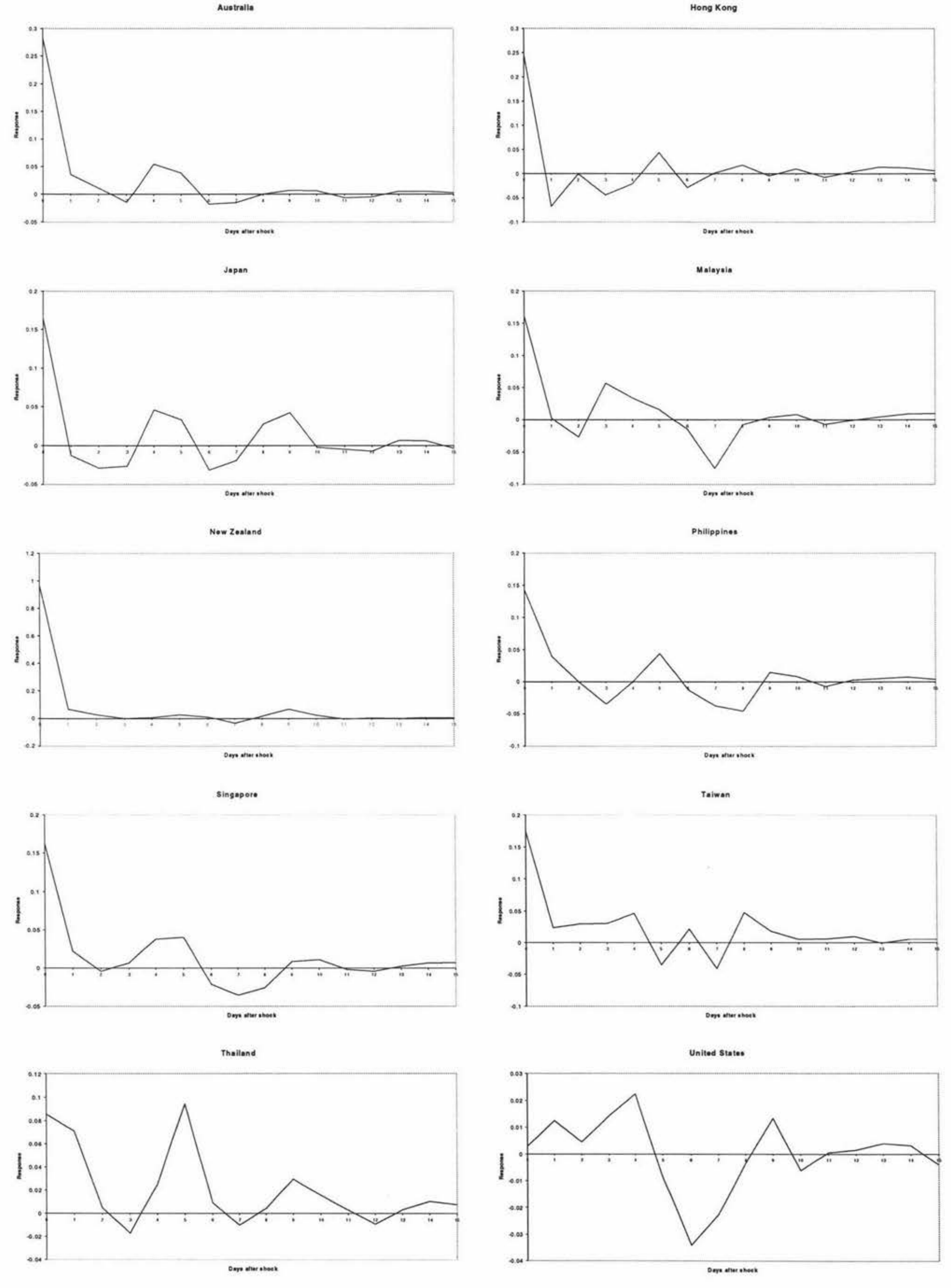


Figure 9.4

TIME PATHS OF GENERALISED IMPULSE RESPONSES TO A ONE STANDARD ERROR SHOCK IN THE SINGAPORE MARKET – LOCAL CURRENCY, 01/01/87 – 29/05/98

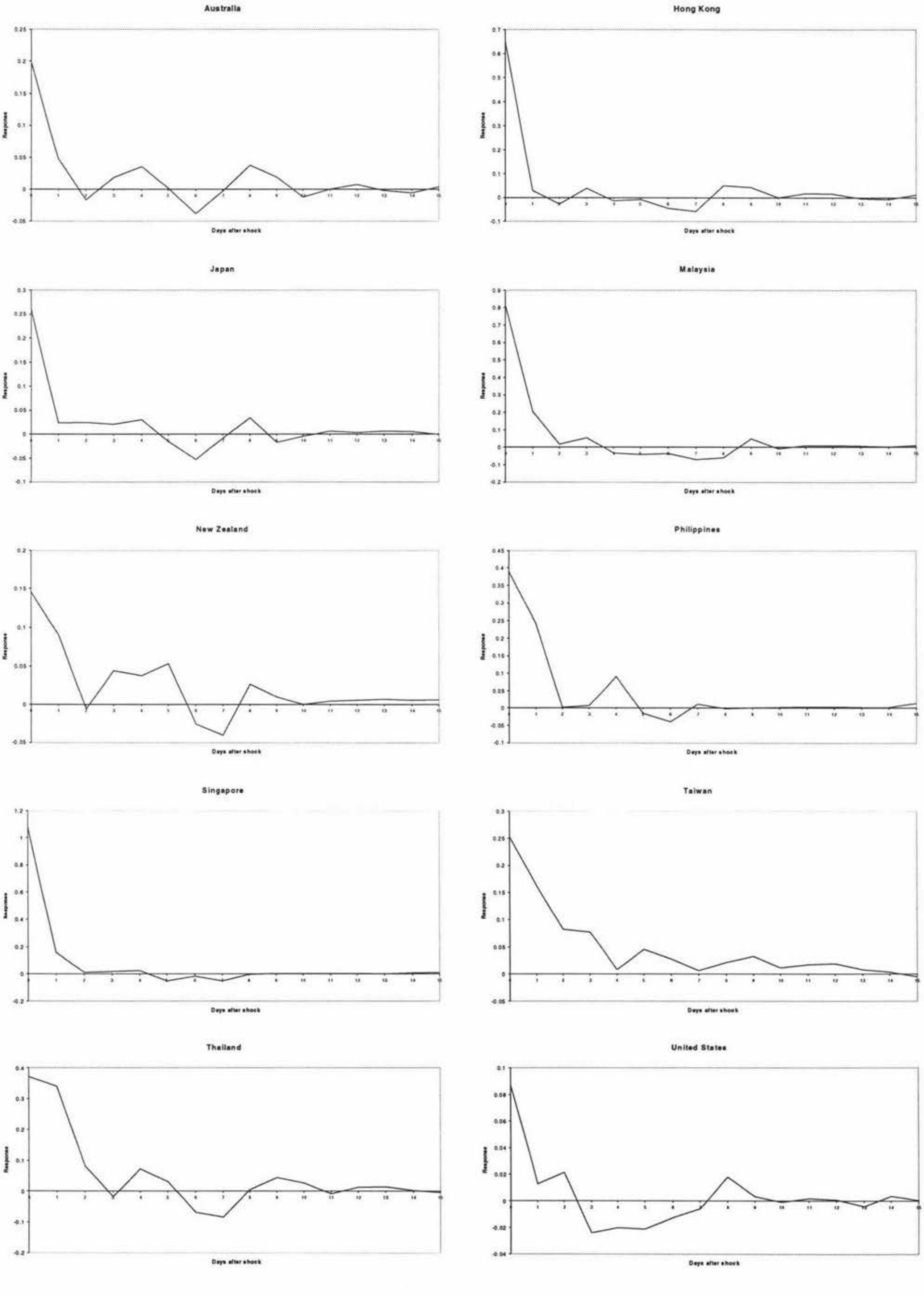


Figure 9.5

TIME PATHS OF GENERALISED IMPULSE RESPONSES TO A ONE STANDARD ERROR SHOCK IN THE MALAYSIAN MARKET – LOCAL CURRENCY, 01/01/87 – 29/05/98

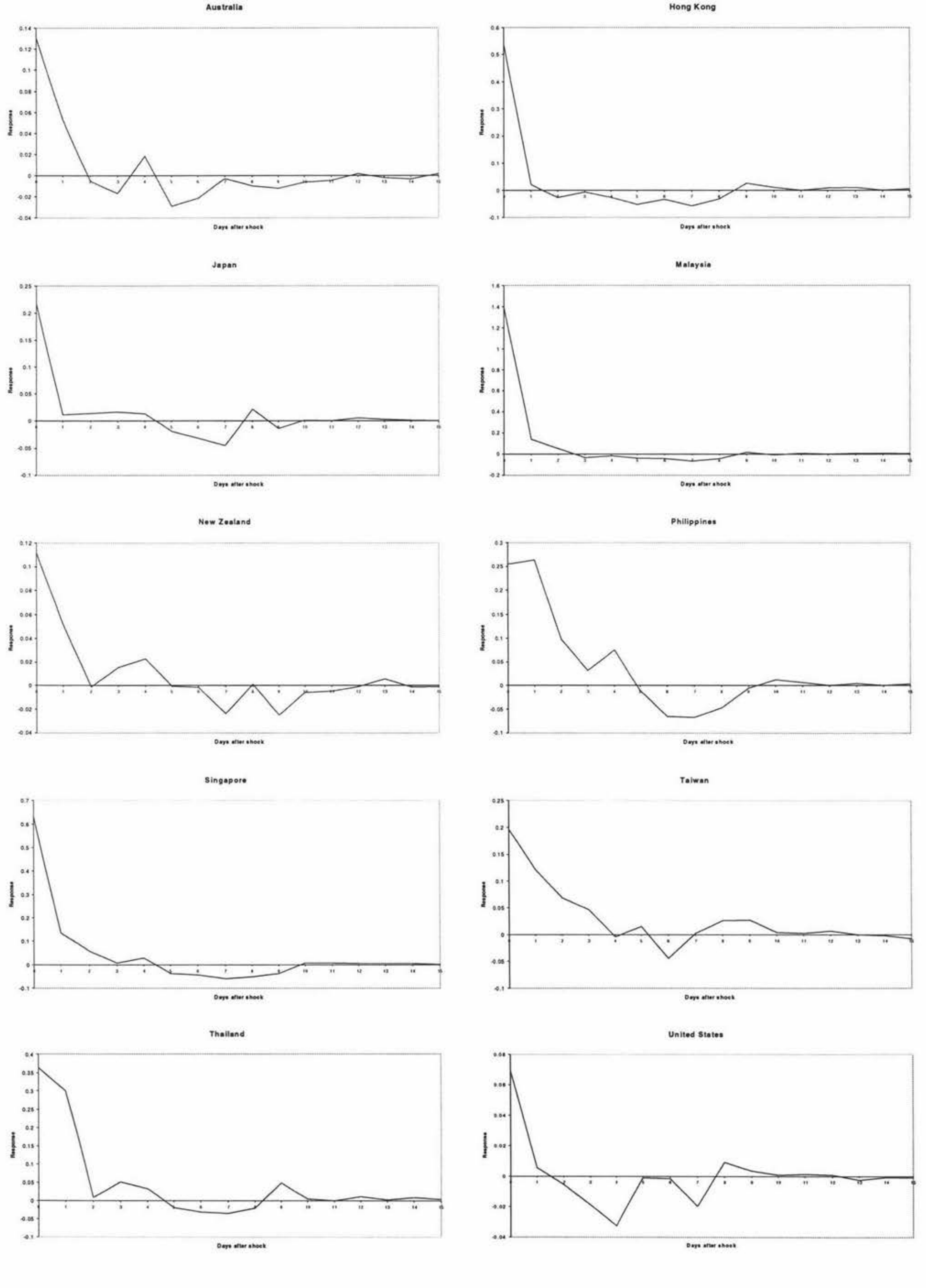
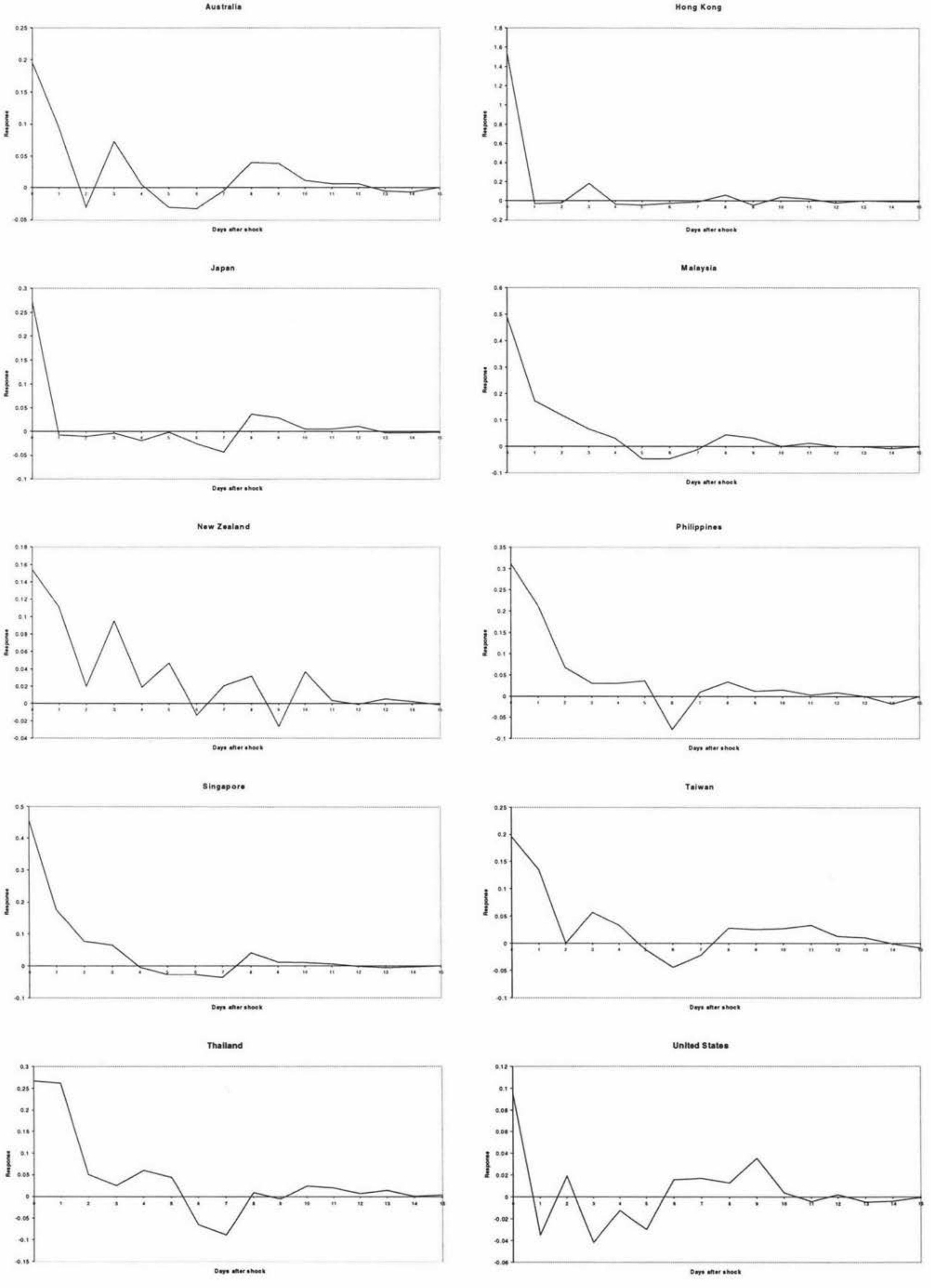


Figure 9.6

TIME PATHS OF GENERALISED IMPULSE RESPONSES TO A ONE STANDARD ERROR SHOCK IN THE HONG KONG MARKET – LOCAL CURRENCY, 01/01/87 – 29/05/98



In the previous section we noted that Hong Kong is the most interactive market in the Asia Pacific region. This has been confirmed in the impulse response analysis. The Hong Kong market reacts strongly to the shocks in most of the markets. As well as this, Figure 9.6 shows that the Hong Kong market also has a reasonably strong influence on a number of the other markets. The Singapore and Malaysian markets which are the most endogenous in the region respond strongly to a shock in the Hong Kong market. The other markets, including even the more isolated markets, respond moderately to shocks in the Hong Kong market. In terms of the efficiency with which markets respond to a shock in the Hong Kong market, Figure 9.6 reveals results which are consistent with the descriptions for the other markets above.

The empirical analysis in this section was also conducted using exchange rate adjusted data so that the effect of exchange rate risk on the impulse responses could be considered. When the impulse response analysis was conducted using the data expressed in U.S. dollars, the effect of the exchange rate adjusted data proved to be minimal. Consistent with the small effect, exchange rate adjusted data had on the forecast error variance decomposition in the previous section, the results from the impulse response analysis were very similar using both data sets. In fact, it was even more difficult to distinguish between the results in the impulse response analysis than it was for the forecast error variance decomposition. For this reason, the impulse response analysis conducted using data expressed in U.S. dollars is not presented here. It is quite clear that exchange rate risk has very little influence on the linkages between markets in the Asia Pacific region, at least not for the time period included in this study. Possible reasons for this are explored in Chapter 10.

9.5 Conclusions

In the first section, the specifications that were used to conduct the VAR models in this study were explained. The second section presented the estimated system covariance matrix of errors. It was very clear that the matrix is not diagonal, with the majority of off-diagonal values clearly non-zero. This means that the outcomes of the orthogonalised approach to forecast error variance decomposition and impulse response analysis will be affected by the ordering of the variables in the VAR model. The generalised approach, which is invariant to the ordering of the variables in the VAR is likely to produce better results that more accurately reflect the linkages between the markets. This conclusion was confirmed when the forecast error variance decompositions and impulse response analysis were conducted. Although care can be taken to minimise the impact, the ordering of the variables has on the output, the results of the generalised approach clearly reflected the linkages between markets in the Asia Pacific region better than the orthogonalised approach did.

The results from the forecast error variance decomposition were presented in the third section. Strong linkages between some of the equity markets in the Asia Pacific region were revealed. In particular, the dominant role of the U.S. market in the Asia Pacific region was confirmed. The U.S. market is the most influential market, exerting a fairly high degree of influence on all of the developed markets, except for Japan. The influence of innovations in the U.S. market is also less on the emerging markets of the Philippines, Taiwan and Thailand in particular. As well as being influential, no market explains more than 2% of the forecast error variance in the U.S. market. Significant linkages between markets in close geographic proximity and with strong economic ties like Australia and New Zealand, and Singapore, Malaysia and Hong Kong were revealed.

The Hong Kong market is the most interactive market in the Asia Pacific region. The Hong Kong market is one of the most endogenous markets in the region, and also exerts a fairly high degree of influence itself, on a number of the markets in the region. The emerging markets of the Philippines, Taiwan and Thailand have very little, if any influence on the other markets in the region, and are themselves not very influenced by innovations in foreign markets. This reflects the isolated nature of financial markets in emerging markets, which are often characterised by high growth phases, independent of what is happening in developed markets. It is the weak linkages between these markets and developed markets that tend to make them attractive propositions for international investors. Malaysia which was also categorised as an emerging market in Chapter 4 proves to be very endogenous. Malaysia's links with the Asian markets in particular, suggests that its financial markets, at least, are quite open. The Japanese market, the only market comparable to the U.S. in size was found to exert very little influence on the other markets. More in line with its size, the Japanese market is not very influenced by innovations in foreign markets.

Because of the significant influence that the U.S. market has on the linkage structure in the Asia Pacific region, the forecast error variance decomposition was also conducted without the U.S. market in the system. The findings were generally consistent with those found when the U.S. market was included. No market took on the role of the U.S. market as the dominant player in the region, with Japan's influence remaining small. In the absence of the U.S. market, the relationships between the remaining markets were strengthened slightly across the board, with the markets also explaining a lower proportion of their own variance. The linkages between markets like Australia and New Zealand, and Singapore and Malaysia remained strong as did the influence of Hong Kong and the influence on the Hong Kong markets. The emerging markets of the Philippines, Taiwan and Thailand remained largely isolated from the other markets. The generally strong linkages between markets in the Asia Pacific region are not very encouraging for investors wishing to diversify outside their domestic markets. Any opportunities that do exist are more likely to be in the more isolated emerging markets like the Philippines, Taiwan and Thailand, which have weaker linkages with the other markets.

One of the interesting findings from this study was again confirmed when the forecast error variance decomposition were conducted using the exchange rate adjusted U.S. dollars. Exchange rate risk appears to have had only a minor influence on the linkages between markets which suggests that investors in the Asia Pacific region give it only minor consideration in their decisions. When the VARs were conducted using U.S. dollar data, the results of the forecast error variance decomposition were very similar to those when local currency was used. There was, however, one interesting contrast in the results. This was the smaller influence of the U.S. market on the other markets when U.S. dollar data was used to carry out the forecast error variance decomposition. This result may be explained by the increased willingness with which investors react to shocks in the U.S. market, when exchange rate risk is not an issue. For the impulse response analysis there were no distinguishable differences in the results.

The results from the impulse response analysis confirmed some of the strong linkages between markets in the Asia Pacific region. Responses to a shock in the U.S. market were found to be quite strong throughout all the markets in the Asia Pacific region. Shocks in some of the other markets like Australia, New Zealand, Singapore, Malaysia and Hong Kong resulted in large responses in some of the other markets, particularly those with close economic and geographic links to the market experiencing the shock. The problem for investors is the high level of efficiency with which innovations in one market are transmitted to others. Markets respond to shocks in the U.S. market most strongly on day 1 which means there is no lag between a shock in the U.S. market and the response in the markets when they open on the next calendar day. Responses to shocks in the Australian, New Zealand, Singapore, Malaysian, and Hong Kong markets are also transmitted to the other markets with a high degree of efficiency. The largest responses to shocks in these markets generally occurs on day 0, again resulting in no lag.

The emerging markets of the Philippines, Taiwan and Thailand were not quite as efficient as the more developed markets in transmitting new information. The lags in these markets were generally a little longer, sometimes continuing a day after the responses in the more developed markets had been felt. In this case the problem for investors wishing to profit on the lag between markets is the smaller size of the responses in these markets to shocks in the developed markets. This is to be expected given the weaker linkages between the developed and emerging markets. The efficiency with which information is transmitted between markets does not present investors with much opportunity to profit by following the innovations in leading markets. Along with the generally strong linkages between markets in the Asia Pacific region it would appear that the best investment opportunities for investors seeking to diversify outside their domestic market would be to diversify their portfolios in the relatively isolated emerging markets of the Philippines, Taiwan and Thailand.

Figure 9.7

TIME PATHS OF ORTHOGONALISED IMPULSE RESPONSES TO A ONE STANDARD ERROR SHOCK IN THE HONG KONG MARKET – LOCAL CURRENCY, 01/01/87 – 29/05/98

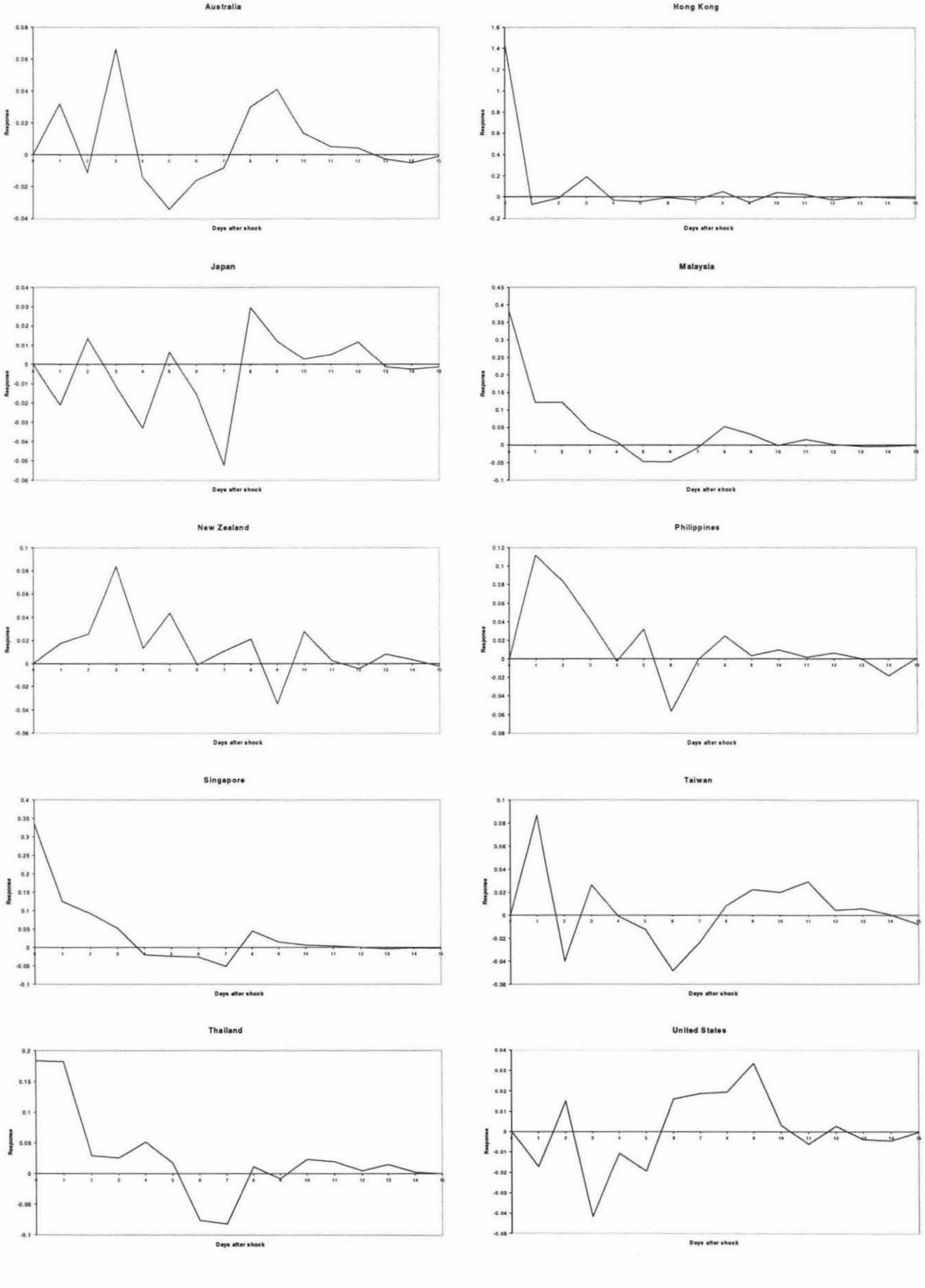
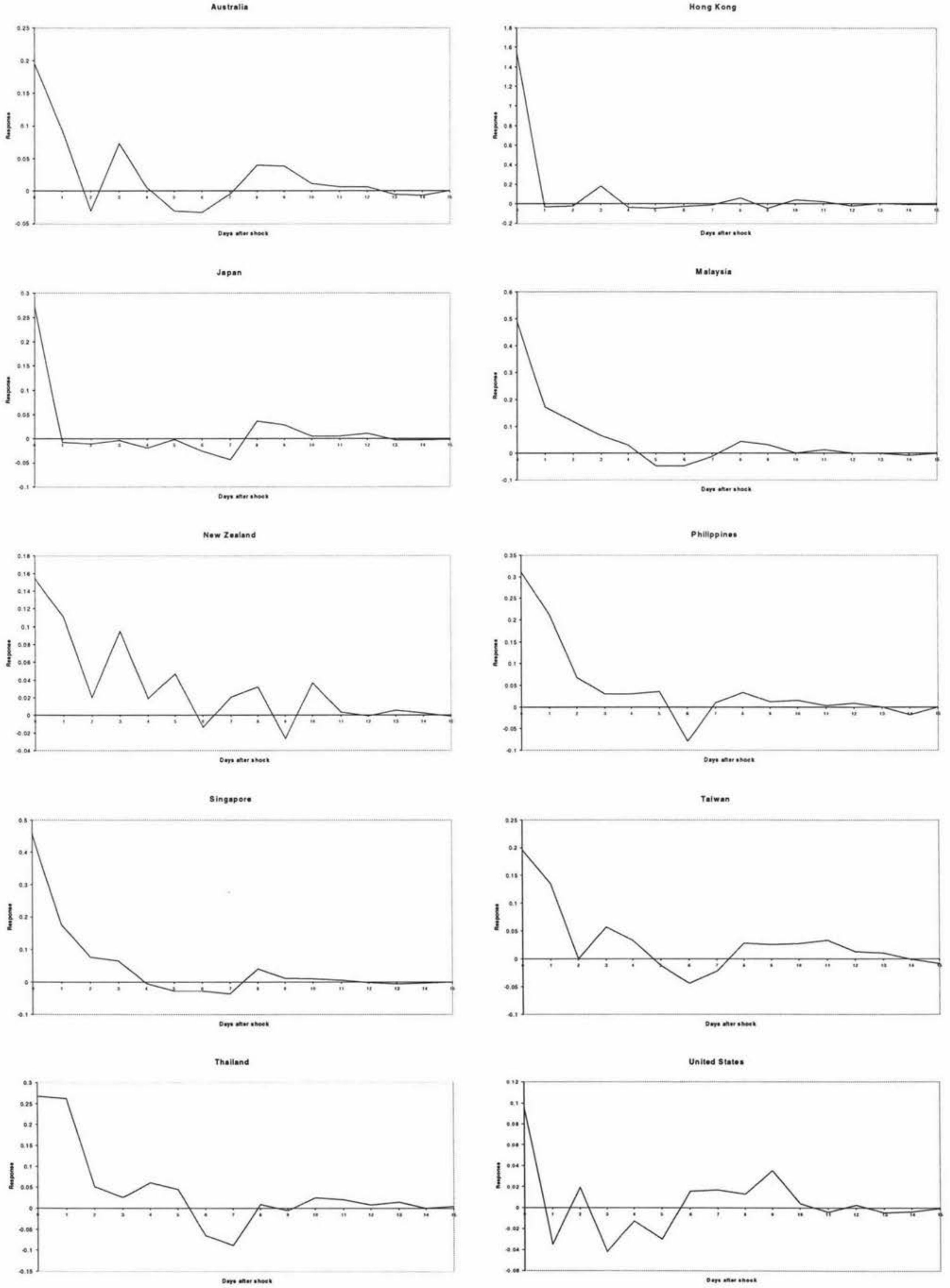


Figure 9.8

TIME PATHS OF GENERALISED IMPULSE RESPONSES TO A ONE STANDARD ERROR SHOCK IN THE HONG KONG MARKET – LOCAL CURRENCY, 01/01/87 – 29/05/98



Chapter 10: Conclusions

The major findings from the empirical testing in this study are discussed in Chapter 10. The evidence presented in Chapters 7, 8 and 9 is brought together to highlight the linkages between equity markets in the Asia Pacific region. The major findings from the exploratory analysis in Chapter 7 and the unit root tests for stationarity in Chapter 8 are discussed first. This is followed by the findings from the cointegration analysis in Chapter 8 and the vector autoregression (VAR) analysis in Chapter 9. The VAR technique is the primary tool used in this study to reveal the nature of the linkages and the transmission of market movements between markets in the Asia Pacific region. Cointegration analysis is also used to study the linkages between markets, but alone, does not provide nearly enough information to answer all of the questions we have about the linkages between markets. The VAR technique, through forecast error variance decomposition and impulse response analysis, provides much more insight in to the linkages between markets. Previous studies have tended to use only one of the two techniques. The findings in this study are enhanced by considering the results of these two complementary techniques together. Before the results are discussed, however, the effect of exchange rate adjusted data on the findings in this study are considered.

The empirical testing techniques used in this study were carried out on exchange rate adjusted data as well as the local currency data. This is because local currency data ignores exchange rate risk. Unless investors have hedged away their currency exposure, a practice which is very expensive, local currency data may not be the most appropriate data to use. There has, however, been very little difference in the results found throughout this study, using the local currency or data expressed in U.S. dollars. For example, the correlation coefficients in Chapter 7, which measure the comovement between markets, were hardly affected by the use of the exchange rate adjusted data. The evidence from earlier studies to consider exchange rate adjusted data is mixed. Some have found that it has impacted on the results while others have found that it has not.

There are two possible explanations for why exchange rate adjusted data has had little impact on the results in this study. Firstly, a number of the Asian markets in the sample have had their currencies fixed to the U.S. dollar for a large part of the time period studied. The Hong Kong market has had it fixed throughout. This was evident in the graphs in Chapter 4 which compared the local currency and exchange rate adjusted market indices of the different countries. The correlation between the two series were quite high. A further explanation may be that, over time, fluctuations in the exchange rate balance out to have a neutral effect. While a particular currency may appreciate for a certain period of time, this may be followed by a period of depreciation. The currency simply fluctuates around a long-run average, so that the overall effect on the results of a study that considers almost eleven and a half years of data, is minimal. Because of this, the study has tended to focus on the results carried out on the local currency data. Some minor differences between the results have been noted where they occur.

The correlation matrices in Chapter 7 revealed that the pairwise comovement between markets in the Asia Pacific varies greatly. The comovement between markets like Singapore and Malaysia, Singapore and Hong Kong, Malaysia and Hong Kong, and Australia and New Zealand was strong, reflecting the strong economic ties and close geographic proximity of these markets. The comovement between some of the other markets was not nearly as strong. The Japanese market appears to be particularly isolated while the Philippines and Taiwan also have low correlation coefficients with the majority of markets. An average correlation coefficient in the matrix of 0.42 indicates that while there may be some opportunities open for investors to diversify outside their domestic markets, the level of comovement between some of the Asia Pacific markets is fairly strong. It is important to realise that these pairwise correlation coefficients cannot be used to fully explain the linkages between markets, or the transmission of market movements either. Based on the underlying comovements between markets, multivariate techniques like the cointegration and VAR analysis that follow have been used to examine further, the linkages between markets.

The 1987 stock market crash with its worldwide impact emphasised for many just how integrated financial markets around the world had become. Since the crash, the literature examining the linkages between markets has grown rapidly. The early testing that followed the crash, focused on the association between volatility and comovement. Some of this testing was replicated in the exploratory analysis in Chapter 7 which revealed a high association between the level of volatility and comovement around both the 1987 stock market crash, and the 1997 Asian market correction. Volatility was, however, shown to return quickly to its pre-crash levels. While the results from these tests of the association between volatility and comovement are interesting, they are not particularly sophisticated and do not tell us much about the linkages between markets. More recently, the literature has focused on the linkages between equity markets and the transmission of market movements between them using more sophisticated techniques like cointegration and VAR analysis. Before we can consider the results of these tests, the results from the unit root tests for stationarity are discussed.

It is common for variables used in time series techniques like VAR analysis to be checked for stationarity. This is because the use of non-stationary variables can lead to spurious results. Stock index data has almost invariably been found to be stationary in its first differences, but not in its levels. Unit root testing was conducted on the ten stock index variables, both in local currency and expressed in U.S. dollars to see if the series were stationary. In 19 out of 20 unit root tests, the variables were found to be I(1) processes, stationary in first differences but not in levels. The one exception was Taiwan, expressed in U.S. dollars, which was found to be an I(0) process. Although the unit root tests in this study included a dummy variable for the 1987 stock market crash, there appears to have been little effect on the outcome of the unit root tests. All of the variables except for the exchange rate adjusted Taiwanese market were found to be individually weak-form efficient. A mean-reverting process may explain the weak-form inefficiency of the Taiwanese market.

Cointegration analysis was conducted on the ten I(1) local currency variables and on the nine I(1) variables expressed in U.S. dollars. Johansen's multivariate cointegration technique was used. At least one cointegrating relationship was found in each of the tests, confirming the existence of a stable long-term relationship between the variables. The results from the cointegration analysis are consistent with a fairly strong underlying comovement structure between the markets. The stable long-term relationship between the variables also suggests that it might be possible for investors to profit on the lag between markets by investing in lagging markets to take advantage of movements in leading markets. The problem with the cointegration analysis is that it does not provide detail about which markets are most strongly linked, which markets are the most influential, the length of the lag between markets, or the size of the response in one market to a shock in another. Neither can the results from the cointegration analysis be used to differentiate between the linkages of emerging markets and developed markets. The forecast error variance decomposition and impulse response analysis results produced using VAR analysis can be used to answer these questions.

Before we discuss the findings from the VAR analysis, it is worth noting two important points about the methodology used in this study. This study has confirmed the benefit of a new development in the VAR methodology. Although the generalised approach to forecast error variance decomposition and impulse response analysis has been used for macroeconomic variables it has not, to the authors knowledge, been used to study the linkages between equity markets before.

The testing in this study clearly demonstrated that the generalised approach is much better than the orthogonalised approach in accurately reflecting the linkages between markets in the Asia Pacific region. The generalised approach has enhanced the findings in this study. Although cointegrating relationships were found between the markets, an unrestricted VAR was used in preference to a vector error correction model (cointegrating VAR). This is because the forecast error variance decomposition and impulse response analysis has only been conducted for short-time horizons of no more than 15 days. The evidence in the literature suggests that a vector error correction model offers very little advantage, if any, over an unrestricted VAR when the variance decomposition and impulse response analysis is only for short-term horizons.

The results from the forecast error variance decomposition revealed a number of important findings relating to the linkages between markets in the Asia Pacific region. The U.S. market is clearly the most dominant market in the region. While no market explains more than 2% of the U.S. markets forecast error variance, the U.S. market has a significant influence on most of the markets in the region. The Australian market is the most influenced by the U.S. market, followed by New Zealand, Singapore and Hong Kong. The U.S. market has less influence on the Japanese market and on the emerging markets of Malaysia, the Philippines, Taiwan and Thailand. Consistent with the size of the Japanese market, none of the markets have much influence on the Japanese market, except for the U.S. market. What is surprising though, is that the Japanese market has very little influence on any of the other markets in the region, even when the U.S. market is excluded. Because the Japanese market is the only market comparable to the U.S. market in size, we would have expected it to have a stronger influence than it appears to.

Malaysia is the second most endogenous market in the region after Singapore. While the Malaysian market was classified as an emerging market, the behaviour of its equity market is much more in line with the developed markets. The linkage between Singapore and Malaysia is particularly strong, although both markets are also strongly linked with the Hong Kong market as well. These linkages are consistent with the high correlation coefficients between these markets in the exploratory analysis and reflect the strong economic ties and close geographic proximity of these markets. The linkage between New Zealand and Australia is strong for much the same reason. The Hong Kong market appears to be the most interactive in the region. As well as being a fairly endogenous market, the Hong Kong market exerts a large amount of influence on the other markets.

After the U.S., the Taiwanese market is the next most exogenous market. Unlike the U.S., however, the Taiwanese market is also the least influential market in the region. The Philippines and Thailand are also isolated. The isolation of these three emerging markets reflects the different growth patterns that we expect to find in emerging markets. It is their unique characteristics that tend to make them attractive investment propositions for investors wanting to diversify outside the domestic market. Because the linkages between most of the developed markets are fairly strong, it would appear that the best opportunities for risk reduction through diversification are likely to be in these markets.

Another important question that the arises from the results in the cointegration analysis, but cannot properly be answered using cointegration analysis, is whether investors can profit on developments in a particular market by investing in markets that lag the innovations in leading markets. Impulse response analysis was used to estimate the dynamic responses of markets to innovations in a particular market in the system. A time horizon of 15 days was specified and the size of the innovations were one standard error shocks to the market concerned. Two things of interest were analysed from the impulse response functions. The first was the size of a markets response to a shock in the lead market. This indicates how influential a market is, and on the other side of the shock, how responsive the markets are to that shock. The length of the lag between a shock and when the response is felt, is also of interest as it indicates how efficiently markets respond to innovations in other markets. This is important because it tells us something about the efficiency with which new information is transmitted between markets.

The results from the impulse response analysis confirmed the linkages found in the forecast error variance decomposition. Not surprisingly, the markets that responded most strongly to shocks in a particular market, were the markets that have strong linkages with the lead market. For example, the Hong Kong and Singapore markets responded most strongly to a shock in the Malaysian market, while a shock in the Australian market was met with the strongest response in New Zealand. The dominance of the U.S. market was confirmed with all of the markets responding strongly to shocks in the U.S. market, while the U.S. markets response to shocks in the other markets was very small. The interaction between the Hong Kong market and the other markets in the Asia Pacific was also confirmed. A shock to the Hong Kong market resulted in strong responses from many of the other markets including the emerging market of Thailand. The Hong Kong market also responded strongly to shocks in most of the other markets. The Japanese market does not respond very strongly to shocks, nor does it influence any of the markets. The isolation of the emerging markets of the Philippines, Thailand, and Taiwan in particular, was also confirmed.

The results from the impulse response analysis show that markets generally respond very quickly and efficiently to new information, or innovations, in the other markets in the Asia Pacific region.

The largest response to shocks in the U.S. market are felt on day 1, which given the time differences between markets, is the most efficient response. There is very little opportunity for investors to profit by responding to a shock in the U.S. market. The largest response to shocks in the other Asia Pacific markets are felt on day 0, which is again, very efficient. The very short length of these lags makes it very difficult for investors to respond to developments in leading markets and profit on the lag between the leading and lagging markets.

The emerging markets of the Philippines, Taiwan and Thailand do tend to respond less efficiently than the other markets, with responses in these markets being felt a day or two after the initial response. These markets may provide investors with an opportunity, although investing on the lag between these markets and a lead market has its own problems. While the lag may be long enough to exploit in these markets, the size of the responses are generally small, reflecting the weak linkages between these markets and developed markets. In light of the findings here, it would appear that an investor's best opportunity to benefit from investment outside the domestic market, is through diversification in emerging markets like the Philippines, Taiwan and Thailand which have weaker linkages than the more developed markets.

There are a number of topics which future research in this area of the finance literature could consider. It would be interesting to see the generalised approach to forecast error variance decomposition and impulse response analysis applied to different sets of equity markets. The generalised approach clearly reflects the linkages between equity markets more accurately than the orthogonalised approach. By considering different groups of markets, a better understanding of the linkages between equity markets around the world will be gained. Over the last ten years the literature in this area has considered the linkages between equity markets around the world. The strength of some of the linkages between markets is consistent with increased integration among equity markets in the Asia Pacific region. It would be interesting to return to some of the techniques used in the early literature and consider whether portfolios comprised of domestic and foreign assets still outperform domestic stock only portfolios, or whether the gap has closed. Further, there remains considerable scope for improvement in the techniques used to consider diversification outside the domestic market. In particular, the use of *ex post* correlation matrices to determine *ex ante* optimal portfolios using modern portfolio theory is difficult given the inherent instability of correlation matrices. Portfolio selection techniques which are not affected by this instability would be very useful for investors.

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