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A Disaggregated Analysis of Movements in East Asian Regional Stock Volatility

by
Stephen J. Sault †

Abstract:

In the absence of comprehensive evidence regarding disaggregated volatility and correlations, this paper applies a disaggregated approach to examine these characteristics in the East Asia region. Testing commences with an examination of portfolio risk faced by an East Asian investor with the application and extension of the models advanced by Campbell, Lettau, Malkiel and Xu (2001) to a portfolio of East Asian stocks. Thereafter, we identify diversification benefits accruing to investors expanding their portfolio composition beyond Australian securities (Sault 2005) to include stocks within the East Asia region. Testing reveals that an increase in the geographical scope of the investment opportunity set is coupled with decreases in mean levels of volatility and correlations. Further, investors holding this regionally diversified portfolio are rewarded by reduced correlations during times of increased volatility, highlighting the benefits of wider-reaching diversification.

Keywords:

VOLATILITY, DISAGGREGATION OF VOLATILITY, CORRELATION, DIVERSIFICATION BENEFITS

† School of Finance and Applied Statistics, Faculty of Economics and Commerce, Australian National University, Canberra, ACT, 0200. Email: Stephen.Sault@anu.edu.au

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1. Introduction

This paper provides a comprehensive analysis of diversification by examining historical movements in disaggregated volatility and correlations, and the resultant benefits from holding a truly diversified portfolio of East Asian stocks. Testing extends the analysis of Campbell et al. (2001) with the inclusion of five innovations. First, we provide formal tests for changes in disaggregated volatility by employing OLS analysis with heteroscedasticity and autocorrelation (HAC) consistent standard errors.[1] Second, the application of the Hodrick-Prescott (H-P) Filter attempts to identify trends in the volatility series. Third, we calculate pairwise correlations between firms, industries, and countries. Fourth, to examine changing patterns in diversification benefits, we adopt the OLS analysis and H-P Filter on all correlation series. Finally, we compare our results to Sault's (2005) Australian disaggregation, examining the diversification benefits from investing in East Asia, the region within which Australia is located.[2]

Markowitz (1952) and Sharpe (1963) emphasise the importance of evaluating both individual stock volatility and inter-stock correlation to determine portfolio variance. While Markowitz (1952) demonstrates that investors can construct mean-variance efficient portfolios by increasing the number of constituent stocks, King (1966) shows that reducing portfolio risk is not only restricted to this increase in stocks. King (1966) argues that it is vital to consider the break-up of an individual stock's risk into firm, industry, country, and regional components. As firms in the same industry are likely to have highly correlated returns, diversification will only be optimal if investment occurs over a range of stocks in different industries.

Volatility studies mainly focus on variance at the country-level (e.g. Brailsford & Faff 1993; Kearns & Pagan 1993; Nicholls & Tonuri 1995; Bekaert, Harvey & Ng 2003), and attempt to model the time-variation in volatility. This emphasis on country-level volatility is anchored in the paradigm of diversification (e.g. Officer 1973; Poterba & Summers 1986; Brailsford & Faff 1993; Whitelaw 1994; Hentschel 1995; Aggarwal, Inclan & Leal 1999). Specifically, investors are assumed to hold well diversified portfolios so that idiosyncratic risk is minimised, and only systematic risk is priced. However, recent studies criticise this focus, by stressing the importance of considering firm-level volatility, as well as arguing for a complete disaggregation into firm, industry and country-level volatility (e.g. Duffee 1995; Malkiel & Xu 1999; Campbell et al. 2001). Indeed, Xu and Malkiel (2003, p. 614) state, 'because of wealth constraints or by choice, many investors do not hold diversified portfolios.' In this case, it is crucial to identify the firm-specific risk of the securities to determine an investor's risk profile. This is supported by Campbell et al. (2001, p. 1) who argue that 'the aggregate market return is only one component of the return to an individual stock.'

In light of this, we do not attempt to model the time-variation in volatility,[3] but rather seek to provide a historical summary of movements in East Asian

1. HAC consistent standard errors are calculated using the method proposed by Newey and West (1987).
2. While Sault (2005) reports all findings in Australian Dollars (AUD), we re-perform their testing on an identical dataset, with all series converted into USD to facilitate comparison with this paper.
3. Campbell et al. (2001) note in their examination of US disaggregated volatility that providing an historical overview of movements in volatility at all levels of disaggregation is extremely informative. The focus is not to forecast volatility, but rather to examine if patterns of diversification benefits have changed through time.

volatility at all levels of disaggregation. Bekaert, Harvey and Ng (2003) examine volatility at a country-level within a broad cross section of South-East Asian countries, and find increasing volatility during the 1990's. However, no study attempts to disaggregate East Asian volatility into firm, industry, country, and regional components.

We argue that there is an increased importance in regional-level volatility as a number of managed and superannuation funds have products dedicated to investing in regional areas. While equity investments have been subject to the well documented home bias (e.g. Black 1974; French & Poterba 1991; Coval & Moskowitz 1999), there is an increasing focus on international investments. For example, Fidelity manages over $739 million (in United States of America (USA) Dollar denominated currency (USD)) in their South-East Asia Fund, with year to date returns of 45.3%, and a tripling of funds under management over the past 3 years.[4] Further the attractiveness of Asian equity investment is evidenced by the $7 billion invested in Asian markets by US investors in 2005, representing a 150% increase since 2000[5]. Therefore, the growing number of people investing in these regional equities and fund types face volatility at a regional-level. Thus, any complete analysis of volatility must involve disaggregation at the regional level.

The creation of variance efficient portfolios not only necessitates the examination of disaggregated volatility, but also the correlations between firms, industries, and countries. Should industry-level volatility be the largest component of an average stock's risk, then assessing inter-industry correlations is vital. High levels of industry volatility and industry correlations, suggests that diversification would have to occur over a larger number of industries.

The extant literature documents that volatility and correlations are not constant over time (e.g. Schwert 1989; Brailsford 1995). Campbell et al. (2001) document that correlations between USA firms decreased between 1962 and 1997, while King and Wadhwani (1990) find that international correlations tend to increase during periods of market stress. Bekaert, Harvey and Ng (2003) find increasing correlations between countries in South-East Asia during the 1990s. They also find that correlations tend to sharply increase during periods of crisis such as the Asian financial crisis of 1997–1998. This increase in correlations between countries during periods of market stress has obvious implications for portfolio diversification, as the benefits of such diversification are diminished, when they are most needed. Further, Longin and Solnik (1995) find that the correlations between major stock markets rise in periods of high volatility. An increase in volatility or correlations may require an increase in the number of stocks to achieve the same level of diversification. As such, this study provides rigorous tests for changes in disaggregated volatility. Further, by applying these tests to firm, industry, and country correlations, we are able to provide a comprehensive analysis of portfolio diversification.

One of the main motivations underpinning this paper is to identify any benefits (due to lower volatility and correlations) that may accrue to investors by diversifying their portfolios across national bounds. As such, we compare our results to the Australian study of Sault (2005). This provides a unique opportunity

4. Obtained from http://www.fidelity.co.uk/adviserclient/select/fidelity/asian/southeastasia.html, as at 1 April 2006.
5. As obtained from www.apec.org as at 1 March 2006.

to identify any diversification benefits from expanding portfolio investment to the region within which Australia is located, namely East Asia.

Testing provides strong evidence of reductions in mean levels of volatility and correlations as the investment universe is increased beyond Australia to include regional stocks. Further, we find that by holding a diversified portfolio of East Asian shares, investors are able to insure their portfolios against the simultaneous increases in volatility and correlations evidenced in Sault (2005). These empirical results support the theoretical underpinnings of modern portfolio finance theory advanced by Markowitz (1952) and King (1966).

The remainder of this paper is structured as follows: section 2 outlines the methodology employed in assessing movements in disaggregated volatility and correlations in East Asia; section 3 describes the characteristics of the dataset utilised in the current paper, also discussing the process employed in collecting it; section 4 presents and discusses key results of testing, section 5 compares the results to the Australian portfolio of Sault (2005) discussing the benefits of portfolio diversification; and, section 6 concludes.

2. Model Design

2.1 Time-Series Volatility Measures

Given the abovementioned importance of adopting a disaggregated approach when investigating volatility, we extend Campbell et al's (2001) methodology to decompose East Asian stock returns into a regional-wide return, as well as country, industry and firm-specific residuals. Each of these components are utilised to construct the time-series volatility measures.

2.1.1 Return Decomposition The first step in performing our return decomposition, is the creation of regional, country and industry-level indices. Returns are calculated on a time interval of one trading day, denoted by the subscript s. All industry and country indices and the regional index are value weighted by market capitalisation.[6] To determine the weight at time s, we use the market capitalisation of a firm at time s–1. The regional, country and industry return indices are formally stated as:

$$R_{is} = \sum_{j \in i} w_{jis} R_{jis} \tag{1}$$

$$R_{cs} = \sum_{i \in c} w_{is} R_{is} \tag{2}$$

$$R_{rs} = \sum_{c} w_{cs} R_{cs} \tag{3}$$

Where: R_{is} = the return of industry *i* at time *s*;

5. The indices are comprised of all constituent firms at time *s*.

w_{jis} = the weight of firm *j* in industry *i* of country *c* at time *s*;
R_{jis} = the return of firm *j* in industry *i* of country *c* at time *s*;
R_{cs} = the return of the country *c* at time *s*;
w_{is} = the weight of industry *i* in the country *c* at time *s*;
R_{rs} = the return of the region at time *s*; and,
w_{cs} = the weight of the country *c* in the region at time *s*.

Arriving at our measures of disaggregated volatility necessitates the decomposition of stock returns into region, country, industry and firm-specific components. The following equations detail the country, industry and firm return decompositions:

$$R_{cs} = R_{rs} + \lambda_{cs} \tag{4}$$

$$R_{ics} = R_{cs} + \varepsilon_{ics} \tag{5}$$

$$R_{jics} = R_{ics} + \eta_{jics} \tag{6}$$

Where: R_{cs} = the return of country *c* at time *s*;
R_{rs} = the regional return at time *s*;
R_{ics} = the return of industry *i* that belongs to country *c* at time *s*; and,
R_{jics} = the return of firm *j* that belongs to industry *i* of country *c* at time *s*.

The residuals (η_{jics}, ε_{ics} and λ_{cs}) obtained from equations (6), (5) and (4) are used to construct our estimates of firm, industry and country-level volatility, respectively.

2.1.2 Volatility Calculation The four volatility measures of the disaggregated approach are outlined below. First, the monthly regional volatility (REG_t) measure is presented in equation (7):

$$REG_t = \hat{\sigma}_{rt}^2 = \sum_{s \in t} \left(R_{rs} - \mu_r \right)^2 \tag{7}$$

Where: $\hat{\sigma}_{rt}^2$ = regional volatility in period *t*;
R_{rs} = the regional return at time *s*; and,
μ_r = the mean regional return for the month in question.

It is important to note that all volatility measures are based on the summation of daily observations. These are calculated at a time interval of one calendar month, denoted by the subscript *t*.

From this, the volatility of country *c* is calculated in two parts. First, the daily country-specific residuals obtained in equation (4) are averaged over countries via equation (8). Subsequently, the monthly measure of country volatility ($CTRY_t$) is

determined by summing the daily volatility estimates over the month *t*. The equations for country volatility are presented below:

$$\hat{\sigma}^2_{\lambda s} = \sum_c w_{cs}\lambda^2_{cs} \tag{8}$$

$$CTRY_t = \sum_{s\in t} \hat{\sigma}^2_{\lambda s} \tag{9}$$

Where: $\sum_c w_{cs}\lambda^2_{cs}$ = the daily squared residuals weighted for that particular country's weight in the region at time *s*; and,

$\sum_{s\in t} \hat{\sigma}^2_{\lambda s}$ = the monthly country volatility measure calculated by summing the weighted daily squared residuals.

We then utilise a similar approach to calculate industry-specific volatility, using residuals acquired from equation (5). The weighted average of the industry-specific residual ($\hat{\sigma}^2_{\varepsilon cs}$) within a country is averaged over that particular country's weight in the region ($\hat{\sigma}^2_{\varepsilon s}$). Monthly industry-level volatility (IND_t) is derived from the summation of these daily observations:

$$\hat{\sigma}^2_{\varepsilon cs} = \sum_{i\in c} w_{ics}\varepsilon^2_{ics} \tag{10}$$

$$\hat{\sigma}^2_{\varepsilon s} = \sum_c w_{cs}\hat{\sigma}^2_{\varepsilon cs} \tag{11}$$

$$IND_t = \sum_{s\in t} \hat{\sigma}^2_{\varepsilon s} \tag{12}$$

Where: $\sum_{i\in c} w_{ics}\varepsilon^2_{ics}$ = the daily squared industry residuals weighted by industry *i*'s membership of country *c*;

$\sum_c w_{cs}\hat{\sigma}^2_{\varepsilon cs}$ = the weighted average of daily industry-specific volatilities; and,

$\sum_{s\in t} \hat{\sigma}^2_{\varepsilon s}$ = the monthly industry volatility measure.

Finally, we follow a similar process to calculate firm-specific volatility, using residuals acquired from equation (6). The weighted average of the firm-specific residual within an industry ($\hat{\sigma}^2_{\eta ics}$) is averaged over that particular industry's weight in the country ($\hat{\sigma}^2_{\eta cs}$), which is then averaged over that particular country's weight in the region ($\hat{\sigma}^2_{\eta s}$). Monthly firm-level volatility is derived from the summation of these daily observations:

$$\hat{\sigma}^2_{\eta ics} = \sum_{j\in i} w_{jics}\eta^2_{jics} \tag{13}$$

$$\hat{\sigma}^2_{\eta cs} = \sum_{i \in c} w_{ics} \hat{\sigma}^2_{\eta ics} \tag{14}$$

$$\hat{\sigma}^2_{\eta s} = \sum_{c} w_{cs} \hat{\sigma}^2_{\eta cs} \tag{15}$$

$$FIRM_t = \sum_{s \in t} \hat{\sigma}^2_{\eta s} \tag{16}$$

Where: $\sum_{j \in i} w_{jics} \eta^2_{jics}$ = the daily squared firm residuals weighted by firm *j*'s membership in industry i;

$\sum_{i \in c} w_{ics} \hat{\sigma}^2_{\eta ics}$ = the daily squared firm residuals weighted by industry *i*'s membership of country *c*;

$\sum_{c} w_{cs} \hat{\sigma}^2_{\eta cs}$ = the weighted average of daily firm-specific volatilities; and,

$\sum_{s \in t} \hat{\sigma}^2_{\eta s}$ = the monthly firm volatility measure.

The above country, industry and firm volatility series represent volatility for an average country, industry and firm, respectively. As such, the methodology does not allow us to identify volatility for a particular firm, industry or country. Rather, the level of volatility is the expected observation of a firm, industry or country selected at random from the East Asian region.[7]

2.2 Graphical Analysis

We are interested in the identification of trends in our analysis of volatility over time in East Asia. We apply the H-P Filter to ascertain the existence of such trends in the four volatility series. The H-P Filter is a smoothing method used to estimate the long-term trend component of a series. It is a two-sided linear filter that computes the smoothed series *s* of *y* by minimising the variance of *y* around *s*. This is subject to a penalty that constrains the second difference of *s*. The penalty parameter λ controls the smoothness of the series.[8] The filter is formally presented in equation (17):

$$\sum_{t=1}^{T} (y_t - s_t)^2 + \lambda \sum_{t=2}^{T-1} \left[(s_{t+1} - s_t) - (s_t - s_{t-1}) \right]^2 \tag{17}$$

7. For brevity, plots of the raw volatility series, and plots of volatility for each individual country are not included in this paper, but they are available from the author on request. In order to calculate the volatility for each individual country, a similar approach is taken to that outlined in equation (7), employing a country specific index.
8. Consistent with Hodrick and Prescott (1997), we employ a smoothing parameter of 14,400 as required for monthly data. Dependant on the time interval of the data, different smoothing parameters must be employed. 100 is used for yearly data, 1,600 for quarterly data and 14,400 for monthly data.

2.3 OLS Analysis

2.3.1 Trend Analysis Any trends identified by the H-P Filter analysis are further investigated using robust OLS regressions[9]. These regressions attempt to ascertain whether there has been a change in the mean level of volatility over time. Specifically, this study examines East Asian volatility from 1973 to 2003, which we split into six time periods. Each period is five years in length, except for the last period which contains six years of monthly volatility estimates. This split up allows us to determine whether there has been a change in the mean level of volatility over the entire sample period. The volatility series are regressed against dummy variables representing each time period. This model is formally presented below:

$$Vol_{kt} = \beta_0 + \beta_1 D_{(78-82)_t} + \beta_2 D_{(83-87)_t} + \beta_3 D_{(88-92)_t} + \beta_4 D_{(93-97)_t} + \beta_5 D_{(98-03)_t} + \varepsilon_t \quad (18)$$

Where:
- Vol_{kt} = the particular disaggregated volatility series at time t (firm, industry, country or regional-level);
- β_0 = the mean level of volatility from 1973–1977 at time t;
- $\beta_1 - \beta_5$ = the difference in mean level volatility from 1973–1977 to the period under study at time t; and,
- $D_{(XX-YY)_t}$ = dummy variable equal to 1 when the volatility lies within the time period (XX–YY) at time t, or otherwise zero.

2.4 Correlation Analysis

We also consider whether any trends are apparent in correlations at a firm, industry and country-level. This analysis provides an insight into any change in East Asian diversification benefits over the past 30 years. In order to construct a monthly firm correlation series, we calculate all pairwise correlations between firm returns using daily observations within each month. We then calculate an equally weighted average of these pairwise correlations. This process is also applied to calculate industry and country correlation series. To determine if any trends are evident in the correlation series we then employ both the H-P Filter and OLS regression outlined in sections 2.2 and 2.3. Further, this correlation analysis, accompanied by the volatility analysis facilitates the identification of any diversification benefits that accrue to investors diversifying from a purely Australian portfolio to a regional East Asian portfolio. Specifically, the results of this analysis will be compared to Sault's (2005) disaggregated analysis of a portfolio of Australian companies in section 5.

3. Data and Variable Measurement

For standardisation purposes (for both country and industry classifications) we utilise daily data from DataStream International over the time period 1 January 1973 to 31 December 2003 to calculate firm returns, for the countries of interest.

9. HAC Standard errors are calculated using the method proposed by Newey and West (1987).

The East Asian countries we include in the sample are: Australia; China; Hong Kong; Indonesia; Japan; Malaysia; New Zealand; the Philippines; Singapore; South Korea; Taiwan; and, Thailand.

To aid in the classification of firms into industries, we collect total return (data which incorporates price, dividends and capitalisation changes) and market capitalisation data for the firm-level constituents of level three DataStream Industry Indices.[10] The total number of firms covered in our data set range from 702 in January 1973 to 6,185 in December 2003.[11]

We remove public holidays and non-trading days common to all East Asian countries from the initial sample. This ensures that the volatility estimates are accurate representations of the volatility faced by an investor with exposure to East Asia. For example, on a particular day when only two of the twelve markets are open, an investor is still exposed to some level of volatility. As such, the resulting sample size comprises 8,064 daily observations, with 372 months of volatility estimates.

All returns must be in a common currency in order to perform the regional disaggregation. This also allows for comparison with Sault (2005)[12]. Therefore, collection of DataStream International exchange rates facilitates an analysis of volatility in USD. Hence, we report results for four volatility series—firm, industry, country and regional-level in USD. Results are also reported in USD for the three correlation series: firm; industry; and, country-level correlations.

Summary statistics for the four volatility series are presented in table 1 below. Examination of the table reveals that all four series suffer from autocorrelation. The Q(10) statistic is the Box-Ljung portmanteau test for first to tenth-order autocorrelation, and is distributed χ^2. At all levels of disaggregation, there is significant autocorrelation at the 1% level. In order to account for this autocorrelation, all standard errors of the estimated regression coefficients in equations (18) and (19) are HAC consistent.[13] Further examination of the table reveals that all series are stationary with ADF test-statistics significant at the 1% level. It is interesting to note that the mean firm-level volatility (0.0044) is more than four times the mean industry, country and regional-level volatility series. These findings are consistent with Campbell et al. (2001, p. 12) results for the USA, supporting their claim that, 'firm specific volatility is the largest component of total volatility of an average firm.' These findings are highlighted by figure 1, which presents a snapshot of the percentage contribution of each level of disaggregated volatility for the average firm in the East Asia region. The figure clearly illustrates that firm-specific volatility is the largest component of risk with regional-specific volatility being the smallest component.

10. Level 3 DataStream industries include: basic industries; cyclical consumer goods; cyclical services; financials; general industries; non-cyclical consumer goods; non-cyclical services; resources; utilities; and information technology.
11. The firms included in the East Asian region also include all of the same firms which are covered in the Australian disaggregated study of Sault (2005).
12. Remember that we compare results of USD denominated series for Sault (2005).
13. The HAC standard errors are calculated using the Newey-West (1987) adjustment.

Table 1

Summary Statistics: East Asia Firm, Industry, Country and Regional-Level Volatility Series

The notation used in the table below is defined as follows: *Regional* is the volatility measure for the East Asia market. *Country* is the volatility measure for an average country in the East Asia region. *Industry* is the volatility measure for an average industry in the East Asia region. *Firm* is the volatility measure for an average firm in the East Asia region.

Series	Mean	Standard Deviation	Min	25th Percentile	Median	75th Percentile	Max	Q (10)	ADF Test- Stat
Regional	0.0010	0.0020	0.0003	0.0005	0.0012	0.0028	0.0403	85.08 (0***)	–6.28***
Country	0.0013	0.0008	0.0001	0.0005	0.0008	0.0016	0.0096	749.48 (0***)	–5.08***
Industry	0.0011	0.0010	0.0003	0.0006	0.0011	0.0018	0.0085	254.84 (0***)	–4.96***
Firm	0.0044	0.0021	0.0015	0.0031	0.0049	0.0078	0.0299	747.23 (0***)	–4.59***

Note: * significant at the 10% level;
** significant at the 5% level; and,
*** significant at the 1% level.

Descriptive statistics for the three correlation series are presented in table 2.[14] All series have significant autocorrelation at the 1% level, and are stationary with ADF test-statistics significant at the 1% level. As with the volatility series, we employ the Newey-West (1987) adjustment in our regression analysis to account for this severe autocorrelation. The table also demonstrates that average industry correlations (17.96%) are much higher than average firm (12.78%) correlations.

14. The number of stocks in the firm correlation calculation range from 702 in January 1973 to 6,185 in December 2003. Thus, the number of pairwise correlations each day range from 246,051 to 19,124,020. At an industry-level, the number of industries range from 40 in January 1973 to 120 in December 2003. Thus, the number of pairwise correlations each day range from 780 to 7,140. At a country level, the number of pairwise correlations each day range from 6 to 66.

Figure 1
Snapshot of East Asian Constituent Volatility

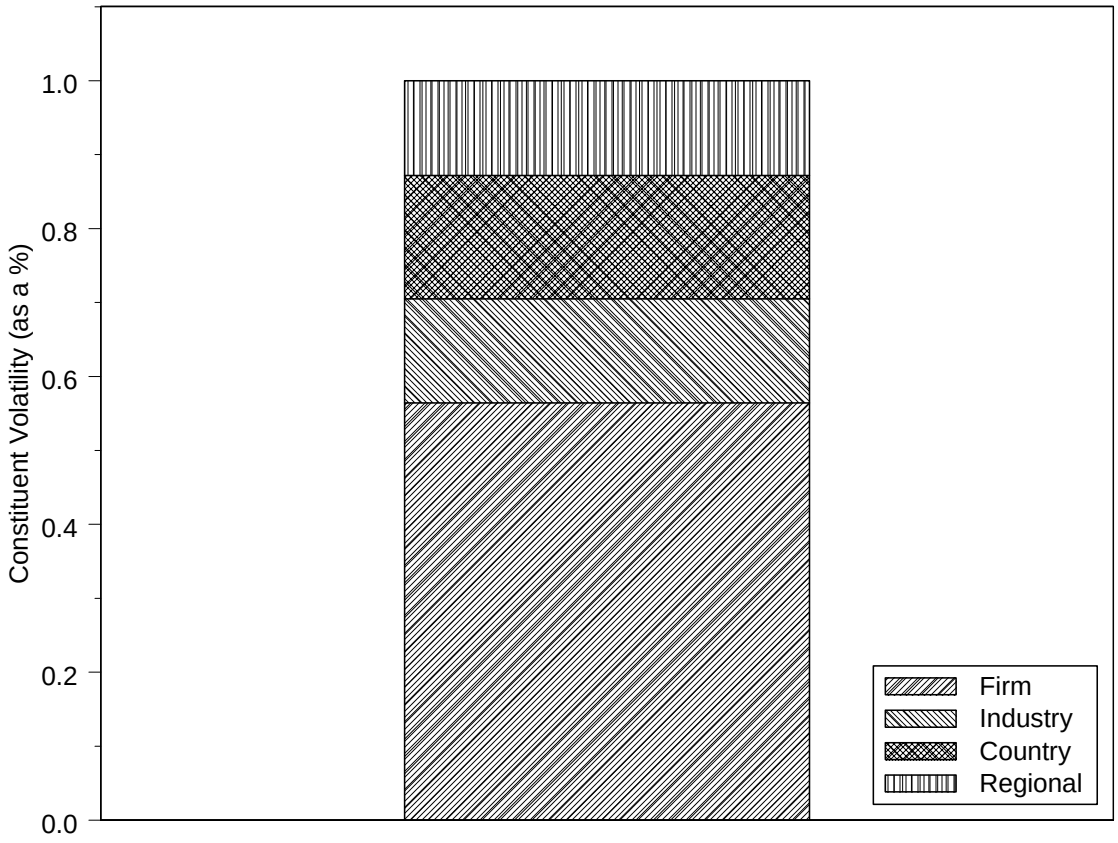


Table 2
Summary Statistics: East Asia Firm, Industry and Country-Level Correlation Series

The notation used in the table below is defined as follows: *Country* is the measure of the average pairwise correlations between all countries in the East Asia region. *Industry* is the measure of the average pairwise correlations between all industries in the East Asia region. *Firm* is the measure of the average pairwise correlations between all firms in the East Asia region.

Series	Mean	Standard Deviation	Min	25th Percentile	Median	75th Percentile	Max	Q (10)	ADF Test- Stat
Country	0.1756	0.1362	–0.1374	0.0685	0.1672	0.2692	0.6922	296.17 (0***)	–4.77***
Industry	0.1796	0.0952	0.0280	0.1066	0.1665	0.2357	0.5016	361.78 (0***)	–4.76***
Firm	0.1278	0.0712	0.0162	0.0767	0.1091	0.1611	0.4921	246.54 (0***)	–5.11***

Note: * significant at the 10% level;
** significant at the 5% level; and,
*** significant at the 1% level.

Further, comparing the descriptive statistics for our East Asian volatility and correlation series with those evidenced by Sault (2005) in Australia provide some revealing insights into portfolio diversification. The mean levels of firm, industry and country-level volatility have all fallen, with country level volatility experiencing a reduction of more than half. The extension of disaggregating at the regional-level reveals that the regional component is the smallest part of an average firm's risk. Additionally, average firm and industry correlations have also fallen, with the average industry pairwise correlation having more than halved. This clearly illustrates the benefits of diversifying portfolios across national bounds onto a regional-level.

4. Empirical Results

4.1 Graphical Analysis of Volatility Series

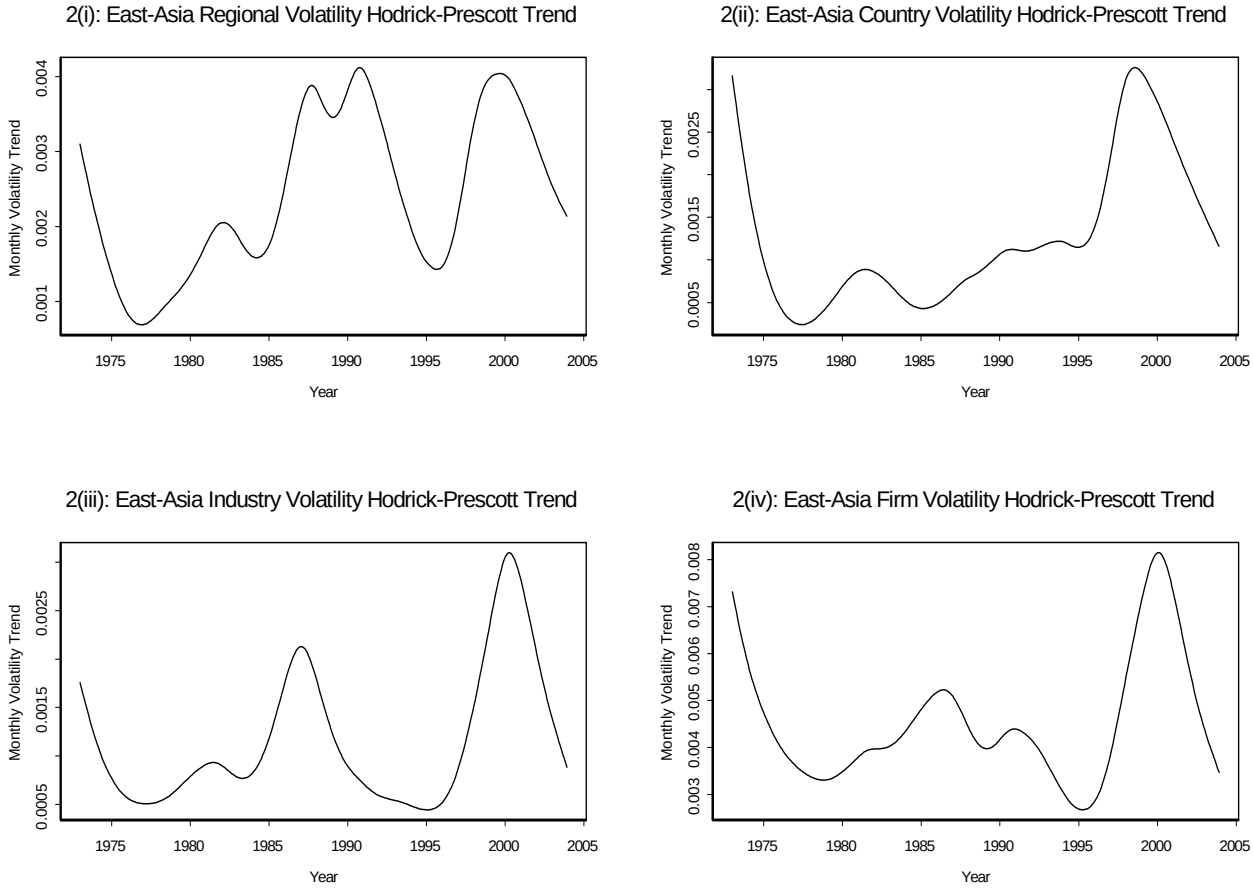
Application of the H-P Filter (illustrated in figure 2(i)) reveals that regional-level volatility rapidly falls from 1973 to 1977, before increasing to 1982 (corresponding with the worldwide recession of 1982), and then trends down for the following three years. Furthermore, a rapid rise occurs during 1987, which we attribute to the 1987 stock market crash. Remaining fairly constant until the end of the global recession of 1991, regional volatility then falls until 1995, followed by a rapid increase to 1999, reflecting the Asian financial crisis of 1997–1998. These trends are further examined in section 4.2 employing OLS regression analysis.

Figure 2(ii) captures high levels of volatility at a country-level during the 1997–1998 Asian financial crisis. These results are consistent with Bekaert, Harvey and Ng (2003) who find an increase in volatility for countries in the East Asia region in the later half of the 1990's. Country-level volatility also appears to be the series least affected by the 1987 crash.

We identify an initial downward trend in industry-level volatility from 1973 to 1978, followed by a relatively stable level of volatility at 0.0005. Again increases are apparent during the global recession of 1982 and stock market crash of 187. We posit that one possible explanation for the 1982 spike may be the worldwide recession of that year. Campbell et al. (2001) and Schwert (1989) note that during periods of recession there are temporary increases in volatility. Further, these changes in volatility are not persistent over time and also occur in periods of market stress, such as the 1987 crash and Asian financial crisis. This may also explain the relatively high level of volatility displayed in all volatility series at the beginning of the sample, when global financial markets were in the midst of the 1973–1975 worldwide recession. Conversely, there are relatively small spikes in volatility during the 1991 global-recession.

In addition, figure 2(iii) illustrates an increase in industry-level volatility from 1996 to 2001. We attribute this increase in volatility to the Asian financial crisis, as well as the technology sector boom and bust. Industry-level volatility appears to be the series most affected by the technology sector expansion and collapse, during 1999–2001. Due to the methodology we employ, the effect of industry specific events on volatility is mainly confined to the industry volatility series. As such, the effect on volatility of the technology industry boom and bust is mainly evident in the analysis at the industry-level. From the end of 2001 onwards, industry-level volatility trends downwards until the end of the sample period.

Figure 2
Monthly East-Asia Volatility Hodrick-Prescott Trends: 1973-2003



Firm-level volatility displays similar results to those identified for industry-level volatility. Figure 2(iv) illustrates that the series commences with a high level of volatility (with a measure of 0.0194 in 1973), before trending down to 0.0041 in 1977. Subsequent increases in firm-level trend volatility are evident during the worldwide recession of 1982, the crash of 1987, and the Asian financial crisis.

Contrary to the findings of Campbell et al. (2001),[15] we find no persistent trend in any of the volatility series over the whole sample. We find periods of temporary increases in volatility (such as the global recession of 1982, stock market crash of 1987 and Asian financial crisis) with no long term directional trend. We posit that this difference may be due to the inclusion of more than one country to enable the regional disaggregation of volatility. While most firms and industries within a country may experience similar trends in volatility, it is unlikely that the same would be true for all countries, industries and firms in a region (especially due to the fact that the East Asia region is comprised of both developed and emerging markets).

15. Campbell et al. (2001) identify an increase in firm-level volatility from 1962 to 1997 in the USA.

4.2 OLS Analysis of Volatility Series

Table 3 extends the above graphical analysis by employing our robust OLS methodology. This analysis attempts to identify significant differences in the mean level of volatility, comparing 1973–1977 with each of the subsequent time periods.

Table 3
Results of the Trend Analysis for East Asia Volatility

The table below presents results for equation (31) using volatility data. t-statistics are included in parentheses below coefficient values. *Regional* is the volatility measure for the East Asia market. *Country* is the volatility measure for an average country in the East Asia region. *Industry* is the volatility measure for an average industry in the East Asia region. *Firm* is the volatility measure for an average firm in the East Asia region. The intercept measures the mean level of volatility in the years 1973–1977. Each of the other time periods measures the difference in mean level volatility from the intercept.

$$Vol_{kt} = \beta_0 + \beta_1 D_{(78-82)_t} + \beta_2 D_{(83-87)_t} + \beta_3 D_{(88-92)_t} + \beta_4 D_{(93-97)_t} + \beta_5 D_{(98-03)_t} + \varepsilon_t \quad (18)$$

Where:
- Vol_{kt} = the particular disaggregated volatility series at time t (firm, industry, market or regional-level);
- β_0 = the mean level of volatility from 1973–1977 at time t;
- $\beta_1 - \beta_5$ = the difference in mean level volatility from 1973–1977 to the period under study at time t; and,
- $D_{(XX-YY)_t}$ = dummy variable equal to 1 when the volatility lies within the time period (XX–YY) at time t, or otherwise zero.

	Volatility Series			
	Regional	Country	Industry	Firm
β_0	0.0014 (3.5750***)	0.0010 (6.9431***)	0.0011 (4.5316***)	0.0071 (18.6442***)
β_1	0.0003 (0.6129)	–0.0003 (–1.5356)	0.0001 (–0.1005)	–0.0016 (–3.0079***)
β_2	0.0014 (2.5850**)	–0.0005 (–2.1581**)	0.0009 (2.6505***)	0.0002 (0.4626)
β_3	0.0019 (3.5315***)	–0.0001 (–0.3871)	–0.0001 (–0.1914)	–0.0010 (–1.8849*)
β_4	0.0005 (0.9477)	0.0005 (2.5198**)	–0.0002 (–0.6769)	–0.0022 (–4.1031***)
β_5	0.0021 (4.0173***)	0.0013 (6.5746***)	0.0017 (5.3372***)	0.0023 (4.4843***)
F-stat	5.523***	22.11***	11.61***	19.97***
Multiple R^2	0.0702	0.2320	0.1359	0.2143
Adjusted R^2	0.0575	0.2215	0.1251	0.2036

Note:
- * significant at the 10% level;
- ** significant at the 5% level; and,
- *** significant at the 1% level.

The OLS results at the regional-level support the analysis in section 4.1, with significant increases in volatility during the years 1983 through to 1992 (which

corresponds to the stock market crash of 1987 and recession of 1991), and during the Asian financial crisis of 1997 to 1998.

At a country-level, the mean level of volatility is significantly higher during the final two time periods of 1993–2003. This corresponds to the findings identified in figure 2(ii), suggesting a high level of volatility during the Asian financial crisis. Conversely, country-level volatility is significantly lower during the period 1983 to 1987. This confirms our result in section 4.1 that volatility at the country-level is lower during the period that captures the stock market crash of 1987.

Consistent with the reported findings in section 4.1, the mean level of industry-volatility is significantly higher from 1983–1987 and 1998–2003. We attribute this to the high level of volatility experienced during the 1987 stock market crash and the Asian financial crisis and technology bubble. Finally, the mean level of volatility at the firm-level is significantly lower during the years 1978–1982, and 1988 through to 1997, whilst it is significantly higher from 1998–2003. Again, this is consistent with our findings in section 4.1.

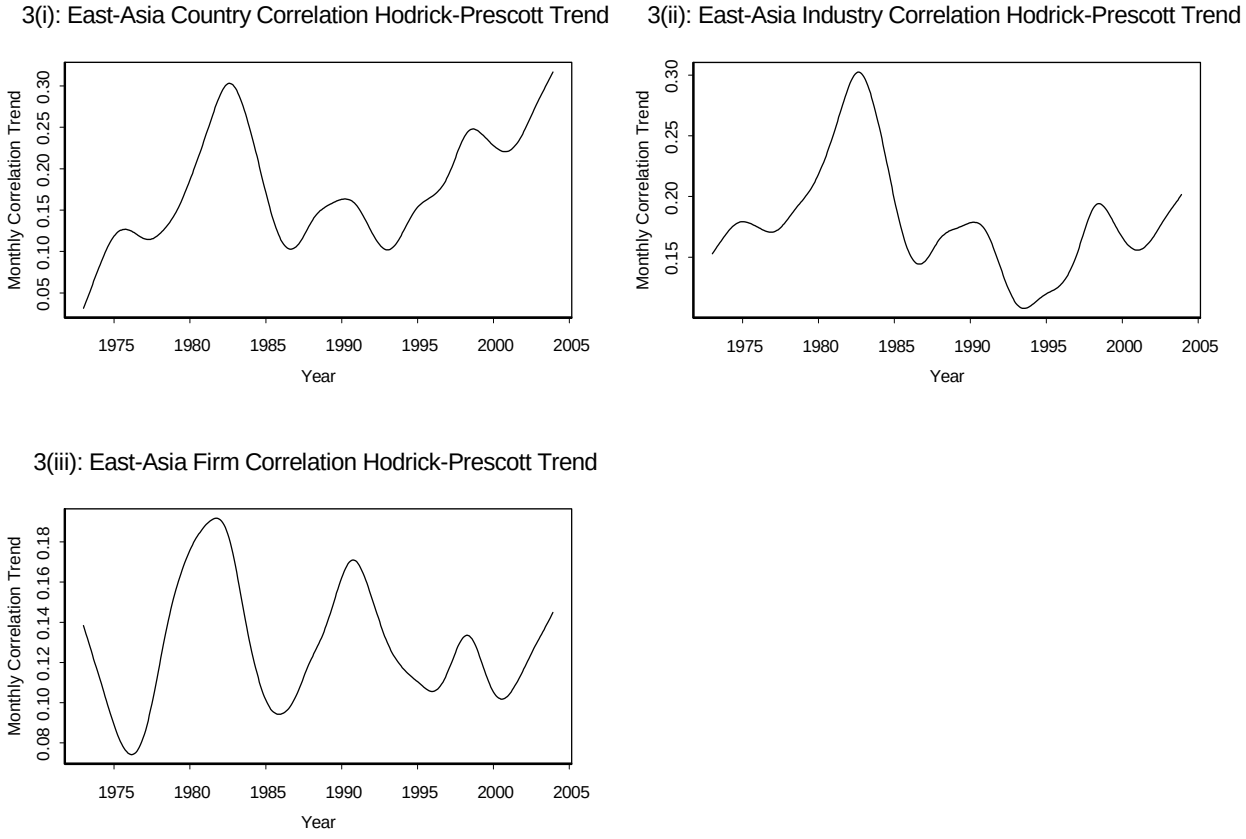
4.3 Graphical Analysis of Correlation Series

We use daily pairwise correlations to document any trends in correlations over time, with figure 3 revealing trends in firm, industry and country-level correlation series. At a country-level, an overall increase in correlations is clearly evident. Figure 3(i) reveals that correlations increase sharply between countries from 3% in 1973 to 30% in 1984, before falling to 13% from 1985 to 1993. Thereafter, consistent with the findings of Bekaert, Harvey and Ng (2003), correlations increase in our East Asian dataset (reaching a high of 30%) over the remaining sample period. This increase in correlations suggests that the East Asian countries in our sample may be becoming more integrated over time.

Figure 3(ii) shows that correlations between industries remain constant at 17% from 1973 to 1980, before rising sharply to 30% in 1982. Correlations then fall dramatically to 13% in 1987, remaining fairly constant until 1991, where it falls to its lowest level in 1993. Correlations then rise to 20% in 1997, before falling to 15% from 1998 to 2001, before gradually rising again. At a firm-level (figure 3(iii)), correlations drop markedly from 14% in 1973 to 8% in 1976, before rising sharply to 19% in 1981. Firm-level correlations then drop until 1987, where they increase sharply to 16% in 1991. They then fall again, until 1996, where there is a small increase in 1997, followed by a drop until 2001.

When the above results are compared to those in section 4.1, it is clear that periods of increased volatility do not necessarily correspond with large increases in correlations. Two exceptions are the global recession of 1982 where there is an increasing trend in volatility and correlations at the industry level, and the Asian financial crisis at a country-level, respectively. At all levels of disaggregation, volatility increases sharply from 1985 to 1987, while the corresponding correlations fall dramatically, offsetting the increase in volatility. At an industry and firm-level, volatility rises sharply during the global recession of 1973 to 1975, the Asian financial crisis, technology sector boom and bust and September 11, 2001 terrorist attacks, yet correlations at both levels of disaggregation fall markedly.

Figure 3
Monthly East-Asia Correlation Hodrick-Prescott Trends: 1973–2003



This finding is in stark contrast to the extant literature, and provides the key result of this paper. Specifically, King and Wadhwani (1990) find that international correlations tends to increase during periods of market crises, while Longin and Solnik (1995) find that the correlations between the major stock markets rise in periods of high volatility. Further, a comparison to Sault (2005) highlights the benefits available to Australian investors from diversifying their portfolios beyond Australian securities to include East Asian stocks. These results are discussed in greater detail in section 5.

4.4 OLS Analysis of Correlation Series

Table 4's findings support the graphical analysis presented in figure 3. The mean country-level correlation is significantly higher from 1978 to 2003, compared with the initial time period of 1973–1977. These results support those of Bekaert, Harvey and Ng (2003) who find increasing correlations between East Asian countries in the 1990s. Consistent with figure 3, our OLS analysis reveals a significant increase in correlations from 1978 to 1982 at an industry and firm-level, and from 1988 to 1992 and 1998 to 2003 at a firm-level. A significant decrease in industry-level correlations is identified from 1993–1997.

Table 4
Results of the Trend Analysis for East Asia Correlations

The table below presents results for equation (31) using correlation data. t-statistics are included in parentheses below coefficient values. *Country* is the measure of the average pairwise correlations between all countries in the East Asia region. *Industry* is the measure of the average pairwise correlations between all industries in the East Asia region. *Firm* is the measure of the pairwise correlations between all firms in the East Asia region. The intercept measures the mean correlation during the years 1973–1977. Each of the other time periods measures the difference in the mean level of correlations from the intercept.

$$Cor_{kt} = \beta_0 + \beta_1 D_{(78-82)_t} + \beta_2 D_{(83-87)_t} + \beta_3 D_{(88-92)_t} + \beta_4 D_{(93-97)_t} + \beta_5 D_{(98-03)_t} + \varepsilon_t \quad (18)$$

Where:
- Cor_{kt} = the particular average correlation series at time *t* (firm, industry or country);
- β_0 = the mean level of average correlation from 1973–1977 at time *t*;
- $\beta_1 - \beta_5$ = the difference in mean level average correlation from 1973–1977 to the period under study at time *t*; and,
- $D_{(XX-YY)_t}$ = dummy variable equal to 1 when the correlation lies within the time period (XX–YY) at time *t*, or otherwise zero.

	Correlation Series		
	Country	Industry	Firm
β_0	0.0967 (5.9706***)	0.1675 (14.7557***)	0.0924 (10.9602***)
β_1	0.1300 (5.6799***)	0.0828 (5.1574***)	0.0911 (7.6400***)
β_2	0.0597 (2.6081***)	0.0229 (1.4274)	0.0187 (1.5657)
β_3	0.0550 (2.4005**)	–0.0026 (–0.1588)	0.0546 (4.5794***)
β_4	0.0505 (2.2047**)	–0.0463 (–2.8853***)	0.0179 (1.5017)
β_5	0.1616 (7.3705***)	0.0149 (0.9696)	0.0313 (2.7387***)
F-stat	14.34***	13.81***	15.01***
Multiple R^2	0.1638	0.1587	0.1701
Adjusted R^2	0.1524	0.1472	0.1587

Note:
- * significant at the 10% level;
- ** significant at the 5% level; and,
- *** significant at the 1% level.

5. Benefits of Portfolio Diversification

One of the key goals of this paper is to examine the benefits available to investors from diversifying their portfolio across national bounds. Specifically, we extend the composition of the investor's portfolio from purely Australian stocks in Sault (2005), to include stocks from countries in East Asia. As a result, the means of firm, industry and country-level volatilities decrease, with the largest drop observed in country-level volatility from 0.0031 to 0.0013. In addition, the regional-level volatility measure is the smallest component of an average firm's risk in East Asia (0.0010). It is apparent that by investing in the region, we see that the other

descriptive statistics, specifically the minimums, maximums and inter-quartile ranges, also decrease in comparison to the Australian findings. This drop in volatility illustrates the benefits of diversifying across a region.

Similarly, falling correlations between stocks and industries are identified as we increase the investor's portfolio to include not only domestic, but regional investment opportunities. The descriptive statistics for the correlation series fall, with the largest drop (by 60%) evidenced in the inter-industry correlations. The mean correlation between countries is also small at only 17.56%.

However, the major finding of this paper is the mitigation to the investor problem, identified in the extant literature, of increases in volatility being accompanied by increases in correlations. Specifically, King and Wadhwani (1990) and Bertero and Mayer (1990) find that correlations between countries are higher during periods of increased market volatility such as the stock market crash of 1987. Similarly, Longin and Solnik (1995) argue that abnormal volatility in the USA stock market is a factor in increasing stock market correlations. Further, Lin and Ito (1994) find correlations increase during periods of large price shocks. Subsequently, these empirical studies all observe a reduction in diversification benefits during periods of market stress. Sault (2005) notes that the simultaneous increases in volatility and correlations in a portfolio of purely Australian stocks has important ramifications for portfolio diversification as investors may not be able to gain the benefits of diversification when they need them most, during periods of market stress. However, our findings illustrate that investors holding regionally diversified portfolios are rewarded by reduced correlations during times of increased volatility.

Accordingly, we argue that the most significant benefit derived from holding a regionally diversified portfolio is the protection against increased portfolio risk in periods of market stress. This is clearly evident during the global recession of 1973–1975, the 1987 crash, the Asian financial crisis, the technology sector bubble and September 11, 2001 terrorist attacks, when increases in volatility are offset by reductions in correlations. This highlights the need for both investors and portfolio managers to ensure that their portfolios are regionally diversified as insurance against large fluctuations in portfolio volatility. As King (1966) argues, any discussion of diversification must consider firm, industry, country and regional components. In agreement with King (1966), these findings highlight the importance of diversifying across a number of countries, rather than investing completely on a domestic-level. In particular, our findings highlight that investing across the East Asia region rather than only investing in Australia confirms the central tenant of modern portfolio theory, that diversification is the key to reducing portfolio risk.

6. Concluding Remarks

In the absence of comprehensive evidence regarding disaggregated volatility and correlations, this paper applies a disaggregated approach to examine these characteristics at a regional-level. Our approach represents a material contribution to the literature, which predominantly focuses on country-level volatility (e.g. Kearns & Pagan 1993; Brailsford 1994; Bekaert, Harvey & Ng 2003). Further, this

paper highlights the benefits of diversifying beyond a portfolio of Australian stocks (Sault 2005), to include securities within the East Asia region.

Testing reveals that an increase in the geographical scope of the investment opportunity set is coupled with decreases in mean levels of volatility and correlations. Further, investors holding regionally diversified portfolios are rewarded by reduced correlations during these times of increased volatility, highlighting the benefits of wider-reaching diversification. While these results confirm the theoretical underpinnings of modern portfolio theory advanced by Markowitz (1952) and King (1966), they are in contrast to the empirical evidence pertaining to diversification benefits, which support the diminution of such benefits during periods of market stress (e.g. King & Wadhwani 1990; Lin, Engle & Ito 1994; Longin & Solnik 1995; Bekaert, Harvey & Ng 2003; Sault 2005).

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