The Volatility and Correlations of Stock Returns of Some Crisis-Hit Countries: US, Greece, Thailand and Malaysia: Evidence from MGARCH-DCC applications

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The Volatility and Correlations of Stock Returns of Some Crisis-Hit Countries: US, Greece, Thailand and Malaysia: Evidence from MGARCH-DCC applications

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Abstract: This paper investigates the volatility and correlations of stock returns of some crisis-hit countries such as, US, Greece, Thailand and Malaysia during the major global financial crises since 1992. The paper makes an attempt to address the following two issues: Firstly, to measure the extent of volatility of the stock indices under study and also the correlation of the Malaysian index with the other country indices. Secondly, given the correlations, how best can a normal investor harness them to ensure maximum return in the short and the long run with a particular reference to the correlation between the Malaysian index and other country indices. The MGARCH-DCC approach is employed for the analysis.

The findings tend to indicate that the investors' behaviour converges and correlations are significantly higher across the two Asian countries in the sample. The level of volatilities of the indices' return of all the four markets has increased significantly for the period under study. The level and magnitude of volatilities and correlations is consistently high between Malaysia and Thailand market (lowest of 0.02 in 1993 to highest of 0.65 in 1998) followed by US and Greece markets. Greece seems to be the most volatile market followed by Malaysia, US and Thailand (except for the period between 1993 and 1998). One possible explanation is that the contagion effect takes place early in the crisis and that herding behaviour dominates the latter stages of the crisis. For our second question, the apparent high correlation coefficients during crisis periods imply that the gain from international diversification by holding a portfolio consisting of diverse stocks from these contagion countries declines, since these stock markets are commonly exposed to systematic risk(beta). An increasing integration and stronger co-movement among stock markets will result in decreasing opportunity to gain from portfolio diversification.

Keywords: Volatility, Correlations, portfolio diversification, MGARCH-DCC

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1. Introduction

Time series of financial variables generally exhibit volatility clustering, and only lately that it was realised that most of the financial variables are non-linear. Correlations are fundamental parameters in most portfolio allocation models, hedging strategies, value-at-risk calculations and pricing formulas for multivariate options. As it is already known that variance cannot be taken as constant over time, so do correlations that vary over time. Correlation can be viewed as a stochastic process, that it evolves over time and can be analysed statistically. Thus, there is the incentive to find the best method to measure, forecast and hedging correlations.

There are many techniques used to analyse volatility (variance). GARCH models have increasingly become important tools to describe, estimate and forecast risks implied by financial variables taking into account the time-dependent volatility. The techniques can be extended to analyse (measure, forecast and hedge) covariance and correlations also. Multivariate Generalised Autoregressive Conditional Heteroscedasticity (MGARCH) are generally class of models designed to measure and forecast the entire variance and covariance matrix of a set of assets based upon historical time series data. Periods of volatility (or high correlations) can be temporary (shock) or permanent (involve trend), and statistical procedures are used to determine how long such period lasted in the past and thereby forecast the future pattern of correlations.

Any investor, whether they are short term speculators or long term investors, the like of institutional long term hedge fund knows and seeks to diversify their portfolio, with the aim of minimising their systematic risk (the market risk) and maximising their return. To this end the portfolio manager will undoubtedly be interested not only knowing which market to put their money in, but also when to enter or exit a market. The concept of market volatility and correlations is important for their decision making. The correlation coefficient must be less than or equal to 1 and greater than or equal to -1. It also holds true that one portfolio of assets must have a correlation with another portfolio of assets, which lies between +1 and -1. The mathematical property which ensures this, for all possible portfolio of assets (and true for maximising return), is that the covariance matrix of the assets must be positive definite. A multivariate system like MGARCH is a good estimator of correlations.

1. Background and Literature Review

Markets around the globe have been buzzed of the increase in activities of cross border trading and the merger and acquisition of bourses, resulting in a globalization of equity trading around the world. However, the globalized financial world has not been free from financial crises. Our study will try to unravel the connection between the shocks created by some of the major crises during the period since 1992.

i. 1994 – the Mexican crisis. Regarded as the first phase of the many financial crisis of the 90's, highlighted the role played by global financial players in the sudden and massive reversal of capital flows, moving from low interest to higher interest rates
ii. 1997 Asian financial crises. Against the macroeconomic and financial background, the second phase started with the Thailand crisis (July 1997), rapidly spreading to its neighbour of Indonesia, Malaysia, Philippines and finally South Korea (December 1997). This crisis highlighted how international contagion operated in the global financial market
iii. 1998 is considered the third phase with the collapse of the Russian rouble and the subsequent Russian's default of its external debt. This has induced the global players to reassess the sustainability of exchange rate pegs with a number of countries on a global scale. The reassessment resulted in the financial turbulence in Brazil (1999), Turkey and Argentina (2001)
iv. The equity bubble burst in 2000 in every stock market in the world, starting from the dot.com bubble burst in the US, as the result of investors optimism and the herd mentality as the main factor driving prices ridiculously high .
v. September 11, 2001 terrorist attack on the World Trade Centre (WTC) New York
vi. The 2007-2008 US sub-prime mortgage crisis was by far considered the biggest major global financial crisis. The problem which started in 2007 whipped like hurricane way until end 2008, forcing the collapse of world's major financial institutions, annihilated the Wall Street broker-dealer model and caused a USD1.4 trillion bank write-downs, and requiring governments to spend USD trillions more in bail-outs. The crisis reduces the global market capitalisation by more than USD32trillion between October 2007 and November 2008, a thirteen month period, an equivalent of 75% of the world GDP. This resulted in the process of restructuring, especially deleveraging of banks in an unprecedented scale.
vii. Adding to the above, the US and EU bank balance sheet contracted by a further USD10 trillion by 2013 (Keith Mullan,Reuters, 2009), selling asset around USD2.4 trillion to non-banks, leaving the balance of USD7.6 trillion as a stock run-off (IMF,2009). This is equivalent to 14.5% of the US and EU's stock of bank credit and the deleveraging process on both sides of the balance sheet; capital raising and asset sales will dominate for years to come. This might be the reason why Greece which is a small member of EU, could inflict a crippling blow to the EU and the European Monetary System (EMS). With a sovereign debt of 160% of its GDP on

top of its five consecutive years of deep recession, Greece broght down EU to its knees. Under the Greek deal, the biggest sovereign debt restructuring in history, creditors would swap their old bonds for new ones with a much lower face value, lower interest rates and longer maturities. This means they will lose about 74 percent on the value of their investments, slicing more than 100 billion euros off Greece's crippling public debt.

However, it cannot be said the crises above is a stand-alone as it involved a continuous shock happening around at the same time. The Mexican tequila crisis was preceded by the liquidity crises due to the collapse of government and corporate bond prices and the consequent sharp rise in the long term interest rate (when the US Federal Reserve raised the interest rates) bond market collapse in 1994 of nearly USD1.5 trillion losses. This also coincides with European Union Monetary System (EMS) crisis of 1992 to 1993. This crisis was due to the competitiveness of the gap between the German mark and the other European currencies arising from the unification of the `two' Germans.

The Concept of Volatility

Volatility is of enormous importance to everyone involved in the financial markets, where it is thought of more in terms of unpredictability. Volatility is a fundamentally important concept in the discipline of finance. Several reasons have been advanced as to why volatility is an important issue in itself. Firstly, when asset prices fluctuate sharply over time differentials as short as one day or less, investors may find it difficult to accept that the explanation for these changes lies in information about fundamental economic factors. This may lead to an erosion of confidence in capital markets and a reduced flow of capital into equity markets.

Secondly, volatility is an important factor in determining the bid–ask spread. The higher the volatility of the stock, the wider is the spread between the bid and ask prices of the market maker. The volatility of the stock thus affects the market's liquidity. Thirdly, economic and financial theory suggests that consumers are risk averse. Increased risk associated with a given economic activity should, therefore, see a reduced level of participation in that activity, which will have adverse consequences for investment.

Finally, increased volatility over time may induce regulatory agencies and providers of capital to force firms to allocate a larger percentage of available capital to cash equivalent investments, to the potential detriment of allocation efficiency.

Volatility can be described broadly as anything that is changeable or variable. Volatility can be defined as the changeableness of the variable under consideration; the more the variable fluctuates over a period of time, the more volatile the variable is said to be. Volatility is associated with unpredictability, uncertainty and risk. Thus, the term is synonymous with risk, hence high volatility is thought of as a symptom of market disruption whereby securities are not being priced fairly and the capital market is not functioning as well as it should. In this context, volatility is often used to describe dispersion from an expected value, price or model. The deviation of prices from theoretical asset pricing model values, and the variability of traded prices from their sample mean are two examples. Substantial changes in the volatility of financial market returns are capable of having significant negative effects on risk-averse investors. In addition, such changes can also impact on consumption patterns, corporate capital investment decisions, leverage decisions and other business cycles and macroeconomic variables.

Volatility is also viewed as synonymous with variance risk. The trade-off between risk and expected return is the foundation upon which much of the modern finance theory such as Capital Asset Pricing Models (CAPM), Arbitrage Pricing Models and portfolio theory is based. Despite numerous literature review on volatilities, the causes of volatility in various financial and commodity markets is still an interesting area of study.

Weber (2007), identifies the impacts between key financial markets in the Asia Pacific region and focuses on determining the causal inter linkages between daily data of the exchange rate, the money market rate and the stock index in the post crisis of 1999 to 2006. His empirical approach takes volatility effect into account as the important aspect for the functioning of financial system using exponential GARCH. The conditional means of the three variables was estimated using the reduced form, taking into consideration the possible cointegrating relations. The heteroscedasticity in the residual is then picked up in multivariate EGARCH model. The methodology allows the author to obtain the causal relationships underlying the correlations between the financial variables and thus leads to interpretations in the sense of relevant economic theories.

Kearney and Poti (2005), examined the correlations dynamics using daily data from 1993 to 2002 on the five largest Euro zone stock market indices, in a conditional setting by applying the DCC-MGARCH model of Engle (2001,2002). In doing so, they facilitate testing for non-stationary, structural breaks and asymmetric dynamics in the correlation process. The results confirm a significant rise in the correlations amongst stock market indexes that can be best explained by a structural break shortly before the introduction of the Euro. On the overall, Kearney and Poti suggested that non-country factors drive the volatility of equity returns, and because of the rise in correlations among the largest national stock market indices, the stochastic components can now be expected to behave almost identical. This suggested that there is little benefit from diversification strategies across Euro-zone market indices, although diversifications across stocks remain useful.

Thus we formulate our research questions:

1. How is the volatility of the indices under study and is there correlation of the Malaysian market index return with the other country based world index
2. Secondly, if such correlations do exist, how best can a normal investor harness them to ensure maximum return in the short and the long run (with reference to correlation between the Malaysian market index and other country based index)

To answer our research questions above, we employ the use of dynamic conditional correlations (DCC) in the multivariate generalised autoregressive conditional heteroscedasticity (MGARCH) environment. While this technique has been widely used in modelling correlations in Asia Pacific financial market (Weber,2007), correlations dynamic in European equity markets (Kearney and Poti, 2006) and volatility and spill over effects of Vietnam's and other Asian markets (Nguyen Vu,2009), we are unaware if there exists any other study on the correlations of the following specific indexes, using the techniques that we have mentioned, at the time of writing.

We have selected Dow Jones US Index (DTUSAM) as the representative of the developed American market, Greece (DJGREC) as the representative of European market, Thailand (DJTHAI) as the representative of the Asian market and KLCI (DJMALY).

Our study is structured as follows: Section 1 – Introduction and Motivation of the Study, Section 2 – Literature Review, Section 3 – Data and Methodology, Section 4 – Empirical Findings and Section 5 Conclusion and Discussions.

2. Data and Methodology

In this study, we have selected Dow Jones US Index (DTUSAM) as the representative of the developed United States market, Greece (DJGREC) as the representative of European market, Thailand (DJTHAI) as the representative of the Asian market and KLCI (DJMALY), the Malaysian stock market. We used the weekly data from the secondary data downloaded from Datastream (Thompson-Reuters) for the period from January, 1992 to February, 2012, with a total of 1,056 observations. Due to non-stationary of level form data, we obtained the first difference form of stock index return.

$\mathbf{R_i = D_i - D_{i-1}}$ where R_i = return D_i = index at period i D_{i-1} = index at period i-1

As such, we obtained the stock indices return of RDJGREC for Greece, RDJMALY for Malaysia, RDJTHAI for Thailand and RDTUSAM for US. We modelled our data based on the MGARCH model as in Pesaran and Pesaran (2002,2009) and test the variables under Gaussian normal distributions and student t-distributions, under the unconditional volatility matrix estimation. We then run the return of the stock indices in the Microfit 5 programme.

We then computed the testing for linear restrictions of the property of the volatility whether they are mean reverting or otherwise (i.e permanent), by estimating lamdas (λ_{i1} and λ_{i2}). Our null hypothesis (H_0) will be;

$$\mathbf{H_0: \lambda_{i1} + \lambda_{i2} = 1 \quad or \quad 1- \lambda_{i1}- \lambda_{i2}=0}$$

Null (H_0) = the process is **non-reverting** (and the unconditional variance does not exist)

3. Empirical findings

Our result in Table 1 and 2 summarizes the maximum likelihood (ML) estimates of λ_{i1} and λ_{i2} (the volatility parameters) for the four indices returns and the δ_1 and δ_2 (the mean reverting parameters) under normal distributions and t-distributions. The volatility decay parameters are all highly significant and that the ML under the t-distributions is higher than under normal distributions (8505 v 8410). With the ML higher in the student t-distributions and the degree of freedom (df=n-k-1) of 9.44 which is significantly lower than 30, signifies that the student t-distribution superiority in capturing the fat-tailed nature of the indices return distribution.

The probabilities indicate significantly for both MGARCH with underlying multivariate normal distributions and student t-distributions.

Table 1 – MGARCH with underlying multivariate Normal Distributions

Parameter	**Estimate**	**T-Ratio**	**Probability**
λ_1_RDJGREC	0.89039	45.0264	0.000
λ_2_RDJGREC	0.09310	6.1033	0.000

λ_1_RDJMALY	0.89072	43.2714	0.000
λ_2_RDJMALY	0.10167	5.6646	0.000
λ_1_RDJTHAI	0.86832	25.2755	0.000
λ_2_RDJTHAI	0.10506	4.2720	0.000
λ_1_RDTUSAM	0.88890	43.900	0.000
λ_2_RDTUSAM	0.09187	6.0389	0.000
δ_1	0.96485	77.7101	0.000
δ_2	0.019734	3.9329	0.000
Max Log-likelihood	**8410.1**		

Table 2 - MGARCH with underlying multivariate t Distributions

Parameter	**Estimate**	**T-Ratio**	**Probability**
λ_1_RDJGREC	0.90555	39.4212	0.000
λ_2_RDJGREC	0.07879	4.5076	0.000
λ_1_RDJMALY	0.89627	43.3190	0.000
λ_2_RDJMALY	0.09833	5.2738	0.000
λ_1_RDJTHAI	0.90747	37.5693	0.000
λ_2_RDJTHAI	0.07954	4.2345	0.000
λ_1_RDTUSAM	0.90614	46.9922	0.000
λ_2_RDTUSAM	0.07706	5.2332	0.000
δ_1	0.96127	72.2257	0.000
δ_2	0.02273	3.9816	0.000
df	9.4400	9.8477	0.00
Max Log-likelihood	**8505.4**		

Table 3 and 4 shows the unconditional volatilities (the on diagonal) elements and the unconditional correlations (the off diagonals) of the indices under study.

Table 3 – Unconditional Volatilities (on Diagonal) and Unconditional Correlations (off Diagonal)

	RDJGREC	RDJMALY	RDJTHAI	RDTUSAM

RDJGREC	0.47993(1)	0.22998	0.23845	0.41067
RDJMALY	0.22998	0.040940(3)	0.52570	0.27203
RDJTHAI	0.23845	0.52570	0.048584(2)	0.30523
RDTUSAM	0.41067	0.27203	0.30523	0.024405(4)

Table 4 - Unconditional Volatilities (on Diagonal) and Unconditional Correlations (off Diagonal)

	RDJGREC	**RDJMALY**	**RDJTHAI**	**RDTUSAM**
RDJGREC	0.47993(1)	0.22998	0.23845	0.41067
RDJMALY	0.22998	0.040940(3)	0.52570	0.27203
RDJTHAI	0.23845	0.52570	0.048584(2)	0.30523
RDTUSAM	0.41067	0.27203	0.30523	0.024405(4)

In table 3 and 4, the number in parenthesis represents the ranking of unconditional volatilities (from the highest to the lowest). It is highly expected and not surprising that Greece is the most volatile of the four, followed by a distant by Thailand, Malaysia and US. Intuitively, this could be due to the fact that a small open economy (as compared to its much bigger economies in the EU), with a history of five consecutive years of deep depression and an external debt of 160% of its Gross Domestic Product (GDP), Greece stock market must be highly volatile and very sensitive to any shocks.

The fact that Malaysian stock market is highly correlated to Thailand stock market and Greece as to US is not surprising. This could be due to the effect that although all four are open economies, they however represents closely linked regional economic group. Malaysia and Thailand are neighbours in the ASEAN free trade zone and that US is the main trading partner of both, Greece (EU) and ASEAN.

Of all the diagonals (unconditional volatilities), it is surprisingly that US is the lowest. One possibility could be that shocks originated from US and that the ripple effect could be temporary and information flows takes time. This could also be due to the fact that after series of financial crisis and instability around the world, there is now a different market sentiment altogether (although that cannot be said of flow of funds from the low interest economy to a higher interest economy).

The key factor guiding the strategies for the global player after the Russian sovereign debt default shifted from emerging economies to safe havens of the US. Instead of looking for growth, the search for quality of risk has found its way into US. This explains why at the same time as interest rate were brought to record low levels in the US, the US dollar and the Wall Street stock market both stood firm and recorded strong gains throughout the period.

Table 5 – Testing for Linear restriction

Indices	**1- λ_{i1}- λ_{i2}**	**Std errors**	**t-Ratio**	**Prob**
Greece	0.015658	.0077283	2.0260	0.043
Malaysia	0.0053981	0.0026682	2.0231	0.043
Thailand	0.012988	0.0067518	1.9236	0.055
US	0.016801	0.0079740	2.1070	0.035

With reference to Table 5 we found that except for Thailand (which indicate a probability of >5%), we reject the null hypothesis of the process is non-reverting. This means that for Greece, Malaysia and US, despite the volatilities, the index return will come back to mean value in the long run. We found that the mean reverting process is a slow one for Greece (0.015658) and US (0.012988). It is however, a much slower and gradual one for Malaysia (0.0053981) though. This denotes that while in the short run the dynamics of conditional volatilities and correlations do have a significant impact, the impact will fizzle out and even out and will be captured by the unconditional volatilities and correlations. However for Thailand, the process is not mean reverting, which implies that the index return will not come back to its mean value and that the volatilities is assumed permanent. This means that the volatilities contained the trend element involving the fundamentals of the macro economy of Thailand. Our findings have the important connotation of portfolio diversification, in the sense that, while one investor intends to invest and stay for a long time, he should invest in Greece, Malaysia and US. He should then include Thailand in his international portfolio if he intends to reap his return for short term investment purposes.

Our study thus far analyses the unconditional volatilities and correlations, which quite imperatively is not too realistic, considering the assumption of constant for the 10 years period of 1992 to 2012.

Based on that, we plot the conditional volatilities as in **Figure 1** and correlations as in Figure 2 for the four indices for period between January 1992 and February 2012. From Figure 1, during the whole period, as we have expected, the index return of Malaysia and Thailand were moving in tandem together, except during the 1997 Asian financial crisis and 2008 US mortgage crisis. The Greece index return was the most volatile throughout the period, which confirm our expectation.

We now turn our focus on the correlation between the market indices for the same period as in **Figure 2**. We noticed an upward trend for correlations between all indices. The correlations between the index return of Malaysia and Thailand is higher as compared to the correlations between Malaysia with Greece and with USA. The correlation of the index return of Malaysia and Greece is the lowest of the three. Secondly, the fluctuation in the correlation is the greatest between Malaysia and Thailand, from zero in 2002 to a highest of 0.6 in 1997 and 2007. The correlation between Malaysia-Greece and Malaysia-USA was less volatile throughout the period. This confirm our expectation that index return of market within a common trade region as Malaysia and Thailand is highly correlated and it be unwise to invest fully in both due to the similar characteristics of the regional market.

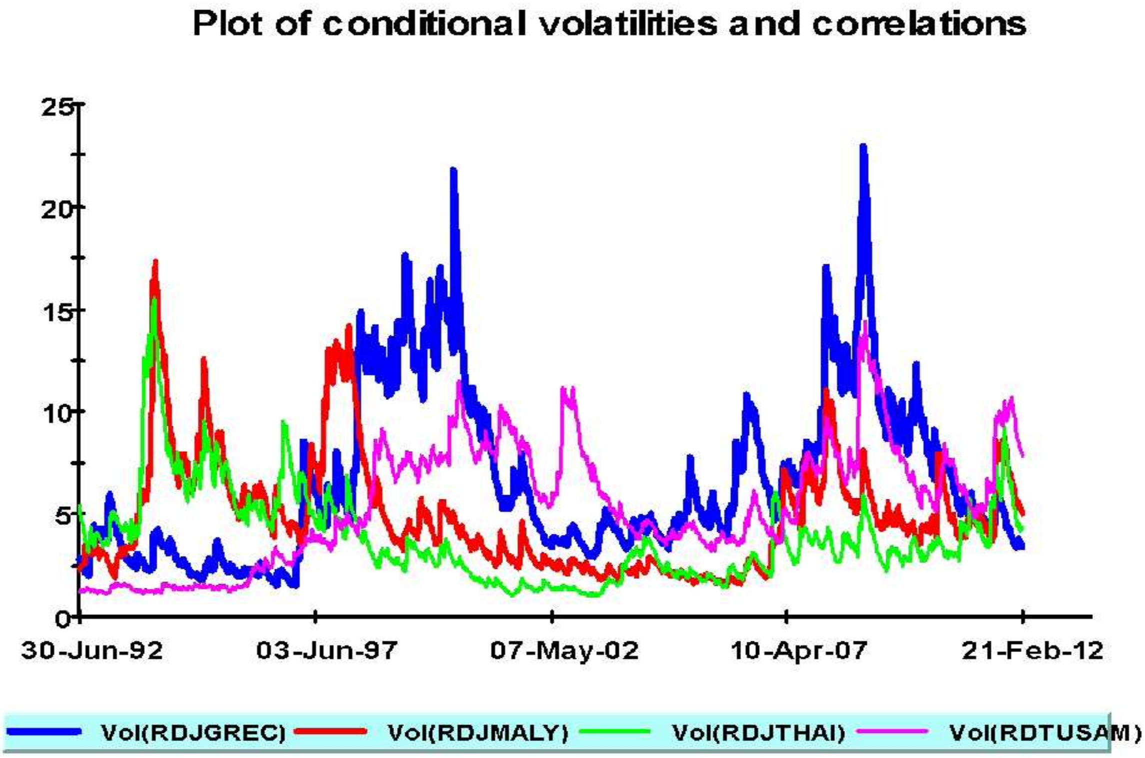

Figure 1 – Plot of conditional volatilities of index return for Greece, Malaysia, Thailand and US

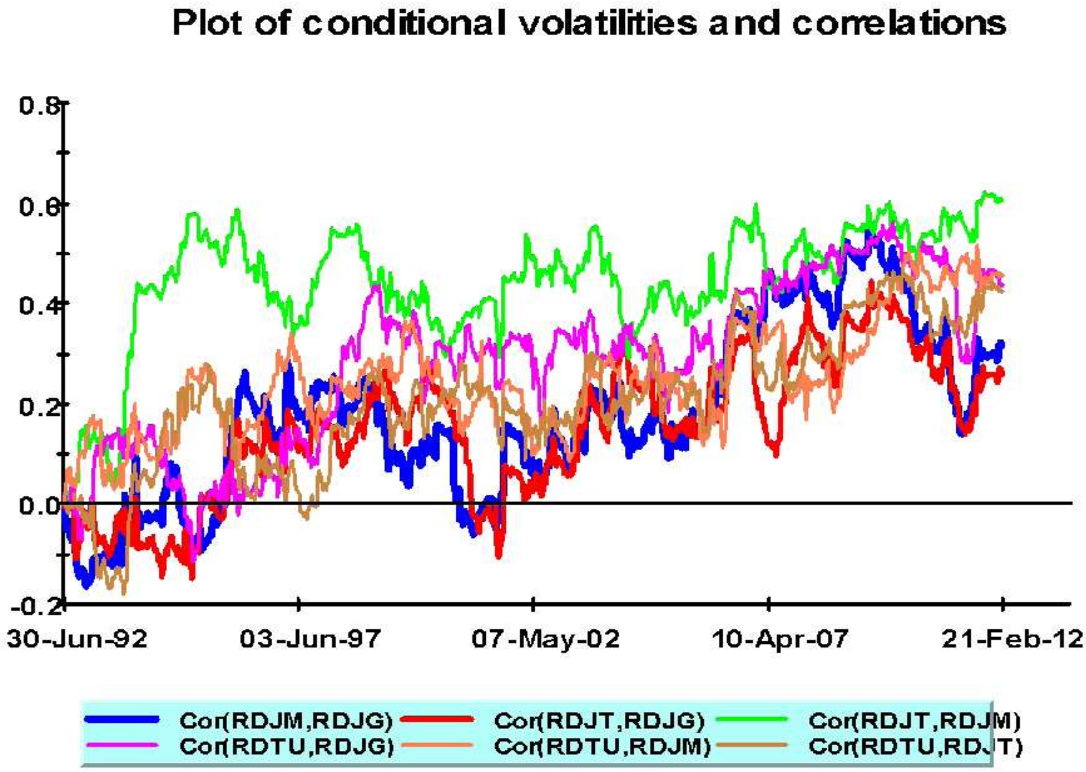

Figure 2 - Plot of conditional correlations of index return for Greece, Malaysia, Thailand and US

5.0 Conclusion

This paper investigates the relationship between the stock returns of various crisis-hit countries during the major global financial crises since 1992. As expected, investors' behaviour converges and correlations are significantly higher across both Asian countries in the sample. The level of volatilities of the indices' return of all the four markets has increased significantly for the period under study, which answers our first research question. The level and magnitude of volatilities and correlations is consistently highest between KLCI and Thailand market (lowest of 0.02 in 1993 to highest of 0.65 in 1998) followed by US and Greece markets. Greece seems to be the most volatile market followed by Malaysia, US and Thailand (except for the period between 1993 and 1998). One possible explanation is that the contagion effect takes place early in the crisis and that herding behaviour dominates the latter stages of the crisis. For our second research question, the apparent high correlation coefficients during crisis periods implies that the gain from international diversification by holding a portfolio consisting of diverse stocks from these contagion countries declines, since these stock markets are commonly exposed to systematic risk(beta). An increasing integration and stronger co-movement among stock markets will result in decreasing opportunity to gain from portfolio diversification.

More importantly, we found that non-country factors drive the volatilities of index returns and because of the rise in correlations among country based stock market indices, the stochastic components of the indices can now be expected to behave rather almost identical. Again, this suggests that there is little expected benefits from diversification strategies across countries within the same regional economic grouping like Malaysia and Thailand. This has confirmed the findings by Eiling et al. (2004) that the outperformance of country based diversification strategies for the Euro zone countries has disappeared after the introduction of the Euro. As the result, fund managers should think of further ramification of diversification of country based indices beyond the regional base. By applying the technique above, we also found that beyond asymmetric correlations reactions to past returns, there must be other important source of asymmetry involved in the distribution of index returns of the country analysed. This could be further explored by future research.

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Appendix 1

MULTIVARIATE GARCH WITH NORMAL DISTRIBUTION

3/5/2012
3:49:51 PM

Multivariate GARCH with underlying multivariate Normal distribution
Converged after 35 iterations

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Based on 1026 observations from 30-Jun-92 to 21-Feb-12.
The variables (asset returns) in the multivariate GARCH model are:
RDJGREC RDJMALY RDJTHAI RDTUSAM
Volatility decay factors unrestricted, different for each variable.
Correlation decay factors unrestricted, same for all variables.

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Parameter	Estimate	Standard Error	T-Ratio[Prob]
lambda1_RDJGREC	.89039	.019775	45.0264[.000]
lambda1_RDJMALY	.89072	.020585	43.2714[.000]
lambda1_RDJTHAI	.86832	.034354	25.2755[.000]
lambda1_RDTUSAM	.88890	.020248	43.9003[.000]
lambda2_RDJGREC	.093103	.015254	6.1033[.000]
lambda2_RDJMALY	.10167	.017948	5.6646[.000]
lambda2_RDJTHAI	.10506	.024591	4.2720[.000]
lambda2_RDTUSAM	.091874	.015214	6.0389[.000]
delta1	.96485	.012416	77.7101[.000]
delta2	.019734	.0050177	3.9329[.000]

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Maximized Log-Likelihood = **8410.1**

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Estimated Unconditional Volatility Matrix
1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
Unconditional Volatilities (Standard Errors) on the Diagonal Elements
Unconditional Correlations on the Off-Diagonal Elements

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	RDJGREC	RDJMALY	RDJTHAI	RDTUSAM
RDJGREC	.047993	.22998	.23845	.41067
RDJMALY	.22998	.040940	.52570	.27203
RDJTHAI	.23845	.52570	.048584	.30523
RDTUSAM	.41067	.27203	.30523	.024405

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For the time-varying conditional volatilities and correlations see the Post Estimation Menu.

Appendix 2

MULTIVARIATE GARCH WITH t-Student DISTRIBUTION

Convergence after 23 iterations

3/5/2012
3:56:00 PM

Multivariate GARCH with underlying multivariate t-distribution
Converged after 24 iterations

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Based on 1026 observations from 30-Jun-92 to 21-Feb-12.
The variables (asset returns) in the multivariate GARCH model are:
RDJGREC RDJMALY RDJTHAI RDTUSAM
Volatility decay factors unrestricted, different for each variable.
Correlation decay factors unrestricted, same for all variables.

****

Parameter	Estimate	Standard Error	T-Ratio[Prob]
lambda1_RDJGREC	.90555	.022971	39.4212[.000]
lambda1_RDJMALY	.89627	.020690	43.3190[.000]
lambda1_RDJTHAI	.90747	.024155	37.5693[.000]
lambda1_RDTUSAM	.90614	.019283	46.9922[.000]
lambda2_RDJGREC	.078793	.017484	4.5067[.000]
lambda2_RDJMALY	.098329	.018645	5.2738[.000]
lambda2_RDJTHAI	.079542	.018784	4.2345[.000]
lambda2_RDTUSAM	.077057	.014725	5.2332[.000]
delta1	.96127	.013496	71.2257[.000]
delta2	.022734	.0057097	3.9816[.000]
df	9.4400	.95860	9.8477[.000]

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Maximized Log-Likelihood = **8505.4**

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df is the degrees of freedom of the multivariate t distribution

Estimated Unconditional Volatility Matrix
1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
Unconditional Volatilities (Standard Errors) on the Diagonal Elements
Unconditional Correlations on the Off-Diagonal Elements

****

	RDJGREC	RDJMALY	RDJTHAI	RDTUSAM
RDJGREC	.047993	.22998	.23845	.41067
RDJMALY	.22998	.040940	.52570	.27203
RDJTHAI	.23845	.52570	.048584	.30523
RDTUSAM	.41067	.27203	.30523	.024405

****

For the time-varying conditional volatilities and correlations see the Post Estimation Menu.

Appendix 3

TESTING FOR THE LINEAR RESTRICTIONS – GREECE AND MALAYSIA

GREECE

```
3/5/2012
4:24:11 PM

                   Analysis of Function(s) of Parameter(s)
******************************************************************************
 The variables (asset returns) in the multivariate GARCH model are:
 RDJGREC  RDJMALY  RDJTHAI  RDTUSAM
 Volatility decay factors unrestricted, different for each variable.
 Correlation decay factors unrestricted, same for all variables.
 1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
******************************************************************************

 List of specified functional relationship(s):
 ZEROS = 1- lambda1_RDJGREC -lambda2_RDJGREC
******************************************************************************
 Function                  Estimate       Standard Error        T-Ratio[Prob]
 ZEROS                     .015658          .0077283             2.0260[.043]
******************************************************************************

       Estimated Variance Matrix of the Function(s) of the Parameters
     1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
******************************************************************************
              ZEROS
 ZEROS       .5973E-4
```

C/C => **REJECT** THE H0: LAMDA1 + LAMDA2 < > 1

MALAYSIA

```
3/5/2012
4:27:39 PM

                   Analysis of Function(s) of Parameter(s)
******************************************************************************
 The variables (asset returns) in the multivariate GARCH model are:
 RDJGREC  RDJMALY  RDJTHAI  RDTUSAM
 Volatility decay factors unrestricted, different for each variable.
 Correlation decay factors unrestricted, same for all variables.
 1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
******************************************************************************

 List of specified functional relationship(s):
 ZEROS = 1- lambda1_RDJMALY -lambda2_RDJMALY
******************************************************************************
 Function                  Estimate       Standard Error        T-Ratio[Prob]
 ZEROS                    .0053981          .0026682             2.0231[.043]
************************************************************************

       Estimated Variance Matrix of the Function(s) of the Parameters
     1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
************************************************************************
              ZEROS
 ZEROS       .7119E-5

************************************************************************
```

Appendix 4

TESTING FOR THE LINEAR RESTRICTIONS – THAILAND AND USA

THAILAND

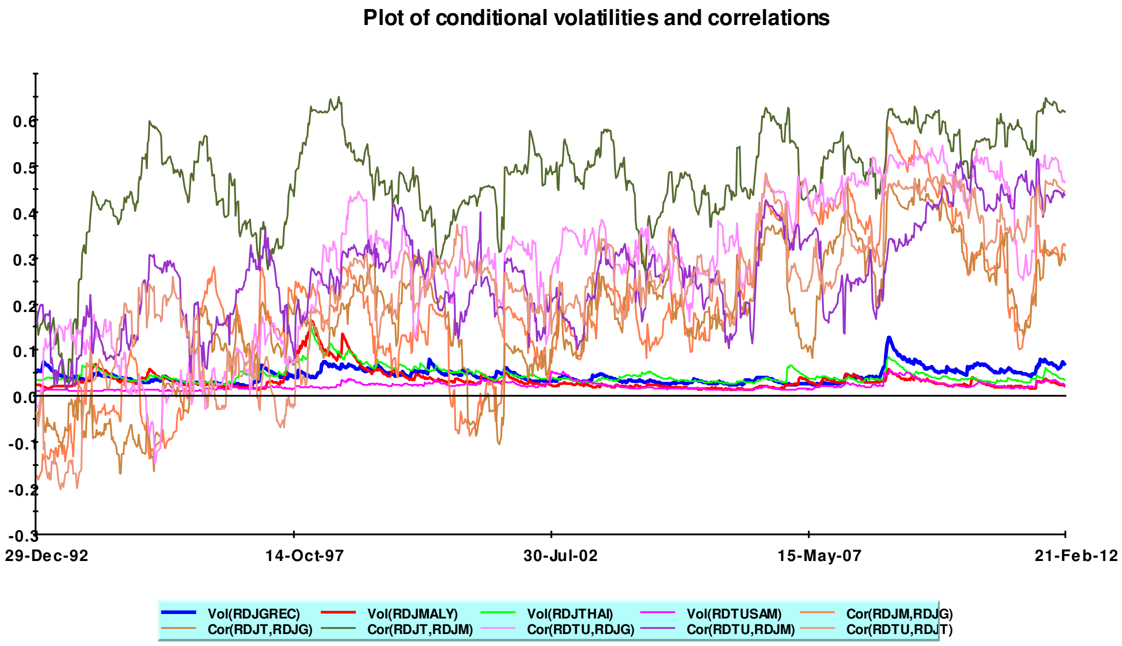
```
3/5/2012
4:31:22 PM

                   Analysis of Function(s) of Parameter(s)
*******************************************************************************
 The variables (asset returns) in the multivariate GARCH model are:
 RDJGREC  RDJMALY  RDJTHAI  RDTUSAM
 Volatility decay factors unrestricted, different for each variable.
 Correlation decay factors unrestricted, same for all variables.
 1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
*******************************************************************************

 List of specified functional relationship(s):
 ZEROS = 1- lambda1_RDJTHAI -lambda2_RDJTHAI
*******************************************************************************
 Function                  Estimate       Standard Error        T-Ratio[Prob]
 ZEROS                     .012988          .0067518             1.9236[.055]
*******************************************************************************

       Estimated Variance Matrix of the Function(s) of the Parameters
     1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
*******************************************************************************
              ZEROS
 ZEROS      .4559E-4

*******************************************************************************
```

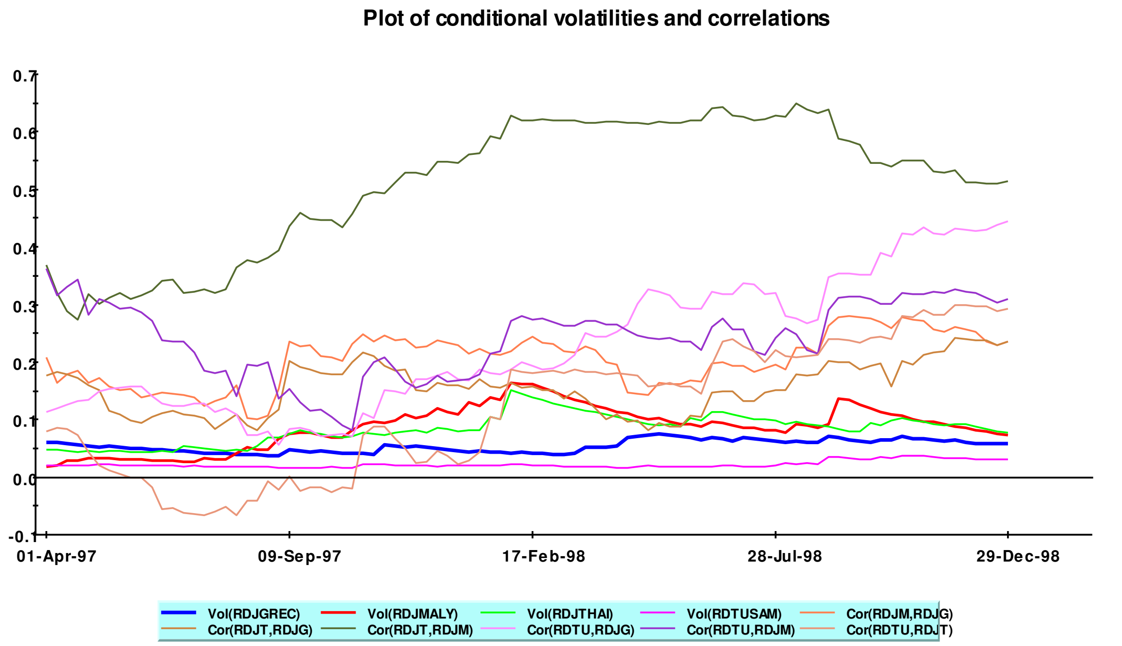
DO NOT REJECT (ACCEPT) THE NULL

USA

```
3/5/2012
4:32:17 PM

                   Analysis of Function(s) of Parameter(s)
*******************************************************************************
 The variables (asset returns) in the multivariate GARCH model are:
 RDJGREC  RDJMALY  RDJTHAI  RDTUSAM
 Volatility decay factors unrestricted, different for each variable.
 Correlation decay factors unrestricted, same for all variables.
 1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
*******************************************************************************

 List of specified functional relationship(s):
 ZEROS = 1- lambda1_RDTUSAM -lambda2_RDTUSAM
*******************************************************************************
 Function                  Estimate       Standard Error        T-Ratio[Prob]
 ZEROS                     .016801          .0079740             2.1070[.035]
*******************************************************************************

       Estimated Variance Matrix of the Function(s) of the Parameters
     1026 observations used for estimation from 30-Jun-92 to 21-Feb-12
*******************************************************************************
              ZEROS
 ZEROS      .6358E-4

*******************************************************************************
```

REJECT THE NULL

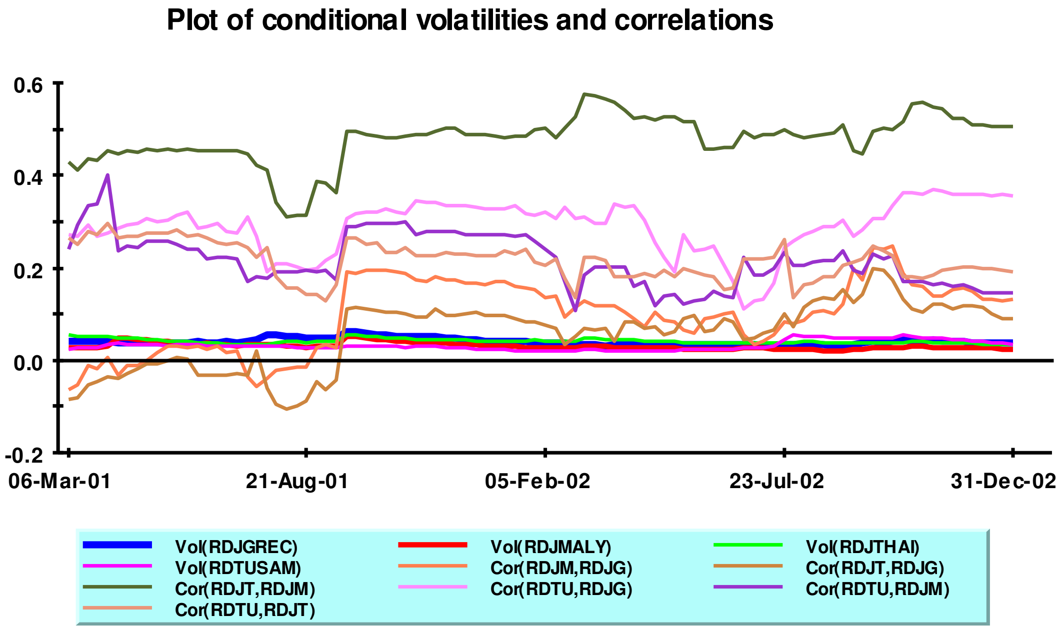

Plot of conditional volatilities and correlations
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
29-Dec-92
14-Oct-97
30-Jul-02
15-May-07
21-Feb-12
Vol(RDJGREC)
Vol(RDJMALY)
Vol(RDJTHAI)
Vol(RDTUSAM)
Cor(RDJM,RDJG)
Cor(RDJT,RDJG)
Cor(RDJT,RDJM)
Cor(RDTU,RDJG)
Cor(RDTU,RDJM)
Cor(RDTU,RDJT)


Plot of conditional volatilities and correlations
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
01-Apr-97
09-Sep-97
17-Feb-98
28-Jul-98
29-Dec-98
Vol(RDJGREC)
Vol(RDJMALY)
Vol(RDJTHAI)
Vol(RDTUSAM)
Cor(RDJM,RDJG)
Cor(RDJT,RDJG)
Cor(RDJT,RDJM)
Cor(RDTU,RDJG)
Cor(RDTU,RDJM)
Cor(RDTU,RDJT)

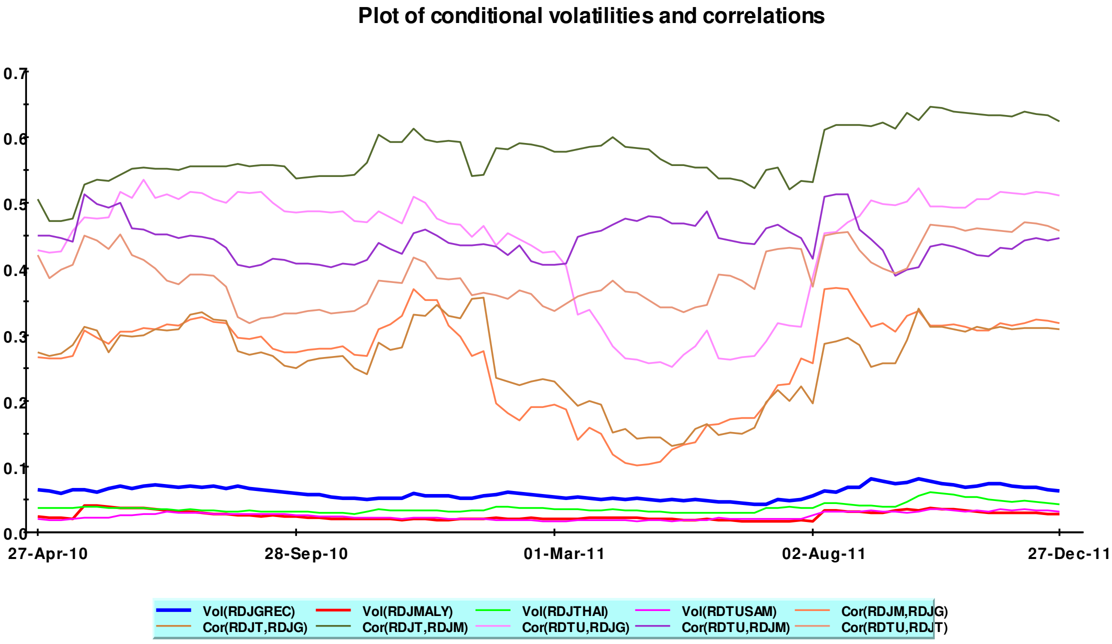
Appendix 5

Graph 1 – Plot of Conditional Volatilities and Correlations (29Dec 1992 – 21Feb 2012)

Graph 2 – Plot of Conditional Volatilities and Correlations (1Apr 1997 – 29 Dec 1998)



VOLATILITY IN 2011 (Before and After September 11)



Appendix 6

Graph 3 – Plot of Conditional Volatilities and Correlations (6Mar 2001 – 31Dec 2002)

Graph 4 – Plot of Conditional Volatilities and Correlations (27Apr 2010 – 27Dec 2011)