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Paramati, Sudharshan Reddy and Gupta, Rakesh and Tandon, Kishore

Griffith University, Griffith University, The City University of New York

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Sudharshan Reddy Paramati
Department of Accounting, Finance and Economics,
Griffith Business School, Griffith University,
Brisbane, Queensland-4111, Australia;
Email: sudharshanreddy.paramati@griffithuni.edu.au
Corresponding author

Rakesh Gupta
Department of Accounting, Finance and Economics,
Griffith Business School, Griffith University,
Brisbane, Queensland-4111, Australia;
Visiting fellow at Chongyang Institute of Financial Studies,
Renmin University, Beijing, China
Email: r.gupta@griffith.edu.au

Kishore Tandon
Zicklin School of Business,Baruch College,
The City University of New York, New York 10010
Email: Kishore.Tandon@baruch.cuny.edu

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Abstract

This paper aims to demonstrate to what extent Australian stock market is correlated with those of eighteen frontier markets of five different regions. We also investigate the long-run relationship between these markets. Empirical results of AGDCC GARCH model reveal that the correlations of Australian stock market with those of frontier markets are changing over time. Results show that Australia has weak correlations with all the frontier markets that are considered in this study. Further, our analysis confirms that the effects of the GFC on correlations of Australia and frontier markets are limited to only few frontier markets where correlations are slightly increased. The cointegration test results display that there is no evidence of long-run relationship between Australia and frontier markets. Similarly, Granger causality test results show that Australian stock market drives some of frontier markets and no evidence of reverse causality from these markets to Australia. Empirical findings of our study suggest that Australian stock market is weakly correlated with those of frontier markets. Therefore, our study findings suggest that the Australian investors can diversify their portfolios into these frontier markets for gaining higher risk-adjusted returns. Our study also contributes to the body of knowledge by addressing the issue of stock market linkages between developed and frontier markets and also the GFC.

JEL classification: G01, G11, G15

Keywords: Conditional correlations, frontier markets, global financial crisis

1 Introduction

The purpose of this study is to examine the comovements of Australian stock market with those of frontier markets. We also investigate long-run relationship between Australia and frontier equity markets. In this study, we considered eighteen frontier equity markets which cover five different regions of the world such as; Africa (Botswana, Ghana, Kenya, Mauritius, Nigeria and Tunisia), Americas (Argentina, Jamaica and Trinidad & Tobago), Asia (Bangladesh, Pakistan and Sri Lanka), Europe (Estonia, Lithuania and Slovenia) and Middle East (Jordan, Kuwait and Lebanon). This study uses weekly data on broad market indices of respective stock markets for the period of July 1996 to August 2012. To estimate time-varying correlations (or comovements) of Australia with frontier equity markets we use AGDCC (Asymmetric Generalized Dynamic Conditional correlations) GARCH models of Cappiello et al. (2006) and to explore long-run relationship we employ multivariate cointegration test based on the VAR (Vector Autoregressive) methodology developed by Johansen (1988, 1991). In addition to this, we also identify short-run causal relationship among these markets using Granger (1969) causality procedure.

Studying comovements between equity markets is very important for the portfolio managers those who wish to diversify their portfolios into other markets for higher risk-adjusted returns. The empirical studies of Eun and Shim (1989); Taylor and Tonks (1989); Campbell and Hamao (1992); Yang et al. (2006) argue that potential benefits from international portfolio diversification reduced due to the high degree of comovements among the stock markets. Some other studies (Brooks and Del Negro, 2004; Pukthuanthong and Roll, 2009) evidence that since late 1990s international stock markets are progressively more interdependent. A study by Kearney and Lucey (2004) argue that if the correlations among different stock markets increase then the portfolio diversification benefits dramatically declines. This signifies that over the period asset return correlations of developed equity markets have increased due to the world stock market integration. Various studies in the past two decades have supported the view that investors of developed markets can benefit by diversifying their portfolios into emerging markets (Solnik, 1991; Divecha et al., 1992; Chang et al., 2008; Gupta and Donleavy, 2009).

The earlier portfolio diversification studies of Grubel (1968); Levy and Sarnat (1970) argue that the motivation for investors to diversify their investments into international stock markets arises from low correlations between the international asset returns. Bekaert and Harvey (1995); Harvey (1995); Korajczyk (1996); Chambet and Gibson (2008) empirically provide evidence that the emerging and leading stock markets are less interdependent and perhaps offer significant diversification benefits for the international investors. The literature suggests that numerous empirical studies have investigated the comovements of asset returns among the developed stock markets (Lin et al. 1994; Longin and Solnik, 1995; Engsted and Tanggaard, 2004) and some other studies focused on developed and emerging stock markets (Bekaert and Harvey, 1995; Korajczyk, 1996; Chambet and Gibson, 2008). A recent study by Lucey and Muckley (2011) empirically investigated the level and advancement of stock markets' interdependence between the Asian (Hong Kong, Japan, Korea, Singapore and Taiwan), European (France, Germany, Italy, the UK and Sweden) and the USA markets using daily data from May 1988 to December 2007. Study results show that short-term comovements are larger from the European markets to the USA market while the short-term comovements of the Asian markets with the USA market are moderately lower. The long-run relationship is found between the Asian and the USA markets. This study suggests that the USA investor can exploit portfolio diversification benefits by focusing on common stochastic trend rather than merely depending on measurement of correlations.

Similarly, the time-varying conditional correlations of seven emerging stock market returns of Central and Eastern Europe (CEE) were examined by Syllignakis and Kouretas (2011). This study also explored contagion effect among the USA, Germany and Russian stock markets and the CEE. The multivariate DCC-GARCH models are employed for the analysis and used daily data for the period of October 1997 to February 2009. Results show that global financial crisis increased the correlations among the USA, German and the CEE stock returns. Study also finds that these emerging markets (CEE) are exposed to external shocks with a substantial regime shift in conditional correlations. Lahrech and Sylwester (2011) explored to what extent bivariate correlations among the Latin American (Argentina, Brazil, Chile and Mexico) and the USA equity returns increased during the period of 1988 to 2004. Study evidences that there is a significant increase in the degree of comovements between these equity markets. Other study by Syriopoulos and Roumpis (2009) examined the time-varying linkages and comovements between

South Eastern European (SEE) countries (Bulgaria, Croatia, Cyprus, Greece, Romania and Turkey) and two leading developed markets (Germany and the USA). Findings show the presence of long-run relationship among these markets. Authors suggest that investors can still benefit by diversifying their portfolios into SEE markets in the short-run. Gupta and Donleavy (2009) explored the benefits for Australian investors from diversifying their investment into emerging markets. Results of this study show that correlations of Australia and emerging markets are increasing over time; however authors suggest that still there are potential diversification benefits for the Australian investors those who wish to diversify their investment into international emerging markets.

The empirical literature on time-varying relationship between developed and frontier equity market is very limited. For instance, a recent study by Sukumaran et al. (2015) examined whether there are significant benefits from portfolio diversification into frontier markets from an Australian and the US investor perspective. Their findings show that there are potential diversification opportunities for the US and Australian investors into frontier markets. However, when compared between the US and Australian investors, authors argue that the US investors can benefit more than Australian investors. Kiviaho et al. (2012) explored the comovements of European frontier stock markets with the USA and three developed markets of Europe (i.e. the UK, Germany and France) by employing three-dimensional analysis of wavelet coherency. Results of this study show that the strength of comovements significantly varies at different frequencies and over time across the frontier markets. This study found that the comovements are moderately weaker for the frontier markets of Central and Southern Europe than that of Baltic region. Study suggests that recent global financial crisis (2008-09) has significantly increased the comovements and also found that the comovements are stronger for lower frequencies. Similarly, Jayasuriya and Shambora (2009) document that frontier equity markets offer considerable diversification benefits. Authors empirically showed that the diversified portfolio into frontier markets improved the risk and return trade off. A study of Speidell and Krohne (2007) mentions that the diversification benefits are the key motivation for investors to include frontier equity markets in their diversified portfolios. Their study found low correlations among frontier and developed markets. This has provided significant incentives for investors to diversifying their portfolios into these markets.

The empirical studies and modern portfolio theory suggest that the diversification benefits arise mainly because of lower correlations among asset returns. Increasing globalization has created enormous investment opportunities and the accessibilities of global equity markets have substantially increased. This provides substantial incentives for the investors to look for the new investment opportunities across the globe for diversifying their portfolios for higher risk-adjusted returns. Therefore, this motivates us to explore the time-varying correlations of asset returns between Australia and frontier equity markets. To the best of our knowledge this is the first study to explore the time-varying dynamics in return correlations of Australia and eighteen frontier equity markets. This study will provide evidence on possible diversification opportunities for the Australian investors into frontier equity markets.

The understanding of stock market cointegration relationship is also very important for practitioners. For instance, if the stock markets are cointegrated then returns from diversification will reduce significantly. Various research studies have explored the cointegration relationship among the developed markets. Empirical evidence from the studies of Friedman and Shachmurove (1997); Quan and Huyghebaert (2006) demonstrate that the developed stock markets are highly integrated. A number of other studies have looked at stock markets integration between developed and emerging markets. A study by Berger et al. (2011) provides evidence that frontier equity markets have no significant integration with world developed markets. Study suggests that frontier equity markets offer significant diversification benefits for the investors. Raj and Dhal (2008) examined the degree of integration of Indian stock market with two Asian markets (Hong Kong and Singapore) and three international leading stock markets (Japan, UK and US). Results from bivariate cointegration test confirm that there is no long-run relationship among these markets. Similarly, Huang et al. (2000) explored the short-run and long-run relationship between the two leading international stock markets (the USA and Japan) and Asian emerging markets (China, Hong Kong, and Taiwan). His analysis shows evidence of short-run relationship but fails to demonstrate long-run equilibrium relationship among these markets. These empirical studies have provided considerable motivations for the global investors to look for possible diversification opportunities.

The above literature evidently suggests that there is no much literature on developed and frontier stock markets integration. Hence, this study will explore the dynamic long-run relationship among Australia and frontier equity markets. We also examine short-run causal relationship among these markets. To the best of our understanding this is the first study to investigate time-varying correlations, long-run dynamics and causal relationship between Australia and frontier markets of five different regions in the world. This study contributes to the body of knowledge by providing comprehensive evidence on correlations, cointegration and causal relationship among Australia and frontier markets. To the best of available information this is the first study to use asymmetric generalized DCC GARCH models to estimate time-varying correlations of Australia and frontier markets[1]. The inferences of this study would be very useful for the practitioners of Australia as this study will provide evidence on how the asset return correlations are changing over time. In addition, study investigates the long-run cointegration relationship among the markets, which is very useful for the diversification point of view. Further, the findings of direction of causality are also useful for the investment decisions to understand which market is driving which one. Therefore, empirical results of this study have important practical implications for the Australian investors, particularly those who wish to diversify their investments into other markets for gaining higher risk-adjusted returns.

The rest of the paper is organized as follows. Section 2 provides information on the methodology that has been adopted in this study. Section 3 deals with the data and preliminary statistics. Sections 4 reports empirical results and summary and concluding remarks are provided in the section 5.

2 Methodology

This section provides brief discussion on the empirical methodology. To estimate time-varying conditional correlations we use AGDCC GARCH model and to examine the long-run equilibrium relationship among the markets we use multivariate cointegration approach and finally to identify the direction of causality among the markets we employ Granger causality test. The details of these models are provided below.

Unit Root Tests

To identify the order of integration of weekly closing price indices of Australia and frontier equity markets, we use the conventional unit root tests such as; Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1979) and Phillips-Perron (PP) test (Phillips and Perron, 1988). These

[1] AGDCC GARCH model is a better model as it incorporates asymmetries and asset-specific news in the analysis for measuring return correlations.

two tests are used to test whether given data series contains a unit root (non-stationarity) or is a stationarity (no unit root) at levels. For both ADF and PP tests the null hypothesis of unit root is tested against the alternative hypothesis of no unit root. Our study uses MacKinnon (1996) critical values for ADF test. The ADF test values are sensitive to the selection of lag length. Therefore, we use Schwarz criteria (SC) to select the appropriate lag length. The PP test incorporates an alternative (non-parametric) method for controlling serial correlation when testing for a unit root. Similarly, we also use MacKinnon (1996) lower-tail critical values for PP test.

Asymmetric Generalized DCC GARCH Model

We aim to examine to what extent stock markets are correlated. To measure the time-varying dynamic conditional correlations between Australia and frontier markets we use the AGDCC GARCH model. Engle (2002) was the first author to introduce a new class of M-GARCH model which is known as DCC-GARCH. This is an important model in measuring the time dynamics in correlations. However, to allow for series-specific news impact and conditional asymmetries in correlations we use the modified version of DCC model i.e. AGDCC-GARCH of Cappiello et al. (2006). This AGDCC GARCH model is also a better model for capturing the heterogeneity that present in the data series.

The evolution of correlation in the standard DCC model of Engle (2002) is given by the following equation:

$$Q_t = (1-a-b)\overline{P} + a\varepsilon_{t-1}\varepsilon'_{t-1} + bQ_{t-1} \quad (1)$$

$$P_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad (2)$$

Where $\overline{P} = E[\varepsilon_t \varepsilon'_t]$, a and b are scalars such that $a+b<1$. $Q_t^* = (q_{iit}^*) = \lfloor \sqrt{q_{iit}} \rfloor$ this is a diagonal matrix with the square root of the ith diagonal element of Q_t on its ith diagonal position. If Q_t holds as long as positive definite then Q_t^* is a matrix which ensures $P_t = Q_t^{*-1} Q_t Q_t^{*-1}$ is a correlation matrix with ones on the diagonal and every other element ≤ 1 in absolute value. The above models explained in the equations of (1) and (2) will not allow for asset-specific news and asymmetries. Therefore, Cappiello et al. (2006) proposed a modified version of DCC model and which is given in the following equation:

$$Q_t = (\overline{P} - A'\overline{P}A - B'\overline{P}B - G'\overline{N}G) + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + G'n_{t-1}n'_{t-1}G + B'Q_{t-1}B \quad (3)$$

Where A, B and G are $k\ x\ k$ parameter matrices, and $n_t = I[\varepsilon_t < 0] o \varepsilon_t$, ($I[.]$ is a $k\ x\ 1$ indicator function which takes the value of 1 if the argument is true and otherwise 0, while "o" indicating Hadamard product), $\overline{N} = E[n_t n'_t]$. The above equation (3) is the AG-DCC model. If the matrices of A, B and G are replaced by scalars, then asymmetric DCC model can be obtained as a special case of AG-DCC. In the same way, if matrix $G = 0$, then generalized DCC is a special case of AG-DCC. The expectations are infeasible for $\overline{P}$ and $\overline{N}$ are replaced with sample analogues, $T^{-1}\sum_{t=1}^{T}\varepsilon_t\varepsilon'_t$ and $T^{-1}\sum_{t=1}^{T}n_t n'_t$, respectively.

Cointegration Test

To test the long-run relationship between Australia and frontier markets we employ VAR (Vector Autoregression) based cointegration test using the methodology developed by Johansen (1988 & 1991). The VAR model with order p can be written as follows:

$$z_t = c + A_1 z_{t-1} + \dots\dots\dots + A_p z_{t-p} + \mu_t \quad (4)$$

Where z_t is an n x1 vector of variables that are integrated of order one i.e. I (1), and μ_t is a zero mean with white noise vector process. This VAR model can be re-written as follows:

$$\Delta z_t = c + \Pi z_{t-1} + \sum_{i-1}^{p-1}\Gamma_i \Delta z_{t-i} + \mu_t \quad (5)$$

Where $\Pi = \sum_{i-1}^{p} A_i - I$ and $\Gamma_i = -\sum_{j=i+1}^{p} A_j$ If the coefficient matrix has reduced rank $r < n$, then there exist n x r matrices α and β each with rank r such that $= \alpha\beta'$ and $\beta' z_t$ is stationary. r is the number of cointegrating relationships, the elements of α are known as the adjustment parameters in the vector error correction model and each column of β is a cointegrating vector. Johansen proposed two different likelihood ratio tests, the trace (λ_{trace}) and maximum eigenvalue $(\lambda_{\max})$ test, these are computed using following equations:

$$\lambda_{trace}(r) = -T\sum_{i=r+1}^{g}\ln(1-\hat{\lambda}_i) \quad (6)$$

$$\lambda_{\max}(r, r+1) = -T\ln(1-\hat{\lambda}_{r+1}) \quad (7)$$

Where T is the sample size, $\hat{\lambda}_i$ and $\hat{\lambda}_{r+1}$ are the estimated values of the characteristic roots obtained from the Π matrix. The trace test tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors while the maximum eigenvalue tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of $r+1$ cointegrating vectors. For this test we use MacKinnon-Haug-Michelis (1999) 5% critical values for the analysis.

Direction of Causality

To identify the direction of causality among the stock markets we employ causality test developed by Granger (1969). The question of whether y causes x is to see how much of the current x can be explained by past values of x and then to see whether adding lagged values of y can improve the explanation. It is said that x is Granger caused by y, if x can predict better from past values of x and y than from past values of x alone. For a simple bivariate model, one can test the following equation:

$$x_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i y_{t-i} + \sum_{j=1}^{m} \beta_j x_{t-j} + + u_t \quad (8)$$

$$y_t = \alpha_0 + \sum_{i=1}^{n} \beta_i x_{t-i} + \sum_{j=1}^{m} \alpha_j y_{t-j} + \varepsilon_t \quad (9)$$

Where the null hypothesis is that y does not Granger causes x in the first regression equation and x does not Granger causes y in the second equation. The rejection of null hypothesis means the presence of Granger causality. The Granger causality test is performed for each pair of stock markets i.e. Australia and each of frontier markets.

3 Data and Preliminary Statistics

In this study, we use weekly (Friday) closing price data on broad market indices of Australia (ASX200), Botswana (IFFMBOL), Ghana (IFFMGHL), Kenya (NSE20), Mauritius (IFFMMAL), Nigeria (IFGDNGL), Tunisia (IFFMTUL), Argentina (ARGMERV), Jamaica (JAMSEIN), Trinidad & Tobago (TTSECOM), Bangladesh (BDTALSH), Pakistan (PKSE100), Sri Lanka (SRALLSH), Estonia (ESTALSE), Lithuania (IFFMLIL), Slovenia (IFFMSL), Jordan (AMMANFM), Kuwait (KWKICGN), Lebanon (LBBLOMI) for the period of July 1996 to

August 2012[2]. The collected data on respective stock market indices are denominated in local currency which is to avoid the problems associated with the exchange rate fluctuations. These data has been collected from the Thomson Financial DataStream.

Table 1 demonstrates the summary statistics on weekly stock index returns on nineteen markets. These results show that all the markets have positive mean returns. The markets of Botswana (0.0037), Pakistan (0.0026), Sri Lanka (0.0026), Estonia (0.0023), Jamaica (0.0022), Trinidad & Tobago (0.0022) and Nigeria (0.0021) have higher mean returns. Similarly, the markets of Kenya (0.0002), Lebanon (0.0003), Australia (0.0008), Tunisia (0.0008) and Lithuania (0.0008) have lowest average returns among all the markets. The standard deviation of return series is higher for Kuwait (0.0654), Argentina (0.0498), Bangladesh (0.0419) and Estonia (0.0413). Results also indicate that the markets of Australia, Mauritius, Nigeria, Argentina, Pakistan, Estonia and Jordan have negative Skewness which implies that these market return series are flatter to the left on a normal distribution curve and while all other markets have positive Skewness and suggest that these market return series are flatter to the right. We found that all the market return series have high Kurtosis values which signify that these series distributions are more fat-tailed than a normal distribution curve. Our results on Jarque-Bera test suggest that the null hypothesis of normal distribution is rejected at 5% significance level for all the markets.

[2] Generally, the weekly data causes fewer problems because of non-synchronous trading and short-term correlations due to noise.

Table.1: Summary statistics on stock index returns

Markets	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Australia	0.0008	0.0213	-0.9719	9.2483	1504.06**
			Africa		
Botswana	0.0037	0.0250	5.1302	62.9823	130073.00**
Ghana	0.0017	0.0227	1.0240	20.2913	10649.35**
Kenya	0.0002	0.0255	0.5186	9.8418	1682.01**
Mauritius	0.0019	0.0247	-0.0174	20.7466	11062.36**
Nigeria	0.0021	0.0333	-0.1205	6.2763	379.07**
Tunisia	0.0008	0.0215	0.3128	28.6831	23182.95**
			Americas		
Argentina	0.0017	0.0498	-0.3218	7.3051	665.54**
Jamaica	0.0022	0.0221	0.8208	10.8592	2264.20**
Trinidad & Tobago	0.0022	0.0170	1.9913	27.4546	21562.90**
			Asia		
Bangladesh	0.0016	0.0419	0.4689	15.1829	5244.23**
Pakistan	0.0026	0.0385	-0.8892	6.4701	534.06**
Sri Lanka	0.0026	0.0284	0.5295	7.1770	652.24**
			Europe		
Estonia	0.0023	0.0413	-0.6238	10.1194	1835.03**
Lithuania	0.0008	0.0347	0.7848	22.6515	13651.17**
Slovenia	0.0013	0.0372	2.2098	32.3900	31026.13**
			Middle East		
Jordan	0.0014	0.0236	-0.4240	8.0213	910.89**
Kuwait	0.0011	0.0654	0.3172	318.4626	3495537.00**
Lebanon	0.0003	0.0323	0.6840	33.5614	32872.46**

Where '**' indicates rejection of null hypothesis of normal distribution at 5 percent significance level.

4 Empirical Results

Unit Root Tests

This section provides the results of unit root tests on the market closing price indices. We have applied conventional unit root tests such as; ADF and PP tests to explore the order of integration of the price series. If we want to explore the long-run relationship among the markets then it is important to find out the order of integration of each series before we apply cointegration methodology. Therefore, both ADF and PP test examine whether the underlying series is stationary (no unit root) or non-stationary (unit root) at levels. The null hypothesis of unit root (non-stationary) is tested against the alternative hypothesis of no unit root (stationary) for both ADF and PP tests. The results of unit root tests are presented in table 2. These results show that the null hypothesis of unit root is not rejected for all the closing price indices with and without a trend at levels. This indicates that all the series have same order of integration that is I (1). We then applied these tests on the first difference data series of all the markets and results suggest that the null hypothesis is rejected at 5 % significance level. Hence, our unit root tests results confirm that all the series have same order of integration and gives an indication to explore the long-run relationship among these markets.

Table 2: Results of unit root tests

Markets	Augmented Dickey-Fuller (ADF) Test				Phillips-Perron (PP) Test			
	Level		First Difference		Level		First Difference	
	Without Trend	With Trend	Without Trend	With Trend	Without Trend	With Trend	Without Trend	With Trend
Australia	-1.917	-1.782	-30.071	-30.103	-1.907	-1.731	-30.074	-30.114
Africa								
Botswana	-2.475	-1.663	-9.395**	-9.633**	-2.553	-1.352	-29.877**	-29.800**
Ghana	-0.562	-2.506	-8.940**	-8.948**	-0.428	-2.432	-28.517**	-28.503**
Kenya	-0.934	-1.411	-25.559**	-25.560**	-1.086	-1.538	-26.093**	-26.085**
Mauritius	-0.804	-1.308	-27.946**	-27.933**	-0.889	-1.689	-28.539**	-28.526**
Nigeria	-1.319	-0.797	-17.579**	-17.611**	-1.332	-0.972	-27.952**	-27.943**
Tunisia	0.383	-2.447	-28.173**	-28.356**	0.143	-2.442	-28.436**	-28.502**
Americas								
Argentina	-0.811	-2.076	-18.353**	-18.344**	-0.918	-2.249	-29.027**	-29.013**
Jamaica	-2.266	-0.477	-25.540**	-25.687**	-2.010	-0.839	-26.113**	-26.121**
Trinidad & Tobago	-2.623	-2.289	-8.002**	-8.181**	-2.845	-2.145	-31.455**	-31.323**
Asia								
Bangladesh	-0.328	-1.922	-25.717**	-25.730**	-0.689	-2.235	-26.359**	-26.352**
Pakistan	-0.387	-1.938	-24.392**	-24.385**	-0.332	-1.934	-24.583**	-24.575**
Sri Lanka	-0.039	-1.812	-24.180**	-24.184**	-0.145	-1.998	-24.891**	-24.885**
Europe								
Estonia	-1.608	-1.952	-15.934**	-15.934**	-1.583	-1.973	-25.279**	-25.266**
Lithuania	-2.324	-2.273	-9.057**	-9.067**	-2.112	-2.033	-28.577**	-28.562**
Slovenia	-2.296	-0.178	-28.668**	-29.019**	-2.186	-0.496	-29.470**	-29.425**
Middle East								
Jordan	-1.143	-0.514	-25.869**	-25.891**	-1.179	-0.889	-27.286**	-27.132**
Kuwait	-1.321	-0.552	-23.042**	-23.083**	-1.406	-1.190	-51.476**	-51.737**
Lebanon	-0.963	-1.438	-28.973**	-28.964**	-1.091	-1.559	-29.139**	-29.127**

Where '**' indicates rejection of null hypothesis of unit root at 5 percent significance level.

Correlations of Market Returns

Unconditional Correlations

The estimated unconditional correlations of Australia with eighteen frontier markets of five different regions are displayed in Table 3. These correlations show that Australia has high correlation with only Argentina (46%) and has weak correlations with all other markets. Australia has negative correlations only with Trinidad & Tobago (-2%) and Botswana (-3%). We found the correlations within frontier markets are also almost negligible. Our unconditional correlations show that Australian stock market is weakly correlated with all the frontier markets that are considered in this study.

Conditional Correlations

In this section, we aim to measure the time-varying correlations of Australia with eighteen frontier markets. The above unconditional correlations are failed to demonstrate time-varying correlations over time. Therefore, we employ various conditional GARCH models of DCC (dynamic conditional correlations) family such as; DCC, Asymmetric DCC, Generalized (Diagonal) DCC and Asymmetric Generalized (Diagonal) DCC to estimate the time-varying conditional correlations of stock returns. All these DCC models are based on Cappiello et al. (2006) using a two-step procedure. In this study we applied all the DCC models to estimate the time-varying correlations of Australia with each of eighteen frontier markets. The empirical results of all the DCC models show slightly varying results. In order to select the appropriate DCC model we use BIS (Bayesian Information Criterion) values. It is found that in all the cases AGDCC model has higher BIS values. Therefore, in this study we use AGDCC model to measure the time-varying correlations of Australia with each of the frontier markets. The AGDCC model is a robust model to capture the time dynamics in return correlations as this model incorporates asymmetries and asset-specific news in the analysis. The motivation for this model to employ for measuring the time-varying correlations of return series is to see how the Australian stock market correlations are changing over time with frontier markets. We also aim to address the issue of how the GFC (global financial crisis) affected these stock market correlations in the recent period.

The estimated conditional correlations of AGDCC GARCH model are demonstrated in Figure 1. We presented separated graphs for the Australian stock market correlations with each of frontier markets. From these graphs, it is found that Australian market correlations with all frontier markets are changing over time. These results show that Australia has higher correlations with Ghana (95% in February, 2002), Estonia (94% in August, 2005), Kenya (90% in November, 2004), Jamaica (88% in October, 2009), Botswana (80% in March, 2007) and Bangladesh (80% in November, 2008). Similarly, Australia has lower correlations with Kenya (-97% in December, 2004), Nigeria (-97% in March, 2005), Botswana (-96% in October, 1999) and Tunisia (-89% in December, 2001). These correlations also suggest that an average Australia has higher correlations with Argentina (48%), Lebanon (25%), Jamaica (20%), Bangladesh (20%) and Estonia (20%) and has less than 20% correlations with Botswana, Ghana, Kenya, Mauritius, Nigeria, Tunisia, Trinidad & Tobago, Pakistan, Sri Lanka, Lithuania, Slovenia, Jordan and Kuwait.

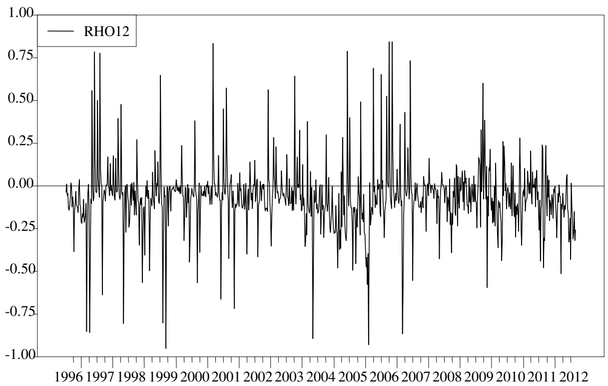
Further, our analysis aim to address the impact of GFC on stock market correlations of Australia and each of frontier markets. The results show that the GFC has impact on the correlations of Australia with the markets of Mauritius, Nigeria, Argentina, Estonia, Lithuania, Slovenia, Jordan and Kuwait, which indicates that Australia's correlations with these markets have significantly increased during the crisis period. Results also display that the GFC has no influence on the correlations of Australia with Botswana, Ghana, Kenya, Tunisia, Jamaica, Trinidad & Tobago, Bangladesh, Pakistan, Sri Lanka and Lebanon. Our analysis therefore suggests that the impact of GFC on the correlations of Australia with frontier markets is limited to only few markets from the regions of Africa (Mauritius and Nigeria), Americas (Argentina), Europe (Estonia, Lithuania and Slovenia) and Middle East (Jordan and Kuwait). The analysis also confirms that the GFC has no influence on the frontier markets of Asia (Bangladesh, Pakistan and Sri Lanka). For the portfolio diversification point of view it is important to estimate the correlations between all the markets. Therefore, we estimated correlations among the frontier markets using AGDCC GARCH model and found almost negligible correlations among all the frontier markets. Our analysis of Australia's correlations with frontier markets suggests that there are potential portfolio diversification opportunities for the investors to diversify their portfolios into these markets for higher risk-adjusted returns.

Table 3: Unconditional correlations between stock index returns

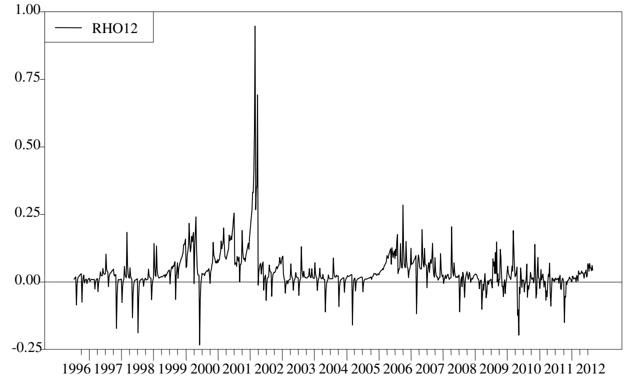
Markets	Aust	Bots	Ghan	Keny	Maur	Nige	Tuni	Arge	Jama	Trin	Bang	Paki	SriL	Esto	Lith	Slov	Jord	Kuwa	Leba
Australia	1.00																		
Africa																			
Botswana	-0.03	1.00																	
Ghana	0.02	0.07	1.00																
Kenya	0.09	0.00	0.06	1.00															
Mauritius	0.19	0.09	0.12	0.11	1.00														
Nigeria	0.06	0.03	0.01	0.03	0.07	1.00													
Tunisia	0.02	-0.03	0.04	0.07	0.07	0.04	1.00												
Americas																			
Argentina	0.46	-0.01	-0.03	0.11	0.13	0.06	0.00	1.00											
Jamaica	0.13	0.06	0.04	0.01	0.12	0.04	-0.03	0.10	1.00										
Trinidad & Tobago	-0.02	0.06	0.14	0.01	0.16	-0.03	-0.10	-0.02	0.10	1.00									
Asia																			
Bangladesh	0.03	-0.03	0.03	-0.01	-0.01	0.03	0.05	-0.01	0.02	-0.03	1.00								
Pakistan	0.13	-0.02	-0.02	0.05	0.05	0.01	0.01	0.12	-0.03	-0.04	0.03	1.00							
Sri Lanka	0.18	0.00	-0.02	0.15	0.16	0.05	0.02	0.19	0.09	0.00	-0.01	0.09	1.00						
Europe																			
Estonia	0.27	0.02	0.03	0.11	0.16	0.09	0.02	0.19	0.08	0.07	-0.04	0.14	0.15	1.00					
Lithuania	0.20	0.12	0.05	0.11	0.26	0.06	0.01	0.17	0.14	0.06	0.02	0.08	0.13	0.30	1.00				
Slovenia	0.22	0.20	-0.02	0.11	0.26	0.03	-0.04	0.20	0.13	-0.02	0.09	0.08	0.12	0.10	0.48	1.00			
Middle East																			
Jordan	0.21	-0.01	0.02	0.11	0.12	0.10	0.03	0.15	0.05	0.01	-0.01	0.09	0.16	0.17	0.21	0.19	1.00		
Kuwait	0.04	0.00	0.00	0.03	0.01	0.03	0.04	0.05	-0.02	0.01	0.00	0.02	-0.01	0.03	-0.01	0.00	0.11	1.00	
Lebanon	0.13	0.03	0.04	0.05	0.08	0.05	0.01	0.10	0.06	0.02	0.06	0.01	0.05	0.05	0.02	0.06	0.11	0.07	1.00

Figure 1: Time-varying conditional correlations

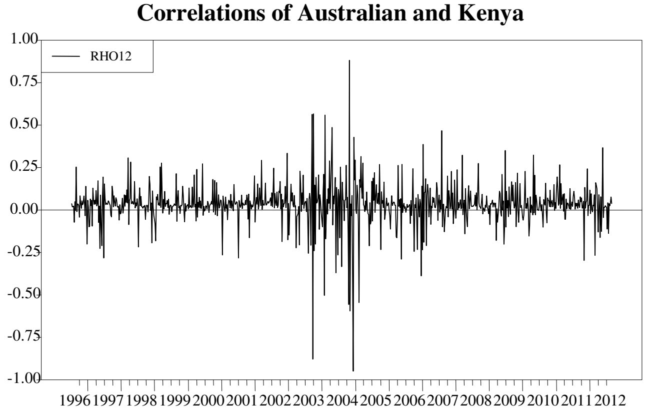
Correlations of Australian and Botswana



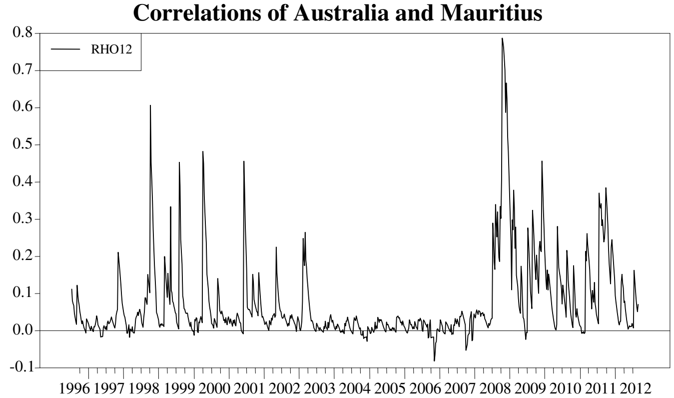
Correlations of Australian and Ghana



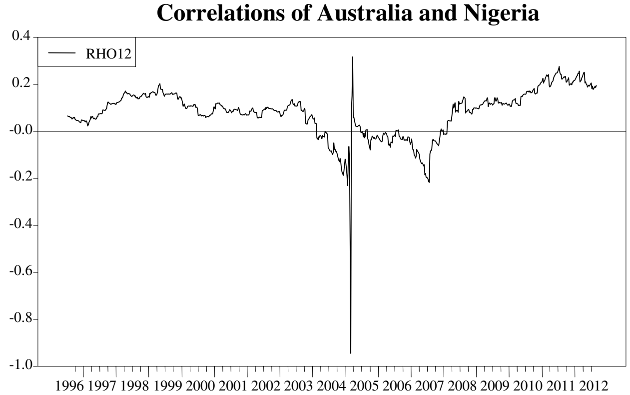
Correlations of Australian and Kenya



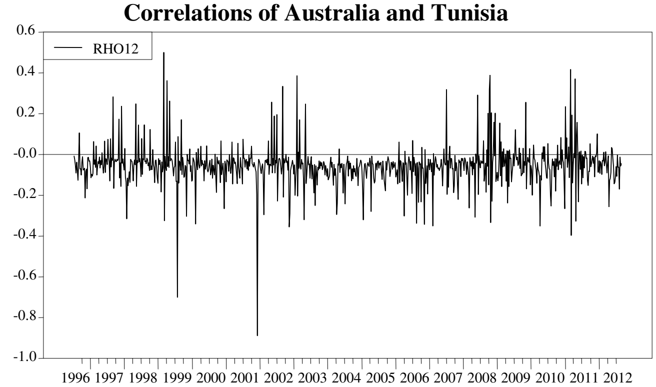
Correlations of Australia and Mauritius



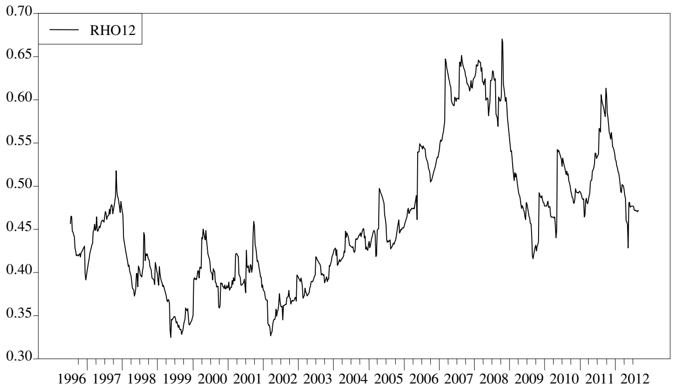
Correlations of Australia and Nigeria



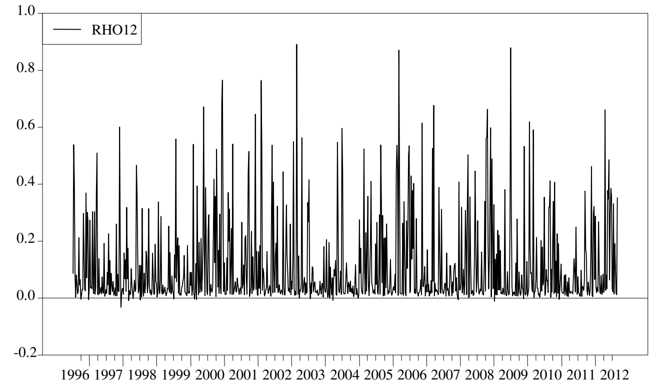
Correlations of Australia and Tunisia



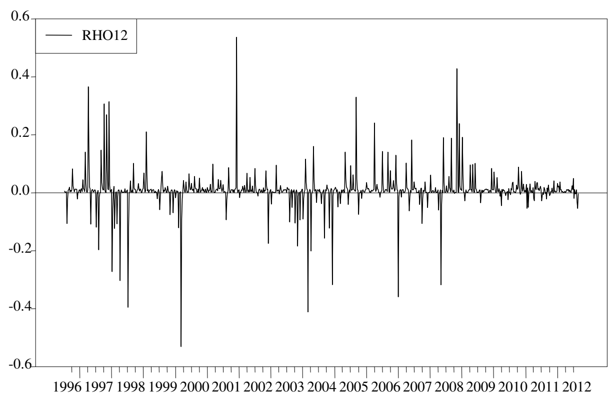
Correlations of Australia and Argentina



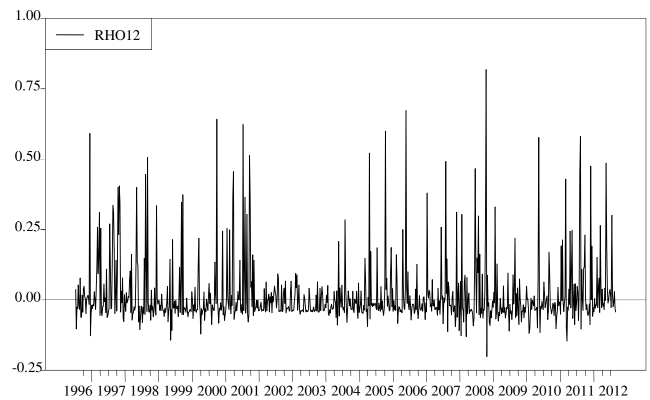
Correlations of Australia and Jamaica



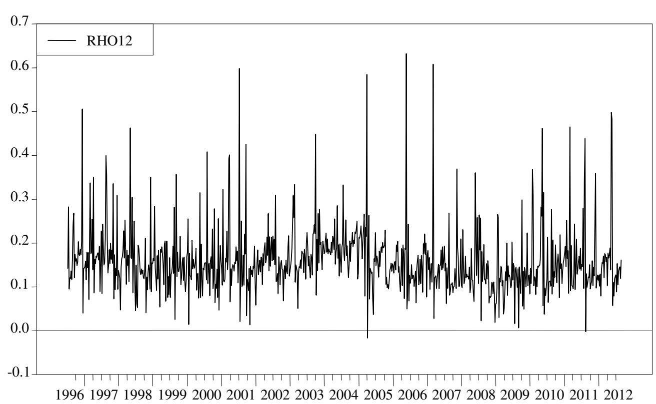
Correlations of Australia and Trinidad & Tobago



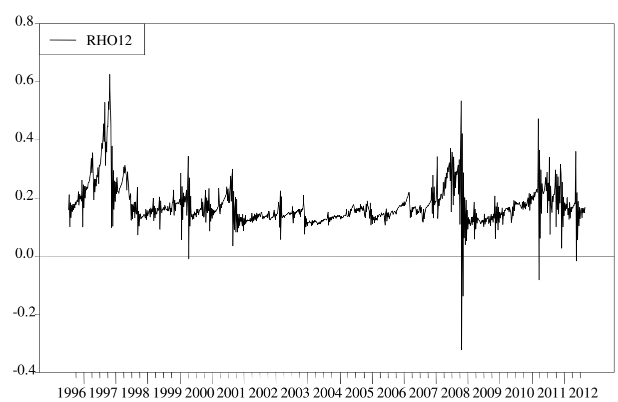
Correlations of Australia and Bangladesh



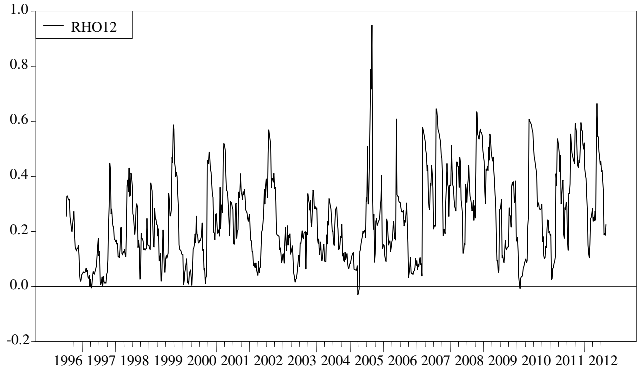
Correlations of Australia and Pakistan



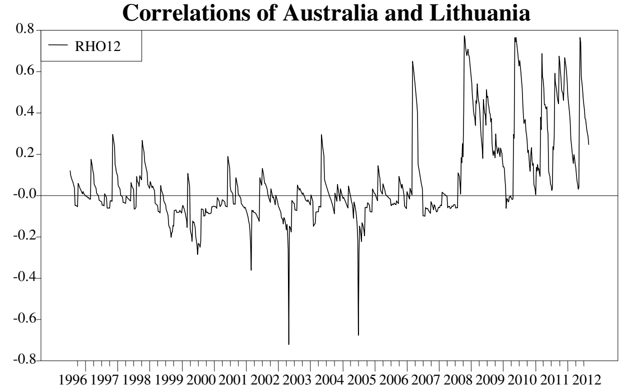
Correlations of Australia and Sri Lanka



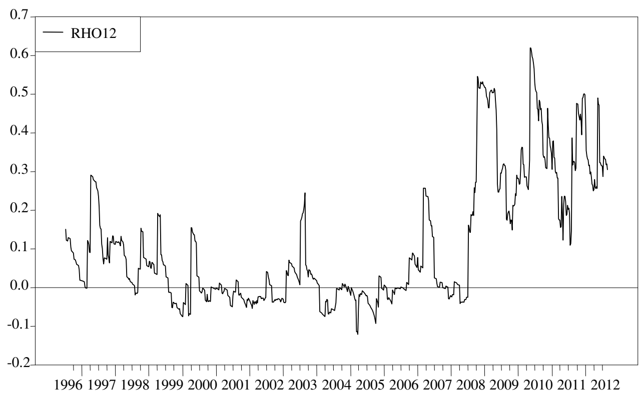
Correlations of Australia and Estonia



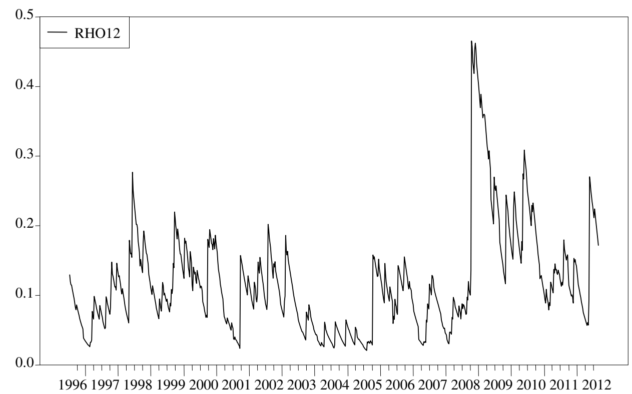
Correlations of Australia and Lithuania



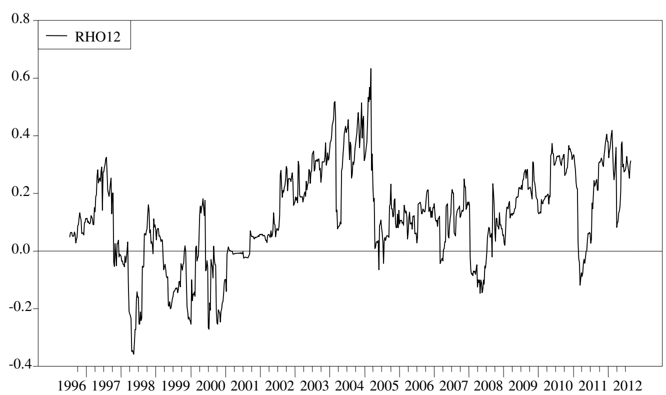
Correlations of Australia and Slovenia



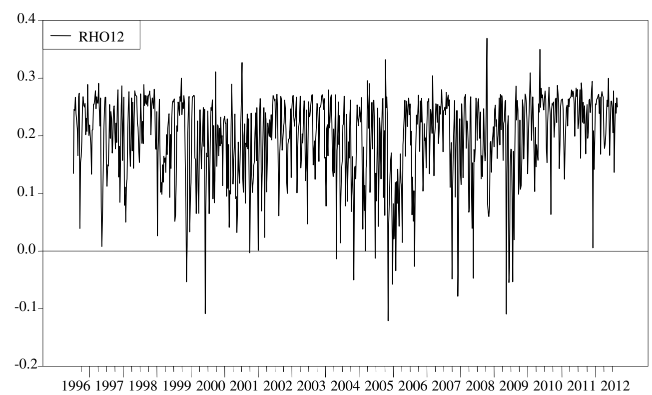
Correlations of Australia and Jordan



Correlations of Australia and Kuwait



Correlations of Australia and Lebanon



Long-Run Equilibrium Relationship

The unit root (ADF and PP) tests confirm that the underlying price series have the same order of integration i.e. I (1) and or non-stationary at levels. This gives an indication to explore the long-run relationship among the stock markets of Australia and eighteen frontier markets from five different regions of the world. In order to investigate the long-run relationship among these markets we applied Johansen's multivariate cointegration test. We use Johansen's cointegration test under the assumption that there is a linear deterministic trend in the data series and have only intercept in the cointegrating equations. Further, we exercise VAR (Vector Autoregressive) based cointegration methodology developed by Johansen (1988 & 1991) to investigate the long-run relationship among the stock markets. This VAR based cointegration methodology requires an appropriate lag length that needs to be used in the analysis. Hence, we selected the lag length based on the Akaike Information Criterion (AIC) and confirmed using autocorrelation LM test that the selected lag length residuals are random.

The empirical results of multivariate cointegration test are reported in Table 4. The results of cointegration test show that there is no evidence of long-run equilibrium relationship of Australian stock market with those of frontier markets of Africa, Americas, Asia, Europe and Middle East. Our results of cointegration test suggest that Australia has no long-run relationship with these frontier markets. These results therefore imply that there are potential portfolio diversification opportunities for the investors.

Table 4: Results of multivariate cointegration test

Null Hypothesis	λ_{trace}	Critical Values (0.05)	$\lambda_{\max}$	Critical Value (0.05)
		Australia-Africa		
$r = 0$	101.567	125.615	35.739	46.231
$r \leq 1$	65.828	95.754	24.248	40.078
$r \leq 2$	41.580	69.819	16.796	33.877
$r \leq 3$	24.784	47.856	10.019	27.584
$r \leq 4$	14.765	29.797	7.494	21.132
$r \leq 5$	7.271	15.495	5.461	14.265
$r \leq 6$	1.810	3.841	1.810	3.841
		Australia-Americas		
$r = 0$	35.821	47.856	17.702	27.584
$r \leq 1$	18.119	29.797	9.041	21.132
$r \leq 2$	9.078	15.495	6.143	14.265
$r \leq 3$	2.934	3.841	2.934	3.841
		Australia-Asia		
$r = 0$	36.899	47.856	18.689	27.584
$r \leq 1$	18.210	29.797	12.229	21.132
$r \leq 2$	5.981	15.495	5.943	14.265
$r \leq 3$	0.038	3.841	0.038	3.841
		Australia-Europe		
$r = 0$	24.099	47.856	12.019	27.584
$r \leq 1$	12.079	29.797	6.044	21.132
$r \leq 2$	6.036	15.495	4.899	14.265
$r \leq 3$	1.137	3.841	1.137	3.841
		Australia-Middle East		
$r = 0$	44.564	47.856	21.164	27.584
$r \leq 1$	23.400	29.797	11.121	21.132
$r \leq 2$	12.279	15.495	6.738	14.265
$r \leq 3$	5.541	3.841	5.541	3.841

Note: The null hypothesis of no cointegrating vector is not rejected for all the case at 5 percent significance level.

Identifying the Direction of Causality

The aim of this section is to explore the direction of causality between the stock markets of Australia and eighteen frontier markets of five regions. It is well documented in the literature that Granger causality test results are sensitive to the lag length selected in the analysis. Therefore, we use AIC to select the appropriate lag length and also confirmed the selected lag length residuals are random. The results of causality test on stock returns are presented in Table 5. We applied Granger causality test on the pairwise markets that is, Australia and each of the frontier markets. The null hypothesis of no Granger causality is tested against the alternative hypothesis of Granger causality. The causality test results demonstrate that the null of hypothesis of Australia does not Granger cause the markets of Kenya, Nigeria, Pakistan, Sri Lanka, Estonia, Lithuania, Kuwait is rejected at 5 % significance level. The Granger causality test results therefore suggest that Australia Granger causes only few frontier markets and no evidence of reverse causality from these markets. Hence, we conclude that the flow of information from Australian market to frontier markets is limited to only few markets and no influence of frontier markets on Australian market.

Table 5: Granger causality test results on stock returns

Null Hypothesis	F- test	Causality
Africa		
Botswana does not Granger Australia	0.325	No Causality
Australia does not Granger Botswana	1.115	
Ghana does not Granger Australia	0.123	No Causality
Australia does not Granger Ghana	0.507	
Kenya does not Granger Australia	0.563	Unidirectional Causality
Australia does not Granger Kenya	8.713**	
Mauritius does not Granger Australia	0.518	No Causality
Australia does not Granger Mauritius	2.501	
Nigeria does not Granger Australia	2.548	Unidirectional Causality
Australia does not Granger Nigeria	3.174**	
Tunisia does not Granger Australia	0.218	No Causality
Australia does not Granger Tunisia	0.576	
Americas		
Argentina does not Granger Australia	0.922	No Causality
Australia does not Granger Argentina	1.634	
Jamaica does not Granger Australia	1.295	No Causality
Australia does not Granger Jamaica	0.542	
Trinidad & Tobago does not Granger Australia	2.023	No Causality
Australia does not Granger Trinidad & Tobago	0.396	
Asia		
Bangladesh does not Granger Australia	0.830	No Causality
Australia does not Granger Bangladesh	0.717	
Pakistan does not Granger Australia	0.123	Unidirectional Causality
Australia does not Granger Pakistan	3.202**	
Sri Lanka does not Granger Australia	0.642	Unidirectional Causality
Australia does not Granger Sri Lanka	6.369**	
Europe		
Estonia does not Granger Australia	0.789	Unidirectional Causality
Australia does not Granger Estonia	5.325**	
Lithuania does not Granger Australia	1.861	Unidirectional Causality
Australia does not Granger Lithuania	2.235**	
Slovenia does not Granger Australia	0.606	No Causality
Australia does not Granger Slovenia	1.826	
Middle East		
Jordan does not Granger Australia	1.291	No Causality
Australia does not Granger Jordan	1.905	
Kuwait does not Granger Australia	0.633	Unidirectional Causality
Australia does not Granger Kuwait	2.444**	
Lebanon does not Granger Australia	0.439	No Causality
Australia does not Granger Lebanon	1.107	

Where '**' indicate the rejection of null hypothesis of no Granger causality at 5 percent significance levels.

5 Conclusion

The motivation for this study is that the international portfolio diversification benefits have been significantly reduced due to the increasing stock markets integration across the world. Particularly, stock markets of developed countries are highly correlated. The literature on the correlations of developed and frontier markets are very scant. However, there are few studies which have explored the stock markets' interdependence between the developed and frontier markets. The empirical findings of these studies document that there are weak correlations among the developed and frontier markets. Therefore, this gives significant motivation to explore the time-varying correlations between Australia and frontier markets of five different regions of the world. We also aim to examine the long-run relationship and direction of causality among these markets.

The empirical results of AGDCC GARCH model demonstrate that the Australian stock market correlations with the frontier markets are changing over time. Results show that in few instances Australia has higher correlations with the markets of Ghana, Estonia, Kenya, Jamaica, Botswana and Bangladesh. Largely, our correlations results display that Australia has weak correlations with all the frontier markets of five different regions. We also found that the impact of recent GFC on the correlations of Australia and frontier markets is also limited to only few markets. Further, our analysis shows that the GFC has no influence on the frontier markets of Asia. Therefore, our results of AGDCC model confirm that there are potential opportunities for the Australia investors to diversify their portfolios into these frontier markets for gaining higher risk-adjusted returns.

We further explored whether Australian stock market is cointegrated with those of frontier markets. We applied cointegration methodology on the stock markets of Australia and a group of frontier markets from each of five regions. Our cointegration test results show that Australian stock market has no long-run relationship with the group of frontier markets. Therefore, these results also support the view that investors have an opportunity to diversify their portfolios into these markets. Similarly, we also investigated the direction of causality between the markets of Australia and each of the frontier markets. The causality test results show that Australian stock market drives the markets of Kenya, Nigeria, Pakistan, Sri Lanka, Estonia, Lithuania and Kuwait. Results also show that there is no evidence of reverse causality from these markets to

Australia. Overall, the causality test results show that the Australian stock market drives the few frontier markets and no evidence of reverse causality from these markets to Australia.

Our empirical finding therefore confirms that Australian stock market has weak correlations with the frontier markets of Africa, Americas, Asia, Europe and Middle East. We also found that the influence of GFC on the correlations of Australia and frontier markets is limited to only few markets. Our analysis shows that Australian stock market is not cointegrated with those of frontier markets. Hence, this study has important practical implications. Our analysis confirms that there are potential portfolio diversification benefits for the Australian investors those who wish to diversify their investments into these frontier markets. This study contributes to the body of knowledge by providing empirical evidence on the stock market linkages between Australia and frontier markets of five regions. To the best of our knowledge this is the first study to consider the frontier markets from five different regions of the world. This study also adds to the literature on how market correlations are changing between developed and frontier markets. In this context, this is also the first study to use the AGDCC GARCH model to measure time-varying correlations. Our study is also the first study to explore the impact of the GFC on the stock market correlations of Australia and frontier markets. Hence, our study has important practical implications in the perspective of portfolio diversification into frontier markets. Our results are similar to those of Sukumaran et al. (2015) who also argue that Australian investors can benefit by diversifying their portfolios into frontier markets. However, our approach in this study is significantly different from their study.

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