TO NOTE: *This paper is currently in development, with further analysis underway*

Testing Market Efficiency across the GFC:

A Sectorial Approach to the Case of Australia

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Abstract: This paper applies a range of tests for weak-form market efficiency to the Australian Stock Exchange across the period of the GFC. In particular, we aim to answer the following question: can we detect changes in the efficiency of the market during the period of volatility and disruption associated with the GFC, and observe any divergence in market efficiency across sectors that demonstrate differing market performance? Spanning a time period of 2000 to 2015, the data is cleaved into three periods of distinct economic conditions: a pre-crisis period of relatively high growth, the GFC period of disruption and contraction, and a post-GFC period of relatively low growth. Furthermore, market returns are split into five industry indices to search for evidence of market inefficiency in those sectors (real estate, consumer discretionary, financials, materials and metals, and mining). A range of tests are applied in order to systematically investigate the structure of the market in each sector. The sectorial divisions demonstrate that the mining sector, a relatively strong sector, is marginally more efficient than the others.

Keywords: Weak Form Efficiency.

JEL Classification: G14 – Market Efficiency.

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I. Introduction

Weak form market efficiency is obtained when current stock prices are said to "fully reflect" all historical market information (Fama, 1970). Such information includes prices, trading data, and any other information which may affect share prices. Weak form efficiency implies that arbitrage opportunities will not persist within an efficiently functioning market. If arbitrage opportunities do appear, they will be quickly eliminated as the market self-corrects to ensure stock prices reflect their fundamental values. Thus it can be said that an efficient stock market will be one that displays price movements that appear to be random and unpredictable.

While Fama's weak form variant of the Efficient Market Hypothesis is the least demanding, empirical support for the hypothesis has been inconsistent. While many studies support the hypothesis, some do not, and a more nuanced understanding of stock return predictability has emerged that emphasises adaptive markets, which can evolve toward efficiency after periods that depart from efficient behaviour (see Lim and Brooks, 2011). Furthermore, the results differ across testing methodologies, and also the contexts. During periods of financial crisis, for example, levels of market efficiency seems to decrease. Studies of the 1997 Asian financial crisis demonstrate higher levels of inefficiency during the crisis (Lim, Brooks, and Kim: 2008), and that these disruptions can affect individual sectors differently (Lim, 2008a and 2008b).

The Australian economy is a particularly interesting context in which to revisit the Efficient Market Hypothesis, and continue to develop our understanding of market efficiency. The Australian economy is one that, in recent times, is understood to have accommodated sectors with significant differences in performance. The "two-speed" economy incorporated booming sectors that attracted high levels of capital investment. Mining and Real Estate were seen to be high performing sectors in the lead of up to the GFC, and the mining industry was demonstrated resilience both during and after the GFC. During the same period, other sectors were negatively affected by the relatively high value of the Australian currency. Manufacturing and tourism, for example, struggled in comparison to the booming sectors.

This paper contributes to the literature by testing market efficiency in different sectors of the Australian economy, in an effort to investigate whether market efficiency diverges between each sector. In the next section we review the previous studies of the Australian stock market to note the context of our own investigation. In section three we introduce our data, time-frame, and explore the descriptive statistics of the data set. Section four presents our tests and the results of each, while in section five we offer a brief conclusion.

2. Previous Tests of the Australian Share Market

The previous studies of the Australian share market demonstrate a series of different approaches and methodologies, and generate a range of results. An early study undertaken by Groenewold & Kang (1993) investigated semi-strong form efficiency on four capitalisation-weighted indices for the period 1980 to 1988. As weak form efficiency is a necessary condition for semi-strong form efficiency to be present, the authors employed a two stage process to investigate semi-strong market efficiency. Box-Ljung portmanteau autocorrelation tests, Lagrange-Multiplier tests, and Phillips-Perron unit root tests were employed to ascertain if the indices exhibited weak form market efficiency. The tests indicated no autocorrelation within the four tested series with the all the series containing a unit root. The second stage of the methodology employed six different forecasting multiple regression equations to test for semi-strong form market efficiency using the share prices of the four indices as the dependent variable, and a number of macroeconomic measures as the independent variables, i.e., money supply, real government expenditure, price level and a risk-free rate of return. Overall, the results are consistent with the presence of semi-strong market efficiency within the four indices under investigation.

Worthington and Higgs (2009) tested for extreme long run random walk behaviour of the All Ordinaries Price Index and its predecessor from the Sydney Stock Exchange. The authors employed monthly and daily continuously compounded closing price returns for the period 1875 to 2006. Both end-of-month and end-of-day data was utilised given the extreme long run nature of the time period investigated. The sample is divided into two overlapping periods: a monthly series for the period 1875 to 2005 and a daily return series from 1958 to 2006. It is interesting to note that the results indicate non-normal distributions within the series with the returns exhibiting leptokurtosis and negatively skewed returns. The results of the study show that the daily return series rejects the presence of random walk, which is a result of short term autocorrelation present within the indices. Tests for serial correlation highlight inefficiency within the daily returns with there being a presence of efficiency in the monthly returns. The interesting aspect of these results is that efficiency is not observed (i.e., random walk rejected) when daily returns are tested. This was over the shorter time period (1958 to 2006). However, the monthly returns do support random walk (1875 to 2005).

Narayan (2005) focuses on the non-linear properties of stock prices for Australia and New Zealand, and whether or not these data sequences are characterized by a unit root. Using monthly returns from both countries, Narayan first confirms statistical evidence for non-linearity in stock returns, using a methodological approach based on the work of Caner and Hansen (2001). Furthermore, the author finds that the stock price series for both countries is a nonstationary process. Narayan (2005) also notes an important implication of nonlinearity in stock prices.[1]

Hasanov (2009) extends on the work of Narayan (2005) explained above. The work of Hasanov is motivated by an interpretation of regime switching that assumes smooth switching rather than the discrete regime switching implicit in the TAR model introduced by Caner and Hansen (2001) and applied by Narayan (2009). To achieve this, Hasanov applies a unit root test that incorporates "…a more general nonlinear framework where the transition between regimes occurs in a smooth manner, rather than instantaneously." (Hasanov, 2009: 269). Specifically, Hasanov uses the nonlinear unit root test developed by Kapetanios *et al*. (2003). Hasanov also suggests that the interaction of heterogeneous agents and their differing beliefs may also contribute to deviations from the fundamental equilibrium (2009: 269).[2] The results of Hasanov contrast with those of Narayan, and the author finds the market to depart from the efficient market hypothesis. The null hypothesis of unit root is rejected for both the Australian and New Zealand stock price series, at the 1% and 5% significance level respectively. This result suggests that weak form efficiency does not hold in these markets.

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[1] "Indeed, if stock prices are nonlinear then univariate and panel unit root tests based on ADF type models, because they are based on the assumption that the data generating process is linear, will give misleading results on whether or not the efficient market hypothesis holds." (Narayan, 2005: 2165)

[2] He also notes the following:

> "The economic theory suggests a number of sources of nonlinearity in the financial data. One of the most frequently cited reasons of nonlinear adjustment is presence of market frictions and transaction costs. Existence of bid-ask spread, short selling and borrowing constraint and other transaction costs render arbitrage unprofitable for small deviations from the fundamental equilibrium. Subsequent reversion to the equilibrium, therefore, takes place only when the deviations from the equilibrium price are large, and thus arbitrage activities are profitable." (Hasanov, 2009: 269).

Finally, in an alternative approach, Simmons (2012) applies a differential evolutionary algorithm using Australian share data from 2000 to 2008. Using the DEA to make forecasts and run an options trading strategy, Simmons' approach outperforms a "buy and hold" strategy. His results suggest that such new methodologies have the potential to make supernormal profits, but only temporarily.

3. Data and Descriptive Statistics

Following Lim (2008a), who argues that aggregate analysis has the potential to mask the effect of financial crises on individual economic sectors, we use disaggregated indexes to consider the market returns. Specifically, the five indices used are the ASX 200 A-REITs, ASX 200 Consumer Discretionary, ASX 200 Financials Excluding A-REITs, ASX 200 Materials and ASX 300 Metals and Mining. These will capture, to some extent, the diverging performance of the Australian economy during the period of study. Furthermore, we cleave this data into three distinct time periods, pre-crisis period, a crisis period, and a post-crisis period. We have defined these sections as the pre-GFC period from 31 March 2000 to June 2008, the Crisis period from 1 July 2008 to 29 January 2009 and the post-GFC period from 1 February 2010 to 31 December 2015. This is across a total time period of 15 years, and is comparable to the time-length of Lim et al (2008) who use 13 year time period to isolate the impact of the Asian financial crisis.

Our testing of these indices across the data begins with a range of diagnostic tests for the normality of stock returns, which assist in understanding the distribution. The measure of Kurtosis suggests that the daily returns for the five indices are leptokurtic in nature for the entire study period. Furthermore, all five indices reject the null hypothesis of normal distribution during the study period, a conclusion that is confirmed by the Jacque-Bera (JB) Test. This is presented in Table 1. For all indices, the calculated JB statistics are greater than 5.99 with their corresponding p-values less than 0.001, further reinforcing rejection of the null hypothesis of normal distribution. Skewness-Kurtosis (SK) tests were employed to ascertain the distribution of the series and to verify the results of the Jacque-Bera (JB) test. The skewness and kurtosis statistics are calculated separately and then combined into an overall test statistic. Whilst most empirical testing within this field utilises the Kolmogorov-Smirnov test to ascertain the normality of the distribution, the current study applies the SK test as a more powerful goodness of fit measure (Ghasemi & Zahediasl 2012).

The Shapiro-Wilk W test provided a comparison of the scores within the series to a normally distributed sample of scores encompassing the same mean and standard deviation.

Unlike the Kolmogorov-Smirnov goodness of fit test, the Shapiro-Wilk W test is a more powerful econometric tool as it is not sensitive to extreme values and is better able to ascertain whether the sample derives from a non-normal distribution (Ghasemi & Zahediasl 2012). The Shapiro-Francia W' test was carried out to verify the results of the Shapiro-Wilk W Test.

Table 2 presents the results for the entire study period with all five indices clearly rejecting the null hypothesis of normal distribution as all the p-values are less than the alpha of 0.001. Furthermore, this result is similar to those attained when the JB Test was applied. Table 3 summarises the sub-period test results. All indices under consideration for all three sub-periods strongly reject the null hypothesis at the 1% level of significance. The results are found to be consistent with the sub-period JB test results. The results for the Shapiro-Wilk W test for the entire sample period is summarised in Table 4. All five indices reject the null hypothesis of normal distribution at 1% level of significance. Series with normal distributions have a V statistic equal to one, thus large V statistics for all indices indicate the non-normality of the series. Larger V statistics result in smaller corresponding W statistics which indicates a non-normal distribution. This further reinforces the non-normality of the distribution for all indices. Using the sub-period data, the results for all five indices indicate non-normal distribution as the null hypothesis is rejected at the 1% level of significance. The V statistics are the largest during the pre-GFC period for all five indices; however, all indices exhibit smaller V statistics during the Crisis period and the post-GFC period.

The results of the Shapiro-Francia W' test for the entire sample is shown in Table 6. The findings are consistent with Shapiro-Wilk W Test with all five indices rejecting the null hypothesis at the 1% level of significance. The Shapiro-Francia V' statistics follow a similar pattern to the Shapiro-Wilk V statistic with the large V' statistics further validating non-normality of the series. Table 7 provides a summary of the results segmented into sub-periods. In the pre-GFC period, all indices reject the null hypothesis as the p-values are less than the alpha of 0.001, once again indicating a non-normal distribution. During the pre-GFC period, all five indices record large V' statistics; with the largest V' statistic exhibited by the ASX 200 A-REITs index. This result also follows the findings of the Shapiro-Wilk W test. Likewise, the Shapiro-Wilk W test results reveal that during the GFC period and post-GFC period, results for all five indices report non-normality at the 1% level of significance.

In summary, all four tests conducted to ascertain normality of the distribution reject the null hypothesis as the indices are leptokurtic in nature. Modern financial theory models investor preference through an assumption of mean-variance behaviour. Thus, an investor's expected-utility maximisation is modelled assuming quadratic utility functions or on the notion that stock returns are normally distributed (Bodie et al. 2007). However, if information is not transmitted to the market in a linear fashion, or market participants do not react to all available information in a linear fashion, a leptokurtic stock distribution may prevail (Aparicio & Estrada 2001). Based on the normality test results of the five indices, it could be argued that information may have been transmitted to the market in clusters rather than in a linear fashion, resulting in investor behaviour mirroring the flow of information into the market. Therefore, while weak-form efficiency is confirmed in some of the tests outlined below, the leptokurtic distribution of information results in non-normal distribution for the series under consideration. In addition, the leptokurtic nature of the series reflects large fluctuations or volatility within the tails of the distribution. However, these erratic movements may not be the result of the arrival of new information into the market or a result of changes within fundamental economic variables. The high volatility present within the heavy tails of the indices' returns may be attributed to crowd effects or herd behaviour within the stock market wherein market participants attempt to imitate each other's trading strategies to achieve stock returns (Cont and Bouchaud, 2000).

4. Outline of Tests and Results

In this section we introduce three types of tests used to gauge market efficiency in stock returns. These three types of tests are: 1. Tests for Randomness and Autocorrelation, 2. Tests for Unit Root, and 3. Runs Tests. After a basic description of each test, the results are reported and discussed.

4.1 Tests for Randomness and Autocorrelation

The Lo-Mackinlay Variance Ratio Test is the most commonly used econometric tool to test for randomness (Hoque, Kim & Pyun 2007). The test is modelled on the underlying statistical property that if the price of a stock emulates a random walk, then the variance of the j-period return is equal to j times the variances of the one period return. The null hypothesis states that the variance ratio (VR) should approximate to one when markets are confirmed as weakly efficient. When the random walk hypothesis is rejected and VR > 1, the series returns are positively correlated. Conversely, when VR < 1, the series returns are negatively correlated. Similar to the methodologies within this field, sixteen lags were applied to this test at 1% level of significance to determine market efficiency or lack thereof with respect to the selected stock indices.

Variance Ratio tests were also performed for the entire study period and the three segmented periods to ascertain randomness of the series. Table 9 provides a representative overview of the findings of the Variance Ratio test for the entire study period. At the first lag, the variance ratios for all five indices are equal to 1, proving that the market is weak form efficient. However, the statistical output does not provide a test statistic or p-value for the first period, thus casting doubt upon the reliability of the result. The lack of a p-value and test statistic for the first period is justified by the fact that previous literature reports the findings of the Variance Ratio test starting from lag 2 only, indicating that the first period findings may not be accurate (Patel, Radadia & Dhawan 2012; Mustafa & Ahmed 2013; Mehla & Goyal 2012).

For all subsequent periods (periods 2 to 16) the variance ratio is less than 1, highlighting the returns for all five indices are negatively serially correlated. Therefore the series reverts to the mean illustrating consistency over time (Patel, Radadia & Dhawan 2012). Thus, the five indices for all three periods reject the null hypothesis of weak form efficiency from lags 2 to 16 at the 1% level of significance. It follows then that all five indices do not follow a random walk and are autocorrelated for the first-order with the variance ratio being a sum of the unit value and the first-order autocorrelation coefficient estimator (Patel, Radadia & Dhawan 2012).

For all lags the results yielded by the Lo-Mackinlay Variance Ratio test rejects the notion of weak form efficiency for the five stock indices for the entire study period, indicating mean reversions within the indices. Evidence of mean reversion over lagged periods suggests the potential of positive expected profit for investors through defying traditional investment strategies and purchasing poorly performing stocks while selling well performing stocks (Poterba & Summers 1988).

Breusch-Godfrey Higher Order Serial Correlation test was employed as an alternative to the Autocorrelation Function test, which is the most common empirical method utilised in the literature. The test examines the relationship between the error term (u_t) and its lagged values at the same time. The Breusch-Godfrey test is not constrained by the limitations present with the Autocorrelation Function test thereby yielding a more accurate result pertaining to the presence of serial dependence (Gupta & Yang 2011). The test has been undertaken at fourteen lags for both the entire sample period and the segmented periods.

Breusch-Godfrey Higher Order Serial Correlation tests were carried out on the five indices for both the entire sample and the segmented time periods to investigate the assumptions of the random walk model. Table 12 provides an overview of the findings. For the entire study period, the ASX 200 A-REITs index rejects the null hypothesis of no serial correlation for all lags at the 5% level of significance. The ASX 200 Materials and ASX 300 Metals & Mining exhibit no serial correlation at the 5% level of significance for all lags while the ASX 200 Consumer Discretionary index shows evidence of serial correlation from lags 7 to 14. The ASX 200 Financials Excluding A-REITs index exhibits mixed results with the series accepting the null hypothesis at lags 1, 2, 4 to 7 while showing serial dependence for lags 3 and 8 to 14.

In terms of the sub-periods, results for the pre-GFC time frame show the ASX 200 Materials and ASX 300 Metals & Mining index accept the null hypothesis at the 5% level of significance implying no serial correlation at all tested lags. Furthermore, the ASX 200 Financials Excluding A-REITs is efficient from lags 1 to 4 with the series rejecting the null hypothesis from lag 5 onwards. It can be concluded that the index shows no serial correlation as the results show an acceptance of null hypothesis at the 5% level of significance for the first three lags. The ASX 200 Consumer Discretionary is has mixed results with the series accepting the null hypothesis at certain lags and rejecting it at others. However, the ASX 200 A-REITs exhibits serial dependence from lags 3 to 14 but with no serial dependence for lags 1 and 2.

During the GFC period, the ASX 200 A-REITs, ASX 200 Consumer Discretionary and ASX 200 Financials Excluding A-REITs indices exhibit serial dependence at later lags with lags 1 to 4 accepting the null hypothesis of independent successive occurrences at the 5% level of significance. The ASX 200 Materials and ASX 300 Metals & Mining indices accept the null hypothesis as all p-values at all lags are greater than the specified alpha of 0.05. A representative overview is summarised in Table 14 and Appendix 6 details the comprehensive findings. Overall, the analysis supports the presence of weak form efficiency during the Crisis period.

Finally, for the post-GFC period, results show serial dependence at the 5% level of significance for the ASX 200 A-REITs index as the series only accepts the null hypothesis for lag 1 with all subsequent lags rejecting the null. The ASX 200 Consumer Discretionary and ASX 200 Financials Excluding A-REITs indices accept the null hypothesis for lags 1 to 4 as all p-values are greater than 0.05. However, the ASX 200 Materials and ASX 300 Metals & Mining indices show no serial correlation for all lags, with the exception of lag 10. Nonetheless, overall, these results are similar to those attained during the Crisis period.

The Breusch-Godfrey Higher Order Serial Correlation test yielded mixed results for the indices. All indices show evidence of serial correlation at certain lags whilst exhibiting no correlation at others. The findings of no serial correlation at most lags for ASX Materials and ASX 300 Metals & Mining indices could be a result of the mining boom in the Australian economy over the past decade. A steady increase in the demand for commodities from rapidly industrialising Asian nations such as China and India could have attributed to the efficient allocation of capital and labour to the materials, metal and mining sectors (Minerals Council of Australia 2012). Furthermore, there has been a rollover effect of mining into companies listed on the Materials index who substantially benefit from mining service revenue (Minerals Council of Australia 2012). These factors may have been reflected in the indices' share price thereby resulting in weak form market efficiency as it provides accurate signals for resource allocation within the Australian economy.

Urquhart & Hudson (2013, p. 130) argue that 'it is reasonable to expect market efficiency to evolve over time due to varying underlying market factors such as institutional, regulatory and technological changes and possibly the demography behaviour of market participants'. Therefore, it can be postulated that on average, the five ASX indices display weak form efficiency with there being periods of inefficiency which may have occurred due to investors attempting to achieve excess returns or overreaction or under reaction to newly released information.

4.2 Unit Root Tests

Unit root tests will enable us to ascertain whether the series exhibit a random walk or not. Unit root tests statistically investigate the proposition that in a time series autoregressive model, the autoregressive parameter is equal to one. Autoregressive refers to the fact that the error now is influenced by the error in the previous period or periods. In the context of the current study, it implies that the shock in the previous period is related to the shock now. Due to the lack of one robust test for unit root (Stock 1994), both a parametric Augmented Dickey-Fuller test is carried out and a non-parametric Phillips-Perron test is also applied. It is important to note that a feature of unit root test involves a two stage process. The first stage involves determining that the calculated market return does exhibit stationarity. In this case, the rejection of the null hypothesis of unit root is a sufficient condition to carry out tests for weak form market efficiency. The second stage requires the raw daily closing share price of each index to exhibit non-stationarity. For these tests, an acceptance of the null hypothesis will help confirm the existence of unit root.

The five indices under investigation were modelled as a random walk, random walk with a drift, and a random walk with drift and trend, at five lags to ensure validity and reliability of the results. As the sample period is significantly large with multiple series being investigated, a maximum lag of 5 has been chosen, as is common within this field of research. Tests were undertaken on both the calculated market return and the raw daily closing share price of the five indices for the entire study period and sub-periods. The results of these two stages are discussed below.

The results reveal that the calculated market return for all five indices rejects the null hypothesis of unit root at 1%, 5% and 10% respectively for both the sub-divided periods and the entire sample period at all five lags. Such a result is consistent with the literature present indicating that all five series are integrated order one, I(1).

Using the entire sample period for the raw share price, all five indices exhibited different forms of random walk and accepted the null hypothesis of non-stationarity for varying lags for different levels of significance (1%, 5% or 10%). Overall, for the entire sample period, it can be posited that all indices exhibit the existence of some form of unit root as the series accept the null hypothesis at the 1% level of significance for differing lags. The results for the sub-periods follow a similar pattern to that of the entire sample period. When sub-period data was used, once again, the raw share price of all five indices exhibited different forms of random walk.

From a sub-period perspective, for the pre-GFC period, the ASX 200 Consumer Discretionary and ASX 200 Financials Excluding A-REITs indices accept the null hypothesis of non-stationarity, with the indices following a random walk, and a random walk with drift and trend. On the other hand, the ASX 200 A-REITs index only follows a random walk. The ASX 200 Materials and ASX 300 Metals & Mining indices accept the null hypothesis of unit root at all three levels of significance for all five lags with the series exhibiting a random walk with drift and trend pattern. During the Crisis period, all five indices show evidence of unit root at the 1% and 5% level of significance. When modelled as a random walk and a random walk with drift and trend, all indices accept the null hypothesis of non-stationarity at 1% level of significance. However, the ASX 200 Materials and ASX 300 Metals & Mining indices are stationary for lags 1 and 2 at the 1% level of significance.

For the post-GFC period, all indices show evidence of non-stationarity with the ASX 200 A-REITs, ASX 200 Consumer Discretionary and ASX 200 Financials Excluding A-REITs accepting the null hypothesis of unit root at all lags. The ASX 200 Materials follows a random walk and random walk with drift pattern. Moreover, the ASX 300 Metals & Mining index exhibits a similar pattern to the ASX 200 Materials index as the series only rejects the null hypothesis at lag 1 at the 10% level of significance when modelled as a random walk with drift and trend. Thus, the results reveal that the series has unit root at the 1% and 5% levels of significance for all lags.

Acceptance of the null hypothesis for the entire study period indicates that the indices' stock prices follow a random walk specification. Thus, investors are unable to forecast stock price movements by utilising any information associated with the previous period's stock price.

The results of the Phillips Perron unit root test results for the calculated market return for each of the five indices for the entire sample and sub-period further reinforce the ADF test results for the calculated market returns of all five indices. Results for the ASX 200 Consumer Discretionary and ASX 200 Financials Excluding A-REITs mirror the ADF test results with both indices exhibiting random walk with a drift and trend characteristics. Furthermore, the ASX 200 Materials and ASX 300 Metals & Mining indices both follow a random walk with drift and trend for all three sub-periods at 1% level of significance.

4.3 Runs Tests

Runs Tests investigate the randomness of the sequence of returns with the null hypothesis testing if successive price changes are independent and move randomly. Such tests were conducted to determine whether price changes within the selected indices are serial or random. This econometric method is appropriate for testing weak form market efficiency as it assists in determining if subsequent price variations should be autonomous to each other. The Runs Test is performed by counting the number of "runs" or the sequence of successive price changes with the same sign i.e. positive, zero or negative with each change classified according to its position with respect to the median test value.

Runs Tests were undertaken for all five indices with the median utilised as the base for the test values. Given that the series analysed does not exhibit a normal distribution (as confirmed by the JB test and others above), the median represents a more effective measure of central tendency. The null hypothesis of temporal independence within the series, or weak form efficiency, is tested through observing the sequence of successive price changes with the same sign. The number of actual runs was compared to the number of expected runs with a test statistic of 1.96 used to reject the null hypothesis and the decisions are based upon the p-value. As detailed in Table 13, the Z statistics for all five indices for the entire sample are less than 1.96, which implies that the successive price changes are not dependent and move randomly at 5% level of significance. This finding is further confirmed by the p-values for the five indices which are found to be greater than 0.05, indicating that the indices were efficient for the entire study period. The findings suggest that investors could not have predicted the market returns for the five indices under study.

Table 14 presents the results for the five indices for all the sub-periods. For the pre-GFC period all indices exhibit weak form efficiency as the Z-statistics are less than 1.96. These findings are similar for the GFC period and the post-GFC period for all five indices, indicating that the indices under consideration follow a random walk. This result implies that investors cannot predict the behaviour of market returns during all three periods.

5. Working Conclusion

In this paper we have conducted preliminary testing on the efficiency of the Australian stock market across the pre and post GFC period. Furthermore, we have disaggregated the stock return data, using five specific industrial indices. The results of this range of tests produce some conflicting evidence regarding market efficiency during this time period. In terms of the five different industrial indices, those indices that are related to the so-called “booming sectors” of the Australian economy appear to operate more efficiently, but this difference is marginal. This early draft paper will be followed by more sophisticated analysis that includes an extensive range of non-linear tests, that will hopefully uncover further evidence of either efficiency, or otherwise.

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Table 1: Summary of Descriptive Statistics

Period	Indices	Mean	Median	SD	Skewness	Kurtosis	Jacque-Bera	P-value	Observations
Pre-GFC Period: 31 March 2000 to 30 June 2008	ASX 200 A-REITS	.0000632	.0000728	.0094083	-1.249354	21.42202	30975.682	0	2151
	ASX 200 Consumer Discretionary	-.0003042	0	.0143236	-.401929	9.171149	3471.1102	0	2151
	ASX 200 Financials Excluding A-REITs	.0002062	.000139	.0099685	-.2616558	9.806221	4176.3899	0	2151
	ASX 200 Materials	.0007482	.000721	.013112	-.3570023	6.426268	1097.8267	0.000	2151
	ASX 300 Metals & Mining	.0007961	.0007404	.0147001	-.346157	5.820796	756.09363	0.000	2151
GFC Period: 1 July 2008 to 29 January 2010	ASX 200 A-REITS	-.0011636	0	.0278205	-.4189985	4.267977	39.847595	0.000	414
	ASX 200 Consumer Discretionary	-.0001109	0	.0163653	-.3925574	4.915856	73.949168	0.000	414
	ASX 200 Financials Excluding A-REITs	.0002287	-.0002501	.0221745	.1472883	4.590324	45.124403	0.000	414
	ASX 200 Materials	-.0007222	0	.0277835	-.3236681	5.176683	88.958112	0.000	414
	ASX 300 Metals & Mining	-.0007175	0	.0293462	-.3430075	5.392034	106.81961	0.000	414
Post-GFC Period: 1 February 2010 to 31 December 2015	ASX 200 A-REITS	.0002547	0	.0098336	.119578	4.184201	93.896295	0.000	1544
	ASX 200 Consumer Discretionary	.0001613	0	.0093162	-.3215875	4.070485	100.335	0.000	1544
	ASX 200 Financials Excluding A-REITs	.0001927	.0003516	.010681	-.2203197	4.682855	194.68329	0.000	1544
	ASX 200 Materials	-.0003258	0	.0133858	-.1577411	3.857342	53.690283	0.000	1544
	ASX 300 Metals & Mining	-.000493	0	.0146951	-.1485223	3.91216	59.204185	0.000	1544
	ASX 200 A-REITS	.0000116	0	.0126737	-.8098818	14.10254	21553.426	0	4109

Entire Study Period: 31 March 2000 to 31 December 2015	**ASX 200 Consumer Discretionary**	-.0001098	0	.0129209	-.4286864	8.9442	6175.2457	0	4109
	ASX 200 Financials Excluding A-REITs	.0002034	.000139	.0120122	-.0417463	8.880988	5922.6085	0	4109
	ASX 200 Materials	.0001965	0	.0153374	-.3965856	8.27548	4872.5567	0	4109
	ASX 300 Mining & Minerals	.0001592	.0000102	.0167702	-.3802424	7.773251	3999.8135	0	4109

Table 2: Skewness Kurtosis Test for Entire Study Period

Entire Study Period	Number of Observations	Pr(Skewness)	Pr(Kurtosis)	Adjusted chi2(2)	p-value
ASX 200 A-REITs	4109	0.0000	0.0000	-	0.0000***
ASX 200 Consumer Discretionary	4109	0.0000	0.0000	-	0.0000***
ASX 200 Financials Excluding A-REITs	4109	0.2740	0.0000	-	0.0000***
ASX 200 Materials	4109	0.0000	0.0000	-	0.0000***
ASX 300 Metals & Mining	4109	0.0000	0.0000	-	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the data is normally distributed

Table 3: Skewness Kurtosis Test for Sub-periods

Period	Indices	Number of Observations	Pr(Skewness)	Pr(Kurtosis)	Adjusted chi2(2)	p-value
Pre-GFC Period: 31 March 2000 to 30 June 2008	ASX 200 A-REITs	2151	0.0000	0.0000	-	0.0000***
	ASX 200 Consumer Discretionary	2151	0.0000	0.0000	-	0.0000***
	ASX 200 Financials Excluding A-REITs	2151	0.0000	0.0000	-	0.0000***
	ASX 200 Materials	2151	0.0000	0.0000	-	0.0000***
	ASX 300 Metal & Mining	2151	0.0000	0.0000	-	0.0000***
GFC Period: 1 July 2008 to 29 January 2010	ASX 200 A-REITs	414	0.0007	0.0003	20.76	0.0000***
	ASX 200 Consumer Discretionary	414	0.0013	0.0000	26.08	0.0000***
	ASX 200 Financials Excluding A-REITs	414	0.2156	0.0000	16.28	0.0003***
	ASX 200 Materials	414	0.0075	0.0000	26.15	0.0000***
	ASX 300 Metal & Mining	414	0.0048	0.0000	28.72	0.0000***
Post-GFC Period: 1 February 2010 to 31 December 2015	ASX 200 A-REITs	1156	0.1727	0.0000	27.87	0.0000***
	ASX 200 Consumer Discretionary	1157	0.0000	0.0000	51.30	0.0000***
	ASX 200 Financials Excluding A-REITs	1157	0.0321	0.0000	42.16	0.0000***
	ASX 200 Materials	1158	0.0183	0.0000	23.01	0.0000***
	ASX 300 Metal & Mining	1157	0.0246	0.0000	22.12	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the data is normally distributed

Table 4: Shapiro-Wilk W Test for Normal Data for the Entire Study Period

Entire Study Period	Number of Observations	W	V	Z	p-value
ASX 200 A-REITs	4109	0.87407	286.318	14.752	0.0000***
ASX 200 Consumer Discretionary	4109	0.94602	122.741	12.543	0.0000***
ASX 200 Financials Excluding A-REITs	4109	0.92811	163.450	13.290	0.0000***
ASX 200 Materials	4109	0.94939	115.073	12.375	0.0000***
ASX 300 Metals & Mining	4109	0.95545	101.293	12.042	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the data is normally distributed

Table 5: Shapiro-Wilk W Test for Normal Data for Sub-periods

Period	Indices	Number of Observations	W	V	z	p-value
Pre-GFC Period: 31 March 2000 to 30 June 2008	**ASX 200 A-REITs**	2151	0.88885	140.844	12.619	0.0000***
	ASX 200 Consumer Discretionary	2151	0.93905	77.226	11.086	0.0000***
	ASX 200 Financials Excluding A-REITs	2151	0.91877	102.929	11.819	0.0000***
	ASX 200 Materials	2151	0.96894	39.358	9.367	0.0000***
	ASX 300 Metal & Mining	2151	0.97534	31.248	8.779	0.0000***
GFC Period: 1 July 2008 to 29 January 2010	**ASX 200 A-REITs**	414	0.97816	6.201	4.349	0.0000***
	ASX 200 Consumer Discretionary	414	0.97764	6.348	4.404	0.0000***
	ASX 200 Financials Excluding A-REITs	414	0.98309	4.800	3.738	0.0000***
	ASX 200 Materials	414	0.97090	8.263	5.033	0.0000***

	ASX 300 Metal & Mining	414	0.96624	9.585	5.387	0.0000***
Post-GFC Period: 1 February 2010 to 31 December 2015	**ASX 200 A-REITs**	1544	0.98736	11.847	6.228	0.0000***
	ASX 200 Consumer Discretionary	1544	0.98982	9.535	5.681	0.0000***
	ASX 200 Financials Excluding A-REITs	1544	0.98058	18.201	7.310	0.0000***
	ASX 200 Materials	1544	0.99198	7.517	5.082	0.0000***
	ASX 300 Metal & Mining	1544	0.99178	7.703	5.143	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the data is normally distributed

Table 6: Shapiro-Francia W' Test for Normal Data for the Entire Study Period

Entire Study Period	Number of Observations	W'	V'	Z	p-value
ASX 200 A-REITs	4109	0.87303	309.197	14.351	0.0000***
ASX 200 Consumer Discretionary	4109	0.94493	134.112	12.261	0.0000***
ASX 200 Financials Excluding A-REITs	4109	0.92719	177.320	12.960	0.0000***
ASX 200 Materials	4109	0.94854	125.327	12.091	0.0000***
ASX 300 Metals & Mining	4109	0.95464	110.451	11.775	0.0000***

Table 7: Shapiro-Francia W' Test for Normal Data for Sub-periods

Period	Indices	Number of Observations	W'	V'	z	p-value
Pre-GFC Period: 31 March 2000 to 30 June 2008	ASX 200 A-REITs	2151	0.88608	152.892	12.097	0.0000***
	ASX 200 Consumer Discretionary	2151	0.93727	84.196	10.662	0.0000***
	ASX 200 Financials Excluding A-REITs	2151	0.91718	111.153	11.330	0.0000***
	ASX 200 Materials	2151	0.96759	43.498	9.074	0.0000***
	ASX 300 Metal & Mining	2151	0.97412	34.731	8.532	0.0000***
GFC Period: 1 July 2008 to 29 January 2010	ASX 200 A-REITs	414	0.97723	6.960	4.205	0.0000***
	ASX 200 Consumer Discretionary	414	0.97540	7.521	4.373	0.0000***
	ASX 200 Financials Excluding A-REITs	414	0.98066	5.914	3.852	0.0000***
	ASX 200 Materials	414	0.96866	9.581	4.898	0.0000***
	ASX 300 Metal & Mining	414	0.96393	11.026	5.202	0.0000***
Post-GFC Period: 1 February 2010 to 31 December 2015	ASX 200 A-REITs	1544	0.98697	12.927	6.030	0.0000***
	ASX 200 Consumer Discretionary	1544	0.98943	10.482	5.536	0.0000***
	ASX 200 Financials Excluding A-REITs	1544	0.97988	19.962	7.053	0.0000***
	ASX 200 Materials	1544	0.99174	8.190	4.954	0.0000***
	ASX 300 Metal & Mining	1544	0.99149	8.439	5.025	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the data is normally distributed

Table 8: Lo-Mackinlay Variance Ratio Test for the Entire Study Period

Indices	Lags	1	2	3	4	5	6	7	8	9	10
ASX 200 A-REITs	**VR**	1.000	0.533	0.370	0.264	0.221	0.181	0.157	0.129	0.112	0.097
	R_S	-	- 29.8885	- 27.0542	- 25.1943	- 22.7648	- 21.2034	- 19.7939	- 18.8462	- 17.9043	- 17.1244
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Consumer Discretionary	**VR**	1.000	0.504	0.348	0.253	0.205	0.171	0.152	0.122	0.111	0.102
	R_S	-	-31.7437	-28.0148	-25.5575	-23.2471	-21.4704	-19.9001	-18.9895	-17.9276	-17.0391
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Financials Excluding A-REITs	**VR**	1.000	0.519	0.353	0.256	0.201	0.173	0.150	0.132	0.110	0.100
	R_S	-	-30.8246	-27.7950	-25.4487	-23.3539	-21.4196	-19.9522	-18.7873	-17.9487	-17.0699
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Materials	**VR**	1.000	0.506	0.344	0.251	0.201	0.167	0.144	0.128	0.113	0.101
	R_S	-	-31.6603	-28.1734	-25.6410	-23.3462	-21.5601	-20.0980	-18.8622	-17.8799	-17.0510
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 300 Metals & Mining	**VR**	1.000	0.510	0.345	0.253	0.202	0.168	0.144	0.129	0.114	0.101
	R_S	-	-31.4066	-28.1281	-25.5768	-23.3207	-21.5337	-20.0976	-18.8488	-17.8664	-17.0421
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the market under study is weak form efficient

Indices	**Lags**	**11**	**12**	**13**	**14**	**15**	**16**
ASX 200 A-REITs	**VR**	0.091	0.087	0.078	0.075	0.073	0.067
	R_S	-16.2944	-15.5822	-15.0504	-14.4738	-13.9662	-13.5702
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Consumer Discretionary	**VR**	0.092	0.084	0.074	0.073	0.067	0.065
	R_S	-16.2783	-15.6224	-15.1140	-14.4975	-14.0489	-13.5959
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Financials Excluding A-REITs	**VR**	0.095	0.086	0.079	0.073	0.068	0.064
	R_S	-16.2261	-15.5947	-15.0229	-14.4984	-14.0415	-13.6093
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Materials	**VR**	0.092	0.087	0.077	0.071	0.067	0.063
	R_S	-16.2792	-15.5787	-15.0567	-14.5279	-14.0500	-13.6270
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 300 Metals & Mining	**VR**	0.092	0.087	0.078	0.072	0.068	0.063
	R_S	-16.2758	-15.5714	-15.0484	-14.5197	-14.0456	-13.6234
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the market under study is weak form efficient

Table 9: Lo-Mackinlay Variance Ratio Test for Pre-GFC Period: 31 March 2000 to 30 June 2008

Indices	Lags	1	2	3	4	5	6	7	8	9	10
ASX 200 A-REITs	**VR**	1.000	0.534	0.368	0.261	0.199	0.167	0.155	0.135	0.114	0.101
	R_S	-	-21.5688	-19.6180	-18.2675	-16.9162	-15.5991	-14.3481	-13.5204	-12.9154	-12.3238
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Consumer Discretionary	**VR**	1.000	0.517	0.354	0.254	0.205	0.172	0.153	0.123	0.113	0.104
	R_S	-	-22.3455	-20.0624	-18.4438	-16.7883	-15.5007	-14.3820	-13.7096	-12.9335	-12.2716
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Financials Excluding A-REITs	**VR**	1.000	0.528	0.348	0.254	0.194	0.165	0.146	0.137	0.112	0.095
	R_S	-	-21.8560	-20.2298	-18.4566	-17.0283	-15.6338	-14.4939	-13.4888	-12.9466	-12.4058
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Materials	**VR**	1.000	0.502	0.321	0.257	0.203	0.166	0.139	0.125	0.110	0.102
	R_S	-	-23.0498	-21.0942	-18.3826	-16.8293	-15.6092	-14.6273	-13.6764	-12.9774	-12.2976
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 300 Metals & Mining	**VR**	1.000	0.507	0.322	0.258	0.205	0.167	0.139	0.125	0.110	0.103
	R_S	-	-22.8183	-21.0534	-18.3483	-16.7952	-15.5962	-14.6206	-13.6638	-12.9723	-12.2929
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the market under study is weak form efficient

Indices	**Lags**	**11**	**12**	**13**	**14**	**15**	**16**
ASX 200 A-REITs	**VR**	0.088	0.087	0.078	0.074	0.071	0.065
	R_S	-11.8060	-11.2546	-10.8519	-10.4843	-10.0880	-9.7947
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Consumer Discretionary	**VR**	0.092	0.086	0.072	0.074	0.068	0.067
	R_S	-11.7546	-11.2619	-10.9206	-10.4787	-10.1271	-9.7803
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Financials Excluding A-REITs	**VR**	0.093	0.089	0.080	0.075	0.066	0.064
	R_S	-11.7446	-11.2321	-10.8277	-10.4711	-10.1434	-9.8133
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Materials	**VR**	0.092	0.084	0.074	0.072	0.067	0.063
	R_S	-11.7630	-11.2976	-10.8954	-10.5090	-10.1340	-9.8172
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 300 Metals & Mining	**VR**	0.092	0.084	0.075	0.072	0.067	0.063
	R_S	-11.7547	-11.2945	-10.8906	-10.5027	-10.1314	-9.8172
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the market under study is weak form efficient

Table 10: Lo-Mackinlay Variance Ratio Test for GFC Period: 1 July 2008 to 29 January 2010

Indices	Lags	1	2	3	4	5	6	7	8	9	10
ASX 200 A-REITs	**VR**	1.000	0.546	0.386	0.278	0.251	0.208	0.176	0.135	0.120	0.098
	R_S	-	-9.1232	-8.2823	-7.7572	-6.8795	-6.4211	-6.0375	-5.8504	-5.5777	-5.3418
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Consumer Discretionary	**VR**	1.000	0.450	0.315	0.237	0.191	0.177	0.171	0.121	0.106	0.101
	R_S	-	-11.0525	-9.2438	-8.1971	-7.4346	-6.6736	-6.0777	-5.9458	-5.6654	-5.3258
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Financials Excluding A-REITs	**VR**	1.000	0.524	0.362	0.259	0.196	0.196	0.174	0.133	0.110	0.111
	R_S	-	-9.5631	-8.6147	-7.9562	-7.3871	-6.5199	-6.0568	-5.8633	-5.6414	-5.2644
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Materials	**VR**	1.000	0.508	0.376	0.232	0.193	0.174	0.159	0.137	0.121	0.110
	R_S	-	-9.8801	-8.4278	-8.2549	-7.4121	-6.7015	-6.1612	-5.8369	-5.5729	-5.2740
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 300 Metals & Mining	**VR**	1.000	0.513	0.380	0.232	0.193	0.175	0.159	0.139	0.122	0.110
	R_S	-	-9.7805	-8.3660	-8.2535	-7.4154	-6.6875	-6.1607	-5.8197	-5.5695	-5.2728
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the market under study is weak form efficient

Indices	Lags	11	12	13	14	15	16
ASX 200 A-REITs	VR	0.101	0.098	0.083	0.085	0.081	0.075
	R_S	-5.0160	-4.7886	-4.6954	-4.4309	-4.3519	-4.2046
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Consumer Discretionary	VR	0.096	0.088	0.081	0.072	0.071	0.065
	R_S	-5.0435	-4.8410	-4.7057	-4.4965	-4.4014	-4.2477
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Financials Excluding A-REITs	VR	0.104	0.088	0.082	0.077	0.073	0.067
	R_S	-4.9980	-4.8411	-4.6994	-4.4688	-4.3906	-4.2399
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Materials	VR	0.099	0.099	0.084	0.078	0.071	0.066
	R_S	-5.0275	-4.7836	-4.6873	-4.4667	-4.3999	-4.2446
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 300 Metals & Mining	VR	0.098	0.100	0.085	0.078	0.071	0.067
	R_S	-5.0295	-4.7778	-4.6824	-4.4628	-4.3996	-4.2408
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the market under study is weak form efficient

Table 11: Lo-Mackinlay Variance Ratio Test for Post-GFC Period: 1 February 2010 to 31 December 2015

Indices	Lags	1	2	3	4	5	6	7	8	9	10
ASX 200 A-REITs	**VR**	1.000	0.506	0.341	0.248	0.203	0.162	0.138	0.125	0.105	0.102
	R_S	-	-19.3512	-17.3217	-15.7243	-14.2535	-13.2629	-12.3897	-11.5673	-11.0291	-10.4018
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Consumer Discretionary	**VR**	1.000	0.510	0.361	0.268	0.220	0.171	0.143	0.130	0.113	0.100
	R_S	-	-19.2062	-16.7954	-15.3101	-13.9433	-13.1170	-12.3132	-11.4913	-10.9256	-10.4257
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Financials Excluding A-REITs	**VR**	1.000	0.503	0.350	0.263	0.223	0.165	0.139	0.132	0.113	0.102
	R_S	-	-19.4551	-17.0707	-15.4231	-13.8917	-13.2144	-12.3717	-11.4642	-10.9332	-10.4063
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Materials	**VR**	1.000	0.505	0.342	0.269	0.214	0.169	0.141	0.133	0.116	0.097
	R_S	-	-19.3704	-17.2825	-15.3017	-14.0513	-13.1556	-12.3332	-11.4594	-10.8977	-10.4582
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 300 Metals & Mining	**VR**	1.000	0.508	0.343	0.271	0.214	0.170	0.142	0.132	0.118	0.099
	R_S	-	-19.2627	-17.2461	-15.2472	-14.0470	-13.1354	-12.3217	-11.4731	-10.8730	-10.4427
	p-value	-	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the market under study is weak form efficient

Indices	Lags	11	12	13	14	15	16
ASX 200 A-REITs	**VR**	0.092	0.080	0.076	0.069	0.067	0.063
	R_S	-9.9504	-9.5807	-9.2225	-8.8982	-8.5879	-8.2986
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Consumer Discretionary	**VR**	0.096	0.082	0.078	0.076	0.069	0.066
	R_S	-9.9061	-9.5560	-9.2100	-8.8265	-8.5686	-8.2737
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Financials Excluding A-REITs	**VR**	0.096	0.089	0.080	0.072	0.070	0.067
	R_S	-9.9075	-9.4833	-9.1836	-8.8660	-8.5638	-8.2667
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 200 Materials	**VR**	0.095	0.087	0.080	0.072	0.070	0.067
	R_S	-9.9195	-9.5033	-9.1890	-8.8719	-8.5676	-8.2661
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***
ASX 300 Metals & Mining	**VR**	0.095	0.088	0.080	0.072	0.070	0.067
	R_S	-9.9162	-9.4944	-9.1818	-8.8696	-8.5605	-8.2663
	p-value	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***	0.0000***

NB: *** implies significance at 1% and rejection of the null hypothesis that the market under study is weak form efficient

Table 12: Breusch-Godfrey Higher Order Serial Correlation Test

Period	Indices	Lags	1	2	3	4	5	6	7	8	9	10
Pre-GFC Period: 31 March 2000 to 30 June 2008	ASX 200 A-REITs	Chi2 p-value	1.154 0.2827	5.493 0.0641	18.846 0.0003**	19.659 0.0006**	20.740 0.0009**	21.039 0.0018**	29.508 0.0001**	33.184 0.0001**	33.196 0.0001**	33.360 0.0002**
	ASX 200 Consumer Discretionary	Chi2 p-value	1.210 0.2713	2.565 0.2773	8.406 0.0383**	8.514 0.0745	8.579 0.1271	8.634 0.1952	12.123 0.0966	17.522 0.0251**	17.630 0.0397**	18.054 0.0541
	ASX 200 Financials Excluding A-REITs	Chi2 p-value	0.984 0.3212	4.164 0.1247	5.978 0.1127	6.000 0.1992	11.214 0.0473**	12.817 0.0460**	12.823 0.0766	21.675 0.0056**	22.158 0.0084**	31.957 0.0004**
	ASX 200 Materials	Chi2 p-value	0.420 0.5169	1.089 0.5800	2.458 0.4829	5.798 0.2148	7.549 0.1829	7.946 0.2421	8.818 0.2660	8.890 0.3517	8.891 0.4474	11.421 0.3257
	ASX 300 Metals & Mining	Chi2 p-value	0.420 0.5169	1.089 0.5800	2.458 0.4829	5.798 0.2148	7.549 0.1829	7.946 0.2421	8.818 0.2660	8.890 0.3517	8.891 0.4474	11.421 0.3257
GFC Period: 1 July 2008 to 29 January 2010	ASX 200 A-REITs	Chi2 p-value	2.184 0.1394	2.262 0.3227	3.937 0.2683	3.938 0.4144	11.494 0.0424**	15.977 0.0139**	18.326 0.0106**	19.028 0.0147**	19.134 0.0241**	24.559 0.0062**
	ASX 200 Consumer Discretionary	Chi2 p-value	0.181 0.6701	2.958 0.2279	4.591 0.2043	5.584 0.2324	6.217 0.2857	7.068 0.3146	18.428 0.0102**	20.025 0.0102**	24.455 0.0036**	25.768 0.0041**
	ASX 200 Financials Excluding A-REITs	Chi2 p-value	0.077 0.7807	0.448 0.7992	1.727 0.6310	1.730 0.7853	3.094 0.6855	9.377 0.1534	15.922 0.0258**	16.005 0.0423**	17.040 0.0481**	17.882 0.0570

	ASX 200 Materials	**Chi2 p-value**	0.002 0.9639	0.032 0.9842	5.347 0.1481	8.008 0.0913	9.106 0.1049	9.471 0.1487	10.370 0.1686	10.777 0.2147	12.068 0.2095	12.771 0.2368
	ASX 300 Metals & Mining	**Chi2 p-value**	0.002 0.9639	0.032 0.9842	5.347 0.1481	8.008 0.0913	9.106 0.1049	9.471 0.1487	10.370 0.1686	10.777 0.2147	12.068 0.2095	12.771 0.2368
Post-GFC Period: 1 February 2010 to 31 December 2015	**ASX 200 A-REITs**	**Chi2 p-value**	2.869 0.0903	8.140 0.0171**	17.282 0.0006**	19.574 0.0006**	24.625 0.0002**	24.829 0.0004**	24.875 0.0008**	25.903 0.0011**	27.327 0.0012**	29.893 0.0009**
	ASX 200 Consumer Discretionary	**Chi2 p-value**	0.988 0.3203	1.018 0.6011	5.843 0.1195	8.608 0.0717	15.654 0.0079**	15.780 0.0150**	17.125 0.0166**	17.448 0.0258**	17.704 0.0388**	19.830 0.0309**
	ASX 200 Financials Excluding A-REITs	**Chi2 p-value**	0.718 0.3968	1.118 0.5716	1.832 0.6080	2.546 0.6363	13.404 0.0199**	16.867 0.0098**	22.494 0.0021**	23.864 0.0024**	24.395 0.0037**	24.921 0.0055**
	ASX 200 Materials	**Chi2 p-value**	0.199 0.6559	0.254 0.8806	0.698 0.8736	5.674 0.2248	9.728 0.0833	9.918 0.1282	11.118 0.1336	13.624 0.0921	14.131 0.1177	18.568 0.0461**
	ASX 300 Metals & Mining	**Chi2 p-value**	0.199 0.6559	0.254 0.8806	0.698 0.8736	5.674 0.2248	9.728 0.0833	9.918 0.1282	11.118 0.1336	13.624 0.0921	14.131 0.1177	18.568 0.0461**
Entire Study Period: 31 March 2000 to 31 December 2015	**ASX 200 A-REITs**	**Chi2 p-value**	5.039 0.0248**	8.696 0.0129**	27.574 0.0000**	28.275 0.0000**	47.130 0.0000**	56.491 0.0000**	71.028 0.0000 **	71.029 0.0000**	72.682 0.0000 **	84.234 0.0000**
	ASX 200 Consumer Discretionary	**Chi2 p-value**	1.196 0.2742	1.202 0.5481	6.371 0.0949	6.415 0.1702	6.417 0.2678	6.509 0.3687	14.468 0.0435 **	21.903 0.0051**	24.068 0.0042**	24.093 0.0074**
	ASX 200 Financials Excluding A-REITs	**Chi2 p-value**	1.592 0.2071	3.024 0.2205	8.943 0.0301**	9.040 0.0601	9.975 0.0759	11.140 0.0841	14.059 0.0501	17.086 0.0292**	22.173 0.0083**	23.754 0.0083**

	ASX 200 Materials	**Chi2** **p-value**	0.003 0.9532	0.557 0.7571	4.622 0.2017	4.669 0.3229	4.830 0.4369	4.917 0.5544	5.048 0.6542	7.364 0.4979	8.292 0.5050	8.484 0.5817
	ASX 300 Metals & Mining	**Chi2** **p-value**	0.003 0.9532	0.557 0.7571	4.622 0.2017	4.669 0.3229	4.830 0.4369	4.917 0.5544	5.048 0.6542	7.364 0.4979	8.292 0.5050	8.484 0.5817

Period	Indices	Lags	11	12	13	14
Pre-GFC Period: 31 March 2000 to 30 June 2008	ASX 200 A-REITs	**Chi2** **p-value**	38.265 0.0001**	38.649 0.0001**	40.182 0.0001**	40.189 0.0002**
	ASX 200 Consumer Discretionary	**Chi2** **p-value**	18.221 0.0766	19.150 0.0850	29.924 0.0048**	32.487 0.0034**
	ASX 200 Financials Excluding A-REITs	**Chi2** **p-value**	32.091 0.0007**	35.068 0.0005**	35.235 0.0008**	37.643 0.0006**
	ASX 200 Materials	**Chi2** **p-value**	11.665 0.3893	11.807 0.4613	13.790 0.3888	14.127 0.4403
	ASX 300 Metals & Mining	**Chi2** **p-value**	11.665 0.3893	11.807 0.4613	13.790 0.3888	14.127 0.4403
GFC Period: 1 July 2008 to 29 January 2010	ASX 200 A-REITs	**Chi2** **p-value**	24.613 0.0104**	25.031 0.0147**	27.591 0.0103**	27.592 0.0161**
	ASX 200 Consumer Discretionary	**Chi2** **p-value**	25.791 0.0070**	25.810 0.0114**	26.408 0.0150**	27.210 0.0181**
	ASX 200 Financials Excluding A-REITs	**Chi2** **p-value**	18.122 0.0788	19.163 0.0847	19.305 0.1139	19.351 0.1520
	ASX 200 Materials	**Chi2** **p-value**	12.771 0.3086	16.143 0.1848	16.328 0.2319	16.575 0.2795
	ASX 300 Metals & Mining	**Chi2** **p-value**	12.771 0.3086	16.143 0.1848	16.328 0.2319	16.575 0.2795
	ASX 200 A-REITs	**Chi2** **p-value**	31.661 0.0009**	32.318 0.0012**	33.104 0.0016**	33.684 0.0023**

Post-GFC Period: 1 February 2010 to 31 December 2015	ASX 200 Consumer Discretionary	**Chi2** **p-value**	20.182 0.0429**	25.735 0.0117**	27.003 0.0124**	27.727 0.0155**
	ASX 200 Financials Excluding A-REITs	**Chi2** **p-value**	25.024 0.0090**	25.627 0.0121**	26.053 0.0167**	27.635 0.0159**
	ASX 200 Materials	**Chi2** **p-value**	18.789 0.0650	19.177 0.0843	19.513 0.1080	21.314 0.0938
	ASX 300 Metals & Mining	**Chi2** **p-value**	18.789 0.0650	19.177 0.0843	19.513 0.1080	21.314 0.0938
Entire Study Period: 31 March 2000 to 31 December 2015	ASX 200 A-REITs	**Chi2** **p-value**	87.828 0.0000**	87.837 0.0000**	94.839 0.0000**	95.051 0.0000**
	ASX 200 Consumer Discretionary	**Chi2** **p-value**	24.103 0.0123**	24.103 0.0197**	35.026 0.0008**	35.741 0.0011**
	ASX 200 Financials Excluding A-REITs	**Chi2** **p-value**	25.688 0.0072**	25.723 0.0117**	25.768 0.0183**	25.772 0.0277**
	ASX 200 Materials	**Chi2** **p-value**	8.884 0.6326	15.306 0.2251	15.310 0.2884	15.726 0.3304
	ASX 300 Metals & Mining	**Chi2** **p-value**	8.884 0.6326	15.306 0.2251	15.310 0.2884	15.726 0.3304

NB: ** implies significance at 5% and rejection of the null hypothesis that there is no serial correlation present

Table 13: Runs Test for the Entire Study Period

Entire Study Period	Test Value (Median)	Cases < Test Value	Cases > Test Value	Total Cases	Number of runs	Z-statistic	Prob>|z|
ASX 200 A-REITs	0	2078	2031	4109	2064	.27	.78**
ASX 200 Consumer Discretionary	0	2087	2022	4109	2056	.03	.97**
ASX 200 Financials Excluding A-REITs	.0001390260003973	2055	2054	4109	2058	.08	.94**
ASX 200 Materials	0	2057	2052	4109	2042	-.42	.67**
ASX 300 Metals & Mining	.0000102000003608	2056	2053	4109	2002	- 1.67	.1**

NB: ** implies significance at 5% and acceptance of the null hypothesis that successive price changes are not dependent and move randomly

Table 14: Runs Test for Sub-periods

Period	Indices	Test Value (Median)	Cases < Test Value	Cases > Test Value	Total Cases	Number of Runs	Z-statistic	Prob>|z|
Pre-GFC Period: 14 July 2000 to 30 June 2008	**ASX 200 A-REITs**	.0000728309023543	1075	1076	2151	1068	-.37	.71**
	ASX 200 Consumer Discretionary	0	1106	1045	2151	1078	.1	.92**
	ASX 200 Financials Excluding A-REITs	.0001390260003973	1076	1075	2151	1074	-.11	.91**
	ASX 200 Materials	.0007209749892354	1075	1076	2151	1075	-.06	.95**
	ASX 300 Metal & Mining	.0007404410280287	1075	1076	2151	1063	-.58	.56**
GFC Period: 8 July 2008 to 29 January 2010	**ASX 200 A-REITs**	0	216	198	414	199	-.85	.4**
	ASX 200 Consumer Discretionary	0	208	206	414	211	.3	.77**
	ASX 200 Financials Excluding A-REITs	-.0002501319977455	207	207	414	195	-1.28	.2**
	ASX 200 Materials	0	211	203	414	212	.4	.69**
	ASX 300 Metal & Mining	0	211	203	414	208	.01	.99**
	ASX 200 A-REITs	0	796	748	1544	805	1.67	.1**

Post-GFC Period: 8 February 2010 to 15 July 2014	**ASX 200 Consumer Discretionary**	0	773	771	1544	768	-.25	.8**
	ASX 200 Financials Excluding A-REITs	.0003516479919199	772	772	1544	797	1.22	.22**
	ASX 200 Materials	0	812	732	1544	757	-.71	.48**
	ASX 300 Metal & Mining	0	811	733	1544	739	-1.63	.1**

NB: ** implies significance at 5% and acceptance of the null hypothesis that successive price changes are not dependent and move randomly