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A Nonparametric Variance-Ratio Test of the Behavior of U.K. Real Estate and Construction Indices

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This study utilizes tests based on ranks and signs suggested by Wright (2000), in addition to the traditional variance-ratio test, to examine the behavior of United Kingdom real estate and construction security indices. The results suggest a positive dependence in the index return series and provide a strong rejection of the random walk hypothesis for the two U.K. index series examined in this study. Thus, the efficient market hypothesis (EMH) is not confirmed for these real estate securities indices in the U.K.

Keywords

variance ratio; heteroskedasticity; stock index; random walk; ranks; signs

Introduction

The efficient market hypothesis (EMH) of asset prices posits that prices traded in a market that is efficient cannot be predicted by using historical price information (Fama, 1965, 1970). This implies, therefore, that prices traded in such a market are serially uncorrelated. The behavior of security prices, in particular, in the context of a weak-form efficient market, has engaged, and continues to engage, the attention of academics, investors, and regulators. While academicians seek to understand the behavior of security prices over time, investors are mainly interested in any observed patterns that can be exploited for profits. Regulators, on the other hand, are interested in the informational efficiency of the securities market. Subsequently, knowledge of the behavior of asset prices is of considerable importance to several interest groups.

Most past studies on the behavior of United Kingdom stock market prices have accepted weak-form market efficiency (see Kendall, 1953; Brealey, 1970; Dryden, 1970; and Cunningham, 1973, among others). However, recent advances in mathematical modeling have sparked a re-examination of the behavior of security returns. A large number of recent studies have applied much more sophisticated techniques to examining the behavior of financial series. (See Lo and Mackinlay, 1988, 1989; Liu and He, 1991; Scheinkman and LeBaron, 1989; Hsieh, 1991; Willey 1992; Poon and Taylor, 1992; Abhyankar, et al., 1995, 1997; Opong, et al., 1999, Wright, 2000; Belaire-Franch, 2003; and Belaire-Franch and Opong, 2002, among others.)

Most of the studies that have used advanced modeling techniques to examine the properties of financial variables are United States-based. Few such studies have used U.K. data and none has used industry-specific data. A major contribution of this current study, therefore, is to add to the small, but growing, research concerning the behavior of returns in the U.K. equity market, and especially in the real estate industry. Extant studies in the United States (see Cochrane, 2001; Malpezzi, 1999; and Malpezzi and Wachter, 2005, among others) clearly suggest that housing prices follow an error-correction model and not the random walk hypothesis (RWH). It is therefore reasonable to expect that the real estate security and construction indices do not follow the RWH, as well. This study is also important for other reasons. First, the U.K. market is among the world's major stock markets and, therefore, understanding the behavior of returns of assets traded there is a worthwhile venture. Given the global nature of modern-day economies, and the fact that the U.K financial market is relatively developed and open, there may be similarities regarding the behavior of returns in the U.S. and the U.K. For example, Bardhan, Edelstein and Tsang (2007) show that all other things being equal, real estate stock returns are affected by some degree of globalization. Second, evidence about what happens in the

U.K. market will permit comparison with studies done elsewhere. Third, if asset returns can be modeled in the U.K. stock market, it will perhaps challenge weak-form market efficiency. As argued by Belaire-Franch and Opong (2002), if asset returns can be modeled, it may also imply that stock returns can be predicted – if the specific form of the underlying price structure can be determined. Such information would be of obvious benefit to investors.[1] Fourth, this study uses industry indices, i.e., the real estate and the construction indices, which may behave differently from general stock market indices, such as the Financial Times Stock Exchange (FTSE) All-Share Index or the FTSE 100 Index. Those indices are normally the focus of most research on time-series properties of equity returns in the U.K. and the U.S. The final contribution of this paper is that it adds to the extant literature on real estate supply in the U.K and provides some understanding of the behavior of construction and real estate indices. Also, given the points raised above, this study may have policy implications regarding the future introduction of real estate-based index options, based on the index series analyzed in this study.[2]

Literature Review

Recent studies that apply modeling techniques to examine the behavior of asset returns in the U.K. are few; most studies are U.S.-based. Hsieh (1991), originally, and later Eldridge, Bernhardt, and Mulvey (1993), cast some doubt as to whether the behavior of returns on the Standard and Poor’s (S&P) 500 Index follow a random walk, as did Peters (1994), who reports long-term dependence in the Dow Jones Industrials Index. Greene and Fielitz (1977) examined 200 return series listed on the New York Stock Exchange (NYSE) and concluded that many security return processes are characterized by long-term dependence, and they reject the notion of weak-form market efficiency. Sewell, et al. (1993) report evidence of dependency in the market index series in Japan, Hong Kong, Korea, Singapore and Taiwan. However, they accept randomness as the characterization for the S&P 500 in the U.S. Errunza, et al. (1994) find evidence of fractal dynamics in Germany, Japan, and the emerging markets of Argentina, Brazil, Chile, India and Mexico.

While Howe, Martin and Wood (1997) find no evidence of deterministic patterns in Australia and Hong Kong, they report evidence of long-term dependence in returns in Korea, Japan, Singapore and Taiwan. Pandey, Kohers and Kohers (1997) report evidence of non-linear dependence in the

[1] It must be noted that any potential benefit derived from such knowledge may be short-lived, since it is likely to be competed away.
[2] Currently, there is no option trading on either the real estate or the construction indices.

index returns of Hong Kong, Japan and the U.S. However, they do not reject the notion of weak-form market efficiency for Hong Kong and the U.S. Hamill, Opong and Sprevak (2000) also report dependence in Irish stock returns.

Cochrane (2001) provides a summary of the literature, which has re-examined and revised earlier accepted views regarding the predictability of asset prices. He argues that the new consensus in the finance literature seems to suggest that asset returns are predictable. Wheaton (1999) demonstrates that cyclical properties exist in the behavior of different types of real estate returns, and that these cycles are linked to the economic activity in the U.S. Piazzesi, Schneider and Tuzel (2004) and Leung (2007), among others, also show that in an efficient equilibrium, housing prices and returns are serially correlated. Piazzesi, Schneider and Tuzel develop a model of housing share, and argue that it can be used to forecast excess returns on stocks. Leung (2007) provides further evidence to these previous studies and demonstrates that in an efficient equilibrium, housing prices and returns can be serially correlated. Leung and Chen (2006) go further to demonstrate a dynamic equilibrium model that shows that land price can exhibit endogenous cycles even with constant aggregate output. Malpezzi (1999) constructs an error-correction model for U.S. housing prices. His analysis supports his previous report that housing price changes are forecast-able. Therefore, this suggests that housing price changes are not random walks. Malpezzi and Wachter (2005) study a housing market with speculation and find that the equilibrium price does not follow a random walk. The above studies clearly show that if the housing price follows an error-correction model but not a random walk, perhaps it is also reasonable to expect that the real estate security and construction indices do not follow a random walk either.3 While the econometric results of this paper are convincing statistically, the authors may still need to provide further motivation and relate their paper to these recent developments, on both the theoretical and empirical fronts.

Most of the earlier studies on the behavior of U.K. stock market prices have accepted security prices as random, independent, and identically-distributed. (See, among others, Kendall 1953; Brealey 1970; Dryden 1970; and Cunningham 1973.) The increasing power of computers, coupled with advances in mathematical modeling techniques, has sparked a re-examination of the behavior of security returns. A number of studies have recently re-examined the behavior of U.K. security prices, using more sophisticated techniques (Poon and Taylor, 1992; Abhyankar, et al., 1995, 1997; Opong, et al., 1999), and provide conclusions which differ from the earlier studies.

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[3] We are very grateful to the anonymous referee for this suggestion.

Lo and Mackinlay (1988) criticized the traditional random walk tests and introduced a more robust volatility-based specification test. Since most asset returns often possess time-varying volatilities and deviations from normality, the importance of developing a test which is robust to heteroskedasticity and non-normality becomes important. Lo and Mackinlay developed tests based on the assumption of homoskedasticity and heteroskedasticity, which they applied to examine the validity of the RWH for NYSE and AMEX weekly stock prices. Their reported results reject the RWH for the series they examined. Their study gave rise to a few other studies around the world. A number of studies have since used the same procedure to test whether stock market prices follow random walks (e.g., Al-Ghamidi and Opong, 1999; Ayadi and Pyum, 1994; Urratia, 1995; Huang, 1995; Blasco, Rio and Santamaria, 1997). Other studies have applied the methodology to test the RWH in world money rates (e.g., Liu and He, 1991; Chou, et al., 1996; Pan, et al., 1996; Fong, Koh and Ouliaris, 1997).

Liu and He (1991) applied variance-ratio tests, based on Lo and Mackinlay (1988), and provide evidence rejecting the RWH for five pairs of nominal exchange rates. Their reported results suggest that autocorrelations are present in weekly increments in nominal exchange rate series. Ayadi and Pyum (1994) applied the variance-ratio test to the daily Korean stock market prices. Their findings indicate the rejection of the RWH under the assumption of homoskedasticity. However, when the heteroskedastic stochastic disturbance term is used, their findings support the RWH for daily data and longer data intervals. Chou, et al. (1996) utilizes the variance ratio to test the RWH of interest rates for eight world countries. Their results indicate that interest rates in the countries they examined do not follow a random walk in the short-run, and vice versa for the long-run. Urrutia (1995) examined the weak-form efficiency of four Latin American stock markets, Argentina, Brazil, Chile and Mexico, using the variance-ratio test. The reported results did not support the RWH for those stock markets. Using the variance-ratio test, Blasco, Rio and Santamaria (1997) found that, for the Spanish stock market, the rejection of the RWH cannot be attributed completely to heteroskedasticity. They maintained that the Spanish stock price changes can be predicted, at least over short periods. Malliaropulos (1996) used the variance-ratio test to examine the predictability of the long-horizon stock returns in the U.K. He generated artificial histories of stock returns from the empirical distribution, using the bootstrap method, and found no evidence of mean reversion in stock prices.

In Saudi Arabia, Butler and Malaikah (1992) reported that the Saudi stock market does not follow a random walk, using traditional autocorrelation and runs tests. However, Al-Ghamidi and Opong (1999) reported that the

Saudi stock market partially follows a random walk.

Data, Research Design and Methodology

Data

This study tests whether the random walk hypothesis is valid for the FTSE Real Estate and FTSE Construction Indices from Datastream/Primark. These indices contain all real estate and construction firms listed on the London Stock Exchange, and contained in the FTSE All-Share Index. They are both value-weighted indices. Data for the study cover the period from January 2, 1997 to December 31, 2002. Daily prices of the index were obtained from Datastream/Primark.

Methodology

The behavior of the return series for the indices tested in this study are examined by first applying the traditional variance-ratio test, and, then, by applying the nonparametric-based test suggested by Wright (2000). The variance-ratio test was proposed by Lo and Mackinlay (1988, 1989) and tests the proportionality (linearity) of the variance of k-differences of the returns series, with the first difference k. It assumes that, for a random walk series, the variance of its k-differences is k times the variance of its first difference. For example, if a series follows a random walk, the variance of its four-day differences will be four times as large as the variance of its daily differences.

The hypothesis to be tested is H_0: the index series follows a random walk, vs. H_1: the index series does not follow a random walk. Let $\{y_t\}$ denote a time series consisting of T observations $y_1,\ldots,y_T$ of asset returns. The variance ratio of the k-th difference is defined as:

$$VR(k) = \frac{\sigma^2(k)}{k\,\sigma^2(1)} \qquad (1)$$

where:

$VR(k)$ is the variance ratio of an index's k-th difference,

$\sigma^2(k)$ is the unbiased estimator of 1/k of the variance of an index's k difference, under the null hypothesis,

$\sigma^2(1)$ is the variance of the first-difference of an index series, and

k is the number of days of base observations interval, or the difference interval.

Following Lo and Mackinlay (1988, 1989), the estimator of the k-period difference, $\sigma^2(k)$, is calculated as:

$$\sigma^2(k) = \frac{1}{Tk}\sum_{t=k}^{T}(y_t + \ldots + y_{t-k+1} - k\hat{\mu})^2 \qquad (2)$$

where:

$$\hat{\mu} = \frac{1}{T}\sum_{t=1}^{T} y_t .$$

The unbiased estimator of the variance of the first difference, $\sigma^2(1)$, is computed as follows:

$$\sigma^2(1) = \frac{1}{T}\sum_{t=1}^{T}\left(y_t - \hat{\mu}\right)^2 . \qquad (3)$$

The test statistic $M_1(k)$ is given by:

$$M_1(k) = \frac{VR(k)-1}{[\phi(k)]^{1/2}} , \qquad (4)$$

which, under the assumption of homoskedasticity, is asymptotically distributed as N(0,1). The asymptotic variance, $\phi(k)$, is given by:

$$\phi(k) = \frac{2(2k-1)(k-1)}{3kT} . \qquad (5)$$

The test statistic $M_2(k)$, which is robust under heteroskedasticity, is given by:

$$M_2(k) = \frac{VR(k)-1}{\phi^*(k)^{1/2}} \qquad (6)$$

where:

$$\phi^*(k) = \sum_{j=1}^{k-1}\left[\frac{2(k-j)}{k}\right]^2 \delta(j) \qquad (7)$$

and

$$\delta(j) = \frac{\sum_{t=j+1}^{T} (y_t - \hat{\mu})^2 (y_{t-j} - \hat{\mu})^2}{\sum_{t=1}^{T} [(y_t - \hat{\mu})^2]^2} . \qquad (8)$$

In a recent study, Wright (2000) proposes the use of signs and ranks to substitute for the differences in the Lo and Mackinlay tests. Wright demonstrates that his nonparametric variance-ratio tests, based on signs (S_1 and S_2) and ranks (R_1 and R_2), are better able to reject violations of the RWH than the tests suggested by Lo and Mackinlay. The test based on the signs of returns, rather than ranks, is given by:

$$S_1 = \left(\frac{\frac{1}{T_k} \sum_{t=k}^{T} (s_t + \ldots + s_{t-k+1})^2}{\frac{1}{T} \sum_{t=1}^{T} s_t^2} \right) \times \phi(k)^{-1/2} \qquad (9)$$

and

$$S_2 = \left(\frac{\frac{1}{T_k} \sum_{t=k}^{T} (s_t(\bar{\mu}) + \ldots + s_{t-k+1}(\bar{\mu}))^2}{\frac{1}{T} \sum_{t=1}^{T} s_t(\bar{\mu})^2} - 1 \right) \times \phi(k)^{-1/2} \qquad (10)$$

where: $\phi(k)$ is defined in (5), $S_t = 2u(y_t, 0)$, $S_t(\bar{\mu}) = 2u(y_t \bar{\mu})$, and

$$u(x_t, q) = \begin{cases} 0.5 & \text{if } x_t > q, \\ -0.5 & \text{otherwise} \end{cases} .$$

Thus, S_1 assumes a zero mean value, whereas to compute S_2, the method employed in Luger (2003) has been used. Wright's proposed R_1 and R_2 are defined as:

$$R_1 = \left(\frac{\frac{1}{T_k} \sum_{t=k}^{T} (r_{1t} + \ldots + r_{1t-k+1})^2}{\frac{1}{T} \sum_{t=1}^{T} r_{1t}^2} - 1 \right) \times \phi(k)^{-1/2} \qquad (11)$$

and

$$R_2 = \left(\frac{\frac{1}{T_k} \sum_{t=k}^{T} (r_{2t} + \ldots + r_{2t-k+1})^2}{\frac{1}{T} \sum_{t=1}^{T} r_{2t}^2} - 1 \right) \times \phi(k)^{-1/2} \tag{12}$$

where:

$$r_{1t} = \frac{\left(r(y_t) - \frac{T+1}{2} \right)}{\sqrt{\frac{(T-1)(T+1)}{12}}}$$

and

$$r_{2t} = \Phi^{-1}(r(y_t)/(T+1) \quad .$$

$\phi(k)$ is defined in (5), $r(y_t)$ is the rank of y_t among $y_1,\ldots y_T$, and Φ^{-1} is the inverse of the standard normal cumulative distribution function.

Results

Table 1 shows the results of the variance-ratio test for the U.K. real estate and construction indices. Column 1 shows the particular period of k = 2, 5, 10 and 30 for each of the series (real estate, construction). Columns 2 to 7 contain the test statistics for each index return series. The top panel shows the results for the real estate index and the bottom panel shows the results for the construction index. M_1 and M_2 show the test statistics for the conventional variance-ratio tests suggested by Lo and Mackinlay. The null of random walk behavior of the index return series examined in this study is rejected for all levels of k for the real estate index at the 0.01 level. There is a much stronger rejection of a random walk for the construction index, for all levels of k, than for the real estate return index series. All the rejections are in the upper tail of the distribution, which suggests that any dependence in the series is positive. A salient feature of the test statistics reported in Table 1 is the preponderance of statistically-significant, positive dependence in the values for both of the index return series examined. The reported results, using the M_1 measure, are under the hypothesis of homoskedasticity. Therefore, any rejection of RWH behavior of the series examined could be due to heteroskedasticity. An investigation of such a scenario is achieved by the implementation of the heteroskedasticity-consistent variance-ratio test given by M_2.

Table 1: Variance-ratio test for U.K. real estate and construction indices

Real Estate Index						
Period	M_1	M_2	S_1	S_2	R_1	R_2
k = 2	8.830	5.810	5.617	5.5107	9.105	9.365
k = 5	9.802	7.203	5.891	5.3854	9.611	10.138
k = 10	9.532	7.482	5.707	5.3032	9.269	9.818
k = 30	6.350	5.420	5.178	4.8409	7.111	6.979
Construction Index						
k = 2	11.983	7.329	7.694	7.2677	10.318	11.218
k = 5	13.930	9.549	8.574	8.1850	12.697	13.565
k = 10	12.780	9.677	8.208	7.5299	11.728	12.643
k = 30	8.534	7.128	3.797	3.1997	6.999	8.107

Note: All tests are significant at the .01 level. Figures in columns 2-7 give the values of the test statistics M1, M2, S1, S2, R1 and R2 for each index series. M1 and M2 are based on conventional variance-ratio tests and S1, S2, R1 and R2 are based on the nonparametric test, following Wright (2000).

The test results for M_2 indicate the rejection of the null for the index return series, under homoskedasticity, is robust to the heteroskedasticity test. This therefore suggests that the variance is different from the expected value of 1, due to autocorrelations, rather than to heteroskedasticity. Therefore, the nonparametric test, based on ranks and signs, is applied, which has power against a wide range of models of serial correlation, including an autoregressive moving average and its fractionally-integrated alternatives.

Columns 4-7 show the results based on the nonparametric variance-ratio test, using signs and ranks. The test based on signs and ranks can be exact, and Wright (2000) shows that in Monte Carlo simulations such tests may have better power properties than the use of M_1 and M_2. Tests based on signs and ranks are also robust to many forms of conditional heteroskedasticity. The results for the sign-based variance-ratio tests, S_1 and S_2, are reported in columns 4 and 5. The results support the M_1 and M_2 tests. Generally, R_1 and R_2 are much stronger tests than S_1 and S_2, and, therefore, if R_1 and R_2 rejects, S_1 and S_2 must reject as well. Table 1 shows that the null hypothesis (that the series follow a random walk) is rejected for all the tests implemented in the study, at any reasonable probability level. The results for R_1 and R_2 are broadly in agreement with the M_1 and M_2 measures, except that the rejection for the same k values for the nonparametric-based test are much stronger than for the conventional variance-ratio tests. The results are broadly in line with those reported by Belaire-Franch and Opong (2003), for some FTSE indices.

Figures 1-8 show a plot for the test of each index return series, with a rolling window of T = 500 for S_1, S_2, R_1 and R_2. Each graph provides a 95% confidence band for the null. If the null hypothesis that each index return series examined in this study behaves in a random walk manner is true, the plot of the test statistics should lie within the confidence band. Figures 1-4 for the real estate index series indicate that, with the exception of k = 30, the plot of the test statistics lie outside the 95% confidence band. For k = 30 in S_1, S_2, R_1 and R_2, a large part of the series is outside the confidence band. There are no persistent deviations outside the confidence band for the series and the rejection of the null is strongly supported by all the graphs.

With the exception of S_2 for k = 30 for the construction index returns series, the plot of the test statistics provides strong support for a rejection of the null, which is in agreement with the previous results for the real estate index return series.

Figure 1. S1 test on real estate returns. Rolling window (T = 500).

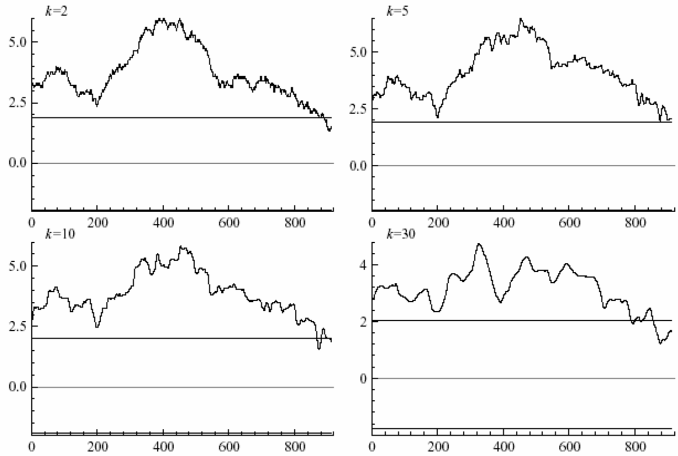


Figure 2. S2 test on real estate returns. Rolling window (T = 500).

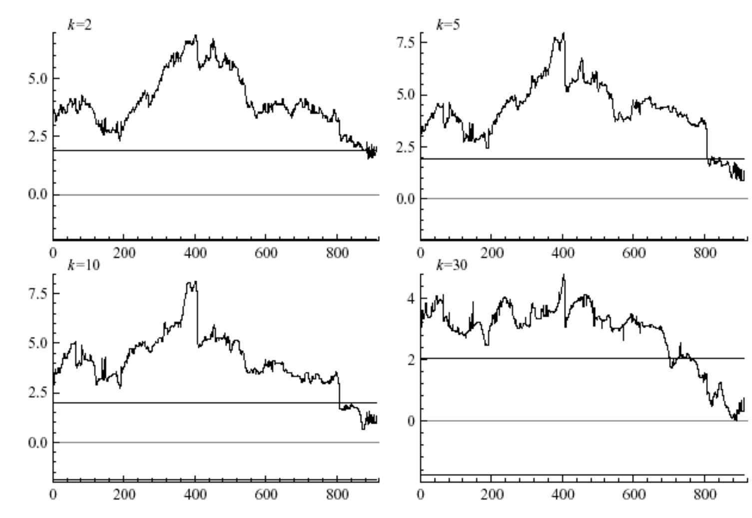


Figure 3. R1 test on real estate returns. Rolling window (T = 500).

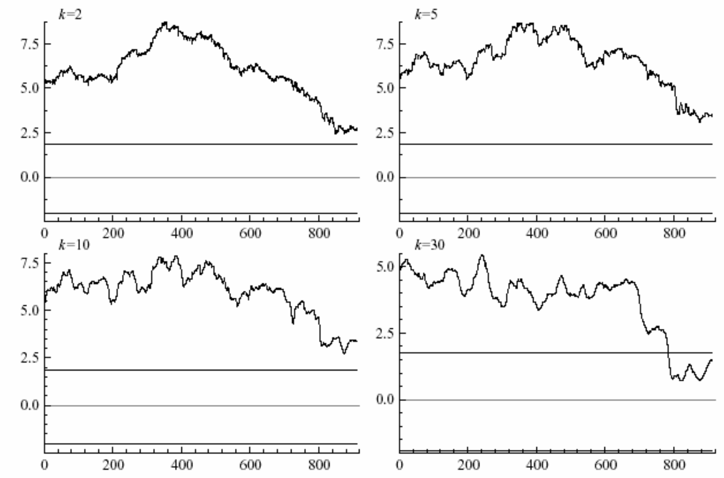


Figure 4. R2 test on real estate returns. Rolling window (T = 500).

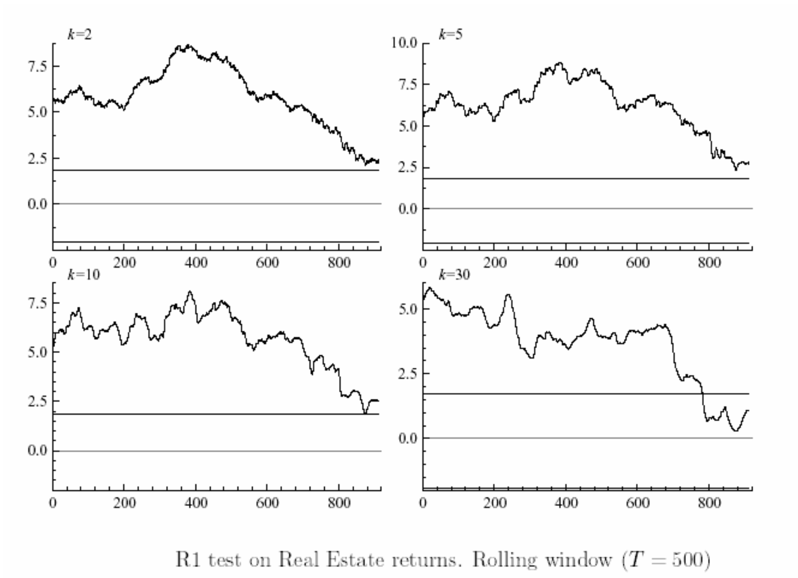


Figure 5. S1 test on construction returns. Rolling window (T = 500).

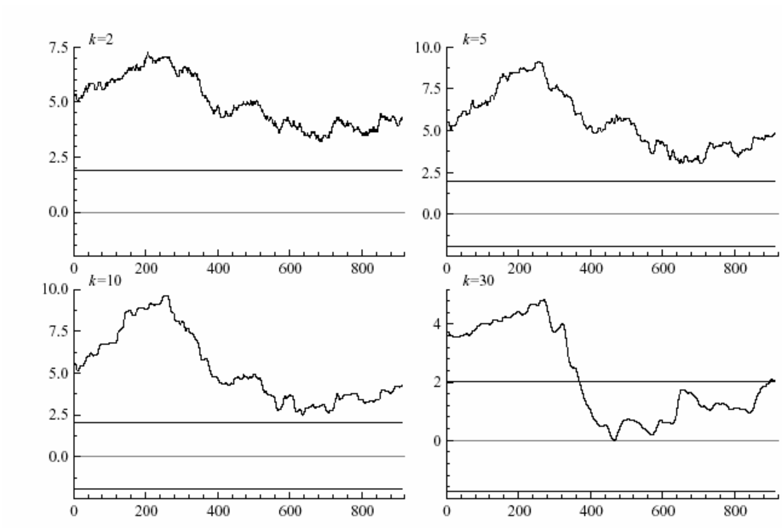


Figure 6. S2 test on construction returns. Rolling window (T = 500).

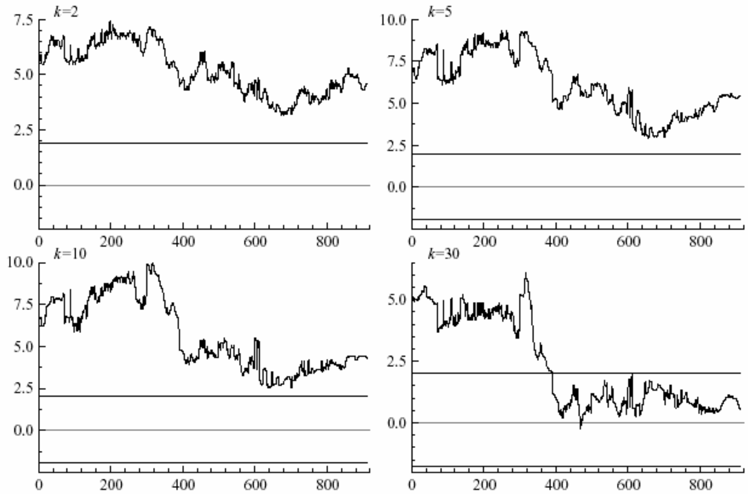


Figure 7. R1 test on construction returns. Rolling window (T = 500).

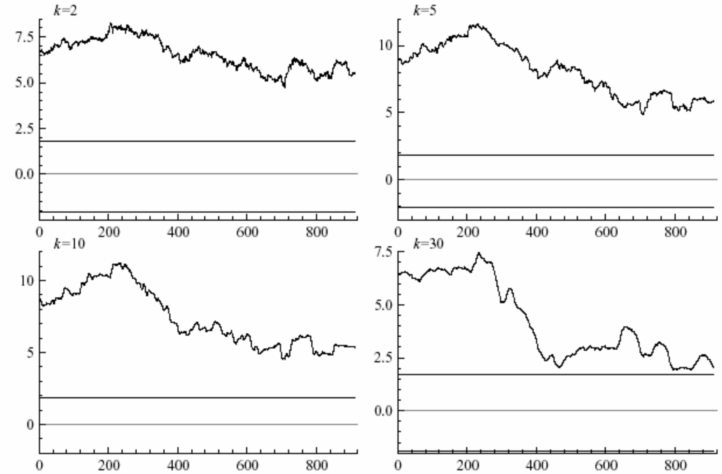
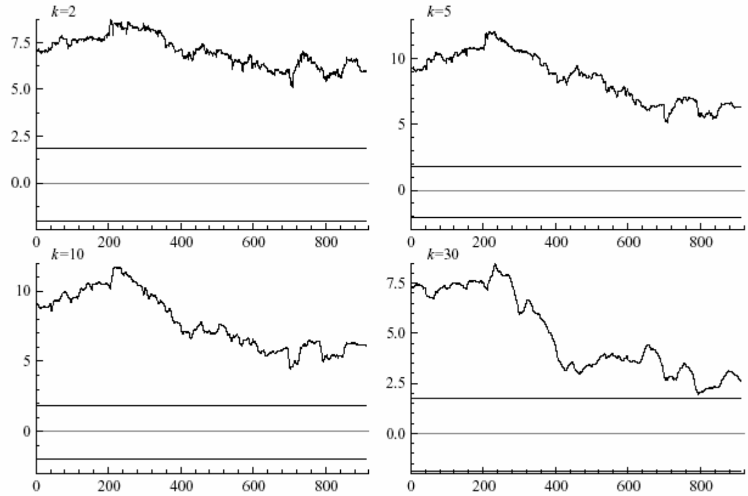


Figure 8. R2 test on construction returns. Rolling window (T = 500).



Summary and Conclusions

This study has examined the behavior of U.K. real estate and construction index returns using the conventional variance ratio and parametric-based variance ratio. The results of the study indicate a positive dependence in the index return series and provide a strong rejection of the random walk hypothesis for the two real estate industry index series examined in this study. A rolling window plot of the return series also appears to provide a strong rejection of random walk behavior for the series. The parametric-based variance-ratio test provides a stronger rejection of random walk behavior than the conventional variance-ratio tests, under conditions of homoskedasticity and heteroskedasticity.

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