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The Random Walk Hypothesis and the Evidence from the Amman (Jordan) Stock Exchange

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Abstract: This study investigates the validity of the random walk model for an emerging stock market (Amman Stock Exchange, ASE). The study examines for all assumptions implied by the random walk model using aggregate daily data. The results suggest that the behaviour of the ASE return series is inconsistent with the random walk model, which implies informationally inefficient.

Key words: emerging markets, non-linear dependence, RWM, securities, trading

JEL Classification: G15

Introduction

Efficient capital markets optimise the process through which capital may be transferred from net savers to net borrowers. According to efficient market hypothesis (EMH), a market is efficient if prices reflect all available information. In the case of capital markets, the intrinsic value of a share is equivalent to the future discounted value of cash flows that will accrue to its investors. If the capital market is efficient share prices must reflect all available information which is relevant for the evaluation of a company's future performance and therefore share prices must be the rational expectation of future discounted profits. Any new information which changes expectations of a company's future profitability must immediately be reflected in the share price since any delay in the diffusion of information to prices would suggest irrationality, as some subset of available information could be used to improve the forecast of future profitability. In an efficient market rational share price variations

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must respond only to changing beliefs about company profitability; that is, a reaction to generated information. Since information arrives randomly, share prices must also fluctuate in a stochastic fashion. The stochastic nature of share price variations has been associated with the random walk model (RWM) which implies that capital markets have no memory, or that there is no persistency in stock returns. On other words, in its weak form, the RWM postulates that successive one period stock returns are independently and identically distribution (IID) (Fama, 1970).

The opinion of economists about the efficiency of capital markets is rather ambiguous. In the literature dealing with the question of efficiency or inefficiency of the US or UK stock exchanges, we find many papers supporting both sides (see Fama, 1970, 1991). Unfortunately, economists are rather pessimistic in their judgment about the efficiency in emerging markets. Emerging markets are characterised by limited numbers of listed companies, participants and involved capital. Furthermore, in most emerging markets, problems with liquidity, market fragmentation, absence of official market makers, thin trading and the imposition of price limits are factors that, it is argued, contribute to their inefficiency.

Recently, there have been a large number of studies that investigate the efficiency of emerging stock markets. Results from these studies suggest that some emerging markets price assets efficiently, while others exhibit predictability and inefficiency. For example, evidence of efficiency has been found in the Greek market (Panas, 1990), the Kuwait market (Butler and Malaikah, 1992) and the Nairobi market (Dickinson and Muragu, 1994), while studies of the Kuala Lumpur stock market (Barnes, 1986; and Berry, 1997), Istanbul stock market (Zychowicz et al. 1995) and the Sri Lanka stock market (Abeysekera, 2001) suggest they are inefficient. Investigating the efficiency of the Turkey (Istanbul) and Jordan (Amman) stock exchanges, El-Erian and Kumar (1995) report statistically significant autocorrelation of daily stock price indices in both markets.

Relative to emerging markets' research, it is perhaps surprising that some of them are found to be efficient. This is based on the argument that these markets are known to suffer from thin trading, and large price movements. It is possible, the evidence of efficiency in emerging markets is the result of the techniques adopted for investigating the issue, rather than being due to a genuine lack of predictability. All these studies merely carry out tests of serial independence, such as the autocorrelation function and the runs test, and establish the absence of serial correlation, which does not in itself imply independence and thereby the prices follow a random walk. None of these studies explicitly tests for the IID assumption implied by EMH.

Furthermore, recent research suggests to errors because they assume that the time series follows a linear stochastic process. The interaction of noise traders with rational traders can generate non-linear deterministic systems which seemingly show random behaviour in stock prices (see for example, Hsieh, 1989; and Brock et al., 1996).

Non-linearity in stock prices has important theoretical and practical implications for asset pricing models and portfolio management technique. Identification of an appropriate non-linear structure may help in the development of improved asset pricing models which can be used to hedge against the predicted increase in volatility. Although a number of research studies provide evidence of non-linear patterns in equity returns, most of these have used data from mature markets such as the US and the UK (see for example, Willy, 1992; Hsieh, 1991 and 1993; and Opong et al., 1999). Research on non-linear dynamics in emerging markets is relatively scarce (see for example, Yadav et al., 1996; and Poshakwale and Wood 1998).

Here we investigate the validity of random walk hypothesis (RWH) for the Jordanian stock market (Amman Stock Exchange, ASE) as an example of an emerging market by testing for all assumptions implied by this hypothesis.

The ASE is the only stock market in Jordan. Since its establishment in 1978, the ASE has developed and expanded greatly, and has become one of the most sophisticated and active stock markets among the emerging markets (World Bank, 1994; Cobham, 1995; Demirguc-Kunt and Huizinga, 2000; and others). For instance, El-Erian and Kumar (1995) point out that, 'Jordan has a relatively highly developed equity market which plays an important part in the economic life of the country' (p.146).

Regardless of the differences in their mechanisms, all securities markets have one thing in common and that is to bring buyers and sellers together. In ASE any investor who wants to buy or sell a security must do so through the agency of a stockbroker. The trading mechanism is continuous and strict price and time priority rules are followed. For example, for any two or more buy (sell) orders on the trading board, the order with the higher (lower) price has priority in execution. Similarly, if two or orders of the same type have similar prices, the one noted on the board first has the priority in execution. Daily price limits (5 per cent) are imposed on all listed shares. These limits are applied as a mechanism to stabilise the movement of prices i.e., to prevent shares from excessive volatility, and to protect investors by limiting potential daily losses to a maximum. The ASE launched the electronic trading system on 15 June 2000. However, it must be noted that the market-making mechanism has not changed. In other words, the 'old' manual system has simply been replaced by an electronic one.

As it stands, the trading mechanism in ASE suffers from one major weakness; lack of immediacy. If, for example, there is an imbalance between buy and sell orders during a trading day, successive buy (sell) orders may well get noted on the trading board without counter sell (buy) orders arriving at the market. Furthermore, any imbalance between buy and sell orders would cause the price of a stock to change suddenly (and by a large percentage) from one transaction to the next. This is due to the absence of somebody (dealer) who stands ready and willing to buy a stock at the bid and sell a stock at the ask. Indeed Cohen et al. (1983) analysed the impact of the specialist on the standard deviation of daily price changes. In their simulation study, they showed that the presence of specialists reduces the standard deviation of daily transaction prices from an average of 1.44 per cent to about 0.89 per cent. In other words, the behaviour of price changes on ASE would be more continuous if there were specialists operating in the market. Moreover, investors would be assured of getting their orders executed immediately when the submit market orders. This is perhaps why the trading volume in the shares of only 10 companies (out of a total of 120 listed companies) accounts for more than 50 per cent of the trading volume in the shares of all listed companies. Moreover, we argue that the price-limit regulation is a factor that may lead to market inefficiency. Theoretically, it is widely argued that if the price is not allowed to settle at its equilibrium level because of the presence of institutional constraints i.e., price-limits, demand may not supply (or vice versa), disequilibrium occurs (see Chou 1997).

This study examines the behaviour of ASE stock prices for the period January 1994 through November 2002. It determines the extent to which daily returns of securities listed on the ASE conform to the RWH. This study makes the following two contributions to the empirical literature. It represents one of the limited number of papers that examine empirically efficiency in the ASE. Thus, the experience of a 'thin' market presents an excellent research opportunity to add to the EMH literature. This study also employs statistical tests capable of detecting linear as well as non-linear dependence. This aims is consistent with Granger and Andersen (1978) who suggest that in testing for the RWH, the absence of both linear and non-linear dependence should be confirmed since rejection of linear dependence does not imply independence but merely suggests a lack of linear autocorrelation.

The statistical evidence in this paper rejects the random walk hypothesis for the emerging Jordanian stock market. The results suggest that daily returns show significant non-linear dependence and persistent volatility effects. The non-linear dependence takes the form of GARCH-type conditional heteroscedasticity and does not appear to be caused by nonstationarity of underlying economic variables.

Methodology

When the term 'efficient market' was introduced into the economics literature thirty years ago, it was defined as a market which adjusts rapidly to new information. It soon became clear, however, that while rapid adjustment to new information is an important element of an efficient market, it is not the only one. A more modern definition is that asset prices in an efficient market fully reflect all available information. This implies that the market processes information rationally, in the sense that relevant information is not ignored, and systematic errors are not made. As a consequence, prices are always at levels consistent with 'fundamentals'.

According to Fama (1965), stock prices in an efficient market should fluctuate randomly through time response to the unanticipated component of news. This implies that 'future path of the price level of an asset is no more predictable than the path of a series of cumulated random numbers'. In statistical terms this hypotheses states that successive price changes are independent. Consequently, there must be no serial correlation between the prices at different times. Furthermore, it is also assumed that successive price changes are identically distributed. This requires that the distribution of the changes in stock price must be stationary over time, i.e. asset prices are I(1). These two requirements constituted the cornerstone of the RWM (Fama, 1970). The important consequence of the model is that best predictor of tomorrow's stock price is today's stock price. This in turn implies that expected gain or loss for any holding period is zero. A further implication of the model is that the stock price series does not contain any purely cyclical or other deterministic components such as seasonal patter or trend.

Mathematically, the (logarithmic) random walk model may be expressed in a number of ways but the simplest model is of the form:

$$\log P_t = \log P_{t-1} + \varepsilon_t \tag{1}$$

where P_t is the price of a stock at time t, P_{t-1} is the price of the stock in the immediately preceding period and ε_t is a random error. Randomness requires that $E(\varepsilon_t) = 0$, $E(\varepsilon_t \varepsilon_{t-1}) = \sigma_\varepsilon^2$ for $s = 0$ and $E(\varepsilon_t \varepsilon_{t-s}) = 0$ for $s \neq 0$. As such, the stock price change, is equal to $\log P_t - \log P_{t-1}$ is equal to ε_t which, being white noise, is unpredictable from previous stock price changes.

To test for all assumptions implies by the random walk model we considering

$$R_t = c + \varepsilon_t \tag{2}$$

where R_t is rate of return on the stock at time t, measured as the log difference of the stock prices ($\Delta \log P_t = \log P_t - Log_{t-1}$). Under the random walk model $\log P_t$ should be I(1) ($\Rightarrow \Delta \log P_t \sim I(0)$, the constant (c) should be insignificantly different from zero and the residuals (ε_t) should be IID random variables.

In order to test for the order of integration, we use two statistical tests; the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) tests. We use both tests because, while the PP test is robust against a greater range of non-white-noise error structures, there are some concerns about its small sample properties. These two tests will be performed on the levels of the return series. Equation 2 will then be estimated using ordinary least squares (OLS). If the constant term proves to be insignificantly different from zero, the zero mean assumption is satisfied. The serial independence assumption will be examined through the application of the Lagrange multiplier (LM) test of residuals. To examine whether stock returns are normally distributed, a test of normality that is based on the skewness and Kurtosis will be applied to the residuals of equation 2.

According to Lui et al. (1992) if linear autocorrelation is detected in the return time series, the nonlinearities in the return time series should also be studied. Willey (1992) find evidence of nonlinear dependencies in the daily, weekly and monthly changes of individual stock prices, portfolios of stocks and major US indices. The presence of nonlinear dependencies raises questions about market efficiency. Hsieh (1991) points out that if returns are not IID it does not contradict market efficiency. Even if returns are not IID, residual autocorrelation of returns may or not be predictable. Market efficiency implies that they are not.

The IID assumption, therefore, will be tested using statistic designed by Brock, Dechert and Sheinkman (BDS) (1987). If the null hypothesis of IID cannot be accepted at this stage, the implication is that the residuals contain some hidden, possibly nonlinear, structure. If this turns out to be the case, we will remove any nonlinear dependence by fitting a generalised autoregressive conditional heteroscedasticity [GARCH (p,q)] model[1] (Bollerslev,1986) with the order chosen according to Schwartz Information Criterion (SIC).

The model to be fitted will be of the form

$$R_t = a_0 + a_1\varepsilon_{t-1} + \varepsilon_t, \quad \varepsilon_t / \psi_{t-1} \sim N(0, h_t) \tag{3a}$$

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-1}^2 + \sum_{j=1}^{q} \beta_j h_{t-1} \tag{3b}$$

where (3a) is the conditional mean equation and (3b) is the conditional variance equation. ψ_{t-1} is the information set. In the above specification, the conditional variance of daily stock return h_t is modeled as a linear function of its own lagged p conditional variances and the lagged q squared residuals where α and β are parameters to be estimated. In this linear GARCH procedure, shocks to the current volatility of stock returns persist if $\sum \alpha_i + \sum \beta_j = 1$.

Finally, we will subject the standardised residuals from the GARCH model to BDS testing to check for any remaining unexplained structure. Since all the tests used in this study are fairly standard and have been thoroughly described in a vast amount previous literature, only the BDS test will be described here. This test is based on the Grassberger and Procaccia (1983) correlation integral as the test statistic. In particular, under the null hypothesis of IID, the BDS statistic is

$$W(T,m,e)=\frac{\sqrt{T}\left\{C(T,m,\varepsilon)-C(T,1,\varepsilon)^{m}\right\}}{\sigma(T,m,\varepsilon)} \tag{4}$$

where $C(T,m,\varepsilon)$ is the correlation function (integral), $T = N - m + 1$, N is the length of the series, m is the embedding dimension, ε is a sufficiently small number, and $\sigma(T,m,\varepsilon)$ is an estimate of the asymptotic standard error of $\left\{C(T,m,\varepsilon)-C(t,1,\varepsilon)^{m}\right\}$. Brock et al., (1991) show that the test statistic is asymptotically as standard normal distribution $N(0,1)$ and that the asymptotic distribution is a good approximation of the finite sample distribution when there are more than 500 observations. Further, they recommend that ε should be between one-half- to two times the standard deviation and that the accuracy of the systematic distribution deteriorates for high embedding dimensions of 5 or above. The BDS is used in testing the hypothesis whether returns are independently and identically distributed. Rejection of IID would indicate that returns are non-linear.

Data

Daily closing price index data from the ASE for the period January 1994 to December 2002 are used. Daily stock returns, R_t, are calculated using first differences of the logarithmic price index, i.e. $R_t = Ln(P_t) - Ln(P_{t-1})$ where P is the price index, the t and t-1 represent the current and immediately preceding days.

Table 1 summarises the basic statistical characteristics of daily stock returns. The evidence for return series indicates significantly flatter tails than does the stationary normal distribution. The coefficient of skewness indicates that series typically has asymmetric distribution skwend to the right. Furthermore, the coefficient of kurtosis shows that the return series is heavily-tailed, suggesting that there is a higher portion of 'large' observations than would be if this series is distributed normally. These two forms of departure from normality are reflected in the results of the Jarque-Bera (1980) normality test reported in the next column. This test clearly rejected the hypothesis of normality at any level of significant. The final column provides the results of a standard LM test for ARCH(6). The statistic has a χ^2 distribution under the null of no ARCH: the 1 per cent critical value is 6.635. There is clearly considerable evidence of ARCH. This result suggests that ARCH type non-linearity may be present and therefore testing for nonlinear dependence is all more worthwhile.

Table 1.: Summary statistics for return series

Mean	Std.Dev	Skewness	Kurtosis	Normality	ARCH(6)
0.34×10^{-3}	0.62×10^{-1}	1.279	7.876	9.876* (0.000)	53.68*

Notes:* significant at 1 per cent. Normality represents the Jarque-Bera (1980) normality test, which follows a chi-squared distribution, with two degrees of freedom. ARCH (6) is a test for conditional heteroscedasticity in returns for sixth order.

Empirical Results

Shown below are the results of estimating a regression of daily returns of the ASE price index, on a constant along with the Bera-Jarqùe test of normality (Berà and Jarque, 1982).

$$R_t = 0.0033 + \upsilon_t$$
$$(1.420)$$
$$\chi^2 = 116505$$

The t-statistic of the estimated constant is below the critical value at the 5 per cent significance level, indicating that the mean of the ASE return series is insignificantly different from zero. This result is consistent with the random walk hypothesis. The large value of the normality test statistic, however, indicates that the ASE return series is not normally distributed.

Two tests for a unit root were carried out – the ADF and PP test. The lag length in the ADF case and the truncation lag in the PP case are chosen on the basis of the sample autocorrelation function of the returns. The lag is chosen as the highest one for which this autocorrelation is significant (provided this is less than $\sqrt{N}$). The results are presented in Table 2. As evidence from the table, the results clearly rejected the null hypothesis of a unit root in favour of the trend-stationary alternative. The outcomes of the tests are not changed if the trend term is omitted from the model or if the drift term is omitted. The lag lengths chosen are large and are close to the maximum of $\sqrt{N}$. Some authors have found results sensitive to choice of lag length but in our case experimentation with shorter lag lengths (1, 2, ...,10) did not change the outcome of the tests. This finding is consistent with the random walk model. Its may also provides evidence of the nonlinear structure underlying return time series.

Table 2.: Test for a unit root in

ADF	PP	Lag	1% critical value	5% critical value
-4.239*	-20.548*	37	-3.442	-2.860

Notes:* significant at 1 per cent.

The results of applying the BDS test to the returns daily series for dimensions 2-5 and ε equalling 0.5, 1, 1.5, and 2 standard deviations are presented in Table 3 [2]. The calculated test statistics are quite high, indicating that the null hypothesis of independently and identically distribution is rejected at the 5 per cent level. This finding adds more favourable evidence suggests of the nonlinear underlying the return time series. However, it is not enough to merely identify non-linear dependence. Previous research has shown that often the non-linear dependence can be successfully described by a GARCH process. Further of causes of acceptance/rejection of non-IID behaviour could facilitate development of appropriate models. We therefore investigate whether the non-linear dependence in the Jordanian stock returns is caused by predictable conditional volatility.

Table 3.: BDS statistics for initial data at dimensions 2 through 5 and equalling 0.5, 1, 1.5, and 2 standard deviations

$\frac{\varepsilon}{\sigma}$	m=2	m=3	m=4	m=5
0.5	23.754*	24.935*	26.042*	27.601*
1	22.268*	23.604*	25.850*	26.468*
1.5	23.064*	24.835*	26.091*	26.962*
2	23.160*	24.065*	26.538*	27.903*

Note: An asterisk indicates significance at the 5 per cent level.

The results of the initial BDS tests suggest that we could fit a GARCH (q,p) model. The model is estimated for all combinations of p=1,2,3,4,5 and q=1,2,3,4,5. The SIC indicates that GARCH (1,1) is the most parsimonious representation of the return series[3]. The estimated results of the GARCH (1,1) model is given as

$$R_t = 0.0008 - 4.161\varepsilon_{t-1} + v_t$$
$$(2.278) \quad (-0.423)$$
$$h_t = 0.00001 + 0.357\varepsilon^2_{t-1} + 0.359h_{t-1}$$
$$(3.972) \quad (5.556) \qquad (3.748)$$

where the figures in parentheses are t-value and the v_t values are the residuals. Note that the constant in the first equation, although smaller than obtained in the simple random walk model, is now significant. It is also clear that the series R_t has significant heteroscedasticity and that the return series most certainly do not follow a random walk. Moreover, the result shows that the sum of $\alpha + \beta$ is less than one. This may indicates that any shock caused to the stock prices in the ASE tends to die out faster.

In order to check out that GARCH (1,1) model removed any nonlinear dependence in the return series, we use the BDS to test the null hypothesis of IID for the GARCH (1,1) standardise residuals. The results are presented in Table 4. It is absolutely clear that the GARCH (1,1) model removes considerable stochastic non-linear dependence from the data and that all structure in the return series has now been identified and explained. In particular, the BDS statistic for the standardised GARCH (1,1) residuals cannot reject the null hypothesis of independent random variables, i.e., IID. This finding suggests that the non-linear dependence appear to have been caused by the conditional heteroscedasticity.

Table 4.: BDS statistics for GARCH standardised residuals at dimensions 2 through 5 and ε equalling 0.5, 1, 1.5, and 2 standard deviations

$\frac{\varepsilon}{\sigma}$	m=2	m=3	m=4	m=5
0.5	-2.327	-3.752	-2.935	-2.653
1	-2.906	-3.583	-2.862	-2.806
1.5	-2.304	-3.062	-3.057	-3.091
2	-2.684	-3.381	-2.530	-3.280

Previous research has shown that nonstationarity can be one of the possible reasons for rejecting the IID hypothesis because the underlying structural and economic variables which influence the price evolutionary process can be nonstationary. This is particularly relevant in the Jordanian case where number of structural changes have been introduced in the process of economic liberalisation initiated by the government of Jordan since 1993. However, as we have shown in Table 1, the stantionarity statistical tests strongly support the absence of unit roots in the return series. This confirms that non-linear dependence is not caused by nonstationarity of underlying economic variables. The evidence supports our conclusions that the non-linear dependence seems be attributable to the ARCH effects.

Conclusion

This paper examines whether stock prices on the Amman Stock Exchange follow a random walk. The study examines the independence and identically distribution of return time series using aggregate daily data. Unit root tests, Jarque-Bera normality tests, and nonlinearity tests, are used. The broad conclusion emerging from this study is that daily returns from the ASE do not confirm to a random walk (independent and identity distributed). Daily returns exhibit significant non-linear dependence. Further examination reveals that most of the non-linear dependence is in the form of ARCH type conditional heteroscedasticity. The non-linearity is successfully explained by a GARCH (1,1) model. The unit root tests confirm that non-linear dependence does not appear to be caused by nonstationarity of underlying economic variables. Our results are largely consistent with the previous research that has shown evidence of non-linear dependence in returns from the stock market indexes in the US and the UK.

NOTES

[1] See foe example, Hsieh (1993) who finds that non-IID behaviour of daily log price changes of currency futures contracts is caused by predictable conditional variance which could be described by an autoregressive volatility model. in another study, Both et al., (1994) confirm that a simple GARCH model is able to capture the non-linear dependence in Finish stock returns.

[2] The BDS statistics are calculated using a program written by W.D. Dechert (Department of Economics, University of Houston). The program can be downloaded from http:// Dechert.econ.uh.edu/Software/ bds.html.

[3] In the interests of brevity, these results are not reported here. They are available from the author upon request.

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