Equitisation and stock-market development

Loc, T.D.

Chapter 8

Testing the Weak-Form Efficiency for the Vietnamese Stock-Market

8.1. Introduction

During the past decades, the efficient market hypothesis (EMH) has been at the heart of the debate in the financial literature because of its important implications. Fama (1970) defined a market as being efficient if prices fully reflect all available information, and suggested three models for testing market efficiency: the Fair Game model, the Submartingale model, and the Random Walk model. Also, according to Fama (1970), EMH can be categorised into three levels based on the definition of the available information set, namely weak form, semi-strong form, and the strong form. Following the work of Fama, the EMH has been widely investigated in both developed and emerging markets. Especially, in emerging stock markets, most empirical studies have focused on the weak form, the lowest level of EMH because if the evidence fails to support the weak-form of market efficiency, it is not necessary to examine the EMH at the stricter levels of semi-strong and strong form (Wong and Kwong, 1984). Although many empirical studies have been devoted to testing for the weak form of EMH in emerging stock markets (see the review of empirical literature in Section 8.4), no published research exists for the Vietnamese stock market. This chapter aims to seek evidence of the weak form market efficiency in the Vietnamese stock market. In order to achieve the objective, a set of complementary tests, namely autocorrelation tests, runs test and variance ratio tests, are employed in this chapter. The data used for these tests primarily comprise daily and weekly observed returns of the market index and five individual stocks listed on the market. Then, the data are adjusted for thin (infrequent) trading that is a prominent characteristic of the Vietnamese stock market and that could seriously bias the results of empirical studies on market efficiency.

The rest of this chapter is organised as follows. The theory of EMH is briefly discussed in Section 8.2. Section 8.3 provides definitions of different levels (forms) of EMH. A summary of empirical studies on the weak form efficiency in emerging stock markets is given in section 8.4. Section 8.5 is devoted to describing the data employed in this study. Statistical techniques used to test for the weak form market efficiency and empirical findings are presented in Section 8.6 and 8.7 respectively. Finally, conclusions of the chapter appear in Section 8.8.

8.2. The Theory of Efficient Market Hypothesis

The EMH, which plays an important role in the financial economics literature, relies on the efficient exploitation of information by economic actors. Generally, an asset market is referred to be efficient if the asset price in question must fully reflect all available information. If this is true, it should not be possible for market participants to earn abnormal profits. Based on the definitional statement of an efficient market above, Fama (1970) suggested three models for testing stock market: the Expected Return or Fair Game model, the Submartingale model, and the Random Walk model.

The Fair Game Model

In general, the fair game model states that a stochastic process X_t with the condition on information set I_t, is a fair game if it has the following property:

$$E\,(X_{t+1}|\,I_t) = 0 \tag{8.1}$$

In the case of stock markets, Fama (1970) introduced a model of the EMH that is derived from the Fair Game property for expected returns and expressed it in the following equations:

$$x_{j,t+1} = p_{j,t+1} - E(p_{j,t+1}|\,I_t) \tag{8.2}$$

$$\text{with } E(x_{j,t+1}|\,I_t) = E[p_{j,t+1} - (p_{j,t+1}|\,I_t)] = 0 \tag{8.3}$$

where $x_{j,t+1}$ is the excess market value of security j at time t+1, $p_{j,t+1}$ is the observed (actual) price of security j at time t+1, and $E(p_{j,t+1}|\,I_t)$ is the expected price of security j that was projected at time t, conditional on the information set I_t or equivalently

$$z_{j,t+1} = r_{j,t+1} - E(r_{j,t+1}|\,I_t) \tag{8.4}$$

$$\text{with } E(z_{j,t+1}|\,I_t) = E[r_{j,t+1} - (r_{j,t+1}|\,I_t)] = 0 \tag{8.5}$$

where $z_{j,t+1}$ is the unexpected (excess) return for a security j at time t+1, $r_{j,t+1}$ is the observed (actual) return for a security j at time t+1, and $E(r_{j,t+1}|\,I_t)$ is the equilibrium expected return at time t+1 (projected at time t) on the basis of the information set I_t.

This model implies that the excess market value of security j at time t+1 ($x_{j,t+1}$) is the difference between actual price and expected price on the basis of the information set I_t. Similarly, the unexpected (excess) return for a security j at time t+1 ($z_{j,t+1}$) is measured by the difference between the actual and expected return in that period conditioned on the set of available information at time t, I_t. According to the Fair Game model, the excess market value and excess return are zero. In other word, Equation 8.3 and 8.5 indicate that the excess market value sequence $\{x_{j,t+1}\}$ and $\{z_{j,t+1}\}$ respectively are fair games with respect to the information sequence $\{I_t\}$.

The Submartingale Model

The Submartingale model is the Fair Game model with a small adjustment in expected return. In this model, the expected return is considered to be positive instead of zero as in the Fair Game model. The adjustment implies that prices of securities are expected to increase over time. In other word, the returns on investments are projected to be positive due to the risk inherent of capital investment. The Submartingale model can be mathematically written as follows:

$$E(p_{j,t+1}| I_t) \geq p_{j,t} \tag{8.6}$$

$$E(r_{j,t+1}| I_t) = \frac{E(p_{j,t+1}| I_t) - p_{j,t}}{p_{j,t}} \geq 0 \tag{8.7}$$

This model states that the expected return sequence $\{r_{j,t+1}\}$ follows a submartingale, conditional on the information sequence $\{I_t\}$, which is meaningless in forecasting stock prices, except that the expected return, as projected on the basis of the information I_t, is equal to or greater than zero (Fama, 1970). The important empirical implication of the submartingale model is that no trading rule based only on the information set I_t can have greater expected returns than a strategy of always buying and holding the security during the future period in question.

The Random Walk Model

According to Fama (1970) an efficient market is a market in which prices reflect all available information. In the stock market, the intrinsic value of a share is equivalently measured by the future discounted value of cash flows that will accrue to investors. If the stock market is efficient, share prices must reflect all available information which is relevant for the evaluation of a company's future performance, and therefore the market price of share must be equal to its intrinsic value. Any new information, which is expected to change a company's future profitability, must be immediately reflected in the share price because any delay in the diffusion of information to price would result in irrationality, as some subsets of available information could be exploited to forecast future profitability. Thus, in an efficient market, price changes must be a response only to new information. Since information arrives randomly, share prices must also fluctuate unpredictably. The Random Walk model can be stated in the following equation:

$$P_{t+1} = P_t + \varepsilon_{t+1} \quad (8.8)$$

where:

P_{t+1}: price of share at time t+1;

P_t : price of share at time t;

ε_{t+1}: random error with zero mean and finite variance.

Equation 8.8 indicates that the price of a share at time t+1 is equal to the price of a share at time t plus given value that depends on the new information (unpredictable) arriving between time t and t+1. In other word, the change of price, $\varepsilon_{t+1} = P_{t+1} - P_t$, is independent of past price changes.

Fama (1970) argued that the random walk model is an extension of the expected return or fair game model. Specifically, the fair game model just indicates that the conditions of market equilibrium can be stated in terms of expected returns while the random walk model gives the details of the stochastic process generating returns. Therefore, he concluded that empirical tests of the random walk model are more powerful in support of the EMH than tests of the fair game model.

8.3. The Forms of EMH

The EMH can be more specifically defined with respect to the available information set (I_t) to market participants. Fama (1970) classified the information set into three subsets and suggested three forms (levels) of EMH, depending on the definition of the relevant information subsets, namely the weak, semi-strong, and strong form. This section highlights these forms with their practical implications.

The weak form of EMH

The weak form of EMH is the lowest form of efficiency that defines a market as being efficient if current prices fully reflect all information contained in past prices. This form implies that past prices cannot be used as a predictive tool for future stock price movements. Therefore, it is not possible for a trader to make abnormal returns by using only the past history of prices.

Semi-strong form of EMH

The semi-strong form of the EMH states that current market prices reflect all publicly available information, such as information on money supply, exchange rate, interest rates, announcement of dividends, annual earnings, stock splits, etc.

This means that it is impossible for market participants to make consistently superior returns just by analyzing annual reports or other published information because market prices will be immediately adjusted to any good or bad news contained in such reports as they are revealed.

Strong form of EMH

If by increasing the information set to include private information, it is not possible for a market participant to earn abnormal profits, then the market is referred as strong form of EMH. In other words, under the strong form of EMH market prices of securities reflect all relevant information, including both public and private information. The strong form of EMH implies that private information (inside information) is hard to obtain for making abnormal returns because if a market participant wants to have it, he/she has to compete with many active investors in the market. It is important to note that an assumption for the strong form is that inside information cost is always zero. However, this assumption hardly exists in reality, so the strong form of EMH is not very likely to hold.

8.4. Review of empirical literature on the Weak Form efficiency in emerging stock markets

The aim of this section is to draw a broad picture of empirical literature on the weak form efficiency in emerging stock markets. A summary of selected studies are given in Table 8.1.

As previously mentioned, the weak form of EMH implies that current market prices of stocks are independent on their past prices. In other words, a market is efficient in the weak form if stock prices follow a random walk process. Therefore, tests of weak form efficiency are naturally based on an examination of the interrelationship between current and past stock prices (Fawson et al., 1996). Practically, several statistical techniques, such as runs test, unit root test, serial correlation tests, and spectral analysis, have been commonly used for testing weak form efficiency[26]. Most studies on the weak form of EMH in emerging stock markets have used the runs test and/or unit root test as a principle method for detecting a random walk, a necessary condition for market efficiency in the weak form. Specifically, Table 8.1 shows that the runs test is adopted by Sharma and Kennedy (1997), Barnes (1986), Dickinson and Muragu (1994), Urrutia (1995), Karemera et al. (1999), Wheeler et al. (2002), Abraham et al. (2002), and the unit root test was employed by Groenwold et al. (2003), Buguk and Brorsen (2003), and Seddighi and Nian (2004) while Fawson et al.

[26] Some of these techniques are presented in the following Section (Section 8.5).

(1996), Moorkerjee and Yu (1999), and Abeysekera (2001) conducted both techniques in their study. A further test for market efficiency in the weak form that has been applied by a number of researchers is the serial correlation test, including the correlation coefficient test, Q-test, and variance ratio tests. Indeed, a combination of correlation coefficient test (testing for significance of individual serial correlation coefficient) and Q-test (testing for significance of a set of coefficients) is adopted by Dickinson and Muragu (1994), Fawson et al. (1996), Moorkerjee and Yu (1999), Abeysekera (2001), and Groenwold et al. (2003) while Urrutia (1995), Dockery and Vergari (1997), Grieb and Reyes (1999), Karemera et al. (1999), Alam et al. (1999), Chang and Ting (2000), Cheung and Coutts (2001), Abraham et al. (2002), and Lima and Tabak (2004) apply variance ratio tests as the main methodology to determine the weak form of market efficiency in their study. Finally, a few researchers use some other techniques, such as spectral analysis (Sharma and Kennedy, 1977; Fawson et al., 1996), GPH (Geweke and Porter-Hudak) fractional integration test (Buguk and Brorsen, 2003), and autoregressive conditional heteroscedasticity (ARCH) test (Seddighi and Nian, 2004) in order to find evidence for market efficiency.

Data obtained for testing weak form of EMH in emerging stock markets include stock price indices and/or individual stock prices series. Specifically, stock price indices are used in studies of Sharma and Kennedy (1997), Urrutia (1995), Fawson et al. (1996), Dockery and Vergari (1997) Abeysekera (2001), Abraham et al. (2002), Lima and Tabak (2004), while individual stock prices are employed by Dickinson and Muragu (1994), Olowe (1999), Wheeler et al. (2002). Especially, Barnes (1986), Grieb and Reyes (1999), Seddighi and Nian (2004) employed both kinds of data for their tests in order to detect the weak form of market efficiency. Another aspect of data used for testing weak form efficiency hypothesis in emerging stock markets is frequency of time series. Based on this respect, the data consist of daily (Mookerjee and Yu, 1999; Cheung and Coutts, 2001; Groenewold et al., 2003, Lima and Tabak, 2004 and Seddighi and Nian, 2004), weekly (Dickinson and Muragu, 1994; Dockery and Vergari, 1997; Grieb and Reyes, 1999; Abraham et al., 2002; and Buguk and Brorsen, 2003), monthly (Sharma and Kennedy, 1977; Barnes, 1986; Fawson et al., 1996; Olowe, 1999; Karemera et al., 1999; and Alam et al., 1999) and even yearly time series (Chang and Ting, 2000).

Empirical findings derived from the studies in emerging stock markets have been mixed. Indeed, some studies provide empirical results to reject the null hypothesis of weak form market efficient while the others show evidence to support the weak form of EMH. Regarding emerging European stock markets, for instance, the empirical evidence obtained from Wheeler et al. (2002) fails to support the weak form efficient hypothesis for the Warsaw Stock Exchange (Poland). On the other hand, Dockery and Vergari (1997) document that the Budapest Stock Exchange is efficient in the weak form. In addition, Karemera et al. (1999) and Buguk and Brorsen (2003) show empirical evidence to support the null hypothesis of weak form market efficiency for the stock market in Turkey. Surprisingly, in the perspective of Africa, Dickinson and Muragu (1994), and Olowe (1999) find that the Nairobi and Nigerian stock exchanges respectively are efficient in the weak form.

Turning to stock markets in the Latin American region, Urrutia (1995) provides mixed evidence on the weak form efficiency for the stock markets in Argentina, Brazil, Chile, and Mexico. Specifically, results of the variance ratio test reject the random walk hypothesis for all markets while findings from the run tests indicate that these markets are weak form efficient. Consistent with the results reported by Urrutia (1995), Grieb and Reyes (1999) show empirical findings, which are obtained from the variance ratio tests, to reject the hypothesis of random walk for all stock market indexes and most individuals stock in Brazil and Mexico. Moreover, Karemera et al. (1999) find that stock return series in Brazil, Chile, and Mexico do not follow the random walk, based on the results of single variance ratio tests, but Argentina does. However, when the multiple variance ratio test is applied, the market index returns in Brazil is observed to follow the random walk process (the others are not changed).

Empirical studies on weak form efficiency in Asian stock markets have been extensively conducted in recent years. Indeed, in the Chinese stock markets, Mookerjee and Yu (1999) and Groenewold et al. (2003) consistently document that these markets (Shanghai and Shenzhen stock exchanges) are not weak form efficient. In addition, Lima and Tabak (2004) find that the B shares index for both Shanghai and Shenzhen Stock Exchange do not follow the random walk. However, they also report that the hypothesis of weak form efficiency can not be rejected for A shares indexes of the two exchanges. Moreover, Seddighi and Nian (2004) document that the Shanghai Stock Exchange is weak form efficiency for the period from Jan. 4th 2000 to Dec. 31st 2000. Regarding the Taiwanese stock market, it is proved that the market is efficient in the weak form (Fawson et al., 1996; Alam et al., 1999; and Chang and Ting, 2000). Similarly, the null hypothesis of random walk can not be rejected for the Hong Kong stock market (Karemera et al., 1999; Alam et al., 1999; Cheung and Coutts, 2001; and Lima and Tabak, 2004). In addition, it is documented that stock market in the ASEAN region (Indonesia, Malaysia, Thailand and Singapore) follow the weak form of EMH (Barnes, 1986; Karemera et al., 1999; Alam et al., 1999). In the Southern part of Asia, Sharma and Kennedy (1977) and Alam et al. (1999) report that the random walk hypothesis can not be rejected for stock price changes on the Bombay (India) and Dhaka Stock Exchange (Bangladesh) respectively. However, Abeysekera (2001) and Abraham (2002) show evidence to reject the hypothesis of weak form efficiency for stock markets in Sri Lanka, Kuwait, Saudi Arabia and Bahrain.

Table 8.1: Summary of empirical studies on the Weak Form efficiency in emerging stock markets

Study	Methodology	Data	Findings
Sharma and Kennedy (1977)	- Run test - Spectral analysis	Monthly stock price index for the Bombay Variable Dividend Industrial Share Index covering the period from 1963 to 1973	Stock price changes on the Bombay stock exchange follow a random walk process.
Barnes (1986)	- Serial correlation tests - Run test - Spectral analysis	Monthly stock prices series of 30 individual stocks and 6 sector indices on the Kuala Lumpur Stock Exchange for the 6 years ended June 30, 1980	Overall, the market is efficient in the weak form (only a few individual stocks do not follow the random walk process).
Dickinson and Muragu (1994)	- Autocorrelation tests - Run test	Weekly price series of 30 individual stocks listed on the Nairobi Stock Exchange for the period of 1979-1989	The majority of individual stock price series satisfy conditions of weak form of EMH.
Urrutia (1995)	- Variance ratio test - Run tests	Monthly data for market indexes in Argentina, Brazil, Chile and Mexico covering from Dec. 1975 to March 1991	Results of the variance ratio test reject the random walk hypothesis for all markets. However, findings from the run tests can not reject the hypothesis.
Fawson, et al. (1996)	- Autocorrelation tests - Taylor's Binomial Distribution test - Run test - Unit root test	Monthly stock market returns for the index of the Taiwan Stock Exchange during the period between Jan. 1967 and Dec. 1993	The null hypothesis of weak form efficiency cannot be rejected for the market.
Dockery and Vergari (1997)	- Variance ratio test	Weekly stock market index of the Budapest Stock Exchange covering the period from Jan. 1991 to May 1995	The Budapest Stock Exchange is efficient in the weak form.

Table 8.1: Continued

Mookerjee and Yu (1999)	- Autocorrelation tests - Run test - Unit root test	Daily stock price indices of Shanghai and Shenzhen stock exchange for the period from Dec. 19 1990 to Dec. 17 1993 and from Apr. 3 1991 to Dec. 17 1993 respectively	The weak form of EMH is rejected for both exchanges.
Olowe (1999)	- Autocorrelation tests	Monthly returns data of 59 individual stocks listed on the Nigerian Stock Market over the period Jan. 1981-Dec. 1992	The null hypothesis of market efficiency in the weak form can not be rejected for the Nigerian Stock Market.
Grieb and Reyes (1999)	- Variance ratio test	Weekly stock price series for the market indexes and individual stocks in Brazil and Mexico during the period from Dec. 30 1988 to Jun. 30 1995	The hypothesis of weak form efficiency is rejected for all market indexes and most individual stocks.
Karemera et al. (1999)	- Variance ratio tests - Run test	Monthly stock market indexes for 15 emerging stock markets (Argentina, Brazil, Chile, Hong Kong, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, the Philippines, Singapore, Taiwan, Thailand and Turkey) during the period from Dec. 1987 to May 1997 (eleven markets) and from Jan. 1986 to Apr. 1995 (the remaining four markets)	Ten of fifteen markets follow the random walk under multiple variance ratio test (Argentina, Brazil, Hong Kong, Indonesia, Israel, Jordan, Korea, Malaysia, Singapore and Thailand) while only six of fifteen markets are found to be consistent with the random walk hypothesis under single variance ratio test (Argentina, Hong Kong, Israel, Korea, Malaysia, and Singapore). Findings of the run tests show nine of the total markets to be efficient in the weak form (Brazil, Hong Kong, Indonesia, Jordan, Korea, Malaysia, Mexico, Thailand and Turkey).

Table 8.1: Continued

Alam et al. (1999)	- Variance ratio test	Monthly return data for market index of Hong Kong, Malaysia, Taiwan, Sri Lanka and Bangladesh covering from Nov. 1986 to Dec. 1995	The hypothesis of weak form efficiency can not be rejected for all markets, except Sri Lanka.
Chang and Ting (2000)	- Variance ratio test	Weekly, monthly, quarterly and yearly returns for the market index of Taiwanese stock market for the period from Jan. 9 1971 to Jan. 6 1996	The random walk hypothesis can not be rejected for all series, except weekly series.
Cheung and Coutts (2001)	– Variance ratio test	Daily stock market index of the Hong Kong Stock Exchange over the period Jan. 1 1985 – Jun. 30 1997	Empirical evidence fails to reject the null hypothesis of weak form efficiency for the market.
Abeysekera (2001)	– Run test – Autocorrelation tests – Unit root test	Daily, weekly and monthly returns of two stock market indices of the Colombo Stock Exchange (Sri Lanka) for the period from Jan. 1991 to Nov. 1996	The weak form of EMH can not be accepted for the Colombo Stock Exchange.
Wheeler et al. (2002)	- Autocorrelation tests - Run test	Daily returns series of 16 individual stocks listed on the Warsaw Stock Exchange covering from 1991 to 1996.	The empirical evidence fails to support the null hypothesis of weak form of market efficiency for most of the individual stocks.
Abraham et al. (2002)	- Variance ratio test - Run test	Weekly market price indexes for the three major Gulf stock markets (Kuwait, Saudi Arabia, and Bahrain) during the period between Oct. 1992 and Dec. 1998	Weak form efficiency is rejected for the Gulf stock markets when the observed indices are used, but it can not be rejected when infrequent trading of these markets is corrected.

Table 8.1: Continued

Groenewold et al. (2003)	– Autocorrelation tests – Unit root test	Daily returns series for seven indices of the Shanghai, Shenzhen stock exchange (China) for the 1992-2001 period	The weak form of EMH is rejected for the Chinese stock exchanges. In addition, the empirical evidence reveals the positive effects of banks' participation on the market efficiency.
Buguk and Brorsen (2003)	– Unit root test – GPH (Geweke and Porter-Hudak) fractional integration test - Variance ratio tests	Weekly market index of the Istanbul Stock Exchange's composite, industrial, and financial index for the period from 1992 to 1999	The results obtained from the augmented Dickey-Fuller, GPH fractional integration, and single variance ratio test consistently indicate that all three series are a random walk. However, the rank- and sign-based variance ratio test shows some evidence to reject the null hypothesis of weak form efficiency.
Lima and Tabak (2004)	– Variance ratio test	Daily stock prices index of Shanghai, Shenzhen (China), Hong Kong, and Singapore Stock Exchange over the period from Jun. 1992 to Dec. 2000	The null hypothesis of weak form efficiency cannot be rejected for Hong Kong and A shares for both the Shanghai, Shenzhen stock exchange. However, it is rejected for Singapore stock exchange and B shares of both two exchanges.
Seddighi and Nian (2004)	- Autocorrelation tests - Unit root test - ARCH test	Daily data of the market index and eight individual shares listed on the Shanghai Stock Exchange for the period from Jan. 4 2000 to Dec. 31, 2000	The null hypothesis of weak form efficiency is accepted for the case of market index and most of individual stock prices series.

8.5. Data description

The data used in this study primarily consist of daily and weekly price series of the market index (VNINDEX) and the five oldest stocks listed on the Ho Chi Minh City stock exchange. Specifically, the market index, namely VNINDEX, is a composite that is calculated from prices of all stocks traded on the STC while individual stocks selected for this study are REE, SAM, HAP, TMS and LAF[27]. All data are obtained over the period from July 28th 2000 (the first trading session of the stock exchange) to Dec. 31st 2004 from the Bank for Investment & Development of Vietnam Securities Co.'s website (www.bsc.com.vn). Then, a natural logarithmic transformation is performed for the primary data. To generate a time series of continuously compounded returns, daily returns are computed as follows:

$$r_t = \log(p_t) - \log(p_{t-1}) = \log(p_t / p_{t-1}) \quad (8.9)$$

where p_t and p_{t-1} are the stock prices at time t and $t-1$.
Similarly, the weekly returns are calculated as the natural logarithm of the index and the stock prices from Wednesday's closing price minus the natural logarithm of the previous Wednesday's close. If the following Wednesday's price is not available, then Thursday's price (or Tuesday's if Thursday's is not available) is used. If both Tuesday's and Thursday's prices are not available, the return for that week is reported as missing. The choice of Wednesday aims to avoid the effects of weekend trading and to minimize the number of holidays (Huber, 1997).
As mentioned in chapter 7, in the first stage of the market, from July 28th 2000 to March 1st 2002, only three sessions are traded every week. Afterward, the market has traded daily (five sessions). Therefore, the stock prices of the first stage in question are not included in the daily data that are used in this study. The weekly data are not affected by the frequent trading of the market, so the sample period for the observed series is from July 28th 2000 up to the end of the year 2004. Descriptive statistics for daily and weekly returns of the VNINDEX and the individual stocks are presented in Table 8.2.

8.6. Methodology

According to Fama (1970), market efficiency under the random walk model implies that successive price changes of a stock are independently and identically distributed, so the past movement or trend of a stock price or market cannot be used to predict its future movement. As reviewed in Section 8.4, in

[27] For more detail of the five stocks, see Appendix 3 in chapter 7.

order to test the weak-form of EMH many techniques have been applied in empirical studies. Following these studies, a set of complementary tests are used to detect the random walk in the observed series of the Vietnamese stock market. First, the parametric autocorrelation test is used to examine whether the consecutive stocks returns are independent each other. Moreover, the results of the Jarque-Bera test (presented in Table 8.2), indicate that the stocks returns are not normally distributed, so a non-parametric test is likely to be more appropriate in testing for the random walk. Consequently, the runs test is also applied in chapter. Furthermore, the variance ratio tests, proposed by Lo and MacKinlay (1988), are conducted to examine whether uncorrelated increments exist in the series, under both assumptions of homoscedastic and heteroscedastic random walks.

Table 8.2: Descriptive statistics for the VNINDEX and the individual stocks returns

	VNINDEX	REE	SAM	HAP	TMS	LAF
Daily returns						
Observations	709	709	709	709	709	709
Mean	0.0001	-6.35E-05	0.0002	-0.0003	-6.28E-05	9.38E-05
Median	-0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
Maximum	0.0204	0.1811	0.1798	0.2168	0.2942	0.1447
Minimum	-0.0206	-0.1811	-0.1798	-0.2117	-0.2942	-0.1567
Std. Dev.	0.0046	0.0138	0.0152	0.0196	0.0182	0.0110
Skewness	0.9	-2.8	-2.0	-1.3	-1.1	-0.8
Kurtosis	7.9	121.5	106.2	83.5	204.3	100.3
Jarque-Bera	800.7[a]	415,586.2[a]	314,917.0[a]	191,786.2[a]	1,196,997.0[a]	279,808.7[a]
Weekly returns						
Observations	225	225	225	224	224	205
Mean	0.0016	0.0007	0.0014	0.0007	0.0016	0.0013
Median	0.0003	0.0000	0.0011	0.0011	0.0000	0.0000
Maximum	0.0840	0.0834	0.0853	0.1718	0.2850	0.1567
Minimum	-0.0894	-0.1774	-0.1768	-0.2553	-0.3010	-0.1467
Std. Dev.	0.0189	0.0259	0.0240	0.0365	0.0376	0.0283
Skewness	-0.4	-1.5	-2.0	-3.1	-0.97	-0.1
Kurtosis	8.0	13.6	17.8	26.4	36.97	11.0
Jarque-Bera	239.9[a]	1,129.9[a]	2,201.8[a]	5485.9[a]	10,808.3[a]	543.5[a]

[a] *: Indicates that the null hypothesis of normality is rejected at the 1% significant level*

Autocorrelation tests

The first approach to detecting the random walk of the stock returns summarised here is the autocorrelation test. Autocorrelation (serial correlation coefficient) measures the relationship between the stock return at current period and its value in the previous period. It is given as follows:

$$\rho_k = \frac{\sum_{t=1}^{N-k}(r_t - \bar{r})(r_{t+k} - \bar{r})}{\sum_{t=1}^{N}(r_t - \bar{r})^2} \qquad (8.10)$$

where ρ_k is the serial correlation coefficient of stock returns of lag k; N is the number of observations; r_t is the stock return over period t; r_{t+k} is the stock return over period t+k; $\bar{r}$ is the sample mean of stock returns; and k is the lag of the period.
The test aims to determine whether the serial correlation coefficients are significantly different from zero. Statistically, the hypothesis of weak-form efficiency should be rejected if stock returns (price changes) are serially correlated (ρ_k is significantly different from zero).
To test the joint hypothesis that all autocorrelations are simultaneously equal to zero, the Ljung–Box portmanteau statistic (Q) is used. The Ljung–Box Q-statistics are given by:

$$Q_{LB} = N(N+2)\sum_{j=1}^{k}\frac{\rho_j^2}{N-j} \qquad (8.11)$$

where ρ_j is the j^{th} autocorrelation and N is the number of observations. Under the null hypothesis of zero autocorrelation at the first k autocorrelations ($\rho_1 = \rho_2 = \rho_3 = \ldots = \rho_k = 0$), the Q-statistic is distributed as chi-squared with degrees of freedom equal to the number of autocorrelations (k).

Runs test

The runs test is a non-parametric test that is designed to examine whether or not an observed sequence is random. The test is based on the premise that if a series of data is random, the observed number of runs in the series should be close to the expected number of the runs. A run can be defined as a sequence of consecutive price changes with the same sign. Therefore, price changes of stocks can be categorized into three kinds of run: upward run (prices go up), downward run (prices go down) and flat run (prices do not change). Under the null hypothesis of independence in share price changes (share returns), the total expected number of runs (m) can be estimated as:

$$m = \frac{\left\{N(N+1) - \sum_{i=1}^{3} n_i^2\right\}}{N} \tag{8.12}$$

where N is the total number of observations (price changes or returns) and n_i is the number of price changes (returns) in each category (N = $\sum_{i=1}^{3} n_i$). For a large number of observations (N > 30), the sampling distribution of m is approximately normal and the standard error of m (σ_m) is given by:

$$\sigma_m = \left\{ \frac{\sum_{i=1}^{3} n_i^2 \left[\sum_{i=1}^{3} n_i^2 + N(N+1) \right] - 2N \sum_{i=1}^{3} n_i^3 - N^3}{N^2 (N-1)} \right\}^{1/2} \tag{8.13}$$

The standard normal Z-statistics that can be used to test whether the actual number of runs is consistent with the hypothesis of independences is given by:

$$Z = \frac{R \pm 0.5 - m}{\sigma_m} \tag{8.14}$$

where R is the actual number of runs, m is the expected number of runs, and 0.5 is the continuity adjustment (Wallis and Roberts, 1956) in which the sign of the continuity adjustment is negative (- 0.5) if R ≥ m, and positive otherwise. Since there is evidence of dependence among share returns when R is too small or too large, the test is a two-tailed one.

Variance ratio test

The variance ratio test, proposed by Lo and MacKinlay (1988), is demonstrated to be more reliable and as powerful as or more powerful than the unit root test (Lo and MacKinlay, 1988; Liu and He, 1991). The test is based on the assumption that the variance of increments in the random walk series is linear in the sample interval. Specifically, if a series follows a random walk process, the variance of its q-differences would be q times the variance of its first differences.

$$\mathrm{Var}(p_t - p_{t-q}) = q\mathrm{Var}(p_t - p_{t-1}) \tag{8.15}$$

where q is any positive integer. The variance ratio, VR(q), is then determined as follows:

$$VR(q) = \frac{\frac{1}{q}\mathrm{Var}(\mathrm{p_t - p_{t-q}})}{\mathrm{Var}(\mathrm{p_t - p_{t-1}})} = \frac{\sigma^2(q)}{\sigma^2(1)} \quad (8.16)$$

For a sample size of *nq + 1* observations (p_0, p_1, …, p_{nq}), the formulas for computing $\sigma^2(q)$ and $\sigma^2(1)$ are given in the following equations:

$$\sigma^2(q) = \frac{\sum_{t=q}^{nq}(p_t - p_{t-q} - q\hat{\mu})^2}{h} \quad (8.17)$$

where

$$h = q(nq+1-q)(1-\frac{q}{nq}) \quad (8.18)$$

and

$$\hat{\mu} = \frac{1}{nq}\sum_{t=1}^{nq}(p_t - p_{t-1}) = \frac{1}{nq}(p_{nq} - p_0) \quad (8.19)$$

$$\sigma^2(1) = \frac{\sum_{t=1}^{nq}(p_t - p_{t-1} - \hat{\mu})^2}{(nq-1)} \quad (8.20)$$

Under the assumption of homoscedasticity and heteroscedasticity increments, two standard normal test-statistics, Z(q) and $Z^*(q)$ respectively, developed by Lo and MacKinlay (1988), are calculated by Equation (8.21) and (8.22) below:

$$Z(q) = \frac{VR(q)-1}{[\phi(q)]^{1/2}} \approx N(0,1) \quad (8.21)$$

$$Z^*(q) = \frac{VR(q)-1}{[\phi^*(q)]^{1/2}} \approx N(0,1) \quad (8.22)$$

where $\phi(q)$ is the asymptotic variance of the variance ratio under the assumption of homoscedasticity, and $\phi^*(q)$ is the asymptotic variance of the variance ratio under the assumption of heteroscedasticity:

$$\phi(q) = \frac{2(2q-1)(q-1)}{3q(nq)} \tag{8.23}$$

$$\phi^*(q) = \sum_{j=1}^{q-1}\left[\frac{2(q-j)}{q}\right]^2 \hat{\delta}(j) \tag{8.24}$$

where $\hat{\delta}(j)$ is the heteroscedasticity – consistent estimator and computed as follows:

$$\hat{\delta}(j) = \frac{\sum_{t=j+1}^{nq}(p_t - p_{t-1} - \hat{\mu})^2 (p_{t-j} - p_{t-j-1} - \hat{\mu})^2}{\left[\sum_{t=1}^{nq}(p_t - p_{t-1} - \hat{\mu})^2\right]^2} \tag{8.25}$$

Estimating the true returns-correcting for thin (infrequent) trading

As mentioned in Chapter 7, the Vietnamese stock market is characterised by thin and infrequent trading. Many studies have pointed out that thin (or infrequent) trading can seriously bias the results of empirical studies on market efficiency (see Cohen *et al*., 1978; Lo and MacKinlay, 1990a; Stoll and Whaley, 1990; Miller *et al*., 1994). To deal with this problem while testing the weak-form of EMH for the Vietnamese stock market, the methodology proposed by Miller *et al.* (1994) is employed in this study. To remove the effect of thin trading, the model basically suggests that a moving average model which reflects the number of non-trading days should be estimated, and then returns are adjusted accordingly. However, due to difficulties in determining the non-trading days, Miller *et al*. (1994) show that it is equivalent to achieve the non-trading adjustment by estimating an AR(1) model. Specifically, the model can be stated in the following equations:

$$R_t = \alpha_0 + \alpha_1 R_{t-1} + \varepsilon_t \tag{8.26}$$

Then, using the residuals from Equation 8.26, adjusted returns are computed as follows:

$$R_t^{Adj} = \frac{\varepsilon_t}{1-\alpha_1} \tag{8.27}$$

where R_t^{Adj} is the adjusted return for thin trading at time t.

It is important to note here that the above model assumes the non-trading adjustment to be constant over time. The assumption may be correct for developed markets, but it is not likely to be the case for emerging market (Antoniou et al., 1997). Therefore, in this study Equation 8.26 is recursively estimated on a yearly basis.
All tests are conducted with both observed and corrected data. The results of these tests are discussed in the following section.

8.7. Empirical findings

8.7.1. Autocorrelation tests

To test the weak form of EMH for the Vietnamese stock market, first the autocorrelation tests with 12 lags are performed for daily weekly returns of the VNINDEX and five individual stocks. The results of these tests are summarised in Table 8.3, Table 8.4, Table 8.5 and Table 8.6.

Results for daily returns

Table 8.3 and Table 8.4 shows the results of the autocorrelation tests for daily observed and corrected returns for thin (infrequent) trading respectively. When the observed returns are used, it is found that the null hypothesis of random walk is rejected for all studied series (except HAP). Specifically, for the VNINDEX, it is evident that autocorrelation coefficients are significant with a positive sign for 1st, 4th, 5th, 6th and 7th lag[28]. It is worth to note here that the positive sign of the autocorrelation coefficients indicates that consecutive daily returns tend to have the same sign, so that a positive (negative) return in the current day tends to be followed by an increase (decrease) of return in the next several days. Especially, the results of the Liung-Box Q-test reveal that the autocorrelation coefficients of all 12 lags are jointly significant at 1% level. Regarding the individual stocks returns, it is observed that serial correlation coefficients are significant at 1st, 4th, 5th, 6th and 7th lag for REE; at 1st, 2nd, 3rd and 6th for TMS; at 1st, 7th and 10th lag for SAM and at 1st and 3rd lag for LAF. Importantly, the results of Q-test fail to support the joint null hypothesis that all autocorrelation coefficients of 12 lags are equal to zero for all individual stocks return series in question.
The empirical results for the corrected returns, presented in Table 8.4, again reject the random walk hypothesis for the Index and all selected individual stocks (except HAP). However, the rejection of the null hypothesis is less pronounced for REE and LAF when observed returns are corrected for thin

[28] They are significantly different from zero.

trading. Specifically, the joint hypothesis that all autocorrelation coefficients are simultaneously equal to zero is only rejected for some lags, not all 12 lags as in the case of observed returns presented above.

Results for weekly returns

Similar to the results for the daily observed returns, it is found that autocorrelation coefficients of the weekly observed index returns are significant with a positive sign at 1st, 2nd, 3rd, 4th, and 5th lags. Additionally, based on the Q-statistics, the null hypothesis of no autocorrelation on the index returns for all lags selected is strongly rejected at the one percent significant level. Furthermore, results of the autocorrelation tests on weekly observed returns for the individual stocks, summarised in Table 8.5, show significant autocorrelation coefficients at the first lags for each individual stock returns series. Specifically, significant autocorrelation coefficients are found at 1st, 2nd, and 4th lag for REE; at 1st, 2nd, 4th, and 5th lag for SAM; at 1st and 2nd lag for HAP; at 1st, 2nd, 3rd, 4th, 5th and 7th lag for TMS; and at 1st, 2nd, 3rd, and 5th lag for LAF. Once again, the Q-statistics fail to support the joint null hypothesis that all autocorrelation coefficients from lag 1 to 12 are equal to zero for all individual stocks observed return series.

Further, the results of the autocorrelation tests for the corrected returns indicate that the random walk hypothesis is also rejected for the market index and all selected individual stocks, except REE. However, the extent of rejection is less pronounced for these series, especially for the market index, SAM and HAP, as the returns are adjusted for thin trading.

On the basis of the empirical results obtained from autocorrelation tests for the observed returns, it can be concluded that the null hypothesis of random walk is rejected for the market index and all selected individual stocks (except HAP). When the corrected returns for thin trading are used, the random walk hypothesis is also rejected for the market index and four out of five selected individual stocks although the extent of rejection is less pronounced.

8.7.2. Run tests

To detect for the weak form efficiency of the Vietnamese stock market, the non-parametric runs test is also used in this study. The runs test is considered more appropriate than the parametric autocorrelation test since all observed series do not follow the normal distribution[29]. Results of the runs tests for daily and weekly returns of the index and the selected individual stocks are reported in Table 8.7. Specifically, the results of the runs test for daily observed returns

[29] See the Jarque-Bera test results in Table 8.2.

Table 8.3: Results of autocorrelation tests for the daily observed returns data

Lag	VNINDEX		REE		SAM		HAP		TMS		LAF	
	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat
1	0.380[a]	102.553[a]	0.166[a]	19.504[a]	0.237[a]	39.937[a]	0.055	2.175	0.083[b]	4.858[b]	0.132[a]	12.381[a]
2	-0.041	103.779[a]	0.019	19.774[a]	-0.056	42.132[a]	0.004	2.189	-0.106[a]	12.831[a]	-0.002	12.384[a]
3	-0.039	104.869[a]	0.067	22.994[a]	0.055	44.292[a]	-0.018	2.422	-0.105[a]	20.735[a]	-0.109[a]	20.938[a]
4	0.081[b]	109.552[a]	0.079[b]	27.486[a]	0.057	46.591[a]	-0.011	2.508	-0.026	21.202[a]	0.039	22.049[a]
5	0.101[a]	116.923[a]	0.083[b]	32.405[a]	0.015	46.758[a]	0.019	2.769	0.009	21.262[a]	-0.000	22.049[a]
6	0.090[b]	122.668[a]	0.094[b]	38.722[a]	0.067	49.939[a]	-0.035	3.645	0.144[a]	36.179[a]	0.067	25.225[a]
7	0.110[a]	131.329[a]	0.097[a]	45.535[a]	0.108[a]	58.319[a]	-0.007	3.680	-0.024	36.579[a]	0.004	25.238[a]
8	0.046	132.829[a]	0.018	45.772[a]	0.026	58.799[a]	-0.037	4.643	0.021	36.892[a]	0.025	25.679[a]
9	0.004	132.839[a]	-0.021	46.079[a]	-0.032	59.557[a]	0.007	4.674	0.003	36.898[a]	0.008	25.722[a]
10	0.031	133.548[a]	0.018	46.307[a]	0.017	59.762[a]	0.007	4.707	0.017	37.101[a]	-0.011	25.813[a]
11	0.063	136.404[a]	0.070	49.845[a]	0.075[b]	63.826[a]	-0.003	4.715	0.035	37.978[a]	-0.050	27.597[a]
12	0.021	136.716[a]	0.022	50.207[a]	0.038	64.869[a]	-0.002	4.717	0.044	39.359[a]	-0.059	30.121[a]

[a], [b]: *Significant at the 1% and 5% levels, respectively.*

Table 8.4: Results of autocorrelation tests for the daily corrected returns data

Lag	VNINDEX		REE		SAM		HAP		TMS		LAF	
	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat
1	0.082[b]	4.748[b]	-0.003	0.0073	0.046	1.494	-0.002	0.003	0.066	3.084	0.007	0.030
2	-0.209[a]	35.818[a]	-0.061	2.6738	-0.135[a]	14.519[a]	-0.002	0.007	-0.111[a]	11.846[a]	-0.024	0.439
3	-0.076[b]	39.915[a]	0.055	4.8596	0.053	16.526[a]	-0.024	0.425	-0.107[a]	19.952[a]	-0.120[a]	10.677[b]
4	0.075[b]	43.886[a]	0.058	7.2573	0.059	19.047[a]	0.004	0.434	-0.030	20.600[a]	0.044	12.061[b]
5	0.059	46.391[a]	0.047	8.8458	-0.026	19.524[a]	0.008	0.480	0.019	20.868[a]	-0.019	12.307[b]
6	0.030	47.037[a]	0.071	12.423	0.047	21.113[a]	-0.033	1.257	0.135[a]	33.868[a]	0.068	15.638[b]
7	0.086[b]	52.375[a]	0.094[b]	18.718[a]	0.106[a]	29.099[a]	-0.009	1.321	-0.019	34.124[a]	-0.019	15.903[b]
8	0.011	52.460[a]	-0.002	18.721[b]	0.009	29.164[a]	-0.024	1.745	0.021	34.437[a]	0.027	16.442[b]
9	-0.030	53.095[a]	-0.041	19.953[b]	-0.052	31.143[a]	0.001	1.745	0.006	34.461[a]	-0.006	16.466
10	0.011	53.175[a]	0.013	20.080[b]	0.003	31.147[a]	0.012	1.847	0.023	34.856[a]	-0.012	16.577
11	0.058	55.595[a]	0.076[b]	24.242[b]	0.078[b]	35.579[a]	-0.006	1.873	0.027	35.363[a]	-0.052	18.528
12	0.000	55.595[a]	-0.004	24.251[b]	0.040	36.754[a]	-0.002	1.875	0.044	36.740[a]	-0.057	20.858

[a], [b]: Significant at the 1% and 5% levels, respectively.

Table 8.5: Results of autocorrelation tests for the weekly observed returns data

Lag	VNINDEX		REE		SAM		HAP		TMS		LAF	
	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat
1	0.328[a]	24.554[a]	0.266[a]	16.090[a]	0.175[a]	6.986[a]	-0.188[a]	8.016[a]	0.200[a]	9.106[a]	0.164[b]	5.588[b]
2	0.250[a]	38.905[a]	0.177[a]	23.271[a]	0.144[b]	11.712[a]	0.310[a]	29.971[a]	0.246[a]	22.922[a]	0.219[a]	15.633[a]
3	0.155[b]	44.434[a]	0.120	26.589[a]	0.040	12.085[a]	-0.066	30.968[a]	0.178[a]	30.196[a]	0.215[a]	25.379[a]
4	0.206[a]	54.280[a]	0.201[a]	35.946[a]	0.172[a]	18.921[a]	0.063	31.883[a]	0.151[b]	35.418[a]	0.097	27.372[a]
5	0.239[a]	67.540[a]	0.118	39.169[a]	0.170[b]	25.666[a]	0.090	33.762[a]	0.232[a]	47.884[a]	0.226[a]	38.241[a]
6	0.075	68.838[a]	0.077	40.550[a]	-0.039	26.029[a]	0.015	33.817[a]	0.088	49.692[a]	0.128	41.709[a]
7	0.089	70.685[a]	0.066	41.577[a]	0.064	26.993[a]	-0.002	33.818[a]	0.136[b]	54.008[a]	0.009	41.727[a]
8	-0.013	70.725[a]	0.096	43.739[a]	-0.031	27.214[a]	0.008	33.833[a]	0.078	55.431[a]	-0.083	43.212[a]
9	0.098	72.993[a]	-0.034	44.020[a]	0.105	29.817[a]	0.068	34.936[a]	0.059	56.246[a]	0.094	45.123[a]
10	-0.077	74.391[a]	0.016	44.082[a]	-0.091	31.773[a]	-0.002	34.937[a]	0.027	56.419[a]	-0.097	47.192[a]
11	0.069	75.516[a]	-0.007	44.093[a]	0.018	31.850[a]	0.061	35.809[a]	0.051	57.037[a]	0.022	47.297[a]
12	0.031	75.741[a]	0.006	44.103[a]	-0.007	31.861[a]	0.048	36.369[a]	0.047	57.561[a]	0.021	47.393[a]

[a], [b]: *Significant at the 1% and 5% levels, respectively.*

Table 8.6: Results of autocorrelation tests for the weekly corrected returns data

Lag	VNINDEX		REE		SAM		HAP		TMS		LAF	
	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat	AC	Q-stat
1	-0.055	0.687	-0.033	0.244	-0.005	0.005	-0.010	0.022	-0.079	1.406	-0.046	0.448
2	0.143[b]	5.377	0.055	0.939	0.069	1.095	0.238[a]	12.863[a]	0.165[b]	7.578[b]	0.181[a]	7.270[b]
3	0.017	5.442	0.047	1.455	-0.022	1.209	0.025	13.006[a]	0.058	8.345[b]	0.165[b]	12.927[a]
4	0.099	7.707	0.100	3.761	0.162[b]	7.213	-0.011	13.035[b]	-0.008	8.360	-0.004	12.930[b]
5	0.178[a]	15.016[a]	0.081	5.265	0.162[b]	13.305[b]	0.089	14.846[b]	0.243[a]	21.917[a]	0.211[a]	22.340[a]
6	-0.040	15.386[b]	0.008	5.280	-0.107	15.944[b]	0.016	14.904[b]	-0.011	21.945[a]	0.062	23.152[a]
7	0.093	17.410[b]	0.051	5.881	0.056	16.662[b]	-0.053	15.569[b]	0.147[b]	26.992[a]	0.026	23.300[a]
8	-0.104	19.948[b]	0.006	5.889	-0.053	17.320[b]	-0.006	15.576[b]	-0.080	28.496[a]	-0.171[b]	29.549[a]
9	0.144[b]	24.800[a]	0.001	5.889	0.139[b]	21.887[a]	0.051	16.175	0.110	31.308[a]	0.131	33.260[a]
10	-0.170[b]	31.648[a]	-0.044	6.345	-0.128	25.769[a]	-0.018	16.249	-0.098	33.548[a]	-0.139[b]	37.422[a]
11	0.107	34.366[a]	0.018	6.425	0.024	25.911[a]	0.069	17.392	0.075	34.865[a]	0.024	37.546[a]
12	-0.055	34.438[a]	0.003	6.427	-0.000	25.911[b]	0.045	17.872	0.123	38.488[a]	0.045	37.986[a]

[a], [b]: Significant at the 1% and 5% levels, respectively.

Table 8.7: Results of the runs test for VNINDEX and selected individual stocks

Variables	Obs. (N)	Actual runs (R)	Expected runs (m)	Z-statistic
Panel A: Daily data				
Observed returns				
VN-INDEX	709	246	354	-8,27[a]
REE	709	390	469	-6,28[a]
SAM	709	398	474	-5,99[a]
HAP	709	425	474	-3,83[a]
TMS	709	412	474	-4,87[a]
LAF	709	415	472	-4,55[a]
Corrected returns				
VN-INDEX	708	320	352	-2.37[b]
REE	708	323	352	-2.14[b]
SAM	708	310	355	-3.34[a]
HAP	708	320	342	-1.70
TMS	708	316	352	-2.71[a]
LAF	708	342	350	-0.56
Panel A: Weekly data				
Observed returns				
VN-INDEX	225	81	113	-4.27[a]
REE	225	111	135	-3.35[a]
SAM	225	100	125	-3.52[a]
HAP	224	123	131	-1.09
TMS	224	103	129	-3.67[a]
LAF	205	105	124	-2.76[a]
Corrected returns				
VN-INDEX	224	95	113	-2.34[b]
REE	224	103	113	-1.24
SAM	224	92	113	-2.71[a]
HAP	223	86	104	-2.50[b]
TMS	223	92	112	-2.59[a]
LAF	204	93	103	-1.33

[a], [b]: Significant at the 1% and 5% levels, respectively.

indicate that the actual runs of all series are significantly smaller than their corresponding expected runs at 1% level, so that the null hypothesis of independence among stock returns is rejected for these series. Moreover, the results of runs test based on the corrected returns also support the null hypothesis of random walk for VNINDEX, REE, SAM and TMS. However, these results fail to reject the null hypothesis for HAP and LAF.

The empirical results of the runs test for weekly observed and corrected returns are presented in Panel B of Table 8.7. For the weekly observed returns, the results indicate that the null hypothesis of independence among stock returns is rejected for the market index and all selected individual stocks, except HAP. However, when the corrected returns are used, the results of the runs test reveal that the null hypothesis can not be rejected for HAP, but it is rejected for REE and LAF. For the remaining series, the rejection of the null hypothesis is unchanged, but the extent is less pronounced as compared with the results for the weekly observed data.

In summary, the runs test provides evidence to reject the null hypothesis of random walk for both daily and weekly observed returns of the market index and all selected individual stocks (except weekly returns for HAP). However, when the corrected returns are used, the empirical results obtained from the test fail to reject the null hypothesis for HAP and LAF with the daily data and for REE and LAF with the weekly one.

8.7.3. Variance ratio tests

This study employs variance ratio tests for both null hypotheses, namely the homoscedastic and heteroscedastic increments random walk. In addition, the variance ratio is calculated for intervals (q) of 2, 4, 8, 16 and 32 observations. The results of the variance ratio tests are reported in Table 8.8, Table 8.9, Table 8.10 and Table 8.11.

Results for daily returns

Empirical evidence obtained from the variance ratio tests for daily observed returns indicates that the random walk hypothesis under the assumption of homoscedasticity is rejected for all series. In the case of VNINDEX, for instance, the Z-statistics suggest that the variance ratios are significantly different from one for all values of q at the one percent level. Therefore, the null hypothesis of random walk is strongly rejected for the market index series. Similarly, the empirical findings reveal that the null hypothesis of random walk for all selected individual stocks can not be accepted for all levels of q at the one percent level of significance.

Moreover, the rejections of the random walk hypothesis under both homoscedasticity and heteroscedasticity assumptions for all series do not change even when the daily corrected returns for thin trading are used. Indeed, all the test-statistics of Z(q) and Z*(q) are still larger than the critical statistic at one percent level of significance (2.57).

Results for weekly returns

Results of the variance ratio tests on the weekly observed return data, presented in Table 8.9, confirm again that the null hypothesis of random walks under the assumption of homoscedasticity is strongly rejected for all series at all cases of q. Indeed, all Z-statistics are greater than the conventional critical value (1.96 for the five percent level). In addition, the heteroscedasticity-consistent variance ratio test provides consistent evidence that the null hypothesis of random walk can not be accepted for all weekly observed return series. Specifically, a comparison the Z^*-statistic to the conventional critical value reveals that the random walk hypothesis is rejected at q = 2, 4, 8, and 16 for TMS and REE, and at q = 2, 4, and 8 for VNINDEX and LAF. Moreover, the evidence against the null hypothesis under the assumption of heteroscedasticity in the case of HAP is weak because only two rejections (q=2 and q=4) are reported.
Further, when the corrected returns are employed, similar results are obtained from the tests. Specifically, the null hypothesis of random walks under the assumption of homoscedasticity is strongly rejected for all series at all cases of q while the null under the assumption heteroscedasticity can not be accepted for all series at some cases of q. The rejection of the null hypothesis is less pronounced for VNINDEX, REE, TMS and LAF, but more pronounced for SAM and HAP as compared with the results for the weekly observed returns.
On the basis of empirical evidence provided above, it can be concluded that the null hypothesis of random walk is rejected for the market index and all selected individual stocks. Moreover, thin trading is unlikely to affect the market efficiency.

8.8. Conclusions

This chapter first provides an overview of the theoretical literature on the EMH. Specifically, three theoretical models suggested by Fama (1970), namely the Fair Game model, the Sub-martingale model, and the Random Walk model, are briefly summarised. The theoretical models of efficient market consistently imply that the future price of stock is unpredictable with respect to the current information, so market participants cannot earn abnormal profits. Additionally, this chapter also highlights three different levels of EMH, weak form, semi-strong form, and the strong form.
Following the theoretical literature, empirical studies on the weak form of EMH in emerging stock markets have been extensively conducted, especially in recent

years. The empirical evidence obtained from these studies is mixed. Indeed, while some studies show empirical results that reject the null hypothesis of weak form market efficiency, the others report evidence to support the weak form of EMH. In general, emerging stock markets are unlikely to be efficient in weak form possibly due to their inherent characteristics, such as low liquidity, thin and infrequent trading, and lack of experienced market participants.

On the basis of the theoretical and empirical literature that is reviewed in this chapter, the weak form of market efficiency for the market index and five selected individual stocks is tested by using both daily and weekly return data for the period from March 1st 2002 to December 31st 2004 and from July 28th 2000 to December 31st 2004. In addition, to deal with the problem of thin (infrequent) trading, which would seriously bias the results of the empirical study on market efficiency, the observed returns are corrected by using the methodology proposed by Miller et al. (1994). Moreover, in order to test the weak form of EMH for the Vietnamese stock market, three different techniques are employed, namely autocorrelation, runs, and variance ratio tests. The results obtained from the autocorrelation indicate that the null hypothesis of random walk is conclusively rejected for the market index and four out of five selected individual stocks, even in the case where the returns are corrected for thin trading. In addition, the runs test shows evidence to reject the null hypothesis of a random walk for both daily and weekly observed returns of the market index and all selected individual stocks (except weekly returns for HAP). However, when the corrected returns are used, the empirical results given by the tests fail to reject the null hypothesis for the daily returns of HAP and LAF and weekly returns for REE and LAF. Moreover, the results of the Lo and MacKinley's variance ratio test under both homoscedastic and heteroscedasticity assumptions for both observed and corrected returns fail to support the random walk hypothesis for the market index and all selected individual stocks. In general, it can be concluded that the Vietnamese stock market is inefficient in the weak form. A question arises here is whether investors can make abnormal profits by establishing a trading strategy on the basis of past information. Motivated by this interesting question, further studies on the issue of of market efficiency are conducted. Empirical results of these studies are presented in the following chapter.

Table 8.8: Variance ratio test results for the daily observed return data

Variables	Number nq of base observations	Number q of base observations aggregated to form variance ratio				
		2	4	8	16	32
VNINDEX	708					
VR(q)		0.84	0.37	0.19	0.10	0.05
Z(q)		-4.22[a]	-8.93[a]	-7.25[a]	-5.42[a]	-3.94[a]
$Z^*(q)$		-2.77[a]	-5.15[a]	-4.47[a]	-3.65[a]	-2.89[a]
REE	708					
VR(q)		0.59	0.28	0.15	0.08	0.04
Z(q)		-10.94[a]	-10.27[a]	-7.65[a]	-5.56[a]	-4.00[a]
$Z^*(q)$		-3.46[a]	-3.85[a]	-3.65[a]	-3.31[a]	-2.86[a]
SAM	708					
VR(q)		0.69	0.31	0.16	0.08	0.04
Z(q)		-8.15[a]	-9.80[a]	-7.54[a]	-5.53[a]	-3.99[a]
$Z^*(q)$		-5.34[a]	-5.72[a]	-4.61[a]	-3.70[a]	-2.97[a]
HAP	708					
VR(q)		0.54	0.27	0.14	0.07	0.03
Z(q)		-12.33[a]	-10.40[a]	-7.72[a]	-5.63[a]	-4.02[a]
$Z^*(q)$		-5.15[a]	-5.00[a]	-4.30[a]	-3.55[a]	-2.87[a]
TMS	708					
VR(q)		0.60	0.28	0.14	0.07	0.04
Z(q)		-10.53[a]	-10.22[a]	-7.77[a]	-5.60[a]	-4.02[a]
$Z^*(q)$		-7.05[a]	-6.84[a]	-5.54[a]	-4.22[a]	-3.20[a]
LAF	708					
VR(q)		0.58	0.28	0.14	0.07	0.04
Z(q)		-11.20[a]	-10.27[a]	-7.72[a]	-5.61[a]	-4.02[a]
$Z^*(q)$		-7.90[a]	-7.11[a]	-5.59[a]	-4.36[a]	-3.35[a]

[a]*: Significant at the 1% level.*

Table 8.9: Variance ratio test results for the weekly observed return data

Variables	Number nq of base observations	Number q of base observations aggregated to form variance ratio				
		2	4	8	16	32
VNINDEX	224					
VR(q)		0.56	0.30	0.20	0.10	0.06
Z(q)		-6.56[a]	-5.59[a]	-4.05[a]	-3.05[a]	-2.21[b]
$Z^*(q)$		-2.92[a]	-2.80[a]	-2.19[b]	-1.71	-1.39
REE	224					
VR(q)		0.58	0.31	0.19	0.11	0.06
Z(q)		-6.23[a]	-5.49[a]	-4.09[a]	-3.01[a]	-2.20[b]
$Z^*(q)$		-3.11[a]	-3.16[a]	-2.68[a]	-2.14[b]	-1.76
SAM	224					
VR(q)		0.52	0.25	0.17	0.08	0.05
Z(q)		-7.14[a]	-5.97[a]	-4.18[a]	-3.11[a]	-2.22[b]
$Z^*(q)$		-3.26[a]	-2.89[a]	-2.16[b]	-1.71	-1.38
HAP	223					
VR(q)		0.36	0.18	0.10	0.06	0.03
Z(q)		-9.59[a]	-6.57[a]	-4.55[a]	-3.19[a]	-2.26[b]
$Z^*(q)$		-2.63[a]	-2.17[b]	-1.95	-1.80	-1.60
TMS	223					
VR(q)		0.52	0.31	0.18	0.10	0.06
Z(q)		-7.20[a]	-5.46[a]	-4.11[a]	-3.05[a]	-2.20[b]
$Z^*(q)$		-3.91[a]	-3.32[b]	-2.75[a]	-2.22[b]	-1.79
LAF	204					
VR(q)		0.47	0.27	0.17	0.08	0.05
Z(q)		-7.55[a]	-5.55[a]	-4.01[a]	-2.98[a]	-2.14[b]
$Z^*(q)$		-3.80[a]	-3.05[a]	-2.29[b]	-1.83	-1.51

[a], [b]: Significant at the 1% and 5% levels, respectively.

Table 8.10: Variance ratio test results for the daily corrected return data

Variables	Number nq of base observations	Number q of base observations aggregated to form variance ratio				
		2	4	8	16	32
VNINDEX	707					
VR(q)		0.66	0.25	0.14	0.07	0.04
Z(q)		-9.04[a]	-10.61[a]	-7.76[a]	-5.60[a]	-4.02[a]
$Z^*(q)$		-4.39[a]	-5.52[a]	-4.68[a]	-3.77[a]	-2.97[a]
REE	707					
VR(q)		0.53	0.24	0.13	0.07	0.03
Z(q)		-12.51[a]	-10.86[a]	-7.85[a]	-5.64[a]	-4.03[a]
$Z^*(q)$		-5.27[a]	-5.34[a]	-4.68[a]	-3.88[a]	-3.10[a]
SAM	707					
VR(q)		0.60	0.25	0.13	0.07	0.03
Z(q)		-10.75[a]	-10.70[a]	-7.81[a]	-5.63[a]	-4.03[a]
$Z^*(q)$		-5.14[a]	-5.40[a]	-4.33[a]	-3.45[a]	-2.74[a]
HAP	707					
VR(q)		0.55	0.27	0.14	0.07	0.03
Z(q)		-11.95[a]	-10.44[a]	-7.73[a]	-5.62[a]	-4.02[a]
$Z^*(q)$		-5.87[a]	-5.72[a]	-4.73[a]	-3.82[a]	-3.00[a]
TMS	707					
VR(q)		0.60	0.28	0.13	0.07	0.04
Z(q)		-10.75[a]	-10.28[a]	-7.80[a]	-5.61[a]	-4.02[a]
$Z^*(q)$		-7.61[a]	-7.22[a]	-5.81[a]	-4.44[a]	-3.37[a]
LAF	707					
VR(q)		0.52	0.24	0.12	0.06	0.03
Z(q)		-12.86[a]	-10.79[a]	-7.88[a]	-5.66[a]	-4.04[a]
$Z^*(q)$		-8.57[a]	-7.28[a]	-5.67[a]	-4.38[a]	-3.36[a]

[a]*: Significant at the 1% level.*

Table 8.11: Variance ratio test results for the weekly corrected return data

Variables	Number nq of base observations	Number q of base observations aggregated to form variance ratio				
		2	4	8	16	32
VNINDEX	223					
VR(q)		0.41	0.22	0.14	0.06	0.04
Z(q)		-8.82[a]	-6.24[a]	-4.35[a]	-3.18[a]	-2.25[b]
$Z^*(q)$		-3.33[a]	-2.69[a]	-2.08[b]	-1.63	-1.32
REE	223					
VR(q)		0.45	0.23	0.13	0.07	0.04
Z(q)		-8.14[a]	-6.17[a]	-4.38[a]	-3.14[a]	-2.25[b]
$Z^*(q)$		-3.11[a]	-2.75[a]	-2.24[b]	-1.80	-1.52
SAM	223					
VR(q)		0.46	0.21	0.14	0.07	0.04
Z(q)		-7.99[a]	-6.33[a]	-4.34[a]	-3.16[a]	-2.24[b]
$Z^*(q)$		3.68[a]	3.14[a]	2.35[b]	1.85	1.49
HAP	222					
VR(q)		0.45	0.20	0.11	0.06	0.04
Z(q)		-8.18[a]	-6.35[a]	-4.46[a]	-3.16[a]	-2.25[b]
$Z^*(q)$		-3.21[a]	-2.96[a]	-2.51[b]	-2.15[b]	-1.81
TMS	222					
VR(q)		0.38	0.24	0.13	0.06	0.04
Z(q)		-9.21[a]	-6.03[a]	-4.38[a]	-3.18[a]	-2.24[b]
$Z^*(q)$		-3.05[a]	-2.34[b]	-1.96[b]	-1.60	-1.30
LAF	203					
VR(q)		0.39	0.24	0.15	0.07	0.04
Z(q)		-8.62[a]	-5.76[a]	-4.11[a]	-3.02[a]	-215[b]
$Z^*(q)$		-3.34[a]	-2.48[b]	-1.85	-1.48	-1.24

[a], [b]: Significant at the 1% and 5% levels, respectively.