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Efficient Market Testing of the Korean Stock Market during the Global Financial Crisis

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Abstract

Recent asset market bubbles and bursts have generated interest in the efficiency of stock market behavior. Efficient market hypothesis (EMH) has been challenged by the global financial crisis and literature on behavioral finance. A period was chosen coinciding with the global financial crisis when the standard efficient market hypothesis (EMH) was less likely to hold. The Korean stock market's (KOSPI) behavior passed standard efficient market tests for random walk, and was efficient. KOSPI investors should not experience abnormal returns when stock prices reflect no news shocks. Stock prices "today" reflect today's news and are independent of price changes yesterday.

Keywords Korean stock market, Efficient Market Testing, global financial crisis, stock prices

The JEL Classifications: G14: Information and Market Efficiency • Event Studies • Insider Trading. C22: Time-Series Models, Dynamic Quantile Regressions, Dynamic Treatment Effect Models & bull Diffusion Processes

Introduction

There have been several studies published of KOSPI's efficiency with studies of the 1980s showing inefficiencies. It is plausible to expect stock market efficiency increases as they develop over time and there is some evidence from past studies[1] that this has been the case with KOSPI. While the studies based primarily on 1980s data uniformly rejected efficiency, data examined through the 2000s have found mixed results. These results suggest

[1] See the literature review

that findings may be very sensitive to the particular tests used. In addition, because testing was conducted over long periods of time, they were not able to shed light on whether the KOSPI had indeed grown more efficient over time.

This research will present results of non-parametric tests employed in an econometric investigation of stock market efficiency in Korea in recent years. To test this hypothesis, the Augmented Dickey-Fuller (ADF) test, Autocorrelation Function (ACF) test, Runs test, and Variance Ratio Test were used to assess the behavior of the KOSPI in recent years only. The date range chosen was August 1, 2007 through March 31, 2010, and coincided with the global financial crisis. It seems plausible that financial markets may perform less efficiently during periods of crisis. So to test the hypotheses of increased efficiency, the date range reflected a slump period where investor's choices could be biased.

To explore this possibility further, it was decided that a sub sample of the data corresponding to the worst KOSPI slump from August 1, 2007 through October 16, 2008 should also be studied. The KOSPI slump began earlier than in most emerging markets, which was reflected by a continuous downward sloping in the graphs presented. This occurred without an enormous or sudden increase during the slump period caused by the oil shock and the Lee administration's weak Won policy preceding the global financial crisis.

Literature Review

Pyun and Kim (1991) investigated daily return data for forty KOSPI stocks from 1980 through 1988 using the Augmented Dickey-Fuller (ADF) test, serial correlation test, and runs test. The results showed that the KOSPI was not market efficient during the research period.

Ayadi and Pyun (1994) investigated the daily closing prices for the KOSPI from January 1984 through December 1988. They applied Lo-MacKinlay variance ratio test to the KOSPI. Under the assumption of a homoscedastic error term, KOSPI did not follow a random walk. However, in the terms of a heteroscedastic stochastic disturbance term, the random walk hypothesis was not rejected. Ayadi and Pyun mentioned that government interference (any official intervention) could cause market inefficiency (the market can result in price overshooting or undershooting).

Huang (1995) examined the efficiency of nine Asian stock markets by using the variance ratio statistic with both homoscedastic and heteroscedastic assumptions. The data set consisted of weekly stock returns from the nine Asian stock market indexes from the period 1988 to 1992. In the Korean stock market, the result of the variance ratio exceeded one indicating the presence of positive serial correlation. In other words, the random walk hypothesis for the Korean stock market was rejected.

Karemera, Ojah, and Cole (1999) examined the random walk hypothesis for fifteen emerging stock markets using Lo and MacKinlay's (1988) single variance ratio, Chow and Denning's (1993) multiple variance ratio, and a runs tests. The data set consisted of monthly national stock price indexes expressed in both local currency and U.S. dollars during the 1986 to 1997 period. According to their research, only the Korean stock market followed a random walk under multiple variance ratios.

Narayan and Smyth (2004) tested the efficient market hypothesis using monthly South Korean stock price data for the period 1981-2003. They applied the Augmented Dickey-Fuller (ADF) test as well as Zivot and Andrews' (1992) one break and the Lumsdaine and Papell (1997) two break unit root tests. They concluded that stock prices for South Korea had a unit root during the research term. In other words, KOSPI was consistent with the efficient market hypothesis.

Hasanov (2009) investigated the monthly KOSPI 200 index for the period September 1987 to December 2005. He applied the nonlinear unit root test procedure. The null hypothesis was rejected using the nonlinear unit root test for unit root. This means that South Korea's stock market was not weak form efficient, which was contrary to Narayan and Smyth's (2004) findings.

Augmented Dickey-Fuller (ADF) test

The EMH requires its agents to have rational expectations; therefore, whenever new relevant information appears, the agents update their expectations appropriately, resulting in a random walk. All subsequent price changes represent random departures from previous prices. In other words, investors react instantaneously to any kind of information advantage, so there will be no profit from information-based trading.

Random walk is defined by the fact that price changes are independent of each other. This researcher tested whether the KOSPI index follows a random walk. If the analyzed time series for KOSPI follows a random walk, KOSPI is non-stationary, so it could be concluded that KOSPI is unpredictable, meaning that the KOSPI market indicates it is efficient.

This author used the Augmented Dickey-Fuller (ADF) test for the stationary test. The ADF test is used to test the unit root hypothesis. If the time series for KOSPI has a unit root, it means KOSPI is non-stationary, and follows a random walk. The test is based on three equations.

Table 1 Equations for ADF test

	Level	First Difference
No Constant or Trend	$Y_t = \beta Y_{t-1} + \varepsilon_t$	$\Delta Y_t = \delta Y_{t-1} + \varepsilon_t$
Constant, no Trend	$Y_t = \alpha + \beta Y_{t-1} + \varepsilon_t$	$\Delta Y_t = \alpha + \delta Y_{t-1} + \varepsilon_t$
Constant and Trend	$Y_t = \alpha + \beta T + \gamma Y_{t-1} + \varepsilon_t$	$\Delta Y_t = \alpha + \beta T + \delta Y_{t-1} + \varepsilon_t$

Note: *t*=day t

The Null hypothesis is:

$$H_0 : \beta = 1 \rightarrow H_0 : \delta = 0 \quad (1)$$

(Unit Root) (Unit Root)

Table 2 Result of ADF test with no constant or trend (08/01/2007~03/31/2010)

Coefficients & Statistics	No Constant or Trend		
	10%	5%	1%
t-statistic	-1.616378	-1.941302	-2.568460
ADF Statistics		-0.483134	
R^2		0.000272	
Adjusted R^2		0.000272	
Durbin-Watson stat		1.997760	

The results in Table 2 are based on the model $\Delta Y_t = \delta Y_{t-1} + \varepsilon_t$. The value of ADF statistics is -0.483134. The value is larger than the critical tau value at a 10% significance level. The Null hypothesis is not rejected. KOSPI passed the ADF test when the equation was with no constant or trend. The time series of KOSPI is non-stationary and it has a unit root. It means KOSPI follows a random walk. If the Durbin-Watson statistic is 2, it means there is no autocorrelation.[2] In this case, the Durbin-Watson statistic for KOSPI is very close to 2 (1.997760), so there is no autocorrelation problem in this research.

Table 3 Result of ADF test with constant and no trend (08/01/2007~03/31/2010)

Coefficients & Statistics	Constant, no Trend		
	10%	5%	1%
t-statistic	-2.569037	-2.865689	-3.439999
ADF Statistics		-1.544975	
R^2		0.003604	
Adjusted R^2		0.002094	
Durbin-Watson stat		1.992478	

Table 3 shows the ADF test for the new random walk model $\Delta Y_t = \alpha + \delta Y_{t-1} + \varepsilon_t$ .ADF value is -1.544975 and it is also larger than the critical tau statistical value for a 10% significance value. The Null hypothesis is net rejected. KOSPI passed the ADF test when the equation only had a constant. The Durbin-Watson statistic for the KOSPI is 1.992478, which is very close to 2. Therefore, we can say that KOSPI is market efficient.

The results in Table 4 are based on the model $\Delta Y_t = \alpha + \beta T + \delta Y_{t-1} + \varepsilon_t$. The value of the ADF statistic is -1.231260. The value is larger than the critical tau value at a 10% significance level. The Null hypothesis is also accepted in this case. KOSPI passed the ADF test when the equation was with constant and trend. If Durbin-Watson statistic is 2, it means there is no autocorrelation. The Durbin-Watson statistic for KOSPI is 1.994943, which is very close to 2.

In order to check the robustness of the ADF test in KOSPI, this author checked a different term that was the worst slump term during the research term (August 1, 2007 to October 16, 2008 [Deadly Cross: Won-dollar rate outpaces KOSPI]).

[2] The Durbin-Watson statistic was always between 0 and 4. A value of 2 means that there is no autocorrelation in the sample. Values approaching 0 indicate positive autocorrelation and values toward 4 indicate negative autocorrelation.

Table 4 Result of ADF test with constant and trend (08/01/2007~03/31/2010)

Coefficients & Statistics	Constant and Trend		
	10%	5%	1%
t-statistic	-3.130644	-3.416620	-3.971976
ADF Statistics		-1.231260	
R^2		0.003983	
Adjusted R^2		0.000960	
Durbin-Watson stat		1.994943	

Table 5 Result of ADF test with no constant or trend (08/01/2007~10/16/2008)

Coefficients & Statistics	No Constant or Trend		
	10%	5%	1%
t-statistic	-1.615983	-1.941899	-2.572798
ADF Statistics		-1.216725	
R^2		0.000054	
Adjusted R^2		0.000054	
Durbin-Watson stat		2.004911	

The results in Table 5 are based on the model $\Delta Y_t = \delta Y_{t-1} + \varepsilon_t$. The value of ADF statistics is -1.216725. The value is larger than the critical tau value at a 10% significance level. The Null hypothesis is not rejected. KOSPI passed the ADF test when the equation was with no constant or trend. The time series for KOSPI is non-stationary and has a unit root. This means KOSPI follows a random walk. If the Durbin-Watson statistic is 2, it means there is no autocorrelation. In this case, the Durbin-Watson statistic for KOSPI is very close to 2 (2.004911), so there is no autocorrelation problem in this research.

Table 6 Result of ADF test with constant and no trend (08/01/2007~10/16/2008)

Coefficients & Statistics	Constant, no Trend		
	10%	5%	1%
t-statistic	-2.571932	-2.871095	-3.452290
ADF Statistics		-0.125515	
R^2		0.000054	
Adjusted R^2		-0.003348	
Durbin-Watson stat		2.004873	

Table 6 contains the ADF test for the new random walk model $\Delta Y_t = \alpha + \delta Y_{t-1} + \varepsilon_t$. The ADF value is -0.125515, and is also larger than the critical tau statistic value for a 10% significance value. The Null hypothesis is not rejected. KOSPI passed the ADF test when the equation was only with constant. The Durbin-Watson statistic for KOSPI is 2.004873, which is very close to 2. Therefore, we can say that KOSPI is market efficient.

Table 7 Result of ADF test with constant and trend (08/01/2007~10/16/2008)

Coefficients & Statistics	Constant and Trend		
	10%	5%	1%
t-statistic	-3.135645	-3.425080	-3.989365
ADF Statistics		-1.907995	
R^2		0.017984	
Adjusted R^2		0.011281	
Durbin-Watson stat		1.982580	

The results in Table 7 are based on the model $\Delta Y_t = \alpha + \beta T + \delta Y_{t-1} + \varepsilon_t$. The value of ADF statistics is -1.907995. The value is larger than the critical tau value at a 10% significance level. The Null hypothesis is also accepted in this case. KOSPI passed the ADF test when the equation is with constant and trend. If the Durbin-Watson statistic is 2, it means there is no autocorrelation. The Durbin-Watson statistic for KOSPI is 1.982580, which is very close to 2.

Autocorrelation Function (ACF) Test

The autocorrelation function (ACF) test is examined to identify the degree of autocorrelation in a time series. It measures the correlation between the current and lagged observation of the time series of KOSPI returns. ACF is defined as:

$$p_k = \frac{\sum_{t=1}^{n-k}(R_t - \overline{R})(R_{t+k} - \overline{R})}{\sum_{t=1}^{n}(R_t - \overline{R})^2} \qquad (2)$$

If a time series has unit root, then the autocorrelation function slowly decreases starting from the value of one and the partial autocorrelation function (PACF) has only a first value, which differs from zero.

Correlation and values of ACF and PACF are as follows:

Table 8 Results for ACF test (08/01/2007~03/31/2010)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.993	0.993	657.11	0.000
		2	0.987	-0.004	1306.3	0.000
		3	0.980	-0.003	1947.7	0.000
		4	0.973	-0.002	2581.4	0.000
		5	0.966	-0.005	3207.3	0.000
		6	0.960	0.019	3825.9	0.000
		7	0.953	-0.048	4436.4	0.000
		8	0.947	0.059	5039.9	0.000
		9	0.941	-0.009	5636.5	0.000
		10	0.935	0.014	6226.3	0.000
		11	0.930	0.066	6810.6	0.000
		12	0.925	0.068	7390.7	0.000
		13	0.921	-0.029	7965.9	0.000
		14	0.916	-0.053	8535.6	0.000
		15	0.911	0.008	9099.8	0.000
		16	0.905	-0.016	9658.5	0.000
		17	0.900	-0.017	10211.	0.000
		18	0.895	0.014	10759.	0.000
		19	0.889	-0.039	11300.	0.000
		20	0.883	-0.031	11834.	0.000
		21	0.876	-0.021	12361.	0.000
		22	0.869	-0.038	12881.	0.000
		23	0.863	0.024	13394.	0.000
		24	0.857	0.030	13900.	0.000
		25	0.850	-0.016	14400.	0.000
		26	0.844	-0.015	14893.	0.000
		27	0.837	-0.090	15378.	0.000
		28	0.829	-0.020	15855.	0.000
		29	0.821	-0.023	16325.	0.000
		30	0.815	0.073	16787.	0.000
		31	0.808	-0.013	17242.	0.000
		32	0.802	0.021	17691.	0.000
		33	0.795	0.017	18134.	0.000
		34	0.789	0.010	18571.	0.000
		35	0.783	-0.035	19001.	0.000
		36	0.776	-0.018	19424.	0.000

According to the result of the correlogram, the ACF slowly decreases starting from 0.993, which is very close to 1. The PACF has only a first value, which is much larger than other values. Also, the other values are very small and close to 0. Therefore, the ACF and PACF statistics show that the KOSPI index represents a non-stationary time series. This non-stationary time series shows the efficiency of the Korean capital market.

In order to check the robustness of the autocorrelation function (ACF) test in KOSPI, this researcher checked a different term, which was the worst slump term during the research term (August 1, 2007 to October 16, 2008 [Deadly Cross: Won-dollar rate outpaces KOSPI]).

Correlation and values of ACF and PACF are as follows:

Table 9 Results for ACF test (08/01/2007~10/16/2008)

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.970	0.970	282.51	0.000
		2	0.948	0.117	553.32	0.000
		3	0.929	0.045	813.91	0.000
		4	0.905	-0.065	1062.3	0.000
		5	0.878	-0.094	1296.7	0.000
		6	0.856	0.049	1520.1	0.000
		7	0.830	-0.054	1730.9	0.000
		8	0.809	0.081	1932.2	0.000
		9	0.788	-0.012	2123.6	0.000
		10	0.770	0.060	2307.2	0.000
		11	0.757	0.072	2484.9	0.000
		12	0.745	0.034	2657.8	0.000
		13	0.733	0.007	2825.6	0.000
		14	0.720	-0.039	2988.3	0.000
		15	0.710	0.033	3146.9	0.000
		16	0.699	-0.013	3301.3	0.000
		17	0.687	-0.006	3451.1	0.000
		18	0.675	-0.012	3596.2	0.000
		19	0.663	-0.008	3736.7	0.000
		20	0.646	-0.072	3870.5	0.000
		21	0.630	-0.009	3998.2	0.000
		22	0.611	-0.063	4118.6	0.000
		23	0.595	0.056	4233.4	0.000
		24	0.579	0.000	4342.4	0.000
		25	0.563	0.011	4446.0	0.000
		26	0.547	-0.024	4543.9	0.000
		27	0.529	-0.064	4635.8	0.000
		28	0.507	-0.081	4720.7	0.000
		29	0.487	-0.033	4799.4	0.000
		30	0.471	0.065	4873.2	0.000
		31	0.454	-0.018	4941.9	0.000
		32	0.436	0.002	5005.7	0.000
		33	0.423	0.049	5065.8	0.000
		34	0.408	-0.014	5122.1	0.000
		35	0.395	0.018	5175.1	0.000
		36	0.381	-0.056	5224.6	0.000

According to the result of the correlogram, the ACF slowly decreases starting from 0.970, which is very close to 1. The PACF has only a first value, which is much larger than other values. Also, the other values are very small and close to 0. Therefore, The ACF and PACF statistics show that the KOSPI index represents a non-stationary time series. Although market efficiency is a little weaker than the result from the whole research term, the non-stationary time series during the worst slump term also shows the efficiency of the Korean capital market.

Runs Test

The Runs test is a non-parametric statistical test that checks a randomness hypothesis for two-valued data sequences. In other words, it is employed to test the hypothesis that the elements of the sequence are mutually independent. A run is defined as the repeated occurrence of adjacent equal elements. The run is indexed by two parameters, which are the type of the run and the length. Therefore, in the case of stock prices (KOSPI), runs can be positive, negative, or have no change. The length is how often a run type occurs in succession. Under the null hypothesis, the successive outcomes are independent, and the total expected number of runs is normally distributed.

- Total Expected Number of Runs: $E(R) = \dfrac{n + 2n_{+}n_{-}}{n} = \mu$ (3)
- Mean: $\mu = \dfrac{2n_{+}n_{-}}{n} + 1$ (4)
- Standard Deviation:

$$\sigma_R = \sqrt{\frac{2n_{+}n_{-}(2n_{+}n_{-} - n)}{n^2(n-1)}} = \sqrt{\frac{(\mu-1)(\mu-2)}{n-1}} \quad (5)$$

Since the Runs test for KOSPI takes into account the signs but not the distances, this author marked data exceeding the mean with + and the other with -. Where n is the total number of observations, n_+ is the number of the +run cycle, and n_- is the number of the -run cycle. The number of runs is marked with R. If the number of observations is large, its distribution is almost equal to normal distribution. In order to test serial dependence, this author compared the actual number of runs (a_r) and the expected number of runs (E(R) = μ) in the price.

In order to check the randomness for a two-valued data sequence, this author created the following null hypothesis:

$$H_0: a_r = E(R) \quad (6)$$

In this research, the number of observations is large enough to employ Z-test based Runs because the distribution is almost equal to normal distribution. Therefore, this author used standard normal Z distribution to implement a Runs test.

- Standard Score: $Z = \dfrac{R - E(R)}{\sigma_R}$ (7)

If the calculated absolute value of Z is greater than the critical value with the appropriate significance level, we can reject the null hypothesis and conclude that changes in the KOSPI cannot be predicted. In other words, the capital market for KOSPI satisfies the weak-form of market efficiency.

In order to check the robustness of the Runs test on the KOSPI, this author checked a different period, which was the worst slump period during the research period (August 1, 2007 to October 16, 2008 [Deadly Cross: Won-dollar rate outpaces KOSPI]).

The results for the basic parameters for the Runs test on KOSPI are given in Table 10.

Table 10 Results for Runs test

Periods	08/01/2007-03/31/2010 (the whole period)	08/01/2007-10/16/2008 (the worst slump period)
n_+	285	163
n_-	378	134
R	8	14
E(R)	325.98	148.08
σ_R	12.61	8.52
Z	-25.21	-15.74
Z_α=0.05	±1.96	±1.96
Z_α=0.01	±2.58	±2.58
Hypothesis	H_1	H_1

Therefore, the definitive conclusion is that the KOSPI capital market satisfies weak-form efficiency. Table 10 shows that the calculated absolute values of Z (25.21 during the whole period and 15.74 during the worst slump period) are much greater than the critical values (1.96 and 2.58, in rows $Z\alpha=0.05$ and $Z\alpha=0.01$) with the appropriate significance levels (5% ±1.96 level and 1% ±2.58 level). We can reject the null hypothesis and conclude that changes in the KOSPI cannot be predicted. Also, although market efficiency is weaker than the result from the whole research period (25.21>15.74), results of the Runs test during the worst slump period also shows the efficiency of the Korean capital market.

Variance Ratio Test

After several tests (ACF, ADF, and Runs test) to check market efficiency and random walk theory, this author considered another important property of random walk hypotheses, linearity in random walk series increments. Therefore, this author decided to use the variance ratio test to examine whether the increments of random walk hypotheses are a linear function of the time interval. Lo and MacKinlay (1988) showed that the variance ratio test is more powerful than unit root tests. Ayadi and Pyun (1994) mentioned that weak-form market efficiency tests are susceptible to errors. The errors are spurious autocorrelations induced by non-synchronous trading. According to Ayadi and Pyun (1994), the acceptance of the random walk hypothesis in variance ratio tests clearly indicates the presence of spurious autocorrelation and heteroscedasticity in the market. These characteristics commonly happen in emerging country stock markets because they are caused by government intervention and non-synchronous trading in the market. Therefore, Ayadi and Pyun (1994) also insisted that the variance ratio test is much more powerful than other market efficiency tests.

The variance ratio test is used to test for random walk in returns. The test uses overlapping *q*-period returns in estimating variances. In other words, the variance of the random walk increments must be a linear function of a time interval (*q*). Returns will follow a random walk when the variance of the (q^{th}) difference is equal to (*q*) times the variance of the first difference. This is the standard terminology based on the properties of the random walk process.

To perform this test, this author first calculated the compounded daily returns on the KOSPI during the full research period (August 1, 2007-March 31, 2010) and the slump period (August 1, 2007-October 16, 2008). Then, this author found its variance and repeated the procedure for 2, 4, 8, and 16-day returns, similar to Ayadi and Pyun (1994). Lastly, this author calculated the variance ratios for all four time intervals and tested the null hypothesis.

H_0 : The variance ratio for all the choosing aggregate intervals, *q* is unity.

An estimated variance ratio less than one implies negative serial correlation, while a variance ratio greater than one, or high *Z* value, implies positive serial correlation. The rejection of one or more calculated variance ratios rejects the null hypothesis for random walk.

Table 11 Variance ratios for the daily values of the KOSPI and corresponding *Z* statistics for the null hypothesis when a ratio has a value of 1

Sampling Period: 08/01/2007-03/31/2010					
q	nq	VR_q	Z_q	Z_q^*	H_0 or H_1
2	661	1.003978	0.102354	0.085421	NOT rejected at 5%
4	659	1.002138	0.029409	0.023323	NOT rejected at 5%
8	655	0.995254	- 0.041715	- 0.032065	NOT rejected at 5%
16	647	0.945216	- 0.320231	- 0.247944	NOT rejected at 5%

Notes: *q* is the number of daily intervals aggregated to compute the variance ratios. The variance ratios, $VR_q \equiv \frac{\sigma_c^2(q)}{\sigma_a^2}$, where σ_a^2 is the estimated variance of the daily differences $X_t - X_{t-1}$, and $\sigma_c^2(q)$ is meant to provide an unbiased estimation of 1/q times the variance of $X_t - X_{t-q}$.

Under the random walk null hypothesis, the variance ratio VR_q is 1. VR_q are reported in the third column, and Z_q statistics are the asymptotic normal test statistics under homoscedasticity; Z_q^* statistics are the asymptotic normal test statistics under heteroscedasticity. The last column tells whether the random walk hypothesis is not rejected at the 5 percent level of significance. *nq* denotes the number of daily observations in the series.

Table 11 presents the variance ratios based on the daily values for KOSPI. Also shown are the corresponding *Z* statistics for the null hypothesis when a ratio has a value of 1. Data from the sampling period were used. The full sample period runs from August 1, 2007 through March 31, 2010 with a total of 662 daily KOSPI values. VR_q represents the variance ratio of the returns. Z_q represents the statistics of the variance ratio under the assumption of homoscedasticity. Z_q^* represents the statistics of the variance ratio under the assumption of heteroscedasticity. The variance ratio test was conducted for various lags of *q* (i.e., 2, 4, 8, and 16 days) for the index.

For the period sampled in Table 13, if the data supports the random walk hypothesis, the VR_qs have values close to 1 for the values of *q* assigned. This is the case with the result presented in Table 13. The random walk hypothesis, i.e., the hypothesis that the variance ratio is equal to 1, is not rejected by the data from the full sample period. Neither of the test statistics Z_q and Z_q^* reject the hypothesis (all of the test statistics Z_q and Z_q^* are in the range of ±1.96: 5 percent level of significance). In other words, the KOSPI during the full sample period (the whole research period) follows a random walk.

If a market is in turbulence, it appears that it does not always fully reflect past information. Therefore, in these kinds of periods, markets may be predictable. In order to check the robustness of the variance ratio test for the KOSPI, this author decided to check the worst slump period.

Table 12 Variance ratios for the daily values of the KOSPI and corresponding *Z* statistics for the null hypothesis when a ratio has a value of 1

Sampling Period: 08/01/2007-10/16/2008

q	nq	VR_q	Z_q	Z_q^*	H_0 or H_1
2	295	0.947781	- 0.898408	- 0.909458	NOT rejected at 5%
4	293	0.887700	- 1.032738	- 0.915787	NOT rejected at 5%
8	289	0.892180	- 0.627107	- 0.539048	NOT rejected at 5%
16	281	0.803327	- 0.768723	- 0.695203	NOT rejected at 5%

Notes: *q* is the number of daily intervals aggregated to compute the variance ratios. The variance ratios, $VR_q \equiv \frac{\sigma_c^2(q)}{\sigma_a^2}$, where σ_a^2 is the estimated variance of the daily differences $X_t - X_{t-1}$, and $\sigma_c^2(q)$ is meant to provide an unbiased estimation of 1/q times the variance of $X_t - X_{t-q}$.

Under the random walk null hypothesis, the variance ratio VR_q is 1. VR_q are reported in the third column, and Z_q statistics are the asymptotic normal test statistics under homoscedasticity; Z_q^* statistics are the asymptotic normal test statistics under heteroscedasticity. The last column tells whether the random walk hypothesis is not rejected at the 5 percent level of significance. *nq* denotes the number of daily observation in the series.

Table 12 represents the variance ratios based on the daily values for KOSPI during the worst slump period. Also shown are the corresponding *Z* statistics for the null hypothesis where a ratio has a value of 1. Data from the slump period were used. The sample period runs from August 1, 2007 through October 16, 2008 with total of 297 daily KOSPI values. VR_q represents the variance ratio of the returns. Z_q represents the statistics of the variance ratio under the assumption of homoscedasticity. Z_q^* represents the statistics of the variance ratio under the assumption of heteroscedasticity. As before, the variance ratio test was conducted for various lags of *q* (i.e., 2, 4, 8, and 16 days) for the index.

For the period sampled in Table 14, if the data still support the random walk hypothesis, the VR_qs have values close to 1 for the values of *q* assigned. This is the case with the result presented in Table 14. The random walk hypothesis, i.e., the hypothesis that the variance ratio is equal to 1, is not rejected by the data from the sample period (the slump period). None of the test statistics Z_q and Z_q^* reject the hypothesis (all of the test statistics Z_q and Z_q^* are in the range of ±1.96: 5 percent level of significance). In other words, the KOSPI followed a random walk during the worst slump period.

Conclusion

This author picked a period during which the standard efficient market hypothesis (EMH) is less likely to hold during the global financial crisis and its immediate aftermath. It was discovered that even during this period of unusual stress, the behavior of the market passed standard efficient market tests (Augmented Dickey-Fuller [ADF] test, Autocorrelation Function [ACF] test, Runs test, and Variance Ratio Test) for random walk, suggesting that the

Korean stock market is efficient in terms of there being no easy opportunities to earn abnormal returns.[3]

Based on the Korean stock market's efficiency, the following facts were found. The Korean stock market responds quickly to new information and it is very hard to predict market movement other than randomly in KOSPI. Since everyone knows about a given stock in KOSPI, the price of a stock should reflect the knowledge and expectations of the behaviors of all investors. Consequently, investors in KOSPI should not experience abnormal returns since there is no way they could know something about a shock that is not already reflected in the stock's price. In other words, this is consistent with the view that the price of stock on a given day ("today") reflects only today's news and is independent of the price changes yesterday.

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[3] Of course, there are an infinite number of statistical rules that could be tried in an effort to earn abnormal returns, so this finding does not imply that the market might not fail some efficiency tests.

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