

## **TESTING OF BIST AND TURKDEX: RANDOM WALK AND MARKET EFFICIENCY**

### **Gizay DAVER**

Giresun University

Lecturer.

E-mail: gizaydaver@gmail.com

### **Merve KARACAER**

Yıldırım Beyazıt University

Research Assistant

E-mail: mervekaracaer@gmail.com

### **Hülya ÜNLÜ**

Çankırı Karatekin University

Research Assistant

E-mail: unluhulya11@yahoo.com

### **—Abstract —**

We implemented several parametric and non-parametric tests to investigate random walk hypothesis and market efficiency theorem for Turkey's two main markets, Turkish Derivatives Exchange and Borsa İstanbul (new name for İstanbul Stock Exchange). 12/02/2007 – 08/02/2013 period is our testing period and we used daily log returns. According to our findings in the very short term null hypothesis of random walk is accepted.

**Key Words:** *Efficient Markets, Random Walk, Borsa İstanbul, ISE, TurkDEX, runs test*

**JEL Classification:** G14, G17

## 1. INTRODUCTION

There have been various studies about market efficiency and random walk in finance. The curiosity of searching such a topic comes from different purposes but the main objective is to find the answers of following questions; How much should I invest? How long should I keep my position? Which financial asset should I invest to? This paper is going to try to answer whether the return of any asset is predictable by using past information or not. Most researchers agree that market price changes must be unpredictable and all market participants should be able to have available information sets. The well-known theory, which is called Market Efficiency, is one of the most argued idea in the literature. Contribution of the Efficient Markets Hypothesis was made in theoretical basis by Bachelier in 1900 and in empirical research by Cowles in 1933. The modern literature of financial economics begins in late 1960s and early 1970s. The idea of random variable appears in the literature of stock prices. How this could be possible? The answer relies on the markets reflection of all available information set.

Due to Roberts (1967) one should consider the availability of the information set and the relationship with the return of the stock. He separates efficiency into three groups among the information criteria;

**Weak-form Efficiency:** The information set contains only the past prices or returns themselves.

**Semistrong-Form Efficiency.** The information set contains all information known to all market participants (*publicly available* information).

**Strong-Form Efficiency:** The information set contains all information known to any market participant (*private* information)

Black (1971) emphasizes that “A perfect market for a stock is one in which there are no profits to be made by people who have no special information about the company, and in which it is difficult even for people who do have special information to make profits, because the price adjusts so rapidly as the information becomes available.” And he continues with the idea of randomness in the prices. According to Black “Randomness means that a series of small upward movements (or small downward movements) is very unlikely. If the price is going to move up it should move up all at once, rather than in a series of small steps. Large price movements are desirable, so long as they are not consistently followed by price movements in the opposite direction.”

Crouch set up a nonlinear test by stating Eugene Fama's vision on random walk hypothesis. In the study Crouch used a method in securities market for special conditions (As an ex. Stock splits or activities that cause abnormal volume changes in the market) elimination and then tested these for intertemporal dependence in successive price changes. Findings of the study showed that even under special conditions there was little or no predictable and persistent pattern of dependence. If a person believes and insists on the idea, the stock price changes possess stable paretian distribution; he must keep in mind the underestimation problem in order to estimate true value by normal procedure. Under any conditions with or without dependencies, because of adjustments of market, taking a position to make big money is useless.

Smith investigated random walk of three different London gold prices by using multiple variance ratio test of Chow and Denning (1993), which allows generalized heteroscedasticity and makes it available to use both symmetrical and asymmetrical returns. According to the findings, only closing prices follow random walk and the best way to estimate tomorrow's closing price is to look at today's closing price. Gold returns calculated from closing prices are only affected by the new information and as the new information is unknown a person can't know the London closing price gold returns.

Kleiman, Payne and Sahu worked on Europe, Asia and North America's real estate markets. They tested random walk and market efficiency by unit root tests (Augmented Dickey Fuller and Phillips-Perron) and Cochrane variance ratio tests. They searched for co-integration by Johansen-Juselius procedure and vector error correction model. And lastly they used runs test to provide support for the condition of market efficiency. Results of their study show that, broader equity markets in the test regions fit random walk and markets are efficient in the weak form. Diversification doesn't derive benefits to investors in the long-run, but investors may drive benefits in the short-run.

Van Home and Parker tested random-walk theory and market efficiency by comparing mechanical trading rules used by a pure chartist and a simple buy-and-hold strategy user. According to their findings they concluded that stock prices about the intrinsic values are random. Payne and Sahu tested random walk hypothesis with augmented Dickey Fuller and Phillips-Perron unit root tests and Cochrane variance ratio test for United States and world commercial real estate markets along with the world stock market. Three world stock market indices; which are world real estate index, world stock market index and domestic real

estate index are used in the study. For the international real estate and equity markets, Morgan Stanley Capital International Perspective (MSCIP) indices are used. They also tested co-integration with Johansen-Juselius co-integration tests. Also, generalized impulse response analysis is used for the transmission of shocks across the three markets. Findings of unit root tests states that markets shows random walk behavior and Cochrane variance ratio states that markets are not co-integrated.

Jasic and Wood tested for efficiency and non-linearity in market and natural time series. For market series they used exchange rates of Deutsche Mark (DEM), Japanese Yen (JPY), Swiss Franc (CHF), British Pound (GBP) and Standards and Poor's 500 Index (S&P500), the German Deutscher Aktienindex (DAX) Index, the Japanese Tokyo Security Exchange Stock Price Index (TOPIX) and London's Financial Times Stock Exchange Index (FTSE All Share) data from Datastream and implemented variance ratio tests, modified rescaled range(R/S) ratios and BDS statistic. According to their findings, the heteroscedasticity-consistent variance ratio tests are found insignificant, which shows a random walk process for all the foreign exchange series except USD/CHF. For S&P 500 and DAX index random walk hypothesis holds but for TOPIX and FTSE index random walk hypothesis doesn't hold.

Borges used serial correlation, runs test, ADF test and Lo and MacKinlay's multiple variance ratio test to investigate random walk for the Lisbon stock market. Tests are run on the PSI-20 index which is the benchmark index of Portuguese market for the period 1993 to 2006, and weak-form efficiency is found in the recent years of the study. Jiang and Tian searched for the random walk hypothesis in S&P 500 index options (SPX options) by calculating forward variances. They used model-free forward variance in SPX options market to find support for informational efficiency and the expectations hypothesis, and they concluded that there is evidence. Urrutia implemented Lo and Macinlay's variance-ratio tests to Argentina, Brazil, Chile and Mexico markets which are four Latin America emerging equity markets, in order to investigate random walk by using International Finance Corporation data. According to findings random walk is rejected due to autocorrelation. Implemented runs tests indicates weak-form efficiency.

Tunçel tested weak form efficiency by using the stocks in İstanbul Stock Exchange 100 (ISE100) index for the year 2005. He implemented runs test and for the analysis period he concluded that random walk doesn't hold. Ergül used

several market indices of İstanbul Stock Exchange ranging from 1988 to 2008 to investigate random walk in the market. Descriptive statistics, graphic method and Augmented Dickey Fuller and Phillips-Perron unit root tests are implemented on the data. According to her findings, data is not stationary and series of indices aren't normally distributed and data has unit root. As a result İMKB is found to be weak form efficient market following random walk.

## 2. Random Walk Hypothesis

Campbell, Lo and Mackinley suggest organizing the versions of random walk hypothesis in to three groups. Before going deep into the groups it is important to give brief information about the several types of dependence between an assets return at time  $t$  and  $t+k$ . As the covariance between two random variables shows whether there exists any relationship or not, their main concern is to establish that the change of price of a certain assets at time  $t+1$  is independent of the price change at time  $t$ . This means that an investor cannot use historical prices to forecast the future prices of a certain asset. Campbell, Lo and Mackinley suggests three different type of random walk.

### 2.1. Random Walk 1 (IID)

This model assumes that the price changes are distributed identically and independent. One can say that this model is the most restrictive among the models.

$$P_t = \mu + P_{t-1} + \varepsilon_t \quad \text{and} \quad \varepsilon_t \square IID(0, \sigma^2)$$

where  $\mu$  is the expected price changes and  $IID(0, \sigma^2)$  indicates that  $\varepsilon_t$  is distributed identically and independently with mean 0 and variance  $\sigma^2$ .

Independence indicates not only the returns which are serially uncorrelated, but also any nonlinear functions of the returns are uncorrelated.

This way ;

$$E \left[ \frac{P_t}{P_0} \right] = P_0 + \mu_t \text{ and } Var \left[ \frac{P_t}{P_0} \right] = \sigma^2$$

### 2.2. Random Walk 2

The assumptions of RWI are relaxed to include processes with independent but not identically distributed (INID) price changes. This type of random walk model offers more realistic demonstration of financial markets behavior.

### 2.3. Random Walk 3

This model is the most relaxed version of the Random walk. It relaxes the independence assumption but keeps the uncorrelated price increments.

### 3. Research Question and Data

The hypothesis that we use to test the Turkish stock and derivative markets efficiency is if daily stock price changes represent a random walk. We developed runs test and variance ratio tests to investigate the random walk hypothesis.

Data has been taken from the BIST and TurkDEX. In this study, we use daily closing price of the TURKDEX 100<sup>1</sup> and the BIST 100 Index traded from the period of February 12, 2007 to February 8, 2013. We multiplied TurkDEX 100 future contract prices by 1000 to have a proper quotation. During the study we used log returns.

$$return = \ln(P_t) - \ln(P_{t-1})$$

where

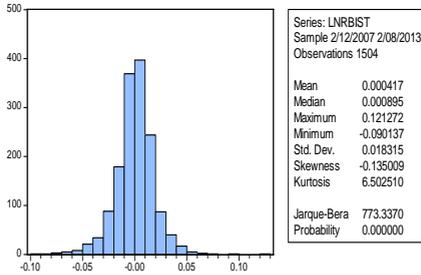
$P_t$  is closing price or value of the related component on day t

$P_{t-1}$  is closing price or value of the related component on day t+1

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<sup>1</sup> TurkDEX has issued many different type of future and option contracts. The underlying asset of the TurkDEX-BIST 100 future contract is BIST National-100 stock price index. To prevent the occurrence of confusion we use TurkDEX100 instead of TurkDEX-BIST 100.

**Table 1 Descriptive statistics of simple return of BIST 100 index**



**Table 2 Descriptive statistics of simple return of VOB 100 index**

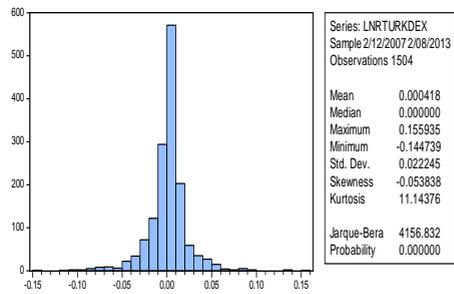


Table 1 and Table 2 report descriptive statistics and histogram for daily returns of the TurkDEX 100 and the BIST 100 Index. In general, values for skewness zero and kurtosis value three denotes that observed distribution is normally distributed. Skewness is negative for two series, which indicates the fat tails on the left-hand side of the distribution. Kurtosis value of all variables also show data is not normally distributed because values of kurtosis are above three. It can be seen from the both table the Jarque-Bera test statistic of 241,97 and 1121.53 exceeds the critical values for any reasonable significance level to lead to the conclusion that the daily returns do not follow a normal distribution.

#### 4. Testing the Random Walk Hypothesis and Results

Market efficiency theory is based on the random walk hypothesis. To test the random walk hypothesis, we employ serial correlation analysis, the runs test, and the variance ratio test.

##### 4.1.1. Tests of serial independence

The serial correlation test is most used test in the literature to examine the weak form efficiency. This test analyzes independency of the price changes from each other. The results for serial correlation tests with lags up to 20 days are represented in Table 3. It can be seen that the price changes of BIST 100 is serially uncorrelated from 1 day to 1 week (5 days) and 2 weeks (10 days) across the time, whereas there exists evidence of serial correlation after 10 days periods. The price changes of TurkDEX 100 is serially uncorrelated from 1 day to 1 week (5 days) across the time, while after 5 days the evidence of serial correlation appears. It can be concluded that the null hypothesis of random walk is accepted

only for short period and it seems it is possible to forecast price changes by using past changes for all indices.

**Table 3 Results of the sample autocorrelation coefficients and Ljung-Box Q-statistics.**

	BIST 100			TurkDEX 100		
	AC	Q-Stat	Prob	AC	Q-Stat	Prob
1	0.049	3.5547	0.059	-0.040	2.3864	0.122
2	0.014	3.8611	0.145	-0.026	3.4021	0.182
3	-0.021	4.5314	0.210	0.029	4.6855	0.196
4	0.017	4.9627	0.291	0.004	4.7158	0.318
5	-0.008	5.0656	0.408	-0.064	10.903	0.053
10	0.041	17.600	0.062	0.015	32.539	0.000
20	-0.046	36.417	0.014	-0.017	53.019	0.000

#### 4.1.2. The Runs Test

The runs test is a non-parametric test and has a considerable advantage that it doesn't require the stock returns to be normally distributed. The test is based on the number of sequences of consecutive positive and negative returns, or runs, which is tabulated and compared against its sampling distribution under the random walk hypothesis. A run is a sequence of repeated price changes with the same sign. The null hypothesis of randomness is tested by observing the number of runs or the sequence of successive price changes with the same sign, positive, zero or negative (Campbell, Lo, Mackinley;1997;38) A positive change appears when the price change is greater than the mean; a negative change vice versa and if there is no change in a series then the price change is equal to the mean.

$$m = \frac{N(N+1) - \sum_{k=1}^3 n_k^2}{N}$$

where N denotes the number of observations, k is the signs of positive, negative, and zero,  $n_k$  is total numbers of changes of each category of signs. For a larger number of observations ( $N > 30$ ), the expected number of runs m is approximately normally distributed with a standard deviation  $\sigma_m$  of runs.

$$\sigma_m = \left[ \frac{\sum_{k=1}^3 \left[ \sum_{k=1}^3 n_k^2 + N(N+1) \right] - 2N \left( \sum_{k=1}^3 n_k^3 - N^3 \right)}{N^2 (N-1)} \right]^{1/2}$$

And the z statistic is

$$Z = \frac{R - m^* \left( \frac{1}{2} \right)}{\sigma_m} \quad Z \sim N(0,1)$$

**Table 4 Results of Runs Test**

	BIST100	TurkDEX 100
Mean	.000416	.0004175
Cases<=test value	729	885
Cases > test value	775	619
Number of observation	1504	1504
Number of Runs	737	674
Z statistic.(prob)	-.79 (.43)	-2.95 (0.00)

The results of the runs test for returns on BIST 100 and TurkDEX 100 are reported in Table 4. The runs test clearly shows that TurkDEX 100 is weak form inefficient. The estimated Z – value is significant at the all significance level for return. So, we reject the null hypothesis of random walk. However, these results fail to reject the null hypothesis for BIST100 index.

### 4.1.3. The Variance Ratio Test

The variance-ratio test, introduced by Lo and MacKinlay (1988), is used to test the hypothesis that a given any price changes is a collection of independent and identically distributed observations (i.i.d.) or that it follows a martingale difference sequence. This test uses the fact that the variance for an i.i.d. return series increases linearly in each observation interval, that is, the variance of a q-sum is equal to q times the variance of the return series, or equivalently that the variance-ratio is equal to one. More generally, if time series follows a random walk process, the variance of q period returns should be q times as large as the one-period returns:

$$VR(q) = \frac{\text{var}(r_t(q))}{\text{var}(r_t) * q} = 1 + 2 \sum_{k=1}^{q-1} \left( 1 - \frac{k}{q} \right) p(k)$$

Lo and MacKinlay (1988) derive asymptotic standard normal test statistic for their variance ratio. As a result, the null hypothesis of no autocorrelation coefficient can be tested by computing the standardized statistic. Under the null hypothesis of homoscedastic, the standard normal test statistic  $Z(q)$  is defined as:

$$Z_q = \frac{VR(q) - 1}{\phi(q)^{1/2}} \quad Z \sim N(0,1)$$

where

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

The heteroscedasticity-consistent standard normal test statistic  $Z^*(q)$  is then defined as:

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

$$\phi^*(q) = 4 \sum_{k=1}^{q-1} \left[ 1 - \frac{k}{q} \right]^2 \hat{\delta}(k)$$

$$\hat{\delta}(k) = \frac{nq \sum_{j=k-1}^{nq} [p_j - p_{j-1} - \hat{\mu}]^2 [p_{j-k} - p_{j-k-1} - \hat{\mu}]^2}{\left[ \sum_{j=1}^{nq} [p_j - p_{j-1} - \hat{\mu}]^2 \right]^2}$$

**Table 5 Results of Variance Ratio Test**

Data period	Nr base obs nq	Horizon q	VRq	test stat Zq	N(0,1) 2-sided sign-level	test stat Zq*	N(0,1) 2-sided sign-level
TurkDEX 100	1504	2	0.9610	-1.5116	0.13064	-0.6295	0.52902
TurkDEX 100	1504	5	0.9300	-1.2385	0.21555	-0.7025	0.48237
TurkDEX 100	1504	7	0.8660	-1.9073	0.05648	-1.2175	0.22342
TurkDEX 100	1504	10	0.8146	-2.1301	0.03317	-1.6634	0.09624
BIST100	1504	2	1.0498	1.9305	0.05354	0.8360	0.40317
BIST100	1504	5	1.0883	1.5637	0.11788	0.8521	0.39415
BIST100	1504	7	1.0803	1.1427	0.25316	0.7288	0.46614
BIST100	1504	10	1.0397	0.4559	0.64848	0.3564	0.72158

We study variance ratio test for both null hypotheses, namely the homoscedastic and heteroscedastic increments of random walk. The results are reported in Table 6. Empirical evidence obtained from the variance ratio test for daily returns indicates that the random walk hypothesis under the assumption of homoscedasticity is not rejected for all series. Similarly, the empirical findings reveal that the null hypothesis of random walk for both BIST 100 and TurkDEX100 are accepted under the assumption of heteroscedasticity. This random walk pattern based on variance ratio test is also consistent with the findings of serial correlation and runs test for BIST 100. On the basis of empirical evidence provided above, it can be concluded that the null hypothesis of random walk is not rejected for all BIST 100 and TurkDEX100.

## **5. CONCLUSION**

This paper has examined random walk hypothesis and tests the weak-form efficiency of BIST 100 index and TurkDEX 100 contracts in Turkey by using daily data. Parametric and nonparametric tests are used to analyze whether the market is efficient or not. The parametric tests include serial autocorrelation test and variance ratio test. The nonparametric tests include runs test. The analysis shows that BIST100 and TurkDEX 100 are not normally distributed.. The results also show that the null hypothesis of random walk is accepted only for short period and it seems it is possible to forecast price changes by using past changes. Moreover, TurkDEX 100 is weak form inefficient according to runs test while the null hypothesis of a random walk fail is rejected for BIST100 index. In addition, the results show evidence of not rejecting the null hypothesis of random walk for both BIST 100 and TurkDEX100.

As a result, one can reach the conclusion of the Turkish stock market is efficient in the weak form. This means that the prices are randomly taking shape on the market and abnormal returns are eliminated by the market itself.

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