Non-Random Walk Behavior of Philippine Stock Prices

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Abstract

Random walk has been held as a sufficient condition for describing the stock market as efficient, which implies that investors cannot predict the market returns or equivalently, abnormal profits cannot be obtained just by knowing the past prices. This study tests the random walk hypothesis in the case of Philippine Stock Prices, using the daily PSE index (PSEi) covering the period 03 January 2005-16 February 2016. Main results, employing the informal or visual methods such as plot analysis of log returns and correlogram, suggest some initial evidence of non-randomness. The formal methods, employing tests for unit root, runs, sequences and reversals, variance ratio, and autocorrelations, show that the PSEi prices do not follow a random walk behavior.

Keywords: Random walk, unit root, autocorrelations, sequences, reversals, runs

1.0 Introduction

Any seasoned investor in Philippine stocks can easily recall that for close to 30 years, the Manila stock exchange and the Makati stock exchange functioned as separate stock bourses. However, to remove arbitrage profiting, the "one price, one market" principle proposed by the Bangko Sentral ng Pilipinas (BSP) gave birth to the Philippine Stock Exchange (PSE), a unification of the two bourses that operates trading floors in Makati City and Pasig City. An all shares float adjusted capitalization of 11,319,909,310,003.3 as of March 16, 2016 (PSE.com), makes it a likely and big fishing ground for wealth maximizers. Its indices include the All Shares, Philippine Stock Exchange Index (PSEi) and six sector indices: Financials, Holding Firms, Industrial, Mining and Oil, Property, and the Services Sector. All shares are computed on full float registered securities while PSEi is an adjusted float on 30 blue-chip companies.

The PSEi

In analyzing the returns of different stock exchanges, Reilly (1971) studied further the inner workings of the indices and found composition as one determining element. Such finding is consistent with the behavioral pattern of investors when they scrutinize returns indicator, so that investing in the Philippine stocks requires paying attention to PSEi especially that BSP website describes it as the best indicator of Philippine stocks' performance. It is a good reminder to note that while PSEi is considered the best indicator, it does not mean that it represents the entire Philippine Stock Martket as a whole. However, the PSE guidelines make it clear that firms in the PSEi possess attributes of attractiveness, an investment grade classification, and common characterization of stocks in indexes. Similar qualities characterize other representative indices, for example, Reilly (1971) describes the Dow Jones Industrial Average stocks as the best of the blue-chips, sharing the same observation about the OTC industrial average of national Quotation bureau. And since the present study assesses Philippine stocks, taking PSEi as the focal point of investigation, investors would check for its efficiency, a market quality whose necessary attributes include prices that follow a random walk.

Random walk

Fama (1965) expounds on the theory of random walk in contrast to technical method of the chartists, explaining that in an efficient market, prices reflect the information available. He further adds that the movement from one price level to the next is not a result of a momentum, describing it as a memory-less movement, that the old information has no bearing on the new price because the old prices had incorporated such information already. Each period's price movement manifests non-reversion to previous level. Random walk, then, relates to market efficiency on account of this, describing a market whose price reflects information fast. Random walk tests include markets other than equity such as bonds (Alexeeva and Maynard, 2012) and currencies (Al-Khazali, Pyun, and Kim, 2011).

Efficient Markets

Markets in developed economies likely possess a more efficient quality as evidenced by random walk findings in past studies with more stringent tests (Fama,1965; Solnik,1973), which coincide with Asian markets results as found by Worthington and Higgs (2005). The latter found markets in Japan, Hongkong and New Zealand showing a random walk behaviour unlike the less developed ones such as Malaysia, Pakistan, the Philippines, Sri Lanka and several others. While they did not discuss what accounts for such, the reason could be the asymmetry of information which, according to Abosede and Osenni (2011), referring to some authors, is one challenge in the emerging markets, adding that the phenomenon extends beyond primary markets. This may account for research efforts that seek some leads from less developed or emerging markets to test random-walk theory. The study of Al-Khazali et al. (2011) finds evidence that some of these markets move toward efficiency. Studies of other territories such as Nigeria (Okpara, 2010) and Iran (Oskooe, Li, and Shamsavari, 2010) find support for market efficiency. Furthermore, a study of the silver futures, found the market weak-form efficient (Harper, Jin, and Sokunle, 2015). More recently, Bolton and Boetticher (2015) present evidence of efficiency in the case of South African stock market.

Inefficient Markets

If some studies lend support to random walk and efficiency, some also present evidence to the contrary. For example, Harper and Jin (2012) find market inefficiency in the case of India by studying stock returns using Box-Jeung. By the Artificial Neurial network model using principal component analysis, Zahedi and Rounaghi (2015) studied the Tehran stock prices and found that the prices are predictable. Dutta and others (2015) studied the Toronto Stock Exchange (TSX) and reject the random walk hypothesis(RWH) after a battery of tests that include unit root and linearity tests. TSX's automation, which modernity brings, paradoxically contradicts market efficiency. Finally, a recent study of Indonesian stock exchange (Yang and Pangastuti, 2016) found that prices in the exchange do not follow a random walk behavior.

Mixed Results

While contradicting evidences from separate studies abound, mixed results in the same studies also exist. An example of such is found in the study of the Portugese stock index that maintains 20 changeable firms stock from *EURONEXT Lisbon and Bolsa de Valores de Lisboa e Porto*(Khan and Vieito, 2012). Its test outcomes from runs, unit root test, variance ratio among others, found mixed findings, although majority of them found inefficiency. It also found indicators that merger of stock exchange improved the efficiency of the market. Another study (Tiwari and Kyophilavong, 2014), this time on BRICS exchanges, with the use of wavelet approach for unit root tests and monthly data for 11 years, results in the rejection of RWH for all countries except Russia. Finally, the investigation of Kilon and Jamroz (2015) on the Warsaw Stock Exchange to check its efficiency using autocorrelation test, series test and unit root test also produced mixed results,

RWH in the Philippine Stock Market

Ang and Pohlman (1978), conclude that Philippine stock market, being part of their data set, possesses a weak-efficient character, albeit the short-period sample of less than a year of observed prices. They have seen that serial correlation decreases with the number of lags, and further found only extreme returns but not price dependencies. The same conclusion was made by Karemera, Ojah and Cole (1999) in their study of stock returns of 15 emerging markets, Philippines being one of them, using variance ratio test on MSIC value weighted index using monthly data from 1986-1997.

While findings as mentioned support RWH and market efficiency in the case of the Philippines, other researchers produced contrasting results. The other findings of Karemera et al. (1999) for instance, after adjusting for exchange rate variable, reveal that Philippine stock returns do not follow a random walk. A study (Kim and Singal, 2000) of selected markets that includes the Philippines and was intended to assess the effects of market liberalization, reveals non-random walk findings, and thus, do not support the efficient market hypothesis. It finds support in the study of Kim and Shamsuddin (2008) of Asian stocks where they found Indonesia, Malaysia and Philippines inefficient, in contrast to what they discovered in the case of the more developed markets of Japan, Hongkong, Taiwan and Korea. Yet another study, using ADF test with and without time trend, found significant rejection of RWH for Philippines at 10% level (Chaudhuri and Wu, 2003).

Since 1990, it is common knowledge that Philippine business landscape has changed, bringing about foreign investments and an expectation of efficient stock trading. The trade liberalization study of Asian stocks (Kim and Singal, 2000), for example, found Japan and Taiwan crawling out of inefficiency to efficiency. Profiting from the financial and welfare payoff of integration, emerging markets such as the Philippines was expected to manifest efficiency, which is a trade liberalization effect.

Chaudhuri and Wu (2003) pointed out the structural break after trade liberalization in 1989, although their data logged Philippines as 40% investable as of 1997. Lean and Smyth (2007), claiming a more superior method than Chaudhuri and Wu(2003) and employing 2 structural breaks, reject RWH for selected pacific countries which include the Philippines, admitting that employing only one break leads to non-rejection. They identified the first break during the height of 1997 financial crisis and the second during the bombing of Bali.

In spite of disagreements in the findings, a focused study on Philippine stocks found little evidence of weak efficiency (Aquino, 2002), leading this study to find out whether Philippine stocks as measured by PSEi follow a random walk.

2.0 Methodolgy

Data

The data set, obtained from PSE, are daily closing stock prices of PSEi from January 3, 2005 to February 16, 2016. This index serves as the approximation of the general performance of the market with companies that are chosen based on stability, liquidity and volume. The index computes its value based on market capitalization (market weighted index). Time frame choice for the data set were influenced by two reasons. First, with the same goal as Kim and Shamsuddin's (2008) to skip the effects of 1997 Asian financial crisis, the samples here start in 2005 when the purported effects of the same crisis subsided. These data are relatively proximate to expected time for financial market liberalization, yet previous contrasting results may be settled moving forward. Second, the "online daily disclosure system (ODiSy)" was installed in 2005 intended to better the "transparency of listed companies and ensure full, fair, timely and accurate disclosure of material information from all listed companies"(2016, PSE.com.ph). Therefore, the inclusive range also captures the period of modernity, which logically should improve market efficiency.

Data Treatment and Analysis

The tests employed both the informal tests or visual tests and the formal tests. Informal methods will check for stationarity, a behavior that suggests a mean-reverting pattern. In contrast, a non-stationary behavior, a non mean-reverting process suggests random walk. The process commenced with an examination of raw prices plotted against time. Further visual examinations checked the plot of log returns along a hypothetical horizontal line representing the mean. Lastly, a correlogram graphically plots the autocorrelation of variable against its lag values.

Formal tests consist of unit root test and selected random test procedures suggested by Campbell, Lo and McKinlay (1997) referred to here as CLM for brevity. Tests for random walk 1 (RW1) include runs test, and sequences and reversals while random walk 3 (RW3) employs Augmented Dickey Fuller (ADF) test, Leung-Box method via Q-statistic and variance ratio test. Explanatory notes in the results section provide a brief context.

Consistent with extant literature in finance on this topic, the raw data is analyzed by graphs and the log return is tested, not the prices as published.

Stationarity and unit root test

It is necessary to define some variable so that:

Y_t =natural log of price index PSE_i in the present period(t)

Y_{t-1}=natural log of price index PSE_i in the previous period(t-1)

ε_t =variable for random shock

Then, random walk formulation would be $Y_t = Y_{t-1} + \varepsilon_t$ for the series without a drift and $Y_t = \mu + Y_{t-1} + \varepsilon_t$ for a series with a drift. Now, if there is a process say, $Y_t = \rho Y_{t-1} + \varepsilon_t$ where ρ is unity, thus the term unit root, it reverts to the original specification $Y_t = Y_{t-1} + \varepsilon_t$

Considering a lag operator L, $LY_t=Y_{t-1,}$ so that $L^2Y_t=Y_{t-2.}$

$Yt= \rho L_{Yt}$ can be $Yt- \rho L_{Yt} = \varepsilon_t$ or $Yt(1-\rho L)= \varepsilon_{t,}$ equivalently, $\Phi(L)Yt= \varepsilon_{t.}$

Defining auto-regressive one, AR(1), characteristic equation in the model as $\Phi(z)=1-\rho z=0$: for $|z|>1$, $|\rho|<1$,when AR(1) is stationary (Danao,2010, T9.5.4, C9.5.5; Gujarati, p.814). From characteristic equation, $\Phi(z)=1-\rho z=0$, when $\rho=1$, $z=1$ the root(unit root) of $\Phi(z)$, so that model 1 is reduced to $Y_t= Y_{t-1}+\varepsilon_{t,}$ a random walk. The null hypothesis for unit root test is:

Ho: $\rho=1$, the series is non-stationary

H1: $\rho<1$, the series is stationary

With $\Delta Y_t=Y_t-Y_{t-1,}$ and $Y_t= \rho Y_{t-1}+ \varepsilon_{t,}$ $\Delta Y_t= \rho Y_{t-1}+ \varepsilon_t-Y_{t-1,}$ it is now equivalent to$(\rho-1)Y_{t-1}+ \varepsilon_{t,}$

3.0 Results and Discussions

Informal-Visual Inspections

The results of informal or visual inspections lend initial insights into the behaviour of the data shown in Figures 1, 2 and 3.

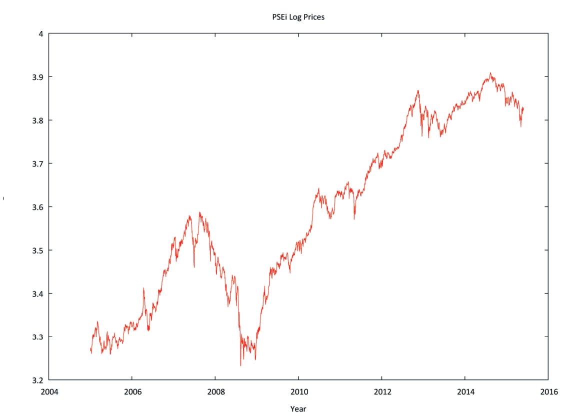

Figure 1. PSEi Log Prices Jan 2005-February 16, 2016

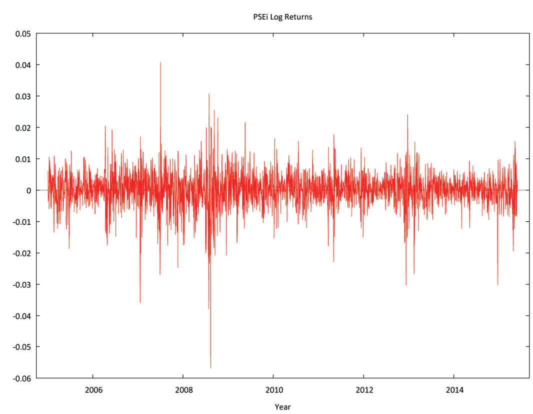

Figure 2. PSEi Log Returns

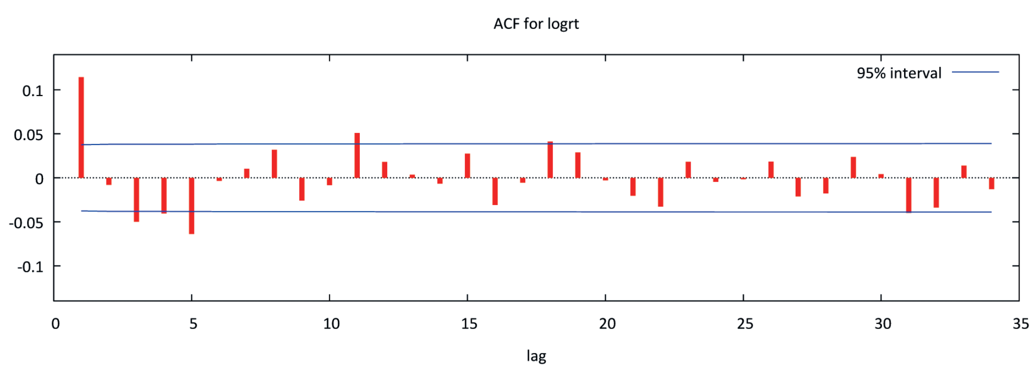

Figure 3. Correlogram of PSEi Log Return

The graph of PSEi raw prices in Figure 1 shows an upward direction or increasing trend suggesting non-stationarity, an indicator of a mean that is changing. Consistent with financial literature, log returns provide a more meaningful data set for reasons CLM explained. Now, Figure 2 shows the visible upward and downward lines crossing the horizontal line, a manifestation of non-discernible "upward or downward trend" (Danao, 2010, p.333), typical of stationary series and thus evidence against random walk. Moreover, the correlogram shown in Figure 3 that rapidly declines to zero suggests a stationary process. These signals can be verified for two various reasons. First, Figure 1 alone cannot help determine whether constant variance is observable between any two adjacent points because in principle, a random process should show points approximately of the same distances with respect to time and value, that is, horizontal and vertical distances should be proportionate. Second, in similar fashion as shown in Figure 2, their distances from the mean should also vary. For which reasons, the graphical methods would be confirmed by formal methods.

Data set was analyzed and checked further for stationarity, and subjected to unit root tests since "terms non-stationarity, random walk, and unit root can be treated as synonymous"(Gujarati, p.744). Campbell et al. (1997) though admit that while random walk unit root test forms part of random walk, its purpose is not for predictability but focuses on the nature of shocks.

If the series, in this case, Y_t (log returns) is stationary, then it is suggestive of the non-random behaviour of stock returns. However, if is non-stationary, then it is random walk. Stationarity tests will be carried out with unit root tests. If the tests find unit root, then there is non-stationarity, implying random walk. If not, then prices do not follow a random walk.

Tests of Random Walk 1

Sequence and Reversal test

CLM prescribes the use of Cowles-Jones (CJ) statistics for sequences and reversals, which tests RW1 with the mechanics as follows. Sequence is defined by an outcome of at least two successive returns within the same group of pre-specified values, say successive positive returns or successive negative returns. In contrast, a reversal is when a sequence is interrupted, that is, when there is at least two successive returns belonging to opposing pre-specified values, say positive return followed by a negative return. These two pre-specified possible returns can be defined in Bernoulli or binary outcomes as:

1 = when returns > 0, or returns ≤ 0; and

0 = when a return ≤ 0, followed by a return > 0; vice versa.

Then, the number of sequences, $\mathbf{N_s}$, is the number of 1s, and number of reversals, $\mathbf{N_r}$, is the number of 0s. However, in CLM, the ε_t distribution is symmetric, positive or negative returns are equally likely outcomes, thus, 1 or 0 outcomes are also equally likely which explains why $\underline{CJ}$ ratio N_s /N_r approximates unity, where:

n=number of reversals

N_s= number of sequences

N_r=number of reversals

$CJ = N_s / N_r = [N_s/n]/[N_r/n] = \pi_s / 1 - \pi_s \xrightarrow{pr} = CJ = \frac{1}{2} / \overline{\tfrac{1}{2}} = 1$

The statistic follows a normal distribution with a mean of ($\pi_s/1- \pi_{s,}$) and variance of [$\pi_s(1-\pi_s)+2(\pi^3+(1-\pi)^{3-} \pi_s^2)$] /($n(1- \pi_s)^4$ (CLM, 2.2.8, p.37). The N_s of 147 from n of 2715 result in $\overline{CJ}$ value of 1.1877 for the data set. At standard deviation of .0384, assuming asymptotic normality, the small p value(.000) rejects the null, providing evidence against the random walk.

Runs Test

Runs test together with sequence and reversal test evaluates RW1 as described in CLM. Runs are defined as uninterrupted return type, type means either positive or negative. For example, in a series of returns 1%, 2%, 7%, -3%, -4%, 6%, 8%, -8%, 9%, -12%, there are 6 runs, the first run being 3 positive returns, the second 2 negative returns, the third 2 positive returns, the fourth 1 negative, the fifth 1 positive and the sixth 1 negative. Thus, continuing the binary classification, 1,1,1,0,0,1,1,0,1,0, it is easy to see the runs by observing how many times the series changed from 1 to 0, or 0 to 1.

CLM defined runs as

$\pi_i=\Sigma n_i/n$

$E(N_{runs})= 2n\pi(1-\pi)+ \pi^2+(1-\pi)^2$

$Z= [N_{runs}+1/2 - 2n\pi(1-\pi)]/2\sqrt{[2\pi(1-\pi)(1-3\pi(1-\pi))]}$ normally distributed with 0 mean and standard deviation of 1.

For the data set in question of with $E(N_{runs})$ of 1,358, n of 2,715 and z statistic of -4.45, the computed p value was small(p=.000), therefore it rejects the random walk.

Tests of Random Walk 3

Augmented Dickey-Fuller Test (ADF)

If $\zeta = \rho-1$, the testable null hypothesis then becomes:

Ho: $\zeta = 0$, the series is non-stationary

H1: $\zeta < 0$, the series is stationary

The first differences of the weakest form of random walk are uncorrelated at all leads and lags, their autocorrelation is zero at different lags (CLM, p.44). Thus, checking for autocorrelation is part of evaluating the randomness of log returns in this study. Gujarati (2004), citing some authors, mentions that no single test of autocorrelation is judged most powerful statistically, thus, the conduct of selected tests. For the purpose ADF as often used tool in literature is also used here whose test specification is similar in form to DF test as shown in the section on stationarity. The test produced τ or tau statistic $\frac{\hat{\zeta}}{se(\hat{\zeta})}$ = -15.537 for specification with a constant, and tau of -15.538 for specification with constant and trend. Both outcomes with very small p values (.000) suggest that the log return series does not have a unit root and therefore, stationary or non-random walk process.

Figure 5. Autocorrelation Test Result

LAG	ACF		PACF		Q-stat.	[p-value]
1	0.1144	***	0.1144	***	35.5911	[0.000]
2	-0.0080		-0.0214		35.7646	[0.000]
3	-0.0499	**	-0.0471	**	42.5286	[0.000]
4	-0.0405	**	-0.0299		46.9938	[0.000]
5	-0.0639	***	-0.0580	***	58.1069	[0.000]
6	-0.0035		0.0073		58.1394	[0.000]
7	0.0102		0.0052		58.4221	[0.000]
8	0.0318		0.0239		61.1831	[0.000]
9	-0.0259		-0.0363	*	63.0131	[0.000]
10	-0.0084		-0.0036		63.2046	[0.000]
11	0.0509	***	0.0560	***	70.2760	[0.000]
12	0.0181		0.0058		71.1726	[0.000]
13	0.0036		0.0031		71.2080	[0.000]
14	-0.0066		-0.0067		71.3254	[0.000]
15	0.0274		0.0329	*	73.3799	[0.000]
16	-0.0308		-0.0315		75.9736	[0.000]
17	-0.0055		0.0051		76.0557	[0.000]
18	0.0412	**	0.0433	**	80.6935	[0.000]
19	0.0288		0.0139		82.9665	[0.000]
20	-0.0028		-0.0028		82.9884	[0.000]
21	-0.0205		-0.0184		84.1363	[0.000]
22	-0.0328	*	-0.0267		87.0762	[0.000]
23	0.0181		0.0280		87.9788	[0.000]
24	-0.0047		-0.0071		88.0386	[0.000]
25	-0.0015		-0.0052		88.0451	[0.000]
26	0.0184		0.0107		88.9780	[0.000]
27	-0.0211		-0.0242		90.2030	[0.000]
28	-0.0177		-0.0071		91.0584	[0.000]
29	0.0237		0.0253		92.6028	[0.000]
30	0.0042		-0.0074		92.6514	[0.000]
31	-0.0399	**	-0.0434	**	97.0267	[0.000]
32	-0.0338	*	-0.0237		100.1612	[0.000]
33	0.0139		0.0217		100.6895	[0.000]
34	-0.0129		-0.0203		101.1442	[0.000]

***, **, * indicate significance at the 1%, 5%, 10% levels

Leung Box test

This test, also a test of autocorrelation, makes use of the statistic shown below. It checks whether the autocorrelation coefficient is zero, a description of RW3 according to CLM.

The null is:

H_o: $\rho_1 = \rho_2 = ... = \rho_m = 0$

and

Q statistic = $T(T+2)\sum_{k=1}^{m}\frac{\hat{\rho}_k^2}{T-k} \sim \chi^2(m)$, where T= series length.

Figure 5 presents the Q-statistic and the corresponding p values on the last two columns of the autocorrelation test result. The null hypothesis that there is no auto-correlation up to 34 lags in this case, shows p values (.000), which implies that the log return series is stationary and therefore, non-random walk.

Variance ratio

In a random walk relation where p_t is the natural log value of PSEi at time t, $p_t = \mu + p_{t-1} + \varepsilon_t$, the right hand side being the usual drift μ, natural log of price of immediately preceding period and random disturbance ε_t . Lo and MacKinlay (1988), drawing from a random walk quality that the variance of increments is directly proportional to time, argue that one-period variance, say X_t-X_{t-1}, should be equal to half of two-period variance X_t-X_{t-2}. To find out whether the general relation VR(q)≡ Var[rt(q)] / q Var(rt) ≈ 1, where q refers to periods, they then

$$z(q) \equiv \sqrt{nq}\,VR(q)\left(\frac{2(2q-1)(q-1)}{3q}\right)^{-1/2} \overset{a}{\sim} N(0,1)$$

Table 1. Variance Ratios of Log Returns

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	0.569987	0.019195	-22.425	0.0000
3	0.395741	0.028625	-21.109	0.0000
10	0.114197	0.064859	-13.657	0.0000

Table 1 above reports the machine computed values of variance ratio for two, three and ten-period groupings. Since these variance ratios are expected to be approximately 1 up to q time differences, the p values (.000) on all periods as reported above demonstrate that variance ratios are significantly different from 1. Therefore, returns are correlated and do not follow a random walk.

Table 2. Summary of Results

Method		**Result**
Visual Inspection		
	Graph of Log prices	Non-stationary
	Graph of Log return	Stationary
	Correlogram	Stationary
Formal test		
RW1	Sequence and Reversal Test	Non-random
	Runs Test	Non-random
RW3	Augmented Dickey-Fuller Test	Non-random
	Leung-Box Test	Non random
	Variance Ratio Test	Non-random

In summarizing the results, Table 2 shows the method and the corresponding result. Visual inspection of the graphs in the preliminary tests produced a non-stationary behavior of the log prices. However, other graphs that used log returns of stock prices reveal a stationary behavior. The formal tests of random walk 1 and random walk 3 unanimously produced non-random behavior of the log returns of the stock prices. Over-all, the tests produced results that heavily favor the non-random behavior of the stock market based on PSEi, considered the primary indicator of Philippine stock market

4.0 Conclusion

This work, tested the main hypothesis that the PSEi follows a random walk. Based on the results, initially by using the visual techniques, and verified by statistical methods, this study produces ample evidence that PSEi, being a good approximation of the Philippine stock market performance, does not follow a random walk behavior. This finding indicates an inefficient market of the weak form, given the methodology utilized in this study. Copeland et al.(2005, p.355) defined weak form of efficient market as that whose prices reflect historical and return information, thus investors cannot arbitrage to generate excess return (Fama, 1965). The idea that random walk is a sufficient condition for efficiency was mentioned by Kawakatsu and Morey (1999), including it even as a support of robustness in their study of emerging markets. A conscientious investor therefore would most likely earn rewarding extra return should he decide to devote his time and effort exploiting information asymmetry in the case of Philippine stock market. The evidence of this study strongly supports this disposition although a different study finds PSEi unpredictable (Janairo and Roleda, 2012). Their study, however, hardly touches on the core content of efficient market hypothesis, which, by its relevance and financial authority, packs more credentials. And yet, another more recent study on PSEi (Chen and Diaz, 2014) using data from 2000 – 2011 found the market inefficient.

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