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Lack of Reform Effect on Exchange Efficiency

- Empirical Evidence from Saudi Market Index –

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Abstract

As development of financial markets has been a growing issue after the financial crisis 2008, this paper has tested efficiency on one of the largest emerging securities markets in the world. It examines lack of reform impact on efficiency of Saudi stock exchange (TASI index) employing random walk hypothesis (RWH) through a battery of parametric and nonparametric tests including autocorrelations, unit root, variance ratio (VR) and Brock, Dechert, and Scheinkman (BDS) test.

The study specifically aims to test weak form efficiency before and after massive efforts implemented to reform Saudi exchange. Findings have concluded in a consensus verdict that there is no change observed in TASI index behaviour, and hence it rejected to be a weak-form efficient market. Thus, policy makers and regulators should initiate further reforms; deep regulations and reorganization development to address inefficiency.

Keywords: Efficient Market Hypothesis (EMH), reform, TASI index, Random Walk Hypothesis (RWH)

1. Introduction

Saudi Stocks Exchange has come across an extreme refurbishing and reform aiming for an entire regulatory environment switching it from a primary market to an instituted stock exchange. Since 2007, huge institutional, constitutional, and regulatory transformation implementations have been put in action, e.g., establishing specialized bodies, issuing policies, and introducing technologies, in addition determine trading and supervision duties.

This dramatic change increases the importance to examine the effect considered by reorganizing Saudi stocks market which ought to be emphatically affected by such vast regulatory reform and restructuring, and supposedly guaranteed remarkable development of such stocks market.

Recently, Saudi stock exchange has been upgraded by Morgan Stanley Capital International (MSCI) from ‘Stand-Alone Market’ status to ‘Emerging market' and listed in MSCI's in 2019. Additionally, it has been added to FTSE Russell as ‘Secondary Emerging’ markets in 2018' (Tadawul, 2018). Restructuring process and regulatory enhancements endeavored over 15 year ago are presumed to be empirically reflected in Saudi stock market efficiency.

The significant point of the study is to investigate effect of essential regulatory reform on a growing stock market index efficiency. It emphases on revealing the dynamic linkage between the regulation and the impact can possibly take place on the index efficiency. By employing weak-form efficient Hypothesis (EMH), the major question investigated in this study is how has TASI index is affected on efficiency level by introducing regulatory and restructuring reform implementations.

2. Saudi Financial Economy

Saudi Arabia is the world's biggest oil reserve and producer. The economy is basically depended on oil revenues which position the kingdom as one of the largest economies in the Middle East and North Africa representing 25% of GDP in the area. Saudi economy has increased in size to rank among the best 20 biggest economies on the world (G20). The average growth rate of GDP is at 4% every year over the previous decade (MCI, 2018). Recently, Saudi government propelled a vast program known as 'Vision 2030', including the ‘National Transformation Plan 2022’. The vision expects to enhance government performance, empowers advancement of the private sector, and furthermore fortifies financial sector related improvements (World Bank, 2018).

2.1 The Saudi Stocks Market

2.1.1 History: Boom and Crisis

History of Saudi Stock Market (SSM) turns back to 1970s when it was informally worked. Since 1980s, trading was practiced through commercial banking with nonappearance of a bourse and market-makers (Kalyanaraman, 2014). Due to liquidity inflow in Saudi economy and increasing demand to invest in stock market, reorganization of Saudi stock market through

a new shaped body has been existed in 2003 to take full obligations under the name of Capital Market Authority (CMA). The new institution has become the sole authority of Saudi capital markets and the issuer of the guidelines, directions, and regulations. In 2007, The Saudi Stock Exchange (Tadawul) was set up to be sole entity authorized and act as the Securities Exchange (the Exchange). All execution of the stocks is estimated by Tadawul All Share Index (TASI).

Tadawul Exchange mainly carries out listing and trading in securities, as well as deposit, transfer, clearing, settlement, and registry of ownership of securities traded on the Exchange.

A situation depicted by the nonappearance of a bourse and market-maker coupled with other global factors, later, for example, increasing of oil prices and 9/11 fear, all among, drove to reform and restructuring the market (Lerner *et al.*, 2017). In mid 2000s, the evolving oil prices and the occurrence of terrorism attack caused Saudi to recover their investment from US. Massive billions of dollars found Saudi stock market a fit place to invest. Since that, securities exchange began an account of a blast and catastrophe.

Table 1. Saudi Stocks Market (*Tadawul*) Indicators (1999-2017)

Year	Listed companies	TASI Index		Market Capitalization		Traded shares	
		points	%	Value (SAR bn) *	%	Number of shares (bn)	%
1999	73	2,028.53	43.55	228.59	42.95	527,5 m***	79.04
2000	75	2,258.29	11.33	254.46	11.32	554,9 m	5.20
2001	76	2,430.11	7.61	274.53	7.89	691,8 m	24.67
2002	68**	2,518.08	3.62	280.73	2.26	11,430	605.2
2003	70	4,437.58	76.23	589.93	110.14	35,414	209.82
2004	73	8,206.23	84.93	1,148.60	94.70	63,674	79.80
2005	77	16,712.64	103.66	2,438.20	112.28	70,995	11.50
2006	86	7,933.29	-52.53	1,225.86	49.72-	73,438	3.44
2007	111	11,038.66	39.14	1,946.35	58.77	58,862	-19.85
2008	127	4,802.99	-56.49	924.53	-52.50	61,147	6.1
2009	134	6,121.76	27.46	1,195.51	29.31	57,074	-6.66
2010	135	6,620.75	8.15	1,325.39	9.8	36,011	-36.9
2011	150	6,417.73	-3.07	1,270.84	-4.12	49,443	37.3
2012	158	6,801.22	5.98	1,400.34	10.19	80,723	63.2
2013	163	8,535.60	25.50	1,752.86	25.17	52,818	-34.57
2014	169	8,333.30	-2.37	1,812.89	3.42	68,710	30.09
2015	171	6,911.76	-17.06	1,579.06	- 12.90	67,112	-2.32
2016	176	7,210.43	4.32	1,681.95	6.52	68,527	2.11
2017	188	7,226.32	0.22	1,689.60	0.45	45,797	-33.17
2018	190	7,827.73	8.3	1,858.95	10.02	39,845	-13.00

Notes: TASI index was assigned on a base value of 1000 point 1985 and restructured in 2008. (*) Values are in Saudi Arabian Riyal which is pegged To US dollar since 1970s at a rate of US 1 dollar = SAR 3.75. (**). (***) denotes million shares. All information is collected from the publications in Tadawul.com and CMA.com.org.sa.

In February 2006, the market dramatically run from 2000 point in 2002 to achieve a notable peak and shut down at 20,634 point where the accident activated on the following day. Toward the end of 2006, TASI index had recorded 65% drop losing $326.9 billion of market capitalization. This financial disaster ignited the regulatory steps (AlKhaldi, 2015). TASI index saw under 4500 point. Table 1 demonstrates the indicators of Saudi stock market.

2.1.2 Reorganization and Regulations

Saudi government recognized the deficiency of stocks market components in all different strides that prompted such disaster. Capital Market Authority (CMA) was an initial move towards proficient management of stocks exchange. Since 2003, the dealers confronted a few difficulties: absence of market institutional maker, trading instruments, declarations rules and market research. Vagueness was portrayed the market and internet websites were viewed as reference of data and buy-sell recommendations by ordinary traders (Lerner et al., 2017).

On the institutional change, comprehensive reform started by the new institutions (CMA), (Tadawul) and Securities Depository Centre (established 2007). In 2008, CMA had restructured market sectors and indexes followed by setting up a separate market for Sukuk (Islamic version of bonds) and bonds Trading in 2009. Furthermore, a Parallel Market was founded in 2016 to be a secondary market. Regulatory environment has completely been improved.

Reforms include issuing number of regulations including ‘Listing Rules’, ‘Authorized Persons’, ‘Securities Business’, ‘Real Estate Investment Funds’, ‘Corporate Governance’ and ‘Investment Funds’ during 2005 and 2006. In addition, the CMA has issued ‘Merger and Acquisition Regulation’, ‘Anti-Money Laundering Rules’, ‘Resolution of Securities’, ‘Disputes Proceedings Regulations’ and ‘Prudential Rules’ during the period 2007 to 2012. For trading purpose, swap agreements and exchange tradable funds (ETFs) were allowed in 2009 and 2010. Regulations for ‘Special Purpose Entities’ and ‘Corporate Governance’ were issued in 2017.

3. Literature Review of efficiency

3.1 Definition

The efficiency of financial market has been deeply researched and investigated during the last four decades. It is considered as key factor plays an essential role in affecting investment and decision of financial markets. Efficient market hypothesis (EMH) theory is used in financial literature over a century since discussing theory of speculation by Bachelier (1900) who provided a descriptive notion of random walks (Shiller, 1999). Since 1960s, Fama has ignited the discussion of efficiency as term in the financial market by his seminal review confirming that the role of information has increasingly become an essential element of financial markets and price setting.

EMH is indicated by ‘informational efficiency’ and generally defined as the new information correctly and quickly mirrored in the present stock prices (Lim and Brooks, 2011). The

efficiency of capital market as information processing is recognized by the speed of available information to reflect on prices of securities (Fama, 1976, p.133). The re-assessment paper by Fama (1970) classified the EMH into three versions: weak-form, semi-strong-form and strong-form of efficiency. Since 1970s, it has been determined three formats of the efficient market hypothesis (EMH).

According to Fama's EMH, the strong-form market efficiency is characterized by firm's publicly available information and privately held information is fully and instantly reflected in present price of the stock. The semi-strong form efficiency is that where the firm's publicly available information is quickly and fully mirrored in its current stocks' price. Lastly, the weak-form efficiency is a financial market which is completely based on historical information to be reflected fully and quickly in the present price of the stock.

3.2 EMH Theory

The theory has defined the efficient market as an information set Φ_t when there is impossibility to achieve abnormal profit in a financial trading based on Φ_t. A broad notation has been presented by Fama (1970) to explain how an investor generates price expectation for the financial securities; described by Cuthbertson (1996) as:

$$E\left(p_{j,t+1}\middle|\Phi_t\right) = [1 + E\left(r_{j,t+1}\middle|\Phi_t\right)]p_{j\,t} \tag{1}$$

where E represents the expected value operator, $P_{j,\,t+1}$ denotes the price of stocks j at time $_{t+1}$, $r_{j,\,t+1}$ signifies the security's return on j during the period, and Φ_t is a notation to represent the set of information available for the investor at time t.

In a technical reading of the equation, the left side formula $E(P_{j,\,t+1} \mid \Phi_t)$ is to denote the expected end of period on security j, given available information at start of the period Φ_t. The right side formula $1+E(r_{j,\,t+1} \mid \Phi_t)$ represents the expected return of the upcoming period of the security taking similar risk amount of stock j.

To conclude, testing market efficiency is relied on the assumption of no arbitrage opportunities, i.e. the absence of earning unusual returns (Fama, 1970). This consistent along with other empirical studies such as Ball (1978), Charest (1978), Banz (1981), Schwert (1983) who examined the market efficiency with asset pricing model. Interestingly, when the null hypothesis is rejected, this would imply the failure of market efficiency.

3.2.1 Random Walk and Common Tests

Consistent with the hypothesis of efficient market, Random Walk Hypothesis (RWH) is considered and accounted, due to some of its characteristics, a form of efficient hypothesis. In financial theory, the random walk indicates to the evolution in stocks market prices that is characterized by a random behaviour. In other word, stocks prices presume to be continuously changeable and thus returns are not predictable. 'This leads to a random walk where the more efficient the market, the more random the sequence of price changes' (Dupernex, 2007).

Since 1990s, new test has proven strong practical examination tool. Brock among others (1996)

found more accurate non-parametric test method to examine the independency of series. Brock, Dechert, Scheinkman (1996) test is known as (BDS). The test has provided robust results to examine efficiency of financial markets and linearity of series employing macroeconomic variables and factors for investigating (Panagiotidis, 2002, 2005, 2010).

3.2.2 EMH in developing Exchanges

Since they are characterized by small size, thin trading, lack of regulations and several frictions, emerging markets have always been perceived as inefficient in the literature of market efficiency. In Latin America, Urrutia (1995) found a positive autocorrelation in monthly returns of most countries. In support to that, Asian emerging markets have exhibited similar results for most of the empirical tests, Hoque et al. (2007) found that emerging Asian markets are not weak form efficient. Malafeyev *et al.* (2017) have concluded in a study on India and China market that both markets exhibited inefficiency.

In Middle East and Africa, Smith *et al.* (2002) and Smith (2007) reported results of rejecting random walk for most of Egypt, Kenya, Mauritius, Morocco, Nigeria and Zimbabwe financial market. However, they found an evidence of weak-form efficiency in South Africa, Lebanon and Jordan.

3.2.3 Saudi Stock Market

The case study of Saudi Stocks Market has been recorded as largest exchange in the Middle East and Arab World region. Limited number of research to investigate EMH has been deducted prior and post reform and reorganization impact on this market. Most of the empirical findings suggested that the Saudi exchange is characterized by inefficiency on the weak-form level.

The first paper published was by Butler & Malaikah, (1992) who used serial correlation and runs tests found that Saudi market during 1985-1989 was not a weak-form efficient. In a PhD thesis, Al-Razeen (1997) has approached a result that Saudi exchange is not informationally efficient. Also, Nourredine (1998) found no evidence of weak-form efficiency on Saudi stock behaviour. Furthermore, Al-Kholifey (2000) has concluded in a PhD thesis that 61 percent of the firms under study showed statistically significant serial correlation. Using Vector Regression (VR) and unit root tests, Onour (2009) examined weak-form efficiency of Saudi exchange and concluded by rejecting the hypothesis of random walk at all levels. Based on linearity tests, AlAshikh (2012) concluded that the hypothesis of market efficiency in weak form has been clearly rejected.

In a PhD dissertation, Ibn rubbian (2012) found a presence of significantly positive correlations in the Saudi stock market. Budd (2012) investigated the random walk by using VR and run tests for sectors and all share index under the assumptions of homoscedasticity and heteroscedasticity, finding that all tests have rejected RWH.

Yet, few studies have found evidence of efficiency. Assiri and Alzeera (2013) examined the efficiency of Saudi exchange employing four test tools and confirmed that all four test found evidence of a weak-form efficiency. Abraham *et al.* (2002) used run tests and the VR tests and

found evidence of weak-form efficienc. Employing two trading strategies on weekly data for 45 companies of 10 years period ended at 2000, Al-Abdulqader *et al.* (2007) has achieved a result evident that Saudi stocks market has improved towards efficiency.

4. Data and Methodology

4.1 Data and Assumption

A data of daily closing prices is used during the period from 1/3/1999 to 31/3/2018 representing 19 years (228 months). It carries out a sample of 5116 observations. Division of periods can provide more accurate results to reflect the dramatic change taken place during the tested time. The data is divided into two sub-period samples seeking to test market behaviour for TASI index before and after the start process of entire reform, as follows:

Pre-regulation: A period from 1/3/1999 to 30/3/2007 where the market has not practically started the reform process.

Post-regulation: A period from1/4/2007 to 29/3/2018 represents the actual intake towards restructuring the market which witnessed central changes in terms of regulatory, technology, structures, transparency, and governance. It is dated after the introduction of Saudi Stock Exchange (Tadawul) – stock platform-.

The assumption under investigation is the following:

H0**:** Lack of market regulations and reform has negatively affected TASI index towards approaching weak form efficiency.

4.2 Methods and Tests

Parametric and nonparametric statistical methods are utilized to test efficiency; namely: *serial correlation test*, *unit roots test (Augmented Dickey-Fuller and Phillips Perron tests), in addition to Variance Ratio and finally BDS test*. The selected tests are of the most accurate models applied to provide answers for whether the time series return under study follows random walk hypothesis (RWH).

4.2.1 Overview of TASI Index

The starting point is to look at overall visual investigation on the time series and log-returns of the total sample and the two sub-samples to examine the descriptive statistics of the returns for pre- and post-reorganization periods.

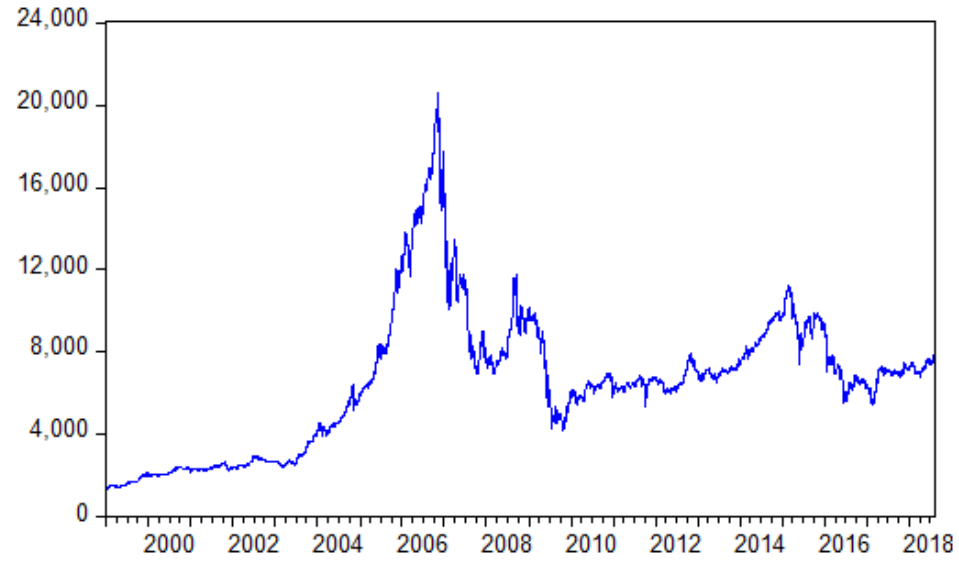

Figure 1. Time Series of TASI Index during 1999-2008

The time series of the daily closing prices shows that TASI index has a disaster experience of price collapse when the index approached 20,600 point, in February 2006, to sharply declined below 8,700 point. Since 2006, the index could not exceed this limit. Furthermore, considerable part of graph reflects that the time series followed a random behaviour.

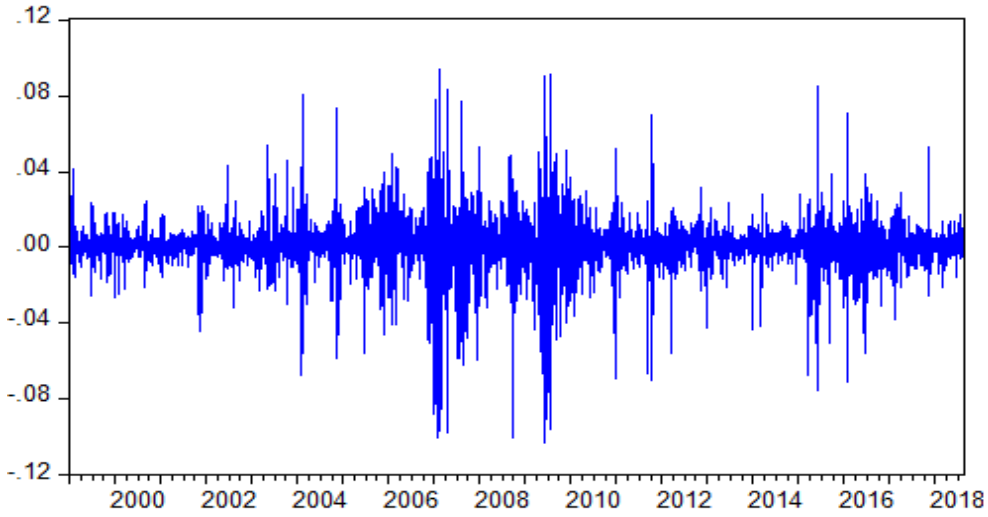

Figure 2. TASI Index Log-returns in Full Sample Period (1999-2018)

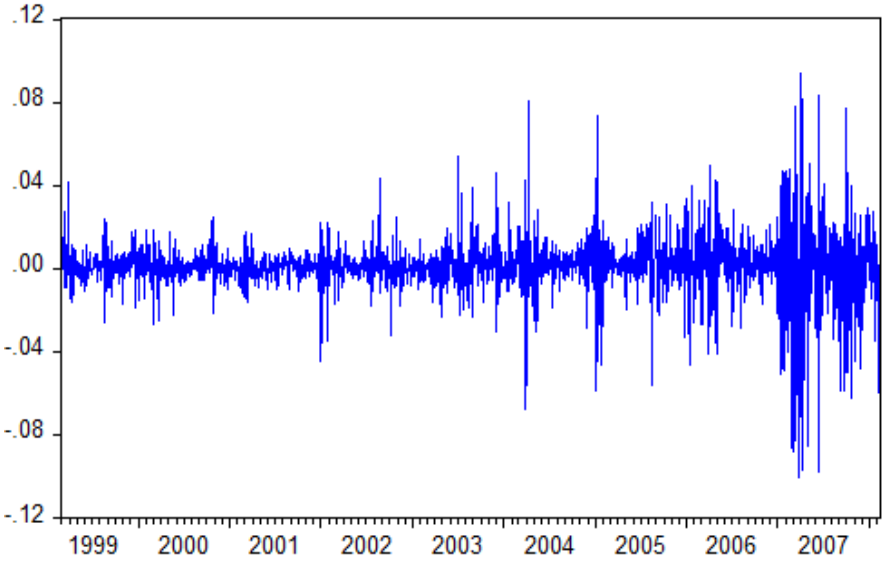

Figure 3. TASI Index Returns in the Pre- reform Period

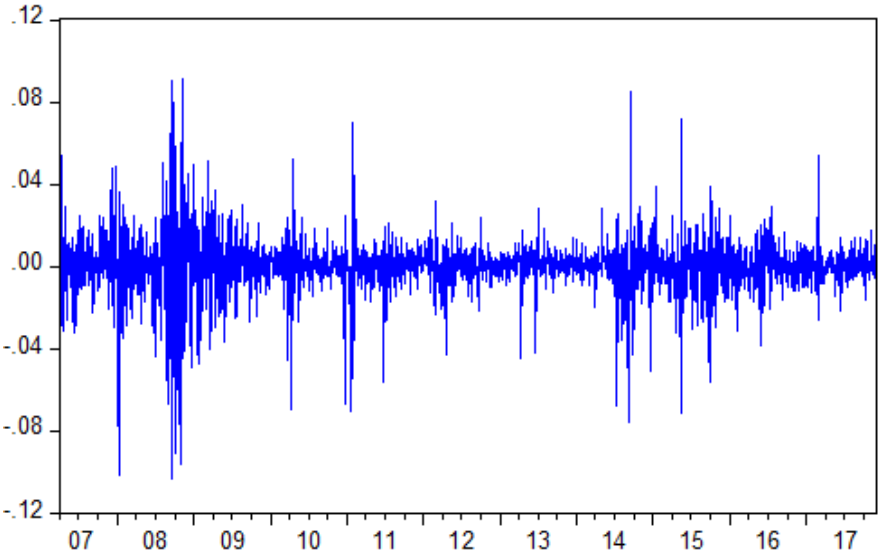

Figure 4. TASI Index Returns in the Post re-form Period

From the figures 2, 3, 4 above, the returns of TASI index appear, in general, to continue the fluctuations around the mean without clear evidence of an impact of the reform in the post-period in terms of volatility, however, this might be in favor of weak form efficiency where it is difficult to predict the prices in future. The figures further explain that periods of reform stocks market witnessed a large ups and downs above and lower +.04 and -.04 approaching sharp spikes in occasions for both before and post- reforms. The range of +.08 increase and -.08 decrease which, in turn, depicts the volatile behaviour maintained for both periods.

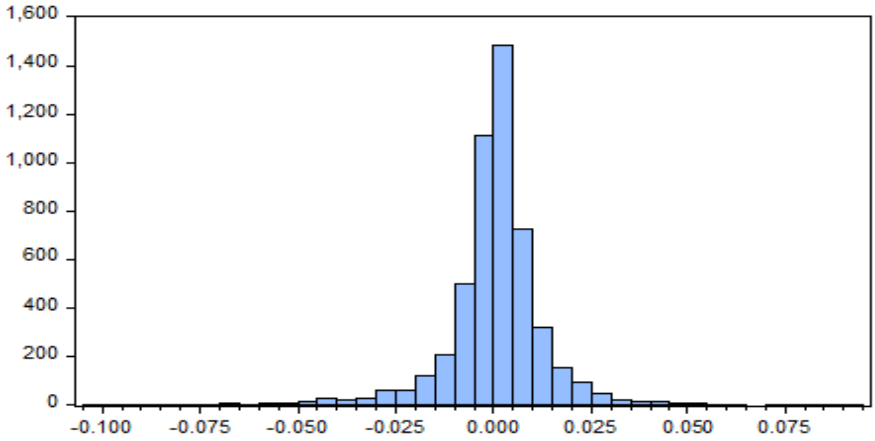

Figure 5. Normal Distribution of TASI Index Log-returns

Table 2. Descriptive Statistics of TASI Index Log Returns pre and Post Reform

	All period Log-returns	Log pre-reform returns	Log post-reform returns
Mean	0.000350	0.000759	-1.94E-06
Median	0.000902	0.001210	0.000582
Maximum	0.093907	0.093907	0.090874
Minimum	-0.103285	-0.100878	-0.103285
Std. Dev.	0.013997	0.014396	0.013641
Skewness	-0.899808	-0.969002	-0.841298
Kurtosis	13.76691	13.67576	13.86171
Jarque-Bera	25402.00	11449.02	13998.60
Probability	0.000000	0.000000	0.000000
Sum	1.789241	1.771390	-0.005385
Sum Sq. Dev.	1.002055	0.483496	0.517301
Observations	5116	2334	2781

Notes: The values are processed and calculated by E-views 10+.

Table 2 exhibits TASI index descriptive statistics for the sample of the whole period, pre- and post-reorganization periods. Apparently, the volatility of the index has not shown different behaviour across the samples where the Std.Dev for entire period are 0.0139; pre-reform 0.0142 and post-reform 0.0136. For normal distribution, skewness indicates the asymmetry of TASI returns' distribution which is assumed to be zero. The table illustrates that TASI index for the whole period returns has negative skewness at -0.89. As overall, negative skewness for the three tested time series provides an insight that the distribution of TASI index returns have, proportional fat left tail indicating that pre- and post-reform process periods have greater chance to obtain extreme outcomes in both periods of market.

In the side of standard normal distribution, kurtosis, as measure of the peakedness of

distributions in both tails, showed that all tested time-series returns have almost the same kurtosis level, as follows: total index is 13.7 (pre-period=13.6 and post-sample = 13.8). As conventionally agreed of kurtosis should be at 3, this indicates that all TASI index returns are characterized by heavier tail than standard normal distribution. This also implies that the investors have a greater chance to get either negative or positive extreme outcomes. In conclusion, TASI index's log returns across all periods are not normally distributed and featured by leptokurtic and skewed.

4.2.2 Random Walk Tests

To start testing efficiency of TASI index, the study obtains log returns from daily closing prices which are calculated by using the continuously compounded formula:

$$R_t = ln(\frac{P_t}{P_{t-1}}) \quad (2)$$

Where P_t represents the current closing price of the index and P_{t-1} is the previous day closing prices while *ln* is the natural logarithm. Then, accurate statistical methods to test weak form efficiency are employed, namely: (**i**) *a serial correlation test*, (**ii**) *unit roots test* (*Augmented Dickey-Fuller and Phillips Perron tests*), in addition to (**iii**) *Variance Ratio,* and (**iv**) finally *BDS test*.

4.2.2.1 Serial Correlation

This parametric test method is used as a first step to check the randomness. For the case of a weak form of EMH, the rises 1st difference of random walk must be uncorrelated at any lags or leads. It basically aims to measure association between current returns and lagged returns in the same series to reveal if the correlation coefficients are significantly different from zero. Autoregression Correlation function (ACF) is employed to detect the random walk attitude. ACF is given by:

$$P_k = \frac{\sum_{t=1}^{n-k}(R_t-\bar{R})(R_{t+k}-\bar{R})}{\sum_{t=1}^{n-k}(R_t-\bar{R})^2} \quad (3)$$

Where k denotes the number of lags, and R_t is the real rate of returns calculated as

$$R_t = ln\left(\frac{I_t}{I_{t-1}}\right) \times 100 = \alpha + \mathcal{u} \quad (4)$$

Standard error test and Box Pierce Q-test are also used to estimate the autocorrelation. The standard error tests autocorrelation of lags for individual basis to identify the significant lag. On the other hand, Ljung–Box (1978) test is a statistical portmanteau tool to check the overall randomness and independence in group basis based on number of lags in the series observations uncovering if these are away from zero. This is given by:

$$Q_{LB} = N(N+2)\sum_{j=1}^{K}\frac{\rho j^2}{N-j} \quad (5)$$

Where ρj represents j^{th} autocorrelation and N denotes observations number. The

distributed Q-statistic as chi-squared with freedom degrees is equal to the autocorrelation number (K), based on the null hypothesis of zero autocorrelation at first K ($\rho_1 = \rho_2 = \rho_3 = \cdots = \rho_k = 0$). The random walk return series is said to be when a zero serial correlation coefficient occurred. A zero correlation indicates that no trading strategy can achieve potential yield, i.e. consistent with RWT.

In table 3, the null hypothesis is rejected for all values at 1% and p-values are statistically significant at 0.0000. Autocorrelation Function (AC) displayed that the TASI index pre-reform is ranging between -.095 and 0.072, with Q-statistics ranges between 5.8714 and 81.596. Hence, the results of period before-reform showed unequal value to zero. This provides an evidence of autocorrelation among returns series prices.

On the other hand, the results for post-reform period have revealed values ranged from -0.042 and 0.100 for AC and values ranged from 27.765 to 46.057 for Q-statistics with significant p-values at 0.000. Since the autocorrelation of all 10 lags are not equal to zero, it provides an evidence of autocorrelation in TASI index return after the reform.

In other word, the results exhibited an indication that prices of TASI index correlates with the previous price and hence can be predictable. The results of ACF and Q-statistics tests are further consistent with Breusch-Godfrey – LM test which both periods showed P-value less than 5% rejecting the null of not having serial correlation.

Table 3. Serial Correlation Tests of TASI Index Returns

Lag	Pre- regulation				Post- regulation			
	ACF	*PAC*	*Q-stat*	*P-value*	*ACF*	*PAC*	*Q-stat*	*P-value*
1	0.050	0.050	5.8714	0.015	0.100	0.100	27.765	0.000
2	-0.095	-0.097	26.781	0.000	0.035	0.025	31.153	0.000
3	0.072	0.083	38.962	0.000	0.013	0.007	31.593	0.000
4	0.074	0.057	51.757	0.000	-0.017	-0.020	32.389	0.000
5	0.070	0.079	63.272	0.000	0.027	0.031	34.462	0.000
6	-0.034	-0.037	66.046	0.000	-0.018	-0.023	35.369	0.000
7	-0.053	-0.046	72.710	0.000	-0.041	-0.038	39.986	0.000
8	0.052	0.036	79.077	0.000	-0.017	-0.010	40.824	0.000
9	0.026	0.008	80.648	0.000	0.011	0.018	41.151	0.000
10	-0.020	-0.007	81.596	0.000	-0.042	-0.045	46.057	0.000
Breusch-Godfrey – LM test					Breusch-Godfrey – LM test			
Prob. F(10,2323)			0.0000		*Prob. F(2,2778)*		0.0000	
Prob. Chi-Square(2-10)			0.0000		*Prob. Chi-Square(2-10)*		0.0000	

Notes: Breusch-Godfrey serial correlation– LM test taken by 2 to 10 lags and resulted in same probabilities values at 0.0000. The null hypothesis of having no serial correlation was rejected. The p-values for both periods are significant at 1%.

4.2.2.2 Unit Roots Tests

Augmented Dickey Fuller (ADF)

To capture the random walk hypothesis in TASI index is commonly known by Unit root test, Augmented Dickey-Fuller (1981) has become a proper test for detecting the randomness, as it includes more lagged difference terms. This test is generated of the following regressions:

$$\Delta P_t = \mu + \alpha_1 t + \gamma P_{t-1} + \sum_{i=1}^{q} \rho \Delta P_{t-1} + \varepsilon_t \quad (6)$$

where Δ denotes 1st difference, P_t represents the log of the index price, μ is the constant, and ρ is coefficient which to be estimated, q denotes lagged terms number, t is the trend, α_1 is estimated coefficient for trend and ε is the error term to be for the assumed white noise.

Phillips Perron (PP)

PP (1988) is a non-parametric alternative method of testing a null hypothesis claiming of a unit root presence in the return at a given level of confidence. *Phillips Perron* test has provided an advantage of robustness in terms of heteroscedasticity general forms as error terms u_t.

Table 4. Unit Root Tests of TASI Index Returns (1999-2018)

Constant										
	Augmented Dickey Fuller Test –ADF					Phillips-Perron Test-PP				
	P-value	*T-statistics*	*Critical Value*			*P-value*	*T-statistics*	*Critical Value*		
			1%	5%	10%			1%	5%	10%
Pre-reform	0.0000	-18.375	-3.4329	-2.8625	-2.5673	0.0001	-46.035	-3.4329	-2.8625	-2.5673
Post- reform	0.0001	-47.725	3.4325	-2.8623	-2.5672	0.0001	-769.63	-3.4325	-2.8623	-2.5672
Constant and linear drift										
	Augmented Dickey Fuller Test -ADF					Phillips-Perron Test-PP				
	P-value	*T-statistics*	*Critical Value*			*P-value*	*T-statistics*	*Critical Value*		
			1%	5%	10%			1%	5%	10%
Pre- reform	0.0000	-9.3648	-3.9620	-3.4117	-3.1277	0.0000	-46.045	-3.9619	-3.4117	-3.1277
Post- reform	0.0000	-47.718	-3.9613	3.4114	-3.1275	0.0001	-768.68	-3.9613	-3.4114	-3.1275

Note: All values are rejected the null hypothesis of having unit root test at all three level of significance 1%, 5% and 10%.

ADF and PP Results:

The results, by using ADF on TASI index prior to the re-reform and after starting reform in table 4, have revealed rejecting the null of having unit roots. This outcome implies that TASI index series has no unit root and hence the series is stationary; showing integrated behaviour with I(0).

Since the results have absence of unit root, it can be said that TASI index is not characterized by following a random walk hypothesis for both periods, i.e. investor can predict the returns of the investment in such stock exchange.

In support to *ADF*, *Phillip-Perron* test found similar results of not having unit root for both periods as all p-values and t-statistics are statistically significant, thus rejecting the null hypothesis that states of having a unit root at all critical values levels 1%, 2% and 10%.

4.2.2.3 Variance Ratio (VR)

As more robust model to test random walk behaviour than the two previous methods, (VR) was developed by Lo and Mackinlay (1988) for an accurate exploration of stock prices randomness. This method has been popularly employed for both exchange index and also for individual stocks (Urrutia, 1995). VR considers the property of linearity of time interval in the increments of random walk series (Lo and MacKinlay, 1988).

It deeply investigates independent and identical distributed (iid) returns of time series over a constant mean with a linear function of a given holding periods. VR test of Lo and MacKinlay (1988) explores the uncorrelated residuals occurred in the series under two random walks' assumptions of homoscedasticity and heteroscedasticity. Asymptotic standard normal tests statistics has been included in VR. The final version of the equation is given as:

$$\hat{\delta}(K) = \frac{\mathrm{nq}\ \sum_{j=k+1}^{nq} (p_j - p_{j-1} - \hat{\mu})^2 (p_j - p_{j-k-1} - \hat{\mu})^2}{[\sum_{\mathrm{j=1}}^{\mathrm{nq}} (p_j - p_{j-1} - \hat{\mu})^2]^2}, \quad (7)$$

Where $\hat{\delta}(K)$ denotes the heteroscedasticity-consistent estimator, p_j represents the index price at time t and $\hat{\mu}$ is average of the return. So, the null hypothesis takes the value of VR is 1 and said to be *I*. If the heteroskedastic RW is rejected, this indicates that there is an evidence of autocorrelation existence in the series (Worthington and Higgs 2004).

Table 5. Variance Ratio Test of TASI Index Returns

Pre-Reform Period								
	With mean				Zero Mean			
	Time interval in Days							
Asymptotic	2	4	8	16	2	4	8	16
P-value	0.0000				0.0000			
VR(k)	0.576604	0.243186	0.124815	0.065309	0.576357	0.242876	0.124441	0.064888
Z(k)*	-7.944267	-8.006415	-6.281585	-4.840039	-7.948548	-8.009343	-6.284057	-4.842119
Post-Reform Period								
Asymptotic	2	4	8	16	2	4	8	16
P-value	0.0000				0.0000			
VR(k)	0.536508	0.282253	0.141506	0.067975	0.536315	0.281947	0.141148	0.067606
Z(k)*	-10.22107	-8.892078	-7.147699	-5.583898	-10.22509	-8.895731	-7.150630	-5.586101

Notes: VR (k) is for asymptotic variance of VR and Z*(K) is the t-statistics under heteroscedastic increments. P-value is reported for all time intervals as carried the similar value (0.000). The Null hypothesis is VR (K)=1, i.e. the TASI index follows random walk hypothesis. Also, the test for the entire period shows VR is less than unity and thus consistent with two divisions in this table.

Estimation and Results:

Testing TASI index by VR, the focus is on the heteroscedastic diagnosis as the sample is based on series return of daily closing prices which is most likely to be of heteroscedastic property test.

In table 5, both periods tested have rejected null of unity VR (K) =1 and all results below one. This provides an evidence that the TASI index is not following random walk for both before and after the reform periods.

Under the assumption of heteroscedasticity before reform period, results imply that we reject the null hypothesis of random walk for every interval provided in the test. Z-statistics associated with intervals K= 2, 4, 8 and 16 are -7.94, -8.00, -6.28 and -4.84 with mean test and zero-mean as follows -7.94, -8.00, -6.28 and -4.84, respectively. All results of p-values are equal to zero. This clearly implies that random walk is not existent.

Finally, results for both periods affirmed that presence of heteroskedasticitya and thus TASI index returns have autocorrelation and implied that this market is inefficient.

4.2.2.4 BDS test

The test is employed for series residuals estimated to explore whether the residuals are independent and identically distributed (*iid*). A distance $\in$ is applied then considers a pair of points. If observations is *iid* for any each pair of points, the probability of the distance between points is less than or equal to $\in$ will be constant while $C1(\in)$ is denoted the probability (LeBaron, 1997).

BDS is utilized to verify the presence of non-linear dependence in the residuals, if P-value is = 0, then the null hypothesis is rejected, and residuals are characterized by absence of non-linear dependencies. Accepting the alternative means the existence of non-linearity property.

Estimation and Results:

In table 6, results obtained from different embedded dimensions and various distances under asymptotic, exhibit that all p-values of the *BDS* test outcomes preformed to test the period's pre and post-reform in TASI index are statistically significant at 0.000 level.

Hence, this presents obvious evidence to reject the null hypothesis of *iid* and thereby random walk, accepting the alternative that TASI index returns is not being characterized by weak form of efficient market hypothesis.

Table 6. BDS Test of TASI Index Daily Returns Pre- and Post-reform Periods

	Pre-reform period			Post- reform period		
Dimension			Asymptotic			
	BDS-Stat	*z-Statistic*	*P-value*	*BDS-Stat*	*z-Statistic*	*P-value*
	EPS=.50				EPS=.50	
2	0.047282	20.82612	0.0000	0.025572	13.40374	0.0000
3	0.068894	26.42532	0.0000	0.040933	18.75815	0.0000
4	0.073849	32.84606	0.0000	0.043952	23.45717	0.0000
	EPS=.75				EPS=.75	
2	0.049039	20.90176	0.0000	0.026713	13.47165	0.0000
3	0.097648	24.44742	0.0000	0.062717	18.58911	0.0000
4	0.136661	26.81558	0.0000	0.093154	21.65417	0.0000
	EPS=.95				EPS=.95	
2	0.008670	14.23679	0.0000	0.005061	8.730267	0.0000
3	0.023077	17.71250	0.0000	0.017480	14.09681	0.0000
4	0.041538	19.91003	0.0000	0.032026	16.13213	0.0000

Notes: The ordinary residuals of TASI index is under the examination of this test. The full sample is also tested and supported the results of both periods with a *P-value* resulted as 0.0000.

5. Conclusion

However, all reform implementations, random walk tests employed in this paper have reached unanimous verdict that Saudi stock index (TASI) has not yet been characterized by a weak-form efficiency. Tests found no evidence of efficiency for both examined periods with a proven autocorrelation in returns. The parametric and non-parametric unit root examinations, specifically *ADF* and *PP* have revealed that returns for both pre-and post-reform periods are stationary and hence do not follow random walk hypothesis. The more powerful tests to explore independence in times series, *VR* and *BDS* have exhibited similar findings of having no indication of weak-form efficiency.

In concluding, TASI index has not yet empirically affected by the regulatory and restructuring reform sand continues to be inefficient market. It is likely that Saudi stocks market is characterized by an expectable trading behaviour and investor in such exchange can predict returns of investment. The findings suggest that Saudi stocks market may further require deep regulatory and structural institutional reforms. For the interest to market policy makers, future study may consider other elements using sectorial data and investigate firm's behaviour to deeply explore market efficiency.

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