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Linear and Nonlinear Causality between Stock Market Volatility and the Business Cycle in Iran

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Abstract

This paper surveys the relationship between stock market volatility and the business cycle in the Iranian economy, where both linear and nonlinear bivariate causality tests are used in the survey. The monthly data of the World Bank from 2000 to October 2016 is used in this survey. The results advocate that there is one-sided linear causality between the business cycle and the stock market volatility, likewise, nonlinear relationship between the two mentioned variables is confirmed. It means that the results of the Granger causality in two-sided analysis show that there is a one-side linear relationship from business cycles to stock market volatility in Iran. On the other hand, by using a nonlinear method, the assumption of nonlinear causality from business cycles to stock market volatility was confirmed, while the results didn't approve the assumption of linear and nonlinear causality from stock market volatility to business cycles. Therefore, to decision making in macroeconomic issues and investors in stock market, nonlinear relationships between macro-variables should be considered alongside linear causality, as it seems that the business cycles can have an impact on the stock market volatility in Iran, so, Investors can make their investment strategies in the stock market based upon the change in the business cycle.

Keywords: Stock Market Volatility, business cycle, linear and nonlinear causality test, Iran

JEL Classification: G10, E32, E30, E44

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1. Introduction

Many studies have documented that there is a relationship between stock market volatility and the business cycle. Fama, 1990; Schwert, 1989, 1990a, 1990b; Corradi et al., 2013; Chauvet et al., 2014, Geske and Roll (1983), Kaul (1987), Barro (1990), Chen (1991) found considerable evidence that variables related to the level or state of economic activity can explain stock market volatility and even forecast expected stock returns. As a review, Schwert, 1989; Hamilton and Lin, 1996 argued that during expansions and crisis stock market volatility display various behavior which can be predicted by different macroeconomic variables.

Likewise, Diebold and Yilmaz, 2010 emphasize that the studies should be focused on measuring, modeling and forecasting volatility rather than investigating the links with its underlying factors. Moreover, it is not clear how important the effects of financial market fluctuations are for real economic activity in a quantitative sense (e.g., Andreou et al., 2000; Fornari and Mele, 2013).

Furthermore, it seems that further study is required on the behavior of stock market volatility and a potential spillover effect on real economic activities, as it can improve investment decision through market participation, where this paper suggest effective impose of different economic policies.

However, this paper makes effort to investigate the aforementioned points for the Iranian Economy, and so, based on previous studies investigation is made on the relationship between the stock market volatility and business cycle for Iranian Economy. It is also worth noting that in this paper, the growth rate of the industrial production index represents the business cycle fluctuations, and so, both linear and nonlinear bivariate causality tests are carried out to survey this relationship in the Iranian Economy; further discussed in the next section of this paper. This research then explains data description and methodology, followed by the survey experimental results and the derived conclusion.

The research illustrated in the literature (e.g., Officer, 1973; Schwert, 1989; Hamilton and Lin, 1996; Brandt and Kang, 2004; Mele, 2007) also illustrates that stock market volatility during recessions is higher during expansions, which is clear evidence for a definite business cycle. Moreover, industrial production growths are known as an important index in the economy of a country. These results have been achieved by using the linear Granger causality test to assess the relationship between stock market volatility and the business cycle. Meanwhile, the literature provides strong evidence, confirming linear relationships (e.g., Keynes, 1936; Shiller, 1993, 2005; Hiemstra and Jones, 1994; Shin et al., 2013; Choudhry et al., 2014).

From 1994, nonlinear causality in finance literature has been introduced by Hiemstra and Jones (1994) and since then some researchers (e.g., Silvapulle and Choi, 1999; Chen and Wuh-Lin, 2004; Diks and Panchenko, 2006; Bekiros and Diks, 2008a, 2008b; Shin et al., 2013; and Bekiros, 2014), have provided empirical evidences to prove the existence of nonlinear financial variables in their researches.

Anderson (1997) believed that disequilibrium errors are emerged due to transaction costs which are generally neglected in the majority of literature. Brock and LeBaron(1996) also believed that diversity and differences in agents' belief can cause to a nonlinear relationship, which was later confirmed by Peters (1994), claiming that heterogeneity in investors' goals is a factor to prove the nonlinear relationship and are emerged from different investing prospect and risks. Moreover, for the first time, Baek and Brock (1992) also presented a general nonparametric test for Granger nonlinear causality which was developed by Hiemstra and Jones (1994). It is, therefore, worth adding that applying a nonlinear relationship is a necessity.

Based on the literature reviewed above, the authors of this paper aims to test the relationship between stock market volatility and the business cycle in Iran, where linear and nonlinear bivariate causality tests are adopted.

It is important to note that, so far, nonlinear tests have not been used to investigate the relationship between stock market volatility and business cycle in Iran; hence a gap in the literature. Therefore, this paper tries to cover this gap in research projects and present new evidence in this area.

2. Methodology

This section covers linear and nonlinear causality, where some different features of linear and nonlinear Granger causality test (as the adopted test) are explained, and the causality relationship between two particular variables are recognized.

2.1 Bivariate Linear Granger Causality Test

Causal direction for the two variables is identified by the Granger causality test which evaluates the correlation between two variables (by the present value of one variable and the previous value of another). According to Granger causality definition, Y is Granger Cause of X while the conditional distribution of Xt, as the past observation of *Xt*-1*, Xt*-2*, ...* and *Yt*-1*, Yt*-2*, ...*, change from the conditional distribution of Xt, as the only past record of *Xt*-1*, Xt*-2 *...* Generally, by adding the previous observation of Y to a data set, Y is taken into account as the Granger cause of X. The following two equations (Equations 2 and 3), the model is considered to estimate Granger Causality:

$$x_t = a_1 + \sum_{i=1}^{p} \alpha_i x_{t-i} + \sum_{i=1}^{p} \beta_i y_{t-i} + \varepsilon_{1t} \qquad (Equation\ 2)$$

$$y_t = a_2 + \sum_{i=1}^{p} \gamma_i x_{t-i} + \sum_{i=1}^{p} \delta_i y_{t-i} + \varepsilon_{2t} \qquad (Equation\ 3)$$

In a classical linear normal regression model, {xt} and {yt} are stationary variables, p is considered as optimal lag and {ε1t , ε2t } are the disturbances. Based on Granger causality definition, if in Equation2, for i=1,2,3, …, p there βi is zero (βi =0). Likewise, if for all i(i=1,2, …, p, γ is 0 (or γi = 0), therefore {xt} does not Granger cause {yt}.

Generally, the following null hypotheses are applied to test linear causal relationships between {xt} and {yt}.

$$H_0^1: \beta_1 = \cdots = \beta_p = 0, and\ H_0^2: \gamma_1 = \cdots = \gamma_p = 0 \qquad \text{(Equation 4)}$$

To estimate the causal linear relationship by testing these two hypotheses, four testing results are expected:

Table 1: The results of estimating the causal linear relationship

NO	Test Result	outcome
1	Hypotheses H_0^1 and H_0^2 are accepted	There isn't any linear causal relationship between {xt} and {yt}.
2	Hypothesis H_0^1 is accepted Hypothesis H_0^2 is rejected	There is a linear causality relationship from {xt} to {yt}.
3	Hypothesis H_0^1 is rejected Hypothesis H_0^2 is accepted	There is a linear causality relationship from {yt}to {xt}.
4	Hypotheses H_0^1 and H_0^2 are rejected	There is a bidirectional linear causality relationship between {yt} and {xt}.

Source: Bai, et. Al., 2010

We can apply the standard reduced-versus-full-model *F*-test like the study carried out by (see Bai, et. Al., 2010). to test the hypothesis $H_0^1: \beta_1 = \cdots = \beta_p = 0$ for equation(2) to detect the existence of the linear causal relationship from *{yt}* to *{Xt}*. This statistic can be used to recognize the linear causal relationship from *{xt}* to *{Yt} by* the null hypothesis $H_0^2: \gamma_1 = \cdots = \gamma_p = 0$.

2.2 Bivariate Nonlinear Causality Test

Regarding the proved inefficiency of linear Granger causality in recognizing the nonlinear causal relationship, there is a need for the introduction of a new solution to detect a nonlinear causal relationship. As it is being specified in various studies, Baek and Brock are the first researchers who developed nonlinear

Granger causality. This test is well-known for the important modifications carried by Hiemstra and Jones and is also known as the H-J test. Based on this modification there are two-separated steps to detect a nonlinear causal relationship between two variables, {xt} and {Yt}:

a) Applying the linear models in equation (2) and equation (3) for {xt} and {yt}, in order to detect their linear causal relationships and find their relevant residuals.

b) Applying a nonlinear Granger causality test to the residual series, $\{\hat{\varepsilon}_{1t}\}$ and $\{\hat{\varepsilon}_{2t}\}$ to detect the remaining nonlinear causal relationship between their residuals.

Hiemstra and Jones's collection tests are then discussed to define the nonlinear Granger causality. Regarding two strictly stationary and weakly dependent series {*xt*} and {*Yt*}, the m-length lead vector of Xt and Lx-length lag vector of Xt are described as:

$$X_t^m \equiv (X_t, X_{t+1}, \dots, X_{t+m-1}), m = 1,2, \dots, = 1,2, \dots \quad \text{(Equation 5)}$$

$$X_{t-Lx}^{Lx} \equiv (X_{t-Lx}, X_{t-Lx}, \dots, X_{t-1}), Lx = 1,2, \dots, t = Lx + 1, Lx + 2, \dots \quad \text{(Equation 6)}$$

The m-length cause vector, $\mathrm{Y_t^m}$, and the Lx-length lag vector, $\mathrm{X_{t-Lx}^{Lx}}$, of Yt can be described in same way. Series {Yt} does not strictly Granger cause another series {Xt} nonlinearly if and only if:

$$\Pr\left(\|X_t^m - X_s^m\| < e \middle| \|X_{t-lx}^{Lx} - X_{s-lx}^{Lx}\| < e, \|Y_{t-ly}^{Ly} - Y_{s-ly}^{Ly}\| < e\right) = \Pr\left(\|X_t^m - X_s^m\| < e \middle| \|X_{t-lx}^{Lx} - X_{s-lx}^{Lx}\| < e\right) \quad \text{(Equation 7)}$$

The maximum norm described as $\|X-Y\| = \max(|x1-y1|, |x2-y2|, \ldots, |xn-yn|)$ for any two vectors X=(x1,…, xn) and Y=(y1, …, yn), is shown by $\|.\|$ *and conditional probability* is presented by $\Pr(.|.)$.

$$\sqrt{n}(\frac{C_1(m+Lx,Ly,e,n)}{C_2(Lx,Ly,e,n)} - \frac{C_3(m+Lx,e,n)}{C_4(Lx,e,n)} \qquad (Equation\ 8)$$

$$C_1(m+Lx,Ly,e,n) \equiv \frac{2}{n(n-1)}\sum_{t<s}\sum I(x_{t-Lx}^{m+Lx}, x_{s-Lx}^{m+Lx}, e).I(y_{t-Ly}^{Ly}, y_{s-Ly}^{Ly}, e),$$

$$C_2(Lx,Ly,e,n) \equiv \frac{2}{n(n-1)}\sum_{t<s}\sum I(x_{t-Lx}^{Lx}, x_{s-Lx}^{Lx}, e).I(y_{t-Ly}^{Ly}, y_{s-Ly}^{Ly}, e),$$

$$C_3(m+Lx,e,n) \equiv \frac{2}{n(n-1)}\sum_{t<s}\sum I(x_{t-Lx}^{m+Lx}, x_{s-Lx}^{m+Lx}, e),$$

$$C_4(Lx,e,n) \equiv \frac{2}{n(n-1)}\sum_{t<s}\sum I(x_{t-Lx}^{Lx}, x_{s-Lx}^{Lx}, e), \ \ and \qquad (Equation\ 9)$$

$$I(x,y,e) = \begin{cases} 0, & if \|x-y\| > e \\ 1, & if \|x-y\| \leq e \end{cases} \qquad (Equation\ 10)$$

Based on Himestra and Jones test, for specific values of m, Lx, Ly, and e > 0, assumption has been made that both {Xt} and {Yt} are strictly stationary, weakly dependent, and fulfill the conditions stated in Denker and Keller; If {Yt} does not strictly Granger cause {Xt}, then the test statistic defined in equation (1) is distributed as $N(o,\sigma^2(m,Lx,Ly,e))$ asymptotically (see Bai, et. Al., 2010).

3. Data description

In order to investigate the causal relationship between stock market volatility and the business cycle in Iran, Global Economic Monitor databank was used to gather the records of our two variables. Based on this data bank, more than 200 records are identified over the determined period (2000-October 2016). The stock market value (in US dollars in the constant prices of 2005) is also presented as the Stock market index; presented by Equation 1:

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \qquad \text{(Equation 1)}$$

*Where Pt and Pt-1 denote the stock index prices at time t and t-1, respectively

In addition, the total industrial production growth rate (like log-changes of the total industrial production index) is considered as a representative variable for the business cycle that is achieved at a monthly frequency from the Global Economic Monitor data bank of the World Bank for Iran during 2000-2016 M10.

Initially, the time trend of two variables during this period was investigated, where the fluctuation of the value of the Iranian stock market has been illustrated in Figure 1. As can be seen, most of the fluctuations have taken place in the early of 2002 and the mid of the year 2013, which was associated with a dramatic increase in the market value index, that is accompanied by the sharp increase of the exchange rate. The fluctuation trend had then been stable until the first month of implementation of the JCPOA in 2016 when the value of the stock market index was increased.

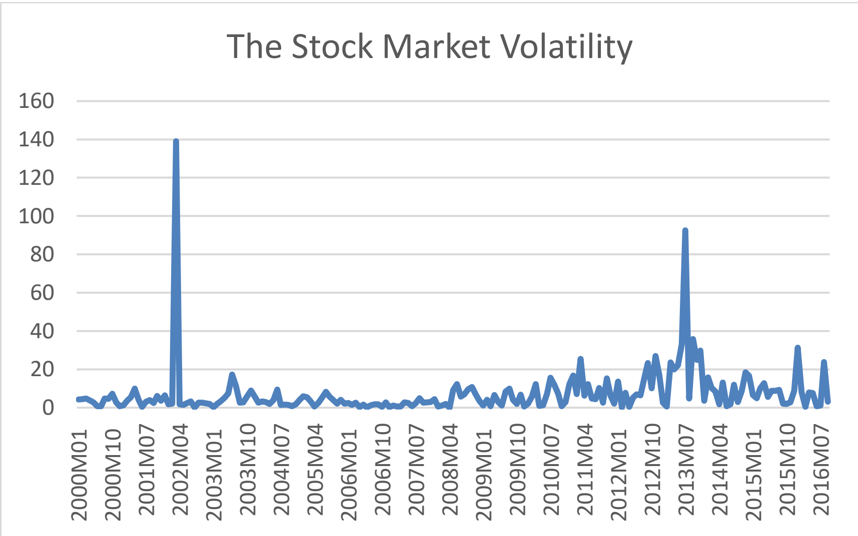

Figure 1: The stock market volatility for I

Figure 2 also depicts Iran's industrial production growth rate stated in this study, covering the period between January 2000- October 2016, where significant fluctuation is evident between this period. The biggest fluctuation of this variable is evident between January 2014-March 2014, where other considerable fluctuations have also arisen in the early months of 2001, 2002 and 2003.

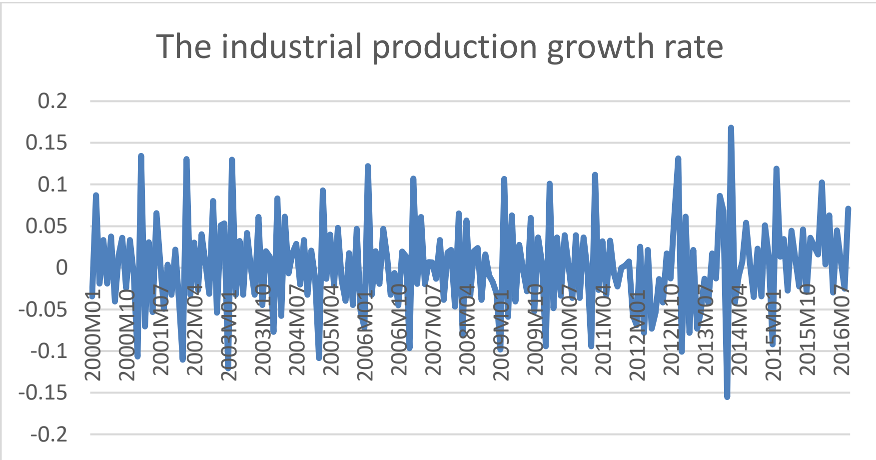

Figure 2: the industrial production growth rate

In this study, the investigation is also made on the relationship between stock market volatility and business cycles, where the causality between two variables including stock market index and industrial production growth rate are investigated.

4. Empirical Test and Result Analysis

4.1. Stationary Tests

Prior to testing Granger causality, and in order to avoid spurious regression unit root test was used for the aforementioned two series. Therefore, to perform the linear and nonlinear causality based on the result of stationary tests, the ADF[1] test was used to investigate the stationary of two mentioned time-series. The results of the unit root test by using ADF are given in Table 2. As can be seen, the calculated T being tock smaller than T MacKinnon, market volatility is stationary in level I(0), the result of which was similarly confirmed for Industrial production growth rate.

Table 2. Dickey-Fuller Stationary Test

	Augmented Dickey-Fuller (ADF) unit root test	
	Level	Prob.
Stock market volatility	-6.231553	0.00
The industrial production growth rate	-7.888670	0.00
CV(10%)	-2.574788	
CV(5%)	-2.876435	
CV(1%)	-3.464460	

4.2 Granger Causality Test

Regarding the results of the stationary test, a VAR model was run between stock market volatility and industrial production growth rate with 2 lag. This was followed by the analysis of the Granger Causality Test, the results of which have been shown in Table 3. Two assumptions were made, tested and confirmed in the Granger causality test:

a) The stock market volatility doesn't approve Granger Cause the business cycle

b) the business cycle doesn't Granger Cause the stock market volatility.

[1]. Augmented Dickey-Fuller

Table 3. Bivariate linear causality between stock market volatility and the business cycle

Null Hypothesis	obs	F-statistic	Prob.
Stock market volatility doesn't Granger Cause the business cycle	194	0.45069	0.6379
The business cycle doesn't Granger Cause stock market volatility.		3.54870	0.0307

The results of the Granger causality show that the Null hypothesis was confirmed for the one assumption, while it wasn't approved for another side. It can be therefore stated that stock market volatility doesn't Granger Cause the business cycle while the business cycle is Granger Cause stock market volatility.

4.3 BDS Test

The nonlinear causality was investigated through performing the BDS test on residuals of VAR, followed by Himestra and Jones test to discover nonlinear causality. To clarify, it can be said that the BDS test was initially established to test for the Null Hypothesis of independent and identical distribution (i.i.d.). In fact, The DBS test is used to detect any remaining dependence and existence of an omitted nonlinear structure. Finally, two probable situations will be supposed:

a) The fitted univariate linear model cannot be rejected, when the null hypothesis cannot be rejected.

b) The fitted univariate linear model cannot be identified, when the null hypothesis is rejected (see Coronado et. Al., 2015).

The BDS test was performed on the residuals of the return time series for dimensions up to the 6th dimension, the result of which is presented in Table 4. The results illustrate the rejection of the Null Hypothesis in four of the 6 cases, from which the nonlinearity of the series can be inferred. In other words, the corresponding amount for dimensions 2-5 present that in these lags, i.i.d. hypothesis can be rejected, and so, it is possible that there is a nonlinear relationship between residuals.

Table 4. BDS Test

Dimension	BDS	Z	Prob.
2	0.027290	3.185535	0.0014
3	0.052284	3.792236	0.0001
4	0.052490	3.157830	0.0016
5	0.047577	2.712245	0.0067
6	0.030876	1.802539	0.0715

It can, therefore, be stated that applying the Granger causality test is not sufficient to investigate the relationship between stock market volatility and the business cycle. In other words, considering the fact the existence of the nonlinear relationship is possible, nonlinear Causality test can be applied to investigate the aforementioned relationship.

4.4. Nonlinear Causality test

a) Based on the approval of the probability of the existence of a nonlinear relationship between stock market volatility and the business cycle in Iran, the nonlinear Granger test was run on the results of the VAR model, to investigate the precise relationship between these two variables. The nonlinear Causality test with the lag

(Lx=Ly) from 1 to 6 and e=1, 5, was also undertaken, where the authors of this paper studies the two hypotheses of:

b) Stock market volatility doesn't Granger Cause the business cycle

c) the business cycle doesn't Granger Cause stock market volatility.

Table 5. nonlinear causality test

lag	Stock market volatility doesn't Granger Cause the business cycle	The business cycle doesn't Granger Cause stock market volatility
Lx=Ly	H-J test	H-J test
1	1.179	1.608
2	1.132	1.094
3	0.725	1.083
4	0.730	1.008
5	0.980	1.986*
6	-0.293	1.293

As can be seen in Table 5, the results do not confirm a nonlinear causality between stock market volatility and the business cycle in Iran. However, the results display that one-side nonlinear causality relationship from the business cycles to stock market volatility is confirmed by H-J test sig. 10% and optimal lag 3 and 4.

5. Conclusion

The current study presented an investigation of the Causality relationship between stock market volatility and the business cycle of monthly information on 2000-2016. Moreover, the dynamism of the relationship between stock market volatility and business cycle was initially estimated, by applying linear and nonlinear causality tests. Despite the previous research carried out in the literature that assumed for a linear relationship, to illustrate the nonlinear nature of relationship between macro-economic variables, this study applied the use of nonlinear analysis based on the existing evidences, it was evident that the current research was the first study to focus on the two-side analysis of linear and nonlinear relationship between mentioned two variables.

The results of the tests in the two-side analysis show that there is only one-side linear relationship from the business cycles to stock market volatility of Iran in the given period. By using a nonlinear method, the assumption of nonlinear causality from business cycles to stock market volatility was confirmed, while the results didn't approve the assumption of nonlinear causality from stock market volatility to business cycles.

First of all, it should be concerned that this result is achieved for a period covering before and after the global financial crisis in 2008, although, Iran didn't have a considerable financial relationship with other countries due to it suffered from sanctions more than half of given period. So, it seems that most of explanation can be presented based on the impact of domestic factors. In fact, we create an opportunity to assess the impact of the crisis by collecting data for a sample which includes the recent global financial crisis. The strong evidence of bidirectional causality between stock market volatility and the business cycle in Iran was estimated by a linear bivariate causality test. The nonlinear framework also was employed to present significant feedback in most cases suggesting that nonlinear structures are present and important in capturing the dynamics between the considered variables.

Besides, it should be mentioned that the exchange rate fluctuation plays a considerable role in the Iranian economy. The increase in exchange rate during research period leads to rise in the cost of production because the remarkable proportion of intermediate and capital goods is imported to Iran. So, one of the consequences of growth in exchange rate in Iran would be the increase in cost of production as well as the fall in profit of production, and finally, stock market index will be dropped. On the other hand, the stock market would be flourishing again, if the economy exit from the crisis period.

The potential explanation for the result of this study is the movement in business cycle leads to the change in economic activity resulting in higher/lower earning for companies. The potential change in earning should result in an increase in stock market volatility. In fact, a nonlinear relationship from the business cycle to stock market can approve the statement that business cycle plays an important role in the cyclical movement of the stock market. Furthermore, it can be mentioned that the business cycle movements can be a common market indicator for the investor to explain stock market volatility. So, investors usually observe the change in the business cycle and then make their long-term investment decision. Investors can make their investment strategies based upon the change in the industrial production growth rate as it presents the business cycle changes. Likewise, designing investment strategies by investors in different scenarios can be a remarkable topic for ongoing research.

It can therefore, be concluded that the results of the current study suggest that for the policy-making of economic activity of any country, the linear and nonlinear relationship between the stock market volatility and the business cycle should be considered, as it seems that the business cycle can have an impact on the stock market volatility in Iran.

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