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Abstract

This paper examines the impacts of changes in interest rates on stock returns by using wavelet analysis with Granger causality test. Financial time series in non-coherent markets should be analyzed by advanced methods capturing complexity of the markets and non-linearities in stock returns. As a semi-parametric method, wavelets analysis might be superior to detect the chaotic patterns in the non-coherent markets. By using daily closing values of the ISE 100 Index and compounded interest rates, it is proven that and starting with 9 days time-scale effect interest rate is granger cause of ISE 100 index and the effects of interest rates on stock return increases with higher time-scales. This evidence shows that bond market has significant long-term effect on stock market for Turkey and traders should consider long-term money markets changes as well as short-term changes.

Key Words: Interest rates, Emerging markets, Wavelets, Stock returns, Multi-scale Granger causality

JEL classification: C45, C14

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1. Introduction

As one of the main parameters in the economy, interest rates reflect the time value of money and affect other parameters in money and capital markets. Investment decision makers in capital markets are influenced by the interest rates because of both valuation of the stock prices and the fact that its volatility directly influence shifts in capital between short-term money market and long-term capital market.

Especially in the non-coherent markets in which non-linearities observed in stock returns arising from the misperceptions of market participants towards risk and return relationship, the effects of interest rates on capital markets might be more influential due to high level of complex interaction between money and capital markets. The crash in a chaotic environment between the two markets makes their parameters both so complex to be analyzed and interdependent in their movements. The crucial point in determining that relationship is to detect the chaotic patterns in their cointegrated movements.

This paper aims to analyze the effects of changes in interest rates on stock returns in chaotic markets with an advanced intelligent semi-parametric model which is able to clearly detect the non-linearities and the complexities in the markets. Wavelets analysis as a superior methodology is selected to examine the relationship between interest rates and stock exchange time series from Turkish markets.

A large component of a stock's price is tied to the expected earnings of the corporation. The stock price of a firm reflects the expected future cash-flows being affected by the future internal and external aggregate demands. Changes in the interest rates affect the fundamental values of the firms, such as their dividend growth rates, net interest margins and sales. Analysis

based on fundamental value approach focus on the future growth prospects of a firm and market participants take buy/sell decisions based on that research. As expected, an increase in the interest rates impacts the valuation of the stocks because it raises the expectations of the investors demanding more profits commensurate with the increased returns on bonds. What is more, an increase in the time value of money leads investors to shift their investments from capital markets to fixed-term income securities market. The transition between the markets continues in reverse form when reduction in interest rates make participants to shift their investments to capital markets whose P/E ratio becomes enough low and the shares provide higher rates of capital appreciation than fixed-term income securities or money market instruments.

In advanced markets whose efficiencies are relatively high, there exist a negative relationship between market P/E and yield of the treasury bills indicating that in the long run the stock markets are affected by the change in interest rates. On the other hand, in the emerging markets in which their informational efficiencies are under question, the effects of interest rates on capital markets might not be clearly defined in the long-run, or should be analyzed in the short-run due to their non-coherent dynamics leading asymmetric and high degree of volatility and intensive effects of random shocks. Especially in emerging markets stock returns tend to have fat-tailed distributions. Mandelbrot (1963) opposite normality as a distributional model for stock returns which behave like non-Gaussian stable processes.

This research tries to model the returns in the Istanbul Stock Exchange with the interest rates of reference treasury bills by using wavelets analysis. In that respect, detecting interest rates effects on stock returns is an indicator for the absence of

market efficiency, as well. Resembling a two-factor arbitrage pricing theory, our model also examines the efficiency of the Istanbul Stock Exchange by an intelligent semi-parametric forecasting model.

This article is constructed as follows. After a brief theory on the stock valuation and the role of interest rates on stock price determination, a recent literature review is presented. The literature review includes researches on both asset pricing models with interest rates and wavelets analysis in finance and economics. After the data used in the research is introduced, the wavelets analysis method and its applications with financial time series prediction is examined in detail. The empirical findings are discussed in terms of both investment decisions of the market participants and theory of financial forecasting. The paper concludes with suggestions for future research based on semi-parametric models in emerging markets.

2. Theory and Literature Review

In financial theory, interest rate as a measurement of time value of money is one of the main determinants in stock returns. Its impacts on stock returns derive from two well-known theories of finance, namely, i) expectations theory ii) theory of valuation.

In terms of expectations theory in behavioral finance, the stock prices reflect the expected future cash-flows of the firms affected by the future aggregate demand. Therefore, expectations of economic recession have a crucial negative impact on stock prices. The observations in different economies have similar conclusions. For example, Andreou, Elena, DeSiano and Sensier (2000) show that value of the stock return in S&P before the recession in the US, and FTSE decreases before recession and reaches its maximum after 10 week from more intense period of the recession in the UK.

The effects come from the fact that changes in the interest rates have earnings effects on firms. A basic algorithm can be set up by the following way. Increase of interest rates leads available cash to borrow to be less which, in turn, decreases the spending. When the spending is getting less, earnings of the companies go down and their stock prices drop. In a reverse way, Titman and Warga (1989) state the stock returns might determine the interest rates by arguing that the market reflects the expectations of the financial variables on the prices.

What is more, when the interest rates falls stock returns become more attractive and a shift from fixed-term investment instruments to shares observed leading market value of the shares to increase. Expectations can reflect the prices of futures and options written on the equities. For example, an increase in interest rates drives up call premiums and lead put premiums to fall. The reason for that effect should be investigated on the expectations of interest rates. As buying a call option than shares of the stock are cheaper, the call buyer pays more for the option when rates are high. Since all stock models include interest rates, at least as a risk free rate, interest rate is an important factor in deciding if to exercise a put option before its maturity. In theory, a stock put option is exercised before its maturity when the interest received on its sale at the strike price is large enough. In that context, expectations of the market participants on the interest rates are important in deciding if the early exercise for a stock put option is optimal by considering the sufficient level of the interest earned. However, since the expectations of the participants are not homogenous and might become chaotic in non-coherent markets, the effects should be tried to captured by intelligent methods taking consideration into non-linearities in the risk and return on the equities.

In terms of the stock options, dividends impact option prices by the underlying stock price. Since the price of a price is expected to fall by the amount of the dividend on the ex-dividend date, high cash dividends requires lower call premiums and higher put premiums. Therefore, the dividends should be considered when determining the intrinsic value of a stock option. For a call option, exercise before maturity is acceptable if it is expected to pay a dividend prior to expiration date. Therefore, dividend growth rate which has sensitivity to the interest rates is important to shape the prices of the stocks by affecting the price expectations with options.

In the literature, effects of changes in interest rates on stock returns are examined in different economies with widespread methods. Fama (1981) argues that equity prices reflect main macroeconomic variables such as real economic growth, industrial production and employment. Evans (1998), on the other hand, states that since inflation risk and interest rates are integrated assets with higher risk should offer higher return to investors which requires a positive correlation between interest rates and inflation.

Modeling of stock returns with macroeconomic variables is suggested by asset pricing theory constructed by Ross (1977). He argues that predicting stock returns with one variable (Beta) is not sufficient to cover the complexity of the capital markets. After his critics on the capital asset pricing model, researches on alternative multi-factors CAPM are conducted in the financial theory of return prediction. For example, Choi, Elyasiani and Kopecky (1992) investigate the co-effects of the interest rates and the exchange rates on stock returns for the first time and conclude that the interest rates and exchange rates have determining role in the share prices of the financial firms.

Ünal and Kane (1987) states that the results of the researches about the effects of interest rates on stock returns vary based on investigation and frequency of the data. Ehrhardt (1991) finds out a powerful effect of the interest rates on stock returns and concludes that using the Beta coefficient and interest rates together increases the explanatory power of the model.

After the intensive liberalization policies in the developing countries, the global investors have started to shift a part of their funds into the emerging market, which in turn, creates an informational complexity of the financial markets. In order to model the complex nature of the markets, alternative econometric models are suggested. For a time, the ARCH models suggested by Engle (1982) and the GARCH models proposed by Bollerslev (1986) are used to capture the additional probability mass in the tails within the distributions. Recently, non-parametric or semi-parametric models have recently started to use in order to model the non-coherent financial markets. As computer based intelligent systems, neural networks and wavelets are employed in forecasting of financial time series. This paper chooses a superior method, namely wavelets analysis to detect the effects of interest rates on stock returns.

Wavelet analysis is one of the most promising methods used in a wide range of researches in science. Wavelet transform presents a multi-scale analysis tool in order to make it possible to study the signal in different scales. That kind of transformation enables researchers to single out short-term local singularities in the signal. What is more, it is also possible to filter out insignificant high-frequency changes of the signal in order to concentrate on its global and long-term behaviors.

Researches on wavelets in non-financial disciplines such as astronomy, engineering and physics are intensively conducted for

fifteen years. A financial application of the wavelets is not so intensive since using wavelets analysis in finance is overlooked. Traditional time-series methods are preferred by the decision makers because of the fact that the intelligent systems are treated as black boxes. However, recent empirical evidence has suggested a promising methodology by wavelets in order to capture the non-linearities in the stock returns and volatilities in the other financial time series. For example, Gencay and Selcuk (2004) construct the wavelet realized volatility at different sampling rates by calculating on index and individual stock prices.

The starting point of the wavelets model is the statement that fixed time scales are not proper to capture the misperception of risk and return. Therefore, a more adequate framework for forecasting stock returns in emerging markets might be conducted by a time-adaptive system simultaneously considering all time-scales of the distributions. A powerful nature of the wavelet analysis in terms of modeling is that with semi-parametric estimations of complex structures, it is possible to model the financial series without dealing with the functional forms of their distributions. Like the Fourier transforms, the wavelets are received by projecting the signal onto a basis space. Wavelets analysis, on the other hand, presents insight in local behavior, while the Fourier analysis does in global behavior.

In the finance literature, Norsworty, Li and Goroner (2000) examine the relationship between the return on an asset and that on

the market by using wavelets analysis based on time-scale decomposition in order to detect if there exist variances for different frequencies. They conclude that the impacts of the return in market portfolio on that in individual asset are greater in the higher frequencies than in the lower.

By employing wavelets to show the time-scale decomposition, Ramsey and Lampart (1998) examine the relationships among consumption, GDP, income and money. They conclude that the relationship among the economic variables change in different scales and the slope with respect to consumption and income decreases with scale indicating that the interest rates have a remarkable impact on the relationship between consumption and income. The other works that applied wavelet analyses for causal relationship are Kim and In (2003), Almasri and Shukur (2003), Zhang and Farley(2004) and Dalkır(2004). Gencay et all. (2002), Gallegati (2005), Cifter and Ozun (2006) and Çifter (2006) applied wavelet analyses on Turkish financial market data.

Wavelets analysis is not widely used in detecting relationships among the financial variables with Turkish data. In that respect, our research is the first in analyzing the effects of interest rates on stock returns in Turkish markets. The research is expected to present clues for research on forecasting financial time series in other emerging markets, as well. In the next part, data used in the analysis are introduced and the methodology of wavelets is discussed in detail.

3. Data and Methodology

Data
Emerging market share price as Istanbul Stock Exchange rate and reference treasury-bill rate as interest rate are from Bloomberg. Our dataset covers 780 daily observations from 02/01/2003 to

22/02/2006. We constituted the series in levels, logarithmic and log-differenced. Fig. 1 shows Istanbul Stock Exchange

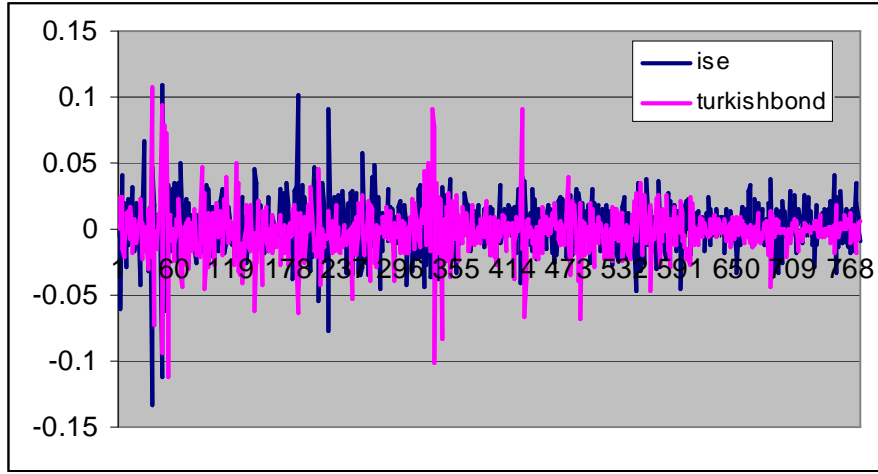index return versus Turkish Bond Index return in log-differenced series.

Fig. 1. Log-differenced series

Methodology

Wavelets theory is based on Fourier analysis which is any function can be represented with the sum of sine and cosine functions. Fourier analysis or Fourier series can be represented as Equation (1).

$$f(x) = b_0 + \sum_{k=1}^{\infty} b_k \cos 2\pi kx + a_k \sin 2\pi kx \qquad (1)$$

$$b_0 = \frac{1}{2\pi} \int_0^{2\pi} f(x)\,dx \quad , \quad b_k = \frac{1}{\pi} \int_0^{2\pi} f(x)\,Cos(kx)\,dx \quad ,$$

$$a_k = \frac{1}{\pi} \int_0^{2\pi} f(x)\,Sin(kx)\,dx$$

a_0, a_k *ve* b_k can be solved with OLS. Fourier to wavelet transition is given Equation (2).

$$f(x) = c_0 + \sum_{j=0}^{\infty} \sum_{k=0}^{2^j-1} c_{jk} \psi(2^j \chi - k) \qquad (2)$$

$\psi(x)$ called as mother wavelet which is mother to all dilations and translations of ψ in Eq.(2). A simple example of mother wavelet is (Tkacz, 2001) in Equation (3).

$$\Psi(x) = \begin{cases} 1 & : 0 \leq x < \dfrac{1}{2} \\ -1 & : \dfrac{1}{2} \leq x < 1 \\ 0 & : other \end{cases} \qquad (3)$$

In high frequency finance the maximal overlap discrete wavelet transform (MODWT) is used instead of DWT as MODWT can handle any sample size *N* and wavelet variance estimator of MODWT is asymptotically more efficient than the estimator based on the DWT.

The MODWT is formulated with matrices (Gencay at all, 2002 and Percival and Walden, 2000) and yields *J* vectors of wavelet filter coefficients $\tilde{W}_{j,t}$, for j=1,…,J and t=1,….,N/2^j, and one vector of wavelet filter coefficients $\tilde{V}_{j,t}$ through(Gallegati, 2005) Eq. (4) and (5)

$$\tilde{W}_{j,t} = \sum_{l=0}^{L_{j-1}} \tilde{h}_{j,l}\, f(t-1) \qquad (4)$$

$$\tilde{V}_{j,t} = \sum_{l=0}^{L_{j-1}} \tilde{g}_{j,l}\, f(t-1) \qquad (5)$$

Where $\tilde{h}_{j,i}$ and $\tilde{g}_{j,l}$ are the scaled wavelet and scaling filter coefficients.

In order to apply wavelet analysis first unit root should be tested in time series. All series should be stationary at the same level. ADF test(Dickey ve Fuller, 1981) is widely used and can be determined as (6).

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \qquad (6)$$

$$\alpha_i \sum_{i=1}^{m} \Delta Y_{t-i} + \varepsilon_t$$

To test cointegration, we employ Johansen cointegration test that offered by Johansen(1988) and Johansen and Joselius(1990).

We apply unrestricted cointegration test without trend and with constant term. (7)

$$H_1^*(r) : \prod y_{t-1} + Bx_t = \alpha(\beta^{'} y_{t-1}) + \rho_0 \qquad (7)$$

Cointegration in stationary time series by Johansen procedure is set with trace and maximum eigenvalue statistics (8, 9)

$$\lambda_{trace(r)} = -T \sum_{i=r+1}^{k} In(1 - \bar{\lambda}_i), r = 0,1,2,3,....,n-1 \qquad (8)$$

$$\lambda_{max(r,r+1)} = -TIn(1 - \bar{\lambda}_{r+1}) \qquad (9)$$

If cointegration exists between variables it states that at least one directional causality exist (Granger, 1969). Granger causality test is applied with eq.(10).

$$Y_t = B_0 + \sum_{n=1}^{M} B_n Y_{t-n} + \sum_{n=1}^{K} \alpha_n X_{t-n} + \varepsilon_t \qquad (10)$$

If cointegration doesn't exists between variables standart cointegration test is applied (Granger, 1969) and if cointegration exists between variables vector error correction model should be applied (Granger, 1988). Since we test only one directional causality from interest rate to stock index we apply Granger causality test for all cases. We apply granger causality test with maximum 12 lags.

Besides, we investigate generalized impulse response analyses developed by Koop. Et all. (1996) and Peseran and Shin (1998) in order to test interest rate shocks on stock index.

4. Empirical Results

We study, using data from 2003 to 2006, the stationarity properties of ISE(Istanbul Stock Exchange Index) and Bond(Interest rate) by performing augmented Dickey–Fuller (Dickey and Fuller, 1981) test. The results of the unit root tests in Table 1 shows that all of the log-differenced variables are stationary.

Table 1
Unit root test statistics of the time series

		ADF Test
Variables	**Nl**	**t-stat.**
ISE	0	-29.2913{<0.01}*
Bond	0	-27.6011{<0.01}*

Notes. Tests for prices in level use a constant but not a time trend. The table reports results of the augmented Dickey–Fuller (Dickey and Fuller, 1981) tests for all the time series. The number of lags (nl) in the tests have been selected using the Schwarz information criterion with a maximum of twelve lags. Probability of the statistic exceeding the computed value under H_0 is given in braces.
* Indicate the rejection of the unit root null at the 1% significance level.

Cointegration test result in Table 2 shows that according to Johansen cointegration test (Johansen(1988) and Johansen and Joselius(1990)) ISE and Bond rates are cointegrated. This result shows that at least one directional causality exists between these two variables.

Table 2
Cointegration test results

	nl		Unrestricted Cointegration Rank Test	
			Trace Stat.	Max-Eigen Stat.
ISE & Bond	12	r=0	125.107 {<0.01}*	69.7868 {<0.01}*
		r ≤ 1	55.3202 {<0.01}*	55.3202 {<0.01}*

* indicates significance of cointegration at the 1 % level. CIVAR lag length is selected with Schwarz Selection Criteria.

Granger causality test result(as in equation 10) in Table 3 shows that causality doesn't exist from Bond rate to ISE with optimal lag determined by Final Prediction Error. This result shows that in shorter time period causality runs from ISE to Bond. Since we use daily data this can be concluded as ISE index is affected by daily news more than Bond rate and causality runs from ISE index to Bond rate with shorter time period.

Table 3
Granger Causality

	FPE*	F-Statistic	Probability	Concentration
From Bond to ISE	1.06E-07	1.00454	0.44264	Bond $\neq$ > ISE
From ISE to Bond	2.41E-04	1.79469	0.08292	ISE = > Bond

* FPE represents Final Prediction Error. Optimal lag is 12.

We test if all the scaled series are stationary with ADF Test. The results of the unit root tests in Table 4 shows that all of the level variables are stationary. Since all the variable are stationary, cointegration test and wavelet analysis can be employed.

Table 4
Unit root test statistics of the scaled time series

	ADF Test	
Variables	nl	t-stat.
ISE_DJT1	6	-24.0401{<0.01}*
ISE_DJT2	6	-18.2565{<0.01}*
ISE_DJT3	5	-25.1268{<0.01}*
ISE_DJT4	6	-10.6405{<0.01}*
ISE_DJT5	6	-9.68321{<0.01}*
ISE_DJT6	5	-8.15716{<0.01}*
Bond_DJT1	5	-25.7715{<0.01}*
Bond_DJT2	6	-17.3412{<0.01}*
Bond_DJT3	5	-27.2326{<0.01}*
Bond_DJT4	6	-10.2068{<0.01}*
Bond_DJT5	6	-8.67434{<0.01}*
Bond_DJT6	6	-7.69156{<0.01}*

Notes. The table reports results of the augmented Dickey–Fuller tests for all the time series. The number of lags (nl) in the tests have been selected using the Schwarz information criterion with a maximum of twelve lags.

Cointegration test result in Table 5 shows that ISE and Bond rates are cointegrated at all time-scaled level. This result shows that at least one directional causality exists between these two variables.

Table 5
Cointegration test results

	nl		Unrestricted Cointegration Rank Test	
			Trace Stat.	Max-Eigen Stat.
	12	r=0	762.694 {<0.01}*	417.894 {<0.01}*
DJT1		r≤1	344.8 {<0.01}*	344.8 {<0.01}*
	12	r=0	455.482 {<0.01}*	239.716 {<0.01}*
DJT2		r≤1	215.767 {<0.01}*	215.767 {<0.01}*
	12	r=0	273.307 {<0.01}*	153.752 {<0.01}*
DJT3		r≤1	119.555 {<0.01}*	119.555 {<0.01}*
	12	r=0	230.712 {<0.01}*	137.211 {<0.01}*
DJT4		r≤1	93.5011 {<0.01}*	93.5011 {<0.01}*
	12	r=0	96.6226 {<0.01}*	55.1371 {<0.01}*
DJT5		r≤1	41.4856 {<0.01}*	41.4856 {<0.01}*
	12	r=0	80.195 {<0.01}*	44.7576 {<0.01}*
DJT6		r≤1	35.4373 {<0.01}*	35.4373 {<0.01}*

* indicates significance of cointegration at the 1 % level. CIVAR lag length is selected with Schwarz Selection Criteria.

Table 6 shows granger causality test results for scaled-time series. These results indicate that Bond rate is granger cause of ISE index starting from third time-scale(DJT3). By using daily closing values of the ISE 100 Index and compounded interest rates, starting with 9 days time-scale effect interest rate is granger cause of ISE 100 index and the effects of interest rates on stock return increases with higher time-scales.

Table 6
Granger Causality

	FPE*	F-Statistic	Probability	Concentration
DJT1 (1-4 days)	2.04E-10	1.47006	0.13001	Bond ≠ > ISE
DJT2 (5-8 days)	1.93E-12	1.13436	0.32836	Bond ≠ > ISE
DJT3 (9-16 days)	2.88E-14	3.14528	0.00022	Bond => ISE
DJT4 (17-32 days)	5.50E-16	1.77887	0.04772	Bond => ISE
DJT5 (33-64 days)	6.17E-18	2.35158	0.00576	Bond => ISE
DJT6 (65-128 days)	4.58E-20	1.88304	0.00676	Bond => ISE

* FPE represents Final Prediction Error. Optimal lag is 12.

Figure 2 shows scatter graph of Bond rate and ISE index and regression results. Regression results show that R^2 is increased at higher time-scales and maximum value of R^2 is at 6th time-scale (65-128 days). This empirical evidence supports granger causality results at Table 6.

Figure 3 shows generalized impulse response analysis of Bond rate on ISE index based on vector autoregression model. The graphs show that a shock on

Bond rate will effect ISE index at higher time scales and the most appropriate effect is at 6th time-scale same as regression result at Figure 2.
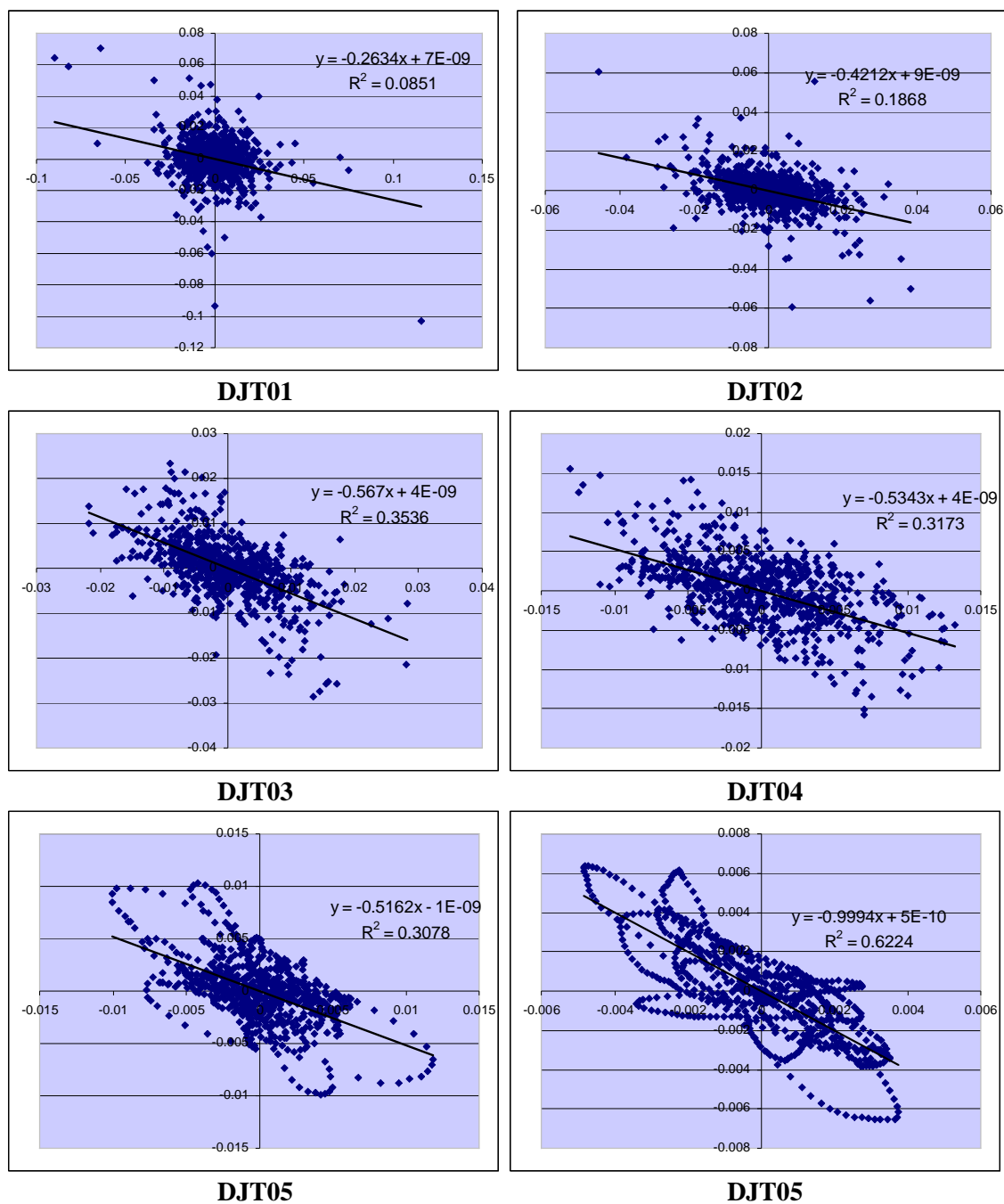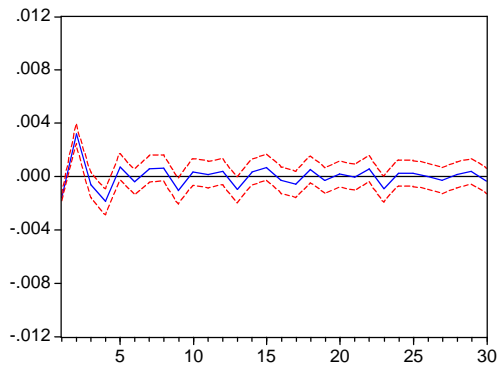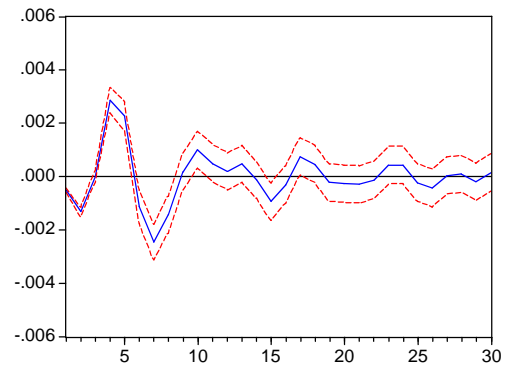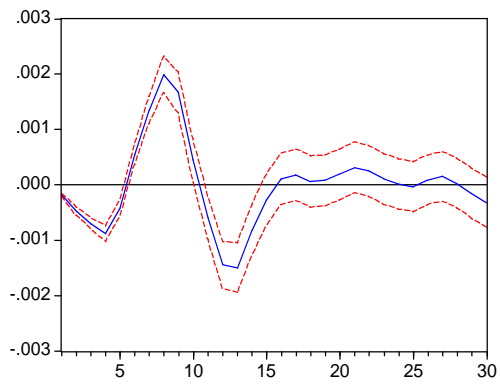

DJT01

DJT02

DJT03

DJT04

DJT05

DJT05

Fig. 2. ISE Index Returns versus Bond Index Returns with Different time-scales

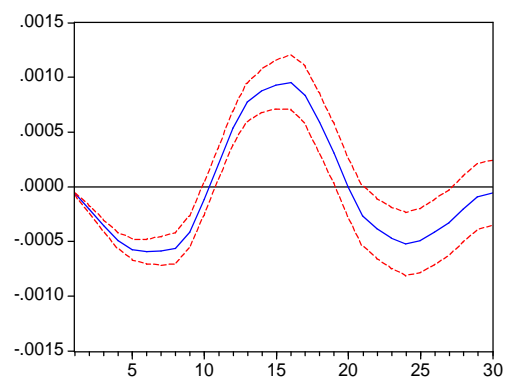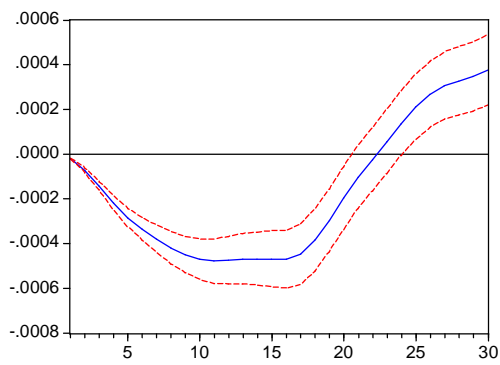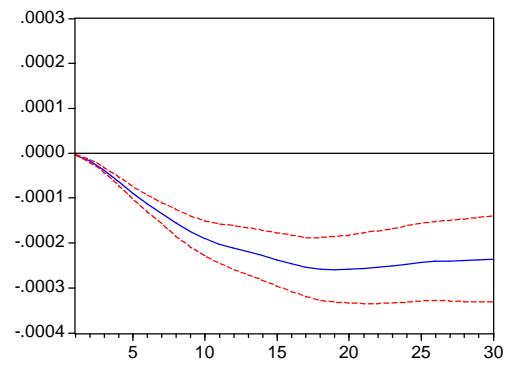**Fig. 3. Impulse Response Analysis – Response of ISE Index to Bond Index**

5. Suggestions For Future Research

This paper examines the role of interest rates in determining stock returns in non-coherent markets by using wavelet analysis as a semi-parametric model having power to detect the non-linearities in the daily stock returns. Due to its effects on valuations and expectations of the stock prices, interest rate has a crucial role in determining stock returns. Starting with the arbitrage pricing theory, effects of changes in interest rates on the stock prices are examined by employing different methodologies including parametric and non-parametric models. Recently, as a semi-parametric method, wavelets are started to use modelling stock returns in emerging markets. With Turkish data, on the other hand, the wavelets have not widely used as a forecasting method in finance.

The empirical tests have important promising results in terms of both theory of finance, applied forecasting and investment decisions. First of all, it is clearly showed that the stock returns might be modelled by using macroeconomic factors including interest rates. The effects of interest rates on stock returns are negative as it is expected. Secondly, semi-parametric forecasting models have superior power on analysing financial time series in chaotic markets on which existing non-linearities should be captured. The result for the investors is also promising. By using daily closing values of the ISE 100 Index and compounded interest rates, it is proven that and starting with 9 days time-scale effect interest rate is granger cause of ISE 100 index and the effects of interest rates on stock return increases with higher time-scales. This evidence shows that bond market has significant long-term effect on stock market for Turkey and traders should consider long-term money markets changes as well as short-term changes.

As it is expected investors should follow the volatility in the interest rates to take decisions in their capital market investments for more than 9 days trading position.

Future research should focus on the new intelligent methods in order to analyse financial time series in the emerging markets. This research use wavelets as a analysing tool for displaying effects of interest rates on stock returns on causality based. In the future research combinations of non-parametric and semi-parametric methods might be employed in detecting chaotic patterns in the financial time series in the emerging markets for not only causality studies but also n-days ahead forecasting positions.

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