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Cifter, Atilla and Ozun, Alper

Marmara University

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Multi-scale Causality between Energy Consumption and GNP in Emerging Markets: Evidence from Turkey

Atilla Cifter^{a*}, Alper Ozun^{b†}

^a Marmara University, Department of Econometrics, and Deniz Investment-Dexia Group, Istanbul, Turkey
^b Marmara University, Department of Informatics, and Is Bank, Istanbul, Turkey

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Abstract

Tests results for causality between energy consumption and economic growth do not have a consensus in the financial economics literature. Empirical evidence varies on the economies examined and methodology employed. This paper proposes a wavelet analysis as a semi-parametric model for detecting multi-scale causality between electricity consumption and growth in emerging economies. Using wavelet analysis we find that in the short run there is feedback relationship between GNP and energy consumption, while in the long run GNP leads to energy consumption. Wavelet correlation between GNP and energy consumption is maximum at 3rd time-scale(5-8 years) and this shows that GNP effects electricity consumption maximally around 5-8 years later in the long-run. We also find that the magnitude of the wavelet correlation changes based on time-scales for GNP and energy consumption and thus indicate that GNP and energy consumption are fundamentally different in the long run.

Key Words: *Economic Growth, Energy Consumption, Employment, Wavelets, Causality*

JEL classification: Q43, C32, C1

1. Introduction

Energy is considered as a filtering factor for economic growth in some researches since production is negatively effected by lack of energy (Jumbe, 2004; Stern, 2000). In reverse, there exists evidence showing that economic growth is an energy consumption resource (Masih and Masih, 1996). According to Soytaş and Sari (2006), the lack of consensus on the causality between energy and output might be because of the fact that the economies have different energy consumption patterns and various sources of energy. Therefore, different sources of energy might have varying impacts on the output of an economy.

* PhD Student in Econometrics, Marmara University, Istanbul, Turkey and Financial Reporting Vice President, Deniz Investment Securities-Dexia Group, Istanbul, Turkey Tel: +90-212-3548373 Address: Deniz Bank Genel Müdürlük Büyükdere Cad. No:106 34394 Esentepe Sisli Istanbul, Turkey, E-Mail address: atilla.cifter@denizyatirim.com

† PhD. in Banking and Finance, PhD. Student in Informatics, Marmara University, Istanbul, Turkey and Inspector, Board of Inspectors/Market Risk Group, Is Bank, Istanbul, Turkey Tel: +90-212-316 4009 Address: Türkiye Is Bankasi A.S., Genel Müdürlük, Teftis Kurulu Başkanlığı, Kat:34, Is Kuleleri 34330 Levent, Istanbul, Turkey, E-Mail address: alper.ozun@isbank.com.tr

Recent financial theory argues that a causal relationship should be expected between the two variables since energy is an important factor for both demand and supply sides of the economy. According to [Chontanawat, Hunt and Pierse \(2006\)](#), on the demand side, customers see energy as a product to maximise their utilities. On the supply side, energy is a crucial factor for production, economic growth and development. Whether the economic growth is a driving factor for energy consumption or vice versa should be investigated with taking into consideration a causal relationship as well. They test for causality between energy and GDP for 30 OECD and 78 non-OECD countries and find out that causality from aggregate energy consumption to GDP and GDP to energy consumption is more prevalent in the advanced OECD countries compared to the developing non-OECD countries. Those findings indicate that a policy to reduce energy consumption aimed at reducing emissions is likely to have greater impact on the GDP of the developed rather than the developing world.

This paper argues that apart from the economy under investigation, the methodology has also crucial effects on the degree and direction of the causality between energy consumption and growth. In emerging financial markets, the test results of financial/economics time series are mostly methodology dependent. In emerging markets, there exist non-linearities, regime switching and chaotic patterns in the financial variables. From that point of motivation, this article use a recent methodology transformed from Physics to the financial economics, namely wavelets in order to reach stronger evidence among electricity consumption and growth in Turkey as an emerging market.

By employing the same data used by [Soytas and Sari \(2006\)](#) from Turkish manufacturing industry, this research seeks further and stronger evidence with Turkish economy. In that respect, the sample period and variables for the data set is fixed to see the methodological effects in the relationship. The methodological motivation behind the paper is that financial and economic time series in emerging markets should be analysed with advanced methodologies which do not relying on the normal distribution assumption restricting time series analysis in accurate level. Advanced models like neural networks, wavelets or wavelets networks are proper methodological solutions for analysing financial and economic time series without assuming normality in data distribution.

The article is constructed as follows. In the next part, a short literature review s presented without giving detail in theoretical background, which is examined in many theoretical or empirical papers on the issue. In the third part, data and variables are introduced with their descriptive statistics and unit root tests. In the same part, wavelet methodology used mostly in Physics and natural sciences is expressed from the point of view of financial economics. The emphasis is given on its applicability in terms of finance and economic theory. Fourth part includes presentation and discussion of the empirical findings. The results are compared to those of [Soytas and Sari\(2006\)](#) to see the methodological effects, as well. The paper ends with suggestions for future research focusing on the financial or macroeconomic factors in chaotic and complex financial markets.

2. Literature Review

The causality relationship between energy consumption, growth, employment level or income is a well-studied research topic in financial economics. [Ghali and El-Sakka \(2004\)](#) argue a neoclassical production function with labour, capital stock and energy consumption. The function states that output, capital, labour, and electricity consumption move together in the

long-run. Therefore, as [Soytas and Sari \(2006\)](#) stress, there might exist a long-run equilibrium relationship between the variables indicating Granger causality. By accepting both the arguments of [Ghali and El-Sakka \(2004\)](#) and [Soytas and Sari \(2006\)](#), we state that long-term memory of the financial variables in the chaotic economies might be captured by the wavelets methods which filter and clean the data from the short-term volatilities and chaotic patterns and display the long-term relationships among the variables.

The past researches use different econometric methodologies in testing the relationship among growth, income and energy consumption. Vector correction based causality test are used to detect the relationship. [Cheng \(1999\)](#), [Eden and Jang \(2002\)](#), [Asafu \(2000\)](#) find remarkable causalities among the mentioned variables in different economies by using cointegration tests detecting the long-term effects. The research of [Masih and Masih \(1996\)](#) should be emphasized in terms of both methodological and empirical reasons. They use a cointegration analysis and vector autoregressive model are used to examine the causal relationships among energy consumption, employment, and output for Taiwan over the period January 1982 to November 1997. They find out that Granger causality tests based on vector error-correction models suggest bi-directional Grange causality for employment-output and employment-energy consumption, but only unidirectional causality running from energy consumption to output.

The research on the causality between the growth and energy consumption is in general in effort to find a distinguished difference between developed and developing countries. In theory, the degree of causality is waited to be stronger in developed economies. Reducing electricity consumption might have greater impact on growth in developed markets due to higher industrialization in those economies. The researches conducted by [Dunkerly \(1982\)](#), [Jumbe \(2004\)](#), [Yong and Lee \(1998\)](#), with data from emerging markets and those of [Samouilidis and Mitropoulos \(1992\)](#), [Erol and Yu \(1987\)](#) with data from advanced economies are also underlined in terms their distinctive evidence on the issue between the types of economies.

Research on the electricity consumption and growth using data from Turkish economy is restricted. [Soytas and Sari \(2003\)](#) test the time series properties of energy consumption and GDP and reexamines the causality relationship between the two series in the top 10 emerging markets-excluding China due to lack of data-and G-7 countries. They find out bi-directional causality in Argentina, causality running from GDP to energy consumption in Italy and Korea, and from energy consumption to GDP in Turkey, France, Germany and Japan. Hence, energy conservation may harm economic growth in the last four countries. [Sari and Soytaş \(2004\)](#) find that over a 3-year horizon the total energy consumption explains 21% of forecast error variance of GDP and it appears to be almost as important as employment in Turkey. Therefore, policy-makers may be interested in identifying the energy dependencies of economic growth in allocating the energy investment budget.

According to [Ogulata \(2002\)](#) the industrial sector energy consumption accounts for the highest share in the primary energy demand in Turkey. He also points out that electricity consumption is a major component in the primary energy demand of the Turkish industrial sector. To see the importance of gas energy for Turkey, the discussion article written by [Kilic \(2005\)](#) can be examined. According to [Kilic \(2005\)](#) energy demand of Turkey is growing by 8% annually, one of the highest rates in the world. In addition, natural gas consumption is the fastest growing primary energy source in Turkey. Gas sales started at 0.5 bcm (billion cubic meters), in 1987 and reached approximately 22 bcm in 2003. Turkey is an important candidate to be the "energy corridor" in the transmission of the abundant oil and natural gas

resources of the Middle East and Middle Asia countries to the Western market. [Karbuz, Birol, Fatih and Gurer \(1997\)](#) also emphasize the increasing electricity demand in Turkey.

The paper employs wavelets in detecting long-term relationships among the variables. Wavelet transform is a multi-scale analysis method to detect the signal in different scales. In that way, insignificant high-frequency changes of the signal are filtered out and the empirical findings concentrate on long-term behaviours. Recent empirical findings in finance show that wavelets are good at capturing long-memory in time series. 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. 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\(2004\)](#).

To the extent of our knowledge, this paper is the first to examine the relationship between energy input and production by using wavelets. By wavelet correlation analysis and multi-scale causality test, the paper aims at scaling the causality and finds the long-term dependence in the time series. In the next part data and methodology used in this paper is introduced in detail.

3. Methodology and Data

3.a. 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).

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

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

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

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

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

$\psi(x)$ 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).

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

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 (Gençay at all, 2002 and Percival and Walden, 2000) and yields J vectors of wavelet filter coefficients $\tilde{W}_{j,t}$, for $j=1, \dots, J$ and $t=1, \dots, N/2^j$, and one vector of wavelet filter coefficients $\tilde{V}_{j,t}$ through (Gallegati, 2005) Eq. (4) and (5)

$$\tilde{W}_{j,t} = \sum_{t=L_j}^N \tilde{w}_{j,t}^X f(t-1) \quad (4)$$

$$\tilde{V}_{j,t} = \sum_{t=L_j}^N \tilde{v}_{j,t}^Y f(t-1) \quad (5)$$

Where $w_{j,t}^X$ and $v_{j,t}^Y$ are the scaled wavelet and scaling filter coefficients.

Wavelet covariance between two series X_t and Y_t is defined as in Eq. 6 (In and Kim, 2006).

$$Cov(\lambda_j) = \frac{1}{N} \sum_{t=L_j}^N \tilde{W}_{j,t}^X \tilde{V}_{j,t}^Y \quad (6)$$

Where, λ_j represents scale. MODWT estimator of the wavelet correlation can be expressed as in Eq. 7 (In and Kim, 2006).

$$\tilde{\rho}(\lambda_j) = \frac{Cov(\lambda_j)}{\tilde{v}_X(\lambda_j) \tilde{v}_Y(\lambda_j)} \quad (7)$$

Where $\tilde{v}_X(\lambda_j)$ and $\tilde{v}_Y(\lambda_j)$ are wavelet variances estimated by the MODWT coefficients for scale λ_j described in Eq. 8 and Eq. 9.

$$\tilde{v}_X(\lambda_j) = \frac{1}{N} \sum_{t=L_j}^N [\tilde{W}_{j,t}^X]^2 \quad (8)$$

$$\tilde{v}_Y(\lambda_j) = \frac{1}{N} \sum_{t=L_j}^N [\tilde{V}_{j,t}^Y]^2 \quad (9)$$

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 (10).

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^m \Delta Y_{t-i} + \varepsilon_t \quad (10)$$

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(11).

$$H_1^*(r) : \Pi y_{t-1} + Bx_t = \alpha(\beta' y_{t-1}) + \rho_0 \quad (11)$$

Cointegration in stationary time series by Johansen procedure is set with trace and maximum eigenvalue statistics (12, 13)

$$\lambda_{\text{trac}(r)} = -T \sum_{i=r+1}^k \ln(1 - \bar{\lambda}_i), r = 0, 1, 2, 3, \dots, n-1 \quad (12)$$

$$\lambda_{\text{max}(r, r+1)} = -T \ln(1 - \bar{\lambda}_{r+1}) \quad (13)$$

If cointegration exists between variables it states that at least one directional causality exist (Granger, 1969). If cointegration doesn't exists between variables standart cointegration test(vector autoregression) is applied (Granger, 1969) and if cointegration exists between variables vector error correction model (Engle and Granger, 1987) should be applied (Granger, 1988). VECM based causality test is applied with eq. 14 and 15.

$$\Delta GDP_t = \alpha_0 + \sum_{i=1}^n \alpha_{1i} \Delta GDP_{t-i} + \sum_{i=1}^n \alpha_{2i} \Delta Energy_{t-i} + \sum_{i=1}^n \alpha_3 EC_{t-n} + \varepsilon_i \quad (14)$$

$$\Delta Energy_t = \alpha_0 + \sum_{j=1}^n \alpha_{1j} \Delta Energy_{t-j} + \sum_{j=1}^n \alpha_{2j} \Delta GDP_{t-j} + \sum_{j=1}^n \alpha_3 EC_{t-n} + \varepsilon_j \quad (15)$$

Where EC_{t-n} parameter is error correction term and $\alpha_{1i}, \alpha_{2i}, \alpha_{1j}$ and α_{2j} parameters are short-run parameters. If there is long-run relationship as the variables are cointegrated, vector error correction model will be employed. From eq. 10 and 11, the null hypothesis that GPD/EC does not Granger cause EC/GDP in the short-run would be rejected if the lagged coefficients of α_{1s} were jointly significant based on a Standard Wald test(Shammugan *et all.*, 2003). Optimal lag lenght of the cointegration and error correction model is determined by Schwartz Information Criteria.

3.b. Data

This paper examines the causality between electricity use and output in the Turkish manufacturing sector in a multivariate setting. In that perspective, the research uses the theoretical relationship among changes in energy consumption and growth.

Electricity consumption is the input indicator and value added is the measure of output. The value added may be seen as the represent the contribution of the manufacturing industry to the Turkish GNP. Electricity consumption might be seen as a proxy for energy consumption in the manufacturing sector. This research use the same data within the same period employed by the research conducted by [Soytas and Sari \(2006\)](#). Since the difference is on the methodology used, the sample period is fixed. However, fixed investment and labor in manufacturing industry used as one of the input variable in the research of [Soytas and Sari \(2006\)](#) is excluded from our research. Since the capital stock data is not readily available and difficult if not impossible to obtain, they assume a constant depreciation rate; and use variance in growth rate of fixed investment as the reliable proxy for variance in the growth rate of capital stock. We are not agree on the proxy role of the variable because of the assumption of constant depreciation rate. The paper uses, as parallel to the research of [Soytas and Sari\(2006\)](#), annual data for the period 1968 to 2002. The data is sourced from [Soytas and Sari\(2006\)](#)[‡] and log-returns of the variables are calculated. The explanations of the variables used in the analyses are as follows:

LEC = natural log of total electricity consumption in industry in 106 kW h.

LVA = natural log of value added-GNP manufacturing in billion TL (1998 prices).

4. Empirical Results

In order to apply wavelet analysis first unit root and unit root level should be tested in time series. All series should be stationary at the same level. Augmented Dickey Fuller(ADF) test ([Dickey ve Fuller, 1981](#)) is widely used and can be determined as in the Eq. 16.

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^m \Delta Y_{t-i} + \varepsilon_t \quad (16)$$

Table 1 shows ADF tests of level and log-differenced series. Lag lengths are determined with Schwartz Information Criteria in ADF test. Level series are not stationary where log-differenced series are stationary at the 1% significance level. So original and multi-scale series are tested as log-differenced level.

We test if all the scaled series are stationary with ADF Test. The results of the unit root tests in [Table 2](#) shows that all of the time-scaled variables are stationary on level. In that respect, cointegration test and wavelet analysis can be employed.

Johansen cointegration test ([Johansen,1988](#) and [Johansen and Joselius,1990](#)) results in [Table 3](#) shows that original data(GNP and electricity consumption represented as LDVA and LDEC) is cointegrated with three lags where time-scaled data are cointegrated with one lag. This result shows that at least one directional causality exists between GNP and electricity consumption and time-scaled production and electricity consumption at all time-scaled level for Turkish economy.

[‡] We present our thanks to Soytaş and Sari for their help in proving data and their recent research paper's draft ([Soytas and Sari, 2006](#))

Vector error based causality test results for original and time-scaled variables are shown in [Table 4](#). These results indicate that VA and EC is caused each other in the short run as wald test χ^2 value and error correction parameters of the original data are statistically significant. Wald test χ^2 values and error correction parameters, EC_{t-1} , statistically significant until 3rd time-scale for $EC \rightarrow VA$ model and thus indicate that Error EC affected VA until 3-4 years. Error correction parameters, EC_{t-1} , statistically significant for 1st, 2nd and 4th time-scales for $VA \rightarrow EC$ and thus indicate that VA affects EC in the short run and in the long run as 1-2 and 5-8 years. Thus shows that in the short run there is feedback relationship between GNP and energy consumption, while in the long run(for 5-8 years) GNP leads to energy consumption.

MODWT wavelet coefficients of VA and EC and Scatter plot of time-scaled VA and EC are shown in [Figure 1](#) and [Figure 2](#). The graphs show that VAs and ECs coefficients move together at 3rd time-scale(DJT3-5-8 years). As shown in [Figure 3](#) Wavelet correlation between VA and EC is also maximum at 3rd time-scale as %90,08. Since the magnitude of the wavelet correlation changes based on time-scales indicating that VA and EC are fundamentally different[§](In and Kim, 2006).

5. Concluding Remarks

Tests results for causality between energy consumption and economic growth do not have a consensus in the financial economics literature. Empirical evidence varies on the economies examined and methodology employed. This paper proposes a wavelet analysis as a semi-parametric model for detecting multi-scale causality between electricity consumption and growth in emerging economies. To the best of our knowledge this paper is the first one that examines GNP and energy consumption integration with wavelet analysis.

Using wavelet analysis we find that in the short run there is feedback relationship between GNP and energy consumption, while in the long run GNP leads to energy consumption. Wavelet correlation between GNP and energy consumption is maximum at 3rd time-scale(5-8 years) and this shows that GNP effects electricity consumption maximally around 5-8 years later in the long-run. We also find that the magnitude of the wavelet correlation changes based on time-scales for GNP and energy consumption and thus indicate that VA and EC are fundamentally different in the long run.

[§] [In and Kim\(2006\)](#) also estimated wavelet correlation for the stock and the futures markets and found that both are not fundamentally different as magnitude of the correlation increases as the time scale increases.

Table 1
Unit root test statistics of the time series

Variables	ADF Test	
	nl ^a	t-statistics
VA	2	-0.519534 {<0.9}
EC	2	-0.327322 {<0.95}
DLVA	0	-5.91364 {<0.01}*
DLEC	0	-5.01811 {<0.01}*

Notes. Lag length is determined as max.12 in accordance to Schwartz Information Criteria. The values on paranthesis are the reject statistics for the unit roots. ^a Lag length. 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 H₀ is given in braces. * Indicate the rejection of the unit root null at the 1% significance level.

Table 2
Unit root test statistics of the scaled time series

Variables	ADF Test	
	nl	t-stat.
DLVA_DJT1	1	-11.2536 {<0.01}*
DLEC_DJT1	3	-6.85783 {<0.01}*
DLVA_DJT2	3	-5.99742 {<0.01}*
DLVA_DJT2	3	-6.53789 {<0.01}*
DLEC_DJT3	1	-5.36138 {<0.01}*
DLVA_DJT3	1	-4.2144 {<0.01}*
DLEC_DJT4	1	-5.24854 {<0.01}*
DLEC_DJT4	1	-4.93221 {<0.01}*
DLVA_DJT5	2	-2.79693 {<0.05}
DLEC_DJT5	1	-6.14593 {<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. Probability of the statistic exceeding the computed value under H₀ is given in braces. * Indicate the rejection of the unit root null at the 1% significance level.

Table 3
Cointegration test results

DLVA & DLEC	nl	Unrestricted Cointegration Rank Test		
			Trace Stat.	Max-Eigen Stat.
DLVA & DLEC	3	r=0	23.4604 {<0.02}*	16.1867 {<0.05}*
		r≤1	7.27366 {<0.2}	7.27366 {<0.2}
DJT1(2 years)	1	r=0	91.9121 {<0.01}	59.8455 {<0.01}
		r≤1	32.0666 {<0.01}	32.0666 {<0.01}
DJT2(3-4 years)	1	r=0	107.556 {<0.01}	71.5965 {<0.01}
		r≤1	35.9598 {<0.01}	35.9598 {<0.01}
DJT3(5-8 years)	1	r=0	44.0876 {<0.01}	27.4587 {<0.01}
		r≤1	16.6289 {<0.01}	16.6289 {<0.01}
DJT4(9-16 years)	1	r=0	21.2946 {<0.01}	24.8791 {<0.01}
		r≤1	3.58448 {<0.5}	3.58448 {<0.5}
DJT5(17-32 years)	1	r=0	80.9206 {<0.01}	126.645 {<0.01}
		r≤1	45.7239 {<0.01}	45.7239 {<0.01}

* indicates significance of cointegration. nl represents lag length that is selected with Schwarz Selection Criteria. Probability of the statistic exceeding the computed value under H₀ is given in braces.

Table 4

Vector error correction based causality/multi-scale causality test

LDVA	nl^a	Wald test	EC_{t-1}	Long-run Causality
LDEC → LDVA	1	14.3652 [0.0002] **	0.747262 [0.001]	EC ⇒ VA
DJT1(2 years)	1	22.7675 [0.0000] **	0.759310 [0.000]	EC ⇒ VA
DJT2(3-4 years)	1	5.59757 [0.0180] *	0.727128 [0.024]	EC ⇒ VA
DJT3(5-8 years)	1	0.0144491 [0.9043]	0.126529 [0.905]	EC ≠ > VA
DJT4(9-16 years)	1	0.795032 [0.3726]	0.237524 [0.379]	EC ≠ > VA
DJT5(17-32 years)	1	0.00246801 [0.9604]	-4.58328 [0.961]	EC ≠ > VA
LDEC	nl^a	Wald test	EC_{t-1}	Long-run Causality
LDVA → LDEC	1	11.0907 [0.0009] **	0.644120 [0.002]	VA ⇒ EC
DJT1(2 years)	1	19.2066 [0.0000] **	0.634292 [0.000]	VA ⇒ EC
DJT2(3-4 years)	1	2.67607 [0.1019]	0.392138 [0.112]	VA ≠ > EC
DJT3(5-8 years)	1	11.1192 [0.0009] **	1.07144 [0.002]	VA ⇒ EC
DJT4(9-16 years)	1	6.00227 [0.0143] *	0.45167 0.2012	VA ≠ > EC
DJT5(17-32 years)	1	22.4727 [0.0000] **	0.42578 [0.879]	VA ≠ > EC

* %1, ** %5 represent acceptance of causality respectively. [] represent t-values. ^a Lag lengths. nl represents lag length that is selected with Schwarz Selection Criteria.

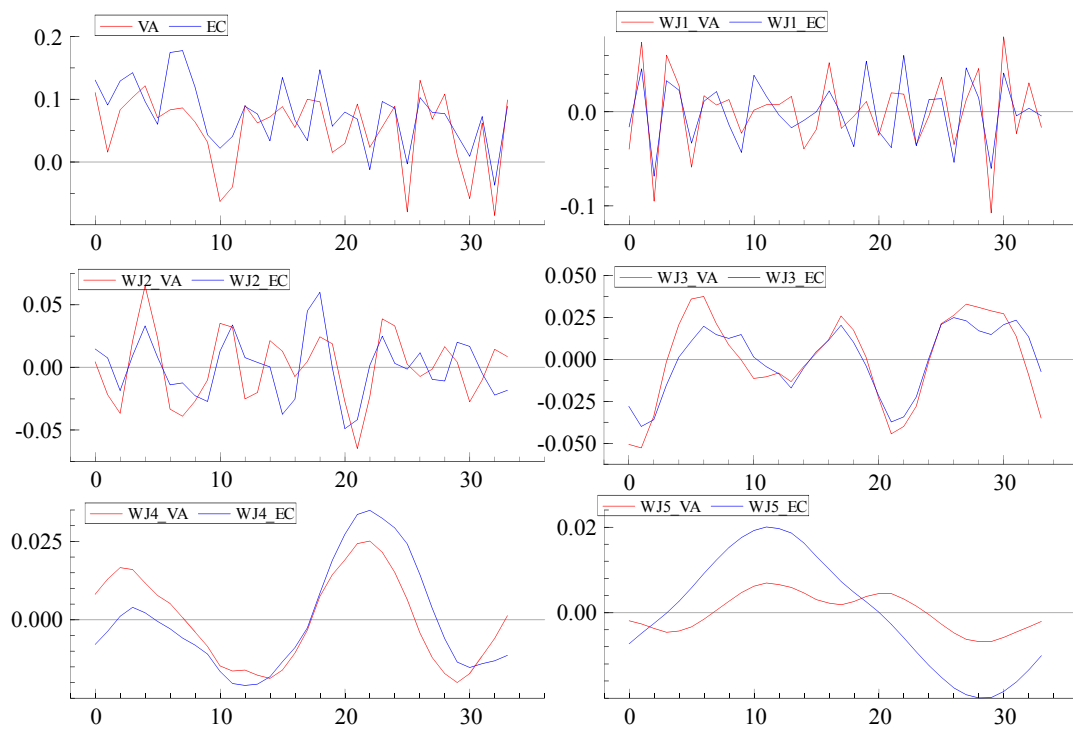


Fig. 1 MODWT wavelet coefficients of VA and EC

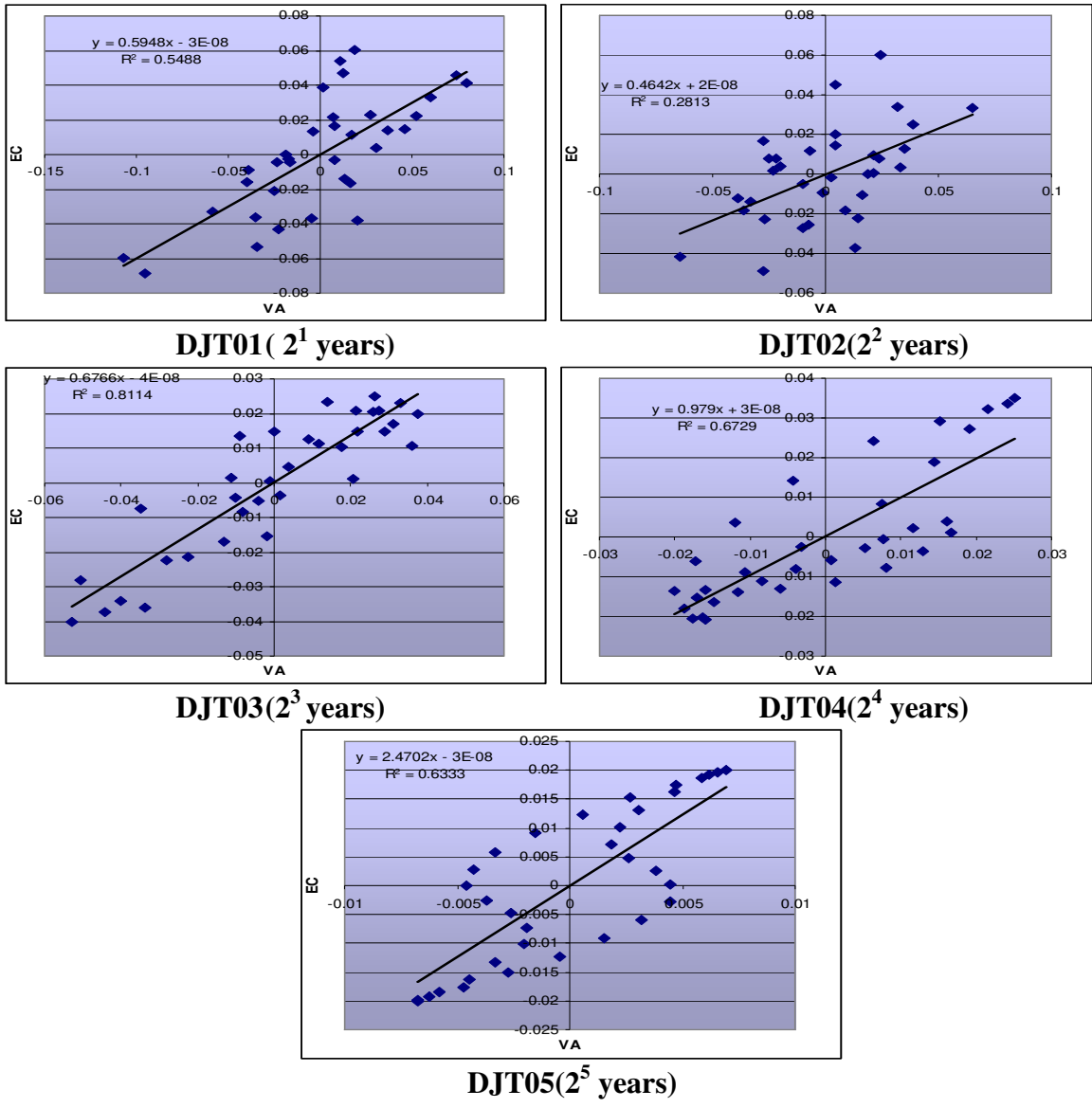


Fig. 2 Scatter plot of time-scaled VA and EC*

* DJT01 2 years, DJT02 3-4 years, DJT03 5-8 years, DJT04 9-16 years, DJT05 17-32 years

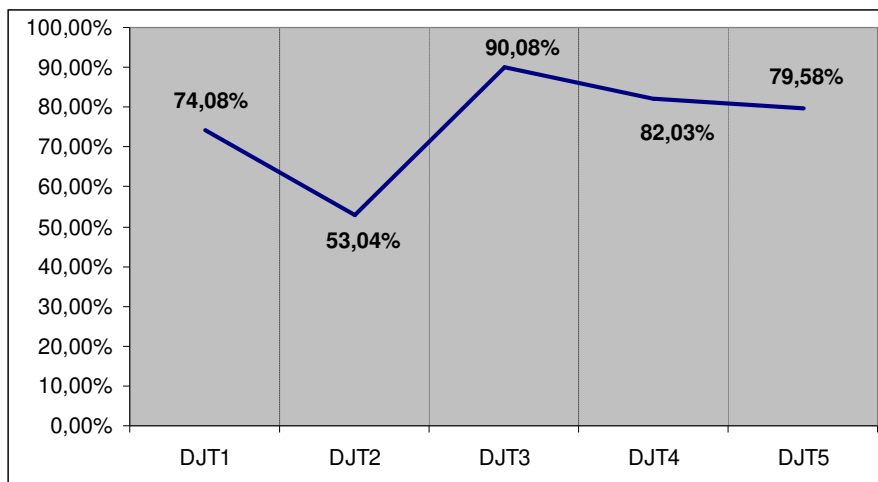


Fig. 3 Estimated wavelet correlations between VA and EC

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