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The Relationship between Energy Consumption, Income, Foreign Direct Investment, and CO_2 Emissions: The Case of Turkey*

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Abstract
The purpose of this study is to explore the relationship between the energy consumption, income, foreign direct investment (FDI) inflows, and CO_2 emission in Turkey, for the period 1974-2011. For this purpose, Maki (2012) cointegration method and Granger causality analysis have been used. The cointegration method results indicate that there is a long term relationship among the variables. Results also show that, both in the short and long run, Environmental Kuznets Curve (EKC) hypothesis is supported in Turkey. In addition, the pollution halo hypothesis, meaning that FDI has positive effects on environment, is valid for Turkey in the short and long run since there is bilateral causality relationship between CO_2 emission and FDI inflows, and also negative coefficients of FDI. According to Granger causality test, the growth hypothesis, which means there is a unilateral causality relation from energy consumption to economic growth, is also valid for Turkey.
Keywords: Energy Consumption, Economic Growth, Foreign Direct Investment, Carbon Emissions, Maki Cointegration Method
JEL Classifications: Q43, O13, N70

Enerji Tüketimi, Gelir, Doğrudan Yabancı Yatırım ve CO_2 Emisyonu Arasındaki İlişki: Türkiye Örneği†

Öz
Bu çalışmanın amacı Türkiye'de enerji tüketimi, gelir, doğrudan yabancı yatırım (DYY) girişi ve CO_2 emisyonu arasındaki ilişkiyi 1974-2011 dönemi için araştırmaktır. Bu amaç doğrultusunda, Maki (2012) kointegrasyon yöntemi ve Granger nedensellik analizi kullanılmıştır. Kointegrasyon metodu sonuçları değişkenler arasında uzun dönem ilişkinin varlığını göstermiştir. Sonuçlar aynı zamanda Çevresel Kuznets Eğrisi hipotezinin Türkiye için geçerli olduğunu göstermiştir. Buna ek olarak, karbon emisyonu ve DYY girişi arasında çift taraflı nedensellik ilişkisi bulunduğundan ve DYY'nin negatif katsayılarından dolayı, DYY'nin çevre üzerinde pozitif etkiye sahip olduğunu savunan kirlilik hale hipotezi Türkiye için hem kısa hem de uzun dönemde geçerlidir. Granger nedensellik testine göre, enerji tüketiminden ekonomik büyümeye doğru tek taraflı nedensellik ilişkisini savunan büyüme hipotezi de Türkiye için geçerlidir.
Anahtar Kelimeler: Enerji Tüketimi, İktisadi Büyüme, Doğrudan Yabancı Yatırımlar, Karbon Emisyonu, Maki Kointegrasyon Yöntemi
JEL Sınıflandırma Kodları: Q43, O13, N7

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† Extended abstract is presented at the end of the article.

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1. Introduction

Global warming, accepted as the most important environmental problem for living beings, results from using of resources with fossil fuel to meet the energy need. As burning fuels like natural gas, petrol, coal increase, the concentration of greenhouse gases in the atmosphere rises and leads to climate change and warming of the earth and sea (IPCC, 2008). Water vapor (H_2O), Nitrous oxide (N_2O), Ozone (O_3), Carbon dioxide (CO_2), and Methane (CH_4) are the main greenhouse gases (Dam, 2014). Among these gases, the most important one released by human activities is carbon dioxide as a dominant contributor to global warming (Acaravcı & Öztürk, 2010). This environmental degradation caused by greenhouse gases has been the main issue for the scientists over the past 20 years.

Rising sea level, changing rain and snow pattern, melting glaciers, higher temperatures, and epidemics are major effects of global warming. The most important legal regulations to mitigate this environmental issue are United Nations Framework Convention on Climate Change (UNFCCC), enacted in 1994, and Kyoto Protocol (KP), entered into force in 2005 (IPPC, 2008). In this context, nations have to fulfill their obligation to cope with climate change and to reduce the effect of greenhouse gases. According to Çelikkol & Özkan (2011), greenhouse gas emissions of Turkey had increased from 180 million tons to 380 million tons, more than 100 %, from 1990 to 2007. Although Turkey signed the Kyoto Protocol in 2009, she has no obligation because of her status on the protocol (Binboğa, 2014). Given the amount of carbon emissions in Turkey and its trend in recent years, investigation of the factors affecting carbon emissions, and the finding out the ways to decrease it effectively are crucial for the environment and the future.

This study has attempted to explore the dynamic relationship between energy consumption, foreign direct investment, income, and CO_2 emission in Turkey for the period 1974-2011. Unlike other related studies, multiple structural breaks in the series have been considered; and in this context, it has been used Carrion-i-Silvestre unit root test, Maki (2012) cointegration method, and Granger causality test. The rest of the paper is organized as follows. In Section 2, brief reviews of theoretical and empirical literature are presented. The data and estimation methodology are discussed in Section 3. Finally, the conclusion and policy recommendations are made in Section 4.

2. Literature Review

2.1. Theoretical Literature

The literature on the relation between carbon emission, growth/income, energy use, and foreign investment has theoretically three strands. The first one focuses on the carbon dioxide emissions, energy consumption, and economic growth nexus. This strand mostly concentrates on the Environmental Kuznets Curve hypothesis. Kuznets (1955) developed the hypothesis that there is an inverted U-shaped relationship between income inequality and economic growth. Later (in 1990s), this thesis has been reformulated as the relationship between economic growth/income and environmental quality, called Environmental Kuznets Curve (EKC). Accordingly, as GDP per capita increases, in early phase of development, CO_2 emissions per capita rises. After the turning point, a certain level of income, CO_2 emissions per capita gradually decreases because after this point the sensitivity of nations and individuals to environmental problems is going to grow, so degradation is going to decrease with measures taken. Therefore, there is an inverted U-shaped relationship between income and environmental degradation, which it can be seen at the Figure 1.

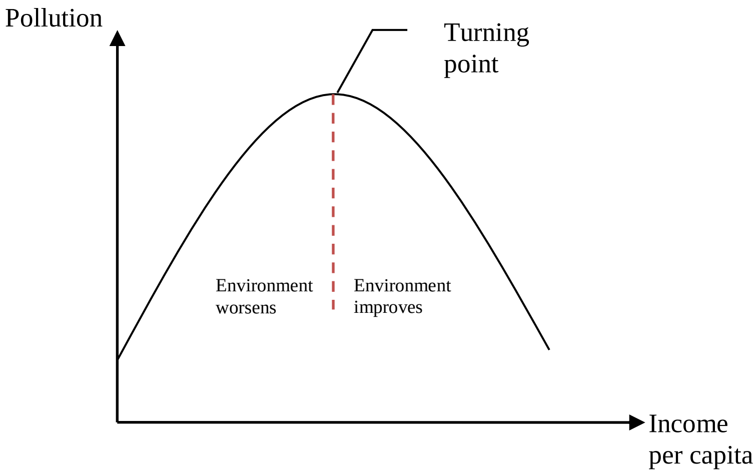


Figure 1: Environmental Kuznets Curve

EKC hypothesis has become well-known by means of the article written by Grossman & Krueger (1991) in which they try to find the relationship between air quality and economic growth. While two variables, namely CO_2 emissions and GDP per capita have been used in early empirical studies about EKC, the later works have developed it by adding the energy consumption to the model. Beside these variables, recently, some researchers put various factors like financial development, trade openness, and FDI into the analysis as control variables.

The second strand is about the correlation between energy consumption and economic growth. In the literature, there are four hypotheses on this relationship:

1. Growth Hypothesis: According to this hypothesis, there is a unilateral causality relation from energy consumption to income growth. In other words, energy

consumption is the Granger cause of growth. That is to say, an increase in energy use stimulates income growth.

2. Conservation hypothesis: This hypothesis indicates the existence of a unilateral causality relation from economic growth to energy consumption. Accordingly, the economies in which this hypothesis is valid are dependent on energy consumption.

3. Feedback hypothesis: The hypothesis claims that there is a bilateral causality relation between energy consumption and income growth. So, the changes in both variables affect each other.

4. Neutrality hypothesis: According to this hypothesis, there is not any causal relationship between energy consumption and growth. So energy policies of countries do not have any impact on their economic growth (Apergis & Payne, 2009:642).

Third strand is on the nexus of the foreign trade and pollution. The effects of foreign direct investment on ecosystem have recently begun to take place in the literature. There are two important hypotheses on this issue, namely Pollution Halo Hypothesis and Pollution Haven Hypothesis. Eskeland & Harrison (1997:1) states that according to pollution haven hypothesis (PHH), "environmental regulations will move polluting activities to poorer countries". As environmental consciousness globally raises, countries settle down to improve new environmental regulations and policies with severe sanctions. The fact that developed countries can manage to implement these leads to that dirty investment run away from developed countries. On the other hand, developing countries generally tend to slur over environment problems by weak environmental regulation. In this way, they get free from the monitoring and controlling expense of these regulations, and also they attract the profit-driven companies willing to get rid of costly regulatory observance in their countries (Hoffmann et. al., 2005). Pollution halo effect, on the other hand, indicates that foreign direct investment leads to improvement in environmental quality in developing countries since foreign firms which use better management and have advanced technologies bring it to host countries (Zarsky, 1999; Khachoo & Sofi, 2014). Therewith multi-national corporations involved in FDI have a tendency to transfer its clean technology to the ones in the host country. By learning and copying effects, the host country achieves to reduce the level of carbon emission (Zarsky, 1999; Zeren 2015).

2.2. Empirical Literature

The first study that examines the relationship between energy consumption, income, foreign trade, and carbon emissions in Turkey has been written in 2009 by Halıcıoğlu. In his study Halıcıoğlu (2009) has found the bidirectional relations between carbon emissions and energy use, and between carbon emissions and income over the period 1960-2005. Akın (2014) has also investigated the relation of these four variables using Pedroni cointegration and Granger causality method for 85 countries, including Turkey. The results that he obtained show that there are four unilateral causality relationships from emission to trade openness, and from income to carbon emission, energy consumption, and trade. Yıldırım (2014), on the other hand, could not find any causal relation between FDI, energy use, and carbon emissions for Turkey.

As mentioned in theoretical literature part, empirical studies on the relationship between CO_2, energy consumption, and GDP have recently included foreign direct investment, trade openness or trade volume to the model as a variable. Pao & Tsai (2011), Chandran & Tang (2013), Chen & Huang (2013), Lee (2013), Khachoo & Sofi (2014), Kivyiro & Arminen (2014), Linh & Lin (2014), Maji & Habibullaha (2015), and Tang & Tan (2015) have examined the relationship between carbon emission, growth, energy consumption, and foreign direct investment for different countries by different cointegration methods and Granger causality analysis. All of them have found long run relationship among variables. According to Pao & Tsai (2011), EKC hypothesis and growth hypothesis are supported for BRIC countries. Khachoo & Sofi (2014) have deduced that Feedback hypothesis is valid for BRICSAM countries in both short and long run. Kivyiro & Arminen (2014) have found that EKC hypothesis is supported in DRC, Kenya, and Zimbabwe over the period 1971-2009. According to Linh & Lin (2014), Feedback hypothesis is valid for Vietnam in the long run, Neutrality hypothesis is valid in the short run while Tang & Tan (2015) have found that Conservation hypothesis is supported for Vietnam in the short run, and Neutrality hypothesis is supported in the long run. Although Johansen cointegration and Granger causality method are used in both studies, results are not similar since time periods of studies are different. Maji & Habibullaha (2015) have investigated relationship among variables for Nigeria, and reach the conclusion that Pollution Halo effect is valid both in the short run and long run.

Chebbi et al. (2010), Shahbaz et al. (2011), Jayanthakumaran et al. (2012), Kohler (2013), Bouttabba (2014), and Lau et al. (2014) have included trade openness or volume instead of FDI in additional to other three variables. According to Shahbaz et al.(2011), Jayanthakumaran et al. (2012), and Lau et al. (2014), Environmental Kuznets Curve hypothesis is supported for Pakistan, China, India, and Malaysia. Kohler (2013) has found that negative relationship between energy consumption and carbon emission for South Africa only in the long run. Bouttabba (2014), on the other hand, concluded that there is a positive relationship between energy consumption and carbon emission for India by similar analysis method, namely ARDL cointegration and Granger causality method.

Al-Mulali (2012) has used the model including carbon emission, energy consumption, GDP, and financial development for 12 Middle Eastern countries by Pedroni cointegration, and supported the validity of Feedback hypothesis in short run. Sbia et al. (2014) have used both trade openness and foreign direct investment variables, in additional to energy consumption, income, and carbon emission, and reach the same result for United Arab Emirates.

To sum up, the relationship between carbon dioxide emissions, income, energy consumption, and FDI remains ambiguous. Results could be change depending on the method used, the time period, the sample country/countries. This study, differently from other studies, considers the multiple structural breaks in series, which will be explained in detail in methodology part, and in this sense it will contribute to the relevant literature.

3. Data and Methodology

3.1. Data Description

The data employed in the analysis part is collected from World Bank Development Indicator (WBDI) for the period from 1974 to 2011. GDP per capita (constant USD) is used as a proxy for economic growth, energy use (kg of oil equivalent per capita) represents energy consumption, foreign direct investment, net inflows (% of GDP) is an indicator for FDI inflows, and CO_2 emissions (metric tons per capita) is employed as proxy for CO_2 emissions.

3.2. Methodology

Following the theoretical literature in this study, three strands are used in one equation including CO_2 emissions, energy consumption, economic growth, and foreign direct investment in linear quadratic form:

$$lnCO_t = \beta_0 + \beta_1 lnY_t + \beta_2 lnY_t^2 + \beta_3 lnEC_t + \beta_4 lnFDI_t + e_t \qquad (1)$$

where CO represents CO_2 emissions, Y represents GDP per capita, Y^2 represents square of GDP per capita, EC represents energy consumption, FDI represents foreign direct investment (% of GDP), and e denotes stochastic error term, normally distributed with zero mean and constant variance. The stochastic error term is assumed to capture all other variables that may influence CO_2 emissions which are not in the model. β_1, β_2, β_3, and β_4 are the slopes of the explanatory variables while β_0 is the drift parameter.

In this context, stationarity of variables has been examined by Carrion-i-Silvestre et al. (2009) unit root test with multiple structural breaks as a first step. Secondly, to test the existence cointegration relation among series, Maki (2012) cointegration test has been used. At the third step, the long run relationship of variables has been estimated by dynamic ordinary least square (DOLS) method. Then, the short run analysis has been examined by error correction model. Finally, the directions of relations have been determined by Granger causality method both in the short and long run.

3.2.1. Unit Root Test under Multiple Structural Breaks

In time series analyses, if there are structural breaks at the data because of wars, policy changes, economic crisis, and natural disasters etc. then the standard unit root tests may give incorrect and spurious results. Therefore, in such cases, it has to be used the unit root tests allowing structural breaks. Perron (1989), Zivot-Andrews (1992), Perron (1997), Rodriguez (2007), and Carrion-i-Silvestre et al. (2009) are some of the most known unit root tests with structural breaks. Among these tests, Carrion-i-Silvestre et al. (2009) (CS) test is the most developed one since the test can consider up to 5 structural breaks, and the test accepts break points as endogenous. CS test finds break points by using Bai & Perron (2003) algorithm and quasi GLS method by minimizing residual sum of squares. As an advantage of CS test, it can be used for small samples (Carrion-i-Silvestre et al., 2009).

Data generating process of CS test is as the following:

$$y_t = d_t + u_t \tag{2}$$

$$u_t = \alpha u_{t-1} + v_t \qquad t = 1,2,3,\ldots,T \tag{3}$$

Carrion-i-Silvestre et. al. (2009) have developed 5 different test statistics which are:

$$P_T(\lambda^0) = \frac{[S(\bar{\alpha},\lambda^0) - \bar{\alpha}S(1,\lambda^0)]}{S^2(\lambda^0)} \tag{4}$$

$$MP_T(\lambda^0) = \frac{[C^{-2}T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2 + (1-\bar{c})T^{-1}\tilde{y}_T^2]}{s(\lambda^0)^2} \tag{5}$$

$$MZ_\alpha(\lambda^0) = (T^{-1}\tilde{y}_T^2 - s(\lambda^0)^2)(2T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2)^{-1} \tag{6}$$

$$MSB(\lambda^0) = (s(\lambda^0)^{-2}T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2)^{1/2} \tag{7}$$

$$MZ_t(\lambda^0) = (T^{-1}\tilde{y}_T^2 - s(\lambda^0)^2)(4s(\lambda^0)^2T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2)^{1/2} \tag{8}$$

where P_T represents feasible point optimal statistic, MP_T stands for modified feasible point optimal statistic, MZ_α, MSB, and MZ_t are M-class test statistics computed by GLS-detrending methods (Carrion-i-Silvestre et al., 2009).

Hypotheses of the test are as follows:

H_0: there is unit root under structural breaks

H_1: there is not unit root under structural breaks

The asymptotic critical values used to test these hypotheses are generated through bootstrap approach. The rejection of null hypothesis means that there is not unit root under structural breaks in the series.

In this study, Carrion-i-Silvestre et al. (2009) unit root test has been used, and results are summarized in Table 1.

Table 1: Carrion-i-Silvestre et.al. (2009) Unit Root Test with Multiple Structural Break

	P_T	MP_T	MZα	MSB	MZ_t	Break Point Dates
LCO	17.2389 [7.1811]	15.8086 [7.1811]	-16.0086 [-34.5268]	0.1750 [0.1204]	-2.8017 [-4.1484]	1986; 1993; 2003
LEC	15.0445 [7.4941]	15.0777 [7.4941]	-17.5691 [-34.0891]	0.1644 [0.1210]	-2.8890 [-4.1187]	1986; 1998; 2003
LFDI	18.0195 [8.1848]	17.9987 [8.1848]	-16.6964 [-36.0981]	0.1694 [0.1173]	-2.8385 [-4.2315]	1983; 1993; 2000
LY	32.9991 [6.7757]	27.9144 [6.7757]	-7.9031 [-31.8916]	0.2513 [0.1259]	-1.9863 [-3.9909]	1987; 2001; 2007
LY2	19.0268 [7.4368]	18.9491 [7.4368]	-13.4991 [-33.7833]	0.1923 [0.1227]	-2.5965 [-4.1089]	1983; 1997; 2007
ΔLCO	5.6106* [6.7139]	5.3763* [6.7139]	-30.1252* [-23.4940]	0.1277* [0.1449]	-3.8485* [-3.4105]	-
ΔLEC	5.9286* [6.6694]	5.6174* [6.6694]	-28.2135* [-23.2548]	0.1320* [0.1456]	-3.7246* [-3.3945]	-
ΔLFDI	5.4529* [6.9913]	5.5074* [6.9913]	-30.4019* [-23.9820]	0.1279* [0.1427]	-3.8899* [-3.4456]	-
ΔLY	3.6267* [6.9469]	3.6658* [6.9469]	-43.7915* [-23.4414]	0.1068* [0.1443]	-4.6791* [-3.4107]	-
ΔLY2	4.8280* [7.0203]	4.9667* [7.0203]	-34.8358* [-23.9939]	0.1189* [0.1426]	-4.1449* [-3.4469]	-

Note: Break years and critical values in brackets are obtained through using the quasi GLS-based unit root tests of Carrion-i-Silvestre et al. (2009).* denotes the rejection of the null hypothesis at the 5 % significance level. In view of the fact that the time period in analysis is short, it has been let 3 structural breaks.

As can be seen from the Table 1, all series have unit root under multiple structural breaks which means they are non-stationary at their levels; on the other hand, they are stationary at their first differences. According to the results of CS unit root test, LCO, LEC, LFDI, LY, and LY2 are integrated of the same order, I(1). So, it can be investigated the cointegration relationship among series by Maki (2012) cointegration method considering multiple structural breaks.

3.2.2. Cointegration Analysis under Multiple Structural Breaks

It is quite important to consider structural breaks at series for the cointegration method as in the unit root tests. The methodological framework adopted for this study is Maki (2012) approach to cointegration although there are other cointegration methods considering structural breaks like Gregory & Hansen (1996), Johansen et al. (2000), Westerlund & Edgerton (2006), and Hatemi-J (2008). The reason of that Maki (2012) has been chosen for this study is the fact that Maki has some advantages over other methods. First of all, Maki test allows for unspecified number of breaks while other test methods generally consider a single break. For the cases that series have more than two breaks, Maki test performs better, compared to Hatemi-J test and Gregory-Hansen method, which is the extension of Engle-Granger (1987) cointegration method. In addition to this, in contrast to Maki method, Johansen et al. method requires exogenous input of break dates and also does not allow breaks in slopes (You & Sarantis, 2012). As another advantage of Maki test, its methodology is less computationally intensive than other methods. According to working mechanism of the test, each period is treated to be a potential break point, and t statistics are calculated for each period. The points where t statistics have minimum values are determined as the break points (Maki, 2012).

Maki (2012) has generated four regression models to test cointegration considering multiple structural breaks:

Model 0: Level shift model (model with break in intercept, and without trend)

$$y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \beta' x_t + u_t \tag{9}$$

Model 1: Regime shift model (model with break in intercept and coefficients, and without trend)

$$y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \beta' x_t + \sum_{i=1}^{k} \beta_i' x_t D_{i,t} + u_t \tag{10}$$

Model 2: Regime shift model with trend (model with break in intercept and coefficients, and with trend)

$$y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \beta' x_t + \sum_{i=1}^{k} \beta_i' x_t D_{i,t} + u_t \tag{11}$$

Model 3: Model with break in intercept, coefficients, and trend

$$y_t = \mu + \sum_{i=1}^{k} \mu_i D_{i,t} + \gamma t + \sum_{i=1}^{k} \gamma_i t D_{i,t} + \beta' x_t + \sum_{i=1}^{k} \beta_i' x_t D_{i,t} + u_t \tag{12}$$

where μ represents constant term, β is the slope coefficient, γ stands for the trend coefficient, and D_i presents dummy variables, also $D_i=1$ if $t>T_B$, and Di takes value of 0 otherwise. Also, T_B stands for the break date. Model 0 captures the changes in the level (1) only while model 1 accounts for structural breaks both in the level (l) and regressors (x). Model 2 has trend in additional to model 1. Model 3 captures structural breaks of levels, trends, and regressors (Maki, 2012).

Hypotheses of the test are as the following:

H_0: There is not any cointegration relation under structural breaks.

H_1: There is a cointegration relation under i number of structural breaks.

The rejection of the null hypothesis means that series are cointegrated under structural breaks.

Results from Maki (2012) test in this study are summarized in Table 2.

Table 2: Maki (2012) Cointegration Test Results

	Test statistics	**Critical values**			**Break point dates**
		1%	**5%**	**10%**	
Model 0	-6.9388***	-6.501	-5.992	-5.714	1984; 1994; 2001
Model 1	-7.2305***	-6.741	-6.214	-5.974	1984; 1994; 2001
Model 2	-7.5441*	-8.336	-7.803	-7.481	1984; 1992; 2000
Model 3	-7.0573	-8.167	-7.638	-7.381	1984; 1993

Note: Critical values and test statistics are obtained from Maki (2012) test. Obtained results are the results of the test allowing for maximum 5 breaks. *, **, and *** denote1%, 5%, and 10% level of significance respectively.

According to the results, for model 0, model 1, and model 2, there is a cointegration relation among series, which means series move together in the long run. In addition, obtained break point dates are meaningful for Turkey, falling mostly post-crisis periods. So, the next step is to investigate the long run cointegration coefficients of model including dummy variables of break points.

3.2.3. Estimation of Long Term Coefficients

In cases that there is a cointegration relation, long term cointegration coefficients can be estimated by dynamic ordinary least square (DOLS) or fully modified OLS (FMOLS) method. On the other hand, if there is not any cointegration relation then the coefficients are estimated by OLS method.

In case that the variables are non-stationary and cointegrated, estimation of the model by ordinary least squares method leads to obtain biased and inconsistent estimators (Küçükaksoy, Çifçi & Özbek, 2015:15-16). Stock & Watson (1993:784) suggest that the lags and leads of first differences of the explanatory variables should be added to the model in order to correct the bias and endogeneity problems in OLS estimator. In this way, dynamic OLS, which is useful even for small samples, has been developed. As a parametric approach, DOLS estimates long run equilibria in systems which involve cointegrated variables (Masih & Masih, 1996:322). This method can generate strong and consistent estimates despite of endogeneity and autocorrelation problem of independent variables (Stock & Watson, 1993).

A DOLS model with two variables is as following:

$$Y_t = \alpha_0 + \alpha_1 t + \alpha_2 X_t + \sum_{i=-q}^{q} \beta_i \Delta X_{t-i} + \varepsilon_t \quad (13)$$

where q represents the lags and leads.

In this study, long run cointegration coefficients are estimated by DOLS method, and results summarized in Table 3.

Table 3: Estimation of Long Term Coefficients

Dependent variable: lnCO2. Long-run covariance estimate (Barlett Kernel, Newey-West fixed bandwidth = 4.000)			
Regressor	**Coefficient**	**Std. Error**	**p-Value**
LEC	0.4749	0.1829	0.0289
LFDI	-0.0305	0.0087	0.0065
LY	7.0223	1.4113	0.0008
LY2	-0.3536	0.0724	0.0009
C	-36.4871	6.0088	0.0002
D84	0.0436	0.0079	0.0004
D94	-0.0514	0.0094	0.0004
D01	-0.0199	0.0073	0.0233

Adj. R^2 = 0.998, D-W stat. = 2.96, JB: 0.84 (prob:0.65)

Note: Break years have been selected based on Model 0 of Maki's (2012) cointegration test.

According to the results, GDP is elastic (β=7.02) and its coefficient is statistically significant ($p<0.01$) while the coefficient of square of GDP is negative (β=-0.35) and statistically significant ($p<0.01$), which means U shaped EKC curve hypothesis is supported for Turkey in the long run. Another finding is that the energy consumption has positive (β=0.47) and significant ($p<0.05$) effect on carbon emissions while foreign direct investment has negative (β=-0.03) and statistically significant ($p<0.01$) coefficient, meaning that 1% increase in FDI inflow would lead to 0.03% decrease in CO_2 emission. This means pollution halo effect is valid in the long run. In addition to all these, three dummy variables obtained from cointegration test (D84, D94, D01) are statistically significant for Turkey. Breakpoint on 1984 has positive effect on carbon dioxide emission; on the other hand, dummies for the year of 1994 and 2001 have negative effect on the emission.

3.2.4 Short Term Error Correction Model

Short term analysis model includes differences of series, and lagged value of error term obtained from long run analysis (ECT_{t-1}).

For this study, the equations representation of error correction model (ECM) is as follows:

$$\Delta CO_t = \alpha_1 + \alpha_2 \Delta EC_t + \alpha_3 \Delta FDI_t + \alpha_4 \Delta Y_t + \alpha_5 \Delta Y2_t + \rho \varepsilon_{t-1} + v_t \quad (14)$$

where Δ stands for the first difference operator. v_t is residual term, and ε_{t-1} is the lagged error-correction term (ECT) derived from the cointegrating vector.

This model is estimated with OLS method and summarized in Table 4.

Table 4: Estimation of Short Term Coefficients

Dependent variable: $\Delta CO2$			
Regressor	**Coefficient**	**Std. Error**	**p-Value**
ε_{t-1}	-0.8907	0.3147	0.0662
ΔEC	-0.2551	0.5555	0.6773
ΔFDI	-0.1684	0.0285	0.0097
ΔY	45.585	9.6689	0.0181
ΔY2	-2.5267	0.5492	0.0193
C	0.0043	0.0054	0.4877
D84	-0.0126	0.0098	0.2885
D94	-0.0115	0.0064	0.1723
D01	0.0645	0.0140	0.0193

Adj. R^2 = 0.923, D-W stat. = 2.66, JB: 0.35 (prob:0.83)

Note: Break years have been selected based on Model 0 of Maki's (2012) cointegration test.

Error correction model results show that the coefficient of error correction term is negative, less than 1 (β=-0.89), and statistically significant at 10 % level of significance ($p<0.10$). So, error correction mechanism for this model is working properly, which means that carbon emission converges to its long run equilibrium by 89 % speed of adjustment. In addition, the short run coefficients of GDP and the square of GDP are positive (β=45.58) and negative (β=-2.52) respectively, and also both are statistically significant ($p<0.05$). Thus EKC hypothesis is supported in the short run.

Results also show that FDI inflows have negative (β=-0.16) and significant effect ($p<0.01$) on carbon emission while the coefficient of energy consumption is negative but statistically insignificant in the short run. Negative coefficient of FDI means that pollution halo effect is also valid in the short run. In contrast to other dummies, dummy for the year of 2001 is positive and statistically significant in the short run. Both long and short term models are appropriate in terms of diagnostic tests, namely Jarque-Bera normality test and Durbin-Watson autocorrelation test.

3.2.5. Granger Causality Analysis

Maki (2012) cointegration test indicates that there is a long run cointegrating relationship but the direction is uncertain. To determine the direction, we use Granger causality test indicating that lagged value of one variable affect the current value of other variables. For such study in which lag length is 1 the equations representation of the model is as follows:

$$\Delta CO_t = \alpha_0 + \alpha_1 \Delta CO_{t-1} + \alpha_2 \Delta EC_{t-1} + \alpha_3 \Delta FDI_{t-1} + \alpha_4 \Delta Y_{t-1} + \alpha_5 \Delta Y2_{t-1} + \rho_1 \varepsilon_{t-1} + v_{1t} \quad (15)$$

$$\Delta EC_t = \beta_0 + \beta_1 \Delta CO_{t-1} + \beta_2 \Delta EC_{t-1} + \beta_3 \Delta FDI_{t-1} + \beta_4 \Delta Y_{t-1} + \beta_5 \Delta Y2_{t-1} + \rho_2 \varepsilon_{t-1} + v_{2t} \quad (16)$$

$$\Delta FDI_t = \Theta_0 + \Theta_1 \Delta CO_{t-1} + \Theta_2 \Delta EC_{t-1} + \Theta_3 \Delta FDI_{t-1} + \Theta_4 \Delta Y_{t-1} + \Theta_5 \Delta Y2_{t-1} + \rho_3 \varepsilon_{t-1} + v_{3t} \quad (17)$$

$$\Delta Y_t = \psi_0 + \psi_1 \Delta CO_{t-1} + \psi_2 \Delta EC_{t-1} + \psi_3 \Delta FDI_{t-1} + \psi_4 \Delta Y_{t-1} + \psi_5 \Delta Y2_{t-1} + \rho_4 \varepsilon_{t-1} + v_{4t} \quad (18)$$

$$\Delta Y2_t = \gamma_0 + \gamma_1 \Delta CO_{t-1} + \gamma_2 \Delta EC_{t-1} + \gamma_3 \Delta FDI_{t-1} + \gamma_4 \Delta Y_{t-1} + \gamma_5 \Delta Y2_{t-1} + \rho_5 \varepsilon_{t-1} + v_{5t} \quad (19)$$

where Δ is the first difference operator. v_{1t}, v_{2t}, v_{3t}, v_{4t}, v_{5t} are residual terms, and ε_{t-1} is the lagged error-correction term (ECT) derived from the cointegrating vector.

With this equation system, it can be estimated both the short run and long run Granger causality. For example, from equation (5) $\alpha_3 \neq 0$ means that foreign direct investment is the Granger cause of carbon emissions in the short run. Also, $\rho_1 \neq \alpha_3 \neq 0$ implies that FDI is the Granger cause of emissions in the long run. Basically, if lagged value of one variable (X) has significant effects on another (Y), it is said that X is the Granger reason of Y.

Since in this study series have structural breaks, models have dummy variables for the break points obtained from Maki cointegration test. In this context, Table 5 and 6 summarize the short run and the long run relations among variables, respectively.

Table 5: Short Run Granger Causality Test Results

	D(LNCO)	D(LNEC)	D(LNFDI)	D(LNY) †
D(LNCO)		-0.4592	-5.9131*	13.008**
D(LNEC)	2.9253***		3.4914**	4.6205
D(LNFDI)	5.8305**	-6.2354*		12.4729**
D(LNY)	5.3817**	-3.4648**	-3.3793**	
D(LNY2)	-5.0883**	3.2133**	3.1063***	

Note: *, ** and *** denote significance at 1 %, 5% and 10% level respectively. † presents D(LNY) and D(LNY2).

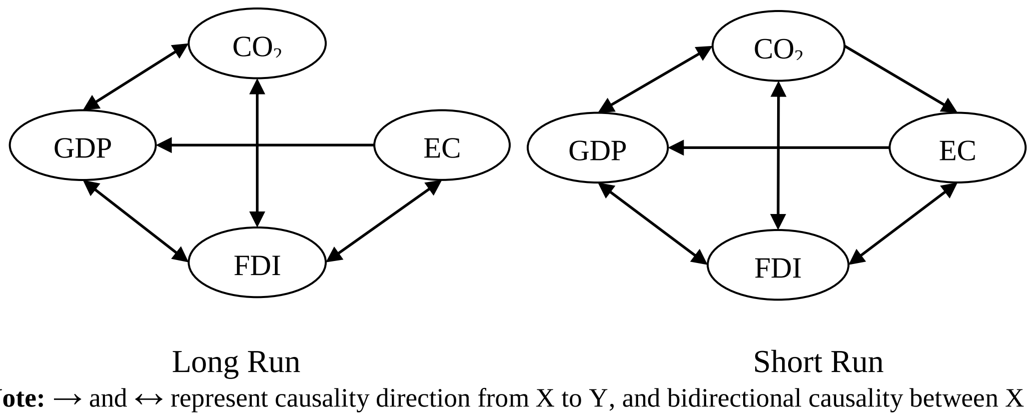
In the short run, there are four bidirectional Granger causality relations between CO_2 emissions and FDI, between CO_2 emissions and GDP, between GDP and FDI inflows, and between FDI inflows and energy consumption. In addition to this, there are two unidirectional relations from energy consumption to GDP, and from carbon emissions to energy consumption.

Table 6: Long Run Granger Causality Test Results

	D(LNCO),ECT	D(LNEC),ECT	D(LNFDI),ECT	D(LNY) †,ECT
D(LNCO)		4.4158	37.2320*	16.7838**
D(LNEC)	5.3850		6.2150***	3.3066
D(LNFDI)	16.9979**	19.8638**		8.3205***
D(LNY)	16.3695**	7.7101***	6.2964***	
D(LNY2)	15.0933**	6.9629***	5.5398***	

Note: *, ** and *** denote significance at 1%, 5% and 10% level respectively. † presents D(LNY) and D(LNY2).

In the long run, just as in the short run, there are four bilateral Granger causality relations between CO_2 emissions and FDI, between carbon emissions and GDP, between GDP and FDI inflows, and between FDI inflows and energy consumption. Also, there is a unilateral relation from energy consumption to GDP, as summarized in Figure 2.



Note: → and ↔ represent causality direction from X to Y, and bidirectional causality between X and Y.

Figure 2: Causal Relations in the Short Run and Long Run in Turkey

Both in the short run and long run, the growth hypothesis, indicating that there is a unilateral causality relation from energy consumption to economic growth, is supported. Also, there is bilateral Granger causality relationship between economic growth and foreign direct investment inflows. In addition to these, there is bidirectional relation between CO_2 and foreign direct investment inflows in the short run and long run. Only difference between short and long run results is the existence of causal relation from carbon emission to energy consumption in short run.

4. Conclusion

The aim of this study is to explore the linkages between the energy consumption, income, foreign direct investment inflows, and CO_2 emission in Turkey, over the period 1974-2011. First, stationarity of variables has been examined by Carrion-i-Silvestre et al. (2009) unit root test with multiple structural breaks. Then, Maki (2012) cointegration and Granger causality method have been used to analyze data with structural breaks. Maki cointegration method results show that there is a long run equilibrium relationship among the variables. The long run elasticity of CO_2 emissions in terms of energy consumption is found as 0.47, in terms of income is found as 7.02-0.35y, and in terms of foreign direct investment is found as -0.03. All variables are statistically significant at 10 % level of significance.

To determine the direction of relations in the short and long run, Granger causality test has been used. According to causality test results, there are four bilateral causal relations between GDP growth and carbon emissions, FDI inflows and carbon emissions, FDI inflows and growth, FDI inflows and energy consumption both in the long run and short run. In addition to these, test results show that there is unilateral causality relation from energy consumption to income growth both in the short and long run. Only difference between short and long run results is that there exists one sided relation from carbon dioxide emissions to energy consumption in short run.

In the theoretical literature part of this study, we have mentioned about three nexus between the CO_2 emissions, energy consumption, income growth, and FDI. First, according to Maki cointegration analysis and error correction model, Environmental Kuznets Curve hypothesis is supported in Turkey, both in the short and long run. Therefore, the environmental degradation increases in early stage of development, and then after the turning point it begins to decrease. In the long run cointegration equation, the coefficient of GDP per capita has positive sign while the square of income has negative sign, and both are statistically significant. Based on this, sustainable growth with less carbon emissions is crucial for Turkey in terms of the environment and the future generations. Turkey should be in search of clean and renewable energy sources like wind or solar power, and so on.

Secondly, the pollution halo hypothesis, suggesting that FDI has positive effects on environment, is supported for Turkey, taking into account both in the short and long run coefficient estimations and Granger causality results. The coefficients of FDI are negative and significant, and also there is bidirectional relation between FDI and growth, and carbon emission in short and long run, it can be said that the increase in FDI leads to develop Turkish economy, and to decrease in environmental degradation (decrease in carbon emissions). In line with the purpose of environmental protection, the technological transfer from foreign companies should be increased in order to place greener production techniques. Thus, Turkey should bring regulations for investors in order to attract FDI leading to achieve development with environmental protection.

Thirdly, according to Granger causality test, the growth hypothesis is valid which means there is a unilateral causality relation from energy consumption to the economic growth. The increase in economic growth leads to increase in energy consumption. It can be concluded that Turkish economy is energy dependent and energy conservation policies may be implemented with adverse effects on real GDP (Belke et .al., 2010:4). So, policies that can solve this dependency problem should be improved.

Finally, in the short run, energy consumption is the Granger reason for carbon emissions. This means that an increase in energy consumption leads to rise in environmental degradation which could cause to both economic and health issues in the future. To solve this problem, Turkey should focus on alternative clean energy sources in the short run. To reduce emissions, fossil fuel energy should be replaced with renewable energy sources.

In summary, as policy implications, Turkey should take the environmental problems seriously, search renewable energy sources, implement new environmental policies and binding regulations, and improve green production techniques.

References

Acaravcı, A, & Öztürk, I. (2010). On the Relationship between Energy Consumption, CO_2 Emissions and Economic Growth in Europe. *Energy*, 35(12). 5412–5420.

Akın, C.S. (2014). The Impact of Foreign Trade, Energy Consumption and Income on CO2 Emissions. *International Journal of Energy Economics and Policy*. 4(3), 465-475.

Al-mulali, U. (2012). Factors Affecting CO2 Emission in The Middle East: A Panel Data Analysis. *Energy*, 44(1), 564-569.

Apergis, N. & Payne J. E. (2009). CO_2 Emissions, Energy Usage, and Output in Central America. *Energy Policy*, 37, 3282-3286.

Bai, J. & Perron, P. (2003). Computation and Analysis of Multiple Structural Change Models. *Journal of Applied Econometrics*, 18 (1), 1–22.

Belke, A., Dreger, C. & Haan, F. (2010). *Energy Consumption and Economic Growth –New Insights into the Cointegration Relationship*. RUHR Economic Papers 190.

Binboğa, G. (2014). Topoloji ve Cebirin Günlük Hayatta Kullanımı. *Journal of Yaşar University*. 9(34), 5732-5759.

Bouttabba, M.A. (2014). The Impact of Financial Development, Income, Energy and Trade on Carbon Emissions: Evidence From the Indian Economy. *Economic Modelling*, 40, 33–41.

Carrion-i-Silvestre, J.L., Kim, D. & Perron, P. (2009). GLS-based Unit Root Tests with Multiple Structural Breaks under Both the Null and Alternative Hypotheses. *Econometric Theory*, 25, 1754-1792.

Chandran, V.G.R. & Tang, C.F. (2013). The Impacts of Transport Energy Consumption, Foreign Direct Investment and Income on CO2 Emissions in ASEAN-5 Economies. *Renewable and Sustainable Energy Reviews*, 24, 445–453.

Chebbi, H.E., Olarreaga, M., & Zitouna H. (2010). *Trade Openness and CO2 Emissions in Tunisia*. Economic Research Forum. Working Paper Series.

Chen, J. & Huang, Y. (2013). The Study of the Relationship between Carbon Dioxide (CO2) Emission and Economic Growth. *Journal of International and Global Economic Studies*, 6(2), 45-61.

Çelikkol, H. & Özkan, N. (2011). Karbon Piyasaları ve Türkiye Perspektifi. *Dumlupınar Üniversitesi Sosyal Bilimler Dergisi*, 31, 203-221.

Dam, M.M. (2014). *Sera Gazı Emisyonlarının Makro Ekonomik Değişkenlerle İlişkisi: OECD Ülkeleri İçin Panel Veri Analizi*. Adnan Menderes University, Institute of Social Sciences, Doctoral Thesis.

Engle, R. & Granger, C. (1987). Cointegration and Error Correction Representation: Estimation and Testing. *Econometrica*, 55, 251–276.

Eskeland, G. & Harrison, A.E. (1997). *Moving to Greener Pastures: Multinationals and the Pollution-Haven Hypothesis*. Policy Research Working Paper Series 1744, The World Bank.

Gregory, A.W. & Hansen, B.E. (1996), Tests for Cointegration in Models with Regime and Trend Shifts, *Oxford Bulletin of Economics and Statistics*, 58, 555-559.

Grossman, G.M. & Krueger, A.B. (1991). *Environmental Impacts of a North American Free Trade Agreement*. NBER Working Paper 3914.

Halıcıoğlu, F. (2009). An Econometric Study of CO2 Emissions, Energy Consumption, Income and Foreign Trade in Turkey. *Energy Policy*, 37, 1156-64.

Hatemi-J, A. (2008). Tests for Cointegration with Two Unknown Regime Shifts with an Application to Financial Market Integration. *Empirical Economics*, 35(3), 497-505.

Hoffmann, R., Lee, C., Ramasamy, B. & Yeung, M. (2005). FDI and Pollution: A Granger Causality Test Using Panel Data. *Journal of International Development*, 17, 311-317.

IPPC, (2008). Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change. ed. by Bryson Bates, Zbigniew W. Kundzewicz, Shaohong Wu, Jean Palutikof. June 2008, Geneva.

Jayanthakumaran, K., Verma R. & Liu Y. (2012). CO2 Emissions, Energy Consumption, Trade and Income: A Comparative Analysis of China and India. *Energy Policy*, 42, 450-460.

Johansen, S., Mosconi, R. & Nielsen, B. (2000). Cointegration Analysis in the Presence of Structural Breaks in the Deterministic Trend. *Econometrics Journal*, 3(2), 216-249.

Khachoo, Q. & Sofi, I. (2014). The Emissions, Growth, Energy Use and FDI Nexus: Evidence from BRICSAM. *International Journal of IT, Engineering and Applied Sciences Research*, 3(8), 1-9.

Kivyiro, P. & Arminen, H. (2014). Carbon Dioxide Emissions, Energy Consumption, Economic Growth, and Foreign Direct Investment: Causality Analysis for Sub-Saharan Africa. *Energy*, 74, 595-606.

Kohler, M. (2013). *CO2 Emissions, Energy Consumption, Income and Foreign Trade: A South African Perspective.* Economic Research Southern Africa, ERSA Working Paper 356.

Kuznets S. (1955). Economic Growth and Income Inequality. *American Economic Review*, 45, 1–28.

Küçükaksoy, İ., Çifçi, İ. & Özbek, R.İ. (2015). İhracata Dayalı Büyüme Hipotezi: Türkiye Uygulaması. *Çankırı Karatekin Üniversitesi İİBF Dergisi*, http://dx.doi.org/10.18074/cnuiibf.226.

Lau, L., Choong C. & Eng, K. (2014). Investigation of the Environmental Kuznets Curve for Carbon Emissions in Malaysia: Do Foreign Direct Investment and Trade Matter?. *Energy Policy,* 68, 490-497.

Lee, J.W. (2013). The Contribution of Foreign Direct Investment to Clean Energy Use, Carbon Emissions and Economic Growth. *Energy Policy*, 55, 483-489.

Linh, D.H. & Lin, S. (2014). CO2 Emissions, Energy Consumption, Economic Growth and FDI in Vietnam. *Managing Global Transitions*, 12(3), 219-232.

Maji, I.K. & Habibullaha, M.S. (2015). Impact of Economic Growth, Energy Consumption and Foreign Direct Investment on CO2 Emissions: Evidence from Nigeria. *World Applied Sciences Journal*, 33(4), 640-645.

Maki, D. (2012). Tests for Cointegration Allowing for an Unknown Number of Breaks, *Economic Modelling,* 29(5), 2011-2015.

Masih, R. & Masih, A. M.M. (1996). Stock-Watson Dynamic OLS (DOLS) and Error-correction Modelling Approaches to Estimating Long- and Short-run Elasticities in a Demand Function: New Evidence and Methodological Implications from an Application to the Demand for Coal in Mainland China. *Energy Economics,* 18(4), 315-334.

Pao, H. & Tsai, C. (2011). Multivariate Granger Causality between CO_2 Emissions, Energy Consumption, FDI (Foreign Direct Investment) and GDP (Gross Domestic Product): Evidence from a Panel of BRIC (Brazil, Russian Federation, India, and China) Countries. *Energy*, 36, 685–93.

Perron, P. (1989). The Great Crash, the Oil Price Shock and the Unit Root Hypothesis. *Econometrica*, 57, 1361-1401.

Perron, P. (1997). Further Evidence from Breaking Trend Functions in Macroeconomic Variables. *Journal of Econometrics*, 80, 355-385.

Rodriguez, G. (2007). Finite Sample Behaviour of the Level Shift Model Using Quasi-Differenced Data, *Journal of Statistical Computation and Simulation*, 77(10), 889-905.

Sbia, R., Shahbaz, M., & Hamdi H. (2014). A Contribution of Foreign Direct Investment, Clean Energy, Trade Openness, Carbon Emissions and Economic Growth to Energy Demand in UAE. *Economic Modelling*, 36, 191-197.

Shahbaz, M., Lean H.H., & Shabbir M. (2011). Environmental Kuznets Curve and the Role of Energy Consumption in Pakistan. *Renewable and Sustainable Energy Reviews*, 16, 2947-2953.

Stock, J.H. & Watson, M. (1993). A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems. *Econometrica*, 61(4), 783-820.

Tang, C.F. & Tan, B.W. (2015). The Impact of Energy Consumption, Income and Foreign Direct Investment on Carbon Dioxide Emissions in Vietnam. *Energy*, 79, 447-454.

Westerlund, J. & Edgerton, D. (2006). *New Improved Tests for Cointegration with Structural Breaks.* Working Papers 2006:3, Lund University, Department of Economics.

Yıldırım, E. (2014). Energy Use, CO2 Emission and Foreign Direct Investment: Is There Any Inconsistence Between Causal Relations?. *Frontiers in Energy*, 8(3), 269-278.

You, K. & Sarantis, N. (2012). Structural Breaks and the Equilibrium Real Effective Exchange Rate of China: A NATREX Approach. *China Economic Review*, 23(4), 1146-1163.

Zarsky, L. (1999). Havens, Halos and Spaghetti: Untangling the Evidence about Foreign Direct Investment and the Environment. *Conference on Foreign Direct Investment and the Environment*, The Hague, Netherlands, 28-29 January 1999.

Zeren, F. (2015). Doğrudan Yabancı Yatırımların CO2 Emisyonuna Etkisi: Kirlilik Hale Hipotezi mi Kirlilik Cenneti Hipotezi mi?, *Journal of Yasar University*, 10(37), 6381-6477.

Zivot, E. & Andrews, K. (1992). Further Evidence on the Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. *Journal of Business and Economic Statistics*, 10 (10), 251–70.

http://www.data.worldbank.com