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THE IMPACT OF TURKISH MANUFACTURING INDUSTRY ON CO_2 EMISSIONS

TÜRKİYE'DE İMALAT SANAYİ SEKTÖRÜNÜN CO_2 EMİSYONU ÜZERİNE ETKİSİ

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Abstract: Global warming has emerged as a result of human activities, and greenhouse gases are the most effective cause of global warming. The accumulations of greenhouse gases have rapidly increased in the atmosphere as a result of the increase in use of fossil fuels, wrong use of land, and industrialization. The aim of the study is to examine the relationship between carbon dioxide emissions, electricity consumption, economic growth, and trade openness on manufacturing industry in Turkey by using time series data between the years 1962 and 2013. The study employs the bound test for ARDL approach, ECM, Granger causality test and Cusum and Cusumsq test. CO_2 emissions are high due to two reasons in Turkey. First, Turkey's energy intensity is high. Second, electricity production depends on non-renewable sources. Turkey should decrease energy intensity while increasing the share of renewable energy sources for energy production to be able to decrease energy CO_2 emissions in the manufacturing industry.

Keywords: CO_2 emissions, electricity consumption, trade, ARDL

Öz: Günümüzün en önemli sorunlarında biri haline gelen küresel ısınma insan faaliyetleri sonucu atmosferde bulunan sera gazlarının artması sonucu ortaya çıkmıştır. Küresel ısınmanın en önemli sebebi olan sera gazlarının atmosferde artması özellikle sanayi devrimi ile birlikte fosil yakıtlarına olan talebin artmasına ve yanlış arazi kullanımına bağlanmaktadır. Atmosferde bulunan sera gazları içerisinde küresel ısınmaya en fazla etki eden CO_2 emisyonudur. Türkiye'de bulunan imalat sanayi sektörleri üzerinde yapılan bu çalışmanın amacı, karbondioksit emisyonları, elektrik tüketimi, ekonomik büyüme ve imalat sanayi sektöründeki ticaret açıklığı arasındaki ilişkiyi 1962 ve 2013 yılları arasında, zaman serisi verilerini kullanarak incelemektir. Araştırmada, ARDL sınır testi yaklaşımı, hata düzeltme modeli, Granger nedensellik testi, ve cusum ve cusumsq testi uygulanmıştır. Türkiye'de CO_2 emisyonunun yüksek olmasının iki nedeni vardır. Birincisi, Türkiye'nin enerji yoğunluğunun yüksek olması, ikincisi ise Türkiye'de elektrik üretiminin büyük bir bölümünün yenilenemez enerji kaynaklarına bağlı olmasıdır. Bu nedenle, Türkiye'de CO_2 emisyonlarını azaltabilmek için enerji üretiminde yenilenebilir enerji kaynaklarının payı arttırılmalı ve imalat sanayinde enerji yoğunluğu azaltılmalıdır.

Anahtar Kelimeler: CO_2 emisyonu, elektrik tüketimi, ticaret, ARDL

INTRODUCTION

Earth's atmosphere consists of various gases and these gases traps heat which creates greenhouse effect. The increase of these atmospheric gases causes the problem of global warming. Since these gases create greenhouse effect, they are called greenhouse gases (GHG). Global warming, which arises as a result of GHG, is one of the main concerns of the recent scientists and policy makers. Global warming is the increase of the temperature of land, sea and air (Dincer, 2000). As the global warming increases, the sea level rises and the glaciers melt. The risk of flood increases.

GHG consist of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFC), hydrofluorocarbons (HCFC) and Sulphur hexafluoride (SF_6). Table 1 represents the properties of the GHG in the atmosphere.

Table 1: Properties of GHG

GHG	Anthropogenic Sources	Concentration (parts per billion)	Global Warming Potential (GWP)	Lifetime in Atmosphere (year)
Carbon Dioxide (CO_2)	Fossil-fuel combustion, Cement production Land-use conversion,	280,000	1	100
Methane (CH_4)	Fossil-fuel, Rice paddies, Waste dumps	700	25	12
Nitrous Oxide (N_2O)	Fertilizer, Combustion, Industrial processes	270	298	114
Chlorofluorocarbons (CFC)	Liquid coolants, Foams	0,534	10,900	100
Hydrofluorocarbons (HCFC)	Refrigerants	0,218	1,810	12
Sulphur Hexafluoride (SF_6)	Dielectric fluid	0,00712	22,800	3,200

Source: Center for Climate and Energy Solutions, 2017

*Global Warming Potential for 100-time horizon.

In the first column of Table 1, the names of GHG in atmosphere are given, followed by a column giving information about the anthropogenic sources of the GHG. The third column influences the concentration of each GHG which influences the intensity of gases in the atmosphere. Fourth column represents the global warming potential (GWP) of the related GHG, and finally in the last column gives the information for how long the gas remains in the atmosphere as measured in years.

Carbon Dioxide (CO_2) occurs as a result of fossil-fuel combustion, cement production and land use conversion. Atmospheric concentration of CO_2 is 280,000 per billion. GWP is taken as constant in CO_2 and it remains 100 years in atmosphere. Methane (CH_4) is caused by fossil-fuels, rice paddies and waste dumps. From Table 1, it can be seen that a CH_4 gas has twenty five times GWP more than CO_2. Atmospheric concentration of CH_4 is 700 per billion and lifetime is 12 years in atmosphere. Nitrous Oxide (N_2O) comes from fertilizers, fossil-fuel combustion and industrial processes. Table 1 shows that N_2O has 298 times GWP more than CO_2. N_2O remains for 114 years and its concentration is 270 per billion in atmosphere. Chlorofluorocarbons (CFC) consist of liquid coolants and foams. CFC atmospheric concentration is 0,534 per billion. CFC has 10,900 times GWP more than CO_2 and remains 100 years in the atmosphere. Hydrofluorocarbons (HFCF) is a refrigerant gases, it has 1,810 times GWP more than CO_2. Atmospheric concentration of HFCF is 0,218 per billion and it remain 12 year in atmosphere. The last listed Sulphur Hexafluoride (SF_6) is used to cut the electricity. SF_6 comes from dielectric fluid, SF_6 22,800% times global warming potential more than CO_2. Atmospheric concentration of SF_6 is 0,00712 per billion. SF_6 has 3,200 years lifetime in atmosphere (Center for Climate and Energy Solutions, 2017). All gases have heat-trapping effect but CO_2 has highest heat-trapping ability among other GHG in the atmosphere (Özmen, 2009).

Turkey have growing rate of population and urbanization, so that Turkey's energy needs are increasing in all sectors (Bilgen *et al*., 2008). As the need for energy is increasing, both energy consumption and energy production are also increasing in Turkey. The increase of energy use increases also GHG generated in Turkey. GHG generation of Turkey increased from 134,4 million tons to 340 million tons between the years 1990 and 2015 (Turk Stat, 2017). Turkey contributes to more GHG emissions during the production of energy process and this energy are mostly used for manufacturing industry. Therefore, the impact of the economic variables that causes CO_2 emissions in Turkey is investigated in this study. This study will be guidance for further research on topic and the results obtained from the empirical analysis can be used to shape the environmental policies to decrease CO_2 emissions in Turkey.

1. LITERATURE REVIEW

The previous studies in literature related to the topic aimed to find the relationship between CO_2 emissions, energy consumption and economic growth (Acaravcı & Ozturk, 2010; Pao *et al*., 2012; Al-mulali, 2011; Apergis & Payne, 2009; Bozkurt & Akan, 2014; Chang, 2010; Çoban & Kılınç, 2015; Ergün & Polat, 2015; Alam *et al*., 2012; Koçak, 2014; Lean & Smyth, 2010; Tiwari, 2011; Pao & Tsai, 2010; Yavuz, 2014; Wang et al., 2011). In some studies in addition to those variables FDI is also included (Altıntaş, 2013; Dinh & Shih-Mo, 2014; Öztürk & Öz, 2016; Tang & Tan, 2015). There are also studies adding trade openness instead of FDI (Akın, 2014; Halıcıoğlu, 2009; Jalil & Mahmud, 2009; Keskingöz & Karamelikli, 2015; Kivyiro & Arminen, 2014).

There are also studies focusing the causal interaction between CO_2 emissions, energy consumption, economic growth (Çoban & Kılınç, 2015) in Turkey. Some of these studies included FDI as a control variable (Altıntaş, 2013; Öztürk & Öz, 2016), while some added trade openness instead of FDI (Halıcıoğlu, 2009). There are also studies adding employment ratio instead of trade openness (Öztürk & Acaravcı, 2010). Some studies found unidirectional causal relationship from energy consumption to CO_2emissions (Altıntaş, 2013; Çoban & Kılınç, 2015), while some studies estimated unidirectional causal relationship from economic growth to CO_2 emissions (Altıntaş, 2013). Some authors found bidirectional causality between economic growth and CO_2 emissions (Halıcıoğlu, 2009; Öztürk & Öz, 2016). Öztürk & Acaravcı (2010) found no causal relationship among the variables. Some studies applied only cointegration test on CO_2 emissions and economic variables (Bozkurt & Akan, 2014; Bozkurt & Okumuş, 2015; Çetin & Şeker, 2014; Keskingöz & Karamelikli, 2015; Koçak, 2014; Yavuz, 2014). The results of those studies found energy consumption, economic growth and CO_2 emissions are cointegrated.

Table 2, summarizes some of the literature by giving the names of the authors, the country studied, the sample used, model employed and the results found.

Table 2: Literature Review Summary

Authors	Country	Sample	Variable	Model	Result
Acaravcı & Öztürk (2010)	Nine European Countries	1960-2005	CO_2, EC ,EG	ARDL, Granger Causality Test	EG → CO_2 EC → CO_2
Adom et al. (2012)	Ghana, Senegal and Morocco	1971-2007	CO_2, EG, TE, IS	Bounds, Granger Causality Test	CO_2 ↔ EG CO_2 ↔ IS CO_2 ↔ TE
Akbostancı et al. (2009)	Turkey	1968-2003	CO_2, EG, POP	EKC, Cointegration	CO_2 andEG cointegration
Akın (2014)	85 countries	1990-2011	CO_2, EG, EC, TO	Cointegration, Granger Causality Test	CO_2 → TO EG → CO_2 EG → TO
Al-mulali (2011)	MENA countries	1980-2009	CO_2, EG, EC	Granger Causality Test	CO_2 ↔ EC CO_2 ↔ EG
Al-mulali et al. (2012)	Seven region	1980-2008	CO_2 ,UR, EC	Granger Causality Test	CO_2 ↔ UR CO_2 ↔ EC
Altıntaş (2013)	Turkey	1970-2008	CO_2, EG, EC, FDI	ARDL, Granger Causality Test	EG → CO_2 EC → CO_2
Anatasia (2015)	Thailand Malaysia	1978-2008	CO_2, EG, EC, Export	Cointegration, Granger Causality Test	Export→ CO_2 EG → CO_2 EG → EC
Apergis & Payne (2009)	Central America	1971-2004	CO_2, EG, EC,	EKC, Granger Causality Test	EC → CO_2 EG → CO_2
Ayeche et al. (2016)	40 European countries	1985-2014	EG, FD, TO, CO_2, EC, FDI, INF, UR	ARDL, Granger Causality Test	EG ↔ FD EG ↔ TO
Aytun & Akın (2015)	Turkey	1971-2010	PSE, SSE, TSE, CO_2	Granger Causality Test	TSE→CO_2
Bozkurt & Akan (2014)	Turkey	1960-2010	EC, CO_2, EG	Cointegration Test	EC is positive effect on CO_2
Bozkurt & Okumuş (2015)	Turkey	1966-2011	CO_2, EG, EC, POP, TO	Cointegration Test	All variable cointegration
Chang (2010)	China	1982-2004	CO_2,EG , EC	Cointegration, VECM ,Granger Causality Test	EG → CO_2
Cowan et al. (2014)	BRICS	1990-2010	CO_2, EG, electricity consumption	Granger Causality Test	EG → CO_2 electricity consumption → CO_2
Çetin &	Sub Saharan	1985-2010	CO_2, EC, UR	VECM,	CO_2 ↔ EC

Ecevit (2015)	Countries			Granger Causality Test	$CO_2 \leftrightarrow$ UR
Çetin & Seker (2014)	Turkey	1980-2010	CO_2, EC, TO	ARDL	All variable cointegration
Çetintaş & Sarıkaya (2015)	USA and UK	1960-2004	CO_2, EG, EC, TO, UR	Cointegration, Granger Causality Test	$CO_2 \rightarrow$ EG EC $\rightarrow CO_2$
Çoban & Kılınç (2015)	Turkey	1990-2012	CO_2, EG, EC	Cointegration, Granger Causality Test	EC $\rightarrow CO_2$
Dinh & Shih-Mo (2014)	Vietnam	1980-2010	CO_2, EC, EG, FDI	Cointegration, Granger Causality Test	$CO_2 \leftrightarrow$ EC
Dogan & Turkekul (2016)	USA	1960-2010	CO_2, EG, EC , TO, UR	Cointegration, Granger Causality Test	$CO_2 \leftrightarrow$ EG $CO_2 \leftrightarrow$ EC $CO_2 \leftrightarrow$ UR
Ergün & Polat (2015)	30 OECD countries	1980-2010	CO_2, EC, EG	Cointegration, Granger Causality Test	EG $\rightarrow CO_2$
Halıcıoğlu (2009)	Turkey	1960-2005	CO_2, EC,EG, TO	ARDL, Granger Causality Test	$CO_2 \leftrightarrow$ EC $CO_2 \leftrightarrow$EG
Hossain (2011)	NIC	1971-2007	CO_2, EC, TO, EG, UR	Cointegration, Granger Causality Test	EC $\rightarrow CO_2$ TO $\rightarrow CO_2$
Hossain (2012)	Japan	1960-2009	CO_2 , EG, EC, TO, UR	Cointegration, Granger Causality Test	$CO_2 \rightarrow$ EG EC $\rightarrow CO_2$
Jalil & Mahmud (2009)	China	1975-2005	CO_2 , EG, EC, TO	EKC, Granger Causality Test	EG $\rightarrow CO_2$
Kapusuzoğlu (2014)	Worldwide OECD EU Turkey	1960-208	CO_2 , EG	Cointegration, Granger Causality Test	$CO_2 \rightarrow$ EG
Kasman & Duman (2015)	New EU member and candidate countries	1992-2010	CO_2, EC, EG, TO, UR	EKC, Granger Causality Test	EC $\rightarrow CO_2$ EG $\rightarrow CO_2$ UR $\rightarrow CO_2$ TO $\rightarrow CO_2$ UR $\rightarrow$ TO
Katırcıoğlu (2017)	Turkey	1960-2010	CO_2, EC, EG, Oil price	Cointegration ECM, Granger Causality Test	EC $\rightarrow$ Oil price
Katırcıoğlu,et al. (2014)	Cyprus	1970-2009	CO_2, EC, IT	Bounds test, Granger Causality test	$CO_2 \leftrightarrow$ EC IT$\rightarrow$ CO_2 EC $\rightarrow$IT
Keskingöz & Karamelikli (2015)	Turkey	1960-2011	CO_2, EG, EC, TO	ARDL	Import has positive effect on CO_2
Kivyiro & Arminen (2014)	Six Sub Saharan Africa	1971-2009	CO_2, EG, EC, TO	ARDL, Granger Causality Test	$CO_2 \rightarrow$ EG
Koçak (2014)	Turkey	1960-2010	CO_2, EG, EC	ARDL	EC positive effect on CO_2
Lean & Smyth (2010)	ASEAN	1980-2006	CO_2, EG, electricity consumption	EKC, Granger Causality Test	$CO_2 \rightarrow$ electricity consumption $CO_2 \rightarrow$ EG
Mohapatra & Giri (2015)	India	1971-2012	CO_2, EG, EC, TO, UR, GFCF	ARDL, Granger Causality Test	EC $\rightarrow CO_2$
Narayan &Narayan (2010)	Malaysia	1980-2004	CO_2, EG	Cointegration	EG effects on CO_2
Niu et al. (2011)	Eight Asian-Pasific	1971-2005	CO_2, EG, EC	Cointegration, Granger Causality Test	$CO_2 \rightarrow$ EG

Öztürk & Acaravcı (2010)	Turkey	1968-2005	CO_2, EG, EC, LF	ARDL, Granger Causality Test	All variable co-integrate
Öztürk & Öz (2016)	Turkey	1974-2011	CO_2, EG, EC, FDI	Cointegration, Granger Causality Test	EC → EG CO_2→ EC
Pao & Tsai (2010)	BRIC countries	1971-2005	CO_2, EG, EC	EKC, Granger Causality	CO_2 ↔ EC CO_2 → EG
Salahuddin et al. (2015)	Gulf Cooperation Council	1980-2012	CO_2, EG, EC, FD	Cointegration, Granger Causality	EC → CO_2 CO_2 ↔ EG
Tang & Tan (2015)	Vietnam	1976-2009	CO_2, EG, EC, FDI	EKC, Granger Causality Test	CO_2 ↔ EG CO_2 ↔ EC
Tiwari (2011)	India	1971-2005	CO_2, EG, EC	Cointegration, Granger Causality Test	CO_2 → EG CO_2 ↔ EC
Xiongling (2016)	China	1961-2010	CO_2, EG	Cointegration, Granger Causality Test	EG → CO_2
Yavuz (2014)	Turkey	1960-2007	CO_2, EG, EC	EKC, Cointegration	CO_2, EG and ECcointegration
Wang et al. (2011)	China	1995-2007	CO_2, EG, EC	Granger Causality Test	CO_2 ↔ EC

CO_2: Carbon Dioxide Emissions
EC: Energy Consumption
EG: Economic Growth
TO: Trade Openness
IT: International Tourism
FDI: Foreign Direct Investment
PSE: Primary School Enrollment
SSE: Secondary School Enrollment
TSE: Tertiary School Enrollment
GFCF: Gross Fixed Capital Formation
TE: Technical Efficiency
FD: Financial Development
POP: Population
UR: Urbanization
LF: Labor Force
INF: Inflation Rate

Different results appear in different studies because of the different variables, different models, different data, and different methods used and different countries included. In those studies the mostly used methods are ARDL and Granger causality tests in both cross country panel studies and time series estimations.

We used electricity consumption instead of energy consumption since electricity consumption has the highest share in total energy consumption in Turkey. Also the shares of imports and exports of manufacturing industries in GDP is used instead of the share of total imports and exports in GDP since manufacturing industry to be able to investigate the impact of the manufacturing trade on CO_2 emissions. To our knowledge, there is no study in the literature integrating those variables in one analysis. It should also be mentioned that the data used in this study covers longer time period than the previous studies applied for the case of Turkey.

2. DATA AND METHODOLOGY

In this paper, the impact of electricity consumption, economic growth and trade openness on CO_2 emissions in Turkey by employing a time series data covering the years from 1962 to 2013 collected from World Bank Development Indicators. The long-run interaction between the dependent (CO_2) and independent variables are estimated by employing the econometric model represented by Equation (1). All variables are in natural logarithms.

$$\ln CO_2 = \beta_0 + \beta_1 \ln EC + \beta_2 \ln GDP + \beta_3 \ln TO + \varepsilon \quad (1)$$

In equation (1) β_0 is the constant term and β_1, β_2, β_3 are the long-run elasticities with respect to electric power consumption, per capita GDP and trade openness. ε is the error term and ln indicates that general logarithmic form of the variables. CO_2 denotes carbon dioxide emissions per capita, while EC is electric power consumption (kWh per capita) which is equal to total net electricity generation plus electricity imports minus electricity exports minus electricity distribution losses. GDP is real GDP per capita calculated by the 2005 US$ prices. GDP calculated as GDP divided by population. To indicate trade openness which is calculated as the sum of percentage of manufacturing exports and percentage of manufacturing imports to GDP as suggested by Yanıkkaya (2003) and the subscript t represents the time period.

3. EMPIRICAL ANALYSES

3.1. Unit Root Tests

In the time series analyzes, firstly, the stability levels of the series should be determined. Non-stationary creates problem of spurious regression (Granger & Newbold, 1974). So, Augmented Dickey Fuller (ADF) (1981), Phillips-Perron (PP) (1988) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (1992) unit root tests are applied to test for stationarity of the series. Table 3 illustrates test results of stationarity of ADF, PP and KPSS for CO_2 emissions, GDP, electricity consumption and trade openness.

Table 3: Unit Root Test Result: with intercept

Variables	lnCO_2	lnEC	lnGDP	lnTO
ADF	I(1)*	I(1)*	I(1)*	I(1)*
PP	I(1)*	I(1)*	I(1)*	I(1)*
KPSS	I(1)	I(0)	I(1)	I(1)

* and ** denotes the statistical significance at the 1% and 5%, levels respectively.

ln CO_2, lnEC, lnGDP and lnTO are stationary both in ADF and PP tests at I(1). According to KPSS test results; all variables are stationary at mix levels. Since variables are stationary at mix level, ARDL approach is applied under bounds test in this study the investigate long run relationship among variables.

3.2. Bounds Test

Bounds test is developed by Pesaran and Shin (1995), Pesaran *et al*., (1999, 2001) under the ARDL approach which estimates the long run interaction among the variables. If all variables are stationary at same level, Engle-Granger (1987), Johansen (1988, 1991) and Johansen-Juselius (1990) cointegration tests can be applied to determine the long-run relationship between the variables. Pesaran et al. (2001) proposed the ARDL approach for testing the relationship between different levels of integrated variables (Verma, 2007; Esen, *et al*., 2012).

The ARDL approach is based on the least squares method. The main advantage of the ARDL model is that with mix order of integration of variables at either I (1) or I (0) it can be applied for cointegration test and the obtained results will be meaningful. In this study the variables are stationary at mix levels so that ARDL test is employed to estimate long run interaction among variables.

According to the unit root test results the regressors have mixed ordered of integration, therefore, Bounds tests based on ARDL approach represented by the following model will be estimated with this respect:

$$\Delta lnCO2_t = \alpha_0 + \sum^{p}_{i=1} \alpha_{1i}\, lnCO2_{t-i} + \sum^{p}_{i=0} \alpha_{2i}\, lnEC_{\,t-i} + \sum^{p}_{i=0} \alpha_{3i} lnGDP_{t-i} + \sum^{p}_{i=0} \alpha_{4i}\, lnTO_{\,t-i} + \varepsilon_t \quad (2)$$

Where, α's are the dynamic coefficients of the attached variables in long-run and ε_t is an error term.

ARDL approach under the Bounds test results follows F-distribution. The critical values for Bounds test is developed by Narayan and Narayan (2005) and Pesaran and Timmermann (2005) which follow F distribution. If F-statistics for bounds test exceeds the upper bound of critical value the null of no long run relationship between the variables is rejected. If F-statistics for bounds test is estimated to be lower than the lower bound of critical value the null hypothesis is not rejected. If F-statistics for bounds test falls between lower and upper bounds than the analysis is said to be inconclusive. This is stage one is necessary step to check whether exist a long run relationship between the variables under investigation is tested by computing F-statistics for the significance of the lagged levels of the variables in the error correction form of the underlying ARDL model. The F-statistics confirms that there is a cointegrating relationship based on the three models.

Bounds test considers five different cases. First case is applied without intercept and trend, second case is applied with restricted intercept and without trend, Third case is applied without deterministic unrestricted intercept and without trend, Fourth case is applied by including the deterministic unrestricted intercept and restricted trend and the last case is applied with unrestricted intercept and restricted trend. In this study, we focused on the results of only the last three since they give more reliable results (Katırcıoğlu *et al.*, 2013).

Table 4 shows critical values of bounds test and table 5 shows the bounds test for level relationship among variables.

Table 4: Critical Values of Bounds Test

Significance	I(0)	I(1)
0.01	3.65	4.66
0.05	2.79	3.67
0.10	2.37	3.2
F statistic : 7.9588		

Table 5: The Bounds Test for level relationship

	Without deterministic unrestricted intercept and no trend	With deterministic unrestricted intercept and restricted trend	With unrestricted intercept and restricted trend	Conclusion
Variables	F_{iii}	F_{iv}	F_v	H_0
CO_2/ EC, GDP, TO	2.700**	2.303***	2.864**	Rejected

** and *** denotes the statistical significance at the 5% and %10.

According to the Bounds test results, there is a long run relationship exist among variables, which indicates EC, GDP and TO are in long run relationship with CO_2 for Turkey.

3.3. Error Correction Model

Error Correction Model (ECM) is developed by Engle-Granger (1987) stated short-term imbalances when there is cointegration of the variables are established. ECM coefficient shows the short run deviation from its long run equilibrium. ECM is given below;

$$\Delta lnCO_{2_t} = \lambda_0 + \sum_{i=1}^{p} \lambda_{1i} \Delta lnCO_{2_{t-1}} + \sum_{i=0}^{p} \lambda_{2i} \Delta lnEC_{t-1} + \sum_{i=0}^{p} \lambda_{3i} \Delta lnGDP_{t-1} + \sum_{i=0}^{p} \lambda_{4i} \Delta lnTO_{t-1} + \varphi ECT_{t-1} + \zeta_t \quad (3)$$

Where λ is the parameter of error correction, Δ is indicates the first differences while the parameter ECT_{t-1} is the error correction term, φ is the speed adjustment coefficient, ζ is the disturbance term in equation 3.

Table 6: ARDL approach long-run and short-run test results

Dependent Variable: ln$\mathbf{CO_2}$			
Long-run results			
Variables	Coefficient	Standard Error	p-value
ln$\mathbf{CO_2}$	0.498	0.139	0.000
lnEC	0.722	0.213	0.001
lnGDP	0.391	0.174	0.007
InTO	0.002	0.001	0.119
Short-run results			
Variables	Coefficient	Standard Error	p-value
ECMT (-1)	-0.334	0.045	0.000

Table 6 shows that long run and short run coefficients, whereas lnCO_2 is taken as the dependent variables. According to the results of ARDL approach lnEC, lnGDP and lnTO have a statistically significant impact on lnCO_2. It show that, when EC increase by 100%, CO_2 emissions will increases by 72.2 % and 100% increase in lnGDP leads to 39.1% increase in CO_2 and when lnTO increase by 100%, CO_2 emissions increasing 0.2%.

The estimation result of ECM is shown in Table 6. ECT (-1) coefficient is statistically significant at 1% significance level and ECT_{t-1} is -0.334 with expected sign, proposing that when emissions is under its equilibrium level, it adjusts by almost 47% per year.

3.4. Granger Causality Test

If there is a long-term relationship between variables, causal relationship among the variables should be estimated. Granger causality test using F statistic. Granger causality is given as below;

$$\begin{bmatrix} \Delta \ln CO_{2_t} \\ \Delta \ln EC_t \\ \Delta \ln GDP_t \\ \Delta \ln TO_t \end{bmatrix} = \begin{bmatrix} \propto_1 \\ \propto_2 \\ \propto_3 \\ \propto_4 \end{bmatrix} + \sum_{i=1}^{p} \begin{bmatrix} \beta_{11i} & \beta_{12i} & \beta_{13i} & \beta_{14i} & \beta_{15i} \\ \beta_{21i} & \beta_{22i} & \beta_{23i} & \beta_{24i} & \beta_{25i} \\ \beta_{31i} & \beta_{32i} & \beta_{33i} & \beta_{34i} & \beta_{35i} \\ \beta_{41i} & \beta_{42i} & \beta_{43i} & \beta_{44i} & \beta_{45i} \end{bmatrix} \begin{bmatrix} \Delta \ln CO_{2_{t-i}} \\ \Delta \ln EC_{t-i} \\ \Delta \ln GDP_{t-i} \\ \Delta \ln TO_{t-i} \end{bmatrix} + \begin{bmatrix} \varphi_1 \\ \varphi_2 \\ \varphi_3 \\ \varphi_4 \end{bmatrix} ECM_{t-1} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \end{bmatrix} \quad (4)$$

The ∝', β's and φ's are the parameters are estimated. ECM_{t-1} represents the one period lagged error-term derived from the cointegration vector and the ε's are serially independent with mean zero and finite covariance matrix in Equation 4.

Table 7: Granger F-test results

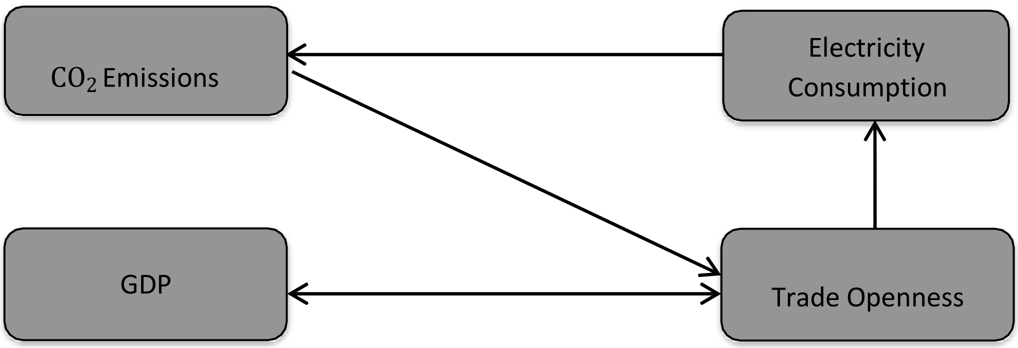
	ΔlnCO$_2$	**ΔlnEC**	**ΔlnGDP**	**ΔlnTO**
ΔlnCO$_2$		(3.232)**	(0.379)	(0.630)
ΔlnEC	(0.000)		(0.292)	(2.788)***
ΔlnGDP	(0.527)	(0.463)		(2.383)***
ΔlnTO	(2.594)***	(1.998)	(2.625)***	

x→y means x Granger causes y.

** and *** denotes the statistical significance at the 5% and %10.

The Granger causality results are represented in Table 7 The numbers in the table represents F-statistic test results. The numbers in parentheses give the probability of F-statistic. According to Table 7; there are three unidirectional granger causality relationships exist among variables running from electricity consumption to CO_2 emissions, from CO_2 emissions to trade openness, and from trade openness to electricity consumption. In addition to the unidirectional causal relationships, the test results indicate that there is one bi-directional causality relationship exists among variables, between trade openness and GDP per capita. Figure 1 illustrates granger causality relationship among the variables.

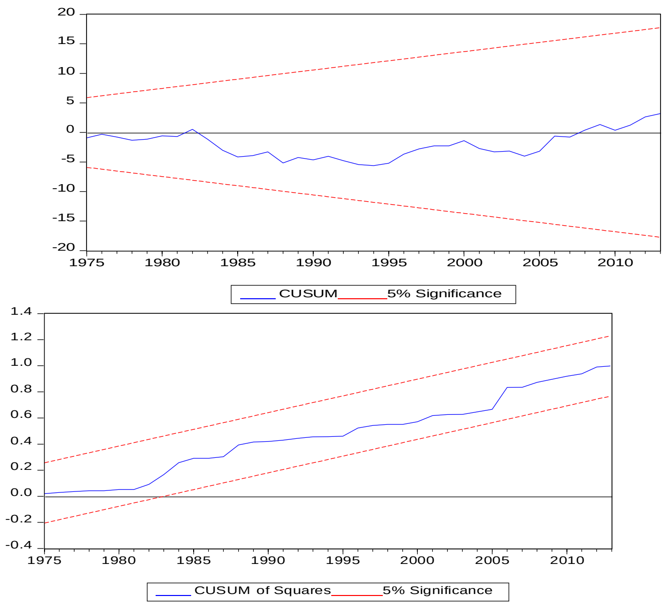
Figure 1: Granger Causality Relationship between the Variables



3.5. Cusum and Cusumsq Test

The Cusum and Cusumsq test are applied to test the stability of the long term coefficients used to obtain ECM, since instability problem might be the result of incomplete modeling of short-run dynamics (Laidler, 1993). According to the test results it can be stated that the estimated coefficients are stable in the long run since the plots of both tests fluctuate inside the 5% critical bounds. Figure 2 shows the plot of Cusum and Cusumsq Tests.

Figure 2: Cusum and Cusumsq Tests



CONCLUSION AND POLICY RECOMMENDATIONS

This papers aims to investigate the interaction between CO_2 emissions, electricity consumption, economic growth and trade openness for the case of Turkey by using time series data covering the years between 1962 and 2013.

To be able to investigate the interaction among variables the empirical analysis employed starting with the tests for stationary of the variables. Since the variables show mix order of integration, the bounds test based on ARDL approach is employed to estimate the long run relationship among the variables. According to the Bounds test results it is found that the electricity consumption, economic growth and trade openness have statistically significant and positive impact on CO_2 emissions.

ECM applied to the short run deviation from its long run equilibrium. The estimated ECT (-1) coefficient of the employed ECM is statistically significant at 1% significance level with expected sign, proposing that when CO_2 emissions is under its equilibrium level, it adjusts by almost 33% per year.

Then, the found that long-term relationship among variables, therefore Granger Causality Test applied. The Granger Causality Test results demonstrated the existence of unidirectional short-run causal relationship from electricity consumption to CO_2 emissions, from CO_2 emissions to trade openness, from trade openness to electricity consumption. Additionally, there is evidence of one bi-directional causality relationships between trade openness and GDP per capita.

Cusum and Cusumsq Test applied to coefficients are stable in the long run. Cusum and Cusumsq Test results are evidence that coefficients in ECM are stable over the period between 1962 and 2013.

Estimation results show that as electricity consumption increases CO_2 emissions also increase in case for Turkey. The main reason behind the increase in CO_2 emissions is due to the use of fossil fuels for electricity generation since fossil fuels have the highest share among the energy resources use to generate electricity in Turkey. Turkey's energy policy has a critical importance both in reducing the environmental problems caused by CO_2 emissions and in terms of economic growth. Turkey's energy production depends highly on foreign countries energy sources since energy production in manufacturing sector is generated from electricity, which is produce mostly from natural gas imported from abroad increasing cost of production.

Turkey is one of the countries which generate highest levels of CO_2 emissions. High level of CO_2 emissions depends on two reasons. First is that Turkey has high energy intensity arising from inefficient use of energy (Islatince & Haydaroğlu, 2009) and second is the dependency of Turkey on non-renewable sources instead of renewable energy sources to generate in energy, in particular electricity. Electricity is one of the main inputs in industrial manufacturing, and it is also a fundamental factor that increases people's quality of life (Karagöl, *et al*., 2007). The priority of Turkey should be to decrease energy intensity and increase the share of renewable energy sources to generate electricity in the manufacturing industry. This can be achieved through carbon taxation of the manufacturing sector. The carbon tax system can be designed to promote the use of renewable energy sources to generate electricity for the manufacturing sector. This will also decrease the importation of natural gas. Thus, the cost of electricity generation will be decreased. Moreover, the cost of the manufacturing industry production will be reduced in long-run.

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Zeliha Özdemir, Dönüşüm İş Sağlığı ve Güvenliğinde İnsan Kaynakları Uzman Yardımcısıdır. Aldığı eğitim sırasıyla, Muhasebe ve Vergi Uygulamaları Ön Lisans (Afyon Kocatepe Üniversitesi, Türkiye), Ekonomi Lisans (Lefke Avrupa Üniversitesi, KKTC), İşletme Yüksek Lisans (Lefke Avrupa Üniversitesi, KKTC). Uluslararası kongrede bildiri sunan Özdemir'in ilgi alanları şunlardır: Genelde Ekonomi özelde ise Enerjidir.

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