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ENVIRONMENTAL TAXES AND CARBON DIOXIDE EMISSION IN EU COUNTRIES: A PANEL VAR APPROACH

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Abstract

In this study, propagation mechanisms between environmental taxes and carbon dioxide emission are analyzed in EU states by employing the panel VAR (PVAR) model. In this respect, use annual data that consists of GDP (current US$ per capita), CO_2 emission (metric ton per capita), energy use (kg of oil equivalent per capita) and environmental tax revenues (proportion of GDP) from 1995 through 2014 for 24 EU countries are used in the PVAR model and short/long run transmission mechanism is identified. Cross-sectional dependence is tested by the Pesaran's CD test and the second-generation panel unit root test is carried out to determine stationarity of the variables. The empirical findings of the study underline the significance of environmental taxes in mitigating CO_2 emission and accordingly, propose the environmental taxes in internalizing negative externalities along with other policy tools. Along wıth that, various policies should be applied simultaneously and globally to mitigate the hazardous effects of green gas emissions for humanity and the environment.

Keywords: *Environmental taxes; CO_2 emission; Panel VAR*.

JEL Classification: *C23, C38, E60, H23*.

AB ÜLKELERİNDE ÇEVRE VERGİLERİ VE KARBONDİOKSİT EMİSYONU: PANEL VAR YAKLAŞIMI

Öz

Bu çalışmada, panel VAR (PVAR) modelini kullanarak AB ülkelerinde çevre vergileri ve karbondioksit emisyonu arasındaki yayılma mekanizması analiz edilmektedir. Bu bağlamda, GSYİH (kişi başına ABD doları), CO_2 emisyonu (kişi başına metrik ton), enerji kullanımı (kişi başına kg petrol eşdeğeri) ve çevre vergisi gelirlerinden (GSYİH oranı) oluşan yıllık veriler 1995-2014 döneminde PVAR modelinde kullanılmaktadır ve değişkenler arasındaki kısa/uzun dönemli aktarım mekanizması elde edilmektedir. Yatay kesit bağımlılığı Pesaran'ın CD testi ile sınanmaktadır ve değişkenlerin durağanlığını belirlemek

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için ikinci nesil panel birimi kök testi kullanılmaktadır. Çalışmanın ampirik bulguları, CO_2 emisyonunu azaltmada çevre vergilerinin önemini vurgulamakta ve bu nedenle çevre vergilerini diğer politika araçlarıyla birlikte negatif dışsallıkların içselleştirmesinde önermektedir. Bununla birlikte, sera gazı emisyonun çevre ve insanlık için zararlı etkilerini azaltmak için çeşitli politikalar eş zamanlı ve küresel olarak politika yapıcılar tarafından uygulanmalıdır.

Anahtar Kelimeler: *Çevre Vergileri; CO_2 emisyonu; Panel VAR.*

JEL Sınıflandırması: *C23, C38, E60, H23.*

1. INTRODUCTION

Increasing levels of greenhouse gas (GHG) emissions over the recent past have obliged states to launch environmental taxes on different levels. Owing to global warming effects of greenhouse gas emissions, policymakers and authorities concentrate on using environmental taxes to mitigate greenhouse gas emissions to the target levels set at the 1997 Kyoto Protocol[4].

Carbon tax is a kind of environmental tax and levied on the carbon content of the fuels. The carbon tax is subjected to a wide range of industries ranging from manufacturing to agriculture. The carbon tax was originally put into effect by Nordic countries in the 1990s. Among them, Finland is the first country to launch a carbon tax. Finland levies the carbon tax on diesel, gasoline, jet fuel, heavy and light fuel oil, coal, and natural gas. Norway launched the carbon tax in 1991 and levies carbon tax on gasoline, fuel oil, oil, and gas in the North Sea. Another Nordic country; Sweden initiated the carbon tax in 1991. Denmark, introduced the carbon tax in 1992.

The Netherlands has levied carbon tax since 1990 to mitigate CO2 levels. In the Netherlands; electricity, natural gas, refinery and coal gases, light fuel and diesel are subjected to the carbon tax. Other countries, regions that apply carbon tax and its initiation dates are given as follows: Costa Rica (1997), The United Kingdom (2001), Colorado (2007), Quebec (2007), British Columbia (2008), California (2008), Switzerland (2008), Ireland (2010), Japan (2012), Mexico (2012) and France (2014). Likewise, European Union (EU) countries apply environmental taxes on energy, transport, pollution and resource (Eurostat, 2017b). The

[4] See https://unfccc.int/process/the-kyoto-protocol.

environmental tax revenue is calculated as a proportion of GDP and it ranges from 1.72 % (Iceland) to 4.02 % (Denmark) in 2015 (Eurostat, 2017a).

It should be noted that the effectiveness of environmental taxes in mitigation of CO_2 emission has been analyzed by the scholars, whereas the literature is scant and relatively new. André *et al*. (2005) simulate the impacts of an Environmental tax reform on CO_2 and SO_2 emissions by implementing a Computable General Equilibrium (CGE) model and find that the double-dividend hypothesis (environmental and non-environmental welfare are improved) arises if CO_2 emissions are selected as environmental target. Ekins *et al*. (2011) analyze economic and environmental effects of an environmental-tax reform (ETR) in the UK, and find that substantial amount of green-gas emission can be achieved by the ETR. Miller and Vela (2013) analyzes the effectiveness of environmental taxation for 50 countries by employing cross-section regression and panel dynamic regression, The authors detect that the countries with higher revenues exhibit higher reduction in CO_2 emission.

Gemechu *et al*. (2014) analyze direct and indirect effects of environmental taxation on CO_2 emission intensities by employing input-output (EIO) models and find that the economic and environmental goals cannot be met by the environmental taxation at the same time. More recently, Lin and Jia (2019) examine the impacts environmental taxation on CO_2 emission reduction for China by implementing (CGE) model and find that adjusting environmental tax has an important effect on CO_2 emission and the CO_2 emission will surge over time of ad valorem tax is implemented on enterprises.

In this study, we analyze short/long run transmissions between CO_2 emissions, environmental taxes, energy consumption and growth for a panel set of 24 European Union countries by employing panel VAR (PVAR) model.

The rest of this study is organized as follows: Section 2 provides brief literature regarding the studies that investigate environmental taxes and greenhouse gas emissions. Section 3 presents the empirical model and the data of the study. Finally, Section 4 highlights the main findings and contributions of this study and concludes it.

2. LITERATURE REVIEW

Environmental taxes are kind of Pigouvian taxes which aim to reduce environmental costs of greenhouse gas emissions. CO_2 emission constitutes 76% of global greenhouse gas emissions[5], scholars have focused on the effects of carbon taxes on global CO_2 emission. A body of studies implements simulation models in order to detect potential impacts of carbon taxes on CO_2 emissions. Among them, Bruvoll and Larsen (2004) employ applied general equilibrium simulation to analyze the effects of carbon taxes on emission and they found little impact of taxes in reducing emission. Liang *et al*. (2007) implement the CGE (Computable General Equilibrium) model to simulate the carbon tax policy for China. The results of the study underline the negative impacts of carbon taxes on the economy. Allan *et al*. (2014) apply AMOSENVI (multi-sectoral energy-economy-environment general equilibrium model) for Scotland to capture the impacts of carbon taxes on CO_2 emission and economic activity. According to the findings of the study, the taxes could improve economic activity and could mitigate emissions. Along similar lines, Elliott and Fullerton (2014) employ a two-sector general equilibrium model to detect the effects of carbon taxes on leakage (CO_2 emission in elsewhere) and report the dependence of emission on elasticity and share parameters. kage (CO_2 emission in elsewhere) and report dependence of emission on elasticity and share parameters.

It is worthwhile considering that the impacts of carbon or energy taxes on CO_2 emission have been analyzed with the application of empirical models yet the number of them is limited. Lin and Li (2011) employ the difference-in-difference (DID) model to determine the effects of carbon taxes on CO_2 emission and growth for 17 EU countries. Jeffrey and Perkins (2015) analyze the relationship between energy taxes and CO_2 emissions by employing the OLS model for EU-27 countries. The authors report a negative, significant relationship between implicit energy taxes and total carbon intensity.

On the other hand, some empirical or simulation studies focus on the relationship between environmental taxes and economic growth. Different findings are reported by these studies. Bosquet (2000) detects positive impacts of environmental taxes on the environment and the economy, meanwhile, Fisher and Van Marrewijk (1998) highlight the beneficial effects of

[5] Global emissions by the green gas are given in the United States Environmental Protection Agency's web site (https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data) as follows: Carbon Dioxide (76%), Methane (14%), Nitrous Oxide (6%) and F-Gases (2%).

pollution taxes on economic activity. Causal bi-directional relationships between economic growth and environmental tax revenues are analyzed by a recent study and a long-run causality running from economic growth to taxes is detected (Abdullah and Morley, 2014).

The aforementioned research question have been analyzed by more recent studies. Silajdzic and Mehic (2018) analyze the impacts on environmental taxes on CO_2 emission for ten emerging economies by employing fully-modified least squares (FM-OLS) model. Empirical findings of the study strongly support an inverted U-shaped relationship between economic growth and the environment, whereas don't find effectiveness of environmental taxes in protecting the environment. Hong *et al*. (2018) examine the existence of double-dividend hypothesis for Taiwan and find that the environmental taxes promote environmental protection and economic growth in the short-run, while this case doesn't exist in the midterm. Boehringer *et al*. (2019) focus on the impacts of green-tax reform in reduction of harmful emissions including CO_2 emission for Spain using coupled microsimulation and computable equilibrium analyses. The authors report that such a green-tax reform entails substantial reduction in green-gas emission. Li and Masui (2019) analyze the impacts of environmental taxes in reducing CO_2 emission for China by simulating the CGE model. According the estimations of the study, environmental taxes are effective in reducing CO_2 emission most scenarious.

3. METHODOLOGY AND DATA

In this study, we use annual data that consists of GDP (current US$ per capita), CO_2 emission (metric ton per capita), energy use (kg of oil equivalent per capita) and environmental tax revenues (proportion of GDP) from 1995 through 2014 for 24 EU countries[6]. CO_2 emission and energy use data has been collected from World Development Indicators, WDI. Environmental tax revenues have been obtained from Statistical Office of European Union (Eurostat)[7].

This section is organized as follows: First, we test for cross-sectional dependence in our data. Second, the panel unit root test is employed to identify the stationarity of the variables.

[6] 24 EU countries are as follows: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden and The United Kingdom.

[7] By the statistical guide of Eurostat, environmental taxes are divided into 4 groups: Energy taxes (including CO_2 taxes), Transport taxes, Pollution taxes and Resource taxes (excluding taxes on oil and gas).

Third, the PVAR model is estimated to capture the short/long-run impacts of environmental taxes on CO_2 emission.

3.1. Test for Cross-Sectional Dependence

Early panel data literature ignored cross-sectional dependence of errors and assumed homogenous slopes. Conventional panel data estimators such as fixed or random effects or generalized methods of moments (GMM) could lead to inconsistent estimators owing to cross-sectional dependence and accordingly, an unobserved shock may be correlated with the regressors (Andrews, 2005; Sarafidis and Wansbeek, 2012)

With a significant increase in the availability of data in terms of countries, regions or industries globally, the panel literature has moved from micro panels to large panel models in which individual units need not be cross-sectionally independent (Chudik and Pesaran, 2013). Accordingly, the second-generation panel data literature has begun to test for cross-sectional dependence.

To test cross-sectional dependence in our panel data, we employ the CD test of Pesaran (2004). The CD test is applicable to unit root dynamic heterogeneous panels with short time span T and large number of units N.

Pesaran (2004) proposes the CD, which is based on pair-wise correlation coefficients as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{I=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right) \sim N(0,1) \qquad i,j = 1, \ldots, N \tag{1}$$

where $\hat{\rho}_{ij}$ is the sample estimate of the pair-wise correlations of residuals. Table 1 provides the CD test results for environmental tax revenues, CO_2 emission per capita, energy use per capita and GDP per capita.

Table 1. CD Test Results

Variable	CD Test
CO_2 Emission	64.631***
Environmental Tax Revenues	52.799***
Energy Use	66.166***
GDP	66.121***

Note: *,** and *** show significance levels at 10%, 5% and 1% confidence intervals, respectively. Null hypothesis is cross sectional independence.

Source: Author's calculations.

According to the CD test results, the null hypothesis of cross-sectional independence is rejected for all variables at 1% significance level.

3.2. Panel Unit Root Test

Due to existence of cross-sectional dependence, second-generation panel unit root test is used to detect stationary of variables. In this respect, we implement the CIPS panel unit root test of Pesaran (2007).

Pesaran (2007) proposes a model in which the standard augmented Dickey-Fuller (ADF) regressions are augmented with the lag levels of cross-sectional levels and the first differences of individual series. This panel unit root test is called cross-sectionally augmented ADF (CADF) and CADF regression is defined as follows:

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + d_i \Delta \bar{y}_t + \varepsilon_{it} \quad (2)$$

In line with the above formulation, the cross-sectionally augmented IPS (CIPS) is obtained as follows:

$$CIPS = N^{-1} \sum_{i=1}^{N} CADF_i \quad (3)$$

Table 2 presents the CIPS panel unit root test results.

Table 2. CIPS Panel Unit Root Results

Variable	Intercept	Intercept + trend
$\Delta CO2EmissionPC$	-14.294***	-12.015***
$\Delta Environmental\,TaxRevenue$	-14.431***	-12.270***
$\Delta EnergyUsePC$	-14.689***	-12.557***
$\Delta GDPPC$	-11.439***	-8.859***

Note: *,** and *** show significance levels at 10%, 5% and 1% confidence intervals, respectively. Null hypothesis is non-stationarity.

Source: Author's calculations.

The CIPS panel unit root test results imply stationarity of the first difference of all variables in their intercept forms at 1% significance level.

3.3. Panel VAR Model

Panel VAR (PVAR) model has the same structure as the VAR models, in which all variables are assumed to be endogenous and independent, and a cross-sectional dimension is added to the representation (Canova and Ciccarelli, 2013:7).The PVAR models are used by earlier studies for micro-dimensional estimations (Holtz Eakin *et al*., 1988).

Panel VAR models able to capture, "*(i) both static and dynamic interdependencies, (ii) treat the links across units in an unrestricted fashion, (iii) easily incorporate time variations in the coefficients and in the variance of the shocks, and (iv) account for cross sectional dynamic heterogeneities*" (Canova and Ciccarelli, 2013:2).

In his study, the PVAR model is specified as follows:

Let Y_t be $N \times 1$ matrix of endogenous variables panel VAR model with order p is defined as follows:

$$Y_{it} = A_{0i}(t) + A_i(l)Y_{it-p} + u_{it}\ , \quad i = 1, \dots, 24 \quad \mathrm{t} = 1995, \dots, 2014 \tag{4}$$

where, $\varepsilon_{it} \sim iid(0, \mu_\varepsilon)$, $A(L)$ is matrix of polynomial in the lag operator, L, for each country $i = 1, \dots, 24$. Y_t is (4×1) vector that consists of $\Delta CO2EmissionPC$, $\Delta Environmental\ TaxRevenue$, $\Delta EnergyUsePC$, $\Delta GDPPC$

Lag order selection criteria in the panel VAR model using GMM estimators is given in Table 3.

Table 3. Lag Order Selection Results

Lag	**CD**	**J**	**J p-value**	**MBIC**	**MAIC**	**MQIC**
1	.1363404	339.7584	1.47e-45	54.63018	243.7584	168.7116
2	.6557164	272.0791	7.20e-40	81.99366	208.0791	158.0479
3	.8819297	114.8138	5.42e-17	19.77105	82.81379	57.79817

In the lag selection, we use the first 4 lags of variables for the first to third panel VAR model[8].

The third order panel VAR model is preferred since it has the smallest MBIC, MAIC and MQIC values.

Based on the selection criteria, the third order panel VAR model is estimated where the first 4 lags of variables are used as instruments. In the next step, causality between variables is analyzed using panel Granger causality test. Table 4 presents the panel Granger causality test results for CO_2 emission per capita, environmental tax revenues.

Table 4. Panel Granger Causality Test Results

Equation \ Excluded	chi2	df	Prob > chi2
Environmental Tax Revenues ⇒ CO_2 Emission	132.848	3	0.000
Energy Use ⇒ CO_2 Emission	141.368	3	0.000
GDPPC ⇒ CO_2 Emission	270.314	3	0.000

[8] We use Hansen's (1982) J statitistic and corresponding p-value and moment model selection criteria of Andrews and Lu (2001) to find optimal lag with GMM estimators.

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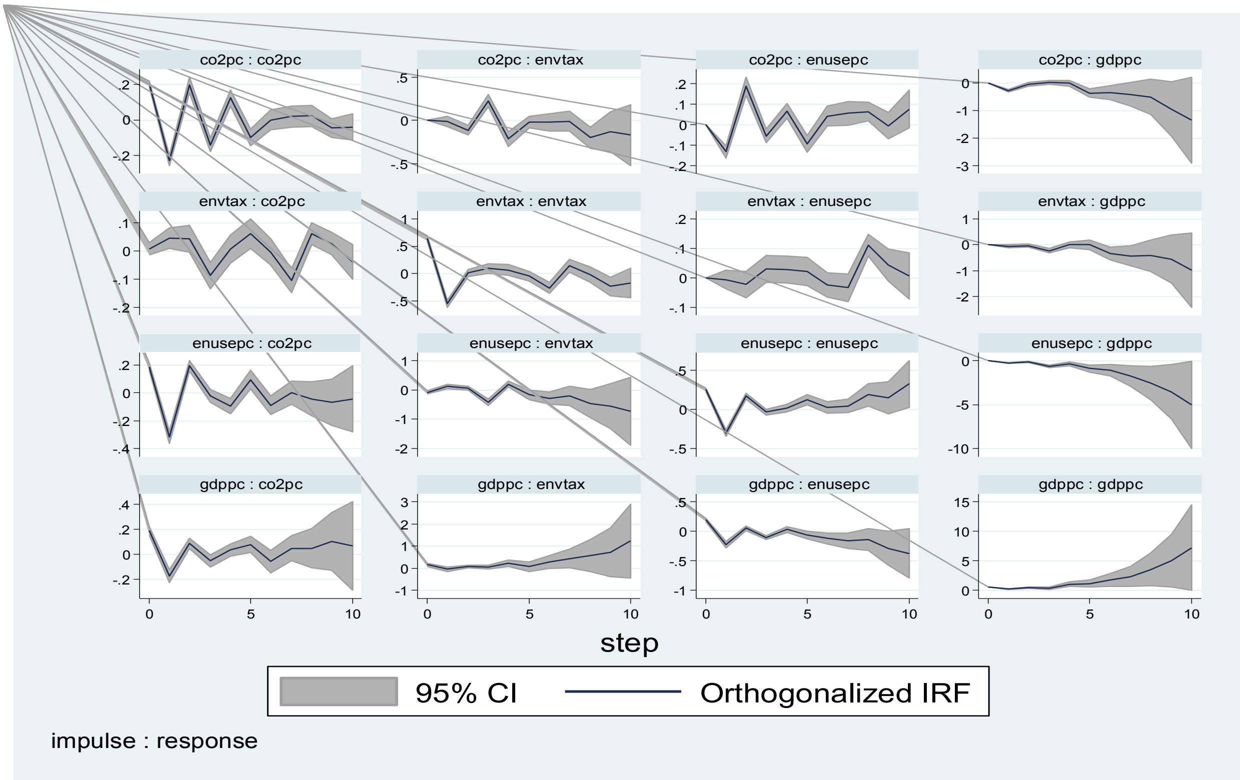
As seen in Table 4, environmental tax revenues, energy use and GDP per capita Granger cause to CO_2 emission per capita.

In the final step, the IRFs are exhibited to detect short/long-run linkages between from CO_2 emission per capita to environmental tax revenues. Figure 1 depicts the IRF plots.

Figure 1. PVAR IRF Plots



As seen in Figure 1, a positive shock on the level of environmental tax leads to a reduce in CO_2 emission in the short-run (after approximately 2 years than the shock), whereas the impact response of CO_2 emission to positive environmental tax reverse back from the 3[3d] year and fluctuates thereafter. As a consequence, CO_2 emission falls in response to a permanent increase in the environmental tax revenue in short-run.

On the other hand, the impact response of CO_2 emission to a one percent positive energy use shock and a one percent positive growth shock is initially negative, reverses back starting from the 1[st] year and fluctuates till 7[th] year and stabilizes in the long-run. The IRF results are in line with the findings in the previous studies and potentially suggest an inverted U shape relationship between GDP and CO_2 emission.

4. CONCLUSION

As a Pigovian tax, the environmental tax has been levied by the states across the world in internalizing negative externalities since the 1990s. However, the efficiency of environmental taxes in mitigating green gas emission has been analyzed by the limited number of studies in the literature. Aiming to fill this gap, this study investigates short/long run transmission mechanisms between environmental taxes and CO2 emission for 24 EU states using the PVAR model in the 1995-2014 period.

Panel Granger causality test results indicate that environmental taxes, gdp per capita and energy use Granger cause to CO_2 emission. IRFs of the PVAR model are estimated to depict the impact response of CO_2 emission to the other variables in the PVAR model. According to the IRFs, the impact response of CO_2 emission to environmental tax is negative in the short-run. This result verifies efficiency of environmental taxes in reducing CO_2 emission in the short term. On the other hand, a positive shock on the level of growth and a positive shock on the level of energy use lead to an increase in CO_2 emission temporarily, yet the impact response of CO_2 emission to a positive growth and a positive energy use shock fluctuates in the long-run. This finding support the Environmental Kuznets Curve hypothesis.

Empirical results of the study underline the efficiency of environmental taxes in mitigating green gas emission and supports the OECD’s argument whıch says “*Taxes can directly address the failure of markets to take environmental impacts into account by incorporating these impacts into prices*” (OECD, 2017).

The findings of the study support the argument that proposes “*environmental taxes could be used as an important policy tool in reducing green gas emissions*”. Nevertheless, various policies should be applied simultaneously and globally along with environmental taxes to mitigate the harmful effects of green gas emissions for humanity and the environment.

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