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Threshold effect in the relationship between environmental taxes and CO2 emissions: A PSTR specification

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Abstract

This paper examines the relationship between environmental taxes and CO2 emissions for the OECD countries over the period 1994-2014, within the framework of the environmental Kuznets curve (EKC). By performing Panel Smooth Threshold Regression (PSTR) model, we found that the nexus between environmental taxes and CO2 emissions is non-linear. Besides, results show that there exists a statistically positive relationship between environmental taxes and CO2 emissions above the threshold level of 2.67\%, above which environmental taxes starts increasing CO2 emissions in OECD countries. Findings indicate also that there is a quadratic relationship between CO2 emissions and economic growth, confirming the existence of an Environmental Kuznets Curve (EKC) for OECD countries. This paper supports the view that a properly-implemented environmental taxes would result in the reduction of CO2 emissions in OECD countries.

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1 Introduction

Most of OECD countries are largely dependent on fossil energy, which significantly contributes to the development of the current life standard, revolutionizing the transportation, communications, and industry. However, from the oil shocks of 1973 and 1979, developed countries realized that their material prosperity, based on the intensive use of exhaustible natural resources, was threatened. Moreover, the industrial development model, largely based on non-renewable resources, is perceived as unsustainable. Therefore, it became essential to implement a new development mode bearing new challenges: sustainable development. Thus, since the Kyoto Protocol was signed in 1997, OECD countries have set voluntary targets for the reduction of pollution and global warming.Hence, to mitigate pollution and to achieve sustainable development, policy makers have become increasingly interested in the use of environmental taxation. Based on the double dividend hypothesis, increased taxes on polluting activities can provide an environmental and economic efficiency improvement. Otherwise, revenues from environmental taxes are used to reduce other taxes such as income taxes which distort labor supply and saving decisions (DÖKMEN (2012)).

While, since the EKC hypothesis was introduced by Kuznets in 1955 several empirical studies have been conducted on the relationship between CO2 emissions and economic growth, relatively little attention has been given to the potential threshold effects in the relationship between environmental taxes and CO2 emissions.For instance, Grossman and Krueger (1991), Grossman and Krueger (1995) and Selden and Song (1995) examined the EKC hypothesis empirically since the 1990s. However, the research into the relationship between economic growth and CO2 emissions has not reached consensus so for. Some researchers have found the traditional inverted U-shaped EKC link between economic growth and CO2 emissions. For example,Narayan and Narayan (2010) tested the EKC hypothesis based on the short- and long-run for 43 developing countries. Their findings confirm the EKC hypothesis. Likewise, Nasir and Rehman (2011) investigated the relationship between carbon emissions, income, energy consumption, and foreign trade in Pakistan for the period 1972-2008. Their results confirm the existence of EKC for Pakistan. By applying the autoregressive distributed lag (ARDL) method, Saboori et al. (2012) studied the casual relationship between economic growth and carbon dioxide emissions for Malaysia for the years from 1980 to 2009. Results show that there is an inverted U-shaped relationship between CO2 emissions and GDP in both the short and long run, confirming the EKC hypothesis. besides, by using threshold cointegration tests, Kanjilal and Ghosh (2013) revisited the cointegrating relationships among carbon emissions,energy use, economic activity, and trade openness for India for 1971-2008. Their results confirm the EKC hypothesis for India.Apergis and Ozturk (2015) tested the EKC hypothesis with annual data from 1990 to 2011 by using the general method of moments (GMM) and found an inverted U-shaped association between emissions and per capita income, supporting the EKC hypothesis.Al-Mulali et al. (2015) analyzed the effect of renewable energy consumption, GDP growth and financial development on CO2 emission by investigating the validity of the Environmental Kuznets Curve (EKC) hypothesis in Latin America and Caribbean developing countries over the period 1980-2010. Findings indicate an inverted U-shape relationship between CO2 and GDP and confirm the Environmental Kuznets Curve hypothesis.Al-Mulali and Ozturk (2016) examined the effect of energy prices on pollution and investigate the existence of environmental Kuznets curve (EKC) hypothesis in 27 advanced economies. Findings show that the inverted U-shaped relationship between GDP and CO 2 emission was confirmed which signifies the presence of the EKC hypothesis. Bilgili et al. (2016) employed a panel data set of 17 OECD countries for 1977-2010 by using panel fully modified ordinary least squares (FMOLS) and panel dynamic OLS (DOLS) estimations and the findings supported the EKC hypothesis for the panel.Onater-Isberk (2016) examined the the use of noncarbohydrate energy on carbon emissions under the Environmental Kuznets Curve (EKC) hypothesis in 27 OECD countries. Their results show that the EKC hypothesis is statistically insignificant in Canada, Greece, Italy and New Zealand, indicating a monotonic increase in relationship between carbon emissions and GDP per capita.

Contrariwise, other researchers have not joined the notion that the EKC always exists. For instance, Akbostancı et al. (2009) and Ozturk and Acaravci (2010) reported that the relationship between CO2 emissions and economic growth is N-shaped.Tsurumi and Managi (2010) examined the EKC hypothesis for 30 OECD countries for the period 1960-2003. Their findings indicate that economic growth is not sufficient to decrease CO2 emissions. Fodha and Zaghdoud (2010), Iwata et al. (2011), Arouri et al. (2012) and Farhani and Ozturk (2015) have found a linear relationship between CO2 emissions and economic growth. Fujii and Managi (2013) analyzed the relationship between the CO2 emissions of different industries and economic growth in OECD countries from 1970 to 2005. By testing an environmental Kuznets curve (EKC) hypothesis, they found that total CO2 emissions from nine industries show an N-shaped trend instead of an inverted U or monotonic increasing trend with increasing income. Moreover, their results indicate that the EKC turning point and the relationship between GDP per capita and sectoral CO2 emissions differ among industries according to the fuel type used. By using a panel data on the European Union countries over the period 1992-2010, Mazur et al. (2015) tested the Environmental Kuznets Curve (EKC) relationship between CO2 emissions and GDP per capita. Their results show that there is no EKC U-shape for the whole EU area. However, their findings indicate that the EKC effect was consistently negative and statistically significant across the high-income EU member countries.

Otherwise, Andrei et al. (2016) using the Granger causality tests, they evaluate the casual relationship between environmental taxes, energy production and consumption and economic growth in Romania over the period 2000-2011. Their results show that there is a long-run casual effect on GDP. Based on panel of European countries and a separate panel of OECD covering the period 1995-2006, Abdullah and Morley (2014) examined the casual relationship between environmental taxes and economic growth. Their results indicate a bidirectional casual relationship between environmental taxes and economic growth. Conefrey et al. (2013) analyzed the medium-term effects of a carbon tax on growth and CO2 emissions in Ireland. They found that double dividend exist if the carbon tax revenue is recycled through reduced income taxes. By using panel data of 29 Chinese provinces from 1999 to 2008, Zhixin and Ya (2011) examined the impact of carbon tax on economic growth in China. They found that the impact of carbon tax on economic growth is various in Chinese regions because of different economic structures.

To the best of our acknowledge, the asymmetric relationship between environmental taxes and CO2 emissions for the OECD countries has not been previously studied. Thus, to fill this gap, we propose to investigate the potential threshold effects in the relationship between environmental taxes and CO2 emissions for OECD countries in addition to verifying the Environmental Kuznets Curve (EKC) hypothesis. Different from previous studies, we use the Panel Smooth Threshold Regression (PSTR) model recently developed by González et al. (2005) which allows for smooth changes in country-specific correlations depending on a threshold variable.

The rest of the paper is structured as follows. Section 2 presents the data and the model specification. Section 3 shows the model estimation and results and section 4 concludes.

2 Data and model specification

In this study, we use a balanced annual data of 546 observation for 26 countries from OECD. The period of the study spans from 1994 to 2014. All variables are collected from the U.S. Energy Information Administration, the Penn World Table (Feenstra et al. (2015)), the OECD database (OECD (2017)) and World Bank Development Indicators (WDI) database. The 26 OECD countries used in the sample include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, South Korea, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States .

The variables used in this study are per capital CO2 emissions in metric tons of carbon dioxide per person is measured from the consumption and flaring of fossil fuels which is the dependent variable for our model. The explicative variables include Renewable energy consumption (net geothermal, solar, wind and biomass energy) measured in millions of kilo watt hours (MkWh), the total environmental tax revenues (the sum of energy taxes, pollution taxes, resource taxes and transport taxes) and real GDP per capita measured in millions of constant 2010 U.S dollars.

To detect the potential non-linear relationship between environmental taxes and CO2 emissions, we apply PSTR model developed by González et al. (2005). We estimate a PSTR model describing the Environmental Kuznets Curve (EKC) with threshold one or two extreme regimes and a single transition function to illustrate relationship between environmental taxes $lntaxes_{it}$ and CO2 emissions $lnCO2_{it}$:

$$y_{it} = \mu_i + \beta_0 x_{it} + \beta_1' x_{it} g(lntaxes_{it}, \gamma, c) + \varepsilon_{it} \quad (1)$$

Where i = 1. . ..N, t = 1. . ...T; N and T denote the cross-section and time dimensions of the panel, respectively; μ_i represents the fixed individual effect and ε_{it} is the errors. The dependent variable y_{it} is a scalar,x_{it} is a k-dimensional vector of time-varying control variables. Transition function $g(lntaxes_{it}, \gamma, c)$ is a continuous function and depends on threshold variable ($lntaxes_{it}$) and normalized to be bounded between 0 and 1, and these extreme values are associated with regression coefficients β_0 and $(\beta_0 + \beta_1)$. González et al. (2005) consider, following Granger et al. (1993) for the time series STAR models, the following logistic transition function:

$$g(lntaxes_{it}, \gamma, c) = \left(1 + exp(-\gamma \prod_{j=1}^{m} (lntaxes_{it} - c))\right)^{-1} \text{ with } \gamma > 0 \text{ and } c_1 \leq c_2 \leq ....c_m \quad (2)$$

Where $c_j = c_1....c_m$, which is an m -dimensional vector of parameters; the slope parameter determines the smoothness of the transition. For $m = 1$, the model has the two extreme regimes separating low and high values of $lntaxes_{it}$ with a single monotonic transition of the coefficients from β_0 and $(\beta_0 + \beta_1)$ as $lntaxes_{it}$ increases. For a higher value , the transition becomes rougher and transition function $g(lntaxes_{it}, \gamma, c)$ becomes the indicator function $g(lntaxes_{it}, c)$. When tends towards infinite, indicator function $g(lntaxes_{it}, c) = 1$ if event $lntaxes_{it} > c$ occurs, and indicator function $g(lntaxes_{it}, c) = 0$ otherwise. When is close to 0, the transition function $g(lntaxes_{it}, \gamma, c)$ is constant. In that case, the PSTR converges towards the tworegime panel threshold regression (PTR) of Hansen (1999). In general, for any value of m, the transition function $g(lntaxes_{it}, \gamma, c)$ is constant when is close to 0. In which case, the model in equation (1) becomes a linear panel regression model with fixed effects.

The empirical model to be estimated is presented as follow:

$$lnCO2_{it} = \mu_i + \alpha lnCO2_{it-1} + \beta_0^0 lny_{it} + \beta_1^0 lny_{it}^2 + \beta_2^0 lntaxes_{it} + \beta_3^0 lnre_{it} + [\beta_0^1 lny_{it} + \beta_1^1 lny_{it}^2 + \beta_2^1 lntaxes_{it} + \beta_3^1 lnre_{it}] g(lntaxes_{it}, \gamma, c) + \varepsilon_{it}$$

The econometric approach is based on four steps. In the first one, the stationarity of each variable is examined by performing two unit roots tests, namely, Levin et al. (2002) and Im et al. (2003), these two tests incorporate both cross-sectional independence (LLC, IPS and Maddala and Wu tests) and cross sectional dependence cases. In the second one, we test both the linearity against the PSTR model and the number of transition function. In the third one, we apply the non-linear least squares methods to estimate our PSTR model.Finlay, we apply the Arellano and Bover (1995) and Blundell and Bond (1998) System-GMM as a robustness check of the PSTR estimates.

3 Model estimation and results

3.1 Panel unit root tests

All the asymptotic theory for STR models and also PSTR model extended by González et al. (2005) are for stationary regressors. Therefore, the procedures of PSTR specification rely on the assumption that all variables in equation (1) are I(0) stationary in level. Results of panel unit root tests are reported in Table 1. From this table it can be noted that panel unit root tests, namely, Levin et al.

(2002) and Im et al. (2003) reject the null hypothesis at the 1% and 5% level of significance for all panel time series taken in level.

Table 1: Panel unit root test in level

Variables	LLC		IPS	
	statistic	prob	statistic	prob
lnco2	-3.6798	0.0001***	-2.1980	0.0140**
lny	-10.3257	0.0000***	-4.71209	0.0000***
lny2	-5.46800	0.0000***	-5.60166	0.0000***
lnre	-2.7650	0.0028**	-2.9954	0.0014**
lntaxes	-3.57942	0.0002***	-4.81617	0.0000***

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

3.2 The linearity test

The goal is to demonstrate that the relation between environmental taxes and CO2 emissions is non-linear. To this end, we conduct a test of linearity against the PSTR model. The null hypothesis is $H_0 : \beta^1 = 0$ against the alternative $H_0 : \beta^1 \neq 0$. However, this test is not standard since under the null hypothesis, the PSTR model contains nuisance unidentified parameters (Hansen, 1996). As suggested by Luukkonen et al. (1988), we replace the transition function by its first-order Taylor around $\gamma = 0$. The null hypothesis becomes $H_0 : \gamma = 0$. After rewriting, we obtain the following regression:

$$lnCO2_{it} = \mu_i + \alpha lnCO2_{it-1} + \beta_0^{*0} lny_{it} + \beta_1^{*0} lny_{it}^2 + \beta_2^{*0} lntaxes_{it} + \beta_3^{*0} lnre_{it} + [\beta_0^{*1} lny_{it} + \beta_1^{*1} lny_{it}^2 + \beta_2^{*1} lntaxes_{it} + \beta_3^{*1} lnre_{it}] g(lntaxes_{it}, \gamma, c) + \varepsilon_{it}$$

where the vectors of parameter $\beta^{*1}......\beta^{*m}$ are multiples of γ and ε_{it}^* is ε_{it} plus the residue of Taylors development. The null hypothesis of the linearity test becomes $H_0 : \beta^{*1} = ... = \beta^{*m} = 0$. The linearity is tested with standard tests. We use Wald test expressed as follows:

$$LM_w = \frac{NT(SSR_0 - SSR_1)}{SSR_0}$$

where SSR_0 and SSR_0 are the panel sum of square residuals under H_0 (linear panel model with individual effects) and the panel sum of square residual under H_1 (PSTR model with m regimes) respectively. For small sample, González et al. (2005) suggest to use the Fisher test defined as:

$$LM_F = \frac{NT(SSR_0 - SSR_1)/mk}{SSR_0/TN - N - mk}$$

with k the number of explanatory variables. LM_F follows a Fisher distribution with mk and TN-N-mk degrees of freedom (F(mk,TN-N-mk)). All these linearity tests are distributed $\chi^2(k)$ under the null hypothesis.

Results of linearity tests are reported in Table 2. From this table it can be noted that the hypothesis of linearity of the model is rejected at 1% and 10% significance level.Moreover, rejection of linearity is stronger for m = 2, the exponent specification (m = 2) is preferred to logistic one (m = 1). The results imply that there exists non-linear relationship between environmental taxes and CO2 emissions in the OECD countries.

Table 2: Linearity tests

Variables	m=1		m=2	
	Statistic	P-value	Statistic	P-value
Lagrange multiplier (LM_w)	2.77526	0.09573*	43.03786	0.0000***
Fisher Test (LM_F)	2.64375	0.10460	22.20603	0.0000***
Likelihood-ratio test (LR)	2.78278	0.09528*	44.94702	0.0000***

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

3.3 The number of regimes test

The test consists to verify the null hypothesis for which the PSTR model has a single transition function (1 = m) against the alternative hypothesis that the PSTR model has at least two transition functions (2 = m). The decision of the test relies on the statistics of LR and LM_F . If the coefficients are statistically significant at the critical level of 5%, we reject the null hypothesis and we conclude that there exist at least two transition functions. Otherwise, we do not reject the null hypothesis and we conclude that the model has two regimes and therefore has one threshold.

Results from Table 3 indicate that both hypothesis without threshold (r = 0) and with at least two thresholds (r = 2) are rejected at the 1% and 5% significance for the two tests. This means that in the context of the OECD countries, the relationship between environmental taxes and CO2 emissions has only one threshold or two regimes.

Table 3: Tests for the number of regimes

Variables	r=0		r=1	
	Statistic	P-value	Statistic	P-value
Fisher Test (LM_F)	6.6803	0.0013**	14.4760	0.0000***
Likelihood-ratio test (LR)	12.4553	0.0019**	48.01194	0.0000***

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

3.4 PSTR

Given the evidence of non-linearity, we estimate PSTR by applying nonlinear least squares technique. The results of the PSTR estimations are reported in Table 4.

Table 4: Parameter estimation using PSTR, 1994-2014.

Variables	PSTR	
	Coefficient	Prob.
lny	0.8344	0.0000 * **
lny2	-0.0359	0.0000 * *
lnre	-0.1915	0.0000 * **
lntaxes	-0.1077	0.0074**
$lntaxes * g(lntaxes_{it}, \gamma, c)$	0.0802	0.0000 * **
	Transition parameters	
c	2.6702	
γ	5.0000	
AIC	-6.98904	
BIC	-6.93127	

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

All the coefficients are significant at the 1% and 5% significance level and they can be interpreted as elasticity estimates. For low environmental taxes regime, environmental taxes coefficient is statistically significant and negative at 5% significance level. An increase of 1 percent of environmental taxes decreases CO2 emissions by 10%.For high environmental taxes regime, environmental taxes coefficient is statistically positive and significant at 1% significance level. An increase of 1 percent of environmental taxes increases CO2 emissions by 8%.The estimated threshold for the environmental taxes for OECD countries is 2.67% and the speed of transition is relatively speed ($\gamma = 5$). This means that, below the estimated threshold level of 2.67% environmental taxes decreases CO2 emissions. However, beyond the estimated threshold the opposite effect on CO2 emissions occurs. Indeed, to maintain a usual level of production, under the 'European Union Emission Trading Scheme', companies with high CO2 emissions are able to purchase an 'Allowances' for emissions from companies with low CO2 emissions.

The results indicate that a 1% increase in economic growth increases CO2 emissions by 83%. This means that economic growth simulate carbon dioxide emissions in OECD countries. The CO2 emissions increases in OECD countries as the production of goods and services grow which requires energy, historically fueled by fossil fuels. Thus, the production of goods and services generates greenhouse gases (GHGs) and air pollution both directly and through the activities of the supply chains on which they depend. For example, trade openness increases embodied emissions in international trade (EET). Especially, the greater the increase in the exporting of mining products, metal products, electrical, electricity, trade and transport, and other manufacturing products, the greater the increase in embodied emission in exports (EEE)(Islam et al. (2016)). Results show also that there are inverse U-shaped relationships between CO2 emissions and real GDP per capita for the EKC model.

Contrary to the effect of economic growth, renewable energy decreases CO2 emissions in OECD countries. Findings show that renewable energy is associated negatively and significantly at 1% with the dependent variable. Specifically, an increase of 1 percent of renewable energy decreases CO2 emissions by 19%. Indeed, most of OECD countries by supporting investments in more efficient and cleaner energies, they accelerated their renewable roll-out and have set voluntary targets for the reduction of CO2 emissions by 20% in 2020 Marchal et al. (2011).

In order to check the robustness of our estimation, we apply The Arellano and Bover (1995) and Blundell and Bond (1998) System-GMM . The estimated results from System-GMM estimates are reported in Table 5. We find that all coefficients sign of System-GMM are consistent with those of PSTR estimate. Furthermore, results show that there is no autocorrelation in our System-GMM estimation, meaning that our result is not biased.

Table 5: Parameter estimation using System-GMM, 1994-2014.

Variables	System-GMM	
	Coefficient	Prob.
L.lnco2	-.1608017	0.568
lny	.3873865	0.124
lny2	-.0201258	0.082 **
lnre	-.3336778	0.0000 ***
lntaxes	-7.64675	0.023**
$lntaxes * lntaxes$	1.437726	0.019 **
const	9.691603	0.053*
$AR(1)$	0.2995	
$AR(2)$	0.3696	
Hansen's J-test (P-Value)	0.9709	

Notes: ***, **, * indicate statistical significance at 1, 5 and 10 percent level of significance, respectively.

4 Conclusion

This paper explores the relationship between environmental taxes and CO2 emissions for the OECD countries over the period 1994-2014. Results from Panel Smooth Threshold Regression (PSTR) model estimates indicate that the nexus between environmental taxes and CO2 emissions is non-linear. Moreover, findings show that there exists a statistically positive relationship between environmental taxes and CO2 emissions above the threshold level of 2.67%, above which environmental taxes starts increasing CO2 emissions in OECD countries. Results indicate also that there is a quadratic relationship between CO2 emissions and economic growth, confirming the existence of an Environmental Kuznets Curve (EKC) for OECD countries.

The findings of this study assert that below the estimated threshold environmental taxes decreases CO2 emissions. Thus, a properly-implemented environmental taxes would result in the reduction of a country's carbon emissions and produce a substantial economic benefits (Economy (2014)). Moreover, environmental taxes correct the negative externalities which negatively affect economic growth. Besides, negative externalities such as climate change, health risks, soil and ocean acidification associated with carbon emissions, require exorbitant spending on repairs and rebuilding (Alagidede et al. (2016),Hübler et al. (2008) and Tol (2002)). Moreover, results report that renewable energy reduces CO2 emissions. Therefore, the expansion of renewable energy would also diminish the dependence on fossil fuels energy and decreases its associated pollution. However, an inverted-U shape relationship between CO2 emissions and income was found. Thus, our results support the EKC hypothesis for the OECD countries.

This paper has some relevant policy implications.To assure a minimum of environmental protection and to achieve sustainable development, both developed and developing countries have to optimize their environmental taxes implementation and reduce there dependence on fossil energy. As a path to the renewable energy, green revenues should favor investments in the promotion of more efficient and cleaner energies.

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