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**How do environmental taxes influence the impact of tourism on environmental performance? Evidence from EU-28 countries**

**Abstract**

Evidence of the accumulation of carbon dioxide (CO2) over the years is placing greater emphasis on the use of taxes to achieve a sustainable environment. This study evaluates the effectiveness of environmental taxes in mitigating the effect of international tourism receipts on environmental performance in EU-28 countries for the period 2002 to 2019. The empirical results suggest evidence of a single threshold effect. The results further show that the effect of international tourism receipts on environmental performance is negative once environmental taxes are below the threshold level of 5.48. However, once environmental taxes cross a threshold level, international tourism receipts would improve environmental performance. This suggests a significant difference in the way international tourism receipts influence environmental performance during periods of low and high environmental taxes. These findings, therefore, provide insights to policymakers and other stakeholders on the use of environmental taxes as an instrument to avert global warming and other significant climate changes from energy-related pollution.

**Keywords:** Environmental taxes, Environmental performance, tourism, Panel Threshold, EU-28 countries

**1. Introduction**

In addition to being implemented as a climate policy instrument toward a transition to a carbon-neutral economy by 2050 and driving the European Commission's 'European Green Deal' that targets a 55% net reduction of greenhouse gas (GHG) emissions by 2030, the environmental taxation system in Europe is also seen as a potential instrument for reform programs. Given its revenue-generating capability, revenues accrue from the environmental tax could avert future economic setbacks arising from potential costs of the welfare system and declining labour tax revenues associated with the region's rising aging population. Specifically, the region's environmental tax policy is being championed as an effective instrument that directly targets revenue collection through taxation of resource use and environmental pollution as against the traditional taxation on labour and capital (European Environment Agency, 2022). Despite this projection, only about 5.4 percent of total taxes and social contributions in the European Union (EU) is accrued from environmental taxes (including energy, resource, pollution, and transport), which is just about 2.2 percent of the EU gross domestic product (GDP) in 2020 (European Commission, 2021). Expectedly, the energy sector which is the engine of sectors of most economies (both tradable and non-tradable) is being taxed such that it generates 77.2 percent of the entire EU's environmental tax in 2020 (European Commission, 2021). In the European region, despite the increasing expansion of the service industry, revenue generation from energy taxation arising from increasing energy demand is not unexpected.

As a service-oriented industry, tourism development stimulates demand for energy consumption, job creation, and hence economic growth (Usman et al. 2020). Tourism has remained an important component of the service industry essentially because it is a channel to make a better life for the people and future generations. Based on the positive role of tourism, the development of tourism becomes a great concern of the government and its managers in most countries of the world. According to the pre-coronavirus (Covid-19) pandemic statistics of the United Nations' World Trade Organization (2019), the world's total earnings from international tourism increased over the years with an unprecedented growth of 6% in 2018, which is higher than the growth of the merchandize exports. In the European countries, the travel and tourism sector alone generated about 14 million direct jobs in 2017 and 14.4 million in 2018. Moreover, the contribution of this sector to the Gross Domestic Product (GDP) of the continent significantly increased from 1,843.1 USD in 2012 to 2,155.5 billion USD in 2018. Despite the ongoing Ukraine-Russian conflict and the slow recovery of the region's tourism activities especially to the 2019 pre-coronavirus level, tourism activities are reportedly paced up in Serbia, Turkey, Bulgaria, Austria, Spain, Croatia, and Monaco (European Tourism Commission, 2022). Irrespective of the development in the region's tourism industry, the infrastructural facilities and high level of energy demand from the tourism sector are found to be the major contributory factors behind the accumulation of carbon dioxide in the atmosphere, leading to environmental degradation (Usman et al. 2020; Eluwole et al., 2020; Alola et al., 2021).

Given the importance of the EU's environment taxation and its huge tourism industry arising from the borderless policy across member states and the high number of medium-distance flights within the EU member countries which is reported to increase even with the implementation of aviation fuel tax (Tol, 2007), the drivers of the region's environmental performance are examined in this study. Then, the objective of the study is outlined; first, to reveal the influence of both environmental tax and tourism development on environmental performance in the panel of EU-28 member countries. Second, the study posits to see whether environmental tax mediates the impact of tourism development on environmental performance. Lastly, the role of other potential instruments of environmental performance such as renewable energy, research and development, and economic growth in the region are investigated. Remarkably, by following the above-outlined objectives which are rarely available in the existing literature, the outcome of this study offers a significant contribution to the literature by deepening both the discussion in theory and practice.

There are other parts of the study that offers guidance through relevant implementations. For instance, the discussion of the supporting theoretical framework and related literature are provided in section 2. The description of the dataset and implementation of the empirical methods are outlined in section 3. In sections 4 and 5, the discussion of the results of the investigation followed by the presentation of the summary of the study with policy recommendations is respectively detailed.

**2. Theoretical and empirical literature**

The nexus between environmental taxes and environmental pollution is a central discussion in the double-dividend hypothesis. According to this hypothesis, environmental taxes as an instrument reduce polluting activities of households, firms and industries thereby bringing about some levels of benefits. Notably, environmental tax potentially improves environmental quality alongside improving economic efficiency and raises revenues to improve the environment (See Aydin & Esen, 2018 Borozan, 2019). In a foremost study, the application of general (and computable) equilibrium theory in empirical studies yielded a significant value in understanding the impacts of the environmental-related tax such as carbon tax. Specifically, by applying the general equilibrium theory, Pearce (1991) pioneered that the application of carbon tax which is found to mitigate carbon emission and limit economic growth is far more beneficial.

Moreover, there are attempted follow-up studies to Pearce (1991) that further explored the criticality of the supposedly two benefits of environmental taxation (Goulder, 1995; Fullerton & Metcalf, 1997). Specifically, in the observation of Fullerton and Metcalf (1997), the green and blue (double dividend) benefit assumption of environmental taxation is not likely practically generalized given the complex dynamism of the associated factors. Meanwhile, Goulder (1995) had earlier motioned that the double dividend hypothesis could better be argued from strong and weak perspectives, such that the latter is adjudged a more theoretically and empirically practicable claim. However, the above-mentioned studies among others in the literature have largely supported the claim that environmental taxation improves environmental quality. Following the above-mentioned pioneering investigation, economic and environmental impacts of the different aspects of environmental taxation such as pollution tax, energy tax, resource tax, and transportation tax have emerged in several studies (Elliott & Fullerton, 2014; Dissou & Karnizova, 2016; Dong et al 2017; Paredes & Rivera, 2017; Alola & Nwulu, 2022; Wolde-Rufael & Mulat-weldemeskel, 2022).

***2.1 Preceding studies: environmental-related tax and tourism***

Given that the tourism industry constitutes a significant part of the economy, especially in several tourism destinations, several studies have been dedicated to the illustration of the significant association between tourism-related aspects and environmental taxation (Palmer & Riera, 2003; Tol, 2007; Dwyer et al 2012, 2013; González & Hosoda, 2016; Meng & Pham, 2017; Cao et al; 2021). For instance, the impact of the Australian carbon taxation policy (introduced on 01 July 2012) on the country's tourism industry was examined in the studies of Dwyer et al (2012 & 2013), and Meng and Pham (2017). By applying the dynamic computable general equilibrium (CGE) modelling, Dwyer's peer studies found that the introduction of a carbon tax in Australia yielded benefits to several tourism activities in the country while causing some macroeconomic contractions that include reductions in employment and the country's growth in the real gross domestic product arising from the decline in consumption. Meanwhile, by considering 42 commodities (including 2 tourism-related sectors) and 42 sectors, Meng and Pham (2017) combined the environmentally extended social accounting matrix approach with CGE to further reveal the tourism effect of environmental-related tax on the Australian tourism industry. Specifically, Meng and Pham (2017) hint that Australia's carbon tax of US$23 per tonne yields a significant emission reduction but not without causing some economic constraints such as a decline in real tourism expenditure, especially from the inbound and domestic tourism demand.

Moreover, the global and Japanese perspectives of the effect of environment-related taxation on tourism industry activities were respectively examined by Tol (2007), and González and Hosoda (2016). On the part of Tol (2007), the international tourist flow is being simulated to examine the extent to which carbon taxation on aviation fuel influences travel behaviour in selected countries across the world. The study revealed that $1000 per tonne of global carbon tax reduced international aviation emissions by 0.8 percent due to its impact on the behaviour of all travellers/tourists. Both international/long-haul travels and domestic/short-haul travels that respectively generate high emissions during flights and take-off or landing are affected by the tax on aviation fuel. Thus, the study further revealed a potential decline in short-haul and international travel while medium-distance flights such as aviation tourism within the European Union member countries could see a rise or be unaffected by a tax on aviation fuel. Meanwhile, González and Hosoda (2016) examined the effect of aviation fuel tax in Japan i.e the koukuukinenryouzei on emissions from the country's flight operation. By using the Bayesian structural model for the time series estimation of the monthly dataset over the period 2004-2013, the study established that the koukuukinenryouzei had played a significant role in reducing carbon dioxide emissions from the country’s aircraft operations.

***2.1 Preceding studies: environmental performance and tourism***

Previous studies reveal evidence of the impact of environmental performance on tourism activities and vice versa. For instance, Usman et al (2020) explored the dataset of the 28 EU countries over the time 2002–2014 to examine the role of tourism development, economic growth, and institutional quality on environmental performance in the region. By using the dynamic panel data estimation technique, the study found that environmental performance limits the development of the tourism industry and the economy at large while tourism development and economic growth also reduce the performance of environmental quality. In a similar but different methodological approach, Erdogan and Tosun (2009) used 73 survey questionnaires from accommodation managers in Goreme Historical National Park to examine 39 environmental indicators. Interestingly, the result shows low environmental performance through several indicators arising from the activities of tourism accommodations. Specifically, the indicators of environmental performance affected by the industry's accommodation section include energy efficiency, environmental training, water conservation and management, environmental awareness, and the aspects of environmental protection and policy.

More so, by examining the impact of environmental performance on travel- and tourism-related industries, Tan et al (2017) considered 811 firms across the casino industry (223), hotel industry (142), restaurant industry (235), and the airline industry (211) while the environmental performances are measured by emission reduction, product innovation, and resource reduction. The study adopted a dataset over the period 2003-2014 for different economic regions and explored to see whether environmental performances in the above-mentioned firms affect the financial performance (a proxy for tourism development) of the firms. Importantly, financial performance in the hotel industry is found to be positively influenced only by the aggregate dimension of environmental performance. But, for the aspects of environmental performance, the following observations ensued: resource reduction positively influenced the hotel industry's financial performance but is detrimental to the airline industry’s financial performance; product innovation desirably influenced the restaurant industry’s financial performance; the airline industry is notably marked with trade-off effect. Moreover, in the travel- and tourism-related firms, the nexus between the dimensions of both financial and environmental performances are moderated by slack resources, thus the validity of the slack resource hypothesis.

Currently, there is increasing body of knowledge on environmental taxation because of the global awakening to climate change challenges. Given the bulk of literature available, which mainly focused on the effectiveness of environmental taxes in mitigating environmental pollution, there is paucity of studies on the indirect impact of environmental taxes. Specifically, to contribute to the existing literature, this paper evaluates the relationship between international tourism receipts and environmental performance at different levels of environmental taxes. Thus, the direct role of tourism development on environmental performance and its indirect effect as moderated by environmental taxation are examined in a rare approach.

**3. Data and Methodology**

**3.1 Data**

The study uses panel data based on 28 countries in Europe (EU-28) over the period 2002 to 2019. The dependent variable is the environmental performance index obtained from calculated based on 2 broad environment policy objectives, 10 environment issue categories, and 24 environment indicators. This data is obtained from the socioeconomic data and application center (SEDAC) (See link <http://www.ciesin.columbia.edu/indicators/ESI/>). The regime-dependent variable, which is the total environmental taxes is measured in million euros. The number of regime-independent variables in the model includes international tourism receipts measured in current US Dollars, real per capita GDP which measures economic activities, R&D is measured as total Research and Development as a percentage of GDP, and the renewable energy consumption is measured as the share of renewables in total final energy consumption. All the regime-independent variables are obtained from the World Development Indicators (WDI) database.

**3.2 Empirical Model**

In achieving the main objective of this study, the following empirical model of environmental performance is developed based on the recent empirical studies of Alola and Nwulu, (2022) and Wolde-Rufael and Mulat-weldemeskel, (2022):

 (1)

Where EP is an index of environmental performance. TRM and ETAX represent international tourism receipts and total environmental taxes. These variables are the main variables of interest in the present study. Other vital control variables include GDP which measures the level of economic activity. R&D is the level of expenditure in research and development, while REN denotes the consumption of renewable energy. The error term is denoted by  where at  and 

In order to examine how total environmental taxes impact tourism-environment linkage, we follow the approach proposed by Hansen (2000), which accounts for the contingent impact of total environmental taxes. Under this technique, the transition across two regimes occurs sharply. Therefore, Hansen's panel threshold model can be expressed as:[[1]](#footnote-1)

 (2)

Where lnEP is the index of environmental performance, lnTRM is the international tourism receipts, *Z* is the threshold variable, which denotes the total environmental taxes,  implies regime-independent regressors, i.e. additional variables that can explain changes in environmental performance such as economic activities, renewable energy and the intensity of research and development.  simply denotes the estimated threshold value while  is the residual term that is assumed to have zero-mean and constant variance. Following this approach, the indicator variable, *Z* is automatically split into two regimes––lower and higher environmental taxes regimes. These two regimes are dependent on whether the threshold variable is less or more than the estimated value. Furthermore, the coefficients,  and  capture the effects of lower and higher environmental tax regimes on international tourism receipts-environment nexus, with the coefficient of  not known prior to the estimation. The equivalent compact representation of Equation (2) is as follows:

 (3)

Where represents an indicator function. Two regimes are identified, i.e. low environmental taxes and high environmental taxes. This implies that the indicator function, $I\left(lnETAX\_{it}\right)$ is captured by 0 if  and 1 if .

Furthermore, to check the robustness of the panel threshold model, we apply the quantile regression of Machodo and Silva (2019) which is also known as the Method of Moments Quantile Regression (MMQR). Unlike the panel threshold model, MMQR allows the effects of environmental taxes on the tourism-environmental pollution nexus to be examined across quantiles distribution. In other words, it makes use of all the information in the distribution as compared with the conditional mean method of the panel threshold model. Therefore, the basic MMQR model is as follows:

 $ $ (4)

where $(α, β^{'}, δ, γ^{'})'$ are unknown parameters, $ i=1,…,k$ where country-specific *i*  represents fixed-effects and time, $t=1.$ $Z'$ is the *k-*vector of parameters that are known, which are the differentiable transformations of the components of *Xit* . The element $l$ is perhaps defined by $Z\_{l}=Z\_{l}(X\_{it})$ where $l=1,…,k$. The probability P{$δ\_{i}$ + $Z΄\_{it}γ>0\}=1, $and ** represents error or random terms that are independently and identically distributed. Equation (4) implies that;

 (5)

where, the conditional quantile function of environmental performance at 𝜃-th quantile is denoted by  with $q\left(τ\right)$ = $F\_{U}^{-1}\left(τ\right)$ while P(U$ <q\left(τ\right)$) = $τ$.

**4. Results and discussion**

**4.1 Preliminary analysis**

Table 1 displays the summary of descriptive statistics of the variables. As can be seen, the mean and other average measures of the variables are large except that of R&D. This implies that these scores are extremely influenced by outliers. That standard deviation which measures the volatilities in the variables shows that REN is the most volatile variable and is followed by EP. The rest of the variables are less volatile with GDP having the lowest volatility. The skewness of the variables indicates that apart from R&D and REN which have positive values, the remaining variables have negative values, and they are all close to zero. Furthermore, all the variables have a positive kurtosis which by approximation equal to three. However, the Jarque-Bera test results show that the statistics are extremely large and hence the probability values provide that the null hypothesis of normal distribution of variables cannot hold.

Furthermore, from the results of the correlation matrix presented in Table 2, the coefficients of the correlation established suggest no evidence of multicollinearity. Another vital information we derive from the correlation matrix is that with exception of a negative correlation between each of the variables we included in the model and REN, all other correlations established are positive and statistically significant. Particularly, the correlation between EP and REN, LNTRM and REN, and LNETAX and REN all reveal a positive and statistically significant except the correlation between LNETAX and REN which is statistically insignificant. Furthermore, there is a positive and significant correlation between R&D and REN.

Before estimating our model, it is the tradition in time series analysis to check the stationarity properties of the series employed. In doing this, we apply both the standard unit root test and the more recent unit root test that controls for cross-sectional dependence. The results of the Levin et al (2002) panel unit-root test reveal that lnEP, lnTRM, and lnGDP exhibit I(0) stationarity properties while the rest of the variables are I(1) process. However, by controlling for cross-sectional dependence in the panel, the results of Pesaran (2007) divulge that all the variables are only stationary after taking their first differences. To this extent, we further conduct a cointegration test to check whether they have a long-run relationship. By doing this, we apply a cointegration test by Westerlund and Edgerton (2007). The results indicate the presence of cointegration among the variables employed.

One of the requirements for applying a threshold model is to test for a threshold effect in the relationship. To do this, the Likelihood Ratio (LR) statistic test is applied. As suggested by Hansen (1999), since the asymptotic distribution of *F*-statistic is nonstandard, reliable and robust *F*-statistic and *p*-value are computed using a bootstrap approach under the null hypothesis. Therefore, to determine whether the threshold is not evident in the relationship, we test the null hypothesis of no threshold, i.e. . We also test the null hypothesis at most one-time threshold. The results based on 1000 bootstrap repetitions (see Table 1) provide strong evidence that the null hypothesis of no threshold is obviously rejected, suggesting that a single threshold is evident in the relationship. The results further provide no statistics to support that the threshold in the relationship is more than one or two.

Table 2 divulges the results of the Hansen (2000) panel threshold method. As demonstrated by Hansen (1999), each of the two regimes, at least, contains 5 percent of total observations in the estimations. As can be seen thereof, the estimated threshold level is 5.48 which is statistically significant, easily passing a significant test of 5% level. This means that in periods when total environmental taxes are lower than 5.48, the effect of international tourism receipt on environmental performance is negative, i.e. -0.0812, which is statistically significant. This result implies that, if other factors remain constant, a 1% increase in international tourism receipt would reduce environmental performance by 0.0812%. However, in periods when total environmental taxes cross the threshold value of 5.48, a 1% increase in international tourism receipt would stimulate environmental performance by 0.0495%, holding other factors remain constant. Furthermore, the effects of regime-independent regressors divulge that while international tourism receipt and economic activities have a negative and significant influence on environmental performance, the effects of renewable energy and R&D are positive and significant on environmental performance.

To check the robustness of these findings, the panel quantile estimation via the Method of Moments-Quantiles Regression (MMQR) proposed by Machado and Silva (2019) is applied. This technique is suitable for quantifying how environmental taxes influence the tourism-environmental pollution nexus by controlling for heterogeneity in the distribution. The results as depicted in Table 3, reveal a negative effect on tourism and a positive effect of environmental taxes across the distribution of environmental performance. However, the interaction term of tourism and environmental taxes have a positive and significant impact on environmental performance across quantiles. The results also show that renewable energy consumption has a positive and significant relationship with environmental performance in the lower and mid quantiles while in the upper quantiles its effect is negative. Similarly, an increase in R&D improves environmental performance across quantiles. These effects are heterogeneous, leading to an asymmetric pattern across the distribution of environmental performance.

**4.2 Discussion of finding**

The results that the effect of international tourism receipt show a negative relationship with environmental performance. This suggests a trade-off between tourism attraction and environmental quality. In other words, as EU countries are more attractive to international tourism inflows, they are exposed to environmental pollution through excessive demand for energy in various sectors of the economy such as transport, catering, hotel and restaurant, accommodation, etc. Moreover, the effect of environmental taxes on the relationship between tourism and environmental performance is dependent on levels of environmental taxes. When total environmental taxes (energy taxes, pollution taxes, and transportation taxes) are lower than the estimated threshold level, an increase in international tourism receipt tends to decrease environmental performance but when environmental taxes cross the estimated threshold level, an increase in international tourism receipt tends to increase environmental performance. Therefore, the negative effect of tourism on environmental performance is consistent with Katircioğlu et al, (2014) and Roudi et al., (2019) while the positive effect of tourism on environmental performance signals successful policies of energy conservation in tourism attraction. Thus, our finding is consistent with Katircioğlu (2014) who finds that an increase in tourism arrival condenses CO2 emissions in Singapore, and Aziz et al. (2020) wherein it is documented that as tourism increases, environmental degradation decreases across quantiles 0.1 to 0.4 in BRICS.

In furtherance of checking the efficacies of environmental taxes in stimulating environmental performance, the quantile results of the interaction term of tourism and environmental taxes unveil an improvement in environmental performance. This means that when tourism and environmental taxes interact with each other, their effect turns out to be environment friendly. The plausible explanation is that, from the perspective of double hypothesis, taxes are always intended to internalize the negative externalities of households, firms, and industries who engage in environmental pollution by changing their behaviours toward cleaner production and consumption of energy. As taxes are imposed on certain commodities by the government, the adverse effects of pollution are averted because of the high cost of consuming such commodities. Thus, the finding is consistent with the earlier findings of Tol. (2017), Costa-Campi et al. (2017), Aydin and Ezen (2018), Borozan (2019) and Wolde‑Rufael and Mulat‑weldemeskel (2022).

Furthermore, the negative effect of economic activities indicates that policies to accelerate economic growth deteriorate environmental performance in the region. This implies that economic growth pursuit requires high demand for energy consumption which increases the level of environmental degradation through an increase in all components of greenhouse gases. This result is consistent with Usman et al. (2019; 2022) who find economic growth to have exerted a negative effect on greenhouse gas emissions in EU-28 countries. Also, the positive effect of renewable energy implies that as renewable energy increases, environmental performance would also increase due to the zero-pollution effect of renewable energy which is consistent with a study by Alola et al. (2021) that renewable energy reduces greenhouse gas emissions in EU-28 countries. This is also consistent with recent studies like Usman et al. (2022) for Nigeria and Iorember et al. (2022) for African OPEC countries. Finally, the positively significant effect of R&D on environmental performance suggests that research and development induce technologies that help to restructure production and consumption patterns of energy towards the eco-friendlier product as demonstrated by Usman et al. (2021) for G7 countries.

**5. Conclusion**

Over the years, governments at all levels, policymakers, and scientists have been committed to finding appropriate ways to combat the environmental consequences of human activities without hurting or compromising economic growth. Therefore, this study aims at evaluating the effectiveness of total environmental taxes in influencing the impact of tourism on environmental performance in EU-28 countries. To realize this objective, a Likelihood Ratio (LR) test is conducted for three null hypotheses to determine the threshold effects in the relationship. The results of these tests suggest a single threshold effect, and hence the estimated threshold value of 5.48 is found. This suggests a negative and significant effect of tourism on environmental performance when environmental taxes are below the threshold. However, when environmental taxes are above the threshold value, the effect of tourism on environmental performance is positive and statistically significant. Furthermore, the effect of regime-independent variables displays that tourism and economic activities deteriorate environmental performance while R&D and renewable energy stimulate environmental performance. To check the robustness of these results, the MMQR is applied. The results reveal that while tourism reduces environmental performance, environmental taxes increase environmental performance. However, the interaction term of tourism and environmental taxes improves the quality of the environment. Also, the results of all regime-independent variables survive and show that they are robust.

**5.1 Policy Implications**

Based on these findings, the study suggests the following policy recommendations: First, environmental taxes are an instrument for averting the adverse effect of global warming and other significant climate changes from energy-related pollution. Therefore, government and policymakers should be encouraged to increase environmental taxes above the threshold level since environmental taxes have the capacity to internalize the negative externalities of environmental polluters. Moreover, by imposing high environmental taxes, individuals and businesses would be induced to change behaviours toward making use of greener technologies and consuming eco-friendly energy. Second, to achieve improved environmental performance, energy transition policies toward greater use of clean energy sources are sacrosanct. In this case, investment in renewable energy should be encouraged by applying some policy instruments such as carbon tax and quota system, which is also known as cap and trade. These instruments, although, are not new in most EU countries. However, as a policy, this study recommends the resuscitation of the use of these instruments. Third, since economic activities deteriorate the environment, it is suggested to engage in green economic activities. To achieve this, there is a need to induce behavioural changes in households, firms, and industries whose activities generate the highest level of pollution through the imposition of taxes on carbon, fuel-intensive, and other activities that are not eco-friendly.

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Table 1: Summary of Descriptive Statistics

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Mean | Median | Maxi | Mini | Std. Dev. | Skewness | Kurtosis | J-B Test | Prob. | Sum | Obs. |
| EP | 69.422 | 69.405 | 84.73 | 45.55 | 7.9106 | -0.6004 | 3.0692 | 30.381 | 0.0000 | 34988.7 | 504 |
| LNTRM | 22.688 | 22.754 | 25.123 | 18.897 | 1.2889 | -0.0914 | 2.4185 | 7.8030 | 0.0202 | 11434.6 | 504 |
| LNETAX | 8.3866 | 8.5121 | 11.064 | 4.9265 | 1.5436 | -0.1859 | 2.1747 | 17.205 | 0.0002 | 4226.86 | 504 |
| LNGDP | 10.085 | 10.092 | 11.63 | 8.3571 | 0.6776 | -0.0933 | 2.4259 | 7.6519 | 0.0218 | 5082.75 | 504 |
| R&D | 1.4839 | 1.2588 | 3.7340 | 0.2374 | 0.8764 | 0.7275 | 2.5001 | 49.707 | 0.0000 | 747.879 | 504 |
| REN | 16.775 | 14.33 | 52.88 | 0.09 | 11.684 | 0.8482 | 3.0536 | 60.489 | 0.0000 | 8454.76 | 504 |

**Note:** Maxi. represents maximum value; Mini means minimum value; J-B Test represents Jarque-Bera Statistic, Prob. denotes probability, Obs. denotes observations.

 Table 2: Correction Matrix

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | EP | LNTRM | LNETAX | LNGDP | R&D | REN |
| EP  | 1.0000 |  |  |  |  |  |
| LNTRM  | 0.3971\*\*\* | 1.0000 |  |  |  |  |
|  | [9.6948] | ----- |  |  |  |  |
| LNETAX  | 0.3434\*\*\* | 0.4839\*\*\* | 1.0000 |  |  |  |
|  | [8.1930] | [35.243] | ----- |  |  |  |
| LNGDP  | 0.5646\*\*\* | 0.4651\*\*\* | 0.4574\*\*\* | 1.0000 |  |  |
|  | [15.328] | [11.771] | [11.523] | ----- |  |  |
| R&D  | 0.4447\*\*\* | 0.4037\*\*\* | 0.4968\*\*\* | 0.6553\*\*\* | 1.0000 |  |
|  | [11.123] | [9.8878] | [12.824] | [19.439] | ----- |  |
| REN  | -0.1049\*\* | -0.1819\*\*\* | -0.0563 | -0.0616 | 0.3734\*\*\* | 1.0000 |
|  | [-2.36323] | [-4.1459] | [-1.2638] | [-1.3823] | [9.0180] | ----- |

**Note:** \*\* and \*\*\* denote significance levels at 5% and 1% respectively.

Table 3: Panel Unit Root Tests

|  |
| --- |
| IM-Pesaran-Shin Unit Root Test |
|  | At Levels | First Difference |
| Variable | Statistic | Statistic |
|  | -4.6840\*\*\* | -23.6043\*\*\* |
|  | -6.3954\*\*\* | -14.3250\*\*\* |
|  | -1.5102 | -9.8631\*\*\* |
|  | -2.4099\*\* | -8.4510\*\*\* |
|  | 0.3275 | -6.1815\*\*\* |
|  | -0.0086 | -7.0263\*\*\* |
| CIPS Unit Root Test |
|  | At Levels | First Difference |
|  | -2.585\* | -5.982\*\*\* |
|  | -2.559 | -3.511\*\*\* |
|  | -1.895 | -3.481\*\*\* |
|  | -1.736 | -3.080\*\*\* |
|  | -1.847 | -3.580 \*\*\* |
|  | -2.463 | -4.231\*\*\* |
| **Critical Value** |  |  |
| 1% = -2.58  | 5% = -2.67 | 10% = -2.83 |

 Note: \*\*\*, \*\*, and \* denote statistical significance level at 1%, 5%, and 10%. The maximum lag length selected for the test is 1 with trend.

Table 4: Westerlund Panel cointegration tests

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Statistics | Gt | Ga | Pt | Pa |
| Value | -3.089 | -4.311 | -14.334 | -4.367 |
| Z-value | -4.631 | 5.108 | -3.582 | 2.439 |
| *p*-value | 0.000 | 1.000 | 0.000 | 0.993 |
| Robust *p*-value | 0.070 | 0.180 | 0.040 | 0.110 |

Note: The tests are conducted with a maximum lag of 0.

Table 5: LR Test for Threshold Effect

|  |  |  |
| --- | --- | --- |
|  **Null hypothesis** | **Statistic** | ***p*-value** |
| There is no threshold effect  | 38.296\*\*\* | [0.0000] |
|  There is at most one threshold effect  |  2.9012 | [0.7092] |

**Notes:** \*\*\* denotes statistically significant at 1% level. [ ] denotes *p*-avule of LR test

Table 6: Results of Threshold Effect

|  |
| --- |
| **Dependent Variable =** $lnEP$ |
|  | **Variables** | **Coefficient** | **Std. Error** |
|  | Estimated Threshold |  |  |
|  | $(\hat{γ})$ Confidence Interval (95%) | 5.4797\*\*\* [5.3657, 5.5441] |  |
|  | ***Regime-Dependent Regressor:*** |  |  |
|  | Lower lnETAX regime $(\hat{β}\_{1})$ | -0.0812\*\*\* | 0.0064 |
|  | Higher lnETAX regime $(\hat{β}\_{2})$***Regime-Independent Regressors:*** | 0.0495\*\*\* | 0.0047 |
|  | $$lnTRM$$ | -0.0363\*\* | 0.0134 |
|  | $$lnGDP$$ | -0.2403\*\*\* | 0.0343 |
|  | $$lnR\&D$$ | 0.0108 | 0.0116 |
|  | $$lnREN$$ | 0.0231\*\*\* | 0.0008 |
|  |
|  | Constant | 9.9569\*\*\* | 0.2656 |
|  | Number of Observations | 504 |  |
|  | Number of Countries | 28 |  |
|  | F(6, 470) | 242.82 (0.0000) |  |

Note: \*\* and \*\*\* denote significance levels at 5% and 1% respectively.

Table 7: Method of Moments Quantile Regression (MMQR)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | (1) | (2) | (3) | (4) | (5) |
| VARIABLES |  |  |  |  |  |
|  |  |  |  |  |  |
| $$lnTRM$$ | -0.0399\*\*\* | -0.0200\*\* | -0.0205\*\*\* | -0.0181\*\*\* | -0.0933\*\*\* |
|  | (0.0068) | (0.0045) | (0.0033) | (0.0039) | (0.0054) |
| $$lnETAX$$ |  0.0899\*\*\* |  0.0926\*\*\* | 0.101\* | 0.188\* | 0.261\* |
|  | (0.0190) | (0.017) | (0.0529) | (0.111) | (0.153) |
| $$lnTRM×lnETAX$$ |  0.0293\*\*\* |  0.0985\*\*\* |  0.0491\*\*\* |  0.0851\* |  0.0115\* |
|  | (0.00816) | (0.0055) | (0.0093) | (0.00477) | (0.00657) |
| $$lnGDP$$ | -0.208\*\*\* | -0.209\*\*\* | -0.209\*\*\* | -0.210\*\*\* | -0.211\*\*\* |
|  | (0.0729) | (0.0487) | (0.0353) | (0.0426) | (0.0589) |
| $$R\&D$$ | 0.0138\*\*\* | 0.0548\*\*\* | 0.0960\*\*\* | 0.0134 | 0.0165 |
|  | (0.0026) | (0.0173) | (0.0125) | (0.0153) | (0.0209) |
| $$REN$$ | 0.0234\*\*\* | 0.0230\*\*\* | 0.0226\*\*\* | -0.0223\*\*\* | -0.0220\*\*\* |
|  | (0.00154) | (0.00103) | (0.000748) | (0.000902) | (0.00125) |
|  |  |  |  |  |  |
| Observations | 504 | 504 | 504 | 504 | 504 |

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

1. The threshold model advanced by Hansen (2000) minimizes the residual sum of squares by making use of the grid search procedure. This is because the parameter is not known. [↑](#footnote-ref-1)