“Investigating the effects of environmental taxes on economic growth: Evidence from empirical analysis in European countries”

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INVESTIGATING THE EFFECTS OF ENVIRONMENTAL TAXES ON ECONOMIC GROWTH: EVIDENCE FROM EMPIRICAL ANALYSIS IN EUROPEAN COUNTRIES

Abstract

This paper empirically analyze the effects of environmental taxes on economic growth using data spanning the period 2009–2019 across 31 European countries (28 from the European Union, including the UK before Brexit, Iceland and Norway, which are candidates to join the EU, and Switzerland). The selected countries are also members of the European Environmental Agency countries (EEA-32). Baseline scenario with Pooled Ordinary Least Squares leads to the evidence that an increase of the environmental taxes in case of any tax policy reform will exacerbate economic growth. Robustness checks by introducing more control variables in response to omitted variables bias, coupling with GMM estimations that control for endogeneity concerns, consistently confirm the results. Deeping more with quantile analysis regression, a negative effect is confirmed in each quantile, and the results are significant at 1%. Nevertheless, there is a discrepancy between each quantile that allows highlighting evidence of countries' threshold effects. In fact, low-income countries are more negatively affected than upper and medium-income countries. As the official communication of the EU Commission is always in demand of empirical research concerning the economic impacts of environmental policy instruments, the paper sheds light on the possibility of discussing and adapting the EU strategy based on a harmonization system. This evidence of differentiated effects among countries' thresholds in the absence of any compensation may raise equity considerations within heterogeneous countries. Therefore, this paper fulfills the gaps in the inconclusive results in the existing literature.

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INTRODUCTION

Environmental taxes, which can play a spillover effect into the green growth challenge, have been increasingly adopted in European Union (EU) countries as one of the main instruments of environmental policy to address environmental objectives such as mitigating greenhouse gas emissions significantly. For all EU Members States, taxes on energy as well as taxes from the transportation sector are major components of the income generated by the environmental taxes system. However, pollution and resource taxes, which are grouping a variety of marginal value of taxes levied on water pollution, waste, for example, account for a small part of the revenue of environmental taxes (Eurostat, 2020) and are not applied in all EU Member States. As confirmed by OECD (2006), there are 375 environmentally related taxes in the OECD countries, with about 90% of the revenue collected from taxes related to

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motor vehicles fuels and motor vehicles. According to Eurostat (2009), energy taxes represent about 75% of environmental taxes among EU-27 member states, of which approximately 80% come from fuel taxes in the transportation sector.

Environmental tax reform is the process of shifting the tax burden from employment, income, and investment, to pollution, resource depletion, and waste (Bosquet, 2000, p. 19). According to OECD (2015), shifting the tax burden in favor of environmental taxation through pricing instruments should represent an important pillar of environmental policies to encourage broad-based actions and policies to mitigate environmental pollution and damages. However, as Baudu (2012, p. 981) underlined, such policies are rarely conceived based on strict environmental criteria and are often modified because of economic policy considerations.

As it could be easily underlined in the public debate and the literature, exploring the nexus between economic growth and environmental taxes is an important issue. Concerns were raised in the debate that such taxes can negatively affect (Ecotec, 2001) the economy through employment and competitiveness issues or will slow the economic growth (William III, 2016, p. 24). In 2015, the percentage of tax revenue attributable to energy/environment taxes in EU-28 was 2.4% of GDP (Böhringer et al., 2019, p. 142).

The EU environmental taxes represent about 6% of total taxes, with an essential variation in each country. The European Green Deal has validated the importance of environmental taxation scheme principles in implementing green economy objectives and a climate-neutral economy. The European Environment Agency (2022) underlined that the amendment and revision of current energy taxation would lead to higher revenues in the coming decade.

For policymakers, it could be vital to have insights into the correlation between instruments of environmental policies such as environmental taxation tools and economic variables. In the situation in which any statistical correlation is confirmed, based on data analysis, it is important to know whether the relationship is positive or negative.

Among the literature that deals with environmental regulation, Beaumais and Chiroleu-Assouline (2002) provide a large scope on environmental fiscal tools or policies.

With various analysis and modeling approaches, Abdullah and Morley's (2014, p. 33) contribution have suggested the use of different types of tools or "alternative sets of instruments (…) as suitable data become available" to test the relationship between environmental taxes and economic long-run growth. As the benefits of environmental taxation are concerned, the official communication of the European Union Commission is always in demand of empirical research and results concerning the abovementioned environmental policy instrument and the direct or indirect effects on the economy. Although some studies are focusing on distributional effects in terms of welfare considerations with microsimulation[1] tools according to the type of goods being consumed (Tchapchet-Tchouto et al., 2022) or carbon reduction schemes (Piggot & Whalley, 1992; Beaumais & Schubert, 1999; Böhringer et al., 2019), other approaches are macroeconomic.

Given the above considerations, the motivation and contribution of this paper are to offer specific alternative insights by gathering these two previous objectives. On the one hand, this paper overcomes the difficulty in terms of the most recent and stabilized available environmental taxes data at the time (Abdullah & Morley, 2014). It addresses an empirical assessment of the issue with a panel consisting of 31 European countries from the European Environmental Agency Countries – EEA-32. In addition, it covers data spanning the period from 2009 to 2019 using econometrics methods jointly (Pooled

1 Schubert and Letournel (1991), Piggot and Walley (1992), Xie and Saltzman (2000).

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Ordinary Least Squares (OLS)) in baseline scenario, to which is added further investigations to clarify the decision around fixed and random effects model, individual random and time fixed effects models. Concerns regarding endogeneity issues that may derive from unobserved heterogeneity or measurement error are addressed and controlled within System-Generalized Method of Moments (S-GMM). At least, quantile regression estimations provided the scope to examine the relationship between environmental taxes and economic growth, specifically under countries' thresholds criterion.

Results of the paper show the evidence that an increase in the environmental taxes level will harm economic growth. Robustness checks based on the introduction of more control variables in response to the control of omitted variables bias, coupling with GMM estimations, also confirm the baseline results. Deeping more with quantile analysis reaches the significant result at 1% that countries of each threshold are still negatively impacted by any environmental tax variations in case of tax level reforms, but different proportions. In fact, low-income countries are more negatively affected (–3.634) than upper (–3.140) and medium (–3.056) income countries. The present results shed light on the possibility of enhancing the debate to discuss and adapt the EU strategy, which is under a harmonization system. Furthermore, evidence of differentiated effects among countries' thresholds in the absence of any compensation may raise equity considerations within countries.

As an important outcome, it contributes through the highlighted findings to the debate regarding the EU Commission's expectations and to the literature update within recent data on this topic, which feeds policy recommendations.

1. LITERATURE REVIEW

Environmental taxes and economic growth have been studied on theoretical and empirical approaches in the literature. The more this question is highlighted, the more it could clearly decline the importance of this issue. Baumol (1988), Goulder and Parry (2008), and UNEP (2010), among others, investigated this topic. Different impacts of environmental taxes on economic growth were analyzed by Goulder (1994), Bovenberg and Mooij (1997), Ligthart (1998), Ekins (1999), Bovenberg and Goulder (2002), OECD (2006, 2010), Ono (2003a, 2003b), Sterner and Khölin (2006), and Oueslati (2015). Moreover, by extension, many arguments have been raised about the relationship between the economy and the environment. Therefore, elements regarding the initial theoretical relationship concerning main environmental instruments issues and economic growth are briefly presented, followed by an overview of some empirical results in the literature.

A negative impact of the economic growth on the environment was underlined. The world would not be able to sustain economic growth indefinitely without running into resource constraints or without destroying the environment beyond repair. This view sees environmental taxes as an important tool for enhancing sustainable development and not only an instrument that can help protect the environment. The double dividend hypothesis explains this approach as originally is underlined by Pearce (1991), Bovenberg and Smulders (1995), Bovenberg and Mooij (1997), and Schöb (2003, p. 3). In this context, as demonstrated by Fullerton and Metcalf (1997), an increase in taxes on activities that generate pollution can bring environmental improvement as well as economic efficiency through the use of revenues from environmental taxes to reduce distortionary taxes on the economy. In this case, a positive outcome instead of the negative impact of environmental taxes on economic performance is expected (Dokmen, 2012, p. 44).

With a consistent approach describing the polluter-pays principle due to the existence of environmental externalities, whereby the polluter is directly responsible for the damage caused, Pigou (1924) proposed the economic rationale for the environmental taxation principle through the use of taxes levied on pollution during production to align private marginal costs with the social marginal costs of production. In theory, the optimal Pigovian tax is equal to the sum of marginal environmental damages (at the optimal level of pollution) in situations where production and consumption side effects are not considered and the economic costs of the entity responsible for the pollution processes. By internalizing the cost of pollution into the decision process, Pigovian taxes give firms an incentive to decrease pollution. As underlined by Ekins (1999), by levying a tax on the activity giving rise to the effect, the external cost can be partially or wholly internalized.

Compared to other instruments such as applying norms, Pigovian taxes are a less costly method of achieving a given pollution reduction (Baumol & Oates, 1988). In fact, under the Pigovian tax scheme, firms have an incentive to innovate by installing abatement equipment to reduce pollution. From a dynamic perspective, Pigovian taxes are also more desirable than norms because taxes incentivize firms to continually seek pollution-reducing technologies. The potential revenue generated through the taxes system could be another reason to prefer environmental taxes to norms.

Environmental policy can have a "win-win situation" (Ambec & Lanoie, 2007, p. 4). In fact, it can generate a positive effect by reducing production costs and improving environmental quality while increasing the growth rate of industrial value added, and then the economic growth. Similarly, Itaya (2008) shows that because an environmental tax reduces the profits of intermediate firms, the resulting reduction in their output through intermediate inputs frees up more resources for research and development activities, which are the engine of economic growth. On the other hand, Grossman and Krueger (1991, 1995) and Selden and Song (1994) presented evidence that economic growth can reduce environmental problems. This phenomenon has been referred to as the Environmental Kuznets Curve (EKC) (see Panayotou, 1997; Stern, 1998; Sachs et al., 1999; Dasgupta et al., 2002; Xepapadeas, 2005), since there is a significant contribution of studying a similar relationship by Kuznets (1955) for income inequality and per capita income.

The debate regarding the effects of environmental taxes on GDP from empirical studies remains inconclusive. In the early stages of the debate, major economists converge that environmental taxation has a negative impact on economic growth (Labandeira et al., 2004; Van der Ploeg & Ligthart, 1994; Gradus & Smulders, 1993). According to Siriwardana et al. (2011), on the one side, one example is that implementation of environmental taxes in general and carbon taxes particularly could slow down productivity and, consequently, national output. They underlined that decreasing the use of energy fossil fuels is considered a factor of production to reduce pollution and yields to a decrease in output level. On the other side, Ricci (2007) explained that firms undertake abatement activities to decrease pollution, resulting in increased production costs. Therefore, higher production costs negatively affect the return on capital and incentives for investment resulting in a decrease in economic growth.

The main empirical work on environmental taxation and economic growth has centered around the simulation of the impact of Environmental Tax Reform (ETR) on the environment, use of natural resources, and the wider economy, as underlined by Abdullah and Morley (2014, p. 5). Therefore, this approach can be qualified as Energy-Environment-Economy model, which can include different simulation techniques.

According to Bakker (2009, p. 7), five theories are well-known to deal directly or indirectly with environmental taxes in the literature: double dividend theory, the precautionary principle, the polluter-pays principle, least-cost reduction, and microeconomic theory. Environmental taxes are considered an economic tool used to reduce market failures to optimal situations due to environmental externalities. Thus, an economic activity results in social costs that are not paid for by the producer or consumer who causes them or, as mentioned by Williams III (2016, p. 2), "because the buyer's and seller's decisions fail to take into account the external cost." However, the perspective of environmental taxes has a negative effect on economic performance. This emphasizes that environmental taxes reduce the amount of fossil fuel use and decrease the volume of industrial production (Dokmen, 2012, p. 44).

Among others, throughout an Energy-Environment-Economy Computable General Equilibrium model, Kumbaroglu (2003) highlighted that an economic benefits second dividend of environ-

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mental taxation is possible as well as environmental improvements when imported energy is located as the primary source of the pollution. In the same line, Andersen et al. (2007) used an Energy-Environment-Economy approach with EU countries data. He found a positive impact on economic growth (through double dividend) and environmental improvements by introducing a carbon energy tax levied to reduce distortionary taxes. These double dividend indirect impacts of environmental taxes on the economic development were also outlined by Anger et al. (2010) and Patuelli et al. (2005) through a regression technique known as the meta-analytical modeling approach.

Under econometric modeling, there is little literature on environmental taxes and economy with panel data applied to European Union countries. Abdullah and Morley (2014) studied the causal link between gross domestic product and environmental tax as well as adjusted net savings by applying the Generalized Method of Moments (GMM) estimation and standard Granger non-causality[2] approach on a panel with data covering 1995–2006. The study concluded on the evidence that environmental taxes increase does not seem to have a strong effect on economic growth. Therefore, it provided scope to Anger et al. (2010) and Bosquet (2000) with mitigating evidence of environmental taxation tools on the gross domestic product.

With the Correlated Random Effects under Expectation Maximization Bootstrapped algorithm derived from Wooldridge (2010), Hassan et al. (2020) have investigated the link between environmental taxes revenues in economic growth and GDP. The study covered 31 countries of the OECD for 1994–2003. These studies have concluded that there is no statistical evidence of the relationship between the aforementioned variables. According to their conclusion, the impacts of environmental taxes on GDP depend on the initial value level of gross domestic product per capita.

Using a theoretical framework approach, Bovenberg and Mooij (1997) explain that environmental taxes can be represented in an endogenous growth framework, followed by Abdullah and Morley (2014) with an applied model (Granger non-causality and GMM tests). This study continues this applied approach by assuming the same assumption in the model specification. Böhringer et al. (2019) have used a microsimulation model of households associated with a static multi-sector computable general equilibrium framework that tracks economic adjustment on the transition path. They evaluated the effects of a green tax reform where income from taxes on vehicle fuels and greenhouse gases are redistributed to the household through lump-sum transfers in the Spanish economy. Social welfare changes are evaluated through the changes in the equally distributed equivalent income in the different environmental policies scenario.

As a result, economic growth, environment and environmental policy tools such as environmental tax mechanisms may not necessarily be the opposite. Since the seminal contribution of Pigou (1924), environmental Pigouvian tax that prevents greenhouse gases as well as other air pollutants considered as environmental negative externalities market failure also aims to reconcile the adequate level of income, environmental quality, and efficient social cost. The above overview of the literature concerning the nexus between economic growth and environmental taxes reveals the main information. Firstly, it is important to use environmental tools to obtain environmental efficiency through environmental quality improvements for welfare gains or household social welfare conditions improvements[3]. Secondly, the inconclusive results of studies towards heterogeneous modeling framework used characterized by static approaches that capture adjustment effects on short term and dynamic models that capture the long-term transition path of the economic growth.

Nevertheless, this seems insufficient because no study examines the threshold effects among countries. Moreover, empirical investigations with static and dynamic models need to be permanently updated with recent data. This study contributes to the debate by mainly attempting to fill these gaps. It provides a clear answer that can elucidate how

2 Panel cointegration and error correction are used in this approach.

3 Reduction of unemployment, households' income effects through redistributive lump-sum transfers, and economics as profits of intermediate firms, reduction of output, distortionary tax rate, and modification in technological adjustments that drive production may occur.

environmental tax is linked to economic growth in European countries and the heated debates involving environmental externalities such as carbon emissions and income level path. Through the applied methods, the paper uses static, dynamic, and non-parametric methodological frameworks combinations with recent data to evaluate the short and long terms effects of environmental taxes on economic growth, as well as countries' threshold effects.

Three hypotheses are considered in this study. First, to move away from studies with inconclusive results, it is assumed that recent data reflecting the last decade business conditions may reach conclusive results, whether negative or not (H1). Considering an environmental tax reform process, the effects of increasing environmental taxes level[4], otherwise, effects of creating additional environmental taxes without innovation substitution mechanisms would lead to the fall of the output level, characterizing a negative effect on economic growth (H2). Finally, given the previous hypotheses and considering that countries can have heterogeneous environmental practices and regulations, different economic characteristics and circumstances due to countries' specific effects, each quantile of countries could be impacted differently (H3), thus resulting in threshold effects.

2. METHODS

The data, sources, measurements, and variables are presented, followed by the estimation strategy.

Data from 31 countries in Europe[5] from 2009 to 2019 were taken from Eurostat (2020) database. Gross Domestic Product and Environmental taxes are based on a constant local concurrency. As the study includes data for 2018 before the Brexit, the paper considers the United Kingdom as part of EU Member States, 2 candidates – Iceland and Norway – and Switzerland[6]. The list of all the countries is available in Table A4 (Appendix A). Table 1 lists the descriptive statistics with basic model variables used in logarithm form in all the estimations strategies. The Pairwise correlation matrix is presented in Table A3 (Appendix A).

Table 1. Descriptive statistics

Source: Computation from database using Stata 17.

Variable	Obs	Mean	Std. dev.	Min	Max
Years	341	2014	3.167	2009	2019
ID	341	16	8.957	1	31
GDP	341	12.047	1.566	8.742	15.054
Environmental Taxes	341	1.959	.239	1.409	2.464
GHG per Capita	319	2.221	.343	1.609	3.281
Environmental Protection Investment	244	6.655	1.578	2.477	9.482
International Environmental Expenditures	239	8.116	1.637	4.777	11.192
Investment	341	10.465	1.585	7.043	13.525

Note: Variables are given in neperian logarithm.

The full set of benchmark control variables is available from summarized statistics, except for greenhouse gases per capita, environmental protection investment, and international environmental expenditures. GDP takes values from 8.742 to 15.054 with a mean of 12.047, while greenhouse gases per capita are between 1.609 and 3.281 with a mean of 2.221. This indicates there is no strong heterogeneity among European countries of the sample in terms of national income level as well as emissions per capita level. The observation is almost the same for the other control variables (investment, environmental protection investment, and international environmental expenditures). Environmental taxes take values from 1.409 to 2.464, with a mean of 1.959. These statistics indicate that European countries have an ambitious non-negative tax levy system, which shows that environmental subsidies are not commonly or predominantly applied to implement environmental policy strategies.

Concerning the variables used in the model, economic growth is approximated by the GDP, which is the dependent variable. Environmental tax represents the interest variable. To avoid the fact that a two variables relationship in a model can introduce concerns of omitted variables, the study also takes into account a set of control variables. National Greenhouse Gas per Capita (Ghgpc), Environmental Protection Investment (Envprotinv), which are the expenditure of each

4 In average, the initial level of environmental taxes are already set an given at a high level in European countries.

5 EU-28, including the United Kingdom and data from Switzerland, Norway, and Island.

6 Switzerland ended the negotiation process to join the EU in 1996 after being a candidate since 1992.

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country on national environmental protection[7], International Environmental Expenditure (Intenvexp), and Investment (Invest). Except Environmental taxes obtained from the OECD database, all the other variables have been taken from the Eurostat database.

Before adding these new variables, a second unit root verification test is performed to check the stationarity of all the variables following Levin et al. (2002) and Im et al. (2003). The unit root test results are presented in Table A1 (Appendix A). Regarding the results obtained from that test, the series are all stationary at level. Therefore, by definition, there is no cointegration analysis to be conducted because results show no long-run relationship.

The estimation strategy is adapted from the works of Abdullah and Morley (2014) as well as Hassan et al. (2020), to specify the relationship between economic growth and environmental taxes by the following regression equation:

$$GDPx_{i,t} = \alpha_0 + \alpha_1 Envtaxx_{it} + \\ + \delta_k X_{k,t} + u_i + v_t + \varepsilon_{it}, \quad (1)$$

where u_i represents an unobserved country-specific effect as usually specified, v_t a time-specific effect and ε_{it} represents the effect of the variables omitted from the equation, assuming that by hypothesis, this error term is identically and independently distributed among each country and time specified in the model. The paper considers the $GDPx_{i,t}$ here in logarithm which represents the Gross Domestic Product of country i during the year t. It can be expressed as a function of the logarithm of the environmental taxes $Envtaxx_{it}$ of the country i at the time t as well. $X_{k,t}$ is a vector of controls variables (Greenhouse Gases per capita, Environmental Protection Investment, International Environment Expenditure, Investment). α_0 is a constant parameter, α_1 is the coefficient of environmental taxes, and δ_k is a vector of the coefficients of the controls variables, which will be determined. The coefficient of the environmental taxes is expected to be negative as increasing the environmental taxes level can have a negative spillover on the GDP.

Environmental tax is the interest variable. It can impact each aspect of green development and indirectly on output and economic growth.

3. RESULTS

Table 2 presents the baseline results of the estimations that describe the relationship between GDP and Environmental tax through different estimation methods:

1) pooled Ordinary Least Squares (OLS);
2) Random Effects (RE);
3) Fixed Effects (FE);
4) Individual random and Time Fixed effects.

Figure 1 represents the relationship trend between environmental taxes and the GDP.

According to the benchmark of the Pooled OLS (see Column (1) in Table 2), environmental tax estimated coefficient value is –3.095, and this result is significant at a 1% level. In this situation, when the environmental tax broad decreased by 3.095 points, GDP decreased by 1 point in a percentage average. As the sign of the coefficient is negative, this also means that when the level of the environmental tax rate decreases, GDP or growth rate will also decrease. Alternatively, a gradual increasing environmental tax policy over the level of 3.095 points over time could have a positive effect by turning out the GDP to increase.

With the value of R-Squared, this is also proof that around 22% of the movement of the GDP is due to environmental tax value. Therefore, this also shows how important environmental taxes are in the European Economy system. Moreover, it could be evident that adding more control variables will rise up the R-Squared and the power of the whole explanatory variables to explain the variation of the GDP.

7 As defined by Eurostat (2009), "National expenditure on environmental protection is obtained from the sum of the environmental protection market output, environmental protection of non-market output, plus gross fixed capital from formation for environmental protection activities, minus intermediate consumption of environmental protection, plus Value Added Tax less subsidies on environmental protection services, plus import of environmental protection services, minus export of environmental protection service, plus transfers balance obtain with the rest of the world".

Source: Construction from the database using Stata 17.

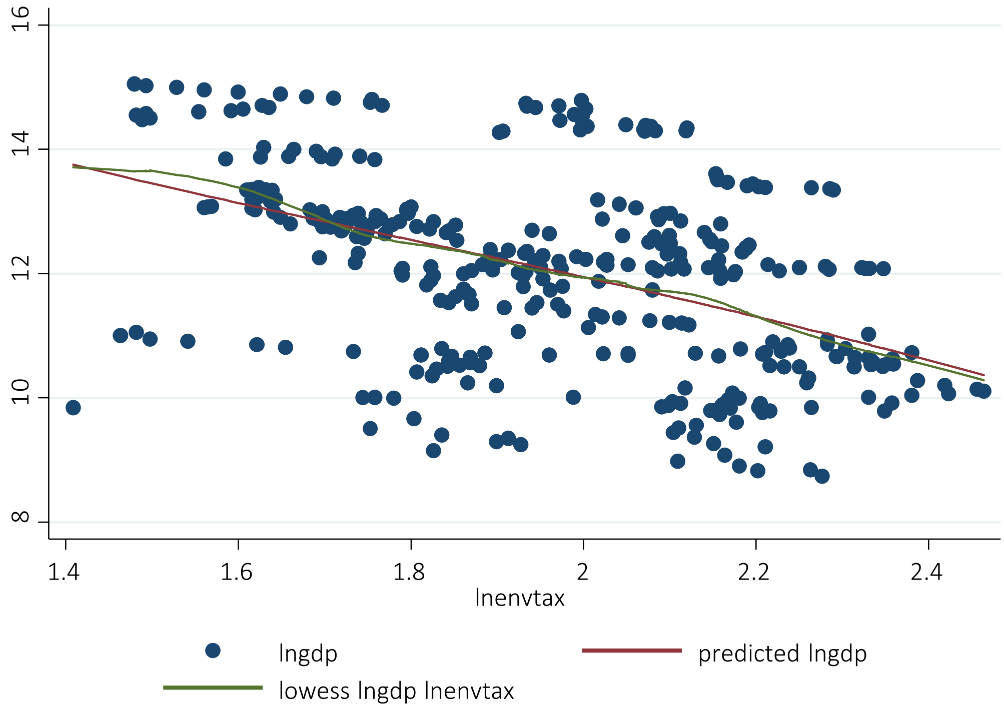

Figure 1. Relationship between environmental taxes and GDP

Table 2. Environmental tax and GDP

Source: Computation from the database using Stata 17.

Variables (In Ln)	Dependent Variable: GDP			
	Pooled OLS	GLS RE	FE	Individual RE and Time FE
Environmental Taxes	−3.095***	−0.816***	−0.794***	−3.334***
	(0.313)	(0.103)	(0.103)	(1.109)
Constant	18.111***	13.646***	13.603***	18.579***
	(0.617)	(0.203)	(0.203)	(2.187)
Observations	341	341	341	297
R-Sq.	0.2241	0.224	0.2241	0.238
Number of country id	31	31	31	31

Note: Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Then, a second regression estimation of the equation is performed by using the panel data method under the method of Random-Effects (see Columns (2-4) in Table 3, Fixed-effects (3) as well as Individual Random Effects and Time Fixed-Effects (4). The estimated coefficients of GLS Random-Effects is –0.816, while it is –0.794 under fixed-effects regression and –3.334 with the between Random and Fixed Effects estimation. In these 3 estimations, environmental tax coefficients are significant at 1% and negative. In each case, this means that any decrease of environmental tax of 1 point, could be turning out the decrease of the GDP by between –0.794 (under fixed effect analysis). R-Squared values found in the regressions estimations (see Table 3) are between 0.224 and 0.238.

As this study is dealing with a panel data model, a Hausman specification test is implemented. The results found from this test are presented in Table A2 (Appendix A). The Hsiao test provides a great P-value (0.000) which confirms that, compared to the Random Effects model, a Fixed Effects model is preferable in this analysis.

At this point, performing a robustness check of the baseline results is necessary regarding the im-

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Table 3. Robustness check with GMM and adding controls variables

Source: Construction from database using Stata 17.

Variables (In Ln)	GDP (GMM)(1)	GDP (GMM)(2)	GDP (GMM)(3)	GDP (GMM)(4)	GDP (GMM)(5)
Environmental Taxes	–3.608***	–2.667***	–0.518**	–0.267**	–0.0788*
	(0.740)	(0.586)	(0.230)	(0.111)	(0.039)
International Environmental Expenditures	–	–	0.865***	1.202***	0.672***
	–	–	(0.0602)	(0.0320)	(0.0351)
GHG per Capita	–	–	–	–0.202	–0.288***
	–	–	–	(0.158)	(0.0706)
Environmental Protection Investment	–	–	–	–0.367***	–0.156***
	–	–	–	(0.0165)	(0.0067)
Investment	–	–	–	–	0.421***
	–	–	–	–	(0.0252)
Constant	19.28***	17.42***	6.159***	5.778***	4.087***
	(1.463)	(1.169)	(0.882)	(0.674)	(0.201)
Obs	310	310	228	202	202
ar1p	0.041	0.0450	0.043	0.044	0.08
ar2p	0.191	0.189	0.156	0.746	0.462
Sargan	770.1	920.0	23.97	21.42	17.10
Hansen	4.546	11.39	6.801	17.02	21.71
F	2684	3244	37882	162765	586643

Note: Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

portance of such sensitivity analysis. In the first part of the post-estimations tests, Generalized Method of Moments (GMM) is used to fix any concerns that may raise endogeneity issues in the econometrics tests and analysis. In the second part, quantile analysis investigates the countries' threshold effects of environmental taxes on economic growth.

Table 3 shows the results with GMM method.First of all, the same single variable model test is applied. The control variables added step by step allow to study different scenarios and see how the independent variable will be sensitive to the scenario of international environmental expenses (Column (3)), greenhouse gases management policy coupled with environmental protection investment (Column (4)) and investment to support innovation in the economy (Column (5)). The results from (1) to (5) provided the same insight as the initial test and confirmed the robustness of the baseline scenario.

Coefficients are negative and significant in the range of 1 to 10%. In the regressions, which consider all the four control variables, results show that the environmental tax coefficient is still negative and significant at 10%. Meanwhile, the control variables that have been added are significant at a 1% level.

The second robustness check implemented is a non-parametric test with Quantile regression. Results (Table 4) show the effects of environmental taxes in each quantile in the thresholds 0.25, median 50, and 0.75. Confirmation of the baseline results is also found here, and each coefficient is associated with the negative sign and is significant at a 1% level. Meanwhile, there are some differentiated effects inside each country's thresholds, which are characterized by their income level. Indeed, the first quantile 0.25, followed by the quantile 0.75, which is much stronger impacted by tax effects of environmental taxes. Because each country's threshold is differently impacted, as seen in Table 4, these results are also highlighting the inequity aspects of the environmental taxes among countries or group of countries in the European Union sample.

At this stage, it might be important to summarize the results of the different hypotheses tested in this study. This study responds with recent data and leads to a conclusive result for the first and second hypotheses. The negative effects of environmental taxes on economic growth are found

Table 4. Quantile regression – economic growth and environmental taxes

Source: Computation from database using Stata 17.

Variables	Dependent Variable: GDP		
	Quantile25	Median50	Quantile75
Environmental Taxes	–3.63445***	–3.05666***	–3.14017***
	(0.74777)	(0.34368)	(0.51168)
Constant	18.48555***	18.04743***	19.21125***
	(1.47961)	(0.68003)	(1.01244)
Observations	279	279	279
R-Squared	–	0.22213	–

Note: Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

in the baseline test and reinforced by the step-by-step robustness checks. Table 4 confirmed the existence of a countries' threshold effect where each quantile is not impacted at the same level, and the effect of the environmental tax in each quantile is kept negative.

4. DISCUSSION

Regarding the literature, the findings of this paper that highlighted the evidence of negative impacts of environmental taxes on economic growth are in the same lines with the conclusions of Gradus and Smulders (1993), Labandeira et al. (2004), Van Der Ploeg and Ligthart (1994), Siriwardana et al. (2011), and Ricci (2007). All these studies have determined that environmental taxes can slow down the productivity or have a negative impact on economic growth. Furthermore, Cuervo and Ghandi (1998) explained this negative mechanism by decreasing the use of one of the main production factors, which is primary energy (fossil fuel), after the introduction of carbon taxes, which induces a decrease in the output.

Ricci (2007) has identified that undertaking abatement activities yields to an increase in production costs with a direct impact on capital return as well as a decrease in investment capacity that automatically leads to a decline in economic growth. Compared to Bovenberg and Smulders (1995) and Bovenberg and Mooij (1997), which have argued the evidence that environmental taxes foster environmental quality without a major negative effect on economic growth, the findings in this study present stronger negative effects in all the estimations results. However, the results of this study are in contrast to Abdullah and Morley (2014) and Hassan et al. (2020). They have found evidence that environmental taxes have no effect on economic growth under their approaches.

CONCLUSION AND RECOMMENDATIONS

The aim of this paper is to explore the effects of environmental taxation on economic growth with the most recent data available in 31 European countries that are also sharing the membership of the European Environmental Agency countries over the timeframe of the study (2009–2019). The study used initially pooled OLS, Fixed and Random Effects model, Individual Random and Time Fixed effects models. The results show a negative and significant effect at 1% of any increase of environmental tax measure on economic growth. Sensitivity analysis based on GMM (in baseline and with the introduction of additional variables that allow controlling the omission bias) confirms the baseline results. Coefficients are significant at [1% to 10%]. Finally, quantile analysis estimations that provide countries' threshold analysis indicated with a 1% significance level in each quantile that effects are negative, but each quantile threshold is not affected by the same magnitude.

The present results shed light on the possibility of discussing the strategy of the European Union, which is under the harmonization system, in the presence of evidence that highlights differentiated effects among countries' thresholds. This can raise inequity considerations. However, the environmental taxa-

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tion role is initially to support sustainable transitions. Regarding inequity issues are reflected by the fact that low-income countries are more negatively impacted by environmental taxes than the others. These negative impacts are compensated by the fact that an environmental tax scheme can positively influence production and consumption behaviors changes in spreading reforms and innovation in the economy.

In the panel, recommendations can be inspired by Chancel and Ilse (2014, p. 2), who suggest that "EU level policy instruments – which is part of EU's economic governance framework with economic, fiscal, labor and social policy coordination – used to protect vulnerable actors should remain at the national, or sub-national level." With the application of the subsidiary principle in each country, policy recommendation encourages to adapt in each country mechanisms for low-income households that generate welfare benefits (green cheques tax abatements, insulation policies financed by governments, subsidies for green cars and transportation), mechanisms in favor of innovation that are efficient energy oriented, energy management information to optimize green consumption and production behaviors, and promotion of subsidies for technical change.

AUTHOR CONTRIBUTIONS

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Formal analysis: Jules-Eric Tchapchet-Tchouto, Noukignon Koné, Loudi Njoya.
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APPENDIX A

Table A1. Testing the unit root of all the variables

Source: Construction from database using Stata 17.

Variables	LLC	IPS	Decisions
GDP	–12.5764	–10.7999	Stat. level I(0)
	(0.0000)	(0.0000)	RSE
Environmental Taxes	–11.2372	–6.52787	Stat. level I(0)
	(0.0000)	(0.0000)	RSE
GHG per Capita	–14.0367	–7.62487	Stat. level I(0)
	(0.0000)	(0.0000)	RSE
Environmental Protection Investment	–7.22863	–1.53898	Stat. level I(0)
	(0.0000)	(0.0619)	RSE
International Environmental Expenditures	–18.7327	–9.14079	Stat. level I(0)
	(0.0000)	(0.0000)	RSE
Investment	–10.6492	–5.74976	Stat. level I(0)
	(0.0000)	(0.0000)	RSE

Note: Robust Standard Errors in parentheses. LLC = Levin et al. (2002); IPS = Im et al. (2003).

Table A2. Hausman test results

Source: Computation from database.

Reference values	Coefficient
Chi-Square test value	14.396
Hausman test P-value	0.000

Table A3. Pairwise correlations matrix

Source: Computation from database using Stata 17.

Variables (In Ln)	(1)	(2)	(3)	(4)	(5)	(6)
(1) GDP	1.000	–	–	–	–	–
(2) Environmental Taxes	–0.471*	1.000	–	–	–	–
(3) GHG per Capita	–0.068	–0.158*	1.000	–	–	–
(4) Environmental Protection Investment	0.948*	–0.429*	–0.082	1.000	–	–
(5) International Environmental Expenditures	0.981*	–0.464*	–0.081	0.963*	1.000	–
(6) Investment	0.993*	–0.499*	–0.068	0.948*	0.979*	1.000

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A4. List of countries of European Countries part of European Environmental Agency member countries

EU 28	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom
Other countries	Iceland, Norway (Candidates to EU) – Switzerland (Former EU Candidate still European Environmental Agency Country)

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Source: Construction from database using Stata 17.

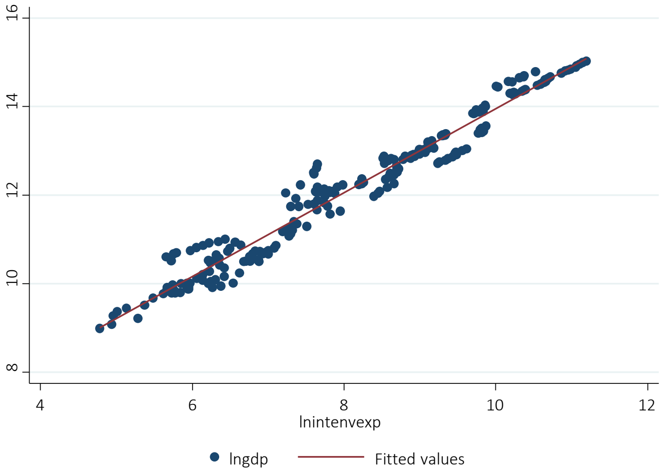

Figure A1. Correlation between GDP and international environmental expenditures

Source: Computation from database using Stata 17.

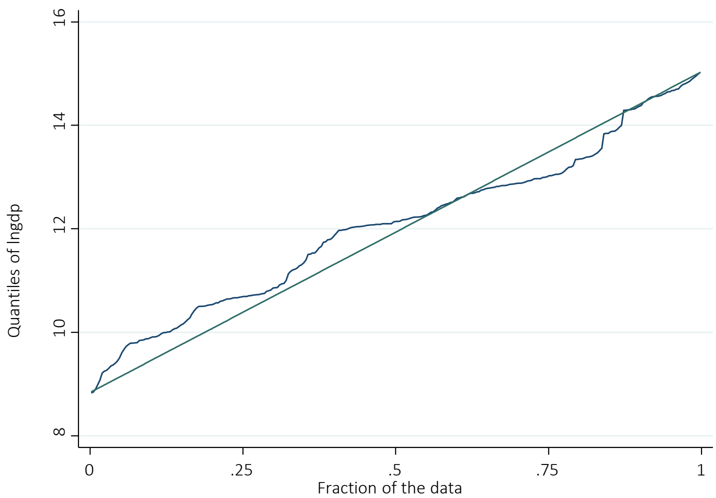

Figure A2. GDP by quantile

Source: Computation from database using Stata 17.

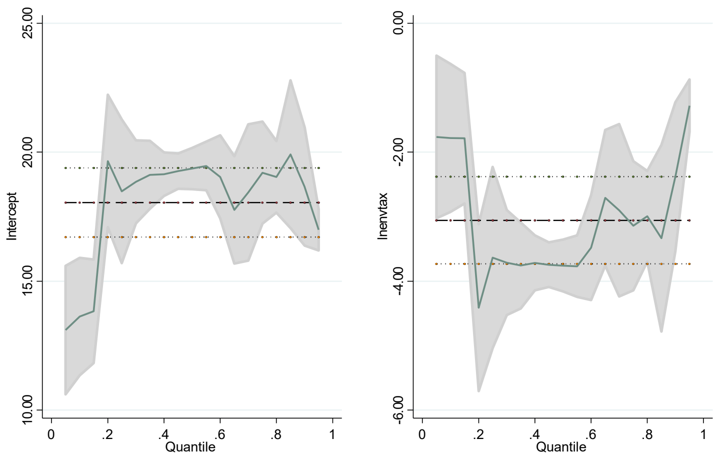

Figure A3. Coefficient of intercept and environmental taxes by quantile