Environmental Tax Convergence and Interdependence in the European Union

Convergencia e interdependencia fiscal ambiental en la Unión Europea

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Abstract

This paper empirically analyzes the convergence and interdependence of environmental taxes in EU-28 from 1998 to 2018. Our results evidence a lack of European integration and reveal a group of converging countries characterized by a lowering tax burden. Moreover, a subsequent spatial regression analysis supports that the converging countries exhibit a significantly greater sensibility to the neighbouring environmental tax policies, compatible with some degree of cross-country tax competition.

Keywords: Convergence clubs, environmental taxes, Europe, tax competition.

Resumen

Este artículo analiza la convergencia e interdependencia de los impuestos ambientales en EU-28 desde 1998 hasta 2018. Nuestros resultados evidencian una falta de integración europea y revelan la presencia de un grupo de países convergentes caracterizados por una carga tributaria decreciente. Además, un análisis de regresión espacial posterior sugiere que los países convergentes muestran una sensibilidad significativamente mayor hacia las políticas fiscales ambientales vecinas, lo cual sería compatible con cierto grado de competencia fiscal interestatal.

Palabras clave: competencia fiscal, convergencia de clubes, Europa, impuestos ambientales.

JEL Classification / Clasificación JEL: C22, H23.

1. Introduction

It is well known that the use of environmentally-related taxes can help states tackle the climate and resource use challenges by guiding production and consumption choices in a more eco-friendly direction. Given the global scope of such challenges, the European member states have been progressively implementing environmental policy instruments (Vehmas et al., 1999; Marín, 2001). In this regard, harmonized environmental taxes could constitute not only a crucial step towards a more integrated economic area with common environmental concerns (Herber and Raga, 1995; Jordan et al., 2003), but also could prevent countries from engaging in harmful tax competition by adjusting their environmental tax standards to attract capital and investment away from other countries (Vlassis, 2013; Cheng et al., 2021). Despite all this, the evident discrepancies in the environmental fiscal pressures (Speck and Paleari, 2016; Sterner and Köhlin, 2017) and revealed difficulties in energy tax harmonization (Dorigoni and Gulli, 2002) raise doubts about the success of the integration process in the environmental tax field.

So far, few studies have formally evaluated the convergence of environmental taxes in Europe. Some exceptions are, for instance, Villar-Rubio et al. (2015) or Villar-Rubio et al. (2017), who evidence the presence of sigma, beta, and gamma convergence of environmental fiscal pressure and environmental fiscal effort, respectively, from 1987 to 2008 for the majority of EU-15 countries. In contrast, Villar-Rubio and Huete-Morales (2017) show no convergence among 27 European countries from 1995 to 2012, despite finding some countries with common patterns of behaviour. In this paper we revisit the issue, providing more recent evidence on the dynamic convergence of EU-28 countries from 1998 to 2018. Unlike previous researches, we use the panel convergence methodology developed by Phillips and Sul (2007, 2009), which presents some advantages over other alternative methods, such as sigma or beta convergence. For instance, it enables to endogenously identify whether groups of countries are diverging or converging over time in different equilibria and it does not require the existence of common stochastic trends, allowing individual transition paths of each country to be temporary divergent. This approach has been widely employed to evaluate convergence of tax revenues (e.g., Apergis and Cooray, 2014; Akram and Rath, 2021), corporate taxes (e.g., Regis et al., 2015; Delgado et al., 2019), or overall tax burden (e.g.,

Delgado and Presno, 2017).[1] Furthermore, we also complement our analysis by identifying the determinants of the environmental tax burden trends, paying special attention to the potential interdependence and tax competition across countries. To our knowledge, this last issue has not been explored in the environmental tax field, although it has been theoretically founded (e.g., Zodrow and Mieszkowski, 1986; Wilson, 1986; Markusen et al., 1995, Rauscher, 1995; Yamagishi, 2019) and empirically supported in other kinds of taxes and/or fiscal measures (e.g., Ladd, 1992; Case et al., 1993; Besley et al., 2001; Genschel and Schwarz, 2011, Devereux et al., 2008; Heinemann et al., 2010; Cassette et al., 2013). For instance, it is not unreasonable that industrial firms, highly sensitive to production costs, tend to locate in countries with loose environmental regulations to reduce operating costs. As discussed by Rauscher (1995), if firms seek to avoid emissions taxes (the "pollution haven effect"), this may lead some governments to lower such taxes to attract business production processes, resulting in a "race to the bottom". Therefore, non-harmonized tax system could lead to environmental tax competition among governments, which may yield to sub-optimal tax levels, with a negative impact on the environment (e.g., Fredriksson and Millimet, 2002, Cremer and Gahvari, 2004; Davies and Naughton, 2014). Additionally, it should also be taken into account that the lack of tax convergence constitutes a potential source of asymmetries in the production/consumption conditions across countries and distortions in the resources redistributive capacity of national governments within an integrated area (e.g., Darolles and Tucci, 1992; Bénassy-Quéré et al., 2000; Leal et al., 2010).

Our study could be useful for determining the degree of convergence and competition of environmental taxes across the European countries, as well as identifying if there are certain groups of economies with idiosyncratic fiscal patterns. This is expected to guide policymakers to determine whether, taking into consideration the global climate ambitions, the current European environmental tax system is appropriate or, in contrast, some measures are needed to promote higher tax integration of certain countries.

The remaining paper is structured as follows. Section 2 describes the methodology framework. Section 3 depicts the data sources, while section 4 presents the empirical results. The final section concludes and discusses some policy implications of our findings.

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[1] The methodology has also been used to study the convergence in variables beyond taxes, such as greenhouse gas emissions (Panopoulou and Pantelidis, 2009, Camarero et al., 2013, Wang et al., 2014, Apergis and Payne, 2017), economic growth (Monfort et al., 2013), housing prices (Kim and Rous, 2012, Montañés and Olmos, 2013), bank efficiency (Matousek et al., 2015); among others.

2. Methodology

2.1. Convergence analysis

Our variable of interest is the environmental tax burden for country $i = 1,...,N$ and year $t = 1,...,T$ (y_{it}), which has been measured as the percentage of environmental tax revenues within the GDP. Following the panel data procedure of Phillips and Sul (2007, 2009), we evaluate its dynamic convergence by decomposing the variable into two elements:

$$log(y_{it}) = \delta_{it} \cdot \mu_t \tag{1}$$

where δ_{it} is a time-varying idiosyncratic factor, which captures the individual deviation of each country i from a common trend μ_t in the panel. In estimating δ_{it}, Equation (1) is re-expressed to remove the common component as follows:

$$h_{it} = \frac{log(y_{it})}{\frac{1}{N} \sum_{i=1}^{N} log(y_{it})} = \frac{\delta_{it}}{\frac{1}{N} \sum_{i=1}^{N} \delta_{it}} \tag{2}$$

where h_{it} captures the transition path of a given country i relative to the cross-sectional average at time t. It allows to evaluate whether time-varying idiosyncratic components converge over time to a steady state, after controlling for a common trend in the analyzed panel series. Then, in presence of convergence, all countries move towards a common trend and, therefore, $lim_{t \to \infty} h_{it} = 1$ for all i values $(i = 1, ..., N)$ and, at the same time, the cross-sectional variance of h_{it} should converge to zero, $lim_{t \to \infty} N^{-1} \sum_{i=1}^{N} (h_{it}-1)^2 = 0$. To construct a formal statistical test for convergence, Phillips and Sul (2007) suggest the following semi-parametric approach to model δ_{it}:

$$\delta_{it} = \delta_i + \frac{\sigma_i}{log(t+1) \, t^{\alpha}} \xi_{it} \tag{3}$$

where $t \geq 1$, $\sigma_i > 0$ for all i, δ_i is the time-invariant component of the idiosyncratic factor δ_{it}, $log(t+1)$ is an increasing function in t, α represents the convergence speed, and ξ_{it} is an error term weakly autocorrelated over t but $iid(0,1)$ across i. Therefore, on the bases of these considerations, the null hypothesis of convergence H_0: $\delta_i = \delta$ and $\alpha \geq 0$ (against the alternative hypothesis H_1: $\delta_i \neq \delta$ for some i or $\alpha < 0$) can be tested by using the following Ordinary Least Squares regression (the log-t regression) for $t = [rT], [rT]+1, ..., T$ and $0 < r < 1$:[2]

$$log\left(\frac{H_1}{H_t}\right) - 2 \, log(log(t)) = \hat{\alpha} + \hat{b} \, log(t) + \hat{u}_t \tag{4}$$

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[2] That is, the log-t regression is run with time series in which the first $(100 \times r)\%$ of the data is discarded. Phillips and Sul (2007) suggest setting $r = 0.30$ for $T \leq 50$.

where $H_t = \frac{1}{N} \sum_{i=1}^{N} (h_{it} - 1)^2$, the ratio $\frac{H_1}{H_t}$ represents the cross-section variance of h_{it} at the beginning of the period concerning the corresponding variance in each moment of time, and $\hat{b} = 2\hat{\alpha}$, where $\hat{\alpha}$ is the estimate of α in H_0. Then, the above-described null hypothesis can be empirically tested through the one-sided t-test of $\alpha \geq 0$, employing $\hat{b}$ and its heteroskedasticity and autocorrelation consistent standard error. It can be rejected at the 1%, 5% and 10% levels of significance if $t_{\hat{b}}$ < -2.33, -1.65 and -1.28, respectively.

Finally, if the null of convergence for the entire sample of countries is rejected, the clustering algorithm of Phillips and Sul (2007) will be conducted to identify the existence of convergent subgroups in the panel by using the algorithm proposed by the authors. The algorithm has the following steps:

1. Cross-section ordering. As a first step, we sort the N countries of the panel in decreasing order of y_{iT} (the last time observation).

2. Core group formation. We obtain the convergence test statistic $t_{\hat{b},k}$ from sequential log-t regressions based on the countries with the first k largest ordered y_{iT}, where $2 \leq k < N$. Then, a core group of k^* countries is selected based on the maximum $t_{\hat{b},k}$, considering only the cases where convergence is certain for the corresponding group (i.e., $min\{t_{\hat{b},k}\}$ > -2.33, -1.65 or -1.28, depending on the chosen significance level).

3. Club membership. We re-evaluate each individual country not included in the core convergence group (according to step 2) for membership in such group. For it, we add one country at a time to the core group and re-estimate the log-t regression. The new country satisfies the membership condition if the corresponding statistic $t_{\hat{b},k}$ is greater than zero. All countries that satisfy the membership condition are added to the core convergence group. Finally, we check whether the whole group (i.e. the members of the initial core group and the additional selected members) supports the previously stated null hypothesis of convergence.

4. Recursion and stopping. The countries not included in the club formed in step 3, form a complement group. Then, we run the log-t regression for this set of countries. If the obtained statistic $t_{\hat{b},k}$ suggests convergence, then these countries form a second convergence club. Otherwise, we repeat steps 1–3 to see if this second group can itself be subdivided into smaller subgroups that constitute convergence clusters. If no other clubs are detected, we conclude that the remaining countries have a divergent behaviour.

2.2. SPILLOVERS

With the aim of better understanding the possible forces behind the environmental tax trends, in a second stage we evaluate whether, after controlling for different socioeconomic features, cross-border tax interdependence might be driving the national environmental tax burdens of the converging group(s) of countries. To do so, we consider the following econometric specification:

$$log(y_{it}) = \sum_{c=1}^{C} \rho_c \left(W_{ij} \, log \left(y_{jt} \right) \right) \cdot D_{i \in c} + X_{it} \beta + \delta_i + \gamma_t + u_{it}$$

(5)

where the dependent variable, $log(y_{it})$, is the log of environmental tax burden in country $i = 1, ..., N$ at time $t = [rT],[rT] + 1, ..., T$,[3] and $W_{ij} \, log \left(y_{jt} \right)$ represents the proximity-weighted average of the log of environmental tax burden in neighbouring countries j around i. This variable is split in different groups according to the term $D_{i \in c}$ that takes a value of 1 if country i belongs to the convergence club c and 0 otherwise. Given these considerations, the parameters ρ_c reflect the intensity of the potential presence of tax interdependence between i and j, when i belongs to the cluster c. It would allow us to assess the degree of fiscal interdependence of each cluster of countries with its corresponding neighbours. The structure of the potential interdependence among each pair of countries i and j has been defined using a weight matrix W_{ij} based on the geographical distances between their capitals (d_{ij}), considering a distance-decay function with weights given by $1/d_{ij}$ where $i \neq j$, and 0 otherwise. By convention, in each case row elements have been standardized such that they sum to one. Additionally, according to the general literature on tax revenue performance, we also introduce in our model a vector of control factors X_{it}, comprising the following variables (in logarithms) that might influence the country's environmental tax burden:

· The openness degree ($open_{it}$), defined as the share of trade in GDP, is expected to be positively associated with fiscal revenues due to import taxes and the economic activity derived from economic integration. Additionally, in those open economies with greater external risks, societies usually demand an expanded role for the government in providing insurance, which requires, *inter alia*, higher tax revenues (Rodrik, 1998; Mahdavi, 2008; Ajaz and Ahmad, 2010; Heinemann et al., 2010). In contrast, an open economy reduces trade barriers and tariffs, which can have a negative influence on tax collection (Baunsgaard and Keen, 2010). The expected net effect of trade openness on environmental tax burden may depend on the dominating forces.

· The share of agriculture on GDP ($agric_{it}$) is expected to negatively affect state revenues because, unlike industrial and urbanization activities, which are energy-intensive and tend to generate large taxable surpluses, agricultural activities and related services (i.e., crop cultivation, livestock production, forestry, hunting, and fishing) are more difficult to tax or benefit from fiscal reductions (Bahl, 2004; Agbeyegbe et al., 2006).

[3] Consistently with the log-t regression test for convergence, Equation (5) is also regressed with the restricted time period, discarding a small fraction r=0.30 of the time series data. Even so, the results remain robust using the whole time period. These alternative results will not be displayed in the paper, but they are available upon request from the authors.

- The share of population older than 64 years ($dpop_{it}$), associated with the expenditure necessities in the country, may exhibit a positive effect on tax burden (Cassette and Paty, 2008).
- The fiscal deficit and public debt determine the need for future funding and, then, tax revenues (Castañeda Rodríguez, 2018). Therefore, to control for the fiscal situation of each country, we consider as regressors the tax expense ($taxe_{it}$) and the non-environmental tax revenues ($taxr_{it}$), both expressed as a share of GDP.
- Percentage of parliamentary seats occupied by social democratic and other left parties ($gleft_{it}$), as a proxy of the left-wing political support in the country. According to the literature (e.g., Allers et al., 2001; Tavares, 2004; Devereux et al., 2008; Molina-Morales et al., 2011), while right-wing parties commonly prefer reducing the public expenses and revenue collection, the left-wing ones tend to be more inclined to resource redistribution with a higher tax burden.[4]
- The institutional quality of each country, measured with the average of the six Worldwide Governance Indicators published by the World Bank (wgi_{it}): voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption. These factors are closely related with the legitimacy of government, which in turn may lower shadow economy and tax evasion (e.g., Bird et al., 2008; Molina-Morales et al., 2011; Besley and Persson, 2014; Oz-Yalaman, 2019).
- The real GDP per capita ($gdpc_{it}$), as a proxy of economic development in the country. In general terms, a high level of development brings more demand for public goods and services (Tanzi, 1983) and enhances the capacity of citizens and firms to pay taxes (Gupta, 2007). However, the empirical evidence is not unanimous. Some other studies support that GDP could negatively affect tax revenues over GDP if, for instance, countries employ higher levels of wealth and economic activity to reduce the corresponding tax rates (e.g., Bird et al., 2008; Cassette and Paty, 2008).
- We control for energy use per capita (energyc$_{it}$) and greenhouse gas emissions per capita (ghgc$_{it}$) to capture the changes in the environmental tax base. In this case, we would expect a positive influence of these two variables on the environmental tax revenues.

Finally, Equation (5) also includes country fixed effects (δ_i) to account for unobserved time-invariant country heterogeneity (e.g., cultural and historical factors that have remained relatively constant), and time fixed effects (γ_t) to account for common shocks (e.g., global crisis). The u_{it} represents the error term.

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[4] In this case, to keep the zero values of the variable $gleft_{it}$ after logarithm transformation, we consider ($gleft_{it} + 1$).

3. Data

We have retrieved from OECD (https://data.oecd.org/) the annual information on our measure of environmental tax burden for the 28 European Union countries over the period 1998-2018. The panel data set gathers the environmentally related tax revenues (expressed as a percentage within the GDP) associated with: energy products (including vehicle fuels), transport services, greenhouse gas emissions, as well as the management of waste, land, biodiversity, and wildlife. Furthermore, Table 1 summarizes the control variables and data sources employed in the complementary analysis aimed at exploring the cross-country interdependence and determinants of the environmental tax burden.

Table 1. Data sources

Variable	Description	Source
$open_{it}$	Share of trade over GDP.	World Bank
$agric_{it}$	Agriculture and related services (ISIC 1-5), value added (% of GDP).	World Bank
$dpop_{it}$	Percentage of people older than 64 years.	World Bank
$taxe_{it}$	Public expense in providing goods and services (% of GDP).	World Bank
$taxr_{it}$	Non-environmental tax revenues (% of GDP).	OECD
$gleft_{it}$	Share of cabinet posts of social democratic and other left parties.	CPDS [†]
wgi_{it}	Averaged Worldwide Governance Indicator, ranging from 0 to 100.	World Bank
$gdpc_{it}$	GDP per capita, in 1998 constant (million) euros.	Eurostat
$energyc_{it}$	Primary energy use in tons of oil equivalent per capita.	Eurostat
$ghgc_{it}$	Greenhouse gas emissions in tons of CO_2 equivalent per capita.	Eurostat

[†] CPDS: Comparative Political Data Set (https://www.cpds-data.org/).

4. Results

4.1. Convergence clubs

As suggested by Phillips and Sul (2007), to focus on the long-run behaviour of the variable of interest, it is often preferable to filter out the business cycle components from the series for implementing the convergence test. So, we have first used the Hodrick-Prescott approach (Hodrick and Prescott, 1997) to isolate the long-term components of our measure of the environmental tax burden.[5] Then, we have subsequently employed these components to calculate the dependent variable of Equation (4) where, as described above, we have discarded the first third of the time series. Next, we run the club convergence analysis. Table 2 below presents the results.

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[5] Following Ravn and Uhlig (2002) and De Jong and Sakarya (2016), we have applied the Hodrick-Prescott filter with the recommended value of the smoothing parameter λ=6.25 for annual data.

TABLE 2. CLUB CONVERGENCE

| Classification	Countries	$\hat{b}$	$t_{\hat{b}}$
Full sample		-1.458	-31.208***
Club 1	Svn, Cro, Grc, Lva, Dnk, Ndl, Ita, Fin, Cyp, Est, Prt, Cze, Mlt, Bgr, Pol, Aut, Hun, Fra, Gbr, Bel, Rom.	-0.714	-15.281***
Club 2	Svk, Ltu, Swe, Spa, Deu, Lux, Irl.	-0.559	-1.152

*** Indicates the rejection of the null hypothesis (convergence) at the 1% level.

Considering the full sample of European countries, the resulting estimated coefficient $\hat{b}$ from Equation (4) is negative, and the corresponding $t_{\hat{b}}$ statistic is large enough (in absolute value) to reject the null hypothesis of overall convergence among member states at the 1% level of significance. However, this finding does not exclude the existence of convergence clubs. To apply the log-t test to environmental tax revenues, a matrix is created with the order of countries based on their average tax revenues in the final year (i.e., 2018). Then, tax revenue convergence is tested by creating a subgroup that contains first the two states with the higher tax revenue and then adding, one by one, states with lower tax revenue to the subgroup.

Indeed, in the following stage of analysis, the Phillips-Sul algorithm identifies twenty-one non-converging countries, and one converging club consisting of the following states: Germany, Ireland, Lithuania, Luxembourg, Slovakia, Sweden, and Spain. As can be seen, the first group of 21 countries has a $t_{\hat{b}}$ statistic that rejects the null hypothesis of convergence at the 1% level, but the corresponding statistic obtained by the second club of previously-mentioned 7 countries is not large enough to reject the null, suggesting the presence of club convergence in this last case.

Figure 1 shows, for each identified club, the transition paths for the environmental tax burden of each country relative to the overall cross-sectional average in each period (as defined in Equation (2)). These curves allow us to visually evaluate the convergence dynamics. The transition paths converge towards 1 (i.e., the overall averaged transition path) under convergence of all sampled countries, while they converge to different constants in the presence of club convergence. Interestingly, the figure reveals that those countries belonging to the converging Club 2 are decoupled from the rest displaying transition paths below the overall average and sharing a negative slope until approximately reaching the value of -0.6 in 2018. That is, the converging Club 2 presents lower and lower relative levels of environmental tax burdens, which contrasts with the remaining non-convergent countries of the sample. Therefore, the results in this first part of the analysis are in line with the findings of Villar-Rubio and Huete-Morales (2017), who report a lack of environmental tax convergence among the EU-27 for a previous period (1995-2012). Additionally, they also highlight that certain countries, such as Germany, Lithuania, Slovakia, and Spain, have recently been characterized by relatively low levels of environmental fiscal pressure.

Figure 1. Transition path curves
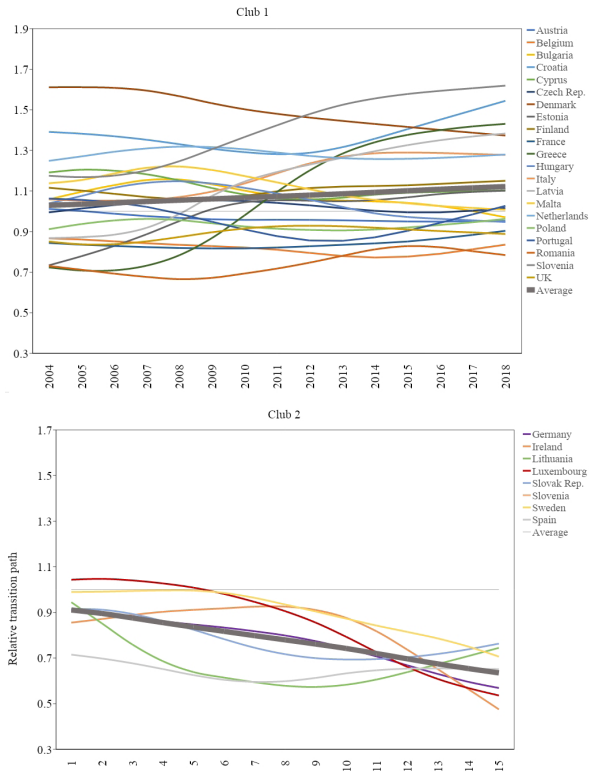
Note: This figure represents the transition path, $h_{it} = \log(y_{it}) / N^{-1} \sum_{i=1}^{N} \log(y_{it})$, where y_{it} is the Hodrick-Prescott trend of environmental tax burden for each country i at time t.

4.2. Spillover effects

The results have evidenced a general heterogeneous evolution of environmental tax policies across the countries, revealing a lack of European harmonization within the EU-28. However, the conducted analysis has identified a converging group of nations that present a notable downward trend of the tax burden. The observed pattern is consistent with a steady economic growth of grouped nations, and/or decreases in environmental tax revenues. Although energy consumption savings and lower greenhouse gas emissions could be behind this last possibility, the observed converging trend is also compatible with horizontal tax competition among governments, who could be tempted to lower their tax rates to attract investment and consumption as economic integration increases. We evaluate this last possibility with the baseline model

from Equation (5), which has been estimated by using the Two Stages Least Squares (2SLS) approach, instrumenting the spatially lagged dependent variables by the spatially lagged values of the remaining explanatory variables, as suggested by Kelejian and Robinson (1993), and Kelejian and Prucha (1998, 1999).

Table (3) reports multiple diagnostic tests confirming the validity of the instruments in the baseline specification,[6] as well as the main regression results.[7] As can be seen, the estimated coefficient ρ_c associated with neighbouring tax policies is statistically insignificant for those countries belonging to the club $c = 1$. This suggests that countries with a non-converging environmental tax burden are independent of the fiscal policy of their neighbours. In contrast, the corresponding estimated coefficient ρ_c for the converging club of countries $c = 2$ is higher than 2 and statistically significant at the 1 % level, indicating that these countries are heavily influenced by the neighbouring fiscal policies. These results support that the observed downward trend of the environmental tax burden established in the converging group of countries could be explained in part by the presence of some degree of strategic interdependence, which would be consistent with the tax competition hypothesis. From our knowledge, this is the first evidence supporting certain degree of environmental tax interdependence across European countries. However, our results are consistent, for example, with Devereux et al. (2008) and Heinemann et al. (2010), who also find strong interdependence in statutory tax rates among open countries without capital controls, which resulted in a downward trend in the average tax rate in the EU at the end of the last century.

Concerning the control variables, most of the estimated coefficients are reasonable and consistent with previous findings in the literature. First, our results suggest that trade openness significantly increases the environmental tax burden. This seems rather natural considering that trade is associated with environmental tax events, such as transport services and energy imports. Second, given that increases in public expenses in providing goods and services could imply further funding necessities for the government, it is not surprising to find a significantly positive association between $taxe_{it}$ and tax burden. Interestingly, our findings are in agreement with Tavares (2004) and Molina-Morales et al. (2011), among others, showing that gains in government support of left-wing parties significantly increase tax revenues. Concerning the energy consumption per capita, it is significantly positively associated with the environmental tax burden, probably because it is one of the elements

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[6] The Kleibergen-Paap rk Wald F statistic exceeds the Stock-Yogo critical values (Stock et al. 2005), rejecting the null hypothesis that instruments are weak, the Kleibergen-Paap rk LM test leads to the rejection of the null hypothesis of under-identification (Kleibergen and Paap 2006), and the Hansen J statistic fails to reject the null hypothesis that the instruments are exogenous.

[7] We have also conducted the variance inflation factor (VIF) test to assess the degree of multicollinearity among the explanatory variables in Equation (5), which may inflate the standard errors of the regression coefficients. According to the test results, the mean VIFs is 3.81, and all individual VIF are below 5, suggesting that multicollinearity is not a concern in the analysis (O'brien 2007).

TABLE 3. 2SLS ESTIMATES OF EQUATION (5) FROM 2004 TO 2018

Dependent variable: $log(y_{it})$		
$w_{ij} \, log\left(y_{jt}\right) \cdot D_{i \in c=1}$(non-converging club)	0.343	(0.355)
$w_{ij} \, log\left(y_{jt}\right) \cdot D_{i \in c=2}$(converging club)	2.222***	(0.588)
$log(open_{it})$	0.319***	(0.118)
$log(agric_{it})$	-0.031	(0.034)
$log(dpop_{it})$	0.149	(0.256)
$log(taxe_{it})$	0.180*	(0.098)
$log(taxr_{it})$	-0.045	(0.098)
$log(gleft_{it} + 1)$	0.009**	(0.004)
$log(wgi_{it})$	0.016*	(0.011)
$log(gdpc_{it})$	-0.685***	(0.135)
$log(energyc_{it})$	0.496***	(0.145)
$log(ghgc_{it})$	-0.010	(0.073)
Kleibergen-Paap rk Wald F statistic	21.828	
Kleibergen-Paap rk LM statistic	42.025	[0.002]
Hansen J statistic	22.706	[0.202]
$N \times T$	420	
Adj. R^2	0.822	

The regression includes country and time fixed effects. Driscoll-Kraay robust s.e. are presented between parenthesis, while p-values are in brackets. We use *, **, and *** to denote statistical significance at 10, 5, and 1%, respectively. The spatially lagged dependent variables have been instrumented by the first order of the spatially lagged explanatory variables.

constituting the own environmental tax base. In contrast, the estimated coefficient for GDP per capita is negative, in line with some previous researches, such as Bird et al. (2008).[8] We do not find a significant relationship between the remaining control factors and the environmental tax burden.

5. CONCLUDING REMARKS

In this paper, we have examined the evolution of environmental tax burdens in EU-28 from 1998 to 2018. The distinctive feature of the study has been in its methodology. Using the Phillips and Sul (2007) club convergence approach, we have evidenced a lack of overall convergence of the environmental tax policies in Europe and the formation of a convergence club of countries with a decreasing tax burden. Additionally, a subsequent regression analysis reveals

[8] Similarly to Bird et al. (2008), we also explore the possibility of a non-linear linkage between tax burden and GDP per capita, estimating an alternative version of Equation (5), where $log(gdpc_{it})$ is replaced by the GDP per capita and its square term. As can be seen in Annex, our main conclusions remain constant and, interestingly, we find that GDP per capita positively affects tax burden when the economic development is large enough (i.e., higher than the estimated turning point $gdpc_{it}^* = -\hat{\beta}_{gdpc_{it}}/2\hat{\beta}_{gdpc_{it}^2} = 0.146$ million euros per capita). So, for instance, considering the sample average GDP per capita, the countries that would present a growing relationship between income and environmental tax pressure are Sweden, Netherlands, Luxembourg, Ireland, and Denmark.

that the downward trend exhibited by the club of converging countries might be explained not only by their income levels, energy consumption savings, and institutional and socio-political factors, but also by their greater sensibility to the neighbouring environmental tax policies in Europe. This contrasts with the remaining group of non-converging countries, whose tax burden is statistically independent of neighbouring countries. Our results suggest that the downward trend of the environmental tax burden in certain European countries may have been partially driven by tax competition, in addition to other alternative explanations, such as efficiency improvements.

Although there have been political intentions to harmonize tax rates in Europe for decades, our results evidence there is still room for greater environmental coordination among the member states. These results are not surprising given the heterogeneity among the European countries. Our findings reveal the need to integrate and prioritize environmental policies among European governments and to promote sustainable development. In general, we appeal for an environmental tax harmonization by unifying the design of environmental taxes as a whole at the European level. To avoid harmful tax competition, the EU should take effective measures to supervise and guide the member states, especially to prevent them from lowering the environmental protection threshold. Recognition of this may be crucial for the development of future agreements.

ACKNOWLEDGMENTS

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Annex. Robustness check

Table 4. 2SLS estimates of an alternative version of equation (5) from 2004 to 2018

Dependent variable: $log(y_{it})$		
$W_{ij} \, log\left(y_{jt}\right) \cdot D_{i \in c=1}$(non-converging club)	0.307	(0.382)
$W_{ij} \, log\left(y_{jt}\right) \cdot D_{i \in c=2}$(converging club)	1.728***	(0.556)
$log(open_{it})$	0.303***	(0.112)
$log(agric_{it})$	-0.016	(0.043)
$log(dpop_{it})$	0.151	(0.236)
$log(taxe_{it})$	0.065	(0.100)
$log(taxr_{it})$	0.115	(0.094)
$log(gleft_{it} +1)$	0.008**	(0.004)
$log(wgi_{it})$	0.009	(0.012)
$gdpc_{it}$	-39.242***	(10.707)
$gdpc_{it}^2$	133.971*	(79.175)
$log(energyc_{it})$	0.298**	(0.145)
$log(ghgc_{it})$	-0.074	(0.066)
Kleibergen-Paap rk Wald F statistic	12.259	
Kleibergen-Paap rk LM statistic	46.737	[0.000]
Hansen J statistic	20.663	[0.297]
$N \, x \, T$	420	
Adj. R^2	0.836	

The regression includes country and time fixed effects. Driscoll-Kraay robust s.e. are presented between parenthesis, while p-values are in brackets. We use *, **, and *** to denote statistical significance at 10, 5, and 1%, respectively. The spatially lagged dependent variables have been instrumented by the first order of the spatially lagged explanatory variables.