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Isabelle Cadoret, Emma Galli, Fabio Padovano

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1 Environmental taxation: Pigouvian or Leviathan?

2 Isabelle Cadoret¹ · Emma Galli² · Fabio Padovano^{1,3}

3
4

5 Abstract

6 This paper empirically examines which type of taxes are environmental taxes, by
7 analyzing how governments actually use them. The theoretical literature is polar-
8 ized between two alternative interpretations of environmental taxes: the Pigouvian
9 and the Leviathan hypotheses, each leading to alternative testable hypotheses. We
10 test them on a sample where the analysts' discretionary evaluations are minimal, the
11 EU-28 countries that committed themselves to correcting a negative environmental
12 externality, the greenhouse gas emissions, by 2020. The estimates lend support to
13 the strict Pigouvian hypothesis, while the Leviathan hypothesis appears less consist-
14 ent with the data.

15 **Keywords** Environmental taxes · Pigouvian taxation · Leviathan government · GHG
16 reduction · Arellano–Bond GMM

17 **JEL Classification** Q28 · H54 · H87 · D72 · D73 · D78

18 1 Introduction

19 What type of taxes are, in fact, environmental taxes (henceafter, ET)? For what pur-
20 poses governments actually use them, and how efficient are they in achieving such
21 goals?

A1 Paper presented at the AISRe 2019 conference at the GSSI L'Aquila, EPCS 2017 conference in
A2 Budapest, EALE 2016 conference in Bologna, SIEP 2016 conference in Lecce and the TEPP
A3 Conference at La Réunion. We thank the participants to these conferences, as well as Nicolas
A4 Gavoille, Benoit Le-Maux and Yvon Rocaboy for helpful comments on previous versions of this
A5 paper. The usual caveat applies.

A6 ✉ Emma Galli
A7 emma.galli@uniroma1.it

A8 ¹ Univ Rennes, CNRS, Condorcet Center for Political Economy, CREM UMR6211,
A9 35000 Rennes, France

A10 ² Department of Social and Economic Sciences, Sapienza University of Rome, Rome, Italy

A11 ³ DSP, Università Roma Tre, Rome, Italy

22 The theoretical literature is polarized between two alternative answers to these
23 questions, which can rationalize why governments resort to ET. The classical Pigou-
24 vian interpretation holds that ET suffice to internalize and correct negative environ-
25 mental externalities, regardless of how their revenues are being spent (Baumol and
26 Oates 1988). The alternative interpretation views ET just like any other tax, with the
27 notable exception that they are the least unpopular among all fiscal levies, because
28 of the citizens' favorable outlook on the protection of the environment (EU Com-
29 mission 2014). Leviathan governments, aiming at maximizing tax revenues at the
30 lowest political cost, exploit this feature and resort to ET relatively more, irrespec-
31 tive of their efficiency at achieving environmental goals (Kirchgassner and Schnei-
32 der 2003). These hypotheses reflect two opposite visions of government: a benevo-
33 lent one, stemming from the welfare economics tradition, and a utility-maximizing
34 one, associated with the public choice school.

35 This paper empirically analyzes how governments actually use ET to verify
36 which of these two alternative theoretical interpretations best represents the real-
37 ity of environmental fiscal policy. To this end we consider the sample of the 28 EU
38 countries over the period 2005-2017 that, within the Lisbon agenda, in 2009 have
39 formally decided to commit themselves to attain a specific environmental protection
40 target: the reduction of Green House Gases (henceafter, GHG). Empirically, we use
41 data on Greenhouse gas emissions in Effort Sharing Decision (ESD) sectors con-
42 cerned by the target¹.

43 Two features make this sample especially suitable for this type of analysis: first,
44 GHG reduction is a clearly measurable objective;² second, the countries in the sam-
45 ple have chosen their reduction target themselves.³ Both features reduce to a strict
46 minimum the analysts' discretion in the evaluation of the governments' use of ET.⁴
47 Such an attribute is quite hard to find in the rest of the literature and it greatly eases
48 the task of identifying which theory best represents the way governments actually
49 use ET.

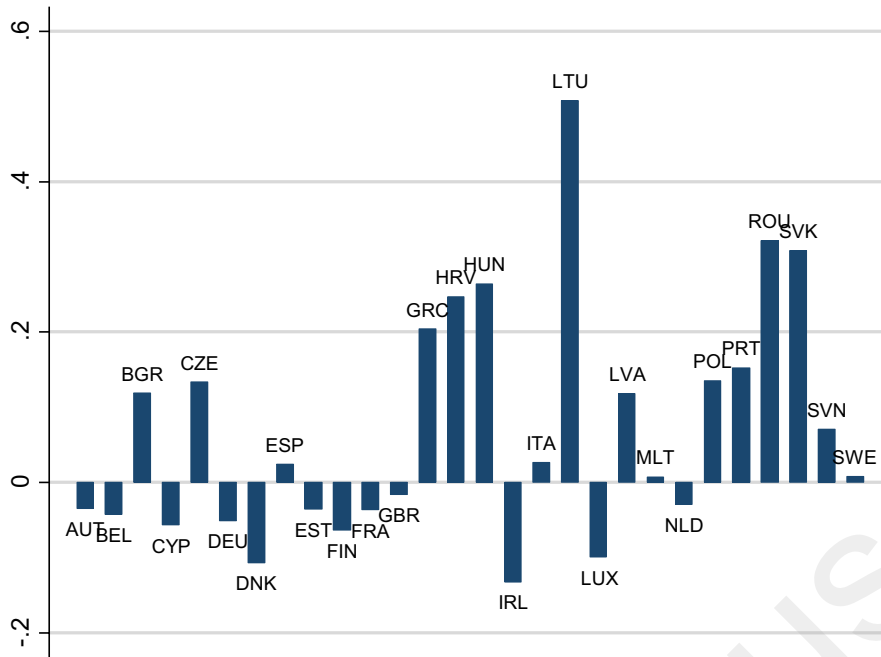
50 The focus on GHG as pollutant calls into question the role of the heterogenous
51 firms, both in terms of technology adopted and of size of production, which are
52 one of the major (albeit not the only) sources of this type of emissions. As our

1FL01 ¹ Data are available since 2005.

2FL01 ² Article 2.1 of decision 406/2009 defines the GHG emissions as "...the emission of carbon dioxide
2FL02 (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and
2FL03 sulphur hexafluoride (SF₆), [...] expressed in terms of tons of carbon dioxide equivalent".

3FL01 ³ Specifically, the EU member states' targets are given by the EU Effort Sharing Decision where "Mem-
3FL02 ber States' reduction efforts should be based on the principle of solidarity between Member States [...]
3FL03 taking into account the relative per capita GDP of Member States". Furthermore, the national 2020 tar-
3FL04 gets apply to non-Exchange Trade System emissions, a crucial fact, since it allows analyzing the impact
3FL05 of ET in reducing a type of emissions and in sectors where an important policy instrument, such as ETS,
3FL06 do not operate (preliminary n. 6 of decision 406/2009).

4FL01 ⁴ Decision 406/2009 of the EU Parliament and Council of the EU commits the EU member countries
4FL02 collectively to reduce GHG to 70% of their 1990 levels by the year 2020. In addition to this EU wide tar-
4FL03 get, the Decision sets also country-specific targets, to account for the economic and environmental start-
4FL04 ing point situations of each country, especially those of the former Eastern European nations. (Annexe II
4FL05 to Decision 4006/2009).



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Fig. 1 Relative distance from country specific targets for GHG emissions set by Decision n. 406/2009 mean over the period 2005–2017)

53 analysis is conducted at the country level, we refer to the average environmental
 54 friendliness of the technology adopted by the industrial sector of the country.

55 Our empirical strategy consists in successively testing the empirical restric-
 56 tions that theory associates with the two alternative interpretations of ET. To ver-
 57 ify the Pigouvian hypothesis we compare the intensity with which each country
 58 has resorted to ET with the degree of success in achieving the GHG reduction tar-
 59 get; a positive correlation between the country’s distance from the target and its
 60 resort to ET confirms the hypothesis that ET are adopted to (and effective at) cor-
 61 recting the negative environmental externality. Conversely, the Leviathan hypoth-
 62 esis, which basically states that governments set taxes just so to maximize rev-
 63 enues, disregarding the environmental goals of ET, is verified if ET revenues are
 64 positively correlated with redistributive, vote buying expenditures items, rather
 65 than with public good type of programs.

66 This type of analysis faces two fundamental difficulties, which the literature
 67 has failed to address so far. The first is that the distance from the environmental
 68 target can be either negative or positive. As Fig. 1 shows, countries can either
 69 fall short of their target, and be therefore supposed to intensify their environ-
 70 mental policies; or they can go beyond their target and might then in principle
 71 relax their fiscal efforts aimed at reducing GHG emissions. The negative and
 72 positive values that the target variable may assume of course affect the inter-
 73 pretation of the estimated coefficients and complicates the analysis. We address
 74 this problem by distinguishing between countries with a positive difference with
 75 respect to the target, i.e., those that have already achieved it or even done better,

76 from those with a negative difference, i.e., those which have still to attain their
77 target. These two sets of countries are illustrated in Fig. 1.

78 The second problem is the choice of the proper fiscal indicator to measure the
79 effect of ET on the GHG target. The theoretical literature is not univocal in this
80 respect. Pigouvian models (Baumol and Oates 1988; Sandmo 2010) advise using
81 the effective marginal ET rate as the policy choice variable, as a measure of the
82 disincentive effect to polluting that taxation engenders. Revenue-based measures
83 of fiscal effort, such as the ratio of ET revenues over total tax revenues, seem
84 instead more appropriate for the Leviathan hypothesis, as they reveal the degree
85 to which the government acts in a revenue maximizing way in environmental pol-
86 icy (Schöb 2003). In addition, the ET's efficiency at correcting the externality—
87 a point to be verified in the analysis—also affects the choice of either the rate-
88 based or the revenue-based indicator of the government's effort at reducing the
89 externality. If governments actually use ET in a Pigouvian way and these taxes
90 are effective at reducing GHG emissions, we should observe in those countries
91 higher than average ET rates but lower than average ET revenues, since the high
92 tax rates reduced the externality and hence the revenue source. Yet, if ETs were
93 inefficient at correcting the externality and governments still acted in a Pigouvian
94 way, the revenue source would still exist, so that both rates and revenues should
95 be higher than average. To sort out this potentially serious problem, we estimate
96 the model using proxies for both ET rates and revenues. Indeed, the correlation
97 coefficient between the two indicators is $r = 0.16$, low enough to legitimize the
98 use of both of them as alternatives in our analysis. Figures 2 and 3 illustrate the
99 average values of these two variables in the countries of our sample.

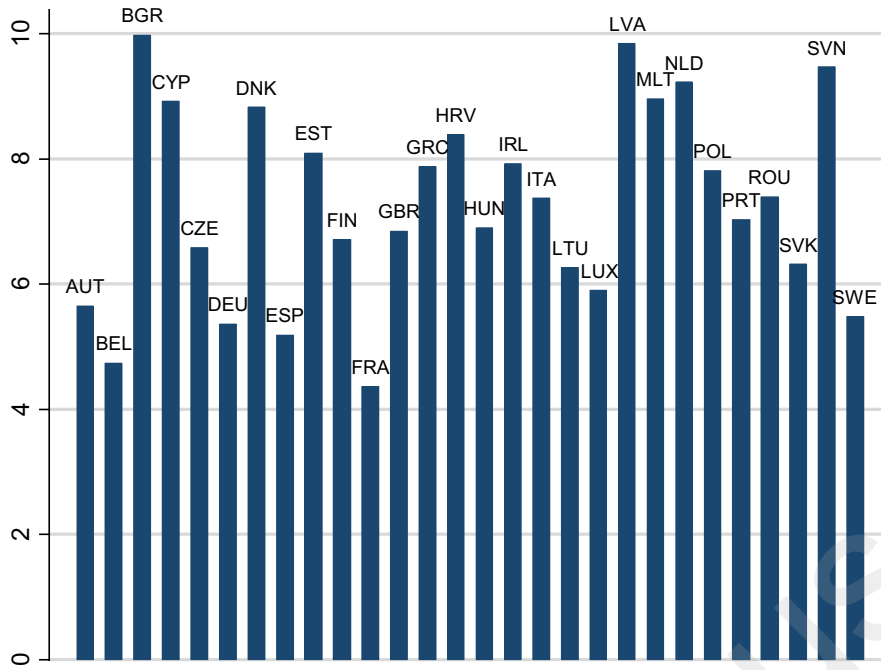
100 As the tested hypotheses refer to two alternatives views of government, we
101 examine the politico-institutional transmission mechanisms between the resort
102 to environmental fiscal means and the attainment of environmental goals—an
103 issue understudied so far (Kirchgassner and Schneider 2003; Cadoret and Pado-
104 vano 2016). In a Pigouvian world the efficiency of government is the only con-
105 ditioning factor to the attainment of the policy goal; in a Leviathan world, meas-
106 ures of the rule of law limit the discretionary action of the government, which
107 should instead be sensitive to the demands of special interest groups. We there-
108 fore introduce in our empirical specification proxies for the stringency of envi-
109 ronmental regulations and for lobbying activity.

110 The rest of the paper is organized as follows. Section 2 illustrates the empiri-
111 cal strategy, the dataset and the specification of the model. The results of the
112 estimates are presented and discussed in Sect. 3. Section 4 summarizes the con-
113 clusions of the analysis.

114 **2 Empirics**

115 **2.1 Empirical strategy**

116 Bringing the two theoretical hypotheses to the data first implies the choice of the
117 dependent variables. These in turn will be regressed, as discussed in Sect. 2.2, on



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Fig. 2 Total environmental taxes as a percentage of total revenues from taxes and social contributions (mean over the period 2005–2017)

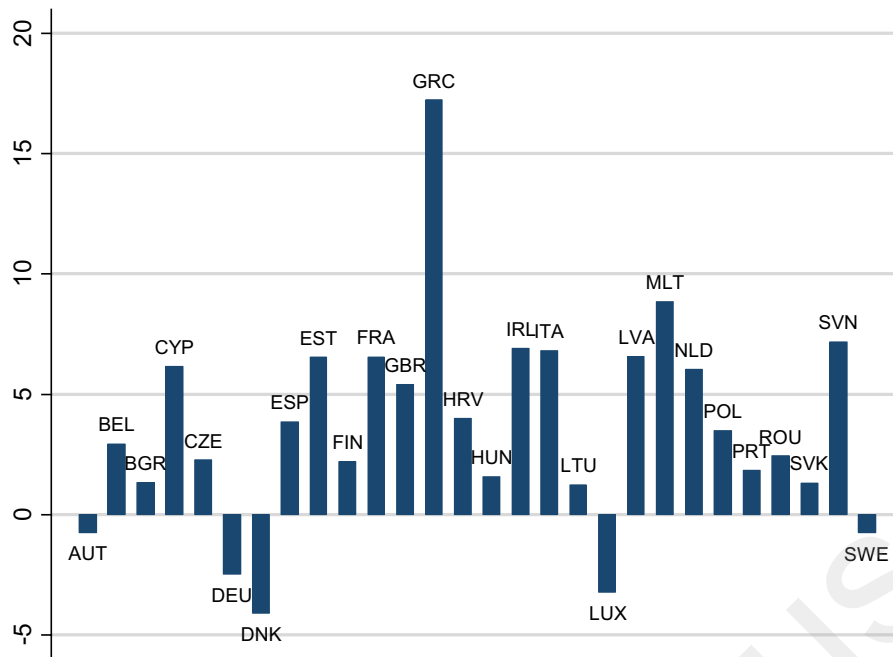
118 the main variables of interest related to each hypothesis plus three sets of controls:
 119 (1) the economic variables \mathbf{X} ; (2) the energy characteristics and environmental pol- **AQ1**
 120 icy variables \mathbf{W} ; (3) the politico-institutional variables \mathbf{Z} .

121 To test the Pigouvian interpretation we select relative the difference between the
 122 country's GHG emissions target and the observed emissions, named GHG_DIFF, as
 123 the endogenous variable (see "Appendix"). It measures the relative distance separ-
 124 ating the country from the target assigned by Decision 406/2009—Annexe II. When
 125 necessary, this variable is separated in two groups, one including the countries that
 126 are doing better than their target (usually, the Eastern European ones) and have thus
 127 a positive difference; the other with the countries that are underscoring their specific
 128 target (mainly the Western Europeans) and show a negative difference. The specifi-
 129 cation of the empirical model is as follows:

$$130 \quad GHG_DIFF_{it} = \alpha_1 GHG_DIFF_{it-1} + \beta_{1R} ET_REV_{it} + \beta_{1T} ET_RATE_{it} \quad (1)$$

$$131 \quad + \gamma_1 \mathbf{X}_{it} + \delta_1 \mathbf{W}_{it} + \theta_1 \mathbf{Z}_{it} + \varphi_i + \varepsilon_{it}$$

132 where i identifies the country and t the year and φ are the country fixed effects. Since
 133 the attainment of the GHG target is progressive over time, the equation includes the
 134 lagged dependent variable; it is estimated dynamically via Arellano–Bond GMM
 135 estimator with robust standard errors, taking into account the potential endogeneity
 136 problem with ET: this may arise because proximity to the GHG target may condition
 137 countries' resort to ET, but at the same time the use of ET (if effective) may affect
 138 the countries' distance from the target.



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Fig. 3 Effective marginal tax rate of environmental taxation (mean over the period 2005–2017)

139 Among the explanatory variables, the Pigouvian hypothesis calls for examining
 140 two complementary measures of ET. The first one represents the revenue of envi-
 141 ronmental taxes (labeled ET_REV). It is measured with the ratio of all the envi-
 142 ronmental tax revenues over total tax revenues.⁵ The second one is a proxy for the
 143 effective marginal tax rate of environmental taxation (labeled ET_RATE). As such
 144 we use the variation of the implicit energy tax rate calculated over two successive
 145 calendar years.⁶ As mentioned in the introduction, if ET_RATE is used in the Pig-
 146 ouvian way and proves effective at reducing GHG emissions, we should observe a
 147 negative correlation between ET_RATE and GHG emissions, which should reduce
 148 the tax base for the ETs. If instead ET are inefficient at correcting the externality,
 149 even in the case when governments acted in a Pigouvian way, the externality would
 150 still remain and the revenue source with it. In this case we should observe both high
 151 ET rates and revenues. We hence estimate the model using both ET_RATE and
 152 ET_REV as proxies for the country’s environmental fiscal effort. We hold that the

⁵ According to Eurostat, our data source, “... an environmental tax is a tax whose base is a physical unit (or a proxy of a physical unit) of something that has a proven, specific negative impact on the environment”. Hence environmental taxes fall within the following economic sectors: energy, transport, pollution, resources. Eurostat data are compatible with the concepts used in the system of national accounts. Throughout the paper, we stick to this definition and to this source of official data.

⁶ The implicit energy tax rate is measured as the ratio of energy tax revenues to final energy consumption. Energy tax revenues are calculated in constant price euros (deflated with the implicit GDP deflator, prices of year 2010) and final energy consumption is assessed in tons of oil equivalent. Eurostat is the source for these data.

153 Pigouvian hypothesis is confirmed if: a) in countries with a positive relative differ-
154 ence between the GHG target and the observed emissions, there is a positive cor-
155 relation between GHG_DIFF and ET_RATE; that because higher tax rates further
156 reduce the emissions and thus increase the positive difference between the target
157 and the observed value of GHG; furthermore GHG_DIFF and ET_REV should be
158 not significantly correlated; b) in countries where instead there is a negative differ-
159 ence between the GHG target and the observed emissions, again a positive correla-
160 tion is found between GHG_DIFF and ET_RATE, because higher tax rates reduce
161 the emissions and therefore reduce the negative difference between the target and
162 the observed value of GHG; once more a not significant correlation should exist
163 between GHG_DIFF and ET_REV.

164 Among the economic variables of vector \mathbf{X} we begin by examining the com-
165 plex relationship between income-related variables and pollution. A first theoretic-
166 al linkage is the well-known “environmental Kutznets curve”; this hypothesis
167 posits a positive relationship between economic development and environmental
168 degradation at low levels of per capita income, which then turns negative when
169 citizens-taxpayers’ support for environmental protection begins to improve envi-
170 ronmental quality, including the reduction of GHG emissions. In the context of
171 our sample of highly developed countries, most observations should be paced in
172 the negatively sloped portion of the curve. More recently, however, Ordás Criado
173 et al. (2011) provide a partially observational equivalent explanation of the rela-
174 tionship between income and environmental protection. In the context of neoclas-
175 sical growth models, they show that, along the pollution optimal path, the growth
176 rate of output per capita has a negative impact on the growth rate of emissions
177 per capita (scale effect), which is in turn negatively related with the initial level
178 of pollution (defensive effect). In the extended version of their model, the impact
179 of the initial level of output per capita is not a priori defined. Their contribu-
180 tion requires considering not only a measure of per capita income growth (which
181 would be sufficient to test the environmental Kutznets curve hypothesis) but also
182 the initial level of per capita income as a control. We then insert in Eq. (1) both
183 indicators of per capita economic growth (G_GDPPC) and of per capita income
184 levels (GDPPC) in logarithm, and let the sign be determined by the empirical
185 analysis.

186 Vector \mathbf{W} includes controls for energy and environmental policies. We control for
187 the energy intensity in production (variable ENERGY_INT), specified as the kilo-
188 gram of oil equivalent per 1000 euros worth of products. The expected sign on this
189 covariate is always negative, since in countries with a positive difference higher val-
190 ues of ENERGY_INT increase GHG emissions, thus reducing the value of GHG_
191 DIFF; in countries with a negative difference, instead, more pollution increases the
192 negative GHG_DIFF, resulting again in an inverse correlation. We also include a
193 linear TREND, which captures the increasing diffusion of environmental regulations
194 over time in our sample (Botta and Kozluk 2014).

195 Variables in vector \mathbf{Z} characterize the transmission mechanism of the envi-
196 ronmental taxation. To capture the opposite visions of government that the wel-
197 fare economics and the public choice traditions propose, we include two control

198 variables. The first is RLE, an indicator of the degree of enforcement of the law in
199 the country, from the World Bank World Governance Indicators. Greater values of
200 RLE suggest that government decisions are more efficiently implemented, which
201 minimizes government discretion that would instead be magnified in a Levia-
202 than world⁷. Conversely, a Leviathan-type government should be privy to special
203 interest groups that stand against environmental regulation; we proxy this possi-
204 ble effect through the variable VA_INDUS, i.e., the share of value added from
205 industry on total GDP. This variable is commonly used in the literature (Fredriks-
206 son 2014; Cadoret and Padovano 2018) and reflects the idea that the greater is
207 the value added of an industry, the higher are the producers' costs of coordina-
208 tion in order to get organized as a lobby. The predicted impact of VA_IND on
209 GHG_DIFF is therefore positive, since more value added increases lobbying costs,
210 which reduces observed GHG thus increasing the positive difference (or increases
211 the negative one).

212 In a Pigouvian world a statistically not significant coefficient would suggest that
213 these pressures have no impact on governments' tax decisions; a positive and signifi-
214 cant coefficient, instead, would capture the effect that the size of the industry exerts
215 on environmental taxation.

216 2.2 Sample

217 The sample encompasses 28 countries that, through Decision 406/2009, have (a)
218 committed themselves to collectively reduce GHG to 70% of their 1990 levels by
219 the year 2020; and (b) agreed to a series of country-specific targets, to account
220 for the economic and environmental starting points of each country, especially
221 the former Eastern European ones (Benjamin et al. 2015). These countries are
222 Austria, Belgium, Bulgaria, Cyprus, Croatia, Czech Republic, Denmark, Esto-
223 nia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithu-
224 ania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia,
225 Slovenia, Spain, Sweden and the United Kingdom. The time interval covers the
226 period 2005–2017, for which Eurostat provides coherent data for the Greenhouse
227 gas emissions in Effort Sharing Decision (ESD) sectors; furthermore, 2005 is the
228 beginning year for the effort sharing policy in the attainment of the GHG target.
229 Each variable thus features a maximum of $13 \times 28 = 364$ observations, quite
230 enough to obtain efficient estimates. Table 1 provides the descriptive statistics,
231 while Table in the “Appendix” reassumes the characteristics of the variables and
232 their data sources.

233 Tables 2, 3 and 4 present the results that are pertinent to the objective of our anal-
234 ysis. We test all the control variables described in 2.2 and keep the significant ones.

7FL01 ⁷ We have also tried alternative variables, such as the World Bank measure of regulatory quality and of
7FL02 control of corruption. The results do not change qualitatively at all, since all these indicators are highly
7FL03 correlated. We choose the measure of the rule of law because of its broader scope. The estimates with the
7FL04 alternative indicators are available upon request.

Table 1 Descriptive Statistics

Variables	(1) N	(2) mean	(3) sd	(4) min	(5) max
GHG_DIFF	364	0.0694	0.167	− 0.195	0.707
D_ET_RATE	364	3.618	14.79	− 49.79	83.35
ET_REV	364	7.263	1.692	4.150	11.63
G_GDP_PC	364	1.728	3.920	− 14.56	23.94
DEBT	364	60.48	34.70	3.700	178.9
logGDP_PC	364	10.37	0.371	9.427	11.49
logENERGY_INT	364	4.980	0.285	4.039	5.717
ET_RATE	364	41.068	13.174	15	62.28
RLE	364	1.134	0.611	− 0.138	2.100
VA_INDUS	364	23.46	5.868	9.368	38.52
SC_EXP	364	16.40	3.906	7.900	25.60
GS_EXP	364	6.393	1.897	2.800	12.90

235 3 Pigouvian or Leviathan taxes?

236 3.1 Testing the Pigouvian hypothesis

237 The estimates of equation (1) are reported in Table 2, which shows the estimation
 238 results for the whole sample of 26 countries (model 1–3), for countries with a nega-
 239 tive GHG_DIFF values (model 4, i.e., those that have still to attain the target, mainly
 240 the western Europeans ones) and for those with a positive value of GHG_DIFF
 241 (model 5, i.e., the countries that have already attained the target, mainly the western
 242 Europeans ones).

243 Our estimates appear consistent with the Pigouvian hypothesis: ET_REV is nega-
 244 tive and not statistically significant, whereas ET_RATE has the expected positive
 245 sign. This pattern of results confirms that high marginal rates on ET actually reduce
 246 the environmental externality represented by the GHG emissions and the tax base
 247 for ET with it. The positive and significant coefficient of ET_RATE in both sub-
 248 samples is consistent with the Pigouvian hypothesis; its impact is quantitatively
 249 similar in both Eastern European countries, which have already achieved their tar-
 250 gets, and in Western European ones, which still have to attain it. The Arellano–Bond
 251 estimation technique here accounts for the potential endogeneity of ET_REV; yet,
 252 since its coefficient is not statistically significant, this does not affect the validity of
 253 the estimates.

254 Coming to the economic controls, we observe that faster economic growth
 255 reduces the distance from the target, consistently with the theory of the environ-
 256 mental Kutznets curve; this effect is especially evident in countries with a positive
 257 distance from the target, i.e., mainly the Eastern European ones, characterized by
 258 rates of economic expansion above the sample average. Higher levels of GDP per
 259 capita instead seem to raise GHG emissions, thereby reducing the distance from
 260 the target in both the short and in the long run, regardless of the country's position

Table 2 Dependent variable GHG_DIFF

Variables	(1)	(2)	(3)	(4)	(5)
	GHG_DIFF	GHG_DIFF	GHG_DIFF	GHG_DIFF < 0	GHG_DIFF > 0
GHG_DIFF _{t-1}	0.4556*** (0.0974)	0.4118*** (0.0245)	0.2927*** (0.0246)	- 0.0191 (0.1299)	0.4957*** (0.0703)
D_ET_RATE	0.0004** (0.0002)	0.0004*** (0.0001)	0.0006*** (0.0001)	0.0003*** (0.0001)	0.0003*** (0.0001)
G_GDP_PC	- 0.0023*** (0.0005)	- 0.0022*** (0.0003)	- 0.0026*** (0.0002)	0.0004 (0.0003)	- 0.0054*** (0.0007)
logGDP_PC	- 0.4594*** (0.0490)	- 0.5396*** (0.0326)	- 0.6736*** (0.0319)	- 0.7302*** (0.0606)	- 0.5238*** (0.0743)
logENERGY_INT	- 0.1592*** (0.0350)	- 0.2290*** (0.0189)	- 0.2143*** (0.0198)	- 0.4088*** (0.0416)	- 0.0894** (0.0361)
VA_INDUS			0.0125*** (0.0013)	0.0059*** (0.0014)	0.0093*** (0.0018)
RLE			0.0299*** (0.0105)	0.0258 (0.0200)	0.0414*** (0.0157)
TREND	0.0028*** (0.0010)	0.0016*** (0.0006)	0.0073*** (0.0008)	0.0010 (0.0018)	0.0085*** (0.0011)
ET_REV	- 0.0023 (0.0085)			- 0.0021 (0.0083)	- 0.0022 (0.0084)
Constant	5.5874*** (0.6332)	6.7782*** (0.4191)	7.7586*** (0.3977)	9.5602*** (0.7607)	5.5513*** (0.9153)
Observations	307	307	307	126	181
Number of id	28	28	28	17	24
AR1 p value	0.0033	0.000	0.0011	0.28	0.002
AR2 p value	0.309	0.241	0.232	0.68	0.06
Sargan p value	1.00	1.00	1.00	1.00	1.00

Arellano-Bond dynamic panel-data estimation, in (1), (4) and (5) variable ET_REV is assumed to be endogeneous, it's not included in the matrix of instrumental variables, Standard errors in parentheses

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

261 with respect to the target. Among the energy/environmental variables of vector \mathbf{W} ,
262 the estimates confirm the expected negative relationship between energy intensity
263 of production and the dependent variable, as well the expected positive relation-
264 ship between the trend and the dependent variable. Specifically, in countries with
265 a positive difference, higher values of ENERGY_INT reflect higher GHG emis-
266 sions, which reduce the value of GHG_DIFF; in countries with a negative difference
267 instead more emissions increase the negative GHG_DIFF, resulting again in a nega-
268 tive correlation. As it is logic to expect, the negative impact of high energy intensity
269 is stronger in countries that still have to attain their target. The trend has a positive
270 coefficient throughout the sample, but it is again stronger in countries with a posi-
271 tive coefficient. To the extent that this variable captures the diffusion of regulation,
272 this result suggests that command and control measures are less effective at reducing
273 GHG emissions than Pigouvian taxes.

274 Among the variables of the political vector \mathbf{Z} , in all the specifications, the coef-
275 ficient on the industry's value added is positive and significant. This sign is not con-
276 sistent with the Leviathan hypothesis, since under this type of governments indus-
277 trial lobbies should be able to obtain fewer (or less stringent) constraints on their
278 polluting activities, resulting in a smaller difference between the targeted and the
279 observed values of GHG emissions (Cadoret and Padovano 2018). Conversely, in a
280 Pigouvian environment, a positive and significant coefficient on VA_INDUS sug-
281 gests that polluting industries are taxed more, pollute less, which increases the dis-
282 tance between the targeted and the observed values of GHG emissions. The posi-
283 tive coefficients on the proxy for the rule of law too corroborates this interpretation;
284 once more, this coefficient is larger in the with a positive difference, i.e., the Western
285 European ones.

286 3.2 Testing the Leviathan hypothesis

287 There are two possible approaches to test the Leviathan hypothesis. One is *a con-*
288 *trario*; in other words, given the stark differences between the implications of the
289 Pigouvian and the Leviathan hypothesis, the empirical support for the former can be
290 taken as falsification of the latter. We take an alternative route and try to make a step
291 further in the analysis, by proposing a direct test of the Leviathan hypothesis. In this
292 respect, our empirical strategy exploits the fact that Leviathan governments maxi-
293 mize revenues to secure their power base and attempt to do so at the lowest political
294 cost. ET lends itself well to these political maneuvers, as ET are known to be the
295 least unpopular of all taxes (EU Commission 2014) because of voters' positive out-
296 look on protecting the environment. Furthermore, in order to secure a power struc-
297 ture the Leviathan should channel the ET revenues to redistributive expenditures,
298 which can target specific groups, thus yielding higher political returns, as opposed to
299 general purpose, public-good like expenditure items, which benefit the population at
300 large in a rather undifferentiated manner.

301 We therefore regress two quite opposite types of expenditure items, social expen-
302 ditures SC_EXP (as classified by Eurostat) and expenditures for general services
303 GS_EXP on ET revenues and the same vector of controls as in Eq. (1). Both are

Table 4 Dependent variable SC_EXP

Variables	(1) SC_EXP	(2) SC_EXP	(3) SC_EXP (GHG_DIFF < 0)	(4) SC_EXP (GHG_ DIFF < 0)	(5) SC_EXP (GHG_DIFF > 0)	(6) SC_EXP (GHG_DIFF > 0)
SC_EXP _{t-1}	0.5679*** (0.0511)	0.6180*** (0.0460)	0.6784*** (0.0726)	0.6594*** (0.0884)	0.5897*** (0.0451)	0.5480*** (0.0394)
ET_REV	0.0686 (0.0462)		0.0487 (0.1563)		- 0.0430 (0.0546)	
DEBT		- 0.0034 (0.0055)		- 0.0119 (0.0077)		0.0016 (0.0101)
OTHER_ REV		- 0.0087 (0.0649)		- 0.1691 (0.2604)		- 0.0601 (0.0865)
G_GDP_PC	- 0.1630*** (0.0099)	- 0.1661*** (0.0060)	- 0.1850*** (0.0181)	- 0.1719*** (0.0158)	- 0.1551*** (0.0041)	- 0.1496*** (0.0071)
logGDP_PC	- 4.9498*** (1.7341)	- 3.5733*** (0.6515)	- 4.6653* (2.7882)	- 8.0887*** (2.8227)	- 1.9339*** (0.6562)	- 1.8281 (1.1423)
RLE	0.3937** (0.1884)	0.4589 (0.4430)	0.2370 (0.3074)	- 0.1799 (0.7152)	0.6643* (0.3732)	0.1877 (0.5402)
TREND	0.0765*** (0.0220)	0.0616*** (0.0173)	0.0887** (0.0348)	0.1462*** (0.0450)	0.0341*** (0.0098)	0.0005 (0.0454)
Constant	57.3412*** (18.5761)	43.5777*** (5.9375)	54.4994* (31.5573)	108.4456*** (41.3246)	25.9914*** (6.8856)	31.1422** (15.0032)
Observa- tions	308	308	126	126	182	182
Number of id	28	28	17	17	24	24
AR1-pval	0.0057	0.001	0.31	0.06	0.00	0.06
AR2-pval	0.015	0.012	0.05	0.02	0.43	0.29
sargan-pval	1.00	1.00	1.00	1.00	1.00	1.00

304 normalized by GDP. According to the Eurostat classification itself, social protec-
305 tion expenditures are the ones with the strongest redistributive profile, while general
306 services are the closest to the concept of public goods. The stark difference between
307 these expenditure items maximizes the power of our test which, admittedly, because
308 of the rather low share of ET over total revenues, remains rather low. Nevertheless,
309 to confirm the Leviathan hypothesis, we should find a positive correlation between
310 ET_REV and SC_EXP, but not with GS_EXP. A lack of statistical significance on
311 the coefficients of ET_REV on both expenditure items is consistent with the impli-
312 cation of the Pigouvian hypothesis that ET are sufficient to correct the externality,
313 and revenues should not be targeted to any specific expenditure. Using once more an
314 Arellano–Bond technique, we estimate the following model:

$$315 \quad \mathbf{Y}_{it} = \alpha_1 \mathbf{Y}_{it-1} + \beta_1 \text{ET_REV}_{it} + \gamma_1 \mathbf{X}_{it} + \delta_1 \mathbf{W}_{it} + \theta_1 \mathbf{Z}_{it} + \varphi_i + \eta_{it} \quad (2)$$

316
317 where vector \mathbf{Y}_{it} includes SC_EXP, but not with GS_EXP. Table 3 reports the results
318 for general services expenditures, while table 4 illustrates the estimates for social
319 protection. None of the estimates, conducted on the whole sample of countries and

320 other the subgroups of under- and over-achievers with respect to the GHG target,
321 ever reveal a statistically significant coefficient on ET_REV; this result further con-
322 firms the Pigouvian hypothesis and disproves the Leviathan one.

323 4 Conclusions

324 Examining how governments use ET is a difficult task, especially in terms of find-
325 ing a proper empirical strategy; our one has the important advantage of minimizing
326 the discretionary intervention of the analyst in evaluating the countries' commitment
327 in achieving environmental goals, since we focus on a clearly measurable environ-
328 mental goal, the reduction of GHG emission, which the EU-27 countries themselves
329 have formally decided to attain. Hence, and with no claim of having provided con-
330 clusive and/or general evidence, our interpretation of the overall results of the analy-
331 sis is that environmental taxation is mainly conducted in a Pigouvian way and that it
332 is efficient at correcting the environmental externality. The test of the theoretically
333 opposite Leviathan hypothesis instead shows no support from the data.

334 The positive correlation between ET rates and distance from the target, together
335 with the negative statistical significance on environmental tax revenues suggests
336 that high Pigouvian tax rates reduce the environmental externality represented by
337 GHG emissions and therefore shrink the tax base for these taxes. Both countries that
338 have already attained their GHG emissions targets and those that still have to meet it
339 are characterized by similar levels of correlation between ET rates and reduction of
340 GHG emissions. This suggests that environmental policies tend to become embed-
341 ded in the fiscal system even after certain policy goals are reached.

342

343 Compliance with ethical standards

344 **Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of
345 interest.

346 Appendix

Name	Definition	Source
GHG	Greenhouse gas emissions in Effort Sharing Decision (ESD) sectors—million tonnes CO ₂ equivalent	Eurostat
Target	DÉCISION (UE) 2017/1471 de la Commission du 10 août 2017 modifiant la décision 2013/162/UE afin de réviser les allocations annuelles de quotas d'émission des États membres pour la période 2017–2020 [notifiée sous le numéro C (2017) 5556]	
GHG_DIFF	(Target – GHG observed)/GHG observed	Calculated
ET_REV	Total environmental taxes as Percentage of total revenues from taxes and social contributions (including imputed social contributions)	Eurostat

347

348

Name	Definition	Source
ET_REV_GDP	Total environmental taxes as Percentage of GDP	Eurostat
ET_RATE	This indicator is defined as the ratio between energy tax revenues and final energy consumption calculated for a calendar year. Energy tax revenues are measured in euro 2010 (deflated with the gross market product implicit deflator) and the final energy consumption in TOE (tonnes of oil equivalent), therefore the ITR on energy is measured in EUR per TOE.	Eurostat
D_ET_RATE	Variation of ET_RATE	
DEBT	Government consolidated gross debt as percentage of GDP	Eurostat
ENERGY_INT	Energy intensity of GDP in purchasing power standards (PPS), Kilograms of oil equivalent (KGOE) per thousand euro in purchasing power standards (PPS)	Eurostat
G_GDP_PC	GDP per capita growth (annual %), aggregates are based on constant 2010 U.S. dollars. GDP per capita	World Bank WDI
GDP_PC	GDP per capita, PPP (constant 2011 international \$)	World Bank WDI
RLE	Rule of law	World Bank WGI
VA_INDUS	Industry, value added (% of GDP)	World Bank WDI
GS_EXP	Total general government expenditure for general public services as a percentage of GDP	Eurostat
SC_EXP	Total general government expenditure for social protection as a percentage of GDP	Eurostat

349

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