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Environmental tax and productivity in a decentralized context: new findings on the Porter hypothesis

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Abstract This paper studies, for the first time, the effects of environmental taxes on efficiency gains and the growth of the regions. To this end, we have estimated a dynamic panel-data model to the context of the Spanish regions that reflects the effects of environmental taxation and regulation separately. The results provides further empirical evidence in favour of the Porter hypothesis, to the extent that a strict environmental policy implemented via green taxes rather than regulation may raise productivity, which may be because they drive organizational and technological change in firms seeking to reduce their tax payments.

Keywords Regional green taxes · Porter hypothesis · Regional growth · Productivity

JEL Classification H23 · H71 · O44

1 Introduction

There has been much debate in recent decades over the possible impact of regulation on productivity and the superiority of economic instruments, particularly environmental taxes,[1] as a weapon in the fight against pollution. It was Porter (1991) who drew attention to the first of these issues, arguing against the conventional view that strict regulation properly implemented would encourage productivity growth by creating benefits capable of offsetting regulatory costs. The second issue came to the

[1] Environmental taxes are those that have the capacity to alter the behavior of the agents in a manner favorable to the environment. For more information about the definition, design and properties of environmental taxes can see Gago and Labandeira (1999).

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fore, meanwhile, as awareness of environmental issues rose in the developed nations in parallel with increasing concerns about the inefficiency of the *command and control* instruments that had traditionally been used to combat pollution. The result has been increasing use of green taxes in environmental policy in recent decades, given their advantages in terms of efficiency and economic growth.[2]

Based on a review of the existing literature, we may identify various factors that are directly or indirectly associated with productivity and economic growth: human capital, infrastructure, technology gap, openness and absorptive capacity, … even environmental aspects. In particular, we might mention the surveys by Isaksson and Ng (2006) and Isaksson (2007), although numerous other papers also examine the determining factors of productivity including, for example, Aghion and Howitt (1998), Hall and Kramarz (1998), Easterly and Levine (2002), Keller and Yeaple (2003), Fisman and Love (2004), and Bloom et al. (2004).

According to the conventional view defended by scholars like Barberá and McConnell (1990), Gollop and Roberts (1983), Gray (1987), and Palmer et al. (1995), a strict environmental policy imposes costs on firms that affect their competitiveness, resulting in adverse socio-economic outcomes for jobs and living standards. This is so because regulation almost always requires firms to allocate a part of their inputs (labour, capital, etc.) to reduce pollution, which is unproductive from a business standpoint. Moreover, regulation may depress investment if it raises the price of energy (a supplementary input to capital), as Ambec and Barla (2006) point out.

However, two decades ago Porter (1991) proposed a different approach to the analysis, arguing that a strict, effectively implemented environmental policy could have the opposite result, fostering productivity and comparative advantages that would enhance the competitiveness of regulated firms in such a way as to offset the costs initially entailed. To put this another way, additional benefits may be generated that are not detected by conventional theory, which fails to consider the dynamic nature of the problem. This hypothesis is defended in Porter and Van der Linde (1995), Shrivastava (1995), Faucheux et al. (1998), Mohr (2002), and Ambec and Barla (2006).

There are three different readings of the Porter hypothesis (Brännlund 2008). The first maintains that regulated firms cut their costs by eliminating internal inefficiencies. The second refers to relative gains in competitiveness (in relation to other firms), which Porter calls the “early mover advantage”: despite the costs inherent in regulation, these costs will be greater for firms that are regulated later. The third interpretation is based on enhanced competitiveness through the increase in demand for products associated with environmental regulation. Thus, the gains do not come from the regulated firms themselves, but from firms supplying them with the materials and equipment required to comply with environmental regulations.[3]

As Brännlund (2008) notes, Porter’s ideas are controversial and they have spurred considerable theoretical research (Simpson and Bradford 1996; Xepapadeas

[2] See Bovenberg (1999), López et al. (2006), and Gago et al. (2007).

[3] This argumentation could really relate to CSR literature (Galán 2006; McWillams et al. 2006 and Porter and Kramer 2006).

and de Zeeuw 1999; Mohr 2002; Feichtinger et al. 2005; Popp 2005, and Greaker 2006, among others).[4] Our approach is to test whether environmental taxes can have a positive impact in terms of productivity gains and/or economic growth, given that such taxes provide an alternative instrument offering considerable advantages over conventional regulation, in terms of cost-effectiveness and dynamic efficiency.[5] The objective is not to show environmental effectiveness but some kind of prerequisite in the sense of economic effectiveness and productivity. It can be argued that environmental policy instruments which put a burden on those who need to comply actually may fail to achieve their environmental effectiveness for that reason. If, however, an environmental policy instrument achieves the opposite and tends to increase the productivity of those who need to comply, one can predict or expect that it may also be environmentally effective.

This hypothesis can be reinforced by others like the theory that defend that environmental taxes can even be used to undertake green reform processes capable of generating what has been called the "double dividend" (see Pearce 1991; Goulder 1994; Bovenberg 1999; Bosquet 2000; Hoerner and Bosquet 2001; Schöb 2003; and, more recently, Fullerton et al. 2008, for an explanation of the double dividend hypothesis).[6] Furthermore, even if this "double dividend" does not occur, it is not unthinkable that more intensive use of environmental taxes would further tax decentralization through revenues, which could also boost economic growth. This renewed interest in decentralization has various roots, including the conviction that it provides a useful tool to improve the efficiency of the public sector (Martínez-Vázquez and McNab 2003). Its potential effect on growth is based on two assumptions. The first is the Leviathan model proposed by Brennan and Buchanan (1980), which implies that the public sector will vary, ceteris paribus, inversely to the scope of decentralization. The second is the hypothesis that sub-central tiers of government have access to privileged information about citizens' needs and preferences given their proximity, and they are therefore better placed to provide public services than central government. The corollary to this is geographical mobility and competition between different administrations, resulting in enhanced living standards and more uniform income distribution.

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[4] Palmer et al. (1995) point out certain weaknesses in the arguments for the Porter hypothesis, including the assumption that private firms systematically ignore opportunities and inefficiencies, whereas the regulator can identify and, what is more, correct market failures of this kind. They also criticize the use of case studies as empirical evidence. Finally, the notions of competitiveness and rivalry are fundamental to the Porter hypothesis, requiring close proximity between competitors, and between firms and their customers (clustering).

[5] Recently, Urpelainen (2010) has argumented that technological standards and market instruments are complements.

[6] Although the Spanish regions have never officially used green taxes as part of a green tax reform (seemingly, they have employed these green taxes to raise extra revenues, with the minimum possible effect on their citizens and hoping for stability), however it is also possible to think that it can be taking place an incipient process of green tax reform at the regional level, as various reforms of direct taxation at the level of the state have cut regional revenues (Income tax rates have diminished, Wealth Tax has been recently eliminated, …), the regions have undertaken a race to the bottom in the Estate and Gift Tax, etc, sometimes making it necessary to impose proportional environmental taxes to offset the revenues lost. These processes may, in turn, have given rise to a "double dividend" with effects on economic growth.

In view of the Porter hypothesis and the superiority of environmental taxes over command and control measures, we ask whether the environmental taxes established in the regions of Spain have had any impact on productivity and the growth of regional economies.[7] In contrast to the few other papers that have looked at this relationship in Spain (Gil and López Laborda 2005; Carrion-i-Silvestre et al. 2007; and Pérez and Cantarero 2009), the scope of the study described here is confined to regional decentralization and green taxes, an issue that is also largely absent from the international literature. Hence, the approach we have taken is new.[8]

The paper is structured as follows. The next section describes the model and examines the factors that may be expected to affect productivity and economic growth, paying special attention to regulation and green taxes. An econometric test is also carried out to validate the hypotheses proposed. The paper ends with a section containing our conclusions.

2 Estimation of the relationship between environmental policy and regional development

Much empirical research exists with regard to the Porter hypothesis, as shown in the recent surveys by Volleberg (2007), and Brännlund and Lundgren (2009). Table 1 summarises a representative cross-section of the existing literature. This literature generally analyze the manufactured industries of America (USA and Canadá), although there are several papers concerning European countries, especially Swedish. There are also some paper about Japan, Mexico, Argentina, Chile, Philippiness and India.

As it can be seen in Table 1, many papers focus on the effects of environmental regulation on investment, innovation and R+D (Nelson et al. 1993; Xepapadeas and de Zeeuw 1999; Gray and Shadbegian 1998; Brunneheimer and Cohen 2003; and De Vries and Withagen 2005), while a second group examines effects on efficiency and productivity gains (Gollop and Roberts 1983; Berman and Bui 2001; Gray and Shadbegian 2003; Marklund 2003; Hamamoto 2006; and Van der Vlist et al. 2007). Finally, a third group of studies examines the effects of regulation on benefits and other type of financial impacts (Brännlund et al. 1995; King and Lenox 2001;

[7] We are aware of the green regional taxes are scarce in Spain (in number and in revenue-raising capacity), so their impact on growth a la Porter in a context of Spanish regions could be limited, especially considering as these burdens can be shifted to other economic agents in the regions (in fact, the coefficient for this variable that we obtain in the empirical estimation is not very quantitatively important). Although the weight of the regional green taxes revenues is not marginal in relation to the own tax of the regions (in 2001, the green regional taxes/own taxes ratio was 76 %), its weight in relation to Gross Domestic Product of the Autonomous Communities scarcely reaches values between 0.05 and 0.08 %, which is probably more revealing (Carrera 2008). Anyway, a study of green taxes is especially appropriate in the case of Spain, given the regions' interest in balancing their budgets in response to budgetary stability legislation.

[8] Some papers analyse the role of decentralization in addressing environmental problems (see Dalmazone 2006). And recently, Fredriksson et al. (2010) shed new light on the determination of environmental tax policies in majoritarian federal electoral systems, such as the US, and derive implications for the environmental federalism debate on whether the national or local government should have authority over environmental taxes.

Table 1 International empirical evidence for and against the Porter hypothesis

Empirical evidence for the Porter hypothesis		
Jaffe and Palmer (1997)	Panel of U.S manufacturing industries, 1973–1991	R&D investment (innovation proxy) increases with environmental regulation (pollution control capital costs)
		No impact of environmental regulations on the number of patents (basically another proxy for innovation)
Albrecht (1998)	OECD CFC-using industries (e.g. manufacture of refrigerators, freezers and air conditioning machines), 1989–1995	Environmental regulation leads to improved competitiveness
Dufour et al. (1998)	19 Canadian manufacturing industries, 1985–1988	Environmental and occupational safety and health (OSH) regulations reduce the productivity growth rate
		The presence of mandatory prevention programs and fines for breaches of OHS rules increase productivity growth
Cohen (1997)	US-based industry data in the manufacturing sector, 1983–1992	Increases in pollution abatement expenditures (regulatory pressure) were associated with a small but significant rise in environmental innovation, using patents as a proxy
Berman and Bui (2001)	US petroleum refining industry, 1987–1995	Comparison of productivity at Californian South Coast refineries (subject to stricter air pollution regulations) and other US refineries. Stricter regulations imply higher abatement costs. However, these investments appear to increase productivity
Dasgupta and Laplante (2001)	126 events involving 48 publicly-traded firms in Argentina, Chile, the Philippiness and Mexico, 1989–1994	20 out of 39 positive environmental events (investment in pollution control, awards) lead to positive abnormal returns
		33 out of 85 negative environmental events (complaints, spills) lead to negative abnormal returns
King and Lenox (2001)	Panel of 653 US manufacturing firms included in the EPA's Toxic Release Inventory, 1987–1996	Positive impact of environmental regulations (number of environmental permits required and average pollution per capita in polluting industries in the State where the firm operates) on financial performance, but only significant in one specification
		Positive link between financial and environmental performance
Alpay et al. (2002)	Mexican and US processed food sectors, 1962–1994	Mexico: Environmental regulations (inspection frequency) have a negative impact on profits but a positive impact on productivity
		US: negligible effect of environmental regulations (pollution abatement expenditures) on both profit and productivity
Brunneheimer and Cohen (2003)	Panel of 146 U.S manufacturing industries, 1983–1992	Positive but small impact of pollution-related operating costs (proxy for environmental regulations) on the number of patents (innovation proxy)
		No impact of number of air and water pollution control inspections (proxy for environmental regulations) on the number of patents
De Vries and Withagen (2005)	Country data for Europe, North American (US and Canada), 1970–2000	Two models show a negative correlation between innovation (patent applications related to abatement of sulphur dioxide) and regulations. The third shows a positive correlation

Table 1 continued

Hamamoto (2006)	Pulp and paper, chemical products, petroleum and coal products, iron and steel, and non-ferrous metals and metal products industries in Japan, 1971–1988	Positive relationship between pollution control expenditures and R&D expenditures. Increases in R&D investment stimulated by regulatory stringency have a positive effect on the productivity growth rate
		Negative effect of pollution control expenditures on the average age of capital stock
Lanoie et al. (2007)	Approximately 4,200 plants in seven OECD countries	Some indirect positive effect of environmental policy stringency on business performance (through environmental R&D), although the direct effect on business performance is negative and greater in size. Flexible "performance standards" are more likely to induce innovation than prescriptive "technology-based standards"
		Environmental policy induces innovation (R&D expenditure)
Telle and Larsson (2007)	Plant-level data for energy intensives industries in Norway: Pulp and paper, Primary aluminum, Ferro alloys and Inorganic chemicals, 1993–2002	Positive effect of regulatory stringency on productivity growth when emissions are included in the calculation of the productivity index. No effect when emissions are not included in the calculation
Van der Vlist et al. (2007)	Panel data for Holland's horticulture industry. Medium and small companies, 1991–1999	Voluntary agreements to reduce environmental impacts are (on average) positively correlated with increased technological efficiency. Correlation between technological efficiency and voluntary agreements depends upon the type of company (type of ownership, experience, size, etc)
Lanoie et al. (2008)	17 sectors (clothing, food and beverages, leather, machinery, textiles, electrical and electronic products, furniture, wood, printing and publishing, metal manufacturing, rubber and plastics, transportation equipment, petroleum and coal products, primary metals, non-metallic minerals, paper and allied products, and chemicals) in the Quebec manufacturing industry, 1985–1994	Negative contemporaneous effect of environmental regulation on productivity
		Positive lagged effect of environmental regulation on productivity
		The positive effects of regulation on performance are most significant in a subgroup of industries that are more exposed to international competition. Contrary to the author's conjecture, the positive effects are confirmed only for the second group of industries when a distinction is drawn between more and less polluting industries
Empirical evidence against the Porter hypothesis		
Gollop and Roberts (1983)	56 US electricity utilities, 1973–1979	Environmental regulations (SO_2) reduce productivity growth
Smith and Sims (1985)	4$ Canadian beer breweries, 1971–1980	Two breweries were submitted to an effluent surcharge and two breweries were not. Average productivity growth was negative for the regulated plants and positive for the unregulated plants
Gray (1987)	450 U. S. manufacturing industries, 1958–1978	Environmental regulations (pollution control-related operating costs) reduce productivity growth
Barberá and McConnell (1990)	5 pollution intensive industries in the US (paper, chemicals, stone-clay-glass, iron-steel, non-ferrous metals), 1960–1980	Abatement capital requirements reduce productivity growth (direct effect of pollution control capital), but the indirect effect (changes in other inputs and production processes) is sometimes positive

Table 1 continued

Jorgenson and Wilcoxen (1990)	USA, 1974–1985	The combined effects of mandatory pollution abatement costs and investments, and compliance costs was to reduce the average growth rate of real Gross National Product, because of the capital investment required to comply with regulations
Wibe (1990)	Sector-specific data for Swedish industry, 1963–1980	No significant correlation between productivity and regulation
Brännlund and Liljas (1993)	Facility-specific data for Swedish pulp and paper industry, 1986–1990	Some evidence that more stringent regulations have negative effects on corporate earnings. However, no clear answer is found because not all tests show a significant effect
Nelson et al. (1993)	44 US electricity utilities, 1969–1983	Environmental regulations (air pollution costs and total pollution control costs per KW capacity) increase age of capital or reduce capital reinvestment
Brännlund et al. (1995)	41 Swedish pulp and paper mills, 1989–1990	Average decline in profits due to regulation. However between 66 and 88% of mills are unaffected by regulations
Khanna et al. (1998)	91 US chemicals firms, 1989–1994	Negative abnormal returns during one-day period following disclosure
		Abnormal losses are higher for firms that do not reduce emissions or perform poorly compared to other firms
		Abnormal losses push firms to increase transfers of waste off site
Boyd and McClelland (1999)	US plants in the paper industry, 1988–1992	Environmental constraints lower production, in part because of the pollution abatement capital constraint
Gray and Shadbegian (2003)	116 US pulp and paper mills, 1979–1990	Abatement efforts reduce productivity, particularly in integrated paper mills
Marklund (2003)	12 Swedish pulp plants, 1983–1990	No evidence that environmental regulation made the pulp plants more resource efficient during the period under study
Nicoletti and Scarpetta (2003)	23 industries in manufacturing and business services in 18 OECD countries, 1984–1998	Negative effect on productivity, mainly by slowing down technological catch-up
Filbeck and Gorman (2004)	24 US electricity utilities, 1996–1998	Negative relationship between financial returns and environmental compliance
Gupta and Goldar (2005)	17 Indian pulp and paper plants, 15 auto firms and 18 chlor alkali firms, 1999–2001	Negative relationship between abnormal returns and environmental rating
Hitchens and Triebswetter (2005)	160 face-to-face interviews undertaken in three industry case studies in the food sector, the packaging industry with the respective supply chain links in the food and retail sector, and the cement industry, in Germany, the UK and Spain. The three sample industries and related regulatory fields were chosen so as to cover a variety of environmental problems (waste water, solid waste and air pollution), 1999	Environmental regulations have not had a great impact on competitiveness in the chosen sectors
Loayza et al. (2005)	76 countries. Country observations for each variable consist of averages for the 1990s	A heavier regulatory burden reduces growth and increases volatility, although these effects are smaller the higher the quality of the overall institutional framework
Brännlund (2008)	Swedish manufacturing sector, 1913–1999	No evident relationship between environment regulations and productivity growth

Nicoletti and Scarpetta 2003; Filbeck and Gorman 2004; and Gupta and Goldar 2005).

This literature does not find clear evidence to validate the Porter hypothesis, because none of these three groups of studies gives clear answers to what extent regulations affects innovation, productivity, efficiency, or benefits. There are positive relationship between these variables and the environmental regulations, as it can see in the first part of Table 1, but many studies show the contrary effect (second part of Table 1), particularly, most studies indicate negative productivity effect from environmental regulations. It is therefore not possible to affirm that the Porter hypothesis is true, either from a theoretical or from an empirical standpoint. However, this does not mean that there are no specific cases and circumstances in which progress may be made in terms of business, productivity and economic growth after the implementation of an environmental policy.[9]

The question of whether or not the Porter hypothesis is in fact applicable cannot be answered definitively based on the existing research. This is presumably the result of several different factors. Perhaps the most important of these is the fact that existing studies fail to apply a formal hypothesis test to Porter's idea, at least in part because there is no general consensus about what should be tested. Measurements and definitions are also problematic. What is meant by the terms "competitiveness" and "environmental regulation", and how can they be measured? Brännlund and Lundgren (2009) also note that most studies fail to distinguish clearly between regulatory measures and instruments, even though Porter is relatively clear that only certain specific types of regulation can actually neutralize the initial costs, suggesting that a better approach might be to try and classify regulations into groups or categories and then analyze the differences in effects.

In light of the above, we shall differentiate between regulation and environmental taxation. The intention is to learn whether both types of instruments have a specific effect on productivity, not of individual entities like enterprises which have to implement the policies, but regions. Thus, our approach will be to examine whether environmental taxes can have a positive impact in terms of productivity gains and/or economic growth, given that such taxes offer considerable advantages over conventional regulation. Finally, we have employed a dynamic specification in our econometric estimates, as it may be that the discrepancies in the findings from existing empirical studies stem from the failure to consider the dynamic nature of the analyzed problem.[10]

[9] All of the requirements necessary for the Porter hypothesis are present in Sweden, but empirical results do not support it. It was recently noted by Ambec and Barla (2006) that the majority of the studies that have sought to test the Porter hypothesis use empirical structures based on very simple or non-existent dynamic structures. These authors point to the work of Lanoie et al. (2001), who obtain positive results for Quebec in a study based on a more dynamic structure that was better aligned with the nature of the Porter hypothesis.

[10] This is what could be deduced from the recent works of Lanoie et al. (2008) and Lundgren and Marklund (2012) that account for dynamics, although Lundgren and Marklund (2010) obtain inconclusive results.

2.1 Empirical model

The aim of this paper is to test, for the first time, the possible efficiency gains in terms of productivity and economic growth that may be generated by green taxes at the regional level in Spain, employing a dynamic specification in our econometric estimates. Consequently, our empirical analysis adapts the proposals contained in Jorgenson and Wilcoxen (1990), Nicoletti and Scarpetta (2003), De Vries and Withagen (2005), and Loayza et al. (2005) to the situation of the Spanish regions. We begin with the multi-factor productivity equation. Thus, if we denote the regions using the subscript i = 1, …, 17, then the value added for a given year "t" in each region will be produced by labour (H) and physical capital (K) applying a standard neo-classical production technology:

$$Y_{it} = A_{it}F(H_{it}, K_{it}) \tag{1}$$

where $F(\cdot)$ is grade one homogenous and displays decreasing returns for each factor of production, and A_{it} is a technology efficiency or multifactor productivity (MFP) index.

We extend the conventional endogenous growth model, in which MFP is generally expressed as a function of knowledge and a residual set of influences (Aghion and Howitt 1998), by assuming that efficiency depends on country characteristics as well as technological and organizational transfers from the technology-leader region ($i = L$). This implies that MFP growth in the leading region leads to faster MFP growth in catch-up regions by expanding production options.[11] We assume that the technology gap between a given region and the technological leader measures the extent of technology transfers. The leading region is defined as that displaying the highest level of MFP. Hence, multifactor productivity growth for a given region may be modeled as follows[12]:

[11] Catch-up economies may be well placed to grow faster than the technological leader by imitating state-of-the-art technologies, while the leader incurs the costs and delays associated with development. It is likely that technologies will spread faster at the regional level, unhindered by the cultural and institutional barriers to the transfer of knowledge that exist internationally.

[12] Multi-factor productivity (MFP) growth is often used as a proxy for technological progress, although it also captures the impact of efficiency gains related with improvements in management, organizational change and other innovations in production methods, as well as the level of competition in markets. MFP estimates are residual rates of variation of gross valued added (GVA) after discounting the weighted contribution of changes in the capital and labour production factors. Consequently, these estimates include various assumptions about the measurement of outputs and inputs. Firstly, given data limitations, we have used total employment as a measure of the labour input, and the total capital stock as a measure of the capital input, which means that we do not consider changes in the composition of the labour force or the stock of capital. Furthermore, these estimates of MFP growth reflect both *disembodied* and *embodied* components of technological progress. The *disembodied* component captures technological and organisational improvements that increase output for a given amount of –qualitatively and compositionally adjusted- inputs. However, we also want to assess the extent to which improvements in the quality of labour and capital boosted productivity in industries and countries that have invested in them. This second component of technological progress is *embodied* and proxies for improvements in production capacity due to shifts to higher quality factor inputs [Greenwood et al. (1997), Hercowitz (1998), and Nicoletti and Scarpetta (2005)]. Secondly, the weightings assigned to the factors of production in the MFP, or residual growth, calculation should represent the marginal productivity of labour and capital. Nevertheless, these values are not observable, and we have therefore followed the standard procedure of proxying them using income shares. These procedures are based, inter alia, on the assumptions that product and input markets are perfectly competitive and that there are constant returns to scale [Morrison (1999), Scarpetta et al. (2000), and Scarpetta and Tressel (2002)].

$$\Delta \ln A_{it} = \delta_{it}\, \Delta \ln A_{Lt} - \sigma_{it} \ln(A_i/A_L)_{t-1} + \xi_{it} \tag{2}$$

where δ_{it} captures the immediate effect of changes in growth in the leader region; σ_{it} denotes the pace of technology transfer; $\ln(A_i/A_L)_{t-1}$ is the technology gap between region "i" and region "L", the technology leader; and ξ_{it} represents all other factors involved in MFP growth, including those related with inter-regional differences in environmental regulation and taxation.[13]

We also assume that environmental policy, whether in the form of green taxes or regulation, can affect opportunities and incentives for the adoption of cutting-edge technologies. Following Nicoletti and Scarpetta (2003), this link between environmental policy (POLAMB) and the rate of technology transfers between non-leading regions can be formulated as follows:

$$\sigma_{it} = \sigma_{1it} + \sigma_{2it}\, \mathrm{POLAMBit} - 1 \tag{3}$$

Substituting [3] in [2], we obtain the following specification:

$$\Delta \ln A_{it} = \delta_{it}\, \Delta \ln A_{Lt} - \sigma_{1it} \ln(A_i/A_L)_{t-1} - \sigma_{2it}\, \mathrm{POLBAMB}_{it-1} \ln(A_i/A_L)_{t-1} + \xi_{it} \tag{4}$$

In deriving a specification of the MFP equation that can be estimated empirically, it is important to observe that Eq. (4) could be considered an error correction equation derived from a first order lagged autoregressive specification, in which the level of MFP in each region is cointegrated with that of the leader region, as follows:

$$\ln \mathrm{MFP}_{it} = \beta_1 \ln \mathrm{MFP}_{it-1} + \beta_2 \ln \mathrm{MFP}_{Lt} + \beta_3 \ln \mathrm{MFP}_{Lt-1} + \omega_{it} \tag{5}$$

Reordering Eq. (5) under the assumption of long-run homogeneousness ($1 - \beta_1 = [\beta_2 + \beta_3]$), we obtain:

$$\begin{aligned} \Delta \ln \mathrm{MFP}_{it} &= \beta_2\, \Delta \ln \mathrm{MFP}_{Lt} - (1-\beta_1)\, \mathrm{RMFP}_{it-1} + \omega_{it}; \\ \text{where}: \mathrm{RMFP}_{it-1} &= \ln(\mathrm{MFP}_{it-1}/\mathrm{MFP}_{Lt-1}) \end{aligned} \tag{6}$$

Equation (6) is equivalent to Eq. (4), in which the relative MFP coefficient is a function of environmental policy. We have also imposed the constraint that the leader region's MFP growth coefficient (β_2) and the technology transfer coefficient ($1 - \beta_1$) do not change.

In addition, the error term in Eqs. (5) and (6) can be broken down into a vector of variables (V_{it}) including structural aspects (e.g. human capital) and environmental policies with potential effects at the MFP level, as well as unobserved regional effects (f_i), national macroeconomic shocks (d_t) and a non-correlated error term (η_{it}).

$$\omega_{it} = \Sigma_k \gamma_k V_{kit-1} + f_i + d_t + \eta \tag{7}$$

From Eq. (6) it is clear that the MFP gap coefficient measures the (conditional) speed of convergence with the long-run stationary state of MFP. In the presence of technological convergence, moreover, the technology gap between each region and the leader converges on a constant value. This implies that the vector of variables (V_{it}) and the fixed effects for each region only translate into differences in MFP levels but not into permanent differences in MFP growth rates.

[13] See Scarpetta and Tressel (2002) for further details of this productivity model. Similar specifications will be found in Griffith and Redding (2000) and Fuente and Doménech (2006).

Following the theoretic approach, the productivity model (6)–(7) has been estimated using as explanatory hypotheses the variable representing the growth of the logarithm of the MFP in the leading region ($\Delta LLEADER_{it}$), the logarithm of technology gap ($LGAP_{it-1}$), the interaction between environmental policy (POLAMB) and the $LGAP_{it-1}$ (calling this interaction $IRLGAP_{it-1}$ and $ITLGAP_{it-1}$, when regulation and taxes, respectively, interact with the logarithm of technology gap) and a vector of variables including both structural aspects ($ESTFACTORS_{it}$, e.g. human capital, stock of public capital per employee, economies of scale and changes in the production structure) and environmental policies ($POLAMB_{it}$, e.g. regulation and tax), with potential effects at the MFP level.[14] All of these variables will be explained in the next section. This equation has been estimated using a dynamic panel-data model, which also includes the dependent variable lagged by one period ($\Delta LMFP_{it-1}$) to capture the inertia behaviour of MFP, with fixed effects estimator for each Spanish region (f_i), as well as dummy time variables to control for common aggregate shocks affecting changes in MFP across all regions (d_t). Consequently, the model we estimate is the following:

$$\Delta LMFP_{it} = f(\Delta LLEADER_{it},\ LGAP_{it-1},\ IRLGAP_{it-1}, ITLGAP_{it-1},\ \Delta LMFP_{it-1},\ POLAMB_{it},\ ESTFACTORS_{it},\ f_i,\ d_t)$$

2.2 Data and empirical estimation

The period considered in the study runs from 1989 to 2001, for which all the relevant information is available. Thus, we have a sample comprising Spanish regions that have enacted environmental regulations and green taxes, although we have also included regions that made use of neither in order to avoid any possible sample selection bias.

MFP growth, the endogenous variable, was measured as follows: $\Delta LMFP_{it} = \Delta y_{it} - \alpha_{it}\,\Delta l_{it} - (1 - \alpha_{it})\,\Delta k_{it}$. where *y, l* and *k* are logarithms of actual aggregate or added value, total jobs and capital stock, respectively. Under conditions of perfect competition, "α_{it}" may be proxied as the participation of labour in GVA. The main source of data at the level of regional disaggregation for the calculation of productivity as we have defined it consists of the Regional Accounts published by the Spanish National Institute of Statistics (INE in its Spanish acronym),[15] which contain comparable regional data on aggregate value and jobs. Data on the stock of fixed capital was obtained from publications by BBVA (Bank of Bilbao, Vizcaya, Argentaria), and the Valencia Institute for Economic Research (http://www.ivie.es/banco/stock.php).

[14] Some scholars have suggested that retards should also be included for the variables capturing regulatory activity and green taxes, and also the interaction between these variables and technology gap. We have also included explanatory variables which reflects the political environment, such as differences between regions in the levels of competencies or financial autonomy enjoyed by the regions; the traditional distinction between left-wing and right-wing parties in the government of regions; the relative weight of the electoral support obtained by the governing party (colligations and absolute majorities); and the square of the regulation and tax variables to test the hypotheses that the relationship between these variables and growth may not be linear. We have not found any of these variables significant so we have not incorporated them into the model.

[15] All of the variables obtained from the National Institute of Statistics may be consulted at http://www.ine.es.

As our objective is to test whether the environmental policies implemented by the Spanish regions have had any impact on efficiency in terms of productivity and economic growth, we have identified the different green taxes enacted by the Spanish regions during the period of the study (1989–2001). This variable has been included as the ratio of the green tax revenues to the total tax take of each region (ENVTAX). These data were supplied by the Ministry of Economy and Finance in territorial statistical publications,[16] and it is not negligible as a percentage of the own tax of the region, as we have pointed out in footnote 7. Table 2 shows the environmental taxes levied by each region in this period, revealing that the most common tax across all regions is some kind of Waste Water Effluent Tax.[17] Some other regions have other taxes, such as on Fuel—Canary Islands, on Hunting—Extremadura, on electricity—Extremadura and on Activities Affecting the Environment—Balearic Islands, …. This table also reveals that ever more regions have legislated in this regard, although some regions still no green taxes in 2001.

The database of the Spanish Institute of Public Law[18] (*Instituto de Derecho Público*) has been used to obtain information on regional environmental regulation (ENVREG). This database provides a complete record of parliamentary activity in the Spanish regions, and thus the total of regulatory acts has been considered, as in the case of Holcombe and Sobel (1995), Rogers (2002, 2005) and Vallés and Zárate (2012b), and as the principal international organisms recommend for the analysis of regulation processes.[19] It contains 22,607 different acts of the regional parliaments (see Table 6 in the "Appendix"), which we have grouped in 22 different types of regulatory acts (Table 7 in the "Appendix"). We have then made use of one of these types, i.e. the environmental acts, for constructing the ENVREG variable. For this, we have counted the number of environmental legislation passed by the Spanish regions in the study period, and which is presented in Table 3. Again, it may be observed that ever more regions enacted environmental regulations in this period.

As the impact of these environmental policies is not necessarily immediate or permanent, we have lagged these variables. We have also included variables that measure the interaction between environmental regulations or taxes and the technology gap (IRLGAP and ITLGAP) in order to capture any possible influence

[16] See http://www.meh.es/es-ES/Estadistica%20e%20Informes/Paginas/estadisticasV2.aspx.

[17] There are numerous publications about drinking water and waste water management in Spain for the quoted time period, explaining that the costs of these activities were not covered by appropriate revenues from the provision of these commodities and services (drinking water prices and waste water treatment charges). See, among others, García (2005), Ministerio de Medio Ambiente (2007), Barberán et al. (2008), Vallés and Zárate (2012a, 2013)). This fact might suggest that if green taxes are supposed to increase productivity, then, by an analogous argument, awarded green subsidies dubbed as negative green taxes would have implied the opposite effect. This question could be analyzed in a future extension of this work.

[18] This database formed the embryo of the Spanish Senate's APCA database of parliamentary activity in the Spanish regions, which contains information drawn from the official publications of the Regional Parliaments. These databases are based on Eurovoc, a multidisciplinary and multilingual thesaurus developed by the European Parliament and the Office for Official Publications of the European Communities (OOPEC) used for indexing in at least fifteen European Parliaments. For further discussion of methodological aspects concerning the data obtained and the construction of the regulation variable, see http://www.senado.es/basesdedatos/index.html y http://europa.eu/eurovoc/.

[19] See, for example, OECD (1997b), OMB (1997, 1998, 2000 and 2001) and ORR (ORR 1995–1996).

Table 2 Environmental taxes levied by the Spanish regions, 1989–2001

	1989–1994	1995	1996	1997	1998	1999	2000	2001
Andalusia		Tax on coastal water discharges	Tax on coastal water discharges	Tax on coastal water discharges	Tax on coastal water discharges	Tax on coastal water discharges	Tax on coastal water discharges	Tax on coastal water discharges
Aragon								
Asturias		Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage
Balearic Islands	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage
	Tax on activities affecting the environment[a]	Tax on activities affecting the environment[a]	Tax on activities affecting the environment[a]	Tax on activities affecting the environment[a]	Tax on activities affecting the environment[a]	Tax on activities affecting the environment[a]	Tax on activities affecting the environment[a]	Tourism tax[b]
Canary Islands	Tax on fuel	Tax on fuel	Tax on fuel	Tax on fuel	Tax on fuel	Tax on fuel	Tax on fuel	Tax on fuel
Cantabria								
Castile-León								
Castile–La Mancha								Tax on activities affecting the environment[c]
Catalonia	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage
						Civil defence charge[d]	Civil defence charge[d]	Civil defence charge[d]
Extremadura	Tax on hunting	Tax on hunting	Tax on hunting	Tax on hunting	Tax on hunting	Tax on hunting	Tax on hunting	Tax on hunting
					Tax on production and distribution of electricity	Tax on production and distribution of electricity	Tax on production and distribution of electricity	Tax on production and distribution of electricity

Table 2 continued

	1989–1994	1995	1996	1997	1998	1999	2000	2001
Galicia	Tax on sewerage	Tax on sewerage	Tax on sewerage Tax on air pollution	Tax on sewerage Tax on air pollution	Tax on sewerage Tax on air pollution	Tax on sewerage Tax on air pollution	Tax on sewerage Tax on air pollution	Tax on sewerage Tax on air pollution
Madrid	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage
Murcia								Tax on sewerage
Rioja	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage
Valencia	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage	Tax on sewerage

Source: Own work based on *Financiación de las CCAA de Régimen Común y Ciudades con Estatuto de Autonomía* (publication of the Spanish Ministry of Economy and Finance), the *OECD/EEA database on instruments used for environmental policy and natural resources managemen*t (available at www.oecd.org/ecoinst/queries) and studies analyzing the environmental taxes in Spain (OECD 1997a, 2004a; López-Gúzman 2004; Gago et al. 2007 and Carrera 2008)

[a] It levies the production, storage and distribution of electrical energy and fuels. It was abolished due to a Court decision on Constitutionality of November 30, 2000

[b] It has been abolished in 2003

[c] It levies atmospheric emissions, thermonuclear production of electrical energy and dangerous waste disposal. It has been abolished in 2005

[d] This charge levies dangerous waste disposal, and production and distribution of electricity

Table 3 Number of environmental legislation enacted by the Spanish regions (1989–2001)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Andalusia	0	0	0	0	12	0	2	0	0	3	1	0	2
Aragon	0	0	0	0	3	0	3	2	3	2	3	0	4
Asturias	0	0	0	2	1	2	2	1	1	1	2	0	2
Balearic Islands	0	0	1	1	0	4	0	0	0	1	2	1	0
Canary Islands	0	0	0	0	2	1	2	0	0	3	0	0	5
Cantabria	4	0	1	1	1	7	1	0	2	3	2	1	1
Castile and Leon	1	0	0	0	1	4	1	0	1	2	2	0	1
Castile–La Mancha	0	0	0	1	3	0	0	0	0	1	7	1	6
Catalonia	1	2	1	0	4	30	3	1	2	4	4	4	9
Extremadura	0	2	1	0	4	2	1	0	0	3	6	1	1
Galicia	0	1	3	1	1	11	1	1	2	3	0	0	2
La Rioja	0	0	0	1	2	1	1	0	2	2	0	0	0
Madrid	0	1	0	2	6	1	2	0	0	0	3	8	8
Murcia	0	0	1	0	0	1	2	0	1	0	0	0	1
Valencia	0	0	0	1	1	1	1	1	0	3	0	1	2
Total regions	6	6	8	10	41	65	22	6	14	31	32	17	44

Source: own work using the Institute of Public Law database

Table 4 Explanatory variables included in the model

		Expected sign
Technological variables		
ΔLLEADER	MFP growth in the leader region	+
$LGAP_{t-1}$	Technology gap (MFP_{it-1}/MFP_{Lt-1})	–
IRLGAP	Interaction of regulation with the technology gap	?
ITLGAP	Possible influence of environmental taxes on convergence between regions in the period considered	?
Environmental policies (POLAMB)		
ENVREG	Environmental legislative activity (Porter hypothesis)	?
ENVTAX	Environmental taxation (Porter hypothesis)	+
Structural factors (ESTFACTORS)		
PUBKW	Stock of public capital per employee	+
ILLITERATE	Human capital	+
PRODUCTEST	Changes in the production structure	+
ΔRGVA	Economies of scale or gross value added growth rate	+

of environmental policy on convergence between regions in the period considered. This interaction is also measured with a lag of up to three periods.[20]

As mentioned in the description of the model, we have also considered other possible explanatory hypotheses for MFP growth in addition to these variables. All of them are shown with the expected sign in Table 4. Thus, the explanatory variables in the model estimated include the technology gap lagged by one period, which we have defined as the coefficient between the MFP of each region and the MFP of the leader region ($LGAP_{t-1}$) as the theoretical model suggests, MFP growth in the leader region (ΔLLEADER), and the stock of public capital per employee (PUBKW). We also consider the different levels of human capital between the regions to capture the influence of variations in the quality of labour, based on INE data, which we include as the percentage of illiterate members of the population according to the National Institute of Statistics' Active Population Survey (ILLITERATE); changes in the production structure, measured as the coefficient of the relative share of services and farming in regional product (PRODUCTEST); and economies of scale or the rate of growth in gross added value in real terms based on the Regional Accounts for Spain published by the National Institute of Statistics (ΔRGVA). The model also includes certain temporal dummy variables to control for any common aggregate shocks that might affect the variation in the MFP of all regions (fixed effects).[21]

As it seems reasonable to expect that the behavior of MFP will display some inertia, the method used to estimate the multifactor productivity model presented consisted of

[20] The additional lags were eliminated in the case of environmental regulation and its interaction with the technology gap after it was confirmed that these variables have no effects beyond 1 year. This was also done with the interaction between environmental variables and the technology gap.

[21] The key descriptive statistics and the correlation matrix for the principal variables are shown in Tables 8 and 9 in the "Appendix".

a dynamic panel-data model, which includes the dependent variable lagged by one period. Consequently, we opted to estimate the model using the generalized method of moments (GMM), which provides a consistent and efficient estimator (see Hansen 1982 and Arellano and Bond 1991). As the unobserved factor, f_i, (representing the specific characteristics of each region), may be correlated with the rest of the variables in the model, we shall estimate the model based on first differences to eliminate individual effects (f_i). All of the estimations therefore relate to first differences and two-stage estimators with standard errors that are robust to heteroscedasticity.

A sufficient number of valid instruments are required to employ the GMM method. In principle, any variable that might be correlated with the regression variables in period t would be classified as a valid instrument wherever it is orthogonal to the error term (otherwise the over-identifying restrictions would be rejected). In our case, we shall use all available lagged levels of the dependent variables, as well as the variables representing human capital, public capital per employee and changes in the production structure.[22] We validate the instruments using the Sargan test for over-identifying restrictions.[23] Tests were also included for the absence of first and second order serial correlation, allowing us to analyse the consistency of estimators. If errors are not autocorrelated, evidence of first-order autocorrelation of differenced residual errors must exist, but no evidence of second-order autocorrelation.

Based on the results obtained, reflected in Table 5, we may conclude that both the dependent variable lagged by one period ($\Delta LMFP_{t-1}$) and the technology gap lagged by one period ($LGAP_{t-1}$) is displaying a significant and negative effect at conventional levels. In view of the definition of the gap in the theoretical model, this outcome for the $LGAP_{t-1}$ might suggest that the regions furthest from the technological forefront have higher rates of productivity growth, which is to say long-run technological progress exists based on imitation of the leader, as Gual et al. (2006), Nicoletti and Scarpetta (2003) and Vallés and Zárate (2012a) appear to find for regulation indicators, although the former did not employ econometric techniques. Short run technological progress (i.e. the coefficient for the leading region) is also significant (ΔLLEADER), so the leader region therefore exerts a drag effect on the other regions.

The estimation also indicates that green taxes lagged by one period ($ENVTAX_{t-1}$) has a positive effect on productivity, which may be because taxes of this kind drive organizational and technological changes in firms seeking to reduce their tax payments, causing a positive effect on multifactor productivity growth. Furthermore, green taxes do not seem to influence the effect of the technology gap on productivity by accelerating technology transfer, as the impact of the gap on productivity growth did not prove to be significant when the two variables interact (ITLGAP).

Environmental regulation (ENVREG), meanwhile, displays a negative, significant coefficient, and it may therefore be deduced that this factor slows multifactor productivity

[22] Some studies suggest that regulation, environmental taxes and economies of scale could be endogenous. Consequently, we have treated these variables as endogenous in the estimates and they are not used as instruments.

[23] This is a test for over-identifying restrictions. The test statistic is asymptotically distributed as Chi squared with the same degrees of freedom as the number of over-identifying restrictions tested. Given that the available sample size is not particularly large in the present case, we report t statistics instead of Z statistics, and F statistics instead of chi-squared statistics.

Table 5 Results of the dynamic panel data model with lag effects for the estimation of multifactor productivity

	Coefficient	*t* student
ΔLLEADER	0.6534797	4.05**
$LGAP_{t-1}$	−0.3238982	−5.95**
$\Delta LMFP_{t-1}$	−0.5797338	−6.93**
IRLGAP	0.0002221	0.45
$IRLGAP_{t-1}$	−0.0001589	−0.55
ITLGAP	−0.0756722	−1.58
$ITLGAP_{t-1}$	0.0606302	1.62
ENVREG	−0.0008331	−1.97*
$ENVREG_{t-1}$	−0.0000543	−0.15
ENVTAX	−0.0179716	−1.26
$ENVTAX_{t-1}$	0.0383316	2.92**
$ENVTAX_{t-2}$	−0.0076448	−0.79
$ENVTAX_{t-3}$	−0.00361	−0.41
PUBKW	0.00000925	6.29**
ILLITERATE	0.00000523	0.01
PRODUCTEST	−0.0000823	−4.26**
ΔRGVA	0.6686047	10.06**
T93	0.0176559	1.62
T94	−0.0353343	−2.09*
T95	0.002046	0.22
T96	0.0161402	1.64
T97	−0.0087712	−0.93
T98	−0.0034294	−0.34
T99	−0.0127335	−1.41
T00	0.013773	1.52
T01	0.0154484	1.71*
C	−0.0015248	−0.18
Observations	153	
First-order serial correlation	−2.67	
Second-order serial correlation	−0.39	
Sargan test: F-statistic	134.91	

* Significantly different from 0 at a level of confidence between 99 and 95 % in the bilateral test

** Significantly different from 0 at a level of confidence of 99 % in the bilateral test

growth, suggesting that policy has not been well instrumented, as Porter argued (1991). As Griffith and Harrison (2004) and Griffith, Harrison and Simpson (2006) argue, these costs do not really represent the economic or efficiency cost of regulation, because regulation also creates significant but unquantifiable burdens for government, the agents regulated and society in general, such as adverse effects on competition, flexibility and innovation (potentially acting as a drag on productivity and economic competitiveness), as well as uncertainties and private incentives that may affect decision making (distorting or overstimulating investment, or reducing the support required for certain activities). Nevertheless, the empirical evidence does not allow any clear conclusions to be drawn with regard to the impact of environmental legislation on technology transfer, as the coefficient for the interaction between the two variables is not significant (ITLGAP).

The influence of public capital per employee (PUBKW) and economies of scale (ΔRGVA) is positive and significant, as was expected. This result reflects the importance of the stock of public capital for productivity gains, as well as the significant role played by economies of scale in the growth achieved by Spain after joining the European Union. The reallocation of resources between productive sectors is measured through the variable (PRODUCTEST). The estimation displays a significant, negative coefficient, and the change in the structure of production may therefore be said to have had a negative influence on productivity growth, which is consistent with the increase in the relative size of the service sector and the expansion of construction, both sectors in which productivity tends to be low. Meanwhile, the results suggest that human capital (ILLITERATE) has an indeterminate effect on the variation in MFP. As Islam (1995) argues, this non-significant result can basically be attributed to the fact that the variables selected are not good proxies for the theoretical concept of human capital. Or it may be that the channels through which human capital affects productivity growth are more complex than can be reflected through the mere inclusion of a multiplier in the equation. There is another possible explanation associated with the fact that human capital presents important shortcomings as was evidenced by the Pisa report OECD (2004b) for Spain.

3 Conclusions

Economic growth and productivity may to some be extent influenced by a series of factors (such as human capital, the technology gap, etc.), and many studies have sought to establish whether environmental policy affects economic growth in the ways predicted either by Porter or by his detractors. Given the successive reforms of direct taxation undertaken by the central and regional government of Spain, and the policy of introduce green taxes in some regions, this study examines whether the environmental policy implemented by the Spanish regions could have had any influence on efficiency in terms of productivity and economic growth. To this end, we have adapted the multifactor productivity model proposed by Jorgenson and Wilcoxen (1990), Nicoletti and Scarpetta (2003), De Vries and Withagen (2005), and Loayza et al. (2005) to the context of the Spanish regions, and we have estimated a dynamic panel-data model for the period 1989–2001 that reflects the effects of environmental taxation and regulation separately. The model also allows dynamic treatment in our econometric estimate, given the possibility that failure to consider the dynamic nature of the problem analyzed may explain the discrepancies appearing in the different empirical studies.

The results from the model, which was estimated using the generalized method of moments estimator (GMM), suggest that short-run technological progress (i.e. the coefficient for the leading regions) is positive and significant. Hence, the leader region exerts a drag effect on the others, and the most technologically backward regions grow faster than the leader, which is to say they achieve long-run technology gains by imitation. This last fact together with the significance of the dependent variable lagged one period, might suggest that history seems to explain quite a lot of the present. Public capital per employee and economies of scale also have a positive influence on productivity growth, as was expected, while changes in the productive structure have had a negative impact on productivity growth, which is consistent with the increasing size of the service sector and construction, both low-productivity industries.

The results concerning the two "key" parameters (e.g. environmental taxes and environmental regulation) would provide further empirical evidence in favour of the Porter hypothesis, to the extent that a strict environmental policy implemented via green taxes rather than regulation may raise productivity or enhance comparative advantage, improving the competitiveness of the firms subject to the environmental policy, thereby offsetting the costs it initially entailed. However, this affirmation should be made with certain reservations, because the results for these lagged variables are not relevant.

The obtained results could also support the hypothesis that tax decentralization on the revenue side via more intensive use of environmental taxation may boost economic growth, and they could form the basis for a study of the validity of the double dividend theory in this context. Future research could develope in these lines.

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Appendix

See Tables 6, 7, 8 and 9.

Table 6 Parliamentary acts contained in the database of the Spanish Institute of Public Law

1. Activities of the regional parliaments related to the statutes of autonomy
2. Participation of the autonomous communities in the legislative activity of the state
3. Parliamentary bills
4. Proposed bills
5. Legislative decrees
6. Parliamentary regulations
7. Relations with other organs and institutions
(a) Designation of senators
(b) Court of accounts
(c) Ombudsman
8. Parliamentary administration
(a) Internal regime and personnel
(b) Budgets of the parliaments
(c) Other affairs concerning the parliamentary administration
9. Composition of the chambers
10. Control and information activities
(a) Control debates
(i) Investitures of presidents of the autonomous communities
(ii) Motions of confidence
(iii) Motions of censure
(iv) Other initiatives of special interest
(b) State of the region debates
(c) Single-subject debates of special interest

Table 6 continued

(d) Government plans, programmes and communications
(e) Commissions of investigation
(f) Appearances

Table 7 Types of parliamentary acts contained in the database of the Spanish Institute of Public Law

Institutional regulations
1. Political life, public safety and public administration
2. International relations and defence
3. European communities
4. Law and justice
Economic regulations
5. Economic life
6. Economic and trade exchanges
7. Financial affairs
8. Public finance
9. Communications
10. Science
11. Companies and competition
12. Work and employment
13. Transport
14. Agriculture, forestry and fisheries
15. Food and agriculture sector
16. Technology and research
17. Energy
18. Industry
Social regulations
19. Social affairs
20. Health and hygiene
21. Education
22. Environment

Table 8 Descriptive statistics for the main variables

Variable	Obs	Mean	SD	Min	Max
$\Delta LMFP_{t-1}$	136	0.0190101	0.0193047	−0.0240265	0.077958
$LGAP_{t-1}$	136	−0.2032526	0.1303527	−0.5763395	0
ΔLLEADER	136	0.0241715	0.0321819	−0.0195599	0.0866127
PUBKW	136	14530.31	3210.464	9049.246	20656.22
ILLITERATE	136	15.25369	7.602436	3.483122	30.0672
PRODUCTEST	136	64.7516	8.027211	46.57741	83.64017
ΔRGVA	136	0.0457396	0.0149259	0.0069719	0.0857797
ENVREG	136	1.823529	3.138488	0	30
ENVTAX	136	0.2002892	0.3887194	0	1.886767

Table 9 Correlation matrix for the main variables

	$\Delta LMFP_{t-1}$	$LGAP_{t-1}$	ΔLLEADER	PUBKW	ILLITERATE	PRODUCTEST	ΔRGVA	ENVREG	ENVTAX
$\Delta LMFP_{t-1}$	1.0000								
$LGAP_{t-1}$	−0.1335	1.0000							
ΔLLEADER	0.3902	0.0352	1.0000						
PUBKW	0.1131	−0.1757	0.0932	1.0000					
ILLITERATE	0.0014	−0.6051	0.0088	−0.1576	1.0000				
PRODUCTEST	0.1024	0.2032	0.0029	−0.4466	0.1853	1.0000			
ΔRGVA	0.3801	0.0343	−0.1436	0.0161	−0.0499	0.3442	1.0000		
ENVREG	0.1185	0.0325	0.1846	−0.1033	0.0139	0.0391	−0.0064	1.0000	
ENVTAX	0.0659	0.0858	0.0339	−0.1923	0.1891	0.5941	0.2197	0.0225	1.0000

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