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Evidence from European Industries

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Abstract

This paper contributes to the empirical literature on the relationship between environmental regulation and firm behavior. In particular, we ask whether and how strongly investment decisions of firms respond to stringency in environmental regulation. Environmental stringency is measured as (i) an industry's total current expenditure on environmental protection, and (ii) a country's revenue from environmental taxes. Focusing on European industry level data between 1995 and 2005, we estimate the differential impact of environmental stringency on four types of investment: gross investment in tangible goods, in new buildings, in machinery, and in 'productive' investment (investment in tangible goods minus investment in abatement technologies). Both environmental variables enter positively, and their quadratic terms exhibit significantly negative parameter estimates. This, in turn, indicates a positive but diminishing impact of environmental regulation on investment.

Keywords: Investment, environmental regulation, pollution abatement costs

JEL classification: D92, H23, Q52

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1 Introduction

Environmental economists typically arrive at very different conclusions about the impact of environmental regulation on firm behavior. For instance, one argument that has recently attracted increasing attention is that firms intend to locate their business activities in countries or regions where environmental standards are relatively low. By way of contrast, others emphasize the availability of (clean) natural resources as factor inputs. In this case, one would expect a positive rather than a negative impact of environmental regulation on firm activities.

This paper analyzes the role of environmental regulation on investment decisions of firms. Unlike the previous literature mainly focusing on the effects of environmental stringency on international investment (i.e., locational choices of multinational firms), we ask whether tighter environmental standards are associated with higher or lower investment at *a given plant location*. Specifically, we are interested in the differential impact of environmental regulation on four types of country-industry specific investment: (i) gross investment in tangible goods, (ii) gross investment in construction and alteration of buildings (henceforth investment in new buildings), (iii) gross investment in machinery, and (iv) 'productive' investment, defined as the difference between gross investment in tangible goods minus investment in abatement technologies. Environmental regulation is measured as (i) an industry's total current expenditures on environmental protection, and (ii) a country's revenue from environmental taxes. Empirically, we rely on a European dataset of 23 countries and three industries (i.e., mining and quarrying, manufacturing and electricity, gas and water supply) between 1995 and 2005. To the best of our knowledge, this is the largest available dataset on industry specific environmental regulation at the country level.

Our empirical findings suggest that environmental regulation as measured by environmental expenditures and revenues from environmental taxation is positively related to (all types of) investment. Further, we observe a significantly negative quadratic term for both measures of environmental regulation. These findings are robust over a wide variety of sensitivity checks (e.g., when using emission-based indicators of environmental regulation such as total greenhouse gas emissions). Taking these results together, environmental regulation obviously reveals a positive but diminishing impact on firm investment in our sample of European industries.

The paper is organized as follows. In Section 2, we briefly review the related literature. Section 3 derives the empirical investment equation, where a special focus is given to the inclusion of environmental regulation. Section 4 summarizes the data and discusses the variables used in the empirical models. In Section 5, we present the empirical findings and the sensitivity analysis. Section 6 concludes.

2 A brief overview over the related empirical research

As mentioned above, most of the previous literature focuses on the effects of environmental regulation on trade and foreign direct investment (FDI).[1] The empirical conclusions from this research are rather ambiguous. While some authors find that environmental stringency is negatively associated with trade and FDI activities of firms, others observe a positive relationship between those variables.[2]

Although the focus of this paper is on local, country-industry specific investment rather than on trade and FDI, we can draw two important conclusions from this literature. From a theoretical point of view, we can firstly derive three potential effects regarding the influence of environmental regulation on investment decisions of firms. The *'pollution haven hypothesis'* states that firms (especially from dirty industries) tend to locate their production activities in countries or regions with low en-

[1] See Jaffe, Peterson, Portney and Stavins (1995), List and Co (2000). Brunnermeier and Levinson (2004) and Copeland and Taylor (2004) provide excellent overviews.

[2] A negative relationship has been found, for example, by Xing and Kolstad (2002), List, Millimet, Fredriksson and McHone (2003), Brunnermeier and Levinson (2004), Jug and Mirza (2005), Spatareanu (2007), Dam and Scholtens (2008), Levinson and Taylor (2008). Positive effects of environmental regulation on FDI and exports are observed in Levinson (1996), Cole and Elliot (2003), Dean, Lovely and Wang (2005) and Costantini and Crespi (2008). Mulatu, Florax and Withagen (2004), Javorcik and Wei (2004) and Cave and Blomquist (2008) provide mixed evidence on this issue.

vironmental standards to avoid higher environmental compliance costs. In this case, we would expect a negative relationship between environmental regulation and investment. The *'factor endowment hypothesis'*, in contrast, emphasizes that abundance in (natural) resources improves the production possibilities of firms. Accordingly, industries may accept stricter regulations in order to benefit from abundant input factors, so that more stringent regulations do not necessarily reduce firm activities (see Copeland and Taylor 2004). Porter and van der Linde (1995) point out that properly designed environmental policies might increase the application of new, innovative technologies. Such investments may lead to higher productivity and, therefore, to an advantage over industries in other countries/regions without such regulations (in the following, we refer to this view as *'Porter hypothesis'*). Then, we would expect a positive impact of environmental regulation on investment activities of firms.

The second lesson that can be drawn from the previous research is that the estimation results are sensitive to the measurement of environmental regulation and to the empirical specification (see Jeppesen, List and Folmer 2002 for a survey). Environmental stringency is mainly measured by expenditures on environmental protection, or emission-based measures (see, e.g., Bartik 1988, Friedman, Gerlowski and Silberman 1992, Levinson 1996, Gray and Shadbegian 1998, List and Co 2000, Keller and Levinson 2002, or Van Soest, List and Jeppesen 2006). We follow this lead using expenditures on environmental protection as the first indicator for environmental regulation. Second, we refer to environmental taxation arguing that a high burden of such taxes is associated with stricter regulation (see Levinson 1999, Dean, Lovely and Wang 2005). Environmental tax burden is measured by the revenue from environmental taxes. Finally, we provide a sensitivity analysis, where both measures are replaced by emission-based indicators, i.e., waste water generated and greenhouse gas emissions.

With regard to the empirical specification, some authors point to the fact that the observed causal influence of environmental regulation on economic activities might be prone to endogeneity. Most importantly, environmental policy not only influences the behavior of firms, but probably is itself affected by firm activity (see Eliste and Fredriksson 2002, Cole, Elliott and Fredriksson 2006, on reversed causality between environmental regulation and trade and FDI). One obvious way to circumvent this problem is to use instrumental variable estimation. However, it turns out that it is nearly impossible to find convincing instruments varying over countries and industries.[3] Therefore, we use an alternative approach by treating the covariates as predetermined.[4]

3 Empirical specification

To estimate the impact of environmental regulation on investment we use a static (long run) framework as proposed by Garofalo and Malhotra (1995), Keller and Levinson (2002), Xing and Kolstad (2002) and Spatareanu (2007), among others. Our basic specification reads as

$$\begin{aligned} I^k_{ic,t} = &\beta_1 E^{TCE}_{ic,t-1} + \beta_2 \left(E^{TCE}_{ic,t-1}\right)^2 + \beta_3 E^{REV}_{c,t-1} + \beta_4 \left(E^{REV}_{c,t-1}\right)^2 \\ &+ \beta_5 Q_{ic,t-1} + \beta_6 C_{ic,t-1} + \lambda_i + \mu_{ct} + \varepsilon_{ic,t}, \end{aligned} \tag{1}$$

where i, c and t are industry, country and time indices. Eq. (1) is estimated for four types of investment, denoted by the superscript k: gross investment in tangible goods (I^T), gross investment in new buildings (I^C), gross investment in machinery (I^M), and productive investments (I^P), defined as the difference between total investments in tangible goods and investments in abatement technologies. E^{TCE} indicates country-industry specific expenditures on environmental protection, and E^{REV} represents a country's revenue from environmental taxes. The inclusion of our control variables, country-industry specific output, Q, and the corresponding cash flow (difference between value added and labor cost), C, is mainly motivated by the empirical investment literature (see, e.g., Blundell, Bond and Meghir 1996). λ_i denotes industry specific ef-

[3] The instruments usually proposed by the literature (e.g., public infrastructure, availability of technological resources, labor force) are typically correlated with environmental regulation but also with economic activities (e.g., trade and FDI, but also investment), serving at best as weak instruments from an empirical point of view. Apart from this, these variables are typically not available annually at the country-industry level.

[4] Of course, this does not guarantee that endogeneity vanishes in our application. However, below we present evidence from an analysis of variance that such a (reversed) causality is rather unlikely in our sample of European industries.

fects not varying over time. μ_{ct} indicates country-time specific effects including country and time effects as well as interactions thereof (e.g., the business cycle effects). ε is the remainder error.

Following the literature on dynamic investment functions, the dependent variable and each of the independent variables (except the dummy variables and the error term) are weighted by the country-industry specific capital stock $K_{ic,t}$. Since this capital stock is not observable in our dataset, we use the perpetual inventory method to derive

$$K_{ic,t} = (1-\delta)K_{ic,t-1} + I^T_{ic,t}, \tag{2}$$

where δ denotes the economic depreciation rate.[5] The initial capital stock $K_{ic,0}$ is calculated as

$$K_{ic,0} = \frac{0.5(I^T_{ic,0} + I^T_{ic,1})}{\overline{\Delta I^T_{ic}}}, \tag{3}$$

with $\overline{\Delta I^T}$ representing the country-industry specific average growth rate of I^T.

Our dependent variable is a ratio, $\frac{I^k}{K}$, strictly bounded between zero and one. Using a logg-odds transformation, i.e., $\log\left(\frac{I^k/K}{1-I^k/K}\right)$, as proposed by Wooldridge (2002: 662) results in a dependent variable which ranges over all real values. Consequently, parameters can be consistently estimated by OLS.

Investments in tangible goods, I^T, represent the main type of investment in our study. Investments in intangible goods like concessions, patents, licenses or software are excluded. We further refer to two subgroups of I^T, investments in new buildings, I^C, and in machinery, I^M, where the former are typically more persistent in the sense that they impose stronger temporal and locational commitments than the latter ones. Therefore, we expect that the effects of environmental stringency on investments in machinery are more pronounced than that on new buildings.

[5] δ is calculated as a weighted average over the economic depreciation rates for machinery (12.25 percent) and for new buildings (3.61 percent). These rates are based on the empirical study of Hulten and Wykoff (1981). According to OECD (1991), the weights are 50 percent for machinery and 28 percent for new buildings (the remaining 22 percent are inventories, not included in our study). These weights are the usual ones taken in the literature.

The fourth type of investment that we rely on is productive investment, I^P, which is calculated as the difference between total investments in tangible goods and investments in abatement technologies. Focusing on this type of investment we follow the previous research recommending to distinguish between capital available for production and abatement capital (see, e.g., Conrad and Wastl 1995, Garofalo and Malhotra 1995, Gray and Shadbegian 1998, Gray and Shadbegian 2003, or Shadbegian and Gray 2005). This allows for testing whether changes in investment are mainly driven by investments in abatement technology or not.

We use two measures of environmental stringency simultaneously. An industry's current expenditure on environmental protection, E^{TCE}, is a common proxy for environmental policies. The underlying idea is that pollution abatement costs are higher if a country imposes stricter environmental regulations. Similarly, it can be argued that environmental tax rates and, therefore, a country's revenue from environmental taxation, E^{REV}, is associated with stronger environmental stringency. In addition to the simple linear measures of environmental regulation, we include quadratic terms of both stringency variables to allow for the possibility that the effects of environmental regulation might change at tighter stringency levels (see, e.g., Jaffe, Peterson, Portney and Stavins 1995, Ederington, Levinson and Minier 2005).[6]

Finally, we treat the explanatory variables in eq. (1) as predetermined to avoid a possible endogeneity bias (see, e.g., Eliste and Fredriksson 2002, Copeland and Taylor 2004, Cole, Elliott and Fredriksson 2006, and Levinson and Taylor 2008). It should be noted that our specification in eq. (1) is very close to a standard investment function as proposed by the dynamic investment literature (see Blundell, Bond and Meghir 1996). The main difference to these studies is the omission of the lagged dependent variable. However, our indicators of environmental stringency are not varying much over time (at least for one variable; see the discussion below). Therefore, it is nearly impossible to measure the impact of environmental stringency on investment precisely in a dynamic setting.

[6] A log-odds transformed model as ours automatically assumes a non-linear relationship between environmental regulation and investment. However, likelihood ratio tests provide evidence that quadratic terms of our stringency measures should be included in the empirical model.

In the robustness section we provide evidence that we arrive at qualitatively similar results to eq. (1) when including the lagged dependent variable in the empirical model.

4 The Data

Data description: The data are taken from the Eurostat databases. The variables used in the empirical analysis and a detailed description thereof are listed in Table A1 in the Appendix. Total current expenditures on environmental protection and revenues from environmental taxation are covered by the Environmental Accounts Database. Information on investment, industry specific output, value added and labor costs are available from the Annual Enterprise Statistics. Overall, our dataset includes 23 countries over a time period from 1995 to 2005.[7] It covers information from three industries according to the NACE 1-digit classification code: mining and quarrying, manufacturing and electricity, gas and water supply.

Total current expenditures on environmental protection are industry specific and represent the private costs for pollution abatement. They comprise all payments related to an industry's operating activities, such as payments of rents, use of energy, or the purchase of services. Transfers (e.g., payments of environmental taxes or fees) and depreciation allowances for environmental equipment are excluded, since these outlays are not directly related to services purchased to monitor, control or reduce negative consequences imposed on environment caused by business activities (Eurostat 2005: 31). Revenue from environmental taxation is available at the country level,[8] and it includes revenues from energy, transport, pollution and resource (except oil and gas) taxation (see Eurostat 2001).

[7] Originally, the Eurostat database includes information from 27 EU member countries and five non-EU member countries (Croatia, Iceland, Norway, Switzerland and Turkey). Due to missing data, especially for the environmental variables, we exclude Croatia, Denmark, France, Greece, Iceland, Luxembourg, Malta, Switzerland, Turkey, leaving a sample of 23 European economies.

[8] Notice that the environmental tax revenue is divided by the country-industry specific capital stock, so that this variable is also available at the country-industry level.

Descriptive statistics: Overall, our sample includes 690 observations. However, due to missing observations in the explanatory variables we only use around 450 observations. Table A2 reports the descriptive statistics of our main variables, Table A3 reports the corresponding correlation matrix. The average investment ratio (investment to capital stock) of tangible goods amounts to 9.2 percent, with a minimum of 0.4 and a maximum of around 42.8 percent. The mean of productive investment is about 9.0 percent, indicating that only a small fraction of overall investment in tangible goods is captured by environmental investments. Investments in new buildings (machinery) are around 2.2 (6.5) percent, on average. With regard to our measures of environmental stringency we can see that firms, on average, spend 0.7 percent of the capital stock per annum to meet environmental standards. Finally, revenue from country-specific environmental taxation amounts to about three quarters of the industry-specific capital stock, on average.

Figure 1 depicts the averages of the four investment ratios between 1995 and 2005. All of them increased steadily over the course of the years. For instance, the share of investment in tangible goods to capital stock increased from about 6 percent in 1995 to about 10.5 percent in 2005. The corresponding share of productive investments changed in a similar way, but is slightly below tangible goods, indicating again, that investment in environmental protection itself seems less of importance in our sample of European economies. Further, Figure 1 clearly demonstrates that the lion's share of investments in tangible goods is due to investments in machinery. The absolute share of investments in new buildings to capital stock stood relatively constant at a value of two percent (or about 20 percent of total tangible goods).

Figure 2 provides information on our measures of environmental stringency, i.e., current expenditures on environmental protection (left-hand scale) and revenue from environmental taxation (right-hand scale), both related to industry-country specific capital stocks. Expenditures on environmental protection are scattered around 0.6 percent until 2003. Since then, this share increased sharply up to 1.3 percent. Revenues from environmental taxation dropped from 55 percent to 37 percent between 1995

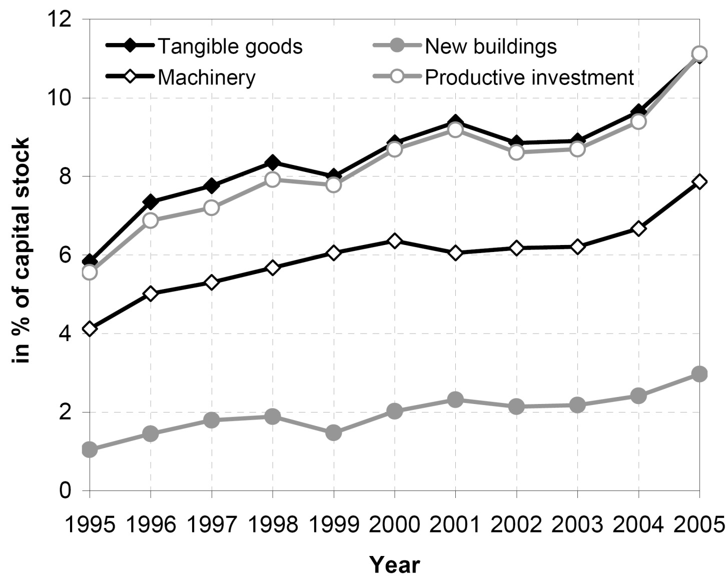

Figure 1: Types of investment, 1995-2005

to 1996, and increased from 40 percent to 87 percent between 1996 and 2000. Afterwards, we observe values around 80 percent.

Generally, our measures of environmental regulation, and especially revenues from environmental taxation, are not varying much over time. This can be shown by means of an analysis of variance (ANOVA), where the total variance of both indicators are dissected into their major components: a set of dummy variables (the 'model') and a remaining error (the 'residual'). In our case, the model variance includes three main effects (country, industry and time) and three interactions (country×industry, country×time and industry×time).[9] The ANOVA-results are presented in Table 1. Columns 1 and 2 (expenditures on environmental protection) and 6 and 7 (revenues from environmental taxation) inform about the absolute and relative share of each of the variance component on the total variance of the stringency measures. Accordingly, more than half of

[9]Since we are only interested in the decomposition of the variance of the environmental stringency measures, we do not include any explanatory variables. Therefore, the model variance and the residual variance add up to the total variance. It is important to note that the main effects are nested in the interactions, putting a restriction on the parameters of the main and the interaction effects (i.e., the main effects add up to zero, and also the sum of the interactions is zero).

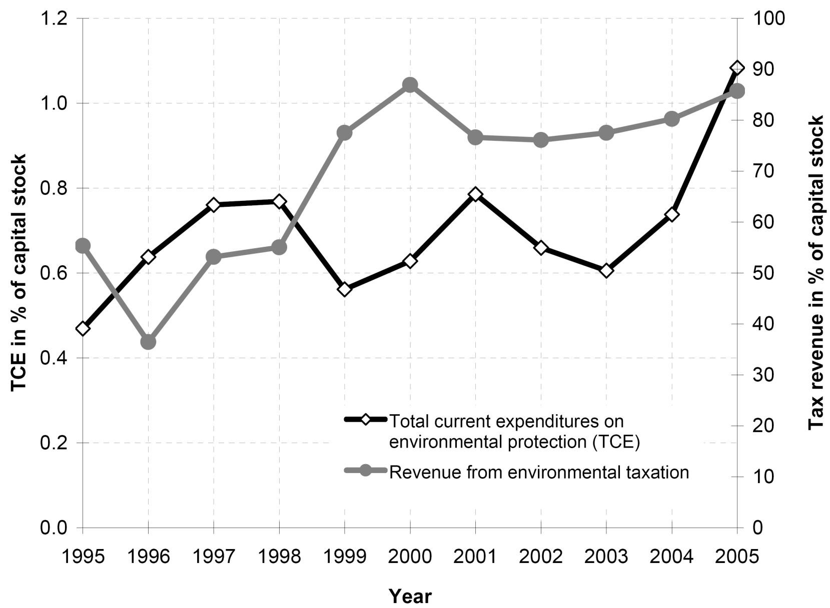

Figure 2: Environmental regulation, 1995-2005

the variance in expenditures on environmental protection is due to time-invariant, country-industry specific effects ($24.2+0.1+24.2+8.6 = 57.1$ percent), the remaining part is due to the time-variant dimension of this variable ($3.9 + 20.8 + 1.9 + 16.3 = 42.9$ percent). For revenue from environmental taxation, we observe a considerably lower share of time-varying components ($= 0.4 + 1.2 + 0.8 + 2.0 = 4.4$ percent). Therefore, it should be not surprising that this variable turns out insignificant in a dynamic panel data model. Our specification in eq. (1) includes industry, country and time fixed effects and interaction terms between country and time effects (along with the constant), wiping out 57.6 percent ($= 24.2 + 0.1 + 3.9 + 20.8 + 8.6$) of the total variation in E^{TCE} and 68.8 percent ($= 20.0 + 13.8 + 28.5 + 33.4$) in the variation of E^{REV}. Therefore, the fixed effects in our empirical model leave out 42.4 (31.2) percent in the total variation of expenditures in environmental protection (revenue from environmental taxation). This should be enough variation to identify effects of environmental regulation on investment.

Next, let us focus on the relationship between our variables of interest, i.e., environmental stringency and investment. In Table 2, we decompose the variance in the change of investment ratios into several components:

Table 1: Analysis of variance for environmental stringency

Source	Environmental protection expenditures to capital stock					Revenue from environmental taxation to capital stock				
	Absolute	in %	d.f.	F-statistic	P-value	Absolute	in %	d.f.	F-statistic	P-value
Country effects	0.00607	24.2	21	13.9	0.000	134.11	20.0	21	94.1	0.000
Industry effects	0.00003	0.1	2	0.7	0.487	92.25	13.8	2	679.3	0.000
Time effects	0.00098	3.9	9	5.2	0.000	2.35	0.4	9	3.8	0.000
Country×industry effects	0.00607	24.2	41	7.1	0.000	191.00	28.5	41	68.6	0.000
Country×time effects	0.00520	20.8	131	1.9	0.000	7.99	1.2	131	0.9	0.746
Industry×time effects	0.00047	1.9	18	1.3	0.222	5.05	0.8	18	4.1	0.000
Constant (overall mean)	0.00216	8.6	1			223.92	33.4	1		
Model	0.02099	83.7	222	4.6	0.000	656.67	98.0	222	43.6	0.000
Residual	0.00409	16.3	197			13.38	2.0	197		
Total	0.02508	100.0	419			670.04	100.0	419		

Notes: 420 observations in both models. Adjusted R^2 is 0.837 for environmental expenditures and 0.958 for environmental tax revenue. d.f. . . . degrees of freedom.

our measures of environmental stringency, E^{TCE} and E^{REV}, fixed country, industry and time effects as well as interactions between country and time effects (the choice of this set of dummy variables is suggested by Table 1). With regard to environmental stringency, we define two indicator variables taking a value of one if a change between the years $t-1$ to t is observed for each variable (in Table 2, this change is indicated as 'contemporaneous' change in E^{TCE} and E^{REV}). Table 2 contains three parts, differing with regard to the timing of the left-hand-side variable. The top panel refers to once-lagged changes of investment ratios (i.e., the change between the years $t-2$ and $t-1$). The panel in the middle relies on the contemporaneous change in investment ratios (i.e., a change between $t-1$ and t), and the bottom panel employs the lead of investment ratios (i.e., the change between t and $t+1$). Such an analysis might be useful to obtain information about the timing of investment decisions and about possible adjustment effects.

As can be seen from the bottom panel in the Table, both measures of environmental regulation are significant in explaining variation in post investment changes (the exception is investment in new buildings). With regard to contemporaneous changes in investment, environmental tax revenue enters significantly, but not current expenditures on environmental protection. Finally, we observe insignificant effects of environmental regulation on past investment growth (the exception here is investment in machinery, where we find weak significance for environmental tax revenue). Taking these findings together, environmental regulation today obviously affects investment tomorrow, but not today's and yesterday's investment decisions. Therefore, it seems that causation runs mainly from stringency to investment (for a discussion, see Cameron and Trivedi 2005: 749). This, in turn, strongly advocates a specification as in eq. (1), i.e., one where investment today is explained by once-lagged stringency measures.

Figures A1 to A4 in the Appendix provide further insights into the relationship between environmental stringency and investment. Specifically, we plot each of the four types of investment on each of the measures of environmental regulation, separately. The entries in the figures indicate country averages over time and industries, the dashed lines rep-

Table 2: Analysis of variance of a change in investment ratios

Category (indicator variable)	*Type of investment*			
	I^T	I^C	I^M	I^P
Past change in investment: $I^k_{t-1} - I^k_{t-2}$				
Contemp. change in E^{TCE} (Partial SS)	0.0020	0.0000	0.0010	0.0020
	(0.240)	(0.906)	(0.402)	(0.264)
Contemp. change in E^{REV} (Partial SS)	0.0026	0.0002	0.0055	0.0026
	(0.182)	(0.311)	(0.053)	(0.201)
Model SS	0.4138	0.0805	0.3036	0.3758
Total SS	0.8353	0.1308	0.6891	0.8089
R^2	0.495	0.615	0.441	0.465
Observations	338	298	315	320
Contemporaneous change in investment: $I^k_t - I^k_{t-1}$				
Contemp. change in E^{TCE} (Partial SS)	0.0000	0.0004	0.0002	0.0000
	(0.940)	(0.164)	(0.696)	(0.994)
Contemp. change in E^{REV} (Partial SS)	0.0053	0.0000	0.0064	0.0056
	(0.055)	(0.959)	(0.034)	(0.059)
Model SS	0.5386	0.1147	0.3314	0.4905
Total SS	1.0633	0.1787	0.7785	1.0179
R^2	0.507	0.642	0.426	0.482
Observations	420	368	371	389
Post change in investment: $I^k_{t+1} - I^k_t$				
Contemp. change in E^{TCE} (Partial SS)	0.0112	0.0000	0.0092	0.0114
	(0.007)	(0.660)	(0.015)	(0.009)
Contemp. change in E^{REV} (Partial SS)	0.0080	0.0000	0.0077	0.0077
	(0.023)	(0.924)	(0.025)	(0.031)
Model SS	0.5015	0.1085	0.3259	0.4576
Total SS	0.9388	0.1587	0.7146	0.8975
R^2	0.534	0.684	0.4561	0.510
Observations	338	308	303	318

Notes: Country, industry and time effects as well as interaction terms between country and time effects are included in the 'model' but are not reported for the sake of brevity. SS ... Sum of squares. p-values in parentheses.

resent the average values from Table A2. Two important conclusions can be drawn from these graphs: First, there is large country level variation not only in investment ratios, but also with regard to the environmental variables. For instance, the share of investment in tangible goods to capital stock is lying between 2.6 percent (Cyprus) and 16.6 percent (Spain). Similarly, there are countries with an environmental tax revenue up to 10 percent (e.g., Cyprus, Romania); other ones obtain a revenue of nearly twice the capital stock (e.g., Spain or Latvia). Second, and more importantly, there is obviously a positive relationship between all measures of environmental regulation and each type of investment (see the solid regression lines in the figures).

5 Empirical Results

5.1 Baseline results

Table 3 summarizes our empirical findings. The dependent variables, represented in columns 1 to 4, are gross investment in tangible goods, I^T, gross investment in new buildings, I^C, gross investment in machinery, I^M, and productive investment, I^P. Each of these variables is log-odds-transformed as described above. All variables reported in the table are weighted by the country-industry specific capital stock, $K_{ic,t}$. In all models discussed below, we exclude observations with a remainder error in the upper and lower end one percent percentile range (about 10 observations of the sample).

The model fit seems generally well. The R^2 measures are around 0.6, the fixed effects are highly significant throughout, and the control variables are broadly as expected. Output, Q, exhibits a significantly positive sign. The cash flow variable is only significant for investment in new buildings, but enters negatively, which is in line with the dynamic investment literature (see, e.g., Bond and Meghir 1994).

With regard to our variables of interest, we can draw the following conclusions from the table: First, the parameter estimates for E^{TCE} and E^{REV} are significantly positive, indicating a positive impact of environmental regulation on investment. Second, the quadratic terms of both variables are significantly negative, suggesting that the positive effect of environmental regulation diminishes with tighter regulations. The exception is investment in new buildings (second column), where we only observe significant parameter estimates for environmental taxation but not so for expenditures on environmental protection (E^{TCE} and its square). Third, comparing the estimation results for environmental expenditures

Table 3: Estimation results

	Type of investment			
Independent variable	I^T	I^C	I^M	I^P
$(E^{TCE}/K)_{t-1}$	10.461***	11.454	23.470***	15.084***
	(3.855)	(10.734)	(6.587)	(5.004)
$(E^{TCE}/K)^2_{t-1}$	−29.311**	−31.700	−73.059***	−45.598***
	(12.984)	(37.658)	(22.696)	(16.692)
$(E^{REV}/K)_{t-1}$	0.372***	1.024***	0.604***	0.484***
	(0.113)	(0.246)	(0.131)	(0.139)
$(E^{REV}/K)^2_{t-1}$	−0.052***	−0.157***	−0.074***	−0.070***
	(0.019)	(0.040)	(0.022)	(0.023)
$(Q/K)_{t-1}$	0.161**	0.157	0.265***	0.177**
	(0.063)	(0.151)	(0.079)	(0.079)
$(C/K)_{t-1}$	0.137	−1.278***	−0.051	−0.097
	(0.300)	(0.427)	(0.363)	(0.381)
Observations	420	366	368	389
Adj. R^2	0.601	0.646	0.627	0.579
F-tests				
Industry effects	4.9***	15.8***	12.9***	5.3***
Country effects	$6.8{\cdot}10^{8}$***	279.9***	2,456.8***	235.7***
Time effects	6.2***	5.4***	5.7***	3.4***
Country×time effects	72.2***	122.3***	10.2***	35.8***

Notes: Constant and fixed effects not reported. Robust standard errors in parenthesis. *, ** and *** indicate 10%, 5% and 1% levels of significance.

in the first three columns of Table 3, we can see that the effects of environmental regulation is most sensitive for investments in machinery. One explanation for this result might be that such investments respond are more sensitive to changes in regulations than the other ones. Finally, we observe a positive but diminishing impact of both measures of environmental regulation on productive investment. The estimated parameters for this investment type are similar to the ones of investment in tangible goods. This is not surprising given the close correlation between both variables (see Table A3 in the Appendix). Further, the estimated parameters for I^T and I^P are very similar indicating that investment in abatement technologies are not a driving force behind the observed relationship between environmental regulation and investment.

Our empirical findings from Table 3 clearly suggest that investment decisions of firms are systematically affected by environmental regula-

Table 4: Marginal effects and elasticities

	Type of investment			
	I^T	I^C	I^M	I^P
Total current expenditure on environmental protection: E^{TCE}				
Marginal effect	0.801	0.221	1.239	1.117
Elasticity	0.103	0.196	0.199	0.141
Revenue from environmental taxation: E^{REV}				
Marginal effect	0.024	0.016	0.027	0.030
Elasticity	0.054	0.254	0.077	0.069

Notes: Marginal effects and elasticities are evaluated at the mean values of environmental stringency variables and investment.

tion. But how important is this effect in quantitative terms? To answer this question we calculate marginal effects of environmental regulation and the corresponding elasticities, evaluated at the mean of investment and our measures of environmental stringency.[10] The results are presented in Table 4. The marginal effect of a one percentage point change in environmental expenditure is around 0.8 for investments in tangible goods, which translates into an elasticity of around 0.1. Accordingly, a 10 percent increase (in the absolute level) in expenditures on environmental protection is associated with an increase in investment in tangible goods by about 1 percent. The corresponding elasticities for investment in new buildings and in machinery are much higher (around 0.2). For environmental tax revenues we obtain elasticities between 0.05 and 0.08, with the exception of investment in new buildings (about 0.25).

5.2 Robustness

We undertake several robustness checks, always based on our specification in eq. (1). First, we address the measurement of environmental stringency. Previous research has emphasized that pollution abatement

[10]Our empirical model might be generalized as $\log\left(\frac{I/K}{1-I/K}\right) = g(z)$, where $g(z)$ is given by the right-hand-side of eq. (1). Rewriting this expression as $\frac{I}{K} = \frac{e^{g(z)}}{1+e^{g(z)}}$, and differentiating with respect to each variable of environmental regulation E^r/K $\forall r \in \{TCE, REV\}$ yields the marginal effect $\frac{\partial(I/K)}{\partial(E^r/K)} = \frac{[\partial g(z)/\partial E^r]e^{g(z)}}{[1+e^{g(z)}]^2}$, which can be evaluated at the mean values of (E^{TCE}/K) and (E^{REV}/K) holding the remaining right-hand-side variables of eq. (1) at their mean values.

costs might capture environmental stringency inappropriately (see, e.g., Jeppesen, List and Folmer 2002, Levinson and Taylor 2008). Therefore, we replace E^{TCE} and E^{REV} by emission-based measures of environmental stringency, i.e., information on waste water generated, E^{WW}, and total green house gas emissions, E^{GHG}. These variables are availaibe from Eurostat's Water Database and Air Pollution/Climate Change Database,[11] where E^{WW} is available at the country-industry level and E^{GHG} is country specific. We control for industry size by weighting emission volumes with the number of enterprises within a country-industry pair. Assuming that higher pollution intensities are associated with weaker environmental regulation, we would expect a positive (negative) impact of E^{WW} and E^{GHG} on investment from the pollution haven (factor endowment and Porter) hypothesis. To account for possible non-linearities we again include quadratic terms of both variables.

The results of this robustness exercise are reported in Table A4. Obviously, the inclusion of E^{WW} and E^{GHG} reduces the sample size drastically. For total green house gas emissions, we observe significant parameter estimates for both the linear and the quadratic terms in all investment specifications. The negative coefficient on E^{GHG} seems to confirm the Porter and factor endowment hypotheses, while the positive sign of the quadratic terms gives some indication in favor of the pollution haven hypothesis. Regarding E^{WW}, we find a negative (positive) parameter estimate for investment in machinery (in new buildings). The quadratic terms are positive in the case of machinery and negative for new buildings. For investment in tangible goods and productive investment we obtain insignificant coefficients. Although we should interpret the estimation results from Table A4 cautiously given the small sample size, we may conclude that they do not contradict our findings from Table 3.

In the second set of sensitivity analysis we include public subsidies intended to provoke environmental protection activities of firms as addi-

[11] Waste water generated is defined as the quantity of water polluted during use by adding waste or heat (in cubic meters). The origin can be industrial or domestic use (used water from bathing, toilets, cooking etc.). Greenhouse gas emissions are based on the aggregated emissions of the six greenhouse gases of the 'Kyoto basket' (in 1000 tonnes CO_2-equivalents): carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).

tional control variable.[12] Subsidies reduce a company's compliance costs and are, therefore, expected to stimulate industrial activities. On the other hand, if abatement costs are initially high it would be worthwhile for a firm to invest in environmental friendly technologies. Receiving a subsidy in this situation might reduce the abatement costs providing benefits for a firm to ignore environmental standards. In this case, subsidies are negatively associated with investment. In addition, Eliste and Fredriksson (2002), relying on the relationship between environmental regulation and trade, demonstrate that the estimation results might be seriously biased when leaving out subsidies from the empirical model. The estimation results in Table A5 indicate that this seems not the case in our sample of European industries. Again, we obtain significantly positive parameter estimates for both indicators of environmental regulation, and their squared terms exhibit significantly negative signs. For environmental subsidies itself we observe negative estimates (with the exception of investments in machinery), and positive coefficients for their squared variables.

Next, it might be argued that our estimation results are sensitive to the way that all variables are standardized in the empirical model. One particular caveat might be that we do not obtain the capital stock from the data, but calculate the corresponding series using the perpetual inventory method. To account for this argument, we use an alternative weighting scheme by dividing each variable of eq. (1) with country-industry specific labor costs, $L_{ic,t}$, rather than the corresponding capital stock. Table A6 in the Appendix reveals that we loose about 50 to 100 observations now, depending on the type of investment. However, compared to the estimation results in Table 3 we arrive at similar conclusions about the impact of environmental regulation on investment when using this standardization. The only exception is that E^{TCE} and its squared term are now insignificant for investments in tangible goods, but we also

[12] Subsidies subsume all types of transfers financing environmental protection activities, and also transfers to or from other countries. If a country pays out more transfers than it receives from subsidies, a negative entry is recorded in the database (see Eurostat 2005: 83). The data are taken from the Eurostat's Environmental Accounts Database.

observe significant parameter estimates for investment in new buildings, which were insignificant before.

Finally, we estimate a dynamic panel model rather than a static one. Such a specification has been proposed by Blundell, Bond and Meghir (1996) and Bond and Meghir (1994), among others. Specifically, we include a lagged dependent variable and its square on the right-hand-side of eq. (1), and estimate this model by applying a system GMM approach as developed by Blundell and Bond (1998). The estimation results are summarized in Table A7. The dynamic model seems to confirm our previous findings with regard to expenditures on environmental protection, but not so for revenues on environmental taxation, where we only obtain insignificant parameter estimates throughout. However, this is not really surprising as this variable is highly persistent over time (see Table 1 and the discussion there).

Overall, our sensitivity analysis summarized in Tables A5 to A7 in the Appendix suggests that our results regarding the impact of environmental regulation on investment activities of firms remain nearly unchanged when using alternative measures of environmental stringency, additional control variables or different empirical specifications.

6 Conclusions

There is no consensus among environmental economists whether environmental regulation causes a positive or a negative impact on firm behavior. Some authors argue that firms are low cost seekers and, therefore, reduce activities when they are confronted with tight environmental standards (pollution haven hypothesis). Others, in contrast, emphasize the role of (clean) natural resources and innovative technologies in the production process (factor endowment hypothesis and Porter hypothesis). Under this view, environmental regulation should foster firm activities.

In this paper we focus on investment decisions of firms and assess how they are influenced by environmental regulation. We analyze four types of investment: Gross investment in tangible goods, gross investment in new buildings, gross investment in machinery and productive investments (investment in tangible goods minus investment in abatement technologies). Environmental stringency is measured as (i) total current expenditures on environmental protection, and (ii) revenue from environmental taxation. Our data set covers country-industry specific information from 23 European countries and three industries (mining and quarrying, manufacturing, and electricity, gas and water supply) between 1995 and 2005.

Our empirical findings allow to derive a consistent picture about the effects of environmental regulation on investment. Both, total current expenditures and revenues from environmental taxation exert a positive impact on all types of investment. However, the quadratic terms of both variables enter significantly negative, suggesting that the positive effects of environmental stringency are diminishing with tighter regulations. On average, we find elasticities of about 0.15 for expenditures on environmental protection, and around 0.06 for revenues from environmental taxation. In other words, a 10 percent increase in expenditures on environmental protection (revenue from environmental taxation) is associated with an increase in investment of about 1.5 (0.6) percent.

The remaining question is how these findings fit into the above mentioned hypotheses regarding the impact of environmental stringency on firm behavior. Obviously, the positive parameter estimates on both measures of environmental regulation lend support to the Porter and the factor endowment hypotheses. However, the negative coefficients of their quadratic terms indicate that the pollution haven hypothesis seems to hold if environmental regulation is relatively strict. After all, the evidence presented in this paper does not entirely confirm one of the above mentioned hypotheses on the impact of environmental regulation on investment decisions of firms.

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Table A1: List of variables and variable definitions

Variable abbreviation	Description
Gross investment (dependent variable)	
(I^T/K)	Gross investment in tangible goods (in % of capital stock)
(I^C/K)	Gross investment in construction and alteration of buildings (in % of capital stock)
(I^M/K)	Gross investments in machinery and equipment (in % of capital stock)
(I^P/K)	Productive investment (in % of capital stock): Gross investment in tangible goods minus investment in abatement technolgies
Independent variables	
(E^{TCE}/K)	Total current expenditures on environmental protection (in % of capital stock)
(E^{REV}/K)	Revenue from total environmental taxation (in % of capital stock)
(Q/K)	Output (in % of capital stock)
(C/K)	Cashflow (value added minus labour costs; in % of capital stock).
Variables used in sensitivity analysis	
(E^{SUB}/K)	Public subsidies for financing environmental protection activities (in % of capital stock)
(E^{WW}/N)	Waste water generated (in million m^3 per enterprise)
(E^{GHG}/N)	Emission of greenhouse gases (CO2 equivalent; in million tons per enterprise)
Variables used for calculation	
K	Capital stock (in million euros), inferred from gross investments in tangible goods via perpetual inventory method
N	Number of enterprises registered in the business register
I^E	Total investment in environmental protection; sum of investment in pollution treatment and investment in pollution prevention (in million euros)
L	Labor costs (in million euros)
V	Value added at factor costs (in million euros)

Table A2: Descriptive Statistics

Variable	Obs.	Mean	Std.Dev.	Min.	Max.
Dependent variable: Gross investment to capital stock (in % of capital stock)					
Tangible goods	420	9.19	5.04	0.35	42.83
New buildings	368	2.19	2.21	0.0007	14.67
Machinery	371	6.46	4.59	0.27	40.91
Productive investment	389	8.96	5.12	0.32	42.65
Independent variables (in % of capital stock)					
Total current expenditures on environmental protection	420	0.73	0.78	0.00	7.09
Revenue from environmental taxation	420	74.31	126.46	1.96	598.64
Output	416	107.34	76.26	1.30	503.16
Cash flow	412	17.48	17.42	−8.51	202.49
Additional variables used in the sensitivity analysis					
Public subsidies to capital stock (in %)	210	3.61	15.54	−120.47	116.90
Waste water generated per enterprise (in thousand m^3)	221	832.04	2,501.52	0.00	17,549.43
Total greenhouse gas emissions per enterprise (in thousand tons)	398	202.61	317.68	0.84	2,427.06
Variables used for calculation					
Capital stock (in billion euros)	420	62.47	128.32	0.04	849.98
Number of enterprises (in tsd.)	416	37.51	96.40	0.01	56.85
Gross investment in tangible goods (in billion euros)	420	4.69	9.07	0.05	58.59
Gross investment in constructions (in billion euros)	368	0.71	1.26	0.0002	7.19
Gross investment in machinery (in billion euros)	371	3.99	8.14	0.003	51.21
Investment in abatement technology (in million euros)	389	180.36	355.51	0.00	2,207.34
Total current expenditures on environmental protection (in million euros)	420	603.71	1,570.56	0.00	10,702.30
Environmental tax revenue (in billion euros)	420	10.81	15.61	0.07	57.35
Value added (in billion euros)	413	27.52	65.61	0.02	42.95
Labour costs (in billion euros)	412	16.59	46.56	0.07	385.01
Public subsidies (in billion euros)	210	362.33	416.91	−248.32	1,718.99
Greenhouse gas emissions (in million tons CO_2 equivalent)	402	218.30	263.69	8.37	1,036.33
Waste water generated (in million m^3)	223	431.44	773.01	0.00	4,235.00

Table A3: Correlation matrix

	Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)	Investment in tangible goods	1.00	0.55	0.82	0.99	0.08	0.23	0.20	0.57	-0.17	-0.02	-0.11
(2)	Investment in new buildings	0.62	1.00	0.37	0.55	0.11	0.05	0.07	0.20	-0.28	0.16	0.05
(3)	Investment in machinery	0.81	0.12	1.00	0.82	0.12	0.25	0.11	0.40	-0.08	-0.08	-0.09
(4)	Productive investment	0.99	0.61	0.80	1.00	0.05	0.23	0.19	0.56	-0.17	-0.01	-0.11
(5)	Total current expenditures on environmental protection	0.00	0.02	0.04	-0.01	1.00	0.14	0.36	0.16	-0.01	0.26	0.17
(6)	Revenue from environmental taxation	0.30	-0.10	0.44	0.30	-0.08	1.00	0.29	0.30	0.06	0.00	-0.04
(7)	Output	0.17	-0.07	0.32	0.15	0.45	-0.29	1.00	0.58	-0.01	0.06	-0.07
(8)	Cash flow	0.35	-0.07	0.42	0.36	0.23	-0.08	0.47	1.00	0.01	0.06	-0.06
(9)	Public subsidies to capital stock	-0.26	-0.11	-0.23	-0.28	0.10	0.15	-0.17	-0.33	1.00	0.01	0.18
(10)	Waste water generated per enterprise	-0.08	-0.06	-0.04	-0.07	0.12	-0.07	0.04	0.01	-0.02	1.00	0.58
(11)	Total greenhouse gas emissions per enterprise	-0.15	-0.11	-0.12	-0.14	-0.04	0.14	-0.23	-0.14	0.03	0.75	1.00

Notes: Entries for demeaned variables $(x_i - \bar{x})$ above the diagonal. All variables except waste water generated and total greenhouse gas emissions are weighted by the country-industry specific capital stock.

Table A4: Alternative measures of environmental stringency (sensitivity)

	Type of investment			
Independent variable	I^T	I^C	I^M	I^P
$(E^{WW}/N)_{t-1}$	0.001	0.121*	−0.150***	0.019
	(0.027)	(0.069)	(0.036)	(0.032)
$(E^{WW}/N)^2_{t-1}$	−0.000	−0.012*	0.007***	−0.001
	(0.001)	(0.006)	(0.002)	(0.002)
$(E^{GHG}/N)_{t-1}$	−1.455***	−3.094***	−1.394***	−1.817***
	(0.269)	(1.106)	(0.441)	(0.388)
$(E^{GHG}/N)^2_{t-1}$	0.728***	3.315***	0.493*	0.966***
	(0.166)	(1.241)	(0.279)	(0.336)
$(Q/K)_{t-1}$	0.362***	0.555***	0.246*	0.466***
	(0.081)	(0.176)	(0.128)	(0.091)
$(C/K)_{t-1}$	0.671	−2.444**	2.007**	0.484
	(0.442)	(1.192)	(0.856)	(0.450)
Observations	264	204	219	212
Adj. R^2	0.760	0.834	0.754	0.713
F-tests				
Industry effects	20.8***	8.6***	19.7***	21.7***
Country effects	293.9***	155.6***	$1.8{\cdot}10^5$***	9.9***
Time effects	356.3***	250.7***	$7.6{\cdot}10^5$***	106.9***
Country×time effects	$3.3{\cdot}10^4$***	$1.1{\cdot}10^4$***	$9.3{\cdot}10^4$***	69.5***

Notes: Constant and fixed effects not reported. Robust standard errors in parenthesis. *, ** and *** indicate the 10%, 5% and 1% level of significance.

Table A5: Inclusion of subsidies (sensitivity)

	Type of investment			
Independent variable	I^T	I^C	I^M	I^P
$(E^{TCE}/K)_{t-1}$	21.696***	13.129	23.364**	22.308***
	(5.642)	(22.325)	(9.692)	(5.829)
$(E^{TCE}/K)^2_{t-1}$	−68.234***	−23.871	−77.464**	−68.737***
	(18.258)	(76.118)	(32.343)	(19.053)
$(E^{REV}/K)_{t-1}$	0.447***	1.336***	0.569***	0.445***
	(0.133)	(0.301)	(0.181)	(0.150)
$(E^{REV}/K)^2_{t-1}$	−0.051**	−0.175***	−0.052*	−0.049**
	(0.021)	(0.048)	(0.028)	(0.023)
$(E^{SUB}/K)_{t-1}$	−0.257**	−0.765**	−0.007	−0.252*
	(0.128)	(0.332)	(0.175)	(0.139)
$(E^{SUB}/K)^2_{t-1}$	0.015*	0.025	0.028	0.014
	(0.009)	(0.233)	(0.121)	(0.009)
$(Q/K)_{t-1}$	0.034	0.170	−0.134	0.035
	(0.087)	(0.244)	(0.113)	(0.108)
$(C/K)_{t-1}$	3.364***	−1.869	4.629***	3.278***
	(0.812)	(1.629)	(1.043)	(0.964)
Observations	199	172	169	188
Adj. R^2	0.627	0.695	0.653	0.631
F-tests				
Industry effects	10.9***	36.7***	6.5***	6.3***
Country effects	9.5***	74.7***	1,199.5***	319.4***
Time effects	369.7***	15.3***	9.1***	94.6***
Country×time effects	6.6***	8.1***	7.8***	38.3***

Notes: Constant and fixed effects not reported. Robust standard errors in parenthesis. *, ** and *** indicate the 10%, 5% and 1% level of significance.

Table A6: Weighting by labour costs (sensitivity)

	Type of investment			
Independent variable	I^T	I^C	I^M	I^P
$(E^{TCE}/L)_{t-1}$	1.819	3.725**	4.685***	5.518**
	(1.911)	(1.788)	(1.408)	(2.538)
$(E^{TCE}/L)^2_{t-1}$	−1.613	−5.151*	−5.238***	−4.448
	(2.276)	(2.671)	(1.609)	(2.903)
$(E^{REV}/L)_{t-1}$	0.135***	0.082***	0.113***	0.119***
	(0.027)	(0.031)	(0.025)	(0.031)
$(E^{REV}/L)^2_{t-1}$	−0.002***	−0.001**	−0.002***	−0.001*
	(0.001)	(0.001)	(0.001)	(0.001)
$(Q/K)_{t-1}$	0.063***	−0.011	0.058***	0.076**
	(0.019)	(0.022)	(0.021)	(0.034)
$(C/K)_{t-1}$	0.080	0.148	−0.030	−0.176
	(0.209)	(0.107)	(0.137)	(0.274)
Observations	293	348	319	280
Adj. R^2	0.753	0.643	0.634	0.655
F-tests				
Industry effects	26.7***	26.9***	8.7***	19.0***
Country effects	$7.0{\cdot}10^9$***	215.8***	271.6***	$1.7{\cdot}10^4$***
Time effects	120.9***	41.6***	6.2***	80.4***
Country×time effects	404.0***	3.9***	$2.6{\cdot}10^4$***	$4.6{\cdot}10^7$***

Notes: Constant and fixed effects not reported. Robust standard errors in parenthesis. *, ** and *** indicate the 10%, 5% and 1% level of significance.

Table A7: Dynamic model (sensitivity)

Independent variable	*Type of investment* I^T	I^C	I^M	I^P
Lagged investment ratio	0.804***	0.854***	0.487***	0.813***
	(0.078)	(0.056)	(0.117)	(0.075)
(Lagged investment ratio)^2	−4.929***	18.031	2.957	−6.174***
	(1.545)	(27.660)	(2.463)	(1.847)
$(E^{TCE}/K)_{t-1}/100$	0.292**	0.139	0.524**	0.349**
	(0.142)	(0.245)	(0.236)	(0.147)
$(E^{TCE}/K)^2_{t-1}/100$	−11.229**	−5.413	−15.108*	−13.799***
	(5.143)	(9.418)	(8.994)	(5.327)
$(E^{REV}/K)_{t-1}$	0.006	−0.009	0.028	0.011
	(0.062)	(0.128)	(0.086)	(0.065)
$(E^{REV}/K)^2_{t-1}$	0.008	0.005	0.020	0.006
	(0.015)	(0.029)	(0.020)	(0.016)
$(Q/K)_{t-1}$	−0.024	−0.041	0.216**	−0.054
	(0.053)	(0.068)	(0.097)	(0.061)
$(C/K)_{t-1}$	1.055***	0.078	0.258	1.271***
	(0.174)	(0.248)	(0.185)	(0.212)
Observations	330	273	284	316
Time effects (χ^2)	14.1	25.6***	5.9	18.6**
Hansen (χ^2)	47.1	39.0	42.7	41.5
	[1.000]	[1.000]	[1.000]	[1.000]
AR(1)	−4.0	−2.5	−2.5	−3.6
	[0.000]	[0.011]	[0.012]	[0.000]
AR(2)	−0.8	0.9	0.7	−1.1
	[0.426]	[0.350]	[0.497]	[0.266]

Notes: Constant and time effects not reported. Robust standard errors in parenthesis. P-values in brackets. *, ** and *** indicate the 10%, 5% and 1% level of significance.

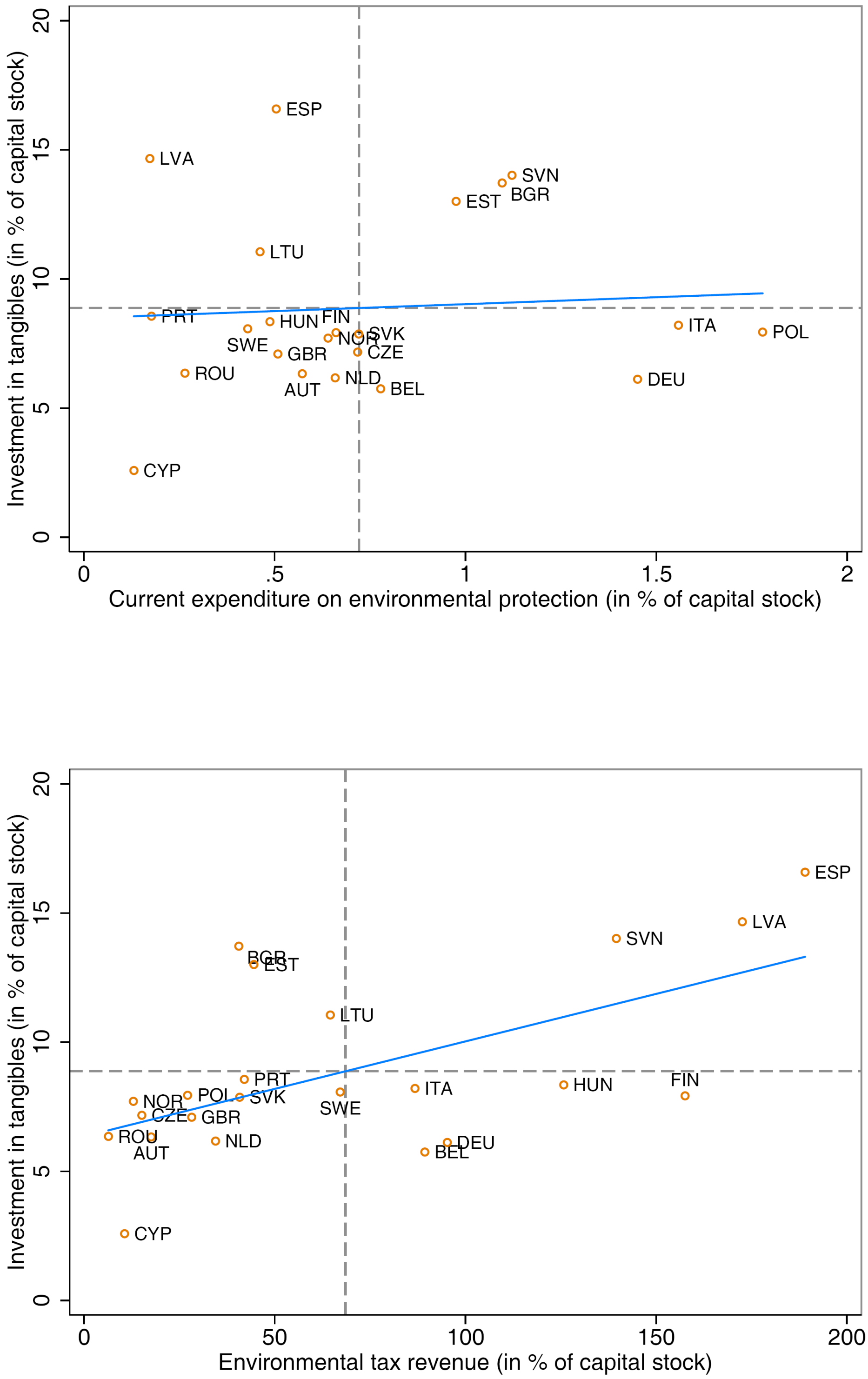


Figure A1: Investment in tangible goods and environmental stringency

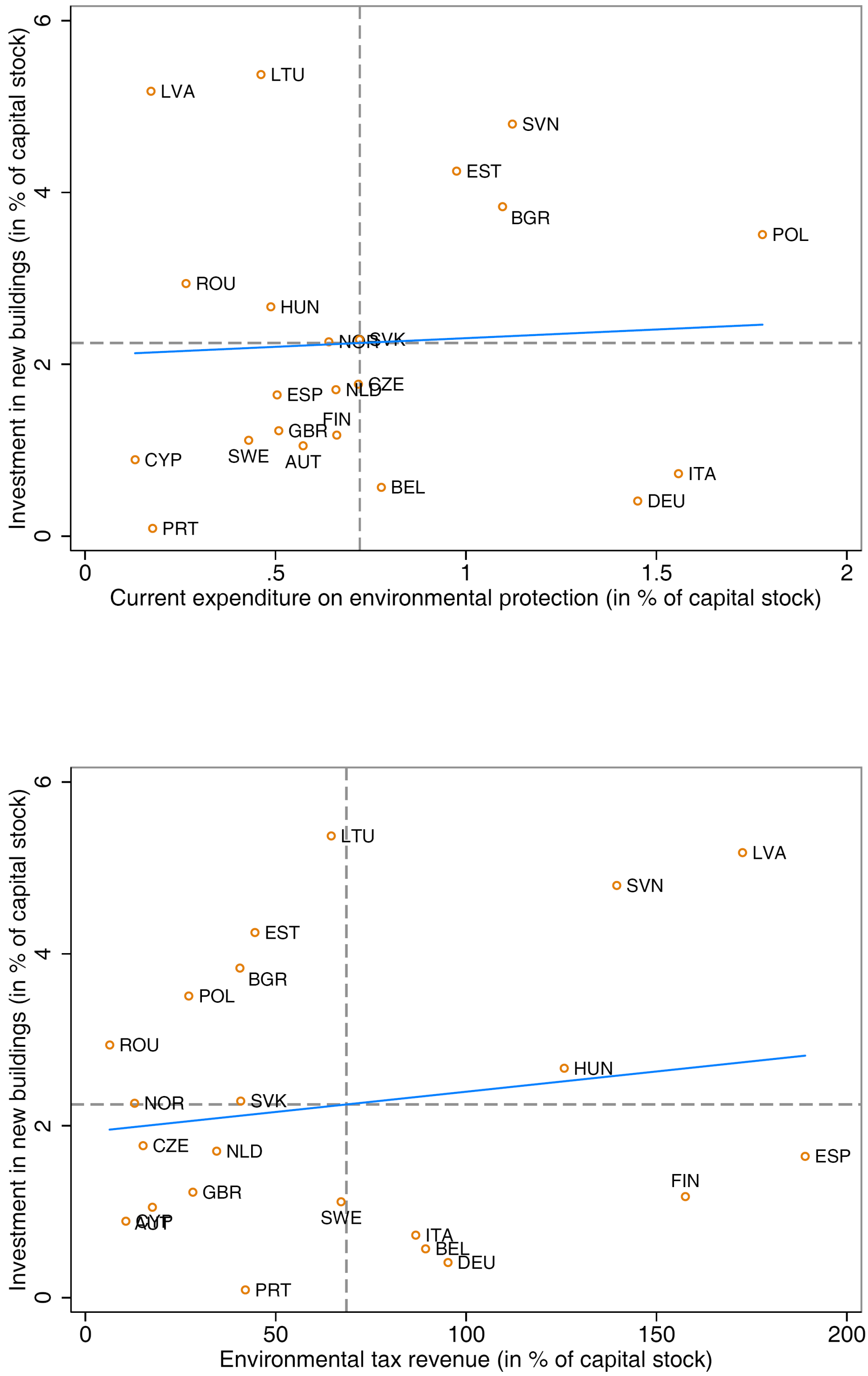
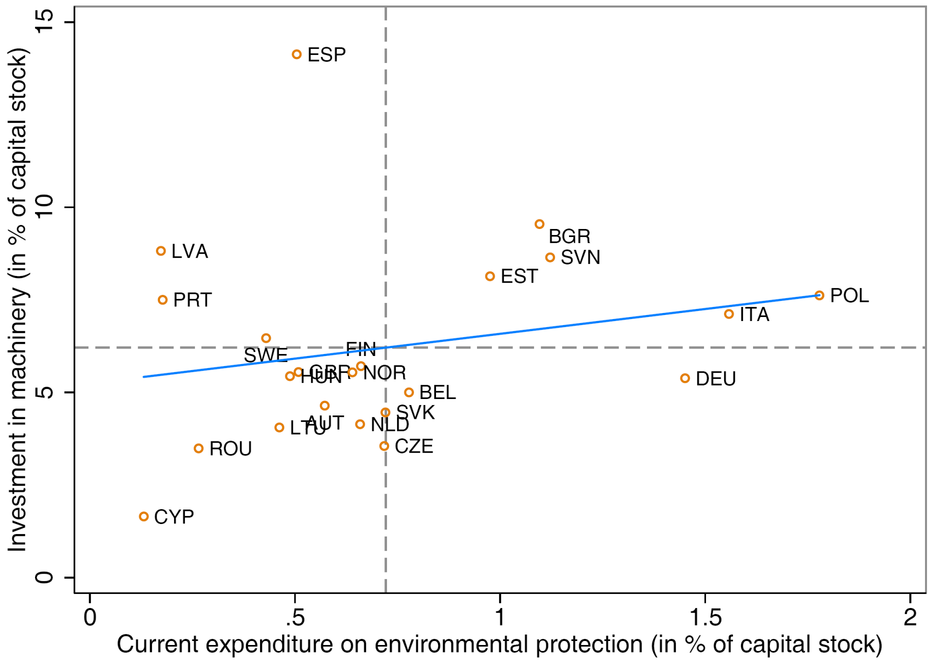


Figure A2: Investment in new buildings and environmental stringency



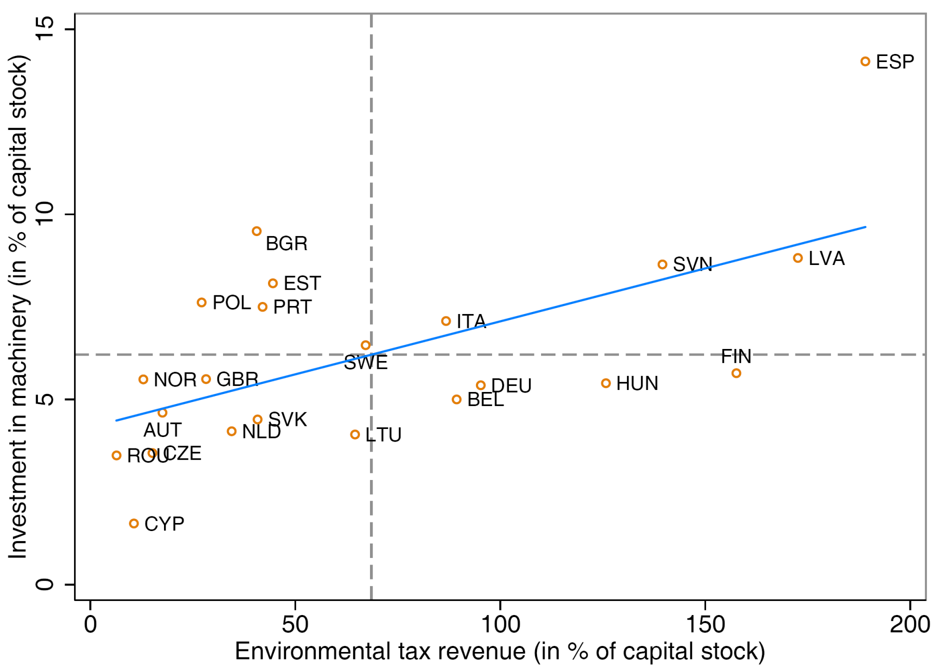


Figure A3: Investment in machinery and environmental stringency

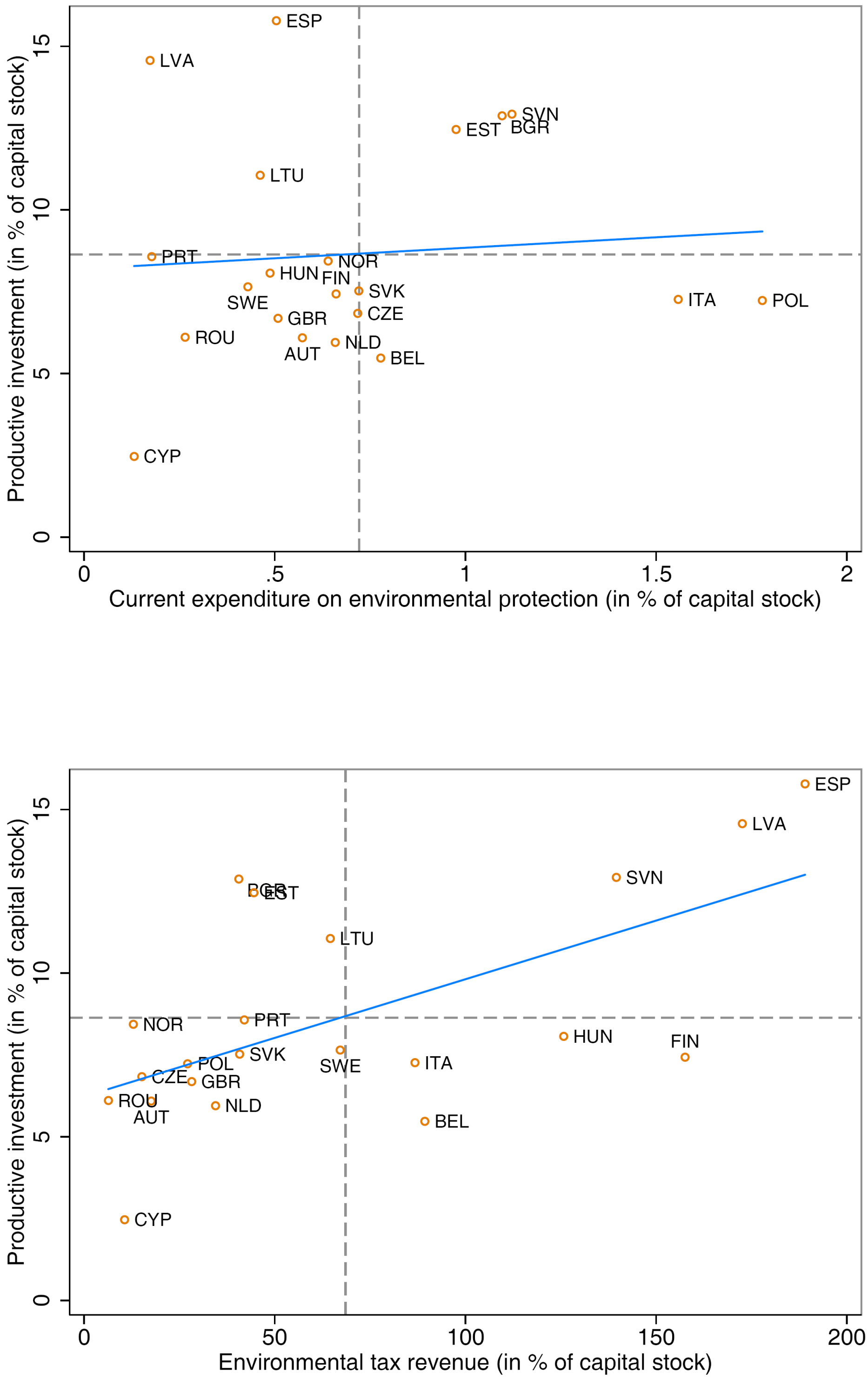


Figure A4: Productive investment and environmental stringency

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Andrea M. Leiter, Arno Parolini and Hannes Winner

Environmental Regulation and Investment: Evidence from European Industries

Abstract

This paper contributes to the empirical literature on the relationship between environmental regulation and firm behavior. In particular, we ask whether and how strongly investment decisions of firms respond to stringency in environmental regulation. Environmental stringency is measured as (i) an industry's total current expenditure on environmental protection, and (ii) a country's revenue from environmental taxes. Focusing on European industry level data between 1995 and 2005, we estimate the differential impact of environmental stringency on four types of investment: gross investment in tangible goods, in new buildings, in machinery, and in `productive' investment (investment in tangible goods minus investment in abatement technologies). Both environmental variables enter positively, and their quadratic terms exhibit significantly negative parameter estimates. This, in turn, indicates a positive but diminishing impact of environmental regulation on investment.

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