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Environmental regulation and sustainable competitiveness: Evaluating the role of firm-level green investments in the context of the Porter hypothesis*

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Abstract

We investigate the impact of environmental regulation on firm performance and investment behavior. Exploiting the case of a German water withdrawal regulation that is managed on the state level, we analyze firms' reactions to an increase in the water tax using a regression-adjusted difference-in-differences approach. We analyze the individual firm's response to a change in environmental regulation, distinguishing between add-on and integrated environmental investments. This allows us to include intra-firm innovations into our analysis, which are likely to be of importance for increasing resource-efficiency. Our results show that the regulation in question shows no sign of affecting firms' overall competitiveness. The results imply that the predicted negative impact of the regulation on firms' economic performance that was brought up before the introduction of the tax, does not seem to weigh heavily in this case. Nevertheless, when placed into a sustainable competitiveness context, the regulation considered does not qualify as an appropriate policy tool for fostering green growth.

Keywords: Environmental regulation, DID, green growth, green investment, Porter hypothesis, sustainable competitiveness, water withdrawal regulation

JEL: L60, O31, O32, Q58, Q55

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1 Introduction

We investigate how environmental regulation impacts firms' competitiveness and how their investment behavior is affected. The effect on investment not only plays a major role in forecasting the economic impact of regulations, but also has potential implications for firms' sustainability and green growth policies. On a more specific level, we provide a contribution to the current debate on increases in water withdrawal fees in Germany.

While the standard neoclassical view suggests that environmental regulation is detrimental to firms' competitiveness, the so-called Porter hypothesis challenges this assumption by stating that "strict environmental regulations do not inevitably hinder competitive advantage against rivals; indeed, they often enhance it" (Porter & van der Linde, 1995). This hypothesis has spurred an intensive debate since its formulation some 20 years ago (for an overview, see e.g. Ambec, Cohen, Elgie & Lanoie, 2013). Empirical evidence shows that the estimated impact is highly case-specific: Results vary e.g. depending on the type of regulation, the specific circumstances in which the regulation is introduced and the estimation approach. Additionally, there is relatively scarce empirical evidence using European data (Rubashkina, Galeotti & Verdolini, 2014). This paper is therefore also inspired by the call for more ex-post policy evaluations at the micro level (Broockmann, Buch & Schnitzer, 2014; OECD, 2015) in order to better understand the impact that (environmental) policies have on firms.

We want to add to the empirical literature by providing evidence on the impact of environmental regulation on firm performance and innovative output by investigating the role of green and other investments in this context. Using a new and unique firm-level dataset we can further differentiate between add-on and integrated green investments. This allows us to uncover specific investment channels of efficiency improvement or deterioration. In our empirical analysis, we proceed in two steps, each addressing a different part of the Porter chain. Firstly, we analyze the strong Porter hypothesis, i.e. the overall impact of an environmental regulation on general firm competitiveness, for a specific change in regulation. Secondly, we address the weak Porter hypothesis, i.e. the effect of environmental regulation on firms' (green) innovation behavior, by investigating the hitherto neglected measure of integrated environmental protection investment (EPI). We consider this second step to be our main contribution to the Porter debate, as the integrated EPI measure has a major advantage over commonly used measures of innovative output, such as technology-related patenting: It captures a broad range of efforts that improve the resource efficiency of a firm's production process from the input side. By definition, these are efforts that save environmental resources. We are thus able to measure the part of a firm's regulation-induced reaction that serves the two goals of environmental resource efficiency and economic competitiveness at the same time. This is precisely what is at the heart of the Porter idea.

To this end, we investigate the impact of environmental regulation on firm performance and investment behavior for the case of water fees in the German manufacturing sector. In particular we look at the effect of the German water withdrawal regulation, which is a fee paid by German firms to use water in their production. Our identification strategy draws on the fact that this particular legislation is handled on the state level (*Bundesland*), which has led to considerable variation between the different states with respect to its level and implementation: Currently, three out of sixteen states do not charge any fee, while the remaining thirteen charge prices up to 31 cent/m^3 (IHK, 2013). In 2008 there was a major change in legislation in Saarland, when a water withdrawal fee was implemented. We investigate the effect of this change in legislation on manufacturing firms, specifically on firms in water-intensive sectors. We conduct a difference-in-differences estimation, thereby exploiting the fact that the change in legislation only affects firms in Saarland.

The rest of the paper is structured as follows: Section 2 presents the theoretical background and previous empirical work, Section 3 offers details on the particular regulation observed, and Section 4 introduces the econometric strategy. The dataset and variables are described in Section 5, and Section 6 presents the empirical results. Section 7 concludes.

2 Theoretical background, hypotheses, and empirical evidence

2.1 Theory and hypotheses

The Porter hypothesis links environmental regulation, innovation, and competitiveness. Porter & van der Linde (1995) famously claim that stricter environmental regulation can actually enhance (firms') competitiveness. They argue that properly crafted regulations can trigger innovations, which may in turn lead to more efficient production. If innovation offsets are higher than the costs caused by the regulation, firms may actually benefit from tighter regulation. Many analyses subsequently investigated the possibility that the economic incentives from more stringent environmental regulation can induce innovation, which in turn may increase a firm's efficiency by so much that it more than offsets the private costs associated with the regulation.[1] Looking for potential win-win

[1] Ambec, Cohen, Elgie & Lanoie (2013) report that Porter & van der Linde (1995) is one of the most highly cited articles in the field of "business and the environment".

situations, i.e. cases and conditions in which tighter environmental regulation actually increases competitiveness, is appealing from both the environmental as well as the business perspective.

The Porter hypothesis itself has been divided by into two sub-hypotheses, the so-called *strong* and *weak* Porter hypothesis (Jaffe & Palmer, 1997). The strong hypothesis looks at the overall impact of environmental regulation on competitiveness, while the weak hypothesis focuses on a regulation's (sub-)impact on innovation. From a theoretical perspective, alternative theories for explaining the weak hypothesis have been proposed and discussed, many of them deviating from the assumption of optimal decision-making of firms' managements. Porter & van der Linde (1995) themselves suggest five channels that may create innovation offsets that may be beneficial to the firm, namely signaling, awareness, reduction of uncertainty, increased innovation pressure, and leveling the playing field.

Inspired by the five channels, a large theoretical literature looks at mechanisms that may explain why firms are in a non-optimal situation in the first place and which implications can be drawn for policies aiming at opening existing gridlocked situations. Roy Chowdhury (2010) lists first mover advantages, changing the composition of capital, the relative efficiency effect and external economies as strategic effects that have been identified by the theoretical literature as formal foundation for the Porter hypothesis.

Regarding the innovation dimension of the Porter hypothesis, Xepapadeas & Zeeuw (1999) model firms' investment decisions in response to changes in the production costs. They show that when firms can choose to invest either in cleaner and more expensive new machines or cheaper but 'dirtier' ones, environmental regulation may result in a restructuring of the capital stock, which can then result in higher average productivity and thus improved competitiveness. Even if the regulation may not increase competitiveness in absolute terms, this regulation-induced modernization of the capital stock can still soften the regulation's impact on profits.

Overall, rather non-general circumstances and mechanisms have to exist for the Porter hypothesis to hold (Brännlund, 2009). Thus, environmental regulation cannot be deemed beneficial per se, but specific circumstances of the regulation in question as well as characteristics of the surrounding circumstances (such as e.g., market structure and firm characteristics) have to be considered (Ambec et al., 2013), which underlines the importance of analyzing specific case studies of particular regulations.

In our empirical analysis, we proceed in two steps, each addressing a different part of the Porter chain. Firstly, we analyze the strong Porter hypothesis, i.e. the overall impact of the regulation on general competitiveness, measured as productivity and export performance (**hypothesis 1**).

Secondly, we address the weak Porter hypothesis by investigating the effect of environmental regulation on firms' innovation behavior, focusing on the fourth channel *innovation pressure* by looking at resource-efficiency enhancing investment (**hypothesis 2**).

2.2 Empirical evidence

Two recent literature overviews conclude that the empirical evidence from a large number of empirical studies on the strong as well as the weak Port hypothesis is inconclusive (Ambec et al., 2013; Brännlund, 2009). Results are very much context-dependent and vary e.g. by regulation, industry, estimation approach, timespan considered (as innovations take time to materialize) (Ambec et al., 2013). For our analysis we therefore focus on empirical studies that are close to our setting in these characteristics, i.e. approaches that analyze specific changes in environmental regulation and their effect on firm-level competitiveness and/or firms' innovation activity.[2]

Looking at the effect of a particular environmental regulation on firm performance, an empirical study that is close to ours analyzes the effect of a tax on energy on competitiveness (Gonseth, Cadot, Mathys & Thalmann, 2015). The type of regulation is thus similar to ours, but used for a different resource. The authors investigate the effect of the tax on total factor productivity on the industry level and find an important role of human capital for an industry's ability to adapt to higher energy costs.

On the other hand, Brännlund & Lundgren (2010) find evidence for a 'reversed Porter effect', i.e. a negative effect of the tax on firm profits, especially for energy-intensive industries, when they look at the effect of a CO2 tax on profitability. They use firm-level data and a model that includes firm-level policy-induced technological progress. Similarly, when investigating the impact of a charge on NOx emissions on the abatement cost functions of Swedish combustion plants, Höglund Isaksson (2005) finds that large emission reductions followed the introduction of the charge. Those reductions were mostly the results of learning and technological developments and are at the same time found to have caused zero or very low costs. Nevertheless, the author finds little evidence for win-win situations in the Porter sense. There is also evidence that firms' responses to environmental regulation varies by their size. Becker, Pasurka & Shadbegian (2013) find that the cost intensity for pollution abatement increases with establishment size. A paper that investigates a different type of environmental regulation in the water sector is Rassier & Earnhart (2015). Constructing a measure of environmental stringency, the authors estimate the effect of

[2] We exclude the evaluation of the Porter hypothesis on the country or industry level from our considerations, e.g. the literature on environmental regulation and international trade and the 'pollution haven hypothesis' (Copeland & Taylor, 2004); for a recent overview see Rubashkina, Galeotti & Verdolini, 2014.

the stringency of firm-specific effluent limits for two regulated pollutants on the profitability of chemical manufacturing firms in the US.

Turning to the weak Porter hypothesis, a number of articles have addressed the firms' reactions. Two of them are closely related to our analysis, as they specifically focus on firms' investment decisions and environmental regulation. Firstly, Gray & Shadbegian (1998) investigate the weak Porter hypothesis and analyze whether environmental regulation affects investment decisions for paper mills. They find that new mills in states with stricter environmental regulations indeed opt for cleaner production technologies. Secondly, Huiban, Mastromarco & Musolesi (2015) estimate the effect of pollution abatement investment on technology for the case of the French food processing industry. The main methodological difference from our approach is that they use a stochastic frontier approach to analyze how the investment affects technical efficiency. Topic-wise, the auhors focus on the interaction between environmental investment and firm performance (productivity) looking at a different resource as well as on a different industry and country. What is more important, the authors do not analyze how a particular policy intervention affects the investment and thus additionally differ in the objective of their research. Since we investigate the impact of a change in a specific regulation using a difference-in-differences approach, we can abstract from using an approach where the production function has to be explicitly modeled. A third paper by Rexhäuser & Rammer (2014) addresses the effect of different types of innovations on firm performance (profits) by using data from an innovation survey for German firms that includes detailed information on firm characteristics. The authors find that only those innovations that increase resource efficiency (material or energy consumption per unit of output) have positive returns to profitability. These findings support our argument that it is not the innovation per se that matters, but rather the process that increases resource efficiency. On that aspect, our data on integrated EPI can hopefully provide some new insights to clarify this aspect.

Against this background, our estimation approach differs mainly in two respects: Firstly, aiming at establishing a causal relationship, we analyze the impact of one particular change in environmental regulation that affects only a subsample of the firms considered. Secondly, the channel of innovation pressure is usually evaluated by focusing on the innovation input, such as R&D expenses or its output, such as patents or other innovation outcomes from firm-specific innovation survey data. A major caveat of these studies is that they fall short when it comes to efficiency-enhancing investment that is not labeled as innovation in the standard inter-firm sense (e.g., patents) but may be a significant innovation in the intra-firm sense (for an overview of the various concepts of innovation, see Fagerberg, Mowery & Nelson, 2005). Although not a direct measure of innovation itself, EPI, by definition do include these. We thus go beyond an inter-firm definition of innovation and use integrated EPI instead of R&D or patents to capture the fact that improvements of resource-efficiency may include a broader set of measures. A second caveat that is solved by using EPI is that not necessarily all R&D expenses or innovations are compatible with the objective of environmental friendliness, i.e. improvements of environmental resource-efficiency, and that R&D and innovativeness not necessarily always comply with sustainability goals.

3 Water withdrawal regulation in Germany

The implementation of water withdrawal fees ("watercent") in a number of German federal states has been subject to ongoing discussions, which have been fueled by political ambitions to raise water taxes at the federal level (Bundesverband der Energie- und Wasserwirtschaft, 31.10.2007). Water withdrawal fee regulations currently differ considerably among German federal states in terms of amount and exemptions and Bavaria, Hesse, and Thuringia do not charge fees at all (for an overview, see Industrie- und Handelskammer (IHK) für die Pfalz, 2013; Gawel, 2015). This regulatory heterogeneity among German regions and the fact that a significant subpopulation of firms is not subject to water withdrawal regulation at all allows us to use a regulatory change as a suitable treatment in a quasi-experimental empirical setting.

Water is a public good while *in situ*, but can be considered a private good from a firm's perspective (Hanemann, 2006). This suggests that there is some merit to the argument that water usage should be regulated in some way from a society's (welfare) perspective in order to avoid overuse triggered by the classic tragedy of the commons. At the same time, firm's treat higher water prices that may result from tighter regulation, as an increase of the price of an input in their production process. This combination makes an increase of the water price for a particularly interesting case study for the effect of an environmental regulation on firms' competitiveness.

Trade associations generally assume a significant negative impact of water withdrawal regulations on the individual firm's competitiveness when compared to less regulated firms within Germany and competitors abroad (Industrie- und Handelskammer (IHK) für die Pfalz, 2013, p.6). However, to the best of our knowledge, an empirical impact evaluation of the introduction of such fees has not been conducted for the German case yet and our study can also be regarded as a contribution to the water fee discussion itself.[3]

[3] A second strand of literature that is connected to our research question deals with the effects of water taxes. A part of the discussion focuses on welfare effects, such as e.g. Kilimani, van Heerden & Bohlmann (2015). This includes the idea of a potential "double dividend", a term that was first used in Pearce (1991), but expresses an idea that goes back to Tullock (1967), cited in Fullerton & Metcalf (1997): In addition to the main benefit, i.e. to reduce environmental pressure, the revenues raised by the tax can be used to reduce other distorting taxes and through this increase economic growth or welfare. In our case study, these arguments can be found in the discussion on the use of revenues raised by the water cent (cf. above, Landtag des Saarlandes, Ausschuss für Umwelt, 11. Januar 2008).

In 2008 the federal state of Saarland implemented a regulation for charging fees on groundwater withdrawal (Landtag des Saarlandes, Ausschuss für Umwelt, 11. Januar 2008, act no. 1643) that entered into force in May 2008.[4] In particular, this meant an increase from 0 to up to 7 Eurocent per m^3. Although this amount appears to be rather moderate, there were serious concerns about negative effects on the economic competitiveness, especially for water-intensive industries, that were inter alia formulated in the official hearing (Landtag des Saarlandes, Ausschuss für Umwelt, 11. Januar 2008, p.12).

With the exception of the federal states of Berlin and Brandenburg, all states with a water withdrawal fee allow for certain exceptions. In the case of Saarland, fees are not charged if the withdrawal is to supply fishponds, or for purposes of healthcare, mental recreation, and sports, as well as for the removal of groundwater pollution or soil rehabilitation. Also, a free volume of $35m^3$ per citizen is guaranteed for public water supply and for small users the charge is not applied if the annual sum of fees stays below a threshold of 200 EUR. In our context, a more relevant exemption is the deduction of 1 Eurocent for firms that comply with either the $ISO14001$ or the (European) $EMAS$ criteria. However, since the reduction is relatively small and these firms are not exempted from paying the fee, we do not consider this potential bias to be crucial for our analysis.

4 Estimation strategy

We aim to test for a causal effect of a change in environmental regulation on firm performance. We do so in two steps: First, we test the strong Porter hypothesis, i.e. the impact of the environmental regulation on overall firm competitiveness. Second, we investigate the particular channel of firm investment with a focus on integrated green investment. To overcome the problem of the unobservability of the counterfactual situation we use the introduction of fees on industrial water withdrawal in a federal state of Germany (Saarland) in 2008 as a natural experiment.[5] The parameter of interest is thus the average treatment effect on the treated (ATT), which can be formulated as follows:

$$ATT \quad = \quad E[ATT|D=1] \quad = \quad E[Y(1)|D=1] - E[Y(0)|D=1]$$

To stay in this line of thought, adding the effect of an environmental tax on firm performance to the discussion means in fact looking for a triple dividend: In addition to revenues and better environmental performance, better firm performance is envisaged (note that we are not investigating environmental performance in our approach).

[4] Technically, the manufacturing firms that do not extract water themselves are not charged directly, but indirectly by the water providing firms, which pay the tax and then subsequently charge an increased price to their customers.

[5] For a general discussion of this empirical strategy see for example Meyer (1995) and Imbens & Wooldridge (2009).

Where D is a binary variable indicating if firm i is regulated ($D = 1$) or not ($D = 0$) and $E[Y(0)|D = 1]$ the expected (potential) output for the regulated firms had they not been regulated. The potential output is constructed from firms that are similar, but located in federal states without any water withdrawal fees (Bavaria, Thuringia, and Hesse). There is no causal link between firm characteristics that may determine firm performance and a firm's probability of falling under the scope of the regulation. Nevertheless, there may be structural differences between firms in the treatment group and those in the control group. Such differences in X must be accounted for to satisfy the conditional independence assumption, which states that the assignment D_i must be conditionally random, given X_i ($D_i \perp\!\!\!\perp (Y_i(0), Y_i(1))|X_i$). This is done by using a nearest neighbor propensity score matching procedure (without replacement) in which every firm from the treatment group is assigned to k closest firms from the control group in terms of their individual treatment probability, i.e. their propensity score (Rosenbaum & Rubin, 1983).

The propensity score of each firm is estimated with a probit regression of the assignment indicator on performance levels in the pre-treatment year 2007 (productivity and export intensity) and general firm characteristics in 2007 (size, age, per capita wages, membership in a domestic enterprise group, controlled by a foreign multinational). Furthermore, to satisfy the condition of common trends, we include trend variables that measure the change of firm size and productivity in the pre-treatment period from 2005 to 2007.[6]

We estimate the causal impact of the water regulation in a regression-adjusted difference-in-differences setting with a firm fixed effects estimator. The estimation equation can be written as follows:

$$y_{i,t} \quad = \quad \alpha D_i + \sum_{j=1}^{3} (\delta_j T_{t,j} + \gamma_j D_i T_{t,j}) + \beta' X_{i,t} + \eta_i + \epsilon_{i,t}$$

Where $y_{i,t}$ represents the performance of firm i in period t. T is a time dummy which is zero in the baseline period and one in the post-treatment follow-up years. In order to account for a potential lag structure of a regulation induced effect, j is introduced, in the sense that if $j = 1$, the post-treatment period (T) starts with the year in which the treatment happened, if $j = 2$ it starts with one year lag, and so on. D is a dummy variable indicating whether a firm received the treatment (1) or not (0). $X_{i,t}$ are firm-level control variables that capture potential matching inaccuracies and confoundedness over time. η denotes a time-constant firm fixed effect to consider unobserved heterogeneity and ϵ is the ideosyncratic error term. We first estimate the equation with

[6] The matching is restricted to firms from the same 2-digit industry to account for structural differences between industries. The treatment group does not contain propensity scores that are out of the propensity score range of the control group (common support). Results of the assignment model estimates are reported in the Appendix Table A.3.

a standard linear OLS estimator without considering the firm-specific fixed effect η_i. Thereafter we use a within estimator to exploit the panel structure of our data by considering η_i and to evaluate the importance of unobserved heterogeneity.

The main coefficients of interest are the γ coefficients of the interaction terms D_iT_t as they provide the difference-in-differences (DID) estimate and thereby the regulation-induced average change in firm performance. In a formal way, the estimated parameter $\hat{\gamma}$ can be defined as follows:

$$\hat{\gamma}_{did} \quad = \quad \Delta\bar{y}_0^1 - \Delta\bar{y}_0^0 \quad = \quad \bar{y}_1^1 - \bar{y}_0^1 - (\bar{y}_1^0 - \bar{y}_0^0).$$

Where the index gives the value of the treatment dummy D and the subscript the value of the time dummy T.

5 Data and variables

We use panel data from official German business statistics that cover all German manufacturing firms with twenty or more employees for the years 2005–2010. This data is of particularly high quality because of its scope and because firms are legally obliged to respond to the surveys. Our specific data set combines data from annual and monthly reports of establishments from the manufacturing, mining and quarrying sectors (Konold, 2007), the general investment survey (Statistisches Bundesamt, 2013), and the enterprise group database (Weche Gelübcke, 2011). A further source is the survey of environmental protection investment, which is also conducted by the German Federal Statistical Office and the statistical offices of the German federal states. This survey covers all firms which reported environmental protection investment (EPI) in the general investment survey and offers detailed information on the type and area of green investment (Statistisches Bundesamt, 2011). For the environmental protection survey and the enterprise group database information is available for the years 2007–2010. All data sets were merged at the enterprise level and restricted to firms in manufacturing industries in line with the NACE classification.

For the test of our first hypothesis, the strong Porter hypothesis, we construct two alternative commonly used measures for firm competitiveness: The first is productivity, which is measured as labor productivity, i.e. by annual total turnover per employee (in EUR). The second measure is export intensity, which is the share of a firm's turnover that is generated abroad (in % of its total turnover) and reflects the firm's competitiveness on international markets.

For the evaluation of our second hypothesis, a resource-efficiency enhancing innovation-supporting

Table 1: Description of the dependent variables

H1: "Strong" Porter hypothesis of positive impact on economic performance	
Productivity	Measured as labor productivity: annual total turnover per employee (in EUR)
Export intensity	Share of total turnover generated abroad (in %)
H2: "Weak" Porter hypothesis of increasing resource-efficiency	
Integrated EPI	Annual investments that make the process of production more resource-efficient in terms of a lower level of consumption and pollution respectively and do not necessarily have to be technological elements (in EUR per employee); Excludes climate protection
Integrated EPI intensity	Share of integrated EPI of overall EPI (in %)

impact of environmental regulation, we construct a set of EPI variables that capture the firms' reaction to the introduction of the water regulation. EPI includes investment that aims exclusively or predominantly at protecting the environment from a harmful impact of production.[7] This includes *production-related measures* such as the purchase of fixed assets to reduce pollution during the production process, as well as *product-related measures* for the production of goods whose application or consumption reduces pollution. Within the category of production-related EPI, add-on (or end-of-pipe) measures can be differentiated from integrated measures. Add-on measures are normally the purchase of equipment which is physically separate from the other production facilities and can therefore be identified relatively easily. These technologies are, for example, facilities for waste incineration or exhaust air filtration, sewage treatment plants, and noise barriers (Statistisches Bundesamt, 2011). Integrated measures are more difficult to identify since they do not necessarily have to be technological elements. Integrated measures make the process of production generally more resource-efficient. They can therefore be technological elements (heat exchanger, absorbing filter, recirculation of cooling water), or it may be impossible to distinguish a specific component (moving to the use of environmentally friendly raw and auxiliary materials, changes in the forming process, changes in the structure of the combustion chambers). In the latter case, firms are only obliged to report the environmentally relevant part of the costs, i.e., the difference between the actual investment and a comparable investment without this environmentally relevant factor (Statistisches Bundesamt, 2011). The main variables of interest discussed here are summarized by hypothesis in Table 1.

As discussed, a major caveat of using R&D expenses or patents for an evaluation of innovation

[7] Information about EPI is available for seven areas of environmental protection: waste management, water protection, noise abatement, prevention of air pollution, nature protection and landscape preservation, soil rehabilitation, and climate protection. The area of climate protection is exempted from a differentiation into add-on and integrated EPI.

pressure through regulation is the exemption of efficiency-enhancing investment that is not an innovation from an economy-wide perspective but may be a significant innovation from the firms' perspective. For example, a move to the use of environmentally friendly raw and auxiliary materials would not be detectable in the former categories, but is important in the latter.

A second caveat is that not necessarily all R&D expenses or innovations are compatible with the objective of environmental friendliness, i.e. improvements of environmental resource-efficiency. The major advantage of using integrated green investment over commonly used innovative output measures is that a broad range of efforts is captured that have an enhancing impact on the resource efficiency of a firm's production process and simultaneously save environmental resources by definition.[8] With these variables we go beyond an inter-firm definition of innovation and are able to account for intra-firm innovations, which play a major role for regulated firms: In a survey conducted by the German chamber of commerce among 1,150 firms in 2008, 69% of the firms reported that investing in efficiency-enhancing measures is their major response to environmental regulation (Deutscher Industrie- und Handelskammertag, 2008) and it is very likely that only a minor share of this investment can be labelled as R&D.

As an additional reference for green investment variables, we also calculate a firm's general investment volume, measured as gross investment in tangible assets (in EUR), excluding EPI. Our additional controls are common variables to capture general differences in firm characteristics used in the literature: firm size, firm age, per capita wages, and two dummy variables: one indicating whether a firm is an enterprise group member and the other whether a firm is controlled by a foreign multinational.[9] All variables in EUR are calculated in relation to the firm size as per capita values.[10] The final sample is a balanced panel of firms that reported in all years from 2007 to 2010. Therefore the sample does not consider firms that were established or have exited the market during this period. The sample covers 339 firms located in the federal state Saarland, where the water withdrawal fee was introduced, and 7,427 firms in the sample of the control group, which are located in the federal states without water withdrawal fees, namely Bavaria, Thuringia, and Hesse. Descriptive statistics for the treatment and the unmatched control group are reported and discussed in the following section.

We carry out our analysis for all manufacturing firms in the regulated state.[11] Additionally, we

[8] The usual problem that efforts of innovation input (R&D spending) not necessarily translate into innovation output (patents) does not apply in our case as we look at a type of investment that has a direct impact on a firms resource efficiency by definition.

[9] A detailed definition of all variables can be found in Table A.1.

[10] An alternative would be to relate values to sales, but the number of employed persons is preferred here, because employment is known to have been much more stable in Germany during the period considered.

[11] The distribution of firms among the particular 2-digit industries is shown in Table A.2 in the Appendix.

evaluate the impact on firms that operate in water-intensive industries separately as we expect a potential effect to be more likely and/or more pronounced in industries where firms depend significantly more on water. Since firm-level information on water intensity is not available, we calculated the water intensity on industry-level, as the sum of own water withdrawal and external water supply over value added, from information of the German Statistical Office for the year 2010 (Statistisches Bundesamt, 2011).[12] We define industries as water intensive if their water intensity lies above the average of the entire manufacturing sector (37.61 m^3 per billion Euro).

6 Results

6.1 Descriptive results

Before we begin the interpretation of our results, it is important to check whether our matching procedure was successful in eliminating structural differences between the treatment and control groups. Table 2 reports descriptive statistics of all variables for the baseline period (2007). All mean values of the unmatched and matched samples have been tested for significant differences against the mean values of the treatments groups. For the full sample integrated EPI was significantly larger in the unmatched control group, firms were smaller and paid lower average wages. All these differences disappear in comparison with the matched sample, suggesting a good matching quality. The same applies to the subsample of water intensive firms, with the only exception of a remaining size difference, which is significant at the 10%-level.

Figure 1 illustrates the mean values of firm performance from one year prior to the regulation enforcement (2007) until the second year after the implementation (2010).[13] All groups, the regulated and the unregulated firms, as well as their water intensive subsamples, show a slight productivity increase from 2007 to 2008, followed by a sharp productivity drop that is most likely due to the global economic crisis. In contrast, the export intensity (in %) has only decreased marginally in all groups after 2008 and appears to be fairly steady across the observation period. This is surprising as Germany suffered an overall foreign trade decline in 2009, mainly driven by intensive margin adjustments (Wagner, 2012). All in all, from this descriptive perspective on mean

[12] Unfortunately this information is only available for the German WZ2008 industry classification and information had to be transferred into the older classification for earlier years according to a conversion key on a 4-digit-level.

[13] The water withdrawal fee in our treatment group entered into force in May 2008. Thus, since we have yearly data, 2008 is the treatment year which is the first to be affected by the new regulation. Generally, new regulations may be anticipated by concerned actors even before they are passed. In our case, we also consider a firms' response prior to the actual regulation enforcement, e.g. through provisions or price increase, possible. However, we do not consider it likely that this has happened already in 2007, but rather that, if firms have responded in advance, they may have done so within the first five months of the year 2008.

performance, there appears to be no evidence for a change in firm competitiveness that may have been caused by the regulation.

Figure 2 offers more diverging developments among the different firm groups in terms of green investment and other business investment. Firms that were regulated show an interesting average investment pattern: on the one hand they lowered their investment in add-on pollution abatement measures after the regulation entered into force, and on the other hand, they increased their investment in integrated measures, consequently improving their integrated EPI intensity towards a more resource-efficient production. These developments are exactly opposing those in the control group that shows an increase in add-on EPI and a decrease in integrated EPI. This may be seen as first descriptive evidence for a regulation-induced incentive for restructuring the production process towards more resource-efficiency.

A similar picture emerges for the water intensive subsample, although the increase in integrated investment happens with one year lag. At the same time, regulated firms report higher (other) general business investment in the baseline and treatment year that slump in the first follow-up year. Although appearing with one year delay, a causal link between regulation and investment restraint may be plausible considering that investment plans may well be made a year in advance and include decisions that are least partly irreversible.

Summing up, what appears from the descriptives in Figures 1 and 2, there is no evidence for a regulation-induced change of overall firm competitiveness, but a shift towards more integrated (and thus more resource-efficient) investment seems to be prevalent in the regulated group. Although we compared regulated firms to adequate control groups in our analysis so far, for any potential causal inference to hold we need to include other time-varying factors that may have influenced the outcome variables ex post regulation enforcement and test the significance of the differences in a regression analysis.

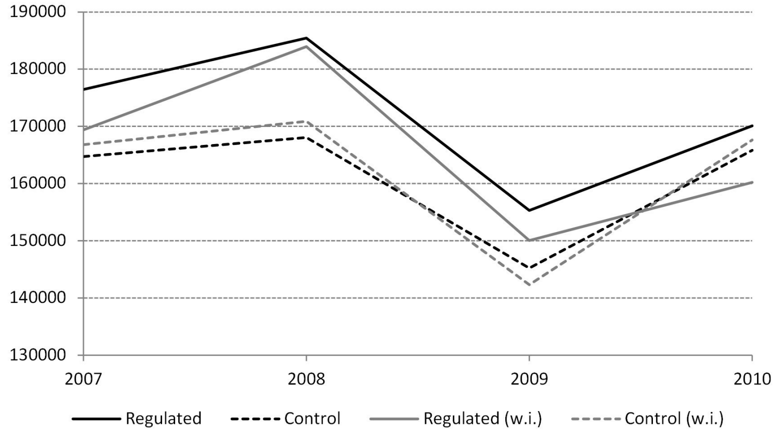
Table 2: Description in baseline period (2007)

	Full sample			Water intensive industries		
	Treatment group	Control group		Treatment group	Control group	
		unmatched	matched		unmatched	matched
N	339	7427	339	211	4436	211
Productivity	176439	164717	176636	169386.30	166797.70	164557.60
	(221193)	(220344)	(154446)	(212899.50)	(241775.20)	(160830.80)
ΔProductivity$_{2007-2005}$	23698	19170	28053	21054.97	20550.56	23485.05
	(73763)	(67013)	(65665)	(75544.62)	(72459.79)	(51809.54)
Export intensity	19.31	20.22	19.63	21.60	25.67**	19.93
	(22.73)	(24.72)	(23.37)	(24.05)	(26.35)	(24.92)
General investment	6934	5834	6502	7196.99	5629.52	5553.97
	(19494)	(16381)	(17365)	(22676.55)	(18217.76)	(8438.59)
Add-on EPI	79	66	55	64.57	83.23	52.17
	(427)	(2357)	(427)	(376.41)	(3038.88)	(420.43)
Integrated EPI	11	28**	22	8.58	33.26***	26.12
	(82)	(481)	(246)	(52.21)	(581.51)	(284.42)
Integrated EPI intensity	3.14	2.41	2.88	2.76	2.74	2.38
	(15.01)	(14.18)	(15.30)	(13.91)	(15.27)	(14.35)
Firm size	708	161**	467	634.56	166.12**	205.23*
	(4348)	(1119)	(4943)	(3124.14)	(437.79)	(691.05)
ΔFirm size$_{2007-2005}$	-17	3	-26	-17.81	4.93	4.42
	(667)	(151)	(583)	(840.97)	(101.67)	(38.02)
Wage	30641	29388**	31384	32945.26	31623.72*	31636.86
	(11471)	(10739)	(11869)	(10690.39)	(10777.76)	(10470.16)
Firm age	0.61	0.58	0.55	0.61	0.58	0.57
	(0.49)	(0.49)	(0.51)	(0.49)	(0.49)	(0.51)
Enterprise group	0.52	0.55	0.54	0.53	0.58	0.48
	(0.50)	(0.50)	(0.51)	(0.50)	(0.49)	(0.50)
Foreign owned	0.08	0.09	0.07	0.09	0.11	0.06
	(0.27)	(0.29)	(0.26)	(0.28)	(0.31)	(0.24)

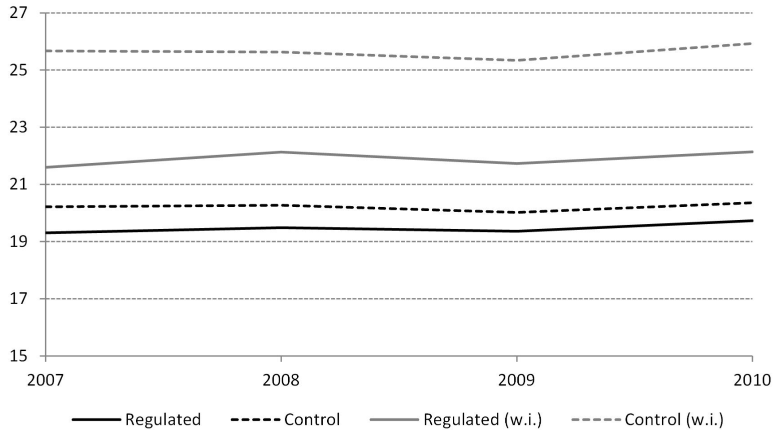
Note: Reported are mean values and standard deviations in parentheses; The control group is defined as firms located in German administrative regions without any water fee regulation; t-tests against treatment group (Significance at the 10% (*), 5% (**) and 1% (***) level); matching with one nearest neighbor on the estimated propensity score (cf. assignment model estimates in Table A.3) with perfect match on 2-digit industry and only on common support.

Figure 1: Changes in firm performance

Productivity (EUR per capita)

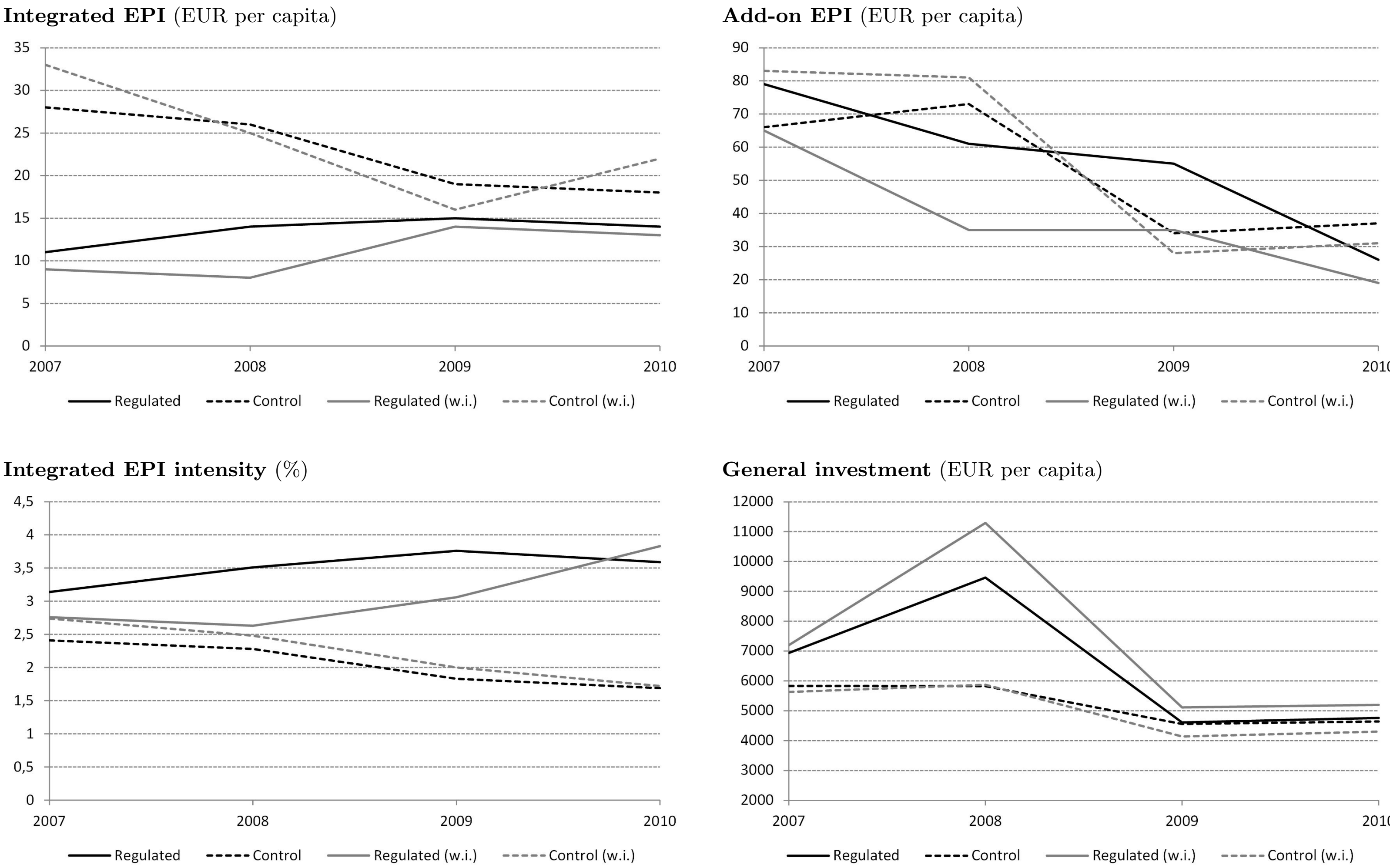


Export intensity (%)



Note: Abbreviation w.i. indicates sample restriction to water intensive industries.

Figure 2: Changes in investment behavior



Note: Abbreviation w.i. indicates sample restriction to water intensive industries.

6.2 Estimation results

Table 3 reports estimated coefficients of the empirical model described in Section 3 for our measures of general firm competitiveness (strong Porter hypothesis). We focus on the results for the within fixed effects estimator to account for unobserved heterogeneity, although we also estimated a simple linear OLS without firm fixed effect. Overall, the results obtained from the two estimation methods do not differ substantially, suggesting a minor role for unobserved heterogeneity due to the matching on baseline characteristics. In the productivity estimates for both the full and the restricted sample, the coefficients of the year dummies mirror the sharp decline in 2009 and a recovery in 2010, but do not show any significant impact of the regulation in the interaction terms. This is in line with our impression from the descriptive figures. The firms in our samples have apparently not suffered a significant average decline in export intensity from 2007 to 2008, but rather showed an increase in 2010. However, the 2010 recovery has been significantly less pronounced for firms that had been regulated two years before, which might point to a negative impact of the higher input cost on international competitiveness. This negative effect appears to be larger in water-intensive industries, a result that fits the picture.

Table 4 presents results for integrated EPI estimates and Table 5 those for other investment outcomes. We first look at the results for the full sample estimates. Although the interaction terms of the first and second follow-up years for integrated EPI have a positive sign, there is no statistically significant average increase caused by the regulation (Table 4). However, at the same time, previously regulated firms show a significant decline in add-on EPI compared to their non-regulated counterparts (Table 5). It could be that increasing resource-efficiency, measured as an increasing share of integrated measures, is merely caused by a decline of add-on investment, but although the difference-in-differences of the share of integrated EPI is positive on average in the first and second follow-up years, they are not statistically significant at any conventional levels. It is noteworthy that both types of EPI, add-on and integrated, have remained stable over the years 2009 and 2010 despite a general investment decline in 2009, presumably caused by the crisis, which had been particularly prevalent in the regulated group. This general investment reluctance may as well be regulation-induced, although it appears only likely that firms omit investment in the second follow-up period but not in the first, if investment decisions for the first were already and irreversibly made.

Table 4 and 5 also show estimates of investment variables for the subsample of firms in water intensive industries. The results suggest no significant average impact of the water withdrawal regulation on the green investment behavior of regulated firms, just as the full sample estimates.

Also similar to the full sample estimates, in contrast to green investment, in terms of general business investment, which appears to be independent of the stable average green investment, regulated firms do show a significantly different investment behavior.

Our results imply no positive or negative impact of the regulation on either general firm performance nor the sustainable restructuring of the production processes. The only exception is that firms in water intensive industries appear to have experienced disadvantages regarding their export intensity at the beginning of the crisis recovery period, two years after the regulation has been enforced. This leads us to the general caveat that the global economic crisis of 2008/2009 happened in the period covered by our data and may affect the results in mainly two potential ways: Firstly, the firms' behavior – and especially investment decisions – may be period-specific and hence our results, too. Secondly, if firms in our treatment group have been affected differently by the crisis compared to the reference group, due to any peculiar time-variant and unobserved factor, our results may not reflect the causal impact. Another caveat is that our analysis is restricted to a selective sample of those firms which have been established before the observation period and survived throughout this period. Therefore, our analysis suffers from a certain selection bias towards more successful and older firms, although the latter is probably not a severe issue since our sample anyway covers only firms with at least twenty employees. A last issue refers to the fact that – other than for the impact analysis of a regulation – the evaluation of the strong and weak Porter hypotheses requires a sufficient variation in the data imposed by a significant impact of the regulation. The absence of such a significant impact may limit the explanatory power for theory-related conclusions. Nevertheless, this does not impair conclusions regarding the particular regulation's impact.

Table 3: Difference-in-differences estimates of firm performance

	Full sample				Water intensive industries			
	Productivity		Export intensity		Productivity		Export intensity	
	pooled OLS	panel FE	pooled OLS	panel FE	pooled OLS	panel FE	pooled OLS	panel FE
Treatment	4468.08	-	0.08	-	-7301.03	-	-0.24	-
	(0.33)		(0.05)		(0.46)		(0.11)	
$\text{Time}_{j=1}$	1603.27	2878.00	-0.31	-0.05	4680.23	5777.55	-0.66	-0.29
	(0.46)	(0.87)	(0.88)	(0.17)	(1.06)	(1.34)	(1.45)	(0.70)
$\text{Time}_{j=2}$	-24468.80***	-25369.34***	0.63	0.07	-22324.70***	-26471.87***	0.71	-0.37
	(6.48)	(7.00)	(1.49)	(0.17)	(4.79)	(6.24)	(1.21)	(0.78)
$\text{Time}_{j=3}$	12123.14***	12190.86***	0.43	0.97**	6132.36	9060.85*	1.17*	2.16***
	(3.24)	(3.55)	(0.97)	(2.39)	(1.11)	(1.81)	(1.65)	(3.44)
$\text{Interaction}_{j=1}$	5964.83	3035.57	0.19	0.23	5952.71	5565.33	0.74	0.81
	(1.31)	(0.69)	(0.36)	(0.48)	(0.98)	(0.92)	(0.99)	(1.12)
$\text{Interaction}_{j=2}$	89.43	1492.69	0.07	-0.11	-2849.19	-1290.08	-0.14	0.11
	(0.01)	(0.21)	(0.12)	(0.17)	(0.32)	(0.14)	(0.17)	(0.13)
$\text{Interaction}_{j=3}$	-6943.83	-5570.18	-1.37**	-0.81	-7439.42	-5887.36	-1.97**	-1.99**
	(0.95)	(0.79)	(2.23)	(1.38)	(0.87)	(0.72)	(2.17)	(2.30)
Firm size	1.81	-1.50	0.001***	0.0004	3.36	-1.86	0.001*	0.001
	(1.28)	(0.41)	(3.09)	(1.24)	(0.62)	(0.69)	(1.71)	(1.37)
Firm age	2520.84	-	1.19	-	-9795.22	-	1.09	-
	(0.22)		(0.74)		(0.71)		(0.50)	
Wage	5.45***	4.70***	0.001***	0.0001**	6.76***	4.19***	0.001***	0.0002**
	(6.61)	(5.59)	(7.99)	(2.05)	(5.22)	(5.30)	(5.61)	(2.42)
Enterprise group	71097.58***	3500.73	4.61***	1.50	41712.68***	6377.42	2.66	2.94**
	(6.40)	(1.01)	(2.85)	(1.42)	(3.20)	(0.96)	(1.31)	(2.20)
Foreign owned	20503.45	17462.94**	7.87**	2.36	10204.39	-13418.26	10.24*	-0.03
	(0.63)	(2.07)	(2.13)	(0.87)	(0.32)	(0.92)	(1.96)	(0.01)
R^2	0.196	0.101	0.209	0.014	0.193	0.102	0.162	0.029
N	2712	2712	2712	2712	1688	1688	1688	1688

Note: Reported are estimated coefficients with |t-values| in parentheses; Significance at the 10% (*), 5% (**) and 1% (***) level; Standard errors are adjusted for firm clusters; R^2 value for FE estimates refers to the within variance.

Table 4: Difference-in-differences estimates of integrated EPI

	Full sample				**Water intensive industries**			
	Integrated EPI		Integrated EPI intensity		Integrated EPI		Integrated EPI intensity	
	pooled OLS	panel FE	pooled OLS	panel FE	pooled OLS	panel FE	pooled OLS	panel FE
Treatment	-10.69	-	0.15	-	-19.35	-	-0.75	-
	(0.77)		(0.14)		(0.97)		(0.57)	
$\text{Time}_{j=1}$	-10.02	-9.02	-0.78	-0.73	-23.02	-23.09	-0.59	-0.59
	(0.86)	(0.78)	(0.94)	(0.87)	(1.17)	(1.17)	(0.64)	(0.65)
$\text{Time}_{j=2}$	-9.45	-11.87*	-0.94	-1.05	7.55	7.29	0.43	0.41
	(1.47)	(1.73)	(1.45)	(1.57)	(1.26)	(1.19)	(0.82)	(0.75)
$\text{Time}_{j=3}$	35.46	37.39	0.45	0.47	-7.21	-6.90	-0.03	0.09
	(1.02)	(1.03)	(0.72)	(0.74)	(1.08)	(1.01)	(0.03)	(0.10)
$\text{Interaction}_{j=1}$	12.59	13.10	1.16	0.97	21.86	21.78	0.53	0.30
	(0.95)	(0.99)	(0.90)	(0.75)	(1.07)	(1.06)	(0.36)	(0.20)
$\text{Interaction}_{j=2}$	11.27	10.75	1.27	1.57	-1.22	-0.94	-0.03	0.35
	(1.13)	(1.07)	(1.09)	(1.35)	(0.10)	(0.08)	(0.03)	(0.31)
$\text{Interaction}_{j=3}$	-37.49	-35.19	-0.75	-0.47	6.37	7.06	0.78	0.96
	(1.08)	(1.05)	(0.67)	(0.43)	(0.53)	(0.59)	(0.53)	(0.66)
Firm size	0.001**	0.02**	0.001***	0.01***	0.003**	0.02***	0.002***	0.01***
	(2.49)	(2.32)	(3.40)	(3.38)	(2.40)	(3.73)	(3.28)	(6.60)
Firm age	-5.61	-	0.42	-	3.98	-	0.29	-
	(0.56)		(0.59)		(0.60)		(0.30)	
Wage	0.0002	-0.002	0.0001**	-9.20e-06	0.0003	-0.0002	0.00002	-0.00002
	(0.41)	(1.15)	(2.40)	(0.16)	(1.41)	(0.27)	(0.58)	(0.21)
Enterprise group	4.51	-0.49	2.20***	-1.11	1.24	-7.81*	2.72***	-0.04
	(0.55)	(0.10)	(3.23)	(0.94)	(0.18)	(1.68)	(3.02)	(0.06)
Foreign owned	-8.71	-0.24	1.09	2.38	-2.86	3.17	1.87	0.12
	(0.97)	(0.02)	(0.49)	(1.14)	(0.39)	(0.55)	(0.56)	(0.07)
R^2	0.002	0.003	0.081	0.025	0.007	0.005	0.127	0.057
N	2712	2712	2712	2712	1688	1688	1688	1688

Note: Reported are estimated coefficients with |t-values| in parentheses; Significance at the 10% (*), 5% (**) and 1% (***) level; Standard errors are adjusted for firm clusters; R^2 value for FE estimates refers to the within variance.

Table 5: Difference-in-differences estimates of other investment variables

	Full sample				**Water intensive industries**			
	Add-on EPI		General investment		Add-on EPI		General investment	
	pooled OLS	panel FE	pooled OLS	panel FE	pooled OLS	panel FE	pooled OLS	panel FE
Treatment	27.13	-	611.35	-	4.54	-	1190.06	-
	(0.11)		(0.79)		(0.61)		(0.42)	
$\text{Time}_{j=1}$	12.57	14.81	-699.31	-788.46	81.61	82.05*	-403.42	-376.87
	(0.34)	(0.41)	(1.44)	(1.63)	(1.65)	(1.65)	(0.44)	(0.41)
$\text{Time}_{j=2}$	-19.39	-27.36	-118.14	6.12	-61.53	-62.73	-1515.19**	-1568.47***
	(0.97)	(1.41)	(0.14)	(0.01)	(1.46)	(1.51)	(2.59)	(2.76)
$\text{Time}_{j=3}$	-20.87	-13.67	483.73	400.45	-26.07	-23.16	-119.05	-73.13
	(1.42)	(0.96)	(0.50)	(0.40)	(1.15)	(1.00)	(0.27)	(0.17)
$\text{Interaction}_{j=1}$	-44.76	-44.12	4579.51*	4710.50*	-101.91*	-103.99*	2805.53	2821.69
	(1.01)	(1.03)	(1.74)	(1.80)	(1.81)	(1.85)	(1.45)	(1.48)
$\text{Interaction}_{j=2}$	25.19	26.80	-5609.16**	-5801.99**	61.13	61.82	-3036.83*	-3076.81*
	(0.94)	(1.01)	(2.17)	(2.24)	(1.19)	(1.20)	(1.80)	(1.85)
$\text{Interaction}_{j=3}$	-1.67	0.25	-953.79	-828.97	-10.53	-7.45	-109.48	-76.54
	(0.08)	(0.01)	(0.50)	(0.47)	(0.32)	(0.23)	(0.10)	(0.07)
Firm size	0.002	0.01	-0.04	-0.02	-0.001	0.01	-0.001	-0.85
	(0.68)	(0.74)	(0.15)	(0.04)	(1.17)	(0.81)	(0.02)	(0.93)
Firm age	19.24	-	859.20	-	32.37	-	952.47	-
	(1.21)		(0.71)		(1.57)		(1.18)	
Wage	0.004	-0.001	0.34*	0.31*	0.01***	0.002	0.25**	0.19*
	(1.49)	(0.84)	(1.80)	(1.72)	(2.64)	(1.46)	(2.22)	(1.70)
Enterprise group	31.65**	5.41	2238.94	1869.87	38.36*	-8.06	2438.43***	2274.53**
	(2.18)	(0.17)	(1.56)	(1.48)	(1.73)	(0.24)	(3.05)	(2.34)
Foreign owned	-22.03	-63.71	-4632.32	606.41	-62.15	-233.30	-3364.01	-3325.25
	(0.40)	(1.63)	(1.58)	(0.71)	(1.57)	(1.40)	(1.65)	(0.97)
R^2	0.031	0.006	0.036	0.021	0.021	0.011	0.035	0.019
N	1688	1688	1688	1688	2712	2712	2712	2712

Note: Reported are estimated coefficients with |t-values| in parentheses; Significance at the 10% (*), 5% (**) and 1% (***) level; Standard errors are adjusted for firm clusters; R^2 value for FE estimates refers to the within variance.

7 Conclusions

Our analysis adds two new aspects to the discussion: Firstly, we use integrated EPI in order to include inter-firm innovations into the discussion on the Porter hypothesis. We argue that, in contrast to commonly used innovation-related measures, this allows us to further specify environment-related aspects of the firms' reaction to the new regulation. Secondly, we use a difference-in-differences estimation aiming at investigating a causal impact of the specific change in regulation on firm performance and environmental investment behavior. We proceed in two steps, estimating the effect of the regulation first on firm performance and subsequently the one on investment behavior.

From the descriptive results we find no evidence of a change in firm performance or competitiveness that is likely to be caused by the regulation. This is supported by the estimation results. Interestingly, we find that regulated firms showed an investment behavior significantly different from their non-regulated counterparts: The firms in the regulated group both lowered their investment in add-on measures and simultaneously increased it more in integrated measures. While these descriptive results seem promising to motivate a closer analysis, the regression results yield no statistically significant results for the coefficients of the interaction terms between integrated EPI and the regulation. Thus, no effect of the regulation on integrated EPI could be found. The same holds for the sub-sample of firms in water-intensive industries.

Although the descriptive results suggest a potential effect of the increased water prices on firms' green investment behavior, there is no evidence of any effect (either detrimental or investment-enhancing) of the regulation in question on firms' competitiveness. One may infer from these results that while firms do react and change their investment behavior (they also report so themselves in Deutscher Industrie- und Handelskammertag, 2008), the regulation in question shows no sign of affecting overall competitiveness. The argument of expected detrimental effects of the regulation to firms' competitiveness that was brought forward in the discussion about its introduction thus seems not to weigh too strongly in this particular case.

Our results may also be interpreted as somewhat encouraging news regarding sustainable competitiveness, as we found some increase in EPI measures, but no negative effects on competitiveness. Analogously to the concept of sustainable competitiveness of countries,[14] we analyze sustainable competitiveness on the firm level by indirectly including an environmental factor into a measure of competitiveness.[15]

[14] This is for example presented in Filipovic & Despotovic (2014) who use data from an initiative by the World Economic Forum and in Tvaronaviciene & Balkyte (2010) who discuss approaches to sustainable competitiveness.

[15] In subsequent steps, social factors should also be included.

A regulation that causes firms to increase their resource efficiency while keeping their economic performance constant can in this context be deemed a useful policy measure for sustainable competitiveness. It can thus be seen as a useful tool when aiming at green growth (cf e.g. Rische, Röhlig & Stöver, 2014). Unfortunately, the regulation we considered does not fulfill the criteria for enhancing sustainable competitiveness and thus falls short of being a candidate for green growth policies.

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A Appendix

Table A.1: Definition of Variables

Variable	Definition	Source
Productivity	Measured as labor productivity: annual total turnover per employee (in EUR)	MB
Export intensity	Share of turnover generated abroad (in % of total turnover)	MB
General investment	annual gross business investment in tangibles without environmental protection investments (in EUR per employee)	I
Overall EPI	annual investments which aim exclusively or predominantly at protecting the environment from a harmful impact of production (in EUR per employee); includes climate protection	SEPI
Add-on EPI	annual investment in equipment which is physically separate from the other production facilities (in EUR per employee); excludes climate protection	SEPI
Integrated EPI	annual investments that make the process of production generally more efficient in terms of a lower level of pollution and do not have to be technological elements (in EUR per employee); excludes climate protection	SEPI
Integrated EPI intensity	Share of integrated EPI (of overall EPI)	SEPI
Firm age	Indicates whether a firm was established before 1996 (value = 1) or after (value = 0)	MB
Wage	Average annual wage per employee without social payments by employer (in EUR)	MB
Firm size	Mean of annual employment	MB
Enterprise group	Indicates whether a firm is part of a national or multinational enterprise group by owning more than half of the capital shares of other firms or having a majority shareholder itself (value = 1) or a firm is independent (value = 0)	EGD
Foreign owned	Indicates whether a foreign entity is the majority owner of a firm (value = 1) or not (value = 0)	EGD

Notes: Datasources are abbreviated as follows: SEPI = survey of environmental protection investments; I = general investment survey; MB = monthly and annual reports of establishments from the manufacturing, mining and quarrying sectors; EGD = enterprise group database.

Table A.2: Industry distribution in treatment group

Industry	WZ2003 code	No. of firms	Share of firms (%)
Other mining and quarrying	14	4	1.18
Manufacture of food products and beverages	15	54	15.93
Manufacture of textiles	17	4	1.18
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20	5	1.47
Manufacture of pulp, paper and paper products	21	3	0.88
Publishing, printing and reproduction of recorded media	22	16	4.72
Manufacture of chemicals and chemical products	24	7	2.06
Manufacture of rubber and plastic products	25	20	5.90
Manufacture of other non-metallic mineral products	26	9	2.65
Manufacture of basic metals	27	16	4.72
Manufacture of fabricated metal products, except machinery and equipment	28	77	22.71
Manufacture of machinery and equipment n.e.c.	29	57	16.81
Manufacture of electrical machinery and apparatus n.e.c.	31	15	4.42
Manufacture of radio, television and communication equipment and apparatus	32	3	0.88
Manufacture of medical, precision and optical instruments, watches and clocks	33	17	5.01
Manufacture of motor vehicles, trailers and semi-trailers	34	16	4.72
Manufacture of furniture; manufacturing n.e.c.	36	11	3.24
Other	10, 18, 23, 35	5	1.47

Note: Number of firms for 2008 cross section (treatment year); The Industries “Mining of coal and lignite; extraction of peat”; “Manufacture of wearing apparel; dressing and dyeing of fur”, “Manufacture of coke, refined petroleum products and nuclear fuel”, and “Manufacture of other transport equipment” are aggregated in category *other* due to confidentiality reasons; Abbreviation n.e.c. stands for not elsewhere classified.

Table A.3: Assignment model estimates (probit)

	Full sample		Water intensive industries	
Variable	*Coefficient*	$\|z\text{-values}\|$	*Coefficient*	$\|z\text{-values}\|$
Productivity_2007	-1.03e-07	0.67	-2.76e-07	1.07
ΔProductivity$_{2007-2005}$	4.57e-07	1.09	3.70e-07	0.66
Export intensity_2007	-0.002	1.71	-0.01	3.38
General investment_2007	1.46e-06	0.96	2.51e-06	1.41
Firm size_2007	0.0001	3.61	0.0002	3.76
ΔFirm size$_{2007-2005}$	0.0001	1.35	0.0001	0.35
Wage_2007	6.65e-06	2.39	9.17e-06	2.56
Firm age_2007 (indicator)	0.05	0.95	0.07	0.98
Enterprise group_2007 (indicator)	-0.09	1.69	-0.11	1.54
Foreign owned_2007 (indicator)	-0.07	0.70	-0.08	0.63
Observations	7766		4647	
McFadden's R^2	0.011		0.028	

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