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Unmasking the Porter Hypothesis: Environmental Innovations and Firm-Profitability

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NON-TECHNICAL SUMMARY

Environmental regulation. What economists usually associate with these words are barriers to competitiveness. The association of Porter (1991) and Porter and van der Linde (1995) is a different one. By relying on a few case studies, they argue that even if stringent regulations impose costs on affected firms, regulations can trigger innovations which finally overcompensate regulatory costs. This view has become known as the Porter hypothesis which postulates a so called "win-win" situation that is supposed to improve both environmental quality and firms' profitability.

We attempt to test this hypothesis based on comprehensive data of firms from Germany. In contrast to previous empirical work, we distinguish innovations that directly reduce resource consumption (and thus externalities) of the innovating firm on the one hand, and innovations that only reduce environmental externalities without increasing resource efficiency on the other. For both types of environmental innovation we separate between regulation-induced and voluntary innovations. Compared to firms that did not introduce any type of environmental innovation, both regulation induced and voluntary innovations that improve resource efficiency increase profitability. This positive effect is larger for regulation driven innovation since they lead to an 1.4 percentage point increase in profitability (measured with return on sales) while voluntary innovations only increase profitability by 0.8 percentage points. However, innovation that reduces environmental externalities reduce firms profitability by 0.8 percentage points if they are regulation-induced whereas voluntary abatement investment of this type does not lead to significant profitability effects.

We use data from the German Community Innovation Survey (CIS) in 2009 (the Mannheim Innovation Panel 2009) since it includes a set of questions on environmental innovation adoption and whether this is due to regulation. German CIS data are an appropriate data source since Germany is one of the most regulated countries in the world.

Das Wichtigste in Kürze

Ökonomen verbinden mit dem Begriff Umweltregulierung üblicherweise staatliche Maßnahmen, die die Wettbewerbsfähigkeit von Unternehmen einschränken. Porter (1991) und Porter und van der Linde (1995) verbinden dagegen mit dem Begriff Umweltregulierung das Gegenteil. Auf Basis einiger weniger Fallstudien stellen sie fest, dass selbst dann, wenn Regulierung zu zusätzlichen Kosten für die betroffenen Unternehmen führt, diese Kosten durch Erträge aus regulierungsinduzierten Innovationen mehr als ausgeglichen werden. Dieser unterstellte Zusammenhang wird als Porter-Hypothese bezeichnet, die eine sog. „win-win"-Situation bei Umweltregulierungen unterstellt, d.h. eine Verbesserung sowohl der Umweltqualität als auch der Wettbewerbsfähigkeit von Unternehmen.

In diesem Beitrag testen wir diese Hypothese mithilfe eines umfassenden Datensatzes von Unternehmen aus Deutschland. Im Gegensatz zu bisherigen Studien unterscheiden wir zwischen Umweltinnovationen, die den Ressourcenverbrauch und somit auch Umweltexternalitäten verringern und solchen, die nur Umweltexternalitäten verringern, ohne gleichzeitig die Ressourceneffizienz des innovierenden Unternehmens zu erhöhen. Weiterhin unterscheiden wir, ob diese beiden Arten von Umweltinnovationen aufgrund staatlicher Regulierung oder freiwillig eingeführt worden sind. Verglichen mit Unternehmen, die keine der beiden Arten von Umweltinnovationen eingeführt haben, ist die Umsatzrendite von Unternehmen, die Ressourceneffizienzinnovationen eingeführt haben, im Durchschnitt höher. Dies trifft sowohl für regulierungsinduzierte als auch für freiwillig eingeführte Innovationen zu. Regulierungsinduzierte Innovationen erhöhen die Umsatzrendite um 1,4 Prozentpunkte und damit höher als freiwillig eingeführte Umweltinnovationen (+0,8 Prozentpunkte). Innovationen, die nur externe Effekte reduzieren, verringern die Umsatzrendite, allerdings nur dann, wenn diese Innovationen durch Regulierungen ausgelöst wurden. Die Umsatzrendite ist in diesem Fall um 0,8 Prozentpunkte geringer als bei Unternehmen ohne Umweltinnovationen. Im Gegensatz dazu haben freiwillig eingeführte Innovationen, die Umweltexternalitäten reduzieren, keinen signifikanten Effekt auf die Rentabilität.

Diese Ergebnisse beruhen auf Daten des deutschen Teils der europaweiten Innovationserhebung (CIS) des Jahres 2009, dem Mannheimer Innovationspanel 2009. Der Datensatz beinhaltet einige Fragen zu Umweltinnovationen und ob diese aufgrund von Regulierungen eingeführt worden sind. Daten zu Unternehmen aus Deutschland eignen sich besonders für unsere Fragestellung, da Deutschland schon seit langer Zeit eine besonders starke Umweltregulierung hat.

Unmasking the Porter Hypothesis: Environmental Innovations and Firm-Profitability

SASCHA REXHÄUSER* & CHRISTIAN RAMMER*

ABSTRACT - We examine impacts of different types of environmental innovations on firm profits. Following Porter's (1991) hypothesis that environmental regulation can improve firms' competitiveness we distinguish regulation induced and voluntary environmental innovations. We find that innovations which reduce environmental externalities reduce firms' profits, as long as they are induced by regulations. However, innovation that increases a firm's material or energy efficiency in terms of material or energy consumption has a positive impact on profitability. This positive result holds both for regulation induced and voluntary innovations, although the effect is significantly larger for regulation-driven innovation. We conclude that the Porter hypothesis does not hold in general for its "strong" version but has to be qualified by the type of environmental innovation. Our finding rest on firm level data from the German part of the Community Innovation Survey in 2009.

KEYWORDS - Environmental innovation, environmental regulation, Porter hypothesis, competitiveness
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I. INTRODUCTION

Economists usually associate negative impacts of environmental regulation on firm competitiveness. Porter (1991) and Porter and van der Linde (1995) proposed a different view, however. By relying on a few case studies, they argue that even if stringent regulation imposes costs on affected firms, regulations will trigger innovations which finally overcompensate regulatory costs. This relationship has become known as the Porter hypothesis, or to be more precisely, the "strong" version of the hypothesis, see Jaffe and Palmer (1997). Moreover, Porter and van der Linde (1995) identified both, environmental (social) and corporate (private) benefits to be a result of more stringent environmental regulation. They conclude that environmental regulation improves firms' competitiveness in the long run accompanied with an improved environmental performance. The advocacies of this point of view refer to this as a "double-dividend" or a "win-win" situation.

This supposed "win-win" situation has not been untouched by opponents since it does not offer any comparison of costs and benefits of environmental regulation. Such a "[...] comparison of the benefits and costs is exactly how one should determine the economic attractiveness of specific programs - not on the false premise of cost-free controls." (Palmer et al. (1995), p. 131).

The approach we decide to adopt is to evaluate the costs and benefits of environmental regulation at the firm level by looking at the profitability effects of regulation-induced innovations. Firm profitability reflects both costs to cope with regulation, as well as either enhancing or decreasing productivity effects of environmental technology.

Environmental innovations are new products, processes or procedures (including the adoption of existing technology) that aim at reducing environmental impacts of firm activity or of using firms' products. Such innovation can either be imposed by government regulation or introduced voluntarily. While any environmental innovation is characterised by decreasing environmental externalities, environmental innovation may also increase the innovator's productivity, e.g. by increasing resource efficiency (energy and material consumption per unit of output) or increasing product demand through higher quality characteristics of products. These productivity gains may overcompensate costs of introducing environmental innovations and thus increase firm profitability.

In line with this argument is the study of Berman and Bui (2001). They pointed to the fact that firms' pollution abatement costs do not correctly predict regulation's impact on their profitability. As they argue, this is the result why the literature founds mixed evidence on the productivity effects of regulation in general. Our approach differs from Berman and Bui (2001) in the way how to unmask the overall firm-level effects of regulation on competitiveness as we look in detail on the profitability consequences of regulation-induced innovations. We analyse whether introduced in response to regulation differ in their impact on profitability compared to voluntarily introduced environmental innovations. We distinguish two types of environmental innovations; those reducing environmental externalities and those reducing per unit consumption of environmental costs (energy, materials). We assume the Porter hypothesis not to hold in general, but only for regulation which forces firms to increase efficiency while regulations aiming at lowering externalities will harm firms' profits. In this regard we provide further empirical evidence referring to Porter's hypothesis. This is needed since "the evidence offered in support of this hypothesis is largely anecdotal" (Jaffe and Palmer (1997), p. 610). We employ firm level data taken from the German part of the Community Innovation Survey conducted in 2009, containing information on environmental innovations and their link to regulations for almost 4,000 firms across all sectors.

The remainder of the paper is organized as follows: The following section provides a brief survey of the literature relevant to our research question. The econometric implementation is described in section III. where we also pay attention to construct reliable controls. A discussion of the results is presented in section IV. Section V. concludes.

II. Related Research

The aim of this paper is to shed more light on the Porter hypothesis and whether it holds in general, especially with regard to different types of environmental innovation introduced in response to regulation. However, doing empirical work on this question is somewhat challenging since a "[...] systematic economic analysis is hindered by ambiguity as to exactly what the hypothesis is" (Jaffe and Palmer (1997), p. 610)[1]. This critique refers to the initial paper of Porter (1991, p. 168), where he claims: "Strict environ-

[1] Using the terminology of Jaffe and Palmer (1997) it is possible to distinguish between three versions of the Porter hypothesis: the "narrow" one, the "weak" one, and the "strong" version. We use the term Porter hypothesis to refer to the strong version. The strong version states that "[...] properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them." (Porter and van der Linde (1995) p. 98). This is a widely adopted interpretation and this is also what the present paper is interested in. The weak and the narrow version are quite similar. While the narrow version states that "*certain kinds*" of regulation induces innovation, the weak version states that regulation in general will induce "*certain kinds*" of innovations, see Jaffe and Palmer (1997).

mental regulations do not inevitably hinder competitive advantage against foreign rivals; indeed, they often enhance it. Tough standards trigger innovation and upgrading."

For the latter sentence in the quoted passage, there is strong evidence for this relationship (the narrow version of the Porter hypothesis) to exist. Newell et al. (1999) find empirical evidence that, beside other factors, governmental regulation induces energy efficiency innovations. Relying on patent data, also Lanjouw and Mody (1996) provide empirical evidence in support of the regulation-induced innovation thesis. Brunnermeier and Cohen (2003) show that pollution abatement and control expenditure, as a measure for regulatory burdens, stimulate innovations. Counter to these studies, Snyder et al. (2003) does not find any significant impact of regulation on technology adoption at all. Using macro-level panel data, Jaffe and Palmer (1997) find no significant impact of regulatory compliance costs on patent applications, remaining the narrow version of the Porter hypothesis unsupported. A survey of the literature dealing with the impact of environmental regulation on environmental innovation - the narrow Porter hypothesis - is offered by Jaffe et al. (2002).

For the first sentence in the quoted passage, there is overwhelming evidence that this relationship does not exist. On of the most seminal contributions demonstrating that regulation is a barrier to competitiveness is the study of Greenstone (2002). He examines the effect of the U.S. Clean Air Act amendment regulation on industrial activity and finds that capital stock, output and jobs (590,000 in 15 years) were lost in counties with more stringent regulations. Gollop and Roberts (1983) identify a negative impact of U.S. Clean Air regulation on productivity growth of 56 examined electric power plants. Christainsen and Haveman (1981) arrive at even stronger conclusions: They attribute 8-12 % of the United States' (U.S.) productivity slowdown between 1965 and 1979 to environmental regulation. Opposed to these finding, Berman and Bui (2001) show that regulated oil refineries faced productivity growths compared to non-regulated ones. Other studies look at the impact of regulation on production plant location. Becker and Henderson (2000) show that Clean Air Act regulation caused production plant births in areas with more stringent regulation to fall "dramatically" compared to areas where regulation was less stringent. There is thus a possibility that tight regulation forces firms in pollution-intensive industries to relocate to areas with less stringent regulation to maintain profitability. Henderson (1996) find that this is indeed the case, see also List et al. (2003). A survey of this strand of the literature is offered by Brunnermeier and Levinson (2004). Jaffe et al. (1995) survey the early literature on the impact of environmental regulation on a country's overall competitiveness and conclude that the adverse effect of regulation on a country's competitiveness is rather small. Another strand of literature looks at the competitiveness effects of regulation in terms of firms' financial situation. Empirical work by Rassier and Earnhart (2010), Konar and Cohen (2001) and many others reveal evidence that regulation lowers a firm's market value and consequently future financial performance. Evidence for this result also appears in Canõn-de-Francia et al. (2007). They identified innovative companies to suffer from smaller losses in market value than non-innovative ones.

In the widely adopted interpretation of Porter's hypothesis (the strong one), Porter and van der Linde (1995) claim that regulation induces innovation that finally improves competitiveness. However, in light of the literature presented above, the question may arise why regulation should be beneficial for the firm via its impact on innovation whereas most of the mentioned studies attributed adverse effects to regulation? Put it otherwise: Also the strong version of the Porter hypothesis may not hold in general. This sceptic view is supported by a study related to the strong version offered by Gray and Shadbegian (1998). They find that pollution abatement investment (i.e. the adoption of clean technology innovation) due to regulation crowds out other productive investment.[2] Crowding-out is found to be very strong (188 percent). This result implies that even if regulation triggers cost saving environmental innovations that might increase profitability, these innovations may crowd out other productive investments that could have increased firms' profitability even the more.

Porter and van der Linde (1995) suppose that firms are unaware of possible gains from innovation and that they, as a consequence, engage in too little innovative activities. This argument seems to be borrowed from evolutionary approaches based on the important contribution of Nelson and Winter (1982). They argue that the allocation of R&D expenditure within a firm, e.g. for process improvement, is determined by routines based on experiences of former R&D projects, rather than by optimization behavior. Consequently, there may be potentials for further process or product improvements by allocating more resources to R&D. The Porter-Hypothesis claims that environmental regulation can solve this information problem.[3] A simulation model offered by Popp (2005) addresses this "under invest-

[2] Popp et al. (2009) find that energy R&D crowds out normal R&D, but energy R&D is not triggered by regulation in this study.

[3] In contrast to this information problem, Ambec and Barla (2002) develop a theoretical foundation of the Porter hypothesis where the information problem is due to asymmetric information between shareholders and the management.

ment" in R&D due to uncertainty of the R&D outcome. It assumes that "[...] a profit maximizing firm will only choose to invest in R&D for environmental innovations if an environmental policy is in place" (Popp (2005) p. 7). An interesting result of the model is that complete offset of regulatory costs due to successful R&D occurs only in a minor share of simulation trials and under very specific parameter specifications. In contrast to this finding, the model of Mohr (2002) offers results generally in support of the strong version of the Porter hypothesis. However, the model rests on the crucial assumption that two technologies exist with the new one always improving both productivity and environmental. Mohr (2002) concludes that an environmental policy that forces firms to adopt the new technology will in the long-run lead to a "win-win" situation. Also assuming the new technology to be more productive and less pollution intensive, Xepapadeas and de Zeeuw (1999) arrive at contrary results, not finding a win-win situation in their theoretical model.

Finally the interested reader is referred to the survey of Brännlund and Lundgren (2009) for further literature approaching the Porter hypothesis rather from theoretical or modeling perspectives. A very recent and by far the most comprehensive survey of the hypothesis is offered by Ambec et al. (2011). Since theoretical literature dealing directly with the strong version of the Porter hypothesis produces ambiguous results, we believe that there is a case for more detailed empirical research at the firm level. The the next section discusses our empirical strategy.

III. Model and Data

Based on the insights from the surveyed literature, this section starts with defining hypothesis which will be brought to an empirical test.

A. Hypotheses Drawn from the Literature

The literature presented above strongly stresses that innovations induced by environmental regulation cannot be expected to improve profitability per se, since environmental innovation is the introduction of an abatement technology in the production process or embodied in products which first of all implies additional costs with limited direct benefits for the innovating firm. However, this view neglects that the abatement technology could lead to energy or material savings in the production process. In addition, a better environmental performance of products may differentiated the innovators products from competitors which may either lead to higher demand or allows for higher product prices. Profitability effects of regulation-induced environmental innovation are thus ambiguous.

Our first hypothesis is that different types of environmental innovations differ in their impact on profitability. Innovations that increase resource efficiency of the innovator or for the user of the innovators' products are expected to positively affect profitability compared to firms refraining from any innovation or firms with environmental innovations that *only* reduce externalities. With regard to regulation-induced environmental innovations, our second hypothesis is that the Porter hypothesis only holds for innovations that improve resource efficiency, but not for pure externalities reducing environmental innovations. In case of voluntary environmental innovations, we expect positive or at least neutral profitability impacts (hypothesis three) as firms will invest in such innovations only in case they expect additional profits.

B. Empirical Model

To investigate these hypotheses, we start from a simple model of firm profitability. Profits per unit of output (π) of firm i equal product price (p) less costs per unit of output (c):

$$\pi_i = p_i - c_i \tag{1}$$

Assuming that all firms in a given market face the same supply and factor market conditions (i.e. prices for inputs, labour and capital are uniform across all firms in the same market), product price (p) will depend on product differentiation (which is regarded as a result of prior product innovation - PD) and market structure (MS), i.e. whether a firm is able to raise its price over the equilibrium price due to market power. Environmental innovations (EI) can affect product prices similar to product innovations in case a better environmental performance of products enables firms to raise prices over competitor products.

$$p_i = f_p(PD_i, MS_i, EI_i) \tag{2}$$

Unit costs of firms may differ as a result of process innovation (PC) which will lead to more efficient production as well as scale economies and the level of technology used (ST). Environmental innovations (EI) will increase unit costs due to higher costs for implementing abatement technology, though they can also lower unit costs if environmental innovations lead to more efficient production.

$$c_i = f_c(PC_i, ST_i, EI_i) \tag{3}$$

Based on this conceptualisation, we derive our empirical model of firm profitability:

$$\begin{aligned}\pi_i &= \alpha + \beta EI_i \\ &+ \gamma_1 PD_i + \gamma_2 PC_i + \boldsymbol{\delta_1}'\boldsymbol{MS_i} + \boldsymbol{\delta_2}'\boldsymbol{ST_i} + \boldsymbol{\delta_3}'\boldsymbol{C}_i + \varepsilon_i \end{aligned} \tag{4}$$

The vector $\boldsymbol{C}$ represents a set of further control variables to account for sector heterogeneity and heterogeneity of regional economies. α is a constant, β to δ are coefficients and ε is a firm specific error term.

The coefficient β represents the effect of environmental innovation in general (EI) on firm-level profitability (π). To investigate the first hypothesis regarding the aggregation bias of environmental innovation in general, a second model will be estimated where EI is distinguished into two types $t = 1, 2$, namely (resource) efficiency improving innovations ($t = 1$) and externality reducing innovations ($t = 2$), see equation 5.[4]

$$\begin{aligned}\pi_i &= \alpha + \sum_{t=1}^{2} \beta_t EI_{t,i} \\ &+ \gamma_1 PD_i + \gamma_2 PC_i + \boldsymbol{\delta_1}'\boldsymbol{MS_i} + \boldsymbol{\delta_2}'\boldsymbol{ST_i} + \boldsymbol{\delta_3}'\boldsymbol{C}_i + \varepsilon_i \end{aligned} \tag{5}$$

If the first hypothesis holds, the coefficients β_1 and β_2 must be significantly different from each other. To investigate the second an third hypotheses, environmental regulation has to be introduced into the model. To do so, both types of innovation are allowed to be regulation-induced ($r = 1$) or non-regulation-induced ($r = 2$), see equation 6.

$$\begin{aligned}\pi_i &= \alpha + \sum_{r=1}^{2} \sum_{t=1}^{2} \beta_{rt} EI_{rt,i} \\ &+ \gamma_1 PD_i + \gamma_2 PC_i + \boldsymbol{\delta_1}'\boldsymbol{MS_i} + \boldsymbol{\delta_2}'\boldsymbol{ST_i} + \boldsymbol{\delta_3}'\boldsymbol{C}_i + \varepsilon_i \end{aligned} \tag{6}$$

If the second hypothesis holds, namely that the Porter hypothesis only holds for regulation-induced resource efficiency improving innovations, β_{11} is must be positive and significant. Furthermore, the coefficient of regulation-induced externality reducing innovations (β_{12}) must be significant and negative since we expect this type of innovation to harm firms profitability if, and only if, it is regulation-induced. For the hypothesis three to hold, we must observe β_{21} and β_{22} to be either positive significant or at least not negative and significant. Porter and van der Linde (1995) argue that firms can be unaware of

[4]To study the impact of regulation-induced environmental innovation on profitability in general, a version of equation 4 is also estimated where EI is either regulation-induced, or non-regulation-induced.

potentials for further process improvement so that regulation can improve firm's profitability. If this would be the case the coefficient of regulation-induced innovations that improve resource efficiency (β_{11}) must be larger than the coefficient of voluntary ones, β_{21}.

C. Firm Innovation Data

In order to test our hypotheses, we use data from the German part of the Community Innovation Survey (CIS). The German contribution to CIS is the so-called Mannheim Innovation Panel (MIP) which is an annual survey based on a panel sample and conducted by the Centre for European Economic Research located in the city of Mannheim. Using German data is particularly useful for our research since Germany has relatively stringent environmental regulations for many years and thus provides an appropriate testing ground for our hypotheses.

We use the 2009 wave of the MIP since this wave includes a set of questions on environmental innovations which allows us to construct our key model variables. In contract to most other CIS, the German CIS also surveys information on firm profitability and market structure which is needed to establish our control variables. The gross sample of the 2009 wave consists of 29,807 enterprises (excluding neutral losses due to firm closure). The sample is stratified by sector (56 sectors at the 2-digit level of NACE rev. 2.0), size class (8 classes according to the number of employees) and region (West Germany and East Germany). The target population are enterprises with 5 or more employees from most economic sectors excluding farming and forestry, hotels and restaurants, public administration, health, education, and personal and cultural services.

The MIP is conducted as a mail survey, including an option to respond online. Following a first contact by postal mail, firms that did not respond after six weeks were contacted by telephone to remind them to participate, accompanied by sending them another copy of the questionnaire. After another six weeks, a second reminder followed. 7,657 firms provided usable responses which corresponds to a response rate of 26 percent which is of usual magnitude for voluntary mail surveys in Germany (Grimpe and Kaiser (2010)), particularly when considering the substantial length of the questionnaire. Sector and size composition of the net sample does not differ significantly from the gross sample, indicating representativeness of the net sample in terms of the sector and size distribution of the German firm population.

In order to control for a possible selection bias between responding and non-responding firms in terms of their innovation status, an extensive nonresponse survey was conducted, surveying 4,829 enterprises by telephone. This survey revealed a higher share of innovating firms among the non-responding firms (63.1 percent) compared to the net sample of responding firms (54.3 percent). This information is used to re-calculate weights when computing weighted figures or running weighted analysis but of less concern for our study (Janz et al. (2001); Peters (2008)).

The sample used in the present analysis includes 3,878 observations, i.e. about half of the total net sample. The reduced sample size for model estimations results from the fact that many firms did not provide information on all our model variables. In terms of sector composition, the subsample does not differ significantly from the full net sample. In terms of firm size, the mean number of employees in the subsample used for estimation is 495 (median: 35), compared to 542 (median: 30) in the full sample of the German 2009 CIS. Smaller firms are thus overrepresented in our sample which mostly covers small and medium sized firms whereas other studies dealing with the Porter hypothesis or regulation driven environmental innovation take large companies into account or rely on macro-economic data.[5] For further descriptive statistics of variables that are going to be discussed in the following subsections, see table 4 in the appendix.

D. Measuring the Model Variables

Profitability - We measure profitability by the 2008 pre-tax returns as a share in total sales. Firms reported return on sales within seven ordered categories with known thresholds, see table 3 in the appendix.

Environmental Innovations - The CIS conducted in the year 2009 contained a harmonised question on environmental innovations (see Kemp and Pearson (2008)). Environmental innovations are defined as product, process, marketing or organizational innovations which lead to a significant reduction of environmental burdens. In this sense it does not play any role whether the environmental benefits of innovations are an explicit goal or rather a byproduct of innovations. The environmental benefits could either appear at the innovating firm or at the customer. Environmental innovations include the introduction of an abatement technology by firms regardless whether this is a market novelty due to own R&D or just the adoption of existing technology. The rational behind this view of innovation is that firms can hardly distinguish whether a new used abatement technology is novel to the whole market or only novel to the firm. The German version of the CIS

[5]The studies of Konar and Cohen (2001) and Canõn-de-Francia et al. (2007) for instance use data of firms listed at the stock market which are without any doubts large firms. Rassier and Earnhart (2010) use data of publicly owned firms.

distinguishes 12 different dimensions of environmental innovations (which deviates from the harmonised CIS questionnaire which distinguishes 9 dimensions). Out of these 12 dimensions, nine refer to processes and three to products. Table 1 below summaries the 12 dimensions.

Table 1: Dimensions of Environmental Innovation Distinguished in the German CIS 2009

Dimension of environmental benefits	Share in Sample	Type of environmental innovation: Efficiency improving (t=1)	Type of environmental innovation: Externality reducing (t=2)
Process innovation			
Reduced material use per unit of output	35.12 %	X	-
Reduced energy use per unit of output	40.82 %	X	-
Reduced CO_2 emissions	32.16 %	-	X
Reduced other air emissions (e.g. SO_x, NO_x)	22.86 %	-	X
Reduced water pollution	22.13 %	-	X
Reduced soil pollution	14.36 %	-	X
Reduced noise burden	23.22 %	-	X
Replaced materials with less hazardous substitutes	22.90 %	-	X
Improved recycling of materials, water, waste	35.44 %	-	-
Product innovation			
Reduced energy use for the customer	35.21 %	X	-
Reduced air, water, soil, noise pollution	27.64 %	-	X
Improved recycling of product after use	23.59 %	-	X
Share in Sample		53.12 %	52.45 %

For each dimension, firms were asked to rate the significance of environmental benefits of introduced innovations on a 4-point ordinal scale with the categories high, medium, low and no environmental benefits. Table 1 shows whether a certain dimension of environmental innovation is assigned to either resource efficiency innovations or only externality reducing innovations. Please note that process innovations that improve recycling possibilities are not assigned to any of the two types while product innovations that improve recycling possibilities of the final products are assigned to innovations that reduce environmental externalities. The reason for this is the following: Better recycling as a process innovation may be beneficial for the firm if it safes the consumption of material, water, etc. If this would be the case, than this effect should already be catched by material saving innovations. If recycling improving process innovations primarily reduce the recyclability of waste which is recycled by others (e.g. through reducing hazardous substances contained in the waste) then it would represent externality reducing innovations rather than resource saving ones. Due to this ambiguity, we do not include recycling improving process innovations. However, for respective product innovations, it is clear that they only reduce externalities from the innovator's point of view. A further issue worth to be mentioned is the expected impact of energy saving product innovation on profitability. Although external to the firm, energy efficiency of products could be rewarded by the market since it directly reduces user costs and therefore could lead to higher profitability. To take this possibility into account, energy saving product innovations are included in the aggregate of (resource) efficiency improving innovations.

We construct a binary indicator variable for each of the two types which takes the value 1 if a firm has introduced an environmental innovation in at least one of the assigned dimensions that had at least a low significance for environmental benefits.[6] In order to investigate hypothesis one, i.e. to see wether the two types differ in their impact on profitability, we also compute a dummy variable for any type of environmental innovations which takes the value 1 if a firm introduced either resource efficiency or externality reducing innovations. If the estimated coefficient of this variable would differ significantly from the coefficients estimated for the two types, investigating environmental innovation in general would lead to an aggregation bias.

To investigate our second and third hypotheses, information is needed whether environmental innovation is induced by government regulation. Therefore, firms were asked whether innovations with environmental benefits were introduced in response to existing regulation or regulations expected to be introduced in the future. In both cases, we speak of regulation-induced innovations.

Combining the two dummies representing the two types of environmental innovations ($t = 1, 2$) with the two outcomes of the regulation status, i.e. regulated ($r = 1$) and non-regulated ($r = 2$), gives us four dummies. Firms that did not introduce innovations with any kind of environmental benefits form the control group.

Product and Process Innovation - Innovation can have a direct impact on firm profitability through product or process innovation (see Geroski et al. (1993)). In terms of product innovations, firms that were able to introduce a product that is new to their market (market novelty) gain a (temporary) monopoly position which can be transferred into a price premium. In terms of process innovation, cost reduction may allow the innovator to keep unit costs below the market average, providing sources for extra profits. We

[6] We also tested a model where environmental innovation variables take the value of one only for innovations with high and medium environmental benefits and zero otherwise. However, all of these variables performed worse.

introduce two dummy variables that take the value 1 if a firm introduced market novelties or cost reducing process innovations in the three year time period previous to the end of the year for which we observe profit margins.

Market Structure - Without any doubts, market structure is a key determinant of firms' profitability, especially when measuring profitability with return on sales as done in the present paper (see Czarnitzki and Kraft (2010)). A key indicator of market structure is market concentration, i.e. the market share of dominant suppliers in a given product market. In general, concentrate markets may give suppliers bargaining power over their customers and ease collusion. A standard measure for market concentration is the Herfindahl index. For this index, we use data at the NACE 3-digit level offered by the German Monopoly Commission.

A further indicator for price setting opportunities is a firm's market share. Shepherd (1972) finds that the market share is a key element of the market structure and performance relationship. We measure a firm's market share by directly asking for the firm's share in total market sales for its main product group.[7]

Finally, the model includes a dummy indicating a perceived hard competitive environment. The dummy aggregates all six questions in the innovation panel regarding the competitive environment. It takes the value 1 if at least one of the six possible threat to firms' competitive position are rated to be rather the case. The hard competition dummy captures for instance market specific differences in profitability due to pressure because of market entries or due to technology factors, i.e. whether technologies in certain markets become more quickly obsolete than in others.

Scale Economies and Technology - Unit costs of production and thus profitability may be affected by the scale of production and the technology employed. Likely scale effects are captured by including firm size, measured as the logarithm of the number of employees at full time equivalents. Efficiency gains stemming from a high level of technology are measured by including the stock of patents since patents represent novel technological knowledge that can be used exclusively by the inventing firm. The patent stock is measured as the logarithm of the number of patent applications over the period 1989 to 2006. We do not include more recent patents since we assume a certain time lag between generating new technological knowledge

[7]We refrain from interacting the market share with the concentration measure as suggested in the seminal contribution of Ravenscraft (1983) because of estimation problems when interaction terms are used in non-linear regressions (see Norton et al. (2004)). A non-linear model is used in this paper for reasons going to be discussed in subsection E.

and its impact on efficiency. Since a large fraction of firms in the database do not patent at all, we construct the logarithm of the patent stock by adding one to the initial number of patents to tackle the zero value problem.

Other-Controls - We control for sector specific unobserved cross-sectional differences by including 21 sector dummies based on two-digit NACE codes. A dummy for a firm's location in East Germany is included since this part of the country is characterised by specific economic and institutional structures resulting from the transformation process, including a high level of public support (see Czarnitzki and Licht (2006)). Finally, the model includes a control for the firms' fixed assets-to-sales ratio. At equal cash flows, firms with a higher stock of fixed assets have higher depreciation rates resulting in lower return on sales.

E. Estimaton Strategy

The dependent variable (pre-tax return to sales) is a categorial variable with known thresholds based on seven categories, see appendix. For the first category of the pre-tax return to sales, the only information we have is that it takes values of less than zero per cent. Furthermore, for the last category, we only know that observations can take values of at least 15 per cent. Thus, the dependent variable in our survey data is censored from both, the left and the right. Following Wooldridge (2002) we can estimate the model by making distributional assumptions. We define the cell limits from the questionnaire to be $a_1 < a_2 < ... < a_7$ and assume the error terms to be normally distributed (instead of standard normally like in the OLS case) and use a maximum likelihood estimation instead of OLS. This approach differs from the standard ordered probit model as follows: it "[...] is exactly ordered probit with cut points fixed and with $\boldsymbol{\beta}$ and σ^2 estimated by maximum likelihood" (Wooldridge (2002) p. 509). Such a model is called an interval regression. Since maximum likelihood is inconsistent under heteroscedasticity, we estimate the model using heteroscedasticity robust standard errors.

IV. Estimation Results

The results from the interval regression are presented in table 2. The table reports marginal effects which can be interpreted like in a standard OLS model for four model variants. While model 1 only includes one dummy for environmental innovations (EI), model 2 separates the effects of environmental innovations by regulation driven and voluntary innovations, and model 3 separates between resource efficiency and only externality reducing innovations. The final model variant contains dummies for each combination of environmental innovation.

Model 1 finds a positive though only weakly significant effect of environmental innovations on firm profitability. When distinguishing between the role of government regulation for introducing environmental innovations, we find that the positive impact on profitability only holds for regulation driven innovation, while we find no effect (neither positive nor negative) for voluntary environmental innovations. A Wald test against the Null that regulation- and non-regulation-induced innovation environmental innovation are equal in their impact on profitability cannot be rejected, however (p-value = 0.3548). If we would stop at this point, the results of the models 1 and 2 must be interpreted in a way similar as the proponents of Porter's hypothesis do. Namely, that regulation improves firms profitability by leading to innovation that over-compensates regulatory costs. To see that this is not true in general, the models 3 and 4 add some more complexity to the analysis.

Table 2: Estimation Results

DEPENDENT VARIABLE: RETURN ON SALES IN PERCENT	ESTIMATED MODELS 1	2	3	4
EI	0.3981*			
	(0.2239)			
EI_REG ($r = 1$)		0.5487**		
		(0.2727)		
EI_NOREG ($r = 2$)		0.3150		
		(0.2438)		
EI_RES ($t = 1$)			0.9827***	
			(0.2694)	
EI_EXT ($t = 2$)			-0.4861*	
			(0.2674)	
EI_RES_REG ($t = 1$), ($r = 1$)				1.4685***
				(0.4842)
EI_EXT_REG ($t = 2$), ($r = 1$)				-0.8121*
				(0.4757)
EI_RES_NOREG ($t = 1$), ($r = 2$)				0.8068***
				(0.3119)
EI_EXT_NOREG ($t = 2$), ($r = 2$)				-0.4265
				(0.3119)
MS_Herfindahl index	0.0001	0.0001	0.0001	0.0001
	(0.0002)	(0.0002)	(0.0002)	(0.0002)
MS_market share	1.5978***	1.6011***	1.6213***	1.6301***
	(0.4062)	(0.4061)	(0.4062)	(0.4062)
MS_perceived hard competition	-1.1487***	-1.1487***	-1.1411***	-1.1412***
	(0.2041)	(0.2041)	(0.2038)	(0.2038)
PD_market novelties†	0.2226	0.2252	0.2319	0.2349
	(0.2613)	(0.2613)	(0.2610)	(0.2612)
PC_reduction of per unit costs†	0.4763*	0.4667*	0.4125	0.4029
	(0.2574)	(0.2576)	(0.2600)	(0.2601)
ST_log of patent stock	0.2806	0.2724	0.2675	0.2543
	(0.1710)	(0.1711)	(0.1709)	(0.1710)
ST_log of full time employees	-0.3528***	-0.3571***	-0.3593***	-0.3637***
	(0.0684)	(0.0685)	(0.0685)	(0.0686)
C_location dummy	-0.0984	-0.0946	-0.0919	-0.0844
	(0.2203)	(0.2204)	(0.2203)	(0.2204)
C_assets-to-sales ratio	-0.1185***	-0.1192***	-0.1211***	-0.1217***
	(0.0446)	(0.0446)	(0.0446)	(0.0445)
C_sector dummies‡	yes	yes	yes	yes
Constant	6.4695***	6.4822***	6.4690***	6.4876***
	(0.4924)	(0.4924)	(0.4899)	(0.4902)
Ln_sigma	1.7881***	1.7880***	1.7867***	1.7865***
	(0.0151)	(0.0150)	(0.0150)	(0.0150)
OBSERVATION SUMMARY:				
left-censored	474	474	474	474
uncensored	0	0	0	0
right-censored	418	418	418	418
interval	2986	2986	2986	2986

* p<0.10, ** p<0.05, *** p<0.01, robust standard errors appear in parentheses
† The model includes two dummies indicating missing values in PD and PC, respectively.
‡ The model includes 21 jointly significant sector dummies based on aggregated NACE 2-digit levels.

Model 3 separates between resource efficiency improving and externality reducing environmental innovations: The prior exerts a statistically highly significant positive effect on profitability while the latter reduce a firm's profit to sales ratio. Rejecting the Null of a Wald test (p-value = 0.0022) that both coefficients are equal in their impact on profitability confirms our hypothesis one that both types differ in their impact on profitability.

Model 4 further distinguishes both types of innovations into regulation-induced and non-regulation-induced ones. If the Porter hypothesis holds, both resource saving innovations and externality reducing innovations induced by regulations must provide a statistically significant positive impact on return on sales. Obviously, this proposition fails an empirical proof. Regulation-induced innovations that reduce environmental externalities have a negative impact on firms' profitability, however this impact is only weakly significant. In such a case a firm faces a 0.8121 percentage points *decrease* in return on sales compared to the control group, i.e. those firms which have not introduced innovations with any kind of environmental benefits. A firm that introduced also innovations that reduce environmental externalities but not due to regulatory constraints does not face a change in profitability significantly different from zero. This seems plausible because it is rather unlikely that a firm would introduce such innovations by its own choice when no firm benefits can be expected. However, firms which introduced innovations that lead to more resource efficiency in response to regulation are rewarded by an 1.4685 percentage point *increase* in returns on sales compared to the control group. For firms having also introduced such innovations but not due to regulatory pressure, the premium is only of 0.8068 percentage points compared to the control group. This result is also quite interesting because it supports Porter's view that regulation can shift firm's attention to potentials for further process improvements, however only for the case of resource efficiency improving innovations and not in general. To provide evidence on this paper's second hypothesis we test the Null that regulation-induced resource efficiency improving and externality reducing innovations have equal impact on profitability. The Wald test's p-value of 0.0129 allows to reject the Null and provides support for out second hypothesis, namely that the Porter hypothesis does not hold in general but for resource efficiency improving innovations. Also the third hypothesis in our papers is supported given the data because voluntary environmental innovations of any type did not significantly reduce profitability. They increase profitability if they improve resource efficiency.

Finally, the most important controls are of their expected signs. Market structure appears to be the most important determinant of return on sales while market concentration is found to have no impact. This finding is consistent with Schmalensee (1989). From an extensive study of the related literature he postulates the stylized fact that there is only a very small and weak relationship between concentration on profitability that even disappears in many studies. Heger and Kraft (2008) provide evidence for this finding and furthermore show that if concentration measures based on firms' perceived competitive environment are used, they are of their predicted sign regarding their effect on profitability. In our model, the dummy for perceived hard competition has a strong statistically significant and negative impact on profitability as expected.

The significant negative impact of firm size measured with the log of full time employees indicates a negative effect of scale similar to Czarnitzki and Kraft (2010). However, the reason for this finding remains unclear. The technological level measured with the log of the patent stock does not provide significant impacts on profitability similar to the innovation variables for product and cost saving process innovations. The latter appears to have an significant impact on return on sales only in the models 1 and 2.

V. Concluding remarks

There is an ongoing debate on likely competitiveness benefits of environmental regulations, initiated by Porter (1991) and Porter and van der Linde (1995). In this debate, two parties can be identified. The opponents' point of view is conventional economic wisdom. They argue that regulation is a barrier to competitiveness, or in other words: There is a conflict between competitiveness and the environment. Porter (1991, p. 168) argues that this is a “false dichotomy” due to a “static view of competition”. Following Porter and van der Linde (1995), regulatory costs may be more than offsetted by profitability gains of innovations that have been introduced to comply with regulations. This is the proponents' point of view in the debate and has become known as the "strong" version of the Porter hypothesis.

Roughly speaking, our approach does not provide evidence in favor of any of the both points of view. The key finding is that the valildity of the Porter hypothesis depends on the nature of regulation-induced innovations. We arrive at this conclusion by distinguishing two types of environmental innovations and whether they are regulation-induced or voluntary. Compared to firms that did not introduce any environmental innovation, both regulation-induced and voluntary innovations that improve resource efficiency increase profitability. This positive effect is larger for regulation-driven innovation. However, innovations that only reduce environmental externalities lower firms' profitability if they are regulation-induced whereas voluntary abatement investments do not affect profitability significantly.

To unmask the impact of regulation-triggered environmental innovations on profitability, several control variables are constructed that may mask the relationship of interest. For the controls, we rely on seminal literature regarding the market structure-performance relationship. Thus, we include proxies for market concentration, market share and innovative performance.

The implication of our approach is very simple. Environmental regulation cannot be seen as to increase firms competitiveness in any case.The strong version of the Porter hypothesis seems to be valid only for regulations that allow firms to reduce environmental externalities by increasing their resource efficiency. However, the present approach leaves important aspects untouched that are worth to be mentioned. In this study, we do not look on the long-term effects of regulation-induced environmental innovations on profitability. Porter and van der Linde (1995) argue that especially in the long run companies will benefit from such innovations, for instance because of a first mover advantage. Our data does not allow to study this supposed relationship since the German innovation survey captured environmental innovations and the role of regulation for the first time in its 2009 version. We will address this question in future research when data on firm performance is available for further years.

APPENDIX: DESCRIPTIVE STATISTICS

Table 3: Summary Statistics of the Dependent Variable

PRE-TAX RETURN ON SALES		CATEGORIES	FREQUENCY	PERCENT
Smaller than 0 %	(left-censored)	a_1	474	12.22
0 % until < 2%		a_2	722	18.62
2 % until < 4%		a_3	656	16.92
4 % until < 7%		a_4	666	17.17
7 % until < 10%		a_5	499	12.87
10 % until < 15%		a_6	443	11.42
15 % and more	(right-censored)	a_7	418	10.78
Total			3878	100.00

Table 4: Summary Statistics of the Independent Variables

VARIABLES	OBS.	MEAN	STD. DEV.	MIN	Max
EI	3878	0.6211965	0.4851516	0	1
EI_REG ($r = 1$)	3878	0.2470346	0.4313426	0	1
EI_NOREG ($r = 2$)	3878	0.3741619	0.4839682	0	1
EI_RES ($t = 1$)	3878	0.5312017	0.4990899	0	1
EI_EXT ($t = 2$)	3878	0.5244972	0.4994639	0	1
EI_RES_REG ($t = 1$), ($r = 1$)	3878	0.2163486	0.4118078	0	1
EI_EXT_REG ($t = 2$), ($r = 1$)	3878	0.2315627	0.4218854	0	1
EI_RES_NOREG ($t = 1$), ($r = 2$)	3878	0.314853	0.4645172	0	1
EI_EXT_NOREG ($t = 2$), ($r = 2$)	3878	0.2929345	0.4551673	0	1
MS_Herfindahl index	3878	4600.8478	8300.9498	20.107	99430.292
MS_market share	3878	0.1732166	0.2675355	0.00001	1
PD_market novelties (1)	3878	0.2075812	0.4056275	0	1
PC_reduction of per unit costs (2)	3878	0.2073234	0.4054415	0	1
Indicator for missing values in (1)	3878	0.0092831	0.0959131	0	1
Indicator for missing values in (2)	3878	0.0144404	0.1193129	0	1
ST_log of full time employees	3878	30.700021	10.703573	-0.6931472	130.03182
ST_log of patent stock	3878	0.2235892	0.7506332	0	90.307014
C_assets-to-sales ratio	3878	0.7355721	20.622633	0	720.72727
C_location Dummy	3878	0.3037648	0.4599416	0	1

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