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Environmental Innovations and Profitability: How Does it Pay to be Green?

An Empirical Analysis on the German Innovation Survey

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Das Wichtigste in Kürze

Die Europäische Kommission verfolgt in ihrer Strategie "Europe 2020" das Konzept einer "intelligenten, nachhaltigen und integrativen Wirtschaft", das mit Verbesserungen in den Bereichen grüner Produktion und grünen Konsums einhergeht. In diesem Konzept sind die Einführung und Diffusion von Umweltinnovationen durch Unternehmen ein Schlüssel für die Verbesserung der Nachhaltigkeit des Produktionsprozesses, sowohl bezüglich des integrierten Umweltschutzes (*Cleaner Production measures*) als auch bezüglich nachgeschalteter Maßnahmen (*End-of-Pipe technologies*).

Während über die Determinanten von Umweltinnovationen in der Literatur wachsende Einigkeit besteht, werden die ökonomischen Implikationen ihrer Adoption immer noch kontrovers diskutiert. Müssen Unternehmen auf rentablere Investitionen verzichten, wenn sie ihre Ressourcen der Verbesserung ihrer ökologischen Performance widmen? Oder handelt es sich um einen neuen Wachstumspfad, der auch Renditen verspricht? Zahlreiche Forschungsprojekte haben sich auf verschiedenen Untersuchungsebenen der Analyse dieser Frage gewidmet, ohne eine klare Antwort zu geben ob sich eine grüne Performance auszahlt oder nicht.

Unser Beitrag zur Diskussion besteht in einer Differenzierung zwischen verschiedenen Typen von Umweltinnovationen. Unser wesentliches Argument ist, dass die Antwort auf die Frage davon abhängt, auf welche Weise ökologisch innoviert wird. Mit anderen Worten: Die "Black Box" von Umweltinnovationen muss geöffnet werden, um ihre Auswirkungen auf die Wettbewerbsfähigkeit differenzieren zu können.

Empirische Evidenz für dieses Argument finden wir in Daten zum Innovationsverhalten deutscher Unternehmen, die wir aus zwei Wellen des Mannheimer Innovationspanels für die Jahre 2011 und 2009 zusammengestellt haben. Unser Ergebnis lautet, dass die Frage *a priori* nicht beantwortet werden kann. Stattdessen ist der Typ von Umweltinnovationen zu spezifizieren. Effizienzverbessernde Innovationen wie beispielsweise Maßnahmen zur Erhöhung der Energie- und Materialeffizienz weisen eine positive Wirkung auf die ökonomische Performance von Unternehmen aus. Negativ sind die Wettbewerbswirkungen dagegen bei jenen Umweltinnovationen, die lediglich negative externe Effekte der Produktion internalisieren, wie beispielsweise die Reduktion von Lärm-, Luft-, Boden- und Wasserbelastungen. Während diese Innovationen – je nach Stand der Umweltregulierung – langfristig durchaus profitabel sein können, zahlen sie sich kurzfristig bei gegebener Umweltregulierung nicht aus.

Bevor eine Umweltinnovation positive Wettbewerbswirkungen zeigt, müssen zunächst bestimmte Schwellenwerte erreicht werden. Unsere Analysen zeigen, dass nur sehr umweltinnovative Unternehmen nach Einführung einer Umweltinnovation Variationen in ihrer Profitabilität aufweisen.

Non-technical Summary

The achievement of the goals set by the broad 10-year growth strategy “Europe 2020” of the European Commission, aiming by 2020 at a smart, sustainable and more inclusive economy, is intertwined with improvements towards greener production processes. The generation and adoption of Environmental Innovations by firms are consequently keys to improve the sustainability of the production processes, either when innovations are integrated in the production process (*Cleaner Production measures*), or when innovations are add-on measures (*End-of-Pipe technologies*). Whereas a consensus on the determinants of Environmental Innovations seems to be growing, still widely debated are the economic implications of their adoption. Are firms missing economic opportunities when they commit resources to improve their environmental performances, or is it true the opposite? A deep research effort has been devoted to the analysis of the economic performance effects of improvements in the environmental performances, at various levels of analysis, but still no clear answer has been provided to the question whether *it pays or not to be green*.

We contribute to this debate by proposing a differentiation between different typologies of Environmental Innovations. Our main argument is that it depends on how to be green, i.e. the “box” of Environmental Innovations has to be opened to disentangle the competitiveness effect of their adoption. We find support to this argument by using data on German firms extracted from the merge of two waves of the Mannheim Innovation Panel for the years 2011 and 2009. Our results suggest that profitability gains depend on the typology of innovation considered. In other terms, it cannot be argued *a priori* whether it pays or not to adopt greener production processes, as it is needed to specify the typology of innovation considered. Efficiency improving innovations, such as those innovations that reduce the use of materials or energy per unit of output are found to positively impact firms’ economic performances. Contrarily, some negative profitability effects might be associated with innovations that are targeted at reducing production negative externalities, such as reduction of air, soil, water and noise pollution as well as those to replace dangerous materials. Although they may be profitable in the long run due to improved environmental regulation, it does not pay off in the short run when environmental regulation has to be faced as an external restriction.

The existence of a threshold before innovations can engender profitability gains is also depicted, as only highly eco-innovative firms are facing profitability variations after the adoption of environmental innovations.

Environmental Innovations and Profitability:

How does it pay to be green?

An empirical analysis on the German Innovation Survey

Claudia Ghisetti[♠*] & Klaus Rennings[♦]

Abstract

Much of the empirical literature analysing the relation between environmental innovation and competitiveness has focused on the question whether "it pays to be green". We differentiate between different types of environmental innovations, which will be disentangled in those aiming at reducing the negative externalities and those allowing for efficiency increases and cost savings. What we analyze is at first the extent to which these two typologies have impacts on firms' profitability with opposite signs, and, secondly, whether the motivations driving the adoption of those innovations make the difference in terms of economic gains. We find empirical evidence that both the typology of Environmental Innovation and the driver of their adoption affect the sign of the relationship between competitiveness and environmental performance. The empirical strategy is based on a sample of German firms and makes use of a merge of two waves of the Mannheim Innovation Panel in 2011 and 2009 that allow overcoming some endogeneity issues which may arise in a cross-section setting.

Key Words: Profitability, Externality Reducing Innovations, Energy and Material Efficiency Innovations, Mannheim Innovation Panel

JEL Codes: Q55 Q20 M10 K32

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1 Introduction

The broad 10-year growth strategy “Europe 2020” of the European Commission, aiming at a smart, sustainable and more inclusive economy” by 2020 (EC, 2010), is depending upon improvements towards a greener production that may lead to a “decoupling” of environmental pressure and economic growth. The generation and adoption of Environmental Innovations (from now on EI[1]) by firms are consequently keys to improve the sustainability of the production processes. This holds either when innovations are integrated in the production process (*Cleaner Production measures*) or when innovations are add-on measures that allow to reduce the negative externalities of the production in the last stage of the production process, for example by including specific filters to reduce pollution (*end-of-pipe technologies*). Previous literature has highlighted the peculiar nature of EI (e.g. Horbach, 2008; Rennings, 1998, 2000) and, suggesting the need of a multidisciplinary approach (e.g. Kemp, 2010), has recently contributed to a better understanding and identification of the determinants that are beyond the generation and the adoption of EI within firms.

Whereas a consensus on the determinants of EI[2] seems to be growing, the economic implications of their adoption are still widely debated, to understand whether firms are missing (getting) economic opportunities in improving (not improving) their environmental performances. We contribute to this debate on whether it pays or not to “be green” by proposing a differentiation between different typologies of EI. Our main argument is that it depends on how to be green, i.e. the “box” of EI has to be opened to disentangle the competitiveness effect of their adoption. Some neutral or even negative profitability effects might be associated with EI that are only aiming at reducing negative production externalities, while some positive economic benefits are indeed expected when EI are cost saving and/or efficiency improving innovations. Our corollary argument is that what drives the adoption of EI can influence the competitive outcome of the EI itself. Section II discusses the theoretical framework our research is based upon. The empirical analysis is carried out on the Mannheim Innovation Panel dataset for the years 2011 and 2009 and will be made clear in Section III. Section IV provides a discussion of our results and highlights a set of robustness checks we implemented to reinforce our estimates. Section V concludes.

2 Theoretical framework

A deep research effort has been devoted to the analysis of the economic performance effects of improvements in the environmental performances at various levels of analysis, where economic performance has been conceived through short-term measures, such as profitability or even longer term measures that capture firms’ competitiveness. While still no clear answer has been provided, the research question whether it pays or not to be green has existed for a long time.

[1] Multiple and exhaustive definitions of EI have been provided by the literature (e.g. Kemp and Pearson 2007; Kemp, 2010; Rennings, 2000). Among them, the one we will be referring to is the following: “the production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the firm [or organization] and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives” (Kemp and Pontoglio, 2007, p. 10).

[2] The extant literature has mainly agreed on the relevance of a cluster of EI determinants, mainly *Market-pull*, *Technology-push*, *Firm specific factors* and *Regulation* (e.g. Horbach et al., 2012; Mazzanti and Zoboli, 2005; Wagner, 2008; Rennings and Rexhäuser, 2010; Ziegler and Nogareda, 2009). The access to knowledge sources coming from outside the firms’ boundaries is more recently also found to be relevant (Mazzanti and Zoboli, 2005): relying on external knowledge sources is indeed positively influencing the adoption of EI and the enlargement of an EI portfolio within firms (Ghisetti et al., 2013) and cooperating in R&D is far more important for EI than for technological innovations (De Marchi, 2012).

A first useful insight comes from the broad literature on Corporate Social Responsibility (CSR) (e.g. Porter and Kramer, 2002 and 2006), given the central role of environmental responsibility in such a framework (e.g. Hart, 1997; Orlitzky et al. 2011). According to these studies, irrespective of whether the adoption of cleaner technologies can be a by-product of a strategy aiming at improving firms' market evaluation, or the access to new (green) markets, or as part of a cost-reduction strategy (Ambec and Lanoie, 2008), such an adoption might still engender positive business performance effects. Furthermore, according to the natural-resource-based view[3] (NRBV) of the firm, it is expected that firms' profitability is positively influenced by the competitive advantages generated by the accounting of the natural environment as this pro-active behavior favors the development of strategic resources that are engendering positive economic returns (Hart, 1995). Ecosystem degradation and resources depletion engender a threat to firms' resources (Hart and Dowell, 2011), and as a reaction, firms can pro-actively adopt an environmental strategy (Hart, 1995), which can be read as the development of a dynamic capability (Aragon-Correa and Sharma, 2003). To this respect, firms facing higher risks associated to climate change are those subject to greater incentives to develop green strategies (Hoffman, 2005). Moreover, the idea that *it pays to be green* became even more attractive when it was linked to the NRBV as "it is a theory of how an individual firm might gain a competitive advantage by going green" (Berchicchi and King, 2007: 516). The economic benefits deriving from pollution reduction are, however, usually underestimated by managers (e.g. Hart, 1995; Berchicchi and King, 2007 for a discussion) and this might lead to sub-optimal levels of environmental efforts if it is acknowledged that innovations might more than offset the cost of compliance to stringent environmental standards (Porter and van der Linde, 1995). This underestimation can be driven by the costs associated to collecting proper information about the values and returns of different pollution reduction factors as firms can be unwilling to bear the search costs and thus can underexploit or abuse certain "greener" production techniques (King and Lenox, 2002). Waste prevention processes, for instance, have proved to be underexploited because of their not-directly-observable benefits (e.g. King and Lenox, 2002; Russo and Fouts, 1997).

Given this framework of analysis, a range of empirical studies have been devoted to test the relationship between financial and environmental performance in a firm-level analysis. Those studies provided a very mixed picture on the signs of this relation and on the empirical strategies to be adopted. According to Horváthová (2010), 15% of them found a negative, 55% a positive, and 30% found no effect of environmental performances on economic performance. In studying the profitability effects, measured as Returns on Equity (ROE), of environmental performance ratings in the pulp and paper industry, Bragdon and Marlin (1972) found support that it pays to be green. The same positive sign, but with different measures of financial performance, can also be found in Russo and Fouts (1997), adopting Returns on Assets (ROA), in Salama (2005), assessing the Corporate Financial Performance, and in King and Lenox (2001) and Dowell et al. (2000), adopting the Tobins'*q* index. King and Lenox (2002) provided some further insights by showing that the positive correlation between financial and environmental performance were driven by a particular type of practice, i.e. the waste prevention methods. A confirmation that less polluting firms benefit from improved financial performances also comes from Hart and Ahuja (1996), who furthermore highlighted that Operating

[3] The NRBV somehow challenges the Resource Based View of the firm as it ignored how the interaction between an organisation and its natural environment helps explaining the competitive advantages (Hart, 1995). According to this view, and without the willingness to be exhaustive, three key strategic capabilities are at stake: *pollution prevention, product stewardship,* and *sustainable development*, each of them facing different drivers, building upon different resources and engendering heterogeneous competitive advantages (Hart and Dowell, 2011).

Performance (Returns on Sales (ROS) and ROA) was benefiting from the year after the initiation of pollution prevention strategies, while it required 2 years before financial performance (in terms of ROE) was positively affected. To overcome the simultaneity problem that may arise in a cross section setting, i.e. that environmental and economic performance usually go hand in hand as they are jointly determined and jointly depending on the unobservable firms' management strategy, Al Tuwaijri et al. (2004) adopted a Three Stages Least Squares estimation (following Ullmann, 1985) and still found support of a positive relationship between environmental and economic performance.

Contrarily to those evidences, in studying the effect of environmental performance on financial performances measured as ROS on a sample of US firms in a cross-section setting, Cordeiro and Sarkis (1997) found support for short-term negative effects, which were stronger for *pollution prevention strategies* than for *end-of-pipe measures*. A negative effect on the Return on Capital Employed (RoCE) was also found in the European context, in particular, on the European paper industry using a simultaneous structural model, but when adopting different measurements for the financial performance, such as ROE or ROS, the effect was no longer significant (Wagner et al., 2002). Similarly, a neutral effect is also detected by Freeman and Jaggi (1992). However, Elsayed and Paton (2005) suggested that previous mixed results were driven by misspecification issues, which were due to the inability of previous contributes to properly account for unobserved firms' fixed effects. In confronting a static and a dynamic panel analysis on UK data, they found that environmental performance has only a weak impact on the financial performance as outlined by their dynamic specification, while the cross-section one suggested stronger (biased) correlations. Coherently, Telle (2006) argued the conclusion that "it pays to be green" is premature, as when applying a random effect panel model instead of a pooled OLS one, the positive economic gains of environmental performances were no longer significant.
These heterogeneous results pointed to the conclusion that the question is no longer *if* it does pay to be green, but rather *when* or *for whom* it pays (Telle, 2006; King and Lenox, 2001).

We argue that the question has to be better qualified in terms of the typologies of environmental innovations to be considered as what we expect is that different EI engender heterogeneous competitiveness effects in a firm-level analysis. Thus, we formulate the research question as *"How does it pay to go green?"*.

EI can indeed be decomposed into at least two typologies, Energy and Resource Efficiency Innovations (from now on EREI), i.e. those innovations whose effects consist in a reduction of material and energy used per unit of output, and Externality Reducing Innovations (ER from now on), i.e. those innovations aimed at reducing production externalities such as air, water, noise pollution and harmful materials. Although both EREI and ER face the "double externality problem" typical for EI, as they still produce innovation spillover and reduce negative production externalities, empirical evidences have been provided that the two typologies are inherently different, either in the drivers (e.g. EREI benefit more from the use of external information sources) or in the productivity (sales over employees) or in the role of barriers to innovation, which are perceived as more intense for EREI than for other EI (Rennings and Rammer, 2011). Evidence is also found that the effects of firm's "green" investment strategy improve firm's productive efficiency only when the investment in cleaner production technologies is targeted at reducing (simultaneously) both the externalities and the use of raw materials (Antonietti and Marzucchi, 2013). Furthermore, firms' ability to generate profits may differ, depending on their resource bases, between those that respond to a policy compliance by introducing *end-of-pipe innovations* and those that redesign their production processes and services (Russo and Fouts, 1997). The introduction of *end-of-pipe technologies* does not fundamentally modify production processes, thus it does not alter neither firms' resources nor capabilities. Consequently, it is not expected to engender any positive effects on firms' competitiveness, while it can rather be just a cost burden to the firm and leading to negative outcomes. Improved environmental performances are indeed expected to engender positive competitive gains when a change in the resource bases and capabilities follows the redesign of the production process (Russo and Fouts, 1997). As EREI are actually leading to a reduction in the use of physical resources, they can consequently be a source of competitive advantage and thus they are expected to exert a positive effect on firms' profitability. Investments in *end-of pipe technologies* are instead found to be associated with lower performance (Klassen and Whybark, 1999), thus we can expect a different sign for ER.

Coherently our main hypothesis is that profitability effects of EI are heterogeneous and depend on the typology considered. EREI are expected to positively affect profitability, as they can lead to a "win win" situation in which the improvement of environmental performance is leading to economic gains. Furthermore, the idiosyncratic characteristics of the resources energy and materials might lead firms to benefit of a competitive advantage when they introduce EREI. ER are instead less related to the exploitation in the production process of scares resources that may engender competitive advantages, in case are uniquely exploited and combined. Those are though not expected to lead to positive profitability gains, as no "win win" situation might be related to their adoption.

Secondly, we test whether the motivations behind firms' decisions to adopt EREI or ER may themselves impact on their profitability gains. In particular we are going to test whether EREI or ER introduced in response to a current or foreseen regulation (*EREI_REG* and *ER_REG*) engender different profitability gains compared to *EREI* or *ER* introduced as a reaction to the availability of financial incentives, grants or subsidies specifically targeted at introducing *EI* (*EREI_GR* and *ER_GR*), and also compared to EREI or EI that were voluntarily introduced by firms thanks to the existence of voluntary codes or agreements for good environmental practices (*EREI_VOL* and *ER_VOL*).

As far as EI introduced as a response to regulation are concerned, a wide strand of research emerged to test the existence of a Porter-like mechanism in assessing the competitiveness effects of the adoption of a stringent environmental regulation. On the one side, environmental regulation has been seen as a threat to firms' competitiveness (e.g. Gollop and Roberts, 1983) or as a cause that induces firms to relocate their production in less regulated areas as the literature on the *pollution haven hypothesis* points out (e.g. Brunnermeier and Levinson, 2004 for a survey). On the other side, since the seminal contribution by Porter (1991) and Porter and van der Linde (1995), a strand of literature aimed at testing the presence of a possible "win-win" solution has emerged, which may arise after the introduction of an environmental regulation[4] (Beise and Rennings, 2005). Since Porter sees resource

[4] Several empirical studies provided a confirmation of this Hypothesis and it is not the aim of the current work to provide an exhaustive revision of such a wide and articulated research field. What we are willing to highlight is that, according to the Porter Hypothesis, strict regulation is not necessarily damaging competitiveness, but can indeed often enhance it (Porter, 1991) as a properly designed regulation may indeed trigger innovation allowing to offset, partially or fully, the cost of complying to those standards (Porter and van der Linde, 1995). Pollution is not only a production externality that diverts the costs from the firm to the whole society, as seen in the standard approaches, but it is often also a waste of resources for the firm, for example in terms of energy-inefficient production processes. Consequently, a properly designed regulation might call firms' attention about these inefficiencies and suggest technological improvements leading firms to a Pareto improvement, coupling environmental protection with competitiveness enhancement (Ambec et al., 2013). Moreover, the introduction of a specific regulation in one industry j in a specific country i, may engender a "first mover" competitive advantage to the firms located in i and belonging to j when compared to firms belonging to countries that will be introducing such environmental constraints only in a further period (e.g. Beise and Rennings, 2005). A confirmation of the hypothesis comes from several empirical studies, for instance, Rassier and Earnhart (2010) found that the Clean Air Act regulation has improved the ROS both in the short and in the long run in a sample of publicly owned firms in the US chemical manufacturing industry and Lanoie et al. (2008), studying the effects of the stringency of regulation and Total Factor

efficiency as a part of firms total efficiency, his hypothesis would imply that mainly *EREI* show positive effects on competitiveness, while the effects of *ER* depend on the degree that environmental external effects are already internalised by regulation. Mixed results have emerged in the empirical literature on the Porter hypothesis. Rexhäuser and Rammer (2013) were the first who properly distinguished between *EREI* and *ER* in testing for the existence of a Porter-like mechanism and indeed found a confirmation of the Porter hypothesis only for EREI, which exert a positive effect on firms' profitability either when they are or are not regulation driven, while negative effects are exerted by *ER*[5].

What follows is our second hypothesis that profitability effects of *EREI* and *ER* vary according to the motivation that was driving their adoption by firms as each of the three motivations may affect the adoption of heterogeneous innovations and this is moderating the profitability effects of the innovation itself. Regulation driven *EI* are mainly leading to an internalisation of negative externalities which can also be beneficial to the firm, according to the argument articulated so far and coherently with the Porter Hypothesis. On the other side, financial incentives are usually provided for the introduction of innovations that are not profitable on their own, thus moderating the adoption of less profitable EI, which are in our case ER rather than EREI, while voluntary adopted *EI* are expected to lead mainly to cost saving innovations rather than to innovations which are perceived as a cost-burden to the firms.

3 Empirical strategy

3.1 Data

The empirical test of our research hypothesis makes use of the Mannheim Innovation Panel (MIP), an annual survey based on a panel sample of German firms conducted by the Centre for European Economic Research (ZEW) in Mannheim.

The 2009 wave of the MIP includes a set of questions on EI that are coherent with the European Community Innovation Survey (CIS) 2006-2008. The advantage of the MIP with respect to the CIS lies in the fact that it also surveys information on firm profitability and market structure that allows building our dependent and control variables. Furthermore, as it will be outlined below, we benefited from the opportunity to merge 2 waves of the survey in order to lag the explanatory variables with respect to the dependent one. The target population are enterprises with 5 or more employees from most economic sectors[6] and the sample is stratified by sector (56 sectors at the 2-digit level of NACE rev. 2.), size class (8 classes according to the number of employees) and region (West Germany and East Germany). The voluntary nature of the survey is the reason for a response rate that is lower than in compulsory surveys (in 2009 it was 26 percent)[7]. More importantly, a non-respondent test has been implemented to test the presence of a selection bias in the responses and this excluded the existence of systemic differences between respondents and non-respondents.

The operative sample used in this research consists of 1063 observations, which is equal to the 15% of the total sample of the MIP 2009. The loss of observations is due to the fact that the samples of the

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Productivity growth in Quebec manufacturing sector, found that the effects are stronger for industries more exposed to international competition and positive in the long run while negative in the short run.

[5] Nevertheless, the negative effect disappears for ER which are driven by current or expected regulation, while it is persistently negative for ER which are not regulation-driven.

[6] Excluding farming and forestry, hotels and restaurants, public administration, health, education, and personal and cultural services. For further details on the MIP, see Janz et al. (2001) and Aschhoff et al. (2013).

[7] But it is not an unusual response rate for voluntary mail surveys in Germany (Grimpe and Kaiser, 2010).

two waves of the MIP that we merged, i.e. the MIP 2009 and the MIP 2011, did not include the same firms, to the high attrition rate of firms, and to the non-responses to all our core variables. We were able to match only 44% of firms surveyed in the MIP 2009 with the MIP 2011. Furthermore, most of the firms surveyed in both waves did not answer all the questions asked, thus reducing the sample for which we have information on all the variables we modeled to 1063. A set of robustness checks have been performed to exclude the presence of a sample selection bias in our estimates and these will be discussed in the following sections.

3.2 Empirical model and variables description

Our first research hypothesis is based on the argument that it is required to differentiate between the typologies of EI, in particular EREI and ER, to assess the profitability effects of those innovations will be tested by confronting the estimations of the model presented in equation (1) and those in equation (2)-(4).

$$OM_i = \alpha + \beta_1 EI_i + \beta_2 MS_i + \beta_3 HHI_i + \beta_4 SIZE_i + \gamma\, SECT_i + \epsilon_i \quad (1)$$

$$OM_i = \alpha + \beta_1 EREI_i + \beta_2 ER_i + \beta_3 MS_i + \beta_4 HHI_i + \beta_5 SIZE_i + \gamma\, SECT_i + \epsilon_i \quad (2)$$

$$OM_i = \alpha + \beta_1 EREI + \beta_2 ER_i + \beta_3 MS_i + \beta_4 HHI_i + \beta_5 SIZE_i + \beta_6 RD_i + \beta_7 LPAT_i + \beta_8 PC_i + \gamma\, SECT_i + \epsilon_i \quad (3)$$

$$OM_i = \alpha + \beta_1 EREI + \beta_2 ER_i + \beta_3 MS_i + \beta_4 HHI_i + \beta_5 SIZE_i + \beta_6 RD_i + \beta_7 LPAT_i + \beta_8 PC_i + \beta_9 EAST_i + \gamma\, SECT_i + \epsilon_i \quad (4)$$

Our dependent variable in all the models is firms' profitability (*OM*). We model firms' profitability empirically in terms of Returns on Sales by adopting as a dependent variable (*OM*) the estimated operating margin, meant as pre-tax profits over sales (as in Czarnitzki and Kraft, 2010 and Rexhäuser and Rammer, 2013). In order to reduce non-responses, *OM* data are collected through categorical values that are self-reported by firms on an interval scale that follows the distribution presented in Table 1. As investing in a new environmental technology is probably leading to increasing costs in the short run, while its competitive gains in possible terms may only be realised in a subsequent period (e.g. Hart and Ahuja 1996, Elsayed and Paton, 2005), we found it more appropriate to expect that the adoption of EI in 2006-2008 may engender profitability gains or losses after a certain time lag. For this reason, our dependent variable is extracted from a subsequent wave of the survey, the MIP 2011, while all the explanatory variables refer to the MIP 2009 wave. The merge of these waves of the survey also allows overcoming those endogeneity problems deriving from the simultaneity between *OM* and the explanatory variables and the possible reverse causality issue. More precisely, this merge allows to model the estimated operating margins in 2010 (*OM*) on a set of explanatory variables all referred to the time lag 2006-2008. However, the choice of *OM* as dependent variables still brings about a set of issues that need to be discussed. At first, the merge of two waves of the survey might engender a selection bias due to the (possible) attrition of firms with similar observable and/or unobservable characteristics within the waves as we anticipated when we described the operative sample. In the section on the robustness checks this is discussed. Furthermore, the choice of using self-reported price-cost margin data instead of more objective data might itself be a limitation. On the other side, it has to be remarked that in Germany the majority of firms were not required to publish their accounting data. Consequently, the alternative of using balance sheet data instead of the self-reported would have engendered a clear selection bias as only data for large firms, in particular stock corporations, would have been available. On the contrary, the use of the Mannheim Innovation Panel variable, although self-reported, guarantees the coverage on a representative sample and this is, in our opinion, a valid motivation for our choice[8].

Table 1 Distribution Operating Margin 2010

OM	Freq.	Percent
< -5%	60	5.64
-5% to 2%	38	3.57
-2% to 0%	59	5.55
0% to 2%	156	14.68
2% to 4%	161	15.15
4% to 7%	216	20.32
7% to 10%	150	14.11
10% to 15%	127	11.95
>15%	96	9.03
Total	1063	100

Recalling that all the explanatory variables refer to the time lag 2006-2008, to assess the first research question, three key environmental dichotomous explanatory variables have been constructed: *EI*, *EREI* and *ER*[9].

The first takes value one when at least one process innovation with high environmental benefits has been introduced out of a scale of 9 different dimensions (see **Table 2**), independently on the specific nature of the innovation, and is estimated in Equation (1).

From equation (2) to (4) the environmental innovation variable will be split into *EREI* and *ER* in order to assess our first research question. *EREI* takes value one when two conditions are simultaneously met: a) the firm has introduced process innovations bringing to a reduction of energy and/or material used per unit of output or to a reduction of CO_2 emissions and b) this process innovations lead to high environmental benefits[10]. Similarly, *ER* is equal to one when externality-reducing process innovations leading to high environmental protection have been adopted by the firm and zero otherwise. Process

[8] We had to test for the possible bias that may arise because of the presence of missing values in the dependent variable. A discussion is available in the robustness checks section.

[9] The CIS 2006-2008 introduced an ad-hoc section on Environmental Innovation in which firms were asked to answer whether a new or significantly improved product, process, organisational method or marketing method that creates environmental benefits were introduced, independently on whether the benefits were the primary objective of the innovation or its by-product and independently on whether the innovation was new to the market or just to the firm adopting it. Firms were asked to choose among a set of typologies of environmental innovations they might have introduced. The German CIS is wider than the harmonised one as it includes more typologies of EI a firm can choose with a set of 9 indicators for process innovations, i.e. 3 more than the harmonised CIS, and 3 for product innovations. Furthermore, the German version of the CIS allows firms to rank the environmental benefits associated to each typology of EI introduced following a 4-point Likert scale (no, small, medium, high environmental benefit).

[10] The questionnaire asks firm to report for each environmental innovation typology introduced its contribution to environmental protection out of a *low, medium, high* scale. As the interest of this analysis lies in the competitiveness effects of environmental innovations leading to effective environmental protection, the decision was to focus only on those with *high* effects. In a subsequent step also those with *high* and *medium* effects will be considered.

innovations that reduce air, soil, water and noise pollution as well as those to replace dangerous materials belong to the externality-reducing category. Coherently with previous literature (Rexhäuser and Rammer, 2013), process innovations that improve recycling possibilities are not assigned to any of the two types mainly because recycling may either be a material-saving innovation (thus *EREI*) or an externality-reducing innovation (*ER*), depending on whether it saves the usage of materials or water, or conversely, it improves the recyclability of wastes[11]. As in Rexhäuser and Rammer (2013), the CO_2 emission reduction dimension has been assigned to *EREI* (and not to *ER*) as it is not feasible to pursue any CO_2 emission reduction without energy efficiency improvements as the major driver of CO_2 emissions comes from the energy mix used (for a discussion see Cainelli and Mazzanti, forthcoming). We acknowledge that CO_2 emission reduction innovations are inherently different from energy and material reduction ones. For this reason we needed to test a) whether the exclusion of these innovations from the analysis and b) whether the assignment of these innovations to the *ER* category would have engendered some changes in the results we provided. Results are stable in both the cases[12]. Lastly, given the nature of the research question, environmental product innovations will be excluded from this analysis[13]. See **Table 2** for details in the distributions and composition of *EREI* and *ER* and the dimensions of EI considered.

In our baseline specifications in Equation (1) and (2) we control for the Herfindahl concentration index (*HHI*), and for some firm observable heterogeneities (*SIZE* and *MS*) taking lagged values from the previous wave of the survey to reduce endogeneity problems. As the literature on firms' profitability suggests, highly concentrated markets may pose different competitive conditions to the firms, and this might impact on firms' own profitability. More precisely, previous literature suggests that highly concentrated industries, i.e. industries in which a small number of firms account for a great number of industrial activities, should show higher profitability possibilities (Capon, Farley and Hoenig, 1990).

Table 2 Key Environmental variables EREI and ER in MIP 2009

Environmental Process Innovations	**Share of EI with *low, medium or high* environmental benefits**	**Share of EI with *high* environmental benefits**	**Type of EI**
Reduced Material per unit of output	37%	5%	EREI
Reduced energy per unit of output	44%	6%	EREI
Reduced CO_2 footprint	34%	6%	EREI
Reduced air pollution	24%	4%	ER
Reduced water pollution	24%	4%	ER
Reduced soil pollution	15%	2%	ER
Reduced noise pollution	24%	2%	ER
Replaced dangerous materials	24%	4%	ER
Recycled waste, water or materials	39%	5%	None

Source: Mannheim Innovation Panel 2009

[11] To be sure that this exclusion does not engender a bias in our results we controlled whether the assignment of the *recycled waste, water or materials* category, first to ER and separately to EREI, would have changed our estimation results. We conclude that results are stable in both the cases. A table with these results is available upon request.

[12] A table with these results is available upon request.

[13] The competitiveness returns of new products or services reducing air, water, soil or noise pollution or energy use, or with improved recycling possibilities after use will be mainly depending on demand condition rather than on direct efficiency gains (EREI) or on direct environmental compliance costs (ER). Their inclusion into either EREI or ER variable might thus be misleading in the interpretation of their effect on competitiveness in this specific context. Nevertheless, future research might be focused on a different research question whose more accurate focus will allow including environmental product innovations.

Furthermore, monopolistic markets may predict higher profitability. Accordingly, the Herfindahl concentration index at Sector-level 3-digit calculated by the German Monopoly Commission (*HHI*), as well as self-reported (in MIP) firms market share within the top-selling line of products (*MS*) have been included in the analysis. As a further robustness check, industry concentration measures of the 3 (*C3*) and 6 (*C6*) biggest firms calculated by the German Monopoly Commission has substituted HHI and as they showed very similar results, they are no longer included in the tables[14]. The natural logarithm of employees corrected for part time workers is used to control for the size of the firm (*SIZE)*.

Description and descriptive statistics of the variables are reported in **Table 3**.

Table 3 Variable description and descriptive Statistics

variable	Description	Source	Year	N	Mean	Std Dev	Min	Max
OM	Estimated Operating Margin, i.e. profit before taxes on income as a percentage of turnover	MIP 2011	2010	1063	5.614	2.123	1	9
EREI	Energy, Material and CO2 reduction process innovations with high environmental benefits (Tab. 2)	MIP 2009	2006-2008	1063	0.106	0.308	0	1
ER	Externality reducing process innovations with high environmental benefits (Tab.2)	MIP 2009	2006-2008	1063	0.104	0.306	0	1
EAST	Eastern Germany Location	MIP 2009	2008	1063	0.332	0.471	0	1
SIZE	Natural Logarithm of employees corrected for the part time workers	MIP 2009	2008	1063	4.028	1.577	0.41	10.27
RD	Engagement in internal or external R&D activities	MIP 2009	2006-2008	1063	0.485	0.500	0	1
PC	Process Innovators	MIP 2009	2006-2008	1063	0.394	0.489	0	1
HHI	Herfindahl concentration index at 3 Digit (German Monopoly Commission GMC)	GMC	2007	1063	46.941	78.590	0.21	644.05
LPAT	Natural Logarithm of Patent Stock, built according to the perpetual inventory method	PATSTAT	1978-2008	1063	-7.489	3.719	-9.21	6.11
MS	Firm´s market share within the top-selling line of products	MIP 2009	2006-2008	1063	0.275	0.302	0	1
EREI_REG	EREI introduced in response to a current or future regulation, excluding overlapping assignments that are captured by MIXED_REG	MIP 2009	2006-2008	1013	0.022	0.146	0	1
ER_REG	ER introduced in response to a current or future regulation, excluding overlapping assignments that are captured by MIXED_REG	MIP 2009	2006-2008	1013	0.039	0.195	0	1
EREI_VOL	EREI introduced voluntarily, i.e.in response to sectoral voluntary codes or agreements for environmental good practices, excluding overlapping assignments that are captured by MIXED_VOL	MIP 2009	2006-2008	1013	0.017	0.129	0	1
ER_VOL	ER introduced voluntarily, i.e.in response to sectoral voluntary codes or agreements for environmental good practices, excluding overlapping assignments that are captured by MIXED_VOL	MIP 2009	2006-2008	1013	0.017	0.129	0	1
EREI_GR	EREI introduced in response to the availability of government grants, subsidies or other financial incentives, excluding overlapping assignments that are captured by MIXED_GR	MIP 2009	2006-2008	1013	0.009	0.094	0	1
ER_GR	ER introduced in response to the availability of government grants, subsidies or other financial incentives, excluding overlapping assignments that are captured by MIXED_GR	MIP 2009	2006-2008	1013	0.003	0.054	0	1
EREI_NOREG	EREI introduced but not in response to a current or future regulation	MIP 2009	2006-2008	1013	0.055	0.229	0	1
ER_NOREG	ER introduced but not in response to a current or future regulation	MIP 2009	2006-2008	1013	0.034	0.180	0	1
EREI_NOVOL	EREI introduced but not in response to sectoral voluntary codes or agreements for environmental good practices	MIP 2009	2006-2008	1013	0.066	0.249	0	1
ER_NOVOL	ER introduced but not in response to sectoral voluntary codes or agreements for environmental good practices	MIP 2009	2006-2008	1013	0.062	0.242	0	1
EREI_NOGR	EREI introduced but not response to the availability of government grants, subsidies or other financial incentives	MIP 2009	2006-2008	1013	0.086	0.280	0	1
ER_NOGR	ER introduced but not response to the availability of government grants, subsidies or other financial incentives	MIP 2009	2006-2008	1013	0.088	0.283	0	1
MIXED_GR	EI induced by the existence of government grants, subsidies or other financial incentives without the possibility to disentangle EREI from ER as they were both introduced in response to this motivation	MIP 2009	2006-2008	1013	0.014	0.117	0	1

[14] These tables are available upon request.

MIXED_ VOL	EI introduced voluntarily without the possibility to disentangle EREI from ER as they were both introduced in response to this motivation	MIP 2009	2006-2 008	10 13	0.0 26	0.15 8	0	1
MIXED_ REG	EI induced by regulation, without the possibility to disentangle EREI from ER as they were both introduced in response to this motivation	MIP 2009	2006-2 008	10 13	0.0 32	0.17 5	0	1

We then add in Equation (3) and in Equation (4) to the baseline specification some further variables that may influence firm' heterogeneous profitability and have been suggested to us by previous literature. Given the pairwise correlation outlined in **Table 4** we found it more appropriate not to proceed with a joint inclusion of all the control variables of the full specified model in Equation (4) as some potentially problematic correlations are depicted.

Table 4 Main Variables Correlation Matrix

		1	2	3	4	5	6	7	8	9	10
1	OM	1									
2	EREI	0.0627	1								
3	ER	0.0026	0.4411	1							
4	EAST	0.0133	-0.0164	-0.0644	1						
5	SIZE	-0.0234	0.1061	0.0713	-0.1439	1					
6	RD	0.0568	0.1291	0.1485	-0.0694	0.2357	1				
7	PC	0.0559	0.1403	0.1715	-0.0537	0.2717	0.4183	1			
8	HHI	0.0083	-0.0081	0.0156	-0.0627	0.1254	0.1338	0.106	1		
9	LPAT	0.0345	0.0672	0.0165	-0.1122	0.3601	0.3621	0.19	0.0757	1	
10	MS	0.0291	0.0195	0.0406	0.0109	-0.0667	-0.0799	-0.1228	0.0502	-0.0381	1

Coherently, in Equation (3) we add to previous controls two variables that capture firms' technological heterogeneities. The first, *RD*, is a dichotomous variable accounting for the existence of R&D activities, either internal or external. We also controlled for firms' technological heterogeneities deriving from differences in the knowledge stock through the natural logarithm of patent stock (*LPAT*), by applying the perpetual inventory method to patent applications at the European Patent Office between 1978 and 2008 and depreciating the stock of knowledge capital by a 15% yearly discount rate (Griliches and Mairesse, 1984).[15]

In Equation (4) we add a control for the role of being a (non-environmental) process innovator with dichotomous variable equal to one if the firm introduced (non-environmental) process innovation (*PC*) in the period 2006-2008[16] and for the East Germany transition process, through a location variable (*EAST*).

In all the equations 19 sector dummies are included (*SECT*) (as described in **Table A1**).

We can now move to the empirical test of the second hypothesis. Recalling that it suggests that EI induced by different determinants heterogeneously affect firms' profitability, its test is conducted by estimating the models in Equations (5) to (7).

[15] The presence of many non-patenting firms engenders a limit when computing the natural logarithm of the patent stock. We then substituted 0 values with 0.001, by adding 0.001 to patent stock before computing its natural logarithm.

[16] As in Czarnitzki and Kraft (2010) we tried to capture the presence of cartelistic behaviors by adding an interaction variable RD* Herfindhal index and the presence of collusion by an interaction variable MS* Herfindhal index. As they were both found not to be significant, they are no longer included in the analysis.

$$OM_i = \alpha + \beta_1 EREI\_REG_i + \beta_2 ER\_ REG_i + \beta_3 EREI\_NOREG_i + \beta_4 ER\_NO\ REG_i$$
$$+ \beta_5 MIXED\_REG_i + \gamma\ CONTROLS_i + \epsilon_i \quad (5)$$

$$OM_i = \alpha + \beta_1 EREI\_VOL_i + \beta_2 ER\_ VOL_i + \beta_2 EREI\_NOVOL_i + \beta_3 ER\_ NOVOL_i$$
$$+ \beta_5 MIXED\_VOL_i + \gamma\ CONTROLS_i + \epsilon_i \quad (6)$$

$$OM_i = \alpha + \beta_1 EREI\_GR_i + \beta_2 ER\_ GR_i + \beta_3 EREI\_NOGR_i + \beta_4 ER\_ NOGR_i +$$
$$\beta_5 MIXED\_GR_i + \gamma\ CONTROLS_i + \epsilon_i \quad (7)$$

The rationale is to include in these Equations (5) to (7) all the controls of the full specified model of the previous Equation (4), which are now synthetically labeled *CONTROLS*, and to modify the key environmental innovation variables. Those will be included separately to avoid multicollinearity among those environmental innovation regressors.

To test our second hypothesis, we consequently built a group of *EREI* and *ER* variables that differ according to the motivation behind their adoption. The MIP 2009 asks the firms to state whether an *EI* was introduced as a response to a list of determinants, among which we are interested in: a) an existing or a foreseen regulation, which allows us to create the regulation-induced variables (*EREI_REG* and *ER_REG*) and the non-regulation induced (*EREI_NOREG* and *ER_NOREG*); b) the availability of government grants, subsidies, or other financial incentives to *EI*, which allowed us to build our grant induced variables (*EREI_GR* and *ER_GR*) as well as the non-grant induced ones (*EREI_NOGR* and *ER_NOGR*) and c) voluntary codes or agreements for environmental good practices, through which we built our voluntary agreements variables (*EREI_VOL* and *ER_VOL*) as well as the non-voluntary agreements driven ones (*EREI_NOVOL* and *ER_NOVOL*)[17]. The survey does not allow to properly distinguish between a regulation that induced *EREI* from one that induced *ER*, it only gives information on whether an *EI* (general) has been induced by regulation and this applies to grants and voluntary codes as well. In the case of regulation, we could not univocally assign 180 regulation-induced innovations either to *EREI* or to *ER*. In the case of voluntary codes, the number of ambiguous assignments is 152, while it is 64 in the case of grant-driven innovations. For this reason we include in each specification in equation (3) to (5) a variable for those situations in which an ambiguous assignment was depicted, i.e. in the cases in which *REG*, *GR* or *VOL* induced both *EREI* and *ER* (*MIXED_REG*; *MIXED_GR* and *MIXED_VOL*). We consequently replace those *EREI* and *ER* with zero for which the assignment was ambiguous not to double count them in the estimations. The underlying rationale for such a structure is to have in each equation as complement to one only the non-introduction of any *EI*[18] in order to use it as the benchmark to interpret the coefficients of the dummy variables we included in the models.

[17] The sample slightly changes when moving to the extended specification in Equation (5) to (7) because of some missing values in the answers provided by respondents on the motivations for EI. The number of observations available for testing the second hypothesis is 1013 instead of 1063, as in **Table 6**.

[18] For each *EREI* and *ER* we can indeed have the following situations: non *EI* (*EREI* or *ER* equal to 0), *EI* driven by one of the three motivations (*EREI* or *ER* equal to one; motivation -*REG*, *GR* or *VOL*- equal to one, *EI* not driven (*EREI* or *ER* equal to one; motivation equal to zero). Moreover for each motivation we have a mixed category we described as *MIXED* above. In the case of regulation, for instance, we have overall the following categories: *EREI_REG, EREI_NOREG, ER_REG, ER_NOREG, MIXED_REG; NO_EREI; NO_ER*. If we had included in the regressions only *EREI_REG* and *ER_REG*, we could have not been able to disentangle the profitability effect among a) *EREI* or *ER* which were not driven by *REG*, b) *MIXED EI* driven by *REG* and c) non-EI firms. For this reason we included in the regressions also *EREI_NOREG*, *ER_NOREG* and *MIXED_REG*, so as to keep as benchmark (complement to one) the only category of non-EI.

Given that our dependent variable is a categorical variable with the known thresholds as outlined in **Table 1,** we can estimate it through an interval regression model, which allows us to model fixed and known cut points, which are in our case both left and right censored, and estimate the coefficients and δ^2 via Maximum Likelihood[19] (Wooldridge, 2002).

4 Results, discussion and robustness checks

Estimation results of Equation (1) to (4) are provided in **Table 5**. Recalling that column (I) reports the results when the *EI* variable does not make any differentiation on the nature of the innovation itself, we find that in general the adoption of an *EI* does not play any effect on firms' profitability.

Table 5 Estimation Results (I)

	(I)	(II)	(III)	(IV)
EI	0.3976			
	(0.4984)			
EREI		1.8502***	1.7776***	1.7403***
		(0.6578)	(0.6591)	(0.6579)
ER		-1.1512*	-1.1915*	-1.2831*
		(0.6753)	(0.6821)	(0.6795)
SIZE	-0.0408	-0.0504	-0.1114	-0.1457
	(0.1305)	(0.1306)	(0.1383)	(0.1397)
MS	0.6053	0.6266	0.6088	0.6964
	(0.7713)	(0.7633)	(0.7627)	(0.7662)
HHI	-0.0041	-0.0040	-0.0041	-0.0044
	(0.0029)	(0.0029)	(0.0029)	(0.0030)
RD			0.4938	0.2890
			(0.4558)	(0.4832)
LPAT			0.0470	0.0469
			(0.0630)	(0.0629)
EAST				-0.0468
				(0.4208)
PC				0.5902
				(0.4520)
Constant	2.8375***	2.8254***	3.2666***	3.3091***
	(0.9344)	(0.9399)	(1.1847)	(1.1855)
lnsigma				
Constant	1.8180***	1.8146***	1.8136***	1.8126***
	(0.0280)	(0.0281)	(0.0281)	(0.0281)
N	1063	1063	1063	1063
MLCox-Snell R^2	0.055	0.061	0.063	0.065

Standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01
19 Sector Dummies, jointly significant (Wald Test), have been included

[19] We further checked the validity of our results by transforming the dependent variable in a Likert scale one, which ranges from 0 to 9 and we estimated the same models with Ordered Probit and Ordinary Least Squares. As expected results remain unaltered. Those are available upon request.

If we had stopped here, we would have concluded that a neutral relationship has been depicted between *EI* and profitability and that *it does not pay to be green*. But when we decompose *EI* by *EREI* and *ER*, we instead find a clear confirmation of our first research hypothesis, namely that it is appropriate to differentiate between Energy and Resource-Efficient innovation and the Externality-Reducing ones as different profitability effects are expected. More precisely, *EREI* are exerting a positive and strongly significant effect on firms' profitability, while on the contrary, *ER* are negatively impacting firms' operating margins (column (II)). This result is robust to the subsequent inclusion of additional control variables (column (III) and (IV)). The expectation that increased resource efficiency engenders a positive economic effect is confirmed. On the one side EREI are innovations that in reducing the use of materials and energy they reduce production costs. On the other side different combinations in the use of these idiosyncratic resources can engender a competitive advantage that a firm can exploit in the market. The magnitude of the positive gain is so depending on the way these two intertwined mechanisms are at work. ERs are conversely neither associated to a cost reduction in the production nor to possible competitive advantages deriving from the exploitation of strategic resources. In general adopting an innovation is a costly process for the firm and when those innovations are ER, the costs actually overcome the benefits in a way that the profitability return of such an adoption becomes negative.

To better appreciate the results outlined above, we now exploit the information on what is the motivation behind the adoption of *EI* and test our second research hypothesis by estimating Equation (5) to (7). Results are reported in **Table 6**.

What emerges is that the motivation behind the adoption of an *EI* makes the difference in terms of profitability gains, given a first confirmation of the validity of our second research hypothesis.

When an *EI* is introduced as a response to a current of future regulation (*EREI_REG* and *ER_REG*) with respect to the case in which it is not driven by regulation (*EREI_NOREG* and *ER_NOREG*), *ER* is still hampering firms' competitiveness, coherently with our previous results, while *EREI* remains positive and significant. This last result is coherent with the Porter Hypothesis framework of analysis, according to which regulation may help firms in seeking new production solutions that allow them to more than offset the costs of compliance and to take advantage of competitive gains that derive from that. However, to properly account for the existence of a Porter-like mechanism, a proper and well-designed regulation might be at stake, while we have no information on the quality of the regulation we are accounting for in our data[20]. As regulation typically induces firms to internalise their externalities, the interpretation of our results can be the following: when regulation works only in the direction of reducing production externalities forcing firms to engage in ER, then it can actually hamper firms' profitability. On the other side, when regulation induces firms to improve their resource efficiency, it results in productivity gains for the firms. Moreover, *EREI* and *ER* introduced not as a response to environmental regulation do not affect firms' profitability.

More interestingly and coherently with the previous result, when *EI* are introduced in response to the availability of government grants, subsidies, or other financial incentives, their effect on competitiveness are confirmed to be negative for *ER*, and no longer significant for *EREI*. This result can be interpreted by considering that a financial incentive is usually paid for innovations that are not profitable on their own.

[20] Furthermore, this is out of the scope of the current paper.

Table 6 Estimation Results (II): EI disentangled by drivers

	(I)	(II)	(III)
EREI_REG	1.7726*		
	(1.0424)		
ER_REG	-1.8817**		
	(0.9110)		
EREI_NOREG	1.3738		
	(1.0072)		
ER_NOREG	-0.7887		
	(1.4041)		
MIXED_REG	0.9503		
	(0.9100)		
EREI_VOL		1.1825	
		(1.3684)	
ER_VOL		-1.8301	
		(1.4693)	
EREI_NOVOL		2.0289**	
		(0.8007)	
ER_NOVOL		-1.1232	
		(0.8536)	
MIXED_VOL		0.2572	
		(1.1979)	
EREI_GR			0.2980
			(1.0669)
ER_GR			-6.7765***
			(1.7819)
EREI_NOGR			2.0365***
			(0.7451)
ER_NOGR			-1.0242
			(0.7398)
MIXED_GR			-0.4049
			(1.6742)
SIZE	-0.1190	-0.1175	-0.1131
	(0.1422)	(0.1422)	(0.1419)
RDdum	0.2106	0.2103	0.2054
	(0.4964)	(0.4962)	(0.4966)
LPAT	0.0421	0.0464	0.0452
	(0.0636)	(0.0643)	(0.0639)
MS	1.0802	1.0674	1.0048
	(0.7899)	(0.7912)	(0.7924)
HHI	-0.0057*	-0.0058*	-0.0056*
	(0.0032)	(0.0032)	(0.0032)
EAST	-0.0670	-0.0772	-0.0446
	(0.4312)	(0.4327)	(0.4314)
PC	0.6033	0.5867	0.5716
	(0.4661)	(0.4675)	(0.4651)
Constant	3.1272**	3.1468***	3.0722**
	(1.2163)	(1.2157)	(1.2092)
lnsigma			
Constant	1.8085***	1.8088***	1.8068***
	(0.0286)	(0.0286)	(0.0287)
N	1013	1013	1013
MLCox-Snell R^2	0.065	0.065	0.067

Standard errors in parentheses * p < 0.10, ** p < 0.05, *** p < 0.01
19 Sector Dummies, jointly significant (Wald Test), have been included

And it is mainly paid for adopting *ER* innovation rather than *EREI*, since *EREI* may not be eligible for state aids with the same frequency. In line with this reasoning, *EREI* are proved to engender positive profitability effects only when they are not introduced as a response to a financial incentive (*EREI_NOGR* is positive and significant). Furthermore, the negative effect of ER on profitability is higher than that reported in Table 5, suggesting that the negative profitability effect of ER is even stronger when those innovations are motivated by the presence of a financial incentive. The explanation might lay in the lack of an "additionality" effect of this subsidy or grant. In other terms, some firms may opportunistically substitute innovations undertaken as a response to the incentive while, at the same time, abandon any further innovation activity. This behavior might end up with stronger losses for the firm. A proper test on the grant additionality is however not possible in this context for the absence of specific data.

Lastly, when the driver of the adoption is the presence of voluntary codes or agreements, no effects on competitiveness are depicted. Intuitively the adoption of such voluntary codes is intertwined with organizational costs, which are not necessarily making the adoption itself profitable. On the other side, *EREI* that are not introduced as a response to voluntary codes or agreements of conduct exert a significant and positive role on the dependent variable (*EREI_NOVOL* is positive and significant).

We previously built our *EREI* and *ER* variables by accounting only for those innovations having a high environmental impact. If we instead include also those innovations reporting medium or high environmental benefits, then we can shed more light on the nature of the relationship between *EI* and profitability. In **Table 7** we report estimation results of Equation (1) and (2) in which we replaced respectively *EI* and *EREI-ER* by adopting a more extensive category of *EI*, to include also those with medium environmental impact. What we find is that none of the key environmental variables is still significantly affecting firms' profitability. This suggests not only that the question whether it pays or not to be green should be better qualified as profitability effects arise not in general. More interestingly, it suggests that a minimum threshold of (green) innovativeness is required before profitability gains arise. Profitability effects might indeed arise only for firms introducing highly innovative innovations, i.e. innovation whose impact on the environment is strong, while it does not arise for the entire spectrum of *EI* one might consider.

Table 7 Estimation results (III): EI with medium or high environmental benefits

	(I)	(II)
EI (medium_or_high)	-0.1600	
	(0.4212)	
EREI (medium_or_high)		-0.0735
		(0.4687)
ER (medium_or_high)		0.1350
		(0.4851)
SIZE	-0.1314	-0.1355
	(0.1399)	(0.1412)
RD	0.3238	0.2972
	(0.4887)	(0.4868)
LPAT	0.0548	0.0560
	(0.0633)	(0.0633)
MS	0.6691	0.6573
	(0.7758)	(0.7778)
HHI	-0.0045	-0.0044
	(0.0029)	(0.0029)
EAST	-0.0023	0.0088
	(0.4224)	(0.4212)
PC	0.6255	0.5813
	(0.4609)	(0.4592)
Constant	3.4456***	3.4098***
	(1.1939)	(1.1902)
Lnsigma		
Constant	1.8161***	1.8161***
	(0.0280)	(0.0280)
N	1063	1063
MLCox-Snell R^2	0.052	0.052

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
19 Sector Dummies, jointly significant (Wald Test), have been included

Several robustness checks have been implemented to support the validity of our estimation results.

At first, we consider that firms may be reluctant in providing profit information data. Indeed, among the 6851 firms of the MIP2011, 1451 did not answer to the operating margin variable and 703 stated that it was unknown. To test for the presence of a bias that may arise from the missing values encountered in our dependent variable *OM*, we constructed a dichotomous variable equal to 1 when information on *OM* are provided and 0 otherwise and we modeled the probability of providing information on *OM* through a probit model and regressed it on all the explanatory variables in equation (2), rejecting the null Hypothesis that the non-response to *OM* is random (as in Rexhäuser and Rammer 2013). As the variable that is driving the non-randomness of the non-responses is *EAST*, significant in the probit model, it has been selected to construct the exclusion restriction in a two-step Heckman selection model (Heckman, 1979). The coefficient of the mills ratio in the Heckman model is not statistically significant. This suggested that a proper selection bias is not depicted in our sample data and that the estimation model we selected above was more appropriate. However, the results we presented were confirmed by this selection model, as *EREI* and *ER* were both reporting the expected signs and were both significant[21].

As we have anticipated, the non-response to all the variables in the sample restricted our operative sample to only 1063 observations. We then controlled that the operative sample did not systematically differ from the full sample in the mean of the main variables included into the analysis, which are reported in **Table A2**. We see that our results are robust as the dependent variable (OM) and our main explanatory variables (EREI, ER and EI) do not present significant differences in the means between the sample we used in the regression and the full sample (that is representative of the population).[22]

5 Conclusion

Whether it pays or not to be green has been a core topic of the empirical literature on environmental and economic performance over the past two decades and assessing this question contributes to evaluate whether it is possible to maintain economic growth without giving up to increasing environmental performances. With a focus on the firm level and by analyzing survey data for the German firms, we contribute to this debate by showing that the question needs to be better qualified if we want to empirically operationalise it. Our main finding is that it is indeed more appropriate to open the box of the environmental realm and separately consider the competitive gains of different typologies of *EI*, those reducing externalities from those increasing energy and resources efficiency. It depends on how to be green.

If we look at innovations leading to a reduction in the use of energy and resources, we can conclude that it definitely *pays to be green*. If we then turn to innovations aimed at reducing externalities, such as harmful materials and air, water, noise and soil pollutions, we should conclude that it *does not pay to be green*. Although it may be profitable in the long run due to improved environmental regulation, it does not pay off in the short run when environmental regulation has to be faced as an external restriction. Energy and Resource Efficient innovations are here confirmed to lead to potential "win win" situations, in which reducing the environmental impact of production is contextually improving firms' economic performances. The same conclusion does not hold for externality reducing innovations, for which the cost burden of the adoption of the innovation seems to overcome the potential gains. A threshold of green innovativeness seems to be at stake and this discriminates between profitable innovations and not profitable one. Only highly (green) innovative firms are indeed found to benefit from the adoption of EREI. When looking at the drivers that work behind the adoption of each typology of *EI* considered, we confirm that the motivation inducing their adoption significantly impacts the profitability effects of the innovations. Again, this confirms our main hypothesis of the need to better articulate the question to allow identifying specific heterogeneous patterns that we found in our data. Lastly, a Porter-like mechanism emerges as far as regulation induced EREI are concerned, confirming previous results in the field (Rexhäuser and Rammer, 2013).

The current work suffers however of a set of limitations we could not solve.

One of the main limitations of this analysis lies in the cross-sectional nature of the data. Although the merge of two subsequent waves of the Mannheim Innovation Panel allows to include an appropriate

[21] These results are not reported here but are available upon request.

[22] We also recognise that some of the control variables we included (*HHI, RD, SIZE, PC, EAST* and *LPAT*) are significantly different in the 2 samples. Although this might change the coefficients of those variables in our

time lag between the dependent variable and the explanatory variables, so as to overcome endogeneity issues, it is still reasonable to assume that profitability is also depending on firms' unobserved heterogeneity, for instance, on technology level or managerial quality, that a panel analysis setting would have allowed to control for. Unfortunately, the key environmental variables were only available for the 2009 wave, thus limiting a panel exploitation of the data. The best effort was made in trying to capture the majority of elements driving to observed heterogeneity by adding a set of lagged comprehensive controls, but the room for unobserved heterogeneity is still open and it is not possible to model for it accurately in a cross section setting.

On the other side, the great advantage of this analysis lies in the use of specific survey data on the adoption of environmental innovation, which allows overcoming the limits of previous studies deriving from the need to find adequate proxies for EI.

Another (smaller) limitation lies in the specific time frame we considered. Although Germany is one of the European countries who recovered faster from the economic downturn and that it is consequently acceptable to assume that values of competitiveness in 2010 have not been underpinned by the crisis, it would have been preferred to account for that in the empirical strategy. Unfortunately, for such a structural break test to be implemented, a time-series data dimension would have been required, and, once again, this dataset does not allow covering such an issue.

Future research might be also directed to further investigate the competitiveness effects of different typologies of EI by focusing on specific technology fields through a patent-based analysis instead of a survey one. That would allow to look more deeply into the technology of each innovation generated and to differentiate between the competitiveness effects engendered by ER technologies and EREI technologies. Another interesting future line of research, if these data will be available, would be to apply panel data methodologies on a panel dataset which collects information on EI for more than one subsequent wave. That would also allow controlling for those unobserved firms' heterogeneities that might impact on firms' profitability that we could not completely take into consideration in the current work.

regression results, we do not consider it a limitation to our analysis as they were just included as control variables and we have not even commented their potentially biased coefficients.

Appendix

Table A1 Sector Variables and Distribution

Description	Sector NACE Rev 2.0	Frequency	Percentage
Agriculture, mining, quarrying	A; B	23	2.16
Food, Beverages, Tobacco	C10-C12	38	3.57
Textile, Leather and wearing app	C13-C15	30	2.82
Wood, paper and printing	C16-C18 (Bench)	51	4.8
Chemicals, Coke and petroleum products	C19-C20	30	2.82
Pharmaceutical industry	C21	7	0.66
Rubber, plastic and o.n.m.p.	C21-C23	67	6.3
Basic and fabricated metals	C24-C25	84	7.9
Computer, Electronic and optical products	C26	72	6.77
Electrical equipment	C27	28	2.63
Machinery and equipment and o.m.	C28; C32; C33	128	12.04
Motor Vehicles and other transport eq.	C29-C30	34	3.2
Furniture	C31	17	1.6
Electricity and Water supply	D-E	93	8.75
Construction	F	13	1.22
Wholesale and retail	G	62	5.83
Transport and communication	H-J	110	10.35
Banking, assurances, renting services	K-L; N	98	9.22
R&D, consulting, education and other se	M; O-T	78	7.34
Total		1063	100

Tab A2 Differences in the Variables' means between Operative and Full sample

variable	N Operative sample	Mean Operative sample	N Full sample	Mean Full sample
OM	1063	5.614299	2274	5.611258
EREI	1063	0.1063029	6369	0.103941
ER	1063	0.1044214	6313	0.0947252
EI	1063	0.1702728	6400	0.1639063
EAST *	1063	0.332079	7061	0.3084549
SIZE *	1063	4.0275	6319	3.646109
RD *	1063	0.4854186	7061	0.4112732
PC *	1063	0.3941675	7061	0.3444271
HHI *	1063	46.94077	7045	44.67348
LPAT *	1063	-7.488904	7061	-7.834
MS	1063	0.2750892	3391	0.2680772

Variables with * are significantly different between the samples with a confidence level of 95%

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