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A review of the empirical literature combining economic and environmental performance data at the micro-level

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A REVIEW OF THE EMPIRICAL LITERATURE COMBINING ECONOMIC AND ENVIRONMENTAL PERFORMANCE DATA AT THE MICRO-LEVEL

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By Antoine Dechezleprêtre and Tobias Kruse

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ABSTRACT/RÉSUMÉ

A review of the empirical literature combining economic and environmental performance data at the micro-level

This article reviews the empirical literature combining economic and environmental performance data at the micro-level, i.e. firm- or facility-level. The literature has generally found a positive and statistically significant correlation between economic performance, as measured by stock market returns, and environmental performance, as measured by emissions of pollutants or adoption of international environmental standards. The main reason for this finding seems to be that firms that reduce their material and energy costs experience both better economic performance and lower emissions. There is also evidence that greener firms are able to attract more productive employees and face smaller costs of capital, and that the introduction of green products enhances firms' profitability.

Only a small and recent literature analyses the joint causal impact of environmental regulations on environmental and economic performance. Interestingly, this literature shows that environmental regulations tend to improve environmental performance while not weakening economic performance. However, the evidence so far is limited to a handful of environmental regulations that are not extremely stringent, so the result cannot be easily generalized. More research is needed to assess the joint effects of environmental regulations on environmental and economic performance, to explore the heterogeneity of these effects across sectors, countries and types of policies, and to understand which policy designs allow improving environmental quality while not altering the economic performance of regulated businesses.

JEL classification codes: Q50, Q58
Keywords : environmental performance, firm performance, microdata sources

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Examen des analyses empiriques associant des données sur les performances économique et environnementale au niveau micro-économique

Il s'agit de passer en revue des travaux empiriques qui associent des données sur les performances économique et environnementale au niveau micro-économique, autrement dit à l'échelon des entreprises ou des installations. Dans l'ensemble, ces travaux font état d'une corrélation positive et statistiquement significative entre la performance économique (mesurée en particulier par la rentabilité boursière) et la performance environnementale (mesurée à l'aune des émissions de polluants ou de l'adoption de normes environnementales internationales). Cette conclusion semble avant tout tenir au fait que les entreprises qui réduisent leurs coûts matériels et énergétiques affichent simultanément un meilleur bilan économique et un plus faible niveau d'émissions. Il est également établi que les entreprises plus soucieuses de l'environnement sont en mesure d'attirer des salariés plus productifs, qu'elles supportent un coût du capital moins élevé et que le lancement de produits écologiques augmente leur rentabilité.
La littérature analysant conjointement l'incidence de la réglementation environnementale sur les performances environnementales et économiques des entreprises est plus récente et moins développée. Il est intéressant de constater que ces travaux font apparaître une tendance doublement vertueuse de la réglementation environnementale. Néanmoins, comme les études se sont limitées pour le moment à un faible nombre de dispositions en général peu contraignantes, il est difficile de généraliser ces résultats. D'autres travaux de recherche sont donc nécessaires pour permettre d'évaluer les effets conjugués de la réglementation environnementale sur les performances environnementales et économiques, d'étudier l'hétérogénéité de ces effets selon les secteurs, les pays et les caractéristiques de la politique poursuivie ainsi que de cerner les critères auxquels l'action publique doit satisfaire afin d'améliorer la qualité de l'environnement sans nuire aux résultats économiques des entreprises soumises à la réglementation.

Code de classification JEL : Q50, Q58
Mots-clés : performance environnementale, résultats des entreprises, sources de microdonnées.

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A review of the empirical literature combining economic and environmental performance data at the micro-level

By Antoine Dechezleprêtre and Tobias Kruse [1]

1. Introduction

1. Ever since the first major environmental regulations were enacted in the 1970s, there have been concerns about their potential impacts on the performance of affected businesses. In particular, in a world characterised by increased integration in trade and capital flows, there is concern that differences in the stringency of environmental policies between countries and regions could affect companies' competitiveness. Countries or regions leading the action against environmental degradation worry that their lead might come at the cost of disadvantaging local businesses, and debates about the impacts of environmental regulations on competitiveness are often framed in terms of 'jobs versus the environment' (Morgenstern et al., 2002), particularly in countries and regions where declining manufacturing employment has become a contentious political issue.[2]

2. Environmental regulations are accused by some of jeopardising economic activity but are viewed by others as potential drivers of economic growth. Economists traditionally think of environmental regulations as adding costs to companies and slowing down productivity, because they divert resources away from productive investments such as investments in research and development and towards pollution-control activities (Rose, 1983; Schmalensee, 1993; Walley and Whitehead, 1994; Jaffe et al., 1995). Since it is reasonable to assume that firms would have reduced pollution in the absence of environmental regulation if it was profitable for them to do so, any environmental regulation is likely to come at a cost for businesses. If the stringency of policies differs across countries or regions, then environmental regulations may not only add costs to businesses, but may also affect the competitiveness of the domestic industry, putting some companies at a competitive disadvantage vis-à-vis their foreign competitors (Levinson and Taylor, 2008). The available empirical evidence shows that environmental regulations can lead to statistically significant adverse effects on trade, employment, plant location and productivity in the short run, in particular in a well-identified subset of pollution- and energy-intensive sectors, but that these impacts are small relative to general trends in production (see Dechezleprêtre and Sato, 2017, for a recent review dedicated specifically at the competitiveness effects of environmental regulations).

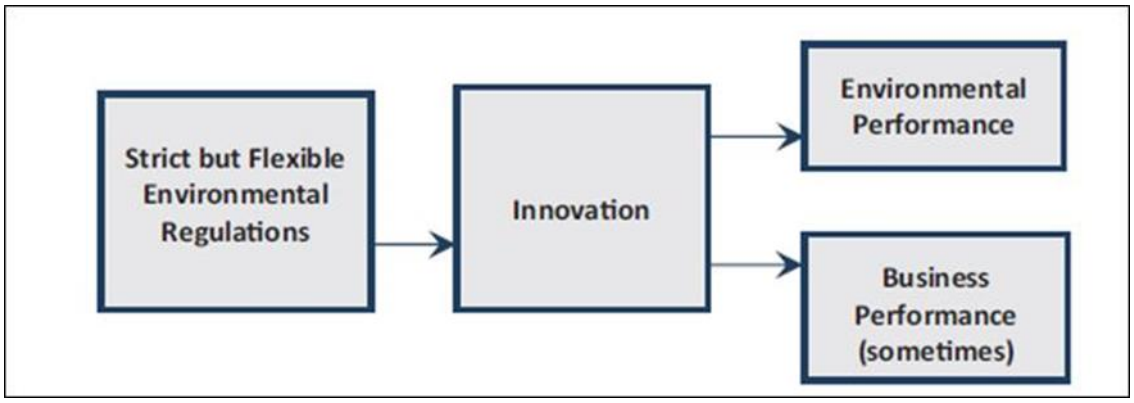
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[2] For example, in the United States, aggregate manufacturing jobs declined by 35 percent between 1998 and 2009, while total manufacturing sector production grew by 21 percent (Kahn and Mansur, 2013).

3. However, a different view of the world has been articulated since the 1990s, with what has become widely known as the Porter hypothesis (Porter and van der Linde, 1995). The basic idea is that environmental regulations should foster innovation in environmentally-friendly technologies which would not have been developed otherwise, and the adoption of these new technologies could well, in the medium run, improve firms' productivity or allow regulated firms to achieve technological leadership.

4. Ambec et al. (2013) illustrate the main causal links involved in the Porter Hypothesis (see Figure 1). If an environmental regulation is well-designed and sufficiently flexible it may not only lead to improved environmental performance, but it may also lead to innovation offsets. These offsets can partially, or sometimes more than fully, offset any additional costs from the regulation, thereby increasing firms' business performance. Thus, according to the Porter Hypothesis, while effective environmental regulation improves the environmental performance of firms, well-designed regulation could also improve business performance.

Figure 1. Causal links involved in the Porter Hypothesis



Source: Ambec et al. 2013

5. The Porter Hypothesis can take different forms according to the strength of the effect and the type of regulation (Jaffe and Palmer, 1997). The 'weak' version states that regulation will spur innovation. Thus, firms respond by innovating to reduce their costs from the environmental regulation (i.e. the first causal link in Figure 1). Yet, this weak version does not indicate if this innovation is good or bad for a firm's performance. The 'strong' version says that the regulation induces firms to find new products or processes that increase profits while complying with the regulation. According to this strong version, the benefits of the regulation more than offset its costs. This would make the regulation socially desirable even ignoring any environmental improvements arising from it. The 'narrow' version of the Porter Hypothesis states that only *certain types* of *regulation* will encourage innovation. The regulation needs to be sufficiently flexible and focus on the *outcome* (i.e. the emission reduction) rather than the *process* (i.e. the technology firms need to adopt) to induce innovation. Market-based regulations (taxation, emission trading schemes) would therefore be preferable to command-and-control regulations (Ambec et al. 2013). The firm-level empirical literature tends to fall into one of two categories: studies testing the *weak* version (i.e. the link between environmental regulation and innovation activity), and those testing the *strong* version (i.e. the impact of environmental regulation through innovation on business performance). The former is often assessed through R&D

expenditures or the number of registered patents. The latter is often assessed through effects on productivity, profits or stock market returns.

6. The Porter Hypothesis was initially criticized for its lack of theoretical foundation, as it rests on the idea that firms ignore opportunities to improve their business performance. Following Porter and van der Linde (1995) a sizeable literature has emerged to provide the theoretical basis for the hypothesis, by highlighting the existence of additional market failures (beyond the environmental pollution externality). Examples for such market failures include asymmetric information within firms (Ambec and Barla, 2002), learning-by-doing (Mohr, 2002), knowledge spillovers (Ambec and Barla, 2005), market power (Graeker, 2003), and investments with contractual incompleteness (Ambec and Barla, 2005). For example, in a theoretical model, Mohr (2002) assumes that the existence of knowledge spillovers prevents the replacement of an old polluting technology by a new, cleaner and more productive technology, as firms have a second-mover advantage if they wait for someone else to adopt. In this case, the introduction of an environmental regulation induces firms to switch to the new, cleaner technology, which simultaneously improves environmental quality and eventually increases productivity. This example illustrates the strong version of the Porter hypothesis is theoretically possible.

7. The growing importance of the debates over the many consequences of pollution on health, biodiversity loss, climate change, etc., and the potential negative consequences of environmental regulations on economic performance has led to a large number of studies that attempt to empirically quantify the impact of environmental regulations on the economic and the environmental performance of businesses. Multiple dimensions of economic performance of regulated businesses have been analysed, including productivity, innovation, employment, profitability, output and trade. Similarly, numerous environmental performance indicators have been used, including energy consumption, carbon emissions, emissions of various local pollutants (NOx, SOx, etc.) as well as composite indicators. These are typically used based on absolute values (e.g. emissions in tonnes, energy consumption in kWh) or relative values (e.g. energy intensity).

8. Most studies have so far assessed the impact of environmental regulations on environmental and economic performance *separately* (for reviews, see Ambec et al., 2013; Arlinghaus, 2015; Dechezleprêtre and Sato, 2017; Jaffe et al., 1995; Lankoski, 2010; Iraldo et al., 2011; Endrikat et al., 2014; Friede et al. 2015; Martin et al., 2016; Cohen and Tubb, 2017). However, a critical input for policy makers implementing environmental regulations is an understanding of how such policies will impact both environmental quality and local businesses' economic performance. As a consequence, some recent studies have started to jointly analyse these dimensions. Another, more developed, strand of the literature asks if economic and environmental performance can go hand in hand, whether or not environmental performance is triggered by environmental regulations or driven by voluntary approaches.

9. The objective of this background paper is to provide an up-to-date review of this relatively recent empirical literature that combines economic and environmental performance data at the micro-level. For each of the papers surveyed, we discuss the pros and cons of the data used and present the empirical approach taken by the authors. A comprehensive table summarizes the studies surveyed.

10. Compared to ex-post analysis based on more aggregated data at sectoral, regional or national level, or to ex-ante Computable General Equilibrium models, analyses based on micro-data have several advantages. Sample sizes are typically much larger, allowing for more precisely estimated effects, smaller biases due to unobserved heterogeneity (for

example, through the inclusion of firm-level fixed effects) and exploration of heterogeneous impacts across time or sectors. More generally, micro databases allow for a more credible identification of the treatment effects of a given regulation by applying the sort of quasi-experimental techniques that are most suited to assessing the causal impacts of environmental policies (List et al., 2003; Greenstone & Gayer, 2009). For example, the European Union Emissions Trading System, which regulates the carbon emissions of around 12 000 industrial sites across Europe, only regulates installations above a certain threshold in terms of production capacity. Therefore, it is possible to construct a control group of unregulated installations the size of which falls just below these administrative thresholds but are very similar, on all observable characteristics, to regulated installations. With a "treated" and a control group that are statistically identical before the introduction of the regulation, it is possible to identify the causal effect of the policy on regulated entities after the introduction of the regulation. Analyses based on micro-datasets also have drawbacks, however. In particular, they are ill-equipped to capture geographical or sectoral spillover effects and other general equilibrium effects. For example, it is not possible to analyse the potential impact of the EU ETS on unregulated firms facing higher energy prices because they buy electricity from regulated firms with the method presented above.

11. The paper is organized along the two main strands of the literature mentioned above. In the first section, we review the literature that analyses the direction of the correlation between environmental and economic performance at the firm level. The key feature of this literature is that it generally abstracts from the drivers of environmental performance, which could come from voluntary efforts of companies or be induced by environmental regulations. Because high environmental performance could be driven by profit- enhancing motivations (for example, improving energy efficiency to reduce input costs), a priori, we do not expect to find a negative relationship between environmental and economic performance. In the second section, we turn our attention to the joint impact of environmental regulations on environmental and economic performance. Here, if anything, we would expect regulations to improve environmental performance while weakening economic performance, bearing in mind that a Porter-like story could lead to a different outcome.

2. Is there a correlation between environmental and economic performance? Micro-level evidence.

12. There is a large literature on the relationship between environmental performance and economic performance at the firm level. However, this literature usually focuses on establishing correlations and does not properly address causality, i.e. the vast majority of studies cannot say with confidence whether improvements in firms' environmental performance *cause* improvements in firms' economic performance or the opposite, or if the direction is bidirectional. This is an important limitation because good environmental and economic performance could be driven by unobserved factors such as good management practices or the quality of the workforce, in which case the solution to improve both environmental and economic performance could reside in implementing policies in the non-environmental domain, for example education policies. Yet, establishing the direction of the correlation between environmental and economic performance at the micro level is interesting in its own right, given the widespread concern that they could be systematically negatively related. Note, finally, that because manufacturing firms represent the main source of pollution across countries, this literature generally focuses on the manufacturing sector. In comparison, the services sector is an understudied area.

2.1. Environmental performance and economic performance: evidence from stock returns.

13. Numerous papers have analysed the sign of the correlation between environmental performance, sometimes defined by broad indicators, and economic performance, as measured by stock returns. The advantage of using stock returns as a measure of economic performance is that they represent an "objective" and comprehensive measure of economic performance, since stock prices should impound information about the firm's future prospects from a vast array of both financial and nonfinancial measures, such as net income, return on assets, operational data, etc. While other financial data, such as profit, capture a short term effect, stock prices will reflect investors' expectations of the long term effects of environmental performance. An obvious limitation of using stock return is that, by definition, data on economic performance is then limited to listed firms.

14. Many articles have surveyed this empirical literature and several meta-analyses are available (for example Wagner, 2001; Blanco et al., 2009; Horvathova, 2010; Albertini, 2013; Crifo and Forget, 2015). Overall, these surveys conclude that better environmental performance is associated with greater financial performance, although there is some variation in the results across studies. For example, Ambec and Lanoie (2007) survey 12 studies that rely on regression analysis of financial performance on environmental performance across multiple years. Different measures of economic performance are used, including Tobin's Q, return on assets, return on sales and return on equity. Environmental performance measures include toxic release inventory (TRI) emissions, ISO 14001 certification[3] and the adoption of other international environmental standards. Nine studies showed that better environmental performance is associated with better economic performance. Two studies show no impact, while one concluded that a negative relationship exists. In her review of the literature, Horvathova (2010) reports that about 15% of studies find a negative effect; about 30% of studies find no effect and 55% of studies find a positive effect. Blanco et al. (2009) provide an in-depth review of empirical studies that analyse the relationship between manufacturing firms' environmental performance or voluntary initiatives and their economic performance. They conclude on a prominent absence of penalty for being green, which is affected by the typology of the firm, the methods utilized for implementing environmental initiatives, the intensity of the abatement efforts and stockholders' valuation of green firms. In this sub-section, we rely heavily on these surveys and focus on their main results and on some of the key papers in that literature.

15. A crude measure of environmental performance is provided by international environmental management standards such as ISO 14001. The limitation of this indicator is that it is binary: within firms having adopted the standard, it is not possible to rank firms according to their performance. It is also a noisy indicator, as there probably is heterogeneity in the environmental performance of firms not adopting the standard. Bearing these limitations in mind, Hibiki et al. (2003) use data on 573 publicly-held firms in the manufacturing industry listed at the Tokyo Stock Exchange. They use adoption of the ISO14001 certification as a measure of environmental performance and consider the firm's Tobin's q as the measure of financial performance. They find that the introduction of the ISO14001 certification system is associated with a statistically significant increase in the market value of the firms in the manufacturing industry by 11% to 14%. A similar finding

[3] ISO 14001 is a standardized environmental performance system that covers many aspects of environmental management such as life-cycle assessment and environmental performance indicators.

is reported by Jacobs et al. (2010). Wagner and Blom (2011) examine nearly 500 firms from the UK and Germany and use the implementation of an environmental management system (EMS) as a proxy for companies' environmental performance. They find that the implementation of an EMS is only positively associated with firms' financial performance for already financially well-performing firms. A negative association exists for financially less-well performing firms. Yet, a limitation of their approach is that the implementation of the EMS does not provide information on the actual environmental outcomes, which remain unobserved.

16. Using toxic releases allows better measurement of environmental performance, and many studies have used this indicator. One of the most cited is by Konar and Cohen (2001), who relate the market value of 321 mostly manufacturing firms in the S&P 500 to two objective measures of their environmental performance: the aggregate pounds of toxic chemicals emitted per dollar revenue of the firm and the number of environmental lawsuits pending against the firm in 1989. After controlling for variables traditionally thought to explain firm-level financial performance (market share of the firm, industry concentration ratio, sales growth, advertising intensity, research and development intensity, firm size, and the import intensity in the markets for the firms' products), they find that bad environmental performance is negatively correlated with the intangible asset value of firms. The average 'intangible liability' for firms in their sample is $380 million—approximately 9% of the replacement value of tangible assets. This shows that legally emitted toxic chemicals have a significant effect on the intangible asset value of publicly traded companies. A 10% reduction in emissions of toxic chemicals is associated with a $34 million increase in market value. The magnitude of these effects varies across industries, with larger losses accruing to the traditionally polluting industries. A similar result is reported by King and Lenox (2001). Other studies have obtained similar results based on improved methodologies, such as Al-Tuwaijri et al. (2004) who analyse the relationship between environmental and economic performance based on a cross-sectional dataset of 198 US firms. They measure a firm's economic performance using an industry-adjusted annual return, which is calculated as the change in stock price during the year (adjusted for dividends), scaled by the beginning-of-year stock price minus the industry median return (based on two-digit SIC codes). This annual industry-adjusted stock return thus represents a measure of the firm's current-period economic performance relative to other firms in the same industry. To measure environmental performance, they use the ratio of toxic waste recycled to total toxic waste generated (thus, if a firm introduces a pollution-abatement process, decreasing the total amount of toxic waste generated, or if the firm adopts processes that recycle toxic waste, such as closed-loop cooling systems, environmental performance will increase). They find that better environmental performance is significantly associated with better economic performance. This result is consistent with the idea that investors view good environmental performance as an intangible asset. They find a similar result when directly using stock price as a measure of environmental performance.

17. While studies using toxic emissions as a measure of environmental performance seem to report a positive relationship between environmental and stock market performance, it is interesting to note that this might not be the case for other environmental outcomes. For example, Fujii et al. (2013) examine the relationship between environmental performance and economic performance in Japanese manufacturing firms. The environmental performance indicators include CO2 emissions and the aggregate toxic risk associated with chemical emissions relative to sales. Return on assets (ROA), Return on Sales (ROS) and Capital Turnover (CT) are used as indicators of economic performance.

Fujii et al. (2013) find heterogeneous effects for the different environmental pollutants. The environmental performance based on CO2 emissions contributed positively to ROA. For toxic releases they demonstrate a significant inverted U-shaped relationship with ROA and CT. While Fujii et al. (2013) solely analyse manufacturing industries, Trumpp and Guenther (2017) include service industries as well. Furthermore, they allow for non-linearities in the relationship by adding quadratic terms in their regressions. Having a global dataset consisting of 2361 firm-years with 696 unique firms, they find a U-shaped relationship between carbon performance and profitability as well as between waste intensity and profitability. Hence, the level of environmental performance affects the direction of the relationship between the two variables. Trumpp and Guenther (2017) conclude that only after passing an environmental performance threshold it starts to 'pay to be green'.

18. Using a 2003 OECD survey, Darnall (2009) examines the relationship between self-reported firm-specific environmental performance and self-reported profitability using survey responses from 4188 facility managers from seven OECD countries (Canada, France, Germany, Hungary, Japan, Norway, United States). To obtain a measure of environmental performance they asked whether the facility manager had experienced a change in environmental impacts per unit of output in the last three years. These were reported separately for six environmental impacts.[4] For information on the financial performance of the facility, managers were asked about any changes in the facility's profits over the past three years. Furthermore, facility managers were asked to rate the environmental policy stringency to which they were subject. They find a positive relationship between environmental performance and financial performance and observe a negative correlation between facility-specific perceived policy stringency and profits. Yet, these findings are limited by the reliability of the managers' responses, as well as the cross-sectional nature of the study.

19. In a series of studies, Rassier and Earnhart (2010a; 2010b; 2015) analyse the extent to which firm-specific emissions limitations has heterogeneous effects on firms' *actual* profitability and investors' *expectations* on firms' *future* profitability.[5] Across all studies, they examine the effects of facility-specific wastewater discharge limits regulated by the US EPA.[6] Although the authors do not observe actual emissions, the enforced facility-specific discharge limits are used as a close proxy for facilities' emissions.[7] Using return on sales (ROS) as their financial performance measure, Rassier and Earnhart (2010a) use quarterly data on 59 firms and annual data of 73 firms to examine the relationship between financial performance and discharge limits. For both datasets, they find a negative relationship between clean water regulation and firms' *actual* profitability. A 10%

[4] The six environmental outcome variables are: Natural resource use, solid waste, waste-water effluent, air pollution, GHG emissions, and overall environmental impact.

[5] For a comprehensive summary on the differences between the studies see Table C.1 in Rassier and Earnhart (2015).

[6] All papers use wastewater discharge limits for biochemical oxygen demand (BOD) and total suspended solids (TSS). These are conventional and highly prevalent pollutants, which receive regulatory scrutiny by the EPA.

[7] The facility-specific discharge limits are based on state-or industry-level water quality standards. These state water quality standards differ across water bodies and time. Moreover, the discharge limits differ across facilities and time since the assimilative capacity of water bodies differs across location and time (Rassier and Earnhart, 2015: 133).

reduction in the average permitted discharge leads to a decline in the return on sales of between 0.8% and 2.7%. Rassier and Earnhart (2010b) examine the effect of permitted wastewater discharge levels on future *expected* financial performance of 54 manufacturing firms in the US using annual data. They find that tighter permitted discharge limits significantly decrease expectations of future profits. Rassier and Earnhart (2015) build upon their earlier studies and estimate the effects on *actual* and *expected* profitability jointly using a sample of 740 observations from 47 unique firms using quarterly data. They are able to improve upon their earlier work by including additional control variables. Their results on actual profitability are consistent with the Porter hypothesis indicating that tighter clean water regulation is positively associated with profitability. However, their results on *expected* profitability suggest that investors appear to expect a negative relationship between clean water regulation and profitability. This finding suggests that investors do not value the positive effect of regulation on firms' profitability, but instead seem to expect a negative impact on firms' profitability from tighter regulation. The authors explain these results with behavioural biases and lack of information among investors.

20. An important question in understanding the relationship between environmental and economic performance is whether improving environmental performance induces costs in the short run but benefits in the longer run. A few studies seem to confirm this hypothesis. Khanna and Damon (1999) evaluate the impact of the EPA's 33/50 program on the economic performance of firms in the US chemical industry relative to non-participants. The 33/50 Program is a voluntary initiative launched by the EPA in 1991 to encourage firms to reduce their emissions of 17 high-priority toxic chemicals. Of the firms emitting one or more of these 17 chemicals in 1988, 14% had pledged their participation in the program by 1993. After controlling for the effects of firm-specific factors, the authors find that an increased probability of participation in the program is significantly associated both with a decline in return on investment and with an increase in market variables (excess of market value over the book value of assets normalized by sales). Therefore, while the immediate impact of participation in the program on profits is negative relative to the profits of non-participants, participating companies, in the long run, are expected to be more profitable, and therefore market variables perform better. Horvathova (2012) uses a sample of 136 Czech firms observed over several years. Her indicator of environmental performance is a composite indicator constructed using the European Pollutant Release and Transfer Register (EPRTR) which provides data on 93 pollutants releases to air, water and land as well as off-site transfers of waste and of pollutants in waste water from industrial facilities in the European Union Member States. Economic performance is measured using Return on Assets and Return on Equity. The results indicate that better environmental performance decreases financial performance in the subsequent year, but increases financial performance after two years. The net (cumulative) effect seems negative, but the author does not test whether it is statistically significantly so. Rassier and Earnhart (2011) also focus on the inter-temporal effect of environmental performance on financial performance. They study U.S. firms and measure the environmental performance by permitted wastewater discharge limits and use the returns on sales as the financial performance measure. In contrast to Horvathova (2012), they find that lower emissions improve firm financial performance both in the short and the long run with a stronger effect in the long run.

21. Some recent studies have evaluated the impact of participation in the European Union's Emissions Trading Scheme on stock returns. Participation in the EU ETS is not a direct measure of environmental performance, but since these companies face a price on their carbon emissions, they should emit less than a comparable firm not covered by the

regulation. However, what has been assessed so far is mostly the impact of free allocations on stock returns. For example, Oestreich and Tsiakas (2015) look at a sample of 65 German firms and find that firms that received free carbon emission allowances on average significantly outperformed firms that did not. This suggests the presence of a large and statistically significant carbon premium, which is mainly explained by the higher cash flows due to the free allocation of carbon emission allowances. Veith et al. (2009) also reported that during Phase I of the EU ETS (2005-2007), there was a positive correlation between carbon prices and the returns on stocks of major European power companies. This correlation suggests that power companies profited from freely allocated permits and could pass-through a large enough share of the permit price. Similarly, Bushnell et al. (2013) show that the fall of the permit price in April 2006 led to a drop in stock prices of companies in both carbon- and electricity-intensive industries. Martin et al. (2014b) show that the free allocation of emission permits lead to substantial overcompensation for a given risk of carbon leakage (the relocation of carbon-intensive industries to non-regulated jurisdictions). They show that permit auctioning in combination with a systematic and targeted industry compensation scheme would lead to a more desirable outcome, preventing firm relocation and carbon leakage at a lower cost, compared to the existing free distribution of permits. It is not possible to conclude based on these studies that better environmental performance (through the inclusion in the EU ETS, which forces firms to control their carbon emissions) is associated with higher stock returns. Rather, it is the design of the policy (i.e. distribution of free allowances based on grandfathering) which explains the positive correlation between inclusion in the EU ETS and stock market performance.

2.2. Understanding the drivers: why environmental performance can go hand in hand with economic performance

22. As shown in the previous section, the vast literature that has looked empirically at the relationship between environmental and economic performance based on stock market data points to a positive correlation between environmental performance and stock returns. Therefore, it is interesting to understand why such a positive relationship emerges empirically. We explore this question in this section.

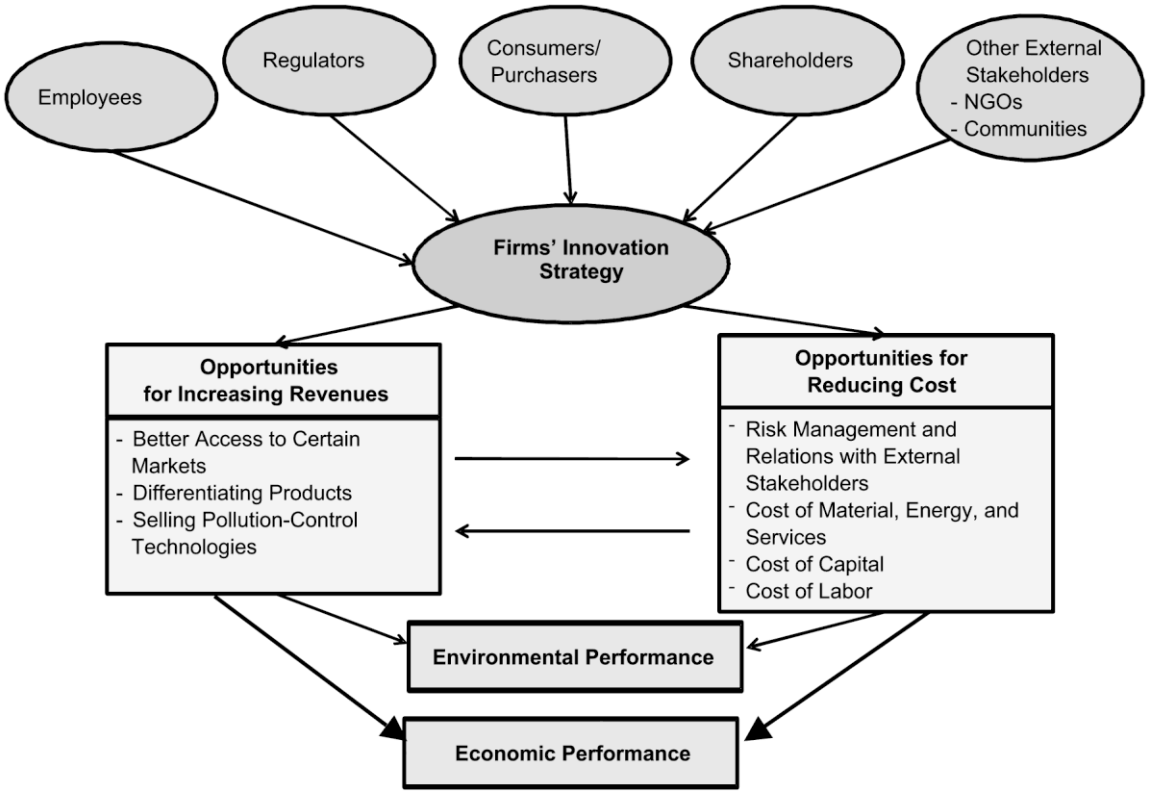
2.2.1. Theoretical background

23. While the conventional wisdom regarding environmental protection is that it comes at an additional cost imposed on firms, which should thus lead to *weaker* economic performance, this plausible prediction has been challenged over the past two decades following the famous paper by Porter & van der Linde (1995), who have argued that improving a company's environmental performance can lead to better economic or financial performance, and not necessarily to an increase in cost. This paper did not provide any strong theoretical motivation for that prediction, but many authors have subsequently provided theoretical grounding for it.

24. Ambec and Lanoie (2008) argue that there are at least seven ways in which improving a company's environmental performance can lead to better economic performance (see Figure 2). This could happen through either an increase in revenue or a reduction in production costs. Better environmental performance could lead to an increase in revenues through three channels: (a) better access to certain markets; (b) differentiating products; and (c) selling pollution-control technology. Better environmental performance can lead to a reduction in costs in four categories: (a) risk management and relations with external stakeholders; (b) cost of material, energy, and services; (c) cost of capital; and (d)

cost of labour. In the following sub-sections we present the empirical literature that has analysed these potential determinants of the positive relationship between environmental and economic performance uncovered by studies reviewed in section 2.1.

Figure 2. Potential positive links between environmental and economic performance



Source: Ambec and Lanoie, 2008.

2.2.2. Better economic performance through increased revenues

25. The empirical evidence on environmental performance providing better access to certain markets is usually available from case studies with small samples. An exception is the paper by Antweiler and Harrison (2003) which tests the prediction that 'environmentally-leveraged' firms with consumer market exposure experience larger emission reductions. To do this, the authors analyse firms' response to the publication of Canada's National Pollutant Release Inventory (NPRI) between 1993 and 1999. NPRI covers around 2 500 facilities who have to report their emissions of 192 pollutants into the air, water, land, and subsoil. The main problem faced by the authors is that they do not observe purchases from households and businesses at a sufficiently high level of disaggregation and they cannot link products to individual plants. Thus, they rely on the idea that, if consumers use the NPRI to identify facilities with high levels of pollution and to identify the companies that own them, the only way they can then punish these firms is by not buying any products from these firms since they cannot link products to particular facilities. Therefore, multi-product firms will experience a "spillover" effect through which high-emission products will negatively impact sales of low-emission products. They find that companies that are relatively more exposed to final consumers and that have a greater

diversity of emissions across products (thus, are more "environmentally-leveraged") reduce their releases to air and transfers of wastes off site most strongly, but also interestingly increase more less visible releases to subsoil via underground injection.

26. Only a handful of papers analyse the correlation between the introduction of green products and firms' economic performance. This small literature has mostly focused on the relationship between introduction of new green products and employment growth. Rennings and Zwick (2002) and Rennings et al. (2004) examine the determinants of employment changes due to the introduction of new environment-friendly products. The data stem from telephone surveys in five European countries. 1594 interviews were conducted with environmentally innovative establishments from both the industry and services sectors. The authors classify environmental innovations of these establishments into new products and services, new processes, adoption of end-of-pipe technologies, and enhanced recycling. Based on results of discrete choice models, they show that if the most important environmental innovation is a product or a service innovation, i.e. the introduction of a new green product or service, it has a significantly positive effect on the probability that the firm increases its number of employees. However, if the most important environmental innovation is an end-of-pipe innovation, this increases the likelihood that the firm decreases its employment base. Horbach (2010) also explores employment effects of environmental product innovations at the firm level. The empirical analysis is based on the establishment panel of the Institute for Employment Research (Nuremberg) and includes 900 firms operating in environmental sectors and 12 400 firms operating in non-environmental fields. The econometric results show that the influence of environmental innovation activities on the employment development is significantly positive. Firms in the environmental sector that developed new or modified products from 2002 to 2003 increased their employment from 2003 to 2005. The magnitude of the impact of innovation on employment seems to be larger than in non-environmental fields. The authors explain that this difference may be due to the fact that environmental technologies and products are characterized by an earlier market development phase compared to other innovative products connected with higher employment dynamics.

27. A recent study conducted by Palmer and Truong (2017) examines the relationship between the introduction of new products based on green technologies and firm profitability. "New technological green products" include any new product that builds on technological advances to limit or lower its environmental footprint or that of other products, for instance, through improved energy efficiency or waste management. While past studies have mostly used survey-based questionnaires to capture firms' new green products, Palmer and Truong (2017) use the press releases of actual new product introductions instead of relying on respondents' reporting which may be less reliable and less objective. The sample consists of 1 020 technological green new product introductions emanating from 79 global firms between 2007 and 2012. The authors find a positive correlation between technological green NPIs and firm profitability, as measured by turnover or return on total capital. Since the authors do not control for new product innovations in general, this result could simply reflect the impact of new product innovations in general. However, when the authors use as an alternative explanatory variable the ratio of technological green NPIs to the total number of NPIs, they interestingly still find a positive effect, although only significant at the 10% level, suggesting that there might be extra profitability associated with a higher proportion of green products. Overall, the findings point to the existence of financial incentives for firms to use green technologies to limit the environmental impact of new product introductions.

2.2.3. Improved economic performance through reduced cost of inputs

28. While there is so far only limited empirical evidence to back the hypothesis that increased environmental performance could cause an increase in revenue, or this evidence is based on small samples from which no general conclusion can be made, much more evidence is available on the cost side.

Energy and materials

29. Perhaps the most natural way in which better environmental performance could be associated with greater economic performance is through reduced cost of inputs, and in particular of energy. The empirical evidence available confirms this prior. Existing studies examine this question often through measures of firms' productivity (*Total Factor Productivity* or TFP). This captures the effect on firms' output from the introduction of an environmental regulation with a constant set of production inputs. According to the Porter Hypothesis, regulation may increase productivity, as it reduces firms' wasteful energy inputs. Firms facing some costly regulation may also react by improving the productivity of other inputs such as labour. The opposing view is that regulation reduces firms' productivity as it poses additional constraints on their production. Overall, the empirical literature shows that environmental regulations do not appear to be a major driver of firms' productivity.

30. Shadbegian and Gray (2003) examine the determinants of environmental performance at 68 US paper mills, measured by air pollution emissions per unit of output. They find that plants with lower emissions are also generally more efficient: plants with 10 percent higher productivity have 2.5 percent lower emissions. This indicates that productive efficiency and pollution abatement efficiency are complements, with better managers being better at both production and abatement (rather than substitutes, with managers concentrating on productive efficiency at the expense of their abatement performance). Shadbegian and Gray (2006) also report a positive correlation between production efficiency and pollution abatement efficiency in the US paper, oil and steel industries, even after controlling for observable factors.

31. Bloom et al. (2010) examine how the quality of management relates both to the energy intensity of firms (and thus, lower energy costs per unit of output) and total factor productivity by matching firm-level information on management practices to production and energy usage data from the UK census for the establishments owned by these firms. They find a robust negative correlation between management practices and energy intensity on the one hand, and a positive correlation between management practices and total-factor productivity on the other hand. In terms of magnitude, improving management practices from the 25th to the 75th percentile is associated with a 17.4% reduction in energy intensity and with a 3.7% increase in total-factor productivity. Thus, better economic performance as measured by TFP is associated with lower energy intensity. Martin et al. (2012) report a similar result when focusing specifically on management practices related to climate change 190 randomly selected manufacturing plants in the UK. The authors interviewed the managers of these plants to derive measures for the companies' practices in the areas of energy use and climate change and combined their responses with energy consumption data from the Annual Respondents Database (ARD) and economic performance data from official business microdata. They find that climate friendly management practices, as measured by an index constructed from survey responses, are associated with lower energy intensity and higher productivity.

32. Similarly, Horbach and Rennings (2013) show that the introduction of cleaner production processes innovations leads to a higher employment within the firm. Noticeably however, end-of-pipe technologies (in particular air and water process innovations) have a negative impact on employment. This confirms an earlier result by Pfeiffer and Rennings (2001) who show that cleaner production processes are more likely to increase employment compared to end-of-pipe technologies. Van Leeuwen and Mohnen (2017) obtain similar results from a panel of Dutch manufacturing firms for the period 2000-2008. They show that only production process innovations are positively correlated with firms' productivity, whereas end-of-pipe innovations are negatively correlated. Kumar and Managi (2010) also find a positive relationship between environmental and economic performance. They analyse the US emission allowance trading scheme for SO_2 emissions, which was introduced as part of the 1990 US Clean Air Act Amendment (USCAAA). Again, as in the case of the EU ETS, participation in the SO_2 trading scheme is not a direct measure of environmental performance. However, since these companies face a price on their firm-specific SO_2 emissions, they should emit less than in the absence of the trading scheme. They find that between 1995 and 2005 electricity-generating plants are able to increase electricity output and reduce SO2 emissions due to the allowance trading scheme.

33. Gray and Shadbegian (2003) and Shadbegian and Gray (2005) find insignificant effects for the relationship between firms' pollution abatement investments and productivity. Assuming that pollution abatement investments result in actual pollution abatement, their indicator is used as a proxy for firms' environmental performance. The former examine 116 US pulp and paper plants between 1979 and 1990 and observe that the effect of pollution abatement investments on productivity differs substantially by plants' technology. On average, they observe that plants with higher abatement costs have lower productivity levels. Yet, this negative relationship between higher abatement costs and lower productivity levels is largely driven by mills, which incorporate a pulping process. For mills without such technology, the impact is negligible. Similarly, Shadbegian and Gray (2005) examine the contribution of pollution abatement expenditure to firms' productivity for 68 paper mills, 55 oil refineries and 27 steel mills. In their sample, they are able to distinguish between productive and pollution abatement expenditures for each production input. They find little evidence that abatement inputs contribute to production with nearly all coefficients being insignificant.

34. Ayerbe and Gorriz (2001), Broberg et al. (2013), and Sanchez-Vargas et al. (2013) find modest negative relationships between firms' environmental performance and productivity. Ayerbe and Gorriz (2001) examine whether pollution abatement investments designated for compliance with environmental performance- and technology standards impact firms' productivity. In their sample of 53 large Spanish companies, they find a weak negative relationship with firms' productivity. Yet, the authors conclude that this finding might be specific to their small sample and the specific pollution abatement technology.

35. Broberg et al. (2013) use a stochastic frontier model to estimate the relationship between environmental protection investment and technical efficiency in five Swedish manufacturing industries. Environmental protection investments are again used as a proxy for environmental performance, assuming that such investments result in actual environmental protection. They observe a weak negative relationship between environmental investments and technical efficiency. Sanchez-Vargas et al. (2013) use a 2002 cross-sectional dataset of 900 Mexican manufacturing plants to identify nonlinearities in the relationship between plants' pollution abatement expenditure and productivity. They find an overall negative relationship between pollution abatement expenditure and firms'

productivity. However, the relationship is nonlinear and depending on plant size: the negative effect is larger for small firms and nearly negligible for larger firms.

36. Alongside papers based on regression analysis of past data, a new literature is emerging that uses experimental data to assess the environmental-economic performance of firms. Gosnell et al. (2017) implemented an experiment in partnership with Virgin Atlantic Airlines in order to test the impact of various incentives (monitoring, performance information, personal targets, and prosocial incentives) on fuel efficiency of their captains in three key flight areas: pre-flight (aircraft fuel load), in-flight (fuel-efficiently between take-off and landing), and post-flight (taxi). They find that, by simply informing the captains that the academic researchers and VAA Fuel Efficiency personnel overseeing the study are measuring their behaviours on three dimensions, captains considerably reduce fuel consumption: captains in this experimental group significantly increased the implementation of Efficient Flight and Efficient Taxi by nearly 50 percent from the pre-experimental period. These behavioural changes generated more than 7 700 tons of fuel saved for the airline over the eight-month experimental period (i.e. $6.1 million in 2014 prices), which translates to approximately 24 500 tons of CO2 abated. Moreover, monitoring and targets also induce captains to improve efficiency in all three key flight areas. The study provides the lowest ever calculated marginal abatement cost per ton of CO2, at negative $250 (i.e. $250 savings per ton abated), showing that airlines can at the same time improve environmental as well as economic performance. Experimental studies of this sort are only emerging, but constitute a fruitful avenue for future research.

Labour costs

37. Some authors have also argued that better environmental performance can lead to a reduction in the cost of labour, because environmentally-friendly companies are able to attract and retain motivated employees who work harder for lower wages. Indeed, if people prefer their employer to be socially responsible, they will, if faced with a choice between two otherwise identical job offers with equal pay, choose the employer they find more responsible. Therefore, to make those people indifferent, the less responsible employer must offer a higher wage. There is empirical support for the idea that social responsibility of firms is valued by employees. For example, it has been reported that job satisfaction is substantially higher when top management is perceived as strongly supporting ethical behaviour. Lanfranchi and Pekovic (2012) use data on 11 600 employees at 7 700 French firms and find that employees of firms that have adopted voluntary environmental standards report a significantly higher feeling of usefulness at work. Nyborg, and Zhang (2013) carried out a survey on 100 000 Norwegian employees and show that firms with higher Corporate Social Responsibility pay substantially, and statistically significantly, lower wages. Three studies using data for French firms and employees find that, for firms that have adopted voluntary environmental standards, employees are more likely to work uncompensated overtime hours (Lanfranchi and Pekovic, 2012), labour productivity is higher (Delmas and Pekovic, 2013), and difficulties with recruitment are smaller (Grolleau et al., 2012). It is not clear, however, whether this is driven by self-selection of more productive and motivated employees into CSR firms or whether working for a socially responsible employer in itself increases motivation at work. This literature is still in its infancy and future research might enable to shed light on this issue.

Cost of capital

38. Better environmental performance could be associated with a lower cost of capital, in particular because of lower exposition to environmental risk and liabilities. For example,

El Ghoul et al. (2011) examine the effect of corporate social responsibility (CSR) on the cost of equity capital for a sample of around 2 000 US firms. They find that firms with better CSR scores exhibit cheaper equity financing. Attig et al. (2013) find that credit rating agencies tend to award relatively high ratings to firms with good social performance. Cheng et al. (2013) show that firms with better CSR performance face significantly lower capital constraints. Goss and Roberts (2011) use a sample of 3 996 loans to US firms and find that firms with social responsibility concerns pay between 7 and 18 basis points more than firms that are more responsible. A common limitation to all these studies is that they use indicators of CSR that include not only environmental performance but also other measures of social responsibility, such as responsible practices towards employees. Therefore, it is not possible to determine whether the relationship stems from better environmental performance or better performing or more committed employees.

3. The joint impact of environmental regulations on environmental and economic performance

39. A large literature has analysed the impacts of environmental regulations on environmental performance, while another strand of the literature has looked at the consequences on economic performance. In comparison, the literature analysing these two outcomes jointly at the level of firms or plants is limited. Almost all of the literature that does this has focused on climate change regulations, and within this literature, most papers analyse the effect of the European Union Emissions Trading System (EU ETS). We start with these papers before reviewing the rest of the literature.

3.1. The joint impact of the EU ETS on carbon emissions and firm performance

40. In 2005, the European Union Emissions Trading System (EU ETS) – the EU's flagship climate change policy – was launched in 24 countries across Europe. The policy regulates the carbon emissions of around 12 000 installations, together representing roughly 40% of the EU's total greenhouse gas emissions, by allocating pollution permits to these installations, which can then be freely traded on an international permit market. The objective of this cap-and-trade programme is to achieve a set reduction of aggregate CO2 emissions at minimal cost. Power stations and industrial plants across Europe were classified according to their main activity: combustion, cement, paper and pulp, and so on. The EU ETS offers a unique opportunity to investigate the causal impact of environmental policy on both environmental and economic performance. It is the first and largest environmental policy initiative of its kind anywhere in the world, which, by itself, would make it an interesting case to study. But more important is the fact that, in order to control administrative costs, the EU ETS was designed to cover only large installations. Activity-specific size criteria determine which installations would be included in the EU ETS. For instance, only combustion installations with a yearly thermal input exceeding 20 MWh are covered. Firms operating smaller installations are not covered by EU ETS regulations. It is therefore possible to exploit these installation-level inclusion criteria to compare firms or installations with similar environmental and economic performance prior to the introduction of the EU ETS, but which have fallen under different regulatory regimes since 2005. This provides an opportunity to apply the sort of quasi-experimental techniques most suited to assessing the causal impacts of environmental policies (List et al., 2003; Greenstone & Gayer, 2009).

41. The central outcome of interest for a policy such as the EU ETS are CO2 emissions. The only source for representative emissions data for both EU ETS and non–EU ETS plants are confidential business surveys maintained by government statistical agencies. Access to these datasets is restricted and subject to disclosure control. This explains why few studies so far have been set out to understand the impact of the EU ETS on the economic and environmental performance of regulated installations, through the use of comprehensive plant-level data. To date, four studies have explored the joint effect of the EU ETS on firms' and installations' environmental and economic performance, respectively in France, Germany, Norway and Lithuania.

France

42. Using comprehensive plant-level data for around 9 500 French manufacturing firms, Wagner et al. (2014) explore the economic and environmental response of plants to the introduction of the EU ETS. The analysis is based on a combination of energy consumption and economic performance data at the facility and firm level. The EACEI (Enquete Annuelle sur les Consommations d'Energie dans l'Industrie) is a survey conducted annually in France. It provides quantities and values of energy consumed by energy type (electricity, vapour, natural gas, coal, lignite, coke, butane, propane, fuel oil, heating oil, wood, etc.). About 12 000 establishments are part of the sample: all industrial establishments employing 20 employees or more in the most energy consuming sectors, all establishments with more than 250 employees, and a sample of establishments with employment between 20 and 249 employees in sectors that are not energy intensive. Fuel consumption information at the plant level is then converted into carbon emissions based on widely available carbon content data on the various fuels consumed. This dataset is combined with EAE (Enquête Annuelle des Entreprises), which collects balance-sheet data at the firm level on turnover, employment, capital, and aggregate wages, as well as information about firm location and industry classification. The data are available for all firms with more than 20 employees and all the plants of those firms. Finally, the data is matched on the European Union Transaction Log, which contains the list of all installations regulated under the EU ETS. Notably, in France, the national registry is managed by the *Caisse des Dépôts* and their website provides a link between the EUTL permit identifier (GIDIC) and the French unique firm identifier SIREN, allowing a quasi-perfect matching of the two databases.

43. To examine the causal effect of the EU ETS on environmental and economic performance, Wagner et al. (2014) combine matching with difference-in-differences. For each EU ETS-regulated plant, they use propensity score matching to identify the most similar non-EU ETS plant (nearest neighbour), which becomes part of the control group and helps determining what would have been the behaviour of regulated plants, had they not been regulated. Ideally, one would want to directly use the production capacity of the plants to create such pairs, since it is production capacity pre-EU ETS that determines inclusion into the system. However, this variable is not observed by the researchers. Therefore, they use carbon intensity of each plant in the year 1999, the announcement year of the EU ETS, as the main matching variable. They also match each plant exactly on sector at the NACE two-digit level. This means that each EU ETS plant is compared with a non-EU ETS plant operating in the same two-digit sector and having the same carbon intensity before the announcement of the EU ETS. A potential problem is the absence of size variables in the matching process, which might induce the authors to compare plants of very different sizes and thus very different on unobserved characteristics as well.

44. Their results suggest that ETS-regulated manufacturing plants in France reduced emissions by an average of 15%. The analysis shows no effect of the EU ETS during Phase I (2005-2007) and a 15% reduction in emissions during Phase II compared to unregulated plants. Having facility level data, Wagner et al. (2014) can explore if there is any evidence of within firm leakage for firms with both unregulated and regulated facilities. One would expect that it would be easier for such firms to shift emissions to unregulated plants as they are incurring less transaction costs than firms who have no pre-existing links with unregulated facilities. However, they do not find any evidence for such within-firm carbon emissions reallocation effects. Instead, the reduction in emissions appears to be driven mostly by reductions in the carbon-intensity of production. In particular, about half of the reduction in emissions can be accounted for by an increase in the share of gas, which is less carbon intensive than coal and oil.

45. In terms of economic outcomes, Wagner et al. (2014) do not find any statistically significant impact on employment, suggesting that the EU ETS was effective at reducing carbon emissions of regulated plants with no statistically significant effect on domestic jobs.

Germany

46. Petrick and Wagner (2014) analyse the causal impact of the EU ETS on German manufacturing firms using comprehensive panel data from the German production census. Contrary to Wagner et al. (2014) who use data on French plants, their analysis is conducted at the firm level. They are able to match 1 658 EU ETS facilities to the German AFiD company database. They use propensity score matching to select a group of comparable but unregulated firms, and base this on a comparably much richer set of observable pre-treatment characteristics: CO2 emissions, gross output, export share of output, number of employees, average wage, the squares of all these variables, and dummies for two-digit industry (WZ classification) and state (Bundesland) wherein the firm is located.

47. Petrick and Wagner (2014) find robust evidence that phase II of the EU ETS caused treated firms to reduce their emissions by a substantial margin, in the order of 25 to 28 percentage points more than non-treated firms. In parallel, carbon intensity fell between 18 and 30 percentage points faster at EU ETS firms than at the control firms. This suggests that firms responded to the introduction of the EU ETS mainly by adjusting intensity, not scale. Furthermore, firms were found to have reduced their carbon emissions by switching from high-carbon fuels (natural gas and oil) to low-carbon fuels (electricity).

48. Turning to economic outcomes, Petrick and Wagner (2014) find no statistically significant effects of the EU ETS on employment. In a word, putting a price on carbon does not seem to come at the expense of domestic job destruction. As for gross output, they estimate that the EU ETS *increased* gross output at regulated firms by a statistically significant amount of between 4 and 7 percent. While this allows the authors to reject the hypothesis that the EU ETS caused firms to reduce the scale of production, the positive effect on gross output is surprising and consistent with both firms producing more or charging higher prices. Unfortunately, they cannot distinguish between these two responses for lack of a measure of physical output. Similarly, they reject the hypothesis that the EU ETS caused regulated firms to reduce their overall exports, but they even find that the EU ETS *increased* total exports by 6% to 11% for phase I and by 7% to 18% for phase II. Again, it is not clear whether the increase in exports reflects an increase in the volume of shipments or a price increase, or both.

Norway

49. Klemetsen et al. (2016) examine the impacts of the EU ETS on the environmental and economic performance of Norwegian plants. They use plant level data from the Norwegian Environment Agency for the period 2001 to 2013 on annual emissions of all Norwegian plants regulated by the Norwegian ETS or the Norwegian Pollution Control Act, including emissions of CO2, N2O and PFCs (measured in CO_2 equivalents). This dataset allows the authors to identify which plants were regulated by the EU ETS. It is then supplemented with annual plant level data from Statistics Norway on number of employees, man hours, value added, energy use and prices and industry classification. The sample includes 665 plants of which 150 plants are regulated by the EU ETS.

50. Propensity score matching techniques are used to construct a control group of similar but unregulated plants. Exact matching is done on type of pollutant (CO2, N2O or PFCs) and on industry classification at two-digit level. Continuous matching variables include emissions levels of emissions (as a proxy for capacity limit) and number of employees (as a measure of plant size) in the pre-treatment year 2001. Not all EU ETS regulated plants can be matched, hence the final matched sample includes 152 plants of which 72 plants are regulated by the EU ETS. However, it is notable that the control group still appears quite different from the treatment group even after matching with, for example, an average CO2 intensity of 62.1% in the treatment group and only 6.8% in the control group. Therefore, it is questionable how comparable the treated and control groups are in this study.

51. Klemetsen et al. (2016) analyse the effect of the EU ETS on emission levels and intensity (defined as emissions divided by man hours). They find weak evidence that regulated plants reduced emissions by a large amount (-30%) in the EU ETS' second phase, and no evidence that emission intensity decreased in any of the phases. This suggests that, to the extent that the ETS participation led to emissions reductions in phase II, this occurred through reduced activity level rather than through reduced emissions intensity.

52. Klemetsen et al. (2016) consider two measures of economic performance: value added at factor prices, which is the plant's annual gross production value minus the cost of intermediates plus subsidies and minus taxes (except VAT), and labour productivity, defined as value added at factor prices per man hour. For Phase II, the estimated effects on both value added and productivity are positive and significant, and suggest increases of around 25%. These surprising effects could result from the impact that free allowances or cost pass-through may have had on value added.

Lithuania

53. Finally, Jaraite and Di Maria (2016) analyse the impact of the EU ETS on CO2 emissions and economic performance in Lithuania for the period 2005-2010 using plant-level data. They compare 41 EU ETS firms with 312 non-EU ETS firms matched through propensity score-matching. They find no reductions in emissions and a slight improvement in emissions intensity in 2006-2007, but their data does not allow them to study effects on emissions beyond 2007. When it comes to economic performance, Jaraite and Di Maria (2016) find no significant impacts of the EU ETS on Lithuanian firms' profitability.

Pan-European studies

54. At present, only one paper has analysed the joint effect of the EU ETS on CO2 emissions and economic performance based on data from the entire European Union. Abrell et al. (2011) use data on 2 101 firms across Europe representing around 60% of EU

ETS regulated emissions to assess reductions in CO2 emissions induced by the transition from Phase I to Phase II of the programme, which occurred in 2008. They find that emission reductions were 3.6% higher between 2007 and 2008 than between 2005 and 2006, a difference which they attribute to the increased stringency of the regulation. This finding is robust to controlling for turnover, employment, profits, and industry and country trends, suggesting that the reduction in emissions is due to the change in stringency from Phase I to Phase II (i.e. the lower allocation of permits) and not to a decrease in production. Abrell et al. (2011) then apply a nearest-neighbour matching procedure to their sample of EU ETS firms and find that the policy caused a small but significant decrease in employment of 0.9 percent between 2004 and 2008. One limitation of the matching procedure is that, as Martin et al. (2014a) explain, taking control firms only from non-regulated sectors is problematic, because of the possible non-random selection of which sectors were regulated under the EU ETS, hence the study is likely to suffer from selection bias at the sector level.

3.2. The joint impact of the UK Climate Change Levy on carbon emissions and firm performance

55. The UK Climate Change Levy (CCL) is a carbon tax associated with a scheme of voluntary agreements (called Climate Change Agreements) available to plants in selected energy intensive industries. Upon joining a CCA, a plant adopts a specific target for energy consumption or carbon emissions in exchange for an 80% discount on the tax liability under the CCL. Martin et al. (2014a) analyse the impact of the CCL on energy use, emissions and economic performance of regulated plants for the period 2001-2004 based on micro-level data.

56. The identification strategy of the paper is to compare changes in outcomes between fully-taxed CCL plants and CCA plants which pay the reduced tax rate. Since plants self-select themselves into a CCA, it is not possible to implement a straightforward difference-in-differences (DiD) strategy. However, a key feature of eligibility for CCAs is that plants needed to emit pollutants subject to environmental regulation under the Pollution Prevention and Control (PPC) act which pre-dated the CCL. This variation in eligibility across plants can hence be used as an instrument for CCA participation. Indeed, since eligibility is based on pollution intensity, many energy intensive industries are ineligible for the tax discount. For instance, textile wet processing was an eligible activity thanks to its high pollution emissions, but not so dry processing which, although energy intensive, emits no pollution regulated under PPC. Similarly, both the production and the recycling of glass containers are very energy-intensive processes. However, since only the former is pollution-intensive, glass container recycling was not eligible for CCA participation. This institutional feature induces exogenous variation in the probability of treatment even within narrowly defined, energy-intensive industrial sectors.

57. The core dataset is the Annual Respondents Database (ARD), an annual production survey that covers about 10 000 plants in the manufacturing sector. Energy use comes from the Quarterly Fuels Inquiry (QFI), a survey among a panel of about 1 000 manufacturing plants which can be matched to the ARD. Information on CCA participation comes from both the DEFRA and HM Revenue and Customs (HMRC) websites. Finally, data for the instrumental variable comes from the European Pollution Emissions Register (EPER). The final dataset includes 6 886 plants, among which 1 079 have detailed information on fuel consumption by type.

58. Instrumental variable estimations show that the CCL had a strong negative impact on energy intensity (-18%), particularly at larger and more energy intensive plants. This

seems mainly driven by a reduction in electricity use which translates into a negative impact on CO2 emissions. The results suggest that firms substituted labour for energy and increased output prices in response to the energy price increase. In contrast, the authors do not find any statistically significant impacts of the tax on employment, revenue (gross output) or total factor productivity (TFP). Similarly, no evidence is found that the CCL accelerated plant exit.

3.3. The joint impact of energy prices on economic and environmental performance

59. To examine more generally the effect of energy prices on firms' environmental and economic performance, Marin and Vona (2017) use three rich datasets provided by the French Statistical Office covering the period 1997 to 2010: the EACAI survey for establishment-level energy purchases and consumption, DADS (Déclaration Annuelle des Données Sociales) for data on employment and wages, and FARES-FICUS for information on firms' balance sheets. By combining these datasets they can use differences across establishments in energy intensities, -prices, and –mixes. Hereby, energy intensities provide a proxy for establishments' exposure to energy price changes, and the energy mix (i.e. the use of electricity versus natural gas and other fuels) indicates establishments' technology and the relative exposure to price changes for the respective energy source. Energy use and CO_2 emissions capture firms' environmental impact, and employment, wages and productivity are used as economic outcomes.

60. To estimate the effect of electricity prices on firms' environmental and economic outcome variables Marin and Vona (2017) use both a simple fixed effects model, as well as an Instrumental Variable (IV) specification. The latter is important to address concerns of endogeneity due to non-observed variables, which could bias the results of the simple fixed effects model. Such variables could be firm-specific demand shocks or technological change as a response to changes in energy prices. These variables are likely to be correlated with both the outcome variables and energy prices, resulting in a biased estimation of the model. To overcome this concern the authors require an instrumental variable that is correlated with the exogenous variation in energy prices but not related to establishment-specific technological responses to changes in energy prices. They use a combination of the nationwide price of energy with a fixed firm-specific energy mix, which does not change over time (shift-share instrument). Changes in nationwide prices are uncorrelated with firm-specific demand shocks dealing with the first concern. Since most endogenous technological change operates through changes in the mix of energy sources, holding fixed the energy mix addresses the second source of potential bias.

61. In their preferred specification with the Instrumental Variable, Marin and Vona (2017) identify a trade-off between environmental and economic goals: A 10% increase in establishment-level energy prices, leads to a reduction in energy consumption and CO2 emissions by 6.4% and 11.5% respectively. Yet, the same increase in energy prices also leads to a modest negative effect on employment (-2.6%), wages (-0.4%) and firm's productivity (-1.1%). The negative employment impacts differ across sectors with energy-intensive and trade-exposed sectors experiencing the largest decline. However, preliminary evidence shows a substantial reallocation of production inputs between establishments of the same firm as a response to energy price changes. This gives reasons to believe that the estimated employment impacts are upper bounds. Some of the employees, which are observed as losing their job at one establishment, are simply relocated to another establishment within the same firm.

3.4. The joint impact of environmental regulation on environmental and economic performance through innovation

62. Several studies have examined the causality chain implied by the Porter hypothesis – from regulation to innovation to profitability – and find that the positive effect of innovation on business performance does not outweigh the negative effect of the regulation itself (Lanoie et al., 2011). Thus, environmental regulation is costly, but it is less costly than if one were to consider only the direct costs of the regulation itself and ignore the ability of innovation to mitigate those costs. This is because over time, regulation-induced innovations that improve a firm's resource efficiency in terms of material or energy consumption, have a positive impact on profitability (Rexhauser and Rammer, 2014).

63. Porter and van der Linde (1995) also argue that countries that take early action in environmental protection will induce higher costs for domestic firms in the short run, but that the induced innovation will generate economic benefits in the long run by giving domestic firms a competitive advantage over foreign firms, which will be constrained by the same regulation later on. However, to our knowledge, no study has empirically analysed whether this first-mover advantage actually leads to competitiveness improvements in the long-run.

4. Conclusion

64. This paper has reviewed the available empirical literature combining economic and environmental performance data at the micro-level. Two strands of the literature can be distinguished.

65. The first strand of literature analyses the sign of the correlation between environmental and economic performance at the firm level. While numerous measures of environmental performance are used, the measure of economic performance usually used is financial performance based on market value data. While market data has the advantage of being widely available, it is also - by definition - restricted to listed firms and, as such, the results may be affected by a sample selection bias and might not be representative of the population of firms, in particular of smaller firms that are typically not listed. Moreover, this literature generally abstracts from the drivers of environmental performance, which could come from voluntary efforts of companies or be induced by environmental regulations. Because high environmental performance could be driven by profit-enhancing motivations (for example, improving energy efficiency to reduce input costs), it is perhaps not surprising that many studies report a positive relationship between environmental and economic performance.

66. The second strand of the literature analyses the joint impact of environmental regulations on environmental and economic performance. Because economists traditionally think of environmental regulations as forcing firms away from the optimum by requiring them to implement costly abatement activities that divert resources away from productive investments, it is all the more surprising and interesting that this literature usually finds that environmental regulations tend to improve environmental performance while not weakening economic performance. However, no study confirms the so-called strong version of the Porter hypothesis, which postulates that environmental regulations can improve at the same time environmental and economic performance.

67. Both strands of the literature have limitations. In addition to using small samples that are usually restricted by the availability of market data, the first strand suffers from weaker methodologies which make the establishment of a causal link (from environmental

performance to economic performance) difficult. In contrast, because the implementation of environmental regulations can sometimes be claimed to be exogenous (this is in particular the case for the European Union Emissions Trading System, which uses arbitrary administrative thresholds to determine inclusion), the second strand of the literature can identify a causal link from environmental regulation to environmental and economic performance.

68. Compared to the first strand, the second strand of the literature is still in this infancy. Most studies have used a single policy experiment, the European Union Emissions Trading System, and focus on a single country. Only one multi-country study is available. Yet, only cross-country studies would enable researchers to determine which combination of public policies (instruments for environmental policy, innovation policy, fiscal policy, etc.) works best at inducing the greatest benefits in terms of improved environmental performance, while implying the smallest costs or, potentially, the greatest improvements in terms of economic performance (productivity, etc.). Carrying out a multi-country analysis would seem a natural extension of the existing literature and could make an important contribution in this respect. As an international organisation, the OECD is well-positioned to make such a contribution in the near future.

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Annex A. Summary Table of Empirical Literature

Papers reviewed in section 2.1: Environmental Performance and economic performance: evidence from stock returns						
Albertini, 2013	Corporate Environmental Management (meta-analysis including pollution control, pollution prevention, product stewardship).	Firm profitability (meta-analysis).	Meta-analysis of 52 studies.	Meta-analysis covering studies between 1975 and 2011.	Correlation	The meta analysis finds a positive correlation between Corporate Environmental Performance and Corporate Financial Performance.
Al-Tuwaijri et al., 2014	Ratio of toxic waste recycled to total toxic waste generated.	Industry-adjusted annual return (expressing the firm's current-period economic performance relative to other firms in the same industry).	198 US firms. IRRC Environmental Profiles database provided by the US EPA (accessed through Freedom of Information Act requests), Compustat for financial data, LexisNexis for annual reports.	Cross-section (year 1994).	Correlation	Better environmental performance is significantly associated with better economic performance (significant only at the 10% level).
Bushnell et al., 2013	EU ETS carbon emissions price.	Stock prices.	552 firms traded on EUROSTOXX.	Panel (2005-2007; event study of price drop in April 2006).	Correlation	The fall of the permit price in April 2006 led to a drop in stock prices of companies in carbon- and electricity-

			EU's CITL database, Carbon Monitoring for Action Project (CARMA) published by the Center for Global Development.			intensive industries. Share prices of firms from the most carbon-intensive industries experienced the largest abnormal declines.
Darnall, 2009	Natural Resource Use, Solid Waste, Waste-water effluent, Air pollution, Greenhouse Gases, Overall environmental impact.	Self-reported profits.	The number of observations varies across models due to different response rates for each environmental performance variable: Natural resource use (2609), Solid Waste (2642), Waste Water (2386), Air pollution (2123), GHGs (1723), Overall environmental impact (1517). Survey conducted by the OECD's Environment Directorate.	Cross-section (survey was conducted in 2003).	Correlation	The authors use an OECD survey across seven countries to test the effect of regulatory stringency on firms' profits. They find that more stringent environmental policy regimes are negatively correlated with facilities' profits. This result holds for each of the individual environmental performance variables.
Fujii et al., 2013	CO2 emissions, chemical emissions relative to sales.	Return on Assets (ROA), Return on Sales (ROS), Capital Turnover (CT).	758 Japanese manufacturing firms for CO2 emissions; 2498 Japanese manufacturing firms for toxic chemicals emissions. GHG emissions from the mandatory GHG Accounting and Reporting System of the Japanese Ministry of Environment, Pollutant Release and Transfer Register (PRTR) from Ministry of Environment,	Panel; for CO2 emissions (2006-2008); for toxic chemicals (2001-2008).	Correlation	The relationship between environmental performance and financial performance differs across pollutants: For toxic chemical substances they find a significant inverted U-shape relationship between ROA and environmental performance. For CO2 Emissions they find a significant positive relationship between ROA, ROS and environmental performance. They find no

			financial data from Nikkei Economic Electronic database system.			significant relationship with CT.
Hibiki et al., 2003	ISO14001 certification.	Stock returns; Tobin's Q (market value of the firm).	573 publicly-held firms in the manufacturing industry listed at the Tokyo Stock Exchange.	Cross-section (year 2002).	Correlation	The authors find that the voluntary introduction of the ISO 14001 certification contributes to a statistically significant increase in the market value of the firm by 11% to 14%. The authors explain this finding with two possible effects: the expected reduction in the potential risk of environmental liabilities, and the lower adjustment cost if environmental policy is tightened in the future.
Horvathova, 2010	Environmental performance (meta-analysis).	Financial performance (meta-analysis).	Meta-analysis of 64 outcomes from 37 empirical studies. Literature search was conducted in 2008/2009.	N/A	Correlation	The results suggest both that the empirical method matters for the findings and that the likelihood of finding a negative link between environmental and financial performance significantly increases when using simple correlation coefficients instead of more advanced econometric analysis. The results also indicate that the portfolio studies tend to report a negative link between environmental and financial performance. This likely

						reflects the omitted factors in portfolio studies. The positive link is found more frequently in common law countries than in civil law countries. The results also suggest that appropriate time coverage is important in order to establish a positive link between EP and FP. This suggests that it takes time for environmental regulation to materialise in financial performance.
Horvathova, 2012	Composite indicator on 93 pollutants (air, water, land, off-site transfers of waste, pollutants in waste water from industrial facilities).	Return on Assets (ROA), Return on Equity (ROE).	136 Czech firms. Environmental performance data from integrated register of pollutant emissions, which is part of the European Pollutant Release and Transfer register (EPRT) (publicly available), data on environmental managerial systems are collected using publicly available database (www.iso.cz) and double-checking the websites of companies, financial data are obtained from a commercial firm database CreditInfo.	Panel (2004-2008).	Correlation	Better environmental performance decreases financial performance in the following year, but increases financial performance after two years.

Jacobs et al., 2010	Corporate Environment Initiatives (CEI) announcements, which are self-reported corporate efforts to avoid, mitigate or offset the firm's environmental impact. Environmental Awards and Certification (EAC) announcements, which are awards granted by third parties. EAC announcements include ISO 14001 and LEED certification, as well as federal, state or local environmental awards.	Abnormal returns on stock prices.	340 firms across 63 three-digit NAICS codes, with a total of 780 announcements; 417 Corporate Environment Initiatives (CEI), 363 Environmental Awards and Certification (EAC). Dataset created by authors through monitoring business announcements in newspapers.	Panel; event study over a 200-day period, which is specific for each firm's announcement.	Correlation	The authors examine the stock market reaction associated with announcements of environmental performance. They find no significant effect for the aggregated sample of CEI and EAC announcements. Yet, they observe significant effects for sub-groups of the announcements. Announcements of philanthropic gifts for environmental causes and ISO 14001 are associated with a significant positive market reaction. Voluntary emissions reductions are associated with significant negative market reactions.
Khanna and Damon, 1999	Toxic releases of 17 high priority toxic chemicals regulated under the voluntary US EPA 33/50 Programme.	Return on Investment (ROI), Excess value per unit sales (EVS).	123 US chemical firms. S&P's Compustat database, CD corporate database, Toxic Release Inventory.	Panel (1991-1993).	Correlation	Participation in the voluntary US EPA 33/50 programme led to a significant decline in toxic releases relative to non-participants, after controlling for sample selection through firm-specific factors. Programme participation had a significant negative effect on current returns on investment

						(ROI) relative to non-participants. Yet, it had a significant positive effect on the Excess Value per unit Sales (EVS). This indicates that investors anticipate that in the long run the current efforts to reduce pollution improve the expected profitability of firms participating in the programme.
King and Lenox, 2001	Total Emissions: Total facility emissions of toxic chemicals; Relative Emissions: Emissions relative to other facilities of similar sector, and size Industry Emissions: Emissions per employee for the sectors in which the firm operates.	Tobin's Q financial performance measure (market valuation of a firm relative to the replacement costs of tangible assets).	652 US manufacturing firms Toxic Release inventory (TRI), facility data from Dun and Bradstreet (D&B), corporate data from Standard & Poor's Compustat database.	Panel (1987-1996).	Correlation	The authors identify three key results: 1) Higher total emissions are associated with lower financial performance. 2) Firms with higher relative emissions compared to firms of similar sector and size have lower financial performance. 3) No effect for Industry Emissions: Operating in a cleaner industry does not have an effect per se on financial performance.
Konar and Cohen, 2001	The aggregate pounds of toxic chemicals emitted per dollar revenue; The number of environmental lawsuits pending against the firm in 1989.	Intangible-asset value (market value).	321 mostly manufacturing firms in the S&P 500; Financial performance data taken from Compustat, market share and concentration data from Ward's Business Directory, R&D expenditures using data from the Disclosure	Cross-section (year 1989).	Correlation	The authors observe that bad environmental performance is negatively correlated with the intangible asset value of firms. They find that a 10% reduction in emissions of toxic chemicals results in a US$34 million increase in market value. Their evidence suggests

			database, advertising expenditures (ADVAL89) were taken from data published by the Arbitron Company, the number of environmental law suits pending and toxic emissions data from Investor Responsibility Research Center.			that firms are rewarded in the marketplace for over-complying with environmental regulation and for externally portraying an image of being environmentally concerned.
Martin et al., 2014b	CO2 emissions, management practices related to climate policy (interview data).	Vulnerability to carbon pricing (interview data).	761 firms across Belgium, France, Germany, Hungary, Poland, UK. Survey on management practices conducted by the authors, ORBIS for economic performance, EU CITL for emissions data, Eurostat.	Cross-section (Interviews conducted in 2009).	Correlation	The authors propose an industry compensation scheme to prevent relocation of firms as a response to carbon pricing. It requires that compensation is distributed across firms to equalize the expected marginal impact of relocation on the regulator. They show that the existing free allocation of permits under the EU ETS results in substantial overcompensation of firms.
Oestreich and Tsiakas, 2015	EU ETS carbon emission allowances.	Stock returns.	65 publicly traded German firms on the two major German stock exchanges (DAX and MDAX). DataStream for stock returns (commercial), EU CITL for emissions (public).	Panel (monthly; 2003-2012).	Correlation	During the first years of the EU ETS, firms which received free carbon emission allowances significantly outperformed firms that did not. Thus, there is a large and significant carbon premium in stock returns. Between 2003 and 2009 the carbon premium

						can be as high as 17%, yet the premium dissipates after 2009. It is largely explained by higher cash flows due to the free allocation of carbon emission allowances.
Rassier and Earnhart, 2010a	Permitted wastewater discharge limits for BOD (biochemical oxygen demand) and TSS (total suspended solids).	Profitability as measured by returns on sales (ROS).	Publicly held chemical manufacturing firms. The sample of annual data contains 337 observations, consisting of 73 chemical manufacturing firms. The sample panel of quarterly data contains 926 observations, consisting of 59 chemical manufacturing firms. US EPA's Permit Compliance System (PCS) database for permitted discharge limits, S&P Compustat for financial data, PCS database for facility level environmental data.	Panel (1995- 2001) yearly data.	Correlation	The authors obtain consistent results across both of their samples. A 10% reduction in the average relative permitted discharge limit causes the return on sales to decrease by as little as 0.8% and as much as 2.7% according to the 90% confidence interval of the estimated coefficient on the discharge limit
Rassier and Earnhart, 2010b	Permitted wastewater discharge limits for BOD (biochemical oxygen demand) and TSS (total suspended solids).	Tobin's Q financial performance measure.	229 observations covering 54 public owned chemical manufacturing firms. Environmental Protection Agency's (EPA's) Permit	Panel (1995-2000).	Correlation	They find a negative relationship between clean water regulations and expected future financial performance. The more stringent clean water regulation induces investors to

			Compliance System (PCS) for permitted limits of wastewater discharge, Standard & Poor's Compustat Research Insight for financial data.			revise downward their expectations of future profits. A 50% decrease in the average firm's permitted discharge limit generates a decrease of 1.3% or approximately $310.4 million in the average firm's market value.
Rassier and Earnhart, 2011	Permitted wastewater discharge limits for BOD (biochemical oxygen demand) and TSS (total suspended solids).	Returns on Sales.	53 US firms belonging to the chemical manufacturing industry. EPA Permit Compliance System database on permitted discharge limits, S&P Compustat for financial data.	Panel (quarterly; 1st quarter of 1995 to 2nd quarter of 2001; maximum of 26 observations per firm).	Correlation	Lower emissions improve firm financial performance both in the short and long run, with a stronger effect in the long run.
Rassier and Earnhart, 2015	Permitted wastewater discharge limits for BOD (biochemical oxygen demand) and TSS (total suspended solids).	Actual Profitability (return on sales), Investors expectations of future profitability measured by Tobin's q.	740 observations from 47 firms. EPA's Permit Compliance System (PCS) database, S&P Compustat for financial data.	Panel (1995-2001) quarterly.	Correlation	Their results on actual profitability are consistent with the Porter hypothesis indicating that tighter clean water regulation is positively associated with profitability. However, their results on expected profitability suggest that investors appear to expect a negative relationship between clean water regulation and profitability.
Trumpp and Guenther, 2017	Carbon performance (negative GHG emissions divided by sales), Waste intensity (negative amount of	Profitability (Return over assets), stock market performance (annual change in	2361 firm-years. GHG emissions from Carbon Disclosure Project (public), waste intensity and financial data from Thomson	Panel (2008-2012).	correlation	They find a non-linear U-shaped relationship between carbon performance and profitability, as well as between waste intensity and profitability. Thus, within their

	waste produced by a firm divided by sales).	stock prices plus dividends).	Reuter's ASSET4 database (commercial).			sample firms with a low corporate environmental performance (CEP) tend to have a negative relationship with corporate financial performance (CFP), whereas firms at high levels of CEP have a positive relationship with CFP.
Veith et al., 2009	EU ETS carbon emission allowances.	Stock returns.	22 European power generation companies. DataStream database.	Panel (daily; 2005-2007).	Correlation	The authors find a positive correlation between carbon prices and returns on stocks. This implies that the market predicts that firms are able to pass on their share of the regulatory burden from the EU ETS and can even achieve windfall profits.
Wagner and Blom, 2011	Environmental Management Systems (EMS).	Firms' financial performance (Return on Sales).	497 firms from Germany and the UK. Survey conducted by authors on EMS system, financial data from AMADEUS database.	Cross-section (survey conducted in 2001).	Correlation	The authors use the implementation of an Environmental Management System (EMS) for firms' level of sustainability. They find a positive association between the implementation of an EMS and financial performance for already well-performing firms only. For less well-performing firms they find a negative relationship between EMS implementation and financial performance. They find no effect for their pooled dataset.

Wagner, 2001	Review study.	NA	NA	NA	NA	Evidence from early studies indicates no significant relationship between environmental and economic performance, the more recent studies carried out on the relationship between the two indicate that a significant relationship exists between environmental and economic performance, but they give no clear indication about whether this is positive or negative.
Papers reviewed in section 2.2: Understanding the drivers: why environmental performance can go hand in hand with economic performance						
Antweiler and Harrison, 2003	192 toxic air, water, land, and subsoil pollutants covered in Canada's National Pollutant Release Inventory (NPRI).	Consumer market exposure.	2500 Canadian facilities, which report emissions under Canada's NPRI. Canada's National Pollutant Release Inventory (NPRI) (publicly accessible through website), Canadian Census for facility location (public), Statistics Canada (public).	Panel (1993-1999).	Correlation	Companies that are relatively more exposed to final consumers and that have a greater diversity of emissions across products (i.e. are more "environmentally-leveraged") reduce their releases to air and transfers of wastes off site most strongly. Yet, they also increase more the less visible releases of subsoil emissions. They argue that this indicates the existence of a "green consumerism", although its overall environmental impact is small.

Horbach, 2010	Environmental product innovations.	Employment at the firm level.	900 German firms operating in environmental sectors; 12.400 German firms operating in non-environmental fields. Establishment panel of the Institute for Employment Research Nuremberg.	Panel (2002-2005).	Correlation	Firms in the environmental sector that developed new or modified products from 2002 to 2003 increased their employment from 2003 to 2005. The employment impact of innovation is larger than for firms in non-environmental sectors.
Palmer and Truong, 2017	Technological green product introductions (NPI).	Firm profitability measured by turnover and return on capital.	79 global firms (1020 technological green product introductions. Authors constructed the dataset of NPIs based on press releases.	Panel (2007-2012).	Correlation	They find a significant positive correlation between technology-based green new product introductions (NPI) and short term profitability measured by turnover or return on capital. They also find a weakly significant relationship when using the ratio of technological green NPIs to the total number of NPIs. This finding might suggest that a higher share of green products is associated with extra profitability.
Rennings and Zwick, 2002	Introduction of new environmental products; environmental innovations.	Employment at the firm level.	1594 interviews of environmentally innovative industry and services firms from Germany, Italy, Switzerland, UK, and Netherlands. The firms span across 8 NACE sectors (D-K). Firms were only	Cross-section (interviews were carried out in 2000).	Correlation	Environmental innovations have a small but positive effect on employment at the firm level. Product and service innovation generate more jobs than process innovations. Employment impacts differ according to the intended goals

			included if they self-reported to have done at least one environmental innovation in the past three years. Survey conducted by authors.			of the innovation: If they are motivated by cost reduction, they tend to reduce employment. If they are motivated by goals to increase the market share, the effect can be positive or negative.
Rennings et al., 2004	Environmental Innovations.	Employment at the firm level.	1594 interviews of environmentally innovative industry and services firms from Germany, Italy, Switzerland, UK, and Netherlands. The firms span across 8 NACE sectors (D-K). Firms were only included if they self-reported to have done at least one environmental innovation in the past three years. Survey conducted by authors.	Cross-section (interviews were carried out in 2000).	Correlation	Environmental product and service innovations increase the likelihood that the firm increases its employment base. Yet environmental end-of-pipe innovations increase the likelihood that the firm decreases its employment base.
Ayerbe and Gorriz, 2001	Firm-specific costs of executing individual environmental project (i.e. firm-specific pollution abatement cost).	Work productivity (measured as value-added per worker).	53 large Spanish companies, quoted on the stock market. Data on participation in the PITMA programme is publicly available through the Official State Gazette from the Department of Industry and Energy (MINER). Balance Sheet and Income Statement information are obtained	Panel (1990-1995).	Correlation	The authors study the effect of participation in the Spanish Industrial and Technological Programme for the Environment (PITMA), a subsidized pollution abatement programme. They find a small negative association between work productivity and pollution abatement investment dedicated to compliance with the pollution

			from the National Securities Market Commission (CNMV), which is available for publicly listed companies.			standard. They argue that this result is specific to the command-and-control regulation studied and may not be generalized to more flexible types of regulation.
Bloom et al., 2010	Energy Intensity.	Total factor productivity, Quality of management.	300 manufacturing firms in the UK. UK establishment-level Census of Production data from the UK ONS (license), survey collected by Center for Economic Performance (CEP).	Cross-section (Management Survey Data from 2006).	Correlation	They find a robust negative relationship between management practices and energy intensity. Improving management practices from the 25th to the 75th percentile is associated with a 17.4% reduction in energy intensity and with a 3.7% increase in total-factor productivity. They also find that better economic performance as measured by TFP is associated with lower energy intensity. The results suggest that management practices that are associated with improved productivity are not linked to worse environmental performance.
Broberg et al. 2013	Environmental protection investment.	Technical efficiency.	Five Swedish industries: wood and wood products (279 obs.), pulp and paper (304 obs.), chemicals (289 obs.), rubber and plastics (223 obs.), basic metals (199 obs.).	Panel (1999-2004).	Correlation	They use unique data on environmental protection investments in the Swedish manufacturing industry as a proxy for environmental stringency. This allows them to separate investments into pollution prevention and pollution control. They use a

			Two data sources from Statistics Sweden: 1) Industrial Economic Statistics, 2) Industries' environmental protection expenditure.			stochastic production frontier model to estimate if environmental regulation affects firms' production efficiency. They do not find support for the Porter Hypothesis as they observe a weak negative relationship between environmental investments and technical efficiency.
Gosnell et al., 2017	Airplane fuel consumption, CO2 emissions.	N/A (Experimental treatments: Monitoring, performance information, personal targets, pro-social incentives).	335 Virgin Atlantic airline captains, 110.000 captain-level observations over 40.000 unique flights. Data provided by Virgin Atlantic to the Authors.	Panel (eight-month experimental study period in 2014).	Causation	The experiment in partnership with Virgin Atlantic Airlines finds that low-cost behavioural treatments (monitoring, performance information, personal targets, and prosocial incentives) reduced captain's fuel consumption pre-flight (aircraft fuel load), in-flight, and post-flight (taxi) significantly. Simply informing pilots that they are being monitored already reduces their fuel consumption significantly. The behavioural changes generated more than 7700 tons of fuel saved for the airline over the eight-month experimental period ($6.1 million in 2014 prices), which translates to about 24.500 tons of CO2 abated. They estimate a marginal abatement cost per

						ton of CO2 at negative $250 (i.e. $250 savings per ton abated) from implementing the low-cost behavioural interventions, which is the lowest marginal abatement cost so far calculated in the literature.
Gray and Shadbegian, 2003	Abatement costs.	Productivity.	116 US pulp and paper plants. Longitudinal Research Database (LRD) containing data from the Annual Survey of Manufacturers and the Census of Manufacturers linked together, PACE survey for annual abatement cost data.	Panel (1979-1990).	Correlation	They test whether the impact of environmental regulation on productivity differs by plant vintage and technology. Plants with higher pollution abatement costs have significantly lower productivity levels. The effect depends strongly on plants' technology. The negative relationship between higher abatement costs and lower productivity levels is largely driven by mills, which incorporate a pulping process. They show a strong negative impact of abatement cost on productivity. For mills without such technology the impact is negligible.
Horbach and Rennings, 2013	Cleaner Production innovations, Environmental end-of-pipe innovations.	Employment at the firm level.	Between 3700 and 4500 German firms from the Community Innovation Survey (CIS), covering mining and quarrying, manufacturing, energy and	Cross-section (Community Innovation Survey 2009).	Correlation	The realization of environmental process innovations leads to a higher employment within the firm. Furthermore, material and energy savings are positively

			water supply, large number of service sectors. 2009 wave of the German Community Innovation Survey (CIS).			correlated to employment because they help to increase the profitability and competitiveness of the firm. Yet, end-of-pipe technologies (in particular air and water process innovations) have a negative impact on employment.
Kumar and Managi, 2010	SO2 emissions price.	Innovation activity.	50 electricity generating plants. Federal Energy Regulatory Commission (FERC) for electricity production at the plant level, employees and capital stock, US EPA Aerometric Information Retrieval System (AIRS) database for SO2 emissions and emissions prices.	Panel (1995-2007).	Correlation	The authors have tested whether an increase in SO2 emissions prices leads to a reduction in pollution emissions. They observe that electricity generating plants experience positive induced technological change. Electricity-generating plants are able to increase electricity output and reduce emissions of SO2 and NOx from 1995 to 2007 due to the introduction of the allowance trading system.
Martin et al., 2012	Energy intensity (energy expenditure / gross output) and (energy intensity / variable cost); Composite Index on management practices related to climate change collected through interviews.	Productivity	190 UK manufacturing plants. ORBIS database for random selection of UK manufacturing plants. Survey data collected by authors.	Cross-section (interview data collected in 2009).	Correlation	Climate friendly management practices, as measured by an index constructed from survey responses are associated with lower energy intensity and higher productivity at the establishment level. They suggest that there might be a win-win scenario from improving environmental

						management, which could also raise firm productivity.
Pfeiffer and Rennings, 2001	Environmental Innovations.	Employment at the firm level.	419 German environmentally innovative manufacturing firms (a company was defined as such if it carried out at least one environmental innovation between 1993 and 1995). Survey of the Mannheim Innovation Panel (licence).	Cross-section (1996 wave of the Mannheim Innovation Panel).	Correlation	Cleaner production processes are more likely to increase employment compared to end-of-pipe technologies. The authors conclude that the transition from end-of-pipe technologies to cleaner production can lead to a net creation of jobs.
Sanchez-Vargas et al. (2013)	Environmental regulation (as measured by plant's pollution abatement expenditures).	Productivity	903 observations of Mexican firms. Data from the national industrial survey in Mexico by the Mexican Statistics agency.	Cross-section (2002).	Correlation	They find a non-linear relationship between environmental regulation and productivity. They find that a decreasing trade-off between productivity and environmental regulation. Moreover, the relationship depends on the plant size and the trade-off is more important for small firms and a nearly negligible one for larger ones.
Shadbegian and Gray, 2003	Air pollution (Particulate Matter, Sulphur Dioxide) per unit of output.	Productivity	68 US pulp and paper mills. Longitudinal Research Database (LRD) (licence), PACE for pollution abatement costs.	Cross-section (year 1985).	Correlation	The authors analyse the link between firm productivity and pollution abatement. They find that plants with a 10 percent higher productivity have 2.5 percent lower emissions, suggesting that productive efficiency and pollution abatement efficiency are

						complements. Better managers are better at both production and abatement, rather than concentrating on productive efficiency at the expense of abatement performance.
Shadbegian and Gray, 2005	Pollution abatement expenditure.	Productivity	68 US pulp and paper mills, 55 oil refineries, and 27 steel mills. Longitudinal Research Database (LRD) for economic outcomes (licence), PACE for pollution abatement costs.	Panel (1979-1990).	Correlation	The authors analyse the impact of traditional environmental regulation on productivity in U.S. paper mills, oil refineries, and steel mills. They find that pollution abatement contributes little or nothing to firms' productivity.
Shadbegian and Gray, 2006	Air pollution (Particulate Matter, Sulphur Dioxide), water pollution (biological oxygen demand, total suspended solids), toxic releases; all in per unit of plant output.	Production efficiency (measured through stochastic frontier production models).	plants in 327 pulp and paper mills, 121 oil refineries, and 83 steel mills; Longitudinal Research Database (LRD) (licence), Census Bureau's Boston Research Data Center (licence), Firm financial data from Compustat, PACE survey for abatement costs, environmental performance measures come from several EPA databases: National Emissions Inventory (NEI), Permit Compliance System (PCS), Toxic Release Inventory (TRI), and	Panel (1990-2000).	Correlation	There is a positive correlation between the environmental and economic performance at the plant level. The finding suggests the importance of unmeasured characteristics that improve both the plant's environmental performance and its economic performance.

			Compliance Data System (CDS).			
van Leeuwen and Mohnen, 2017	Eco-innovations (process-, and end-of-pipe).	Total factor productivity.	Approximately 2000 Dutch manufacturing firms. Environmental Cost of Firms (ECF) survey for eco-innovations, Community Innovation Survey (CIS) for existence or anticipation of environmental regulation and for environmental innovation targets, Production Statistics Survey for production and financial firm data.	Panel (2003-2008) yearly, but with imputation.	Correlation	There is a significantly positive correlation between existing or anticipated environmental regulation and eco-innovations. Moreover, they observe that production process eco-innovations are positively correlated with firms' productivity, whereas end-of-pipe innovations are negatively correlated with firms' productivity.
Delmas and Pekovic, 2013	Adoption of environmental standards (ISO14001, organic labelling, fair trade labelling, other types of environmental-related standards).	Labour productivity.	10.663 employees from 5220 firms. French Organizational Changes and Computerization (COI) 2006 survey, Annual Enterprise Survey (EAE), Annual Statement of Social Data (DADS).	Cross-section (2006).	Correlation	Firms that have adopted environmental standards enjoy a one standard deviation higher labour productivity compared to firms that have not adopted such standards. Furthermore, the adoption of such standards is associated with increased employee training and interpersonal contacts, which can in turn contribute to improved labour productivity.
Grolleau et al., 2012	Adoption of environmental standards (ISO14001, organic labelling, fair trade labelling, other types of	Self-reported difficulties in recruiting professional and non-professional staff.	10.840 French firms. French Organizational Changes and Computerization's (COI) 2006 survey, Annual	Cross-section (2006).	Correlation	The adoption of voluntary environmental standards is associated with reduced self-reported difficulties in the recruitment of professional and non-professional employees.

	environmental-related standards).		Statement of Social Data (DADS) and the Annual Enterprise Survey (EAE) for information on wages and export respectively.			
Lanfranchi and Pekovic, 2012	Firm registration with at least one environmental standard (ISO14001, organic labelling or fair trade labelling).	Self-reported employee attitudes (usefulness to others, equitable recognition for work, employee's involvement, absence of compensation for supplementary work hours).	11600 employees at 7700 French firms from a representative French employer-employee dataset of firms with more than 20 employees. French Organizational Change and ICT's (COI) 2006 survey, French Organizational Change and ICT's (COI) 2006 survey for employee compensation, Annual Enterprise Survey (EAE) for firm export levels.	Cross-section (2006 survey).	Correlation	Employees of firms that have adopted voluntary environmental standards report a significantly higher feeling of usefulness at work. Firms' registration for environmental-related standards is associated with higher feelings of usefulness to others and feelings of being equitably recognized among the employees. While the employees do not claim to be more involved in their jobs, they are more likely to work uncompensated for supplementary work hours compared to workers in non-green firms.
Nyborg and Zhang, 2013	Corporate Social Responsibility (CSR) reputation rating collected through a survey. Respondents stated whether they associate a given firm with CSR activities. This response was combined with the	Employee wages.	100.000 Norwegian employees. Young Professionals Survey and Graduate Student survey conducted by Universum (commercial), official Norwegian employee-employer register for wages (licence).	Cross-section (2007).	Correlation	Firms with higher CSR ratings pay substantially and significantly lower wages. The authors therefore conclude that even if CSR is associated with higher costs (e.g. higher emission abatement expenses), responsible firms are still able to compete in the market even

	respondent's opinion on whether they consider the firm an "ideal employer" to obtain a relative CSR reputation score.					in the absence of ethical consumers or investors.
Attig et al., 2013	Corporate Social Responsibility (CSR) score provided by a third party research company.	Firm credit ratings (compiled by S&P).	1585 US firms. S&P credit ratings, Compustat, Center for Research in Security Prices database (CRSP), Thompson's Institutional Brokers Estimate System, MSCI ESG Stats.	Panel (1991-2010).	Correlation	The authors find a significant positive impact of CSR on firm credit ratings. They suggest that by investing in CSR, firms' financing costs are likely to decrease due to the better credit rating, which all else equal should enhance firm value and shareholders' value.
Cheng et al., 2013	Corporate Social Responsibility (CSR) score provided by a third party.	Capital constraints expressed through five accounting ratios: 1) cash flow to total capital, 2) market to book ratio, 3) debt to total capital, 4) dividends to total capital, 5) cash holdings to total capital.	2439 publicly listed firms across 49 countries. Thompson Reuters ASSET4 database.	Panel (2002-2009).	Correlation	Firms with better CSR performance face lower capital constraints.
El Ghoul et al., 2011	Corporate Social Responsibility (CSR) ratings provided by a third party research company.	Ex-ante cost of equity capital implied in stock prices and analysts' earnings forecasts.	2809 US firms; Thompson Institutional Brokers Earnings Services for analyst forecast data, Compustat North America for industry affiliation and	Panel (1992-2007).	Correlation	Firms with higher CSR scores enjoy significantly lower cost of equity capital. The authors conclude that improved CSR can enhance firm value by reducing the firm's cost of

			financial data, KLD STATS for CSR data, CRSP monthly return files for stock returns.			equity capital. They argue that CSR activities can enhance the company's investor base by attracting socially responsible investors.
Goss and Roberts, 2011	Corporate Social Responsibility (CSR) ratings provided by a third party.	Spread basis points (the amount the borrower pays over LIBOR for each loan dollar).	3996 loans to US firms. KLD Research and Analytics Inc. for measure of social responsibility, Compustat for financial information, Thompson CDA spectrum for institutional ownership, Dealscan for loan pricing data.	Panel (1991-2006).	Correlation	Firms with social responsibility concerns pay between 7 und 18 basis points more than firms that are more responsible. Lenders demand higher yield spreads from borrowers with the worst records in social responsibility. Yet, they recognize greenwashing activities and punish CSR activities that are unlikely to add value.
Papers reviewed in section 3: The joint impact of environmental regulations on environmental and economic performance						
List et al., 2003	Air pollution (Nitrogen oxide and volatile organic compounds as the primary chemical precursors to ozone).	Plant location (openings, closing, expansions, contractions).	280 pollution-intensive plants across the 62 counties in New York State. Industrial Migration File that was maintained by the New York State Department of Economic Development.	Panel (1980-1990).	Causation	Pollution-intensive plants respond adversely to more stringent environmental regulation.
Wagner et al., 2014	Greenhouse Gas Emissions, Carbon Intensity.	Employment.	9500 French manufacturing firms (approximately 12.000	Panel (1999-2010).	Causation	French manufacturing plants regulated under the EU ETS reduced carbon emissions by

			establishments) with more than 20 employees. EACEI (Annual survey of energy consumptions in the industry) for energy consumption, French annual business survey (Enquete Annuelle des Entreprise) for balance sheet data, ETS transaction log for emissions allowances.			15% during Phase II (2008-2013) compared to unregulated plants. No effect has been found during Phase I (2005-2007). They do not find significant impacts on employment or on emission reallocation. Reductions in emissions appear to be largely driven by reductions in the carbon-intensity of production.
Petrick and Wagner, 2014	Carbon emissions and carbon intensity.	Employment, turnover, exports.	1658 German manufacturing facilities with more than 20 employees. AFiD-Betriebspanel from German Research Data Centre (licence), CITL for list of treated plants, AMADEUS.	Panel (2007-2010).	Causation	The EU ETS caused treated firms (firms that were regulated by the EU ETS) to reduce their emissions by 25 to 28 percentage points more than non-treated firms (non-regulated firms which were otherwise similar). The carbon intensity of treated firms declined between 18 and 30 percentage points faster for EU ETS firms relative to control firms. Firms largely reduced their carbon emissions by switching from high-carbon fuels to low-carbon fuels. The authors find no evidence that being regulated under the EU ETS had a negative impact on employment. The authors estimate that the EU ETS increased gross output between

						4 and 7 percent for regulated firms compared to non-regulated firms. The evidence suggests that firms responded to the EU ETS regulation by reducing their carbon intensity and not by reducing the scale of their production.
Klemetsen et al., 2016	Air pollutants (CO2, N2O, PFCs) all measured in CO2 equivalents, Emissions Intensity (emissions divided by man hours), Emissions Level.	Value added at factor prices, labour productivity.	152 Norwegian plants, of which 72 plants are regulated by the EU ETS. Annual emissions of Norwegian plants from the Norwegian Environment Agency (licence), Statistics Norway for plant level data on employment, value added, energy use and prices (licence).	Panel (2001-2013).	Causation (yet there remain differences in treatment and control group after matching).	Plants regulated under the EU ETS reduced emissions by 30% in Phase II of the EU ETS, but not in the other phases. Plants did not reduce their emissions intensity in any phase. The authors find positive effects on value added and labour productivity for plants regulated under the EU ETS compared to the control group.
Jaraite and Di Maria, 2016	CO2 emissions, CO2 intensity.	Profitability, Investment.	353 Lithuanian firms (41 ETS firms, 312 non-ETS firms). Sample survey of non-financial enterprises (F-01) from Statistics Lithuania for main financial indicators. EU CITL for emissions data.	Panel (2005-2010).	Causation	During Phase I the EU ETS did not cause a reduction in CO2 emissions. Yet, CO2 intensity decreased slightly between 2006 and 2007. They find no significant effect on firm profitability from the EU ETS. Yet, the authors suggest that the EU ETS might have induced the retirement of old and less efficient capital stock during Phase I, and led to some additional investments

						into new capital equipment from 2010.
Abrell et al., 2011	CO2 emissions.	Profits, employment, value added.	2101 European firms. Community Independent Transaction Log (CITL) collected by the European Commission for emission allowances, AMADEUS for firm production data.	Panel (2005-2008).	Causation	Emission reductions were 3.6% higher between 2007 and 2008 than between 2005 and 2006, which the authors attribute to the increased stringency of the regulation of the EU ETS. They argue that the shift from Phase I to Phase II of the EU ETS had a significant impact on firms' emission reductions. They find that the EU ETS did at most modestly affect profits, employment and value added of regulated firms. This study finds a causal effect, yet they take control firms only from non-regulated sectors, which likely introduce a selection bias at the sector level).
Martin et al., 2014a	Energy intensity, electricity use.	Employment, Revenue, Total factor productivity, plant exit.	6886 UK plants. Annual respondents database (ARD) which is maintained by the Office for National Statistics (licence), Quarterly Fuels Inquiry (QFI) for energy use information, information on CCA participation from both DEFRA and HM Revenue and Customs (HMRC)	Panel (2001-2004).	Causation	The UK Climate Change Levy had a strong negative impact on energy intensity (-18%) and electricity use (-22.6%). No statistically significant impacts are found for employment, revenue, total factor productivity or plant exit. The results suggest that firms substituted labour for energy and increased output prices in

			websites, European Pollution Emissions Register (EPER) (public).			response to the energy price increase.
Marin and Vona, 2017	CO2 emissions, energy consumption.	Employment, wages, productivity.	French manufacturing establishments with 61153 establishment-year observations. Datasets provided by the French Statistical Office (INSEE) (Licence): EACEI survey on energy purchase and consumption, DADS for employment and wage data, FARES-FICUS on firms' balance sheets.	Panel (2000-2010).	Correlation	The authors find that a 10 percent increase in energy prices leads to a 6 percent reduction in energy consumption and to an 11 reduction in CO2 emissions. They find a modestly negative impact on employment of negative 2.6 percent and small negative effects on wages and productivity. The negative employment effects are mostly concentrated in energy-intensive and trade-exposed sectors.
Lanoie et al., 2011	Environmental performance (self-reported survey answer), Environmental R&D (self-reported survey answer).	Business performance (self-reported survey answer).	4144 facilities across 7 OECD countries covering facilities with more than 50 employees across all manufacturing sectors. OECD survey.	Cross-section (survey conducted in 2003).	Correlation	Using a survey across 7 OECD countries, the authors obtain self-reported data on environmental and business performance to test different versions of the Porter Hypothesis and its causality chains. The authors find support for the "weak" version of the Porter Hypothesis, showing that environmental regulation induces innovation. Furthermore, they also find that more flexible "performance standards" are more likely to induce

						innovation than more prescriptive "technology-based standards". Yet, they find no support for the "strong" version of the Porter Hypothesis. They find a negative direct effect of policy stringency on business performance, which exceeds the indirect positive effect, mediated through R&D.
Rexhauser and Rammer, 2014	Environmental Innovation (Defined as a new or significantly new product introduced between 2006 and 2008 in the firm that creates environmental benefits compared to alternatives; self-reported).	Firm profitability.	3618 German firms. German part of the Community Innovation survey (Mannheim innovation panel) (licence).	Cross-section (Survey conducted in 2009).	Correlation	The authors provide evidence that environmental innovation, which improves firms' resource efficiency, can provide positive profitability effects. Yet, for any other environmental innovation, which does not improve resource efficiency, they find some weak evidence for adverse profitability effects.