2018
#GGSD Forum & #GGKP6 Annual Conference
OECD, Paris
27-29 November

Inclusive solutions for the green transition

Issue Paper

Green policies and firms'competitiveness

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Authorship & Acknowledgements

This issue note was prepared for the 2018 GGSD Forum to steer discussion around the theme of Session 2 on "Green growth and Competitiveness: firms who win, firms who lose." A previous version of this note was published as "*The impacts of environmental regulations on competitiveness*" (2017), Review of Environmental Economics and Policy 11(2), 183–206. The authors are Antoine Dechezleprêtre (OECD) and Misato Sato (Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science). The note benefitted from comments and suggestions by Enrico Botta and Jaco Tavenier from the OECD. The previous version was reviewed by Milan Brahmbhatt, Raphael Calel, Baran Doda, Damien Dussaux, Carolyn Fischer, Matthieu Glachant, Colin McCormick, and Dimitri Zenghelis. The note was produced under the supervision of Kumi Kitamori, Head, Green Growth and Global Relations Division, OECD. Financial contribution by the Global Green Growth Institute, the Grantham Foundation for the Protection of the Environment, the European Union Seventh Framework Programme and the UK Economic and Social Research Council through the Centre for Climate Change Economics and Policy is gratefully acknowledged. The opinions expressed herein do not necessarily reflect the official views of the OECD member countries.

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1. Introduction

A major concern in the context of the green transition is the potential impacts of environmental policies, and of green growth policy packages more generally, on the competitiveness of companies affected by these regulations. Businesses and policy makers fear that, in a world characterised by integrated global value chains and capital flows, differences in the stringency of environmental policies across countries could shift pollution-intensive production capacity towards regions with less ambitious regulation. For example, many countries are concerned that their efforts to achieve carbon emission reductions will put their own carbon-intensive producers at a competitive disadvantage in the global economy, and such concerns are often used by policy makers as a justification for not introducing more ambitious environmental policies.

Yet, environmental regulations are sometimes viewed as potential drivers of economic growth. For example, the famous Porter hypothesis (Porter and van der Linde, 1995a) argues that more stringent environmental policies can actually have a net *positive* effect on the competitiveness of regulated firms because such policies promote cost-cutting efficiency improvements, which in turn reduce or completely offset regulatory costs, and foster innovation in new technologies that can help firms achieve international technological leadership and expand market share.

The growing importance of this debate among policy makers has given rise to a large number of studies that attempt to quantify the effects of environmental regulations on key aspects of firms' competitiveness, including trade, industry location, employment, productivity, and innovation. **The objective of this briefing note is to review this recent empirical literature in order to inform the political debate concerning the potential economic impacts of the green transition**.

The note starts by explaining how environmental regulation may cause competitiveness effects and how these effects are measured. It then reviews the existing empirical evidence, discussing first the impact of relative environmental stringency on trade, industry location and employment, and then examining the effects on productivity and innovation, which could also impact firms' competitiveness. It concludes with a summary identifying knowledge gaps and a discussion of priorities for future research.

Competitiveness concerns stem largely from differences in environmental regulation across countries. Thus, this note focuses primarily on studies that empirically examine cross-country differences in environmental stringency. It also includes some studies that examine differences between smaller-scale jurisdictions (e.g., cross-county differences in the United States). Importantly, the review covers only *ex post* evaluation studies, thus excluding *ex ante* modelling studies, which have recently been reviewed by Carbone and Rivers (2017). It also focuses on environmental regulations that affect the manufacturing sector and target industrial emissions, which are at the centre of most competitiveness debates.[1]

[1] Regulations on fishing, agriculture, forestry, mining, or waste, which are sometimes directed explicitly at protecting the environment and human health, are not included.

2. How does environmental regulation affect firms' competitiveness?

In the context of environmental policies, competitiveness[2] effects result from differences or asymmetries in regulatory stringency[3] applied across entities (e.g., firms or sectors) that are competing in the same market. For example, some firms may be regulated while others are exempt; some sectors may face stricter pollution standards than others; or environmental stringency may vary across jurisdictions as is the case with climate change mitigation policies where different regions are expected to take carbon mitigation action at different speeds under the UNFCCC's Paris Agreement. If two competing firms face identical regulation, then competitiveness effects are not an issue.[4] Thus, **competitiveness effects can be distinguished from the general effects of regulations on polluting firms' economic outcomes, which are caused by the policy itself rather than by differences in environmental policy faced by polluting firms relative to their competitor(s)**.

Asymmetric Environmental Regulations and Relative Production Costs

Environmental regulations generally require polluting facilities to undertake abatement activities and may impose costs on businesses. Thus, regulatory differences across firms, sectors or jurisdictions can cause changes in relative production costs. Such changes could arise from differences in *direct* costs. For example, the European Union Emissions Trading System (EU ETS), which regulates carbon emissions of approximately 12,000 installations across Europe, is estimated to have increased average material costs (including fuel) for regulated firms in the power, cement and iron & steel sectors by 5% to 8% (Chan et al. 2013).[5] Increases in relative costs could also result from higher *indirect* costs caused by policy-induced changes to input costs. For example, even if they are not directly regulated by the EU ETS, European consumers of electricity face higher electricity costs due to the price on carbon emissions paid by electricity producers. Differences in environmental regulations can thus alter the competition between firms by changing their relative production costs.

Pasurka (2008) finds evidence that **differences in environmental stringency across countries induce important differences in pollution abatement costs**. Across nine countries in Europe, North America and Asia, the share of manufacturing capital expenditure assigned to pollution abatement in 2000 ranged from 1 percent (Taiwan) to 5 percent (Canada). In terms of sectoral variation, abatement costs are typically higher for pollution intensive industries such as pulp and

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[2] 'Competitiveness' is a term that is often used but ill-defined. In general, it refers to the ability of a firm or sector to survive competition in the market place, grow and be profitable (Bristow 2005). Some concepts of competitiveness discussed in the literature include the 'ability to sell' (which reflects the capacity to increase market share), 'ability to earn' (the capacity to increase profit), ability to adjust and ability to attract (see e.g. Berger 2008 for an overview).

[3] The term "policy stringency" is used to describe a general level of policy ambition. In practice, measuring relative policy stringency across different forms of regulation and enforcement regimes is far from straightforward.

[4] Note, moreover, that if there are no regulatory differences across companies, it is not possible to establish a counterfactual scenario (i.e., what would have happened had the policy not been implemented) against which to evaluate the impact of a given regulation.

[5] In addition to affecting marginal and average costs of production, environmental regulations can affect entry and investment costs for companies. Ryan (2012) finds that the 1990 US Clean Air Act Amendments (CAAA) had no effect on the cement industry's marginal (variable) costs, but the average sunk costs of entry increased, with the costs of building a new, greenfield facility increasing by $5 million to $10 million due to the rigorous environmental certification and testing requirements of the CAAA.

paper, steel, and oil refining. In the US, for example, in 2005 each of these sectors spent approximately 1% of their turnover to comply with environmental regulations, while the average for all manufacturing plants was 0.4% (Ferris et al, 2014). Importantly, differences in relative costs may arise not only from the stringency of the regulation, but also from its nature and design (Irlado et al., 2011), in particular because of the uncertainty associated with different types of instruments (Goulder and Parry, 2008).

As illustrated in Table 1, **asymmetric environmental policies induce changes to relative production costs (the first order effect) and trigger different responses by firms**. Firms may respond through decisions concerning pricing, output or investment in particular in abatement technologies (second order effects). For example, in the case of pricing, firms may decide to absorb the increase in production costs or pass it through to consumers.[6] These firm responses in turn influence outcomes along various economic, technology, international, and environmental dimensions (third order effects). .

Table 1. Competitiveness effects due to differences in the stringency of environmental regulations

1st order effect	2nd order effect	3rd order effects			
Cost impacts	Firm responses	Technology outcomes	Economic outcomes	International outcomes	Environ-mental outcomes
Changes to relative costs (direct and indirect costs)	- Production volume - Product prices - Productive investments - Investment in abatement	- Product innovation - Process innovation - Input saving technologies - Total factor productivity (TFP)	- Profitability - Employment - Market share	- Trade flows - Investment location - Foreign direct investment (FDI)	- Pollution leakage

Source: authors

The Pollution Haven Hypothesis vs the Porter Hypothesis

There are two opposing views on the likely competitiveness effects arising from asymmetric environmental policies worldwide. **The pollution haven hypothesis** goes back more than thirty years (e.g., McGuire 1982) and **predicts that if competing companies differ only in terms of the environmental policy stringency they face, then those facing relatively stricter regulation will lose competitiveness**.

Higher regulatory costs could, for example, crowd out productive investment in innovation or efficiency improvements and slow down productivity growth. If increased regulatory costs are passed through to product prices in fiercely competitive product markets, distortions in trade could occur, as product prices will rise more in countries with relatively strict regulation. Companies in countries with higher costs will then lose market share to competitors in countries producing pollution intensive exports more cheaply. If environmental regulatory differences are expected to last, companies' decisions regarding new production facilities location or foreign direct investment may also be affected, with pollution intensive sectors and thus manufacturing employment possibly gravitating towards countries with relatively lax policies, thus creating pollution havens.

[6] In order to drive a demand-side switch toward cleaner products, it is both desirable and necessary to have product prices reflect pollution abatement costs. How firms respond to pricing has important distributional consequences.

The Porter Hypothesis takes the more dynamic perspective that more stringent policies should trigger greater investment in developing new pollution-saving technologies. If these technologies induce input (e.g., energy) savings which would not have occurred without the policy, they may offset part of the compliance costs. Porter and van der Linde (1995a) go further, arguing that environmental regulations can actually "trigger innovation that may *more than fully* offset the costs of complying with them" -- i.e., lowering overall production costs and boosting the competitiveness of firms.[7] This Porter hypothesis outcome may occur if cleaner technologies lead to higher productivity, input savings, and innovations, which over time offset regulatory costs (dynamic feed back to the first order effect) and improve export performance and market share. For example, the existence of learning externalities might prevent the replacement of an old polluting technology by a new, cleaner and more productive technology because firms have a second-mover advantage if they wait for someone else to adopt. In this situation, the introduction of an environmental regulation would induce firms to switch to the new, cleaner technology, which improves environmental quality and eventually increases productivity (Mohr, 2002). An argument that is related to the Porter hypothesis postulates that a country can generate a **first-mover advantage** to domestic companies by regulating pollution sooner than other countries, which leads domestic firms towards international leadership in clean technologies that are increasingly in demand globally (Porter and van der Linde, 1995b).

[7] See Ambec et al. (2013) for a discussion of the theoretical justifications for the Porter hypothesis that have been proposed in the literature.

Key conclusions

- In the context of environmental policies, competitiveness[8] effects result from *differences* or *asymmetries* in regulatory stringency[9] applied across entities (e.g., firms or sectors) that are competing in the same market. Competitiveness effects can be distinguished from the general effects of regulations on polluting firms' economic outcomes, which are caused by the policy itself rather than by differences in environmental policy faced by polluting firms relative to their competitor(s).

- There is evidence that differences in environmental stringency across countries induce important differences in pollution abatement costs.

- Asymmetric environmental policies induce changes to relative production costs and trigger different responses by firms, in terms of pricing, output and investment. These firm responses in turn influence outcomes along various economic, technology, international, and environmental dimensions.

- The pollution haven hypothesis predicts that if competing companies differ only in terms of the environmental policy stringency they face, then those facing relatively stricter regulation will lose competitiveness.

- The Porter Hypothesis argues that more stringent policies should trigger greater investment in developing new pollution-saving technologies and that these innovations may *more than fully* offset the costs of complying with regulations.

[8] 'Competitiveness' is a term that is often used but ill-defined. In general, it refers to the ability of a firm or sector to survive competition in the market place, grow and be profitable (Bristow 2005). Some concepts of competitiveness discussed in the literature include the 'ability to sell' (which reflects the capacity to increase market share), 'ability to earn' (the capacity to increase profit), ability to adjust and ability to attract (see e.g. Berger 2008 for an overview).

[9] The term "policy stringency" is used to describe a general level of policy ambition. In practice, measuring relative policy stringency across different forms of regulation and enforcement regimes is far from straightforward.

3. Measuring competitiveness effects empirically

Since Jaffe et al. (1995), empirical analyses of the competitiveness effects of environmental regulation have benefited from improvements in data availability, empirical methodology, and policy stringency measurement. There is yet no single accepted test or measure of the competitiveness effects of environmental regulation and the literature uses a variety of outcome measures linked to competitiveness (summarized in Table 1). Despite some progress made, there are still a number of challenges to conducting credible empirical analysis of the competitiveness impacts of environmental regulations.[10]

Measuring competitiveness at the micro-level with firm data

The greater availability of detailed data, in particular at the firm or facility level, over the last couple of decades has been key to obtaining more robust evidence on competitiveness impacts. Using country or sector level data can be problematic because it does not allow researchers to distinguish between the production facilities that are covered or exempt and the particular policy being evaluated, leading to aggregation bias (Levinson and Taylor 2008). Moreover, an important challenge to empirically analysing the competitiveness impacts of environmental regulation is that the policies could be endogenous. This could be the case if environmental policies are correlated with the unobserved determinants of the outcome variable of interest such as trade (e.g., supply chain linkages, other firm specific factors, political institutions, the stringency of other regulations). Governments could also set stringency levels strategically, for example, by exempting key export sectors from environmental regulations, suggesting the possibility of reverse causality when using sectorally-aggregated data. The recent economic geography literature also suggests the presence of bias if the location of polluting firms is influenced by other firms in that location (e.g., Zeng and Zhao 2009). Firm-level panel data sets over long time periods both before and after the introduction of the policy and improved estimation methods can overcome these problems by controlling for unobserved heterogeneity across firms.[11] However, numerous policies, in particular in developing countries, can still not be the subject of rigorous evaluation because of the lack of high-quality data. Going forward, ensuring that data collection is built into the design of policies from the outset will enable researchers to evaluate the impacts of the many new environmental policies that are being implemented.

Measuring environmental stringency

To evaluate the impact of a given regulation, there needs to be an accurate measure of environmental stringency so that a control group can be constructed that captures what happens in the absence of a policy or in the event of a weaker policy. In within-country analyses, variation in environmental regulatory stringency can arise if a policy is implemented in a random subset of regions, or if the rollout is staggered over time. For example in the US context, the federal designation of counties into "attainment" or "non-attainment" status depends on local air quality for various pollutants, hence providing a convenient source of exogenous variation. Counties in nonattainment then face much stricter environmental regulation.[12]

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[10] Jaffe et al. (1995) argued that the ideal measure to study competitiveness would be the effect of relative policies on net exports. With aggregated sector level data, this is a theoretical measure because it is impossible to measure the reduction in net exports 'before' adjustments in the exchange rates holding real wages and exchange rates constant. However, it is less of a problem when using data at a disaggregated level, because changes to trade are unlikely to affect exchange rates.

[11] This occurs when firms' unobserved characteristics may be correlated with both regulatory stringency and the outcome measure (e.g., productivity).

[12] Being federally mandated, this status is unlikely to be related to differences in tastes, geographic attributes, or underlying economic conditions across counties. Moreover, local

In an international context, however, it is often the case that different policies need to be compared. This is a difficult task due to the complex nature of environmental regulation. Although the measurement of relative stringency is likely to be fraught with measurement error, a number approaches have been used in the literature. One popular option is to proxy stringency using either the environmental outcome (pollution level) or measures of compliance costs as a share of value added. The latter option has typically used data on pollution abatement and control expenditures (PACE), which has been collected for the United States since the 1970s and for Europe and Asia Pacific countries since the 1990s. However, PACE is far from an ideal proxy for stringency. First, because the production level is used as a denominator, it is unlikely to be exogenous. Second, because it is based on survey data, PACE is not readily comparable across countries since the survey methodologies differ across countries in terms of what should and should not be considered as abatement expenditures. Third, PACE data do not account for how compliance costs may impact market competition (Ryan, 2012; Sweeney, 2015). Finally, PACE data are available only for surviving firms. Thus, impacts on firms that exit because of the environmental regulation would not be included in the measure.

Several alternative measures of stringency have been used in the literature, including environmental or energy tax revenue, renewable energy capacity, recycling rates, legislation counts, and composite indicators. However, as discussed in Brunel and Levinson (2013) and Sato et al. (2015), all of these have shortcomings. For example, although price-based policies such as emissions trading would appear to be easy to compare, they are complicated by differences in the set-up of systems (e.g., sectoral coverage) and exemption rules, such as differences in free allowance allocation provisions, which not only affect the level of policy stringency, but also alter incentives and influence the behaviour of firms.[13] However, few measures of stringency account for such provisions. Although these shortcomings do not prevent analysis of the impacts of environmental policies, it is important to keep them in mind when reviewing the available evidence.

Key conclusions

- There is no single accepted test or measure of the competitiveness effects of environmental regulation and the literature uses a variety of outcome measures linked to competitiveness, such as trade, investment, profits, output, innovation activity or productivity

- The greater availability of detailed data, in particular at the firm or facility level, over the last couple of decades has been key to obtaining more robust evidence on competitiveness impacts. However, numerous policies, in particular in developing countries, can still not be the subject of rigorous evaluation because of the lack of high-quality data.

- Measuring competitiveness effects in an international context requires to compare the stringency of different policies. This is a difficult task due to the complex nature of environmental regulation. Several alternative measures of stringency have been used in the literature, including environmental or energy tax revenue, renewable energy capacity, recycling rates, legislation counts, and composite indicators. However, all of these have shortcomings, and accurately measuring the stringency of environmental regulation across jurisdictions is still an active research area.

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pollution levels depend heavily on weather patterns (in particular wind and precipitation), which are unlikely to be systematically related to local manufacturing sector activity (Greenstone et al., 2012).

[13] For example, see Branger et al., (2015) for an analysis of the impact of the EU ETS free allocation rules on operational, investment, and trade decisions.

4. Empirical evidence: impacts on trade, industry location, and employment

A central focus of the competitiveness debate has been the potential impact of environmental regulation on international trade and the location of production and investment, as well as the employment consequences of these effects.[14] This section examines the evidence concerning these impacts.

Impacts on trade

Much of the early literature tested the pollution haven hypothesis[15] by examining the overall effect of international trade on the quality of the environment. Grossman and Krueger (1995), for example, asked how openness to trade affects the environment through its effects on the scale of economic activity, sector composition, and technology adoption, and found limited empirical evidence that trade made developing countries dirtier.[16] In a study of 43 countries, Antweiler et al. (2001) find that international trade is in fact beneficial to the environment (as measured by sulphur dioxide concentration) because the increase in economic activity (scale effect) is offset by changes in both technology and the composition of output in the economy. One explanation for this result is that in low-income countries, the higher price of capital offsets their 'advantage' of having lax environmental policies because pollution intensive industries are also capital intensive. Levinson (2010) instead examines the composition of US imports, following the adoption of environmental regulation. Taking account of intermediate inputs, he finds that between 1972 and 2001, US imports increasingly shifted away from pollution intensive goods. This, he argues, does not contradict the pollution haven hypothesis because the shift toward less polluting imports may have been smaller without environmental regulations. However, he suggests that if there was indeed a pollution haven effect, it was likely overwhelmed by other forces such as availability and costs of raw materials, transport costs, market structure, and fixed plant costs. Subsequent analyses have found that **international trade has a modest impact on pollution** (e.g. McAusland and Millimet 2013).

Several studies have more directly assessed whether environmental regulation causes changes in trade flows. These studies use a variety of measures of relative environmental stringency, with PACE being a popular choice. For example, Ederington and Minier (2003) treat PACE as an endogenous variable and, for a panel of US manufacturing industries, find that between 1978 and 1992, net imports rose with higher PACE,[17]suggesting that policy stringency is indeed determined strategically by governments. Using the same data but taking account of factors that limit the geographical mobility of economic activity (e.g., transportation costs, fixed plant costs, and agglomeration economies of an industry), Ederington et al. (2005) find that the pollution haven effect is difficult to detect in capital intensive industry. They note that quantifying average effects on competitiveness across all sectors understates the effects of regulatory differences on 'footloose' (i.e., not geographically mobile) sectors. Levinson and Taylor (2008) use a panel for 1977-86 and find that a 1% increase in PACE in the US is associated with an increase in net imports of 0.4% from Mexico and 0.6% from Canada.[18] Levinson (2010), however, argues that the

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[14] Related to this are political economy concerns about governments' use of environmental policy as an implicit trade barrier to circumvent international free-trade agreements.

[15] Some scholars also refer to a pollution haven "effect", which occurs if asymmetric environmental policies, at the margin, influence firms' trade and investment location decisions. See Copeland and Taylor (2004) for a detailed discussion of the pollution haven arguments.

[16] For a review of such earlier studies, see Jaffe et al (1995) and Taylor and Copeland (2004).

[17] The authors used an instrumental variables approach.

[18] They use a fixed effects model that accounts for unobserved sector characteristics that are correlated with regulation and trade, unobserved foreign pollution regulation levels, and

result in Levinson and Taylor (2008) does not actually show that higher levels of PACE causes higher imports; rather, it shows that imports are rising in sectors where the gap in the stringency level across countries is increasing.

While carbon pricing policies are relatively new and coverage is limited, a number of recent studies conduct *ex-post* analysis on their trade impacts.[19] Branger et al (2016) examine the impact of the EU ETS – to date the world's largest carbon market – using a time-series analysis for the period 2004 to 2012. They test whether carbon prices increased net EU imports of cement and steel, but they find limited evidence. Two studies use an alternative approach -- exploiting the historic variation in energy prices to estimate the effect of carbon price differences on trade -- thus taking advantage of the fact that carbon prices essentially work by increasing energy prices. In the first study, Aldy and Pizer (2015) use U.S. state-level variation in industrial energy prices and fuel composition to estimate how production and net imports change in response to energy prices between 1974 and 2005.[20] When averaging across all sectors, they find that **the effect of energy price on net imports is statistically indistinguishable from zero. However, they find evidence that both net imports and production are more sensitive to energy prices in more energy intensive sectors**, including iron and steel, chemicals, paper, aluminium, cement, and bulk glass, but that the magnitude of the effect is small (a 0.1-0.8% increase in net imports). In the second study, Sato and Dechezleprêtre (2015) examine the influence of an energy price gap between two trading partners on bilateral trade flows for 42 countries and 62 manufacturing sectors between 1996 and 2011. On average, they find that a 10% increase in the energy price gap increases bilateral imports by 0.2%, and that overall, energy price differences explain 0.01% of the variation in trade flows.[21]

To summarize, the recent evidence appears to offer broad support for the existence of a pollution haven effect, with imports of pollution- or energy- intensive goods increasing in response to tighter regulation. However, the effects tend to be small and concentrated in few sectors. Overall, the effect of relative stringency on trade flows is overwhelmed by other determinants of trade such as skilled labour availability, access to raw materials, and transport costs.

Impacts on Location of Production and Foreign Investment

Addressing concerns that trade liberalisation is creating a 'race to the bottom', in which governments competing for FDI are strategically undercutting each-others' environmental standards, another active area of empirical investigation has been the exploration of the effects of environmental regulation on investment location as evidence of pollution havens. This literature

aggregation bias in sectoral data (due to changes to industry composition). Because they use data from only one country, they can estimate the effects of environmental regulation on trade only by comparing sector level net imports as a function of industry characteristics. The variation in pollution abatement expenditures across sectors may reflect unobserved heterogeneity rather than relative stringency.

[19] There is a substantial literature on carbon leakage that explores the potential environmental consequences of the trade effects of regulatory differences (see Branger and Quirion (2014) for a review). However, this literature mostly uses ex-ante modelling and is thus excluded from our review. The carbon leakage literature can be distinguished from the literature on trade-embodied carbon (e.g., Peters et al 2011), which includes all embodied emissions in trade regardless of whether they are induced by asymmetric policies or other underlying economic factors that influence trade patterns.

[20] They use a detailed panel of state-level manufacturing production data covering 450 sectors.

[21] The more recent time-frame of these two studies means we can interpret the results in the post 2000 context, which saw rapid growth in global trade, particularly between industrialised countries and emerging economies such as China, as well as a rise in competitiveness concerns.

broadly examines two distinct questions: first, whether relatively lax policies are a pull factor in attracting incoming manufacturing investments and second, whether stringent policies are a push factor that influences the decision on outward investment flows or relocation decisions.

Location choice of new and relocating domestic firms

A number of studies use the variation in environmental standards across U.S. States and counties to examine its effect on manufacturing plant location. Using establishment-level data for 1982 from the Census of Manufacturers and six different measures of environmental stringency, Levinson (1996) finds that interstate differences in environmental regulations do not systematically influence the location choice of new manufacturing plants. Using the Levinson index,[22] Henderson and Millimet (2005) examine the impact of environmental policy between 1977 and 1986 and find no effect on state-level aggregate output. In contrast, studies that used more disaggregated data for New York State find that between 1980 and 1990, county-level differences in the regulatory status of the 1997 Clean Air Act Amendments (CAAA) had very large statistically significant effects. More specifically, relative to an "attainment" county, being a strictly regulated "nonattainment" county decreases the flow of relocating plants by nearly 63% (List et al. 2003) and decreases the expected flow of new dirty plants by 44-61% or 150-600%, depending on the estimator used (List et al. 2004). A comparison of these inter and intra-state studies of the United States suggests that studies with smaller geographical scope tend to find stronger effects, possibly because smaller areas tend to have less variation in the other determinants of production location. Indeed, also using the dataset for New York State, Millimet (2004) finds that the effect of stricter regulation is spatially heterogeneous and varies systematically with location-specific attributes such as unemployment levels.

Impacts on inward Foreign Direct Investment

A number of studies use the within-country variation in environmental stringency and find inconclusive evidence on its impact on inward FDI location. List et al. (2004) uses US data and find that environmental stringency has very strong effects on new plant births for *domestic* companies' plants, but no effect on locational choice for foreign-owned pollution-intensive plants. Dean et al. (2009) examine inward FDI in China between 1993 and 1996 and find that equity joint ventures in polluting industries are generally not attracted by weak environmental standards. In contrast, using US state level data, Keller and Levinson (2002) find that between 1977 and 1994, a 10% increase in relative manufacturing pollution abatement cost is associated with a 0.79% fall in manufacturing FDI and, more specifically, a 1.98% fall in FDI in the chemical industry. Fredrikson et al. (2003) and Millimet and Roy (2015) also find that environmental regulation plays a role in the location outcome of FDI into the United States, and both studies highlight the importance of treating environmental regulation as endogenous in this type of analysis, because the influx of FDI can lead to a change in environmental regulation.

With international studies, determining whether countries use environmental regulation strategically to attract FDI faces the major challenge of accurately measuring environmental stringency across countries. Xing and Kolstad (2002) study 22 countries between 1985 and 1990 using SO_2 emissions, but this approach likely captures only one component of environmental stringency (i.e., regulation of coal combustion), which biases estimates towards energy intensive industries. Indeed, Xing and Kolstad (2002) find a significant effect for only two of the six sectors studied -- with a 1% decrease in SO_2 emissions associated with 0.27 and 0.20 million dollar increases, respectively, in new investments from US multinational companies in the chemicals and primary metals sectors. However, this effect is small relative to the total outflow of US FDI (e.g., $4 billion in 1991 in the chemicals sector). Wagner and Timmins (2009) use the World Economic Forum (WEF) index of environmental stringency and enforcement, which is based on interviews with business executives, to study the effect of relative environmental stringency on German FDI

[22] This is a state-year level industry adjusted index of environmental stringency based on pollution abatement costs.

destination across 163 countries and 23 industrial sectors. They find that in the chemicals sector, if a country reduces its environmental stringency by one standard deviation (e.g., moving from Austria's to Slovakia's stringency), German FDI would increase by 122,000 euros per year, which is very large in magnitude -- corresponding to almost two-thirds of the standard deviation of annual investment flows in the chemical industry. However, they find no effects for other sectors. Kellenberg (2009) also uses the WEF index and finds strong evidence that countries with lax environmental policy *enforcement* (rather than a lax stringency) attracted more US multinational firms' production.[23] In contrast, although Raspiller and Riedinger (2008) and Ben-Kheder and Zugravu (2012) experiment with a number of different measures of stringency, they find no systematic evidence concerning French firms' FDI activity.

Impacts on outward Foreign Direct Investment

Whether stringent environmental policies encourage firms to increase foreign assets also remains empirically unresolved. Using energy intensity as a proxy, Eskeland and Harrison (2003) find little evidence that stringent regulation in the United States encourages outbound investment to Mexico, Cote d'Ivoire, Morocco, and Venezuela. Manderson and Kneller (2012) use UK firm level data to explicitly account for heterogeneous firm behaviour, and also find no evidence that firms with high environmental compliance costs are more likely to establish foreign subsidiaries than those with low environmental compliance costs. Hanna (2010) also uses firm-level data to examine whether exogenous changes in regulatory status under the CAAA caused US multinational firms to increase their foreign assets and foreign output in the 1980s and 1990s.[24] She finds that for "nonattainment" counties, their resident multinational firms increased their foreign assets by 5.3% and their foreign output by 9%.

Overall, **the empirical evidence suggests that the existence of a pollution haven effect for foreign investment remains unclear**. In a meta-analysis of eleven studies on the impact of environmental regulations on new plant location, Jeppsen et al. (2002) find that the estimates are highly sensitive to the empirical specification, the data, the definition of the regulatory variable, the control variables, and geographical coverage. Our updated review of the new plant and FDI location literature here suggests that this conclusion still holds.

Impacts on Employment

Given that the offshoring of pollution-intensive production corresponds to the offshoring of pollution-intensive jobs, 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 regions where declining manufacturing employment has become a contentious political issue.[25] Hafstead and Williams (2016) show that at the macroeconomic level, **in the long run, environmental regulations might simply induce a substitution between polluting and non-polluting activities, with the impact on net employment impossible to determine a priori but likely small** because of general equilibrium effects. However, at the microeconomic level and in the short-run, the available evidence shows that the effects of environmental regulations on employment in energy- and pollution-intensive sectors are small but statistically significant.

[23] More specifically, they find that for countries in the top 20th percentile in terms of the value added of US multinational affiliates from 1999 to 2003, 8.6% of the value added growth was attributed to lower environmental policy stringency.

[24] The use of disaggregated data allows Hanna (2010) to avoid reverse causality issues, control for unobserved heterogeneity at the firm level as well as industry trends, thus going a long way towards avoiding the problem of omitted variable bias.

[25] 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).

Unfortunately, the evidence to date is based exclusively on within-country differences in environmental stringency across subnational jurisdictions. This suggests that, if relocation barriers are assumed to be higher across than within countries, then it is reasonable to consider the results we will present here as being upper bounds on the likely effect of an equivalent cross-border difference in environmental stringency.

Sectoral studies

Using PACE as a proxy for environmental stringency, Morgenstern et al. (2002) find that stricter environmental regulation generally does not have a statistically significant effect on employment. In fact, they even find statistically significant and positive employment effects in two industries (plastics and petroleum), although the total number of affected jobs remains quite small. More specifically, they find that environmental regulation accounted for at most 2 percent of the observed decline in employment from 1984 to 1994. Similarly, in one of the very few non-US studies, Cole and Elliott (2007) find no evidence that environmental regulations reduced employment in 27 industries in the UK.

Plant and firm-level studies

Studies using sector-level data cannot capture job reallocation within firms, industries or regions. However, a few studies have used plant or firm-level data and can thus account for these impacts. For example, Berman and Bui (2001b) compare petroleum refineries in the Los Angeles area, which are subject to some of the strictest air pollution regulations in the United States, to all other refineries in the country. They find no evidence that environmental regulation decreased labour demand, even when allowing for induced plant exit and discouraged plant entry. They actually find weak evidence that the strict environmental regulations in Los Angeles may have resulted in a small net *increase* in employment, possibly because more labour is required for pollution control activities. This finding is similar to Morgenstern et al. (2002), with the lower bound of the Berman and Bui (2001b) estimates implying that over a 12-year period, fewer than 3,500 jobs were lost due to regulation (and the upper bound implying 11,700 jobs were *gained*).

By combining large micro datasets with long panels, Kahn (1997) and Greenstone (2002) are able to provide the most compelling evidence to date on the impact of the US Clean Air Act Amendments on employment. Kahn (1997) finds that the growth rate in manufacturing employment over the 1982-1988 period is 9% lower in "nonattainment counties" that have more stringent air pollution regulations than in attainment counties. However, the magnitude of this effect differs across sectors, with the impact of differences in relative stringency ranging from not statistically significant (but negative) in half of the sectors examined to more than a 10% slower growth rate in the chemicals, primary metals, industrial machinery and instruments sectors. Interestingly, plants in "non-attainment" areas are *less likely* to close but, conditional on staying open, grow more slowly than their counterparts in attainment counties. A possible explanation for this finding is that strict environmental regulation of new sources in these counties conveys some monopoly power to the incumbents. Using a longer panel of plant-level data (1972-1987), Greenstone (2002) estimates that **the U.S. Clean Air Act Amendments of the 1970s resulted in a loss of around 590,000 jobs in "nonattainment counties". This represents 3.4 percent of manufacturing employment in the United States and less than 0.5 percent of total employment**. However, Greenstone (2002) cannot reject the hypothesis that the pollutant regulation effects are equal across industries. Clearly, **part of the lost activity in "nonattainment" counties may have simply moved to "attainment" counties. This suggests that the net *national* effect of the CAAA on employment is likely to be smaller**, but from a cross-country perspective and assuming the same effects of environmental regulation, the jobs would have been lost to foreign competitors. In a study of the employment effects of Phase I of the Title IV cap-and-trade program for SO_2 emissions implemented under the 1990 CAAA, Ferris et al. (2014) provide evidence suggesting that the **impact of environmental regulations on employment may be only temporary**. Using a small panel data set of 61 regulated and 109 unregulated plants, they find that employment is significantly lower in regulated plants than in non–regulated plants, but only in the first year of compliance.

Walker (2013) finds that the labour transition costs associated with reallocating workers to other sectors because of the CAAA are large, estimating that the average worker in a regulated sector experienced a total earnings loss that is equivalent to 20 percent of the worker's pre-regulatory earnings. In aggregate, workers in newly regulated plants experienced more than $5.4 billion in forgone earnings for the years after the change in policy, with almost all of the estimated earnings losses driven by unemployment.[26]

Impacts of energy price levels

A few recent studies have examined the impact of differences in energy price levels on employment, providing insights into the effect of carbon tax differentials on jobs. Using within-state variation in electricity prices in the US, Deschênes (2011) finds that employment rates are weakly related to electricity prices: a 1 percent increase in electricity prices leads to a change in full-time equivalent employment that ranges from -0.16 percent to -0.10 percent. Kahn and Mansur (2013) examine variations in energy prices and environmental regulations among adjacent counties from 1998 to 2009 and find evidence that **energy-intensive sectors tend to locate in low electricity-price areas and that polluting sectors seek out low regulation areas, thus reducing employment in high regulation areas**. Although the effects are modest and only weakly significant for the typical manufacturing industry, the most electricity-intensive industry -- primary metals -- has an implied price elasticity of employment of −1.65, which means that a 10% increase in the price of electricity leads to a 16.5% decrease in employment in that sector. Based on these estimation results, Kahn and Mansur (2013) predict that a hypothetical $15 per ton carbon tax would affect employment very differently across states, depending on the carbon intensity of electricity production and the energy intensity of the local industry. The impacts would range from a 3.8 percent decline in employment in Ohio to a 0.3 percent decline in California.

Role of policy design

Importantly, the effects of relative environmental stringency on employment levels and distribution depend on the policy design. In an econometric analysis of the impact of British Columbia's unilateral revenue-neutral carbon tax, Yamazaki (2015) finds that **the carbon tax generated a small but statistically significant 2 percent *increase* in employment in British Columbia relative to other (free of carbon taxes) provinces** over the 2007-2013 period, but that the magnitude of the effect differs according to the sector's carbon intensity and trade exposure. For example, with a carbon tax of CAD10/tonne of CO_2 equivalent, the basic chemical manufacturing sector, one of the most emission-intensive and trade-exposed industries, experiences the largest decline in employment (30 percent),[27] while the health care industry experiences a 16% increase in employment, which the author attributes to the positive demand shock induced by the redistribution of tax revenues to residents of British Columbia. Thus, Yamazaki (2015) finds that **while there are clearly winners and losers, a revenue-neutral carbon tax may not adversely affect aggregate employment**.

[26] However, earnings losses also depend on the strength of the local labour market, suggesting that policy-induced labour market reallocation may be more costly in periods of high unemployment.

[27] The 95% confidence interval ranges from -15% to -48%.

Key conclusions

- The recent evidence supports the existence of a pollution haven effect, with imports of pollution- or energy-intensive goods increasing in response to tighter regulation, in line with what trade theory would suggest. However, the effects tend to be small and concentrated in few sectors. Overall, the effect of relative environmental policy stringency on trade flows is overwhelmed by other determinants of trade such as skilled labour availability, access to raw materials, and transport costs.

- The existence of a pollution haven effect for foreign investment remains unclear. The results from the literature are mixed, and where environmental policy has been shown to matter for FDI destination choice, the effect is again overwhelmed by other determinants of foreign investment, such as local demand.

- Differences in environmental regulations between states or counties within the United States have led to small negative effects on employment in polluting sectors. However, employment effects might be even smaller *across* than within countries. More work is needed on the employment effects of environmental regulations using data from multiple countries, in particular combining both developed and developing economies.

- Policy design seems to matter a lot for the regulation impact, for example if the product of the pollution tax is redistributed, as was the case with British Columbia's unilateral revenue-neutral carbon tax. An important avenue for future research is to identify policy designs that mitigate or cancel out competitiveness effects.

5. Empirical evidence: impacts on productivity, innovation and competitiveness

Environmental regulation may also alter firms' decisions concerning the volume, type, or timing of their investments, whether in adopting cleaner technologies through plant refurbishment or replacement or in the development of innovative production technologies or products. Environmental policies can thus affect firms' long-term competitiveness through these channels.

Environmental Regulations and Productivity

By lowering firms' marginal production costs (and hence product prices in competitive markets), increased productivity can enhance the competitiveness of firms that operate in international markets, thus boosting exports and market share.[28] However, **because investment in pollution control diverts resources away from production, economic theory suggests that environmental regulation will hamper productivity growth**.

Early studies of the relationship between environmental regulation and productivity did find empirical evidence to support this theory, at least for some sectors of the economy. For example, Gollop and Roberts (1983) found that SO_2 regulations in the US reduced productivity growth in 56 fossil-fuelled electricity utilities by an estimated 44% during the 1973–1979 period. More recently, Gray and Shadbegian (2002) found a link between higher pollution-abatement operating costs and lower productivity in 116 pulp and paper plants. However, most of these early studies used small samples.

Thus far, Greenstone et al. (2012) have conducted the largest plant-level study, with 1.2 million plant observations from the 1972-1993 Annual Survey of Manufacturers. This large data set allows them to control for many confounding factors that may affect both productivity and regulation. Specifically, Greenstone et al. (2012) investigate the economic costs of the 1970 CAAA using nonattainment designation as a measure of regulation. They find that total factor productivity (TFP) declines by 4.8 percent for polluting plants in strictly regulated counties relative to weakly or unregulated counties. Almost all of the effect occurs in the first year of nonattainment status, suggesting that capital investments in pollution abatement have only a short-term impact on productivity.

The evidence also suggests that the impacts of the relative stringency of environmental regulations on productivity vary across pollutants and industries, and can sometimes be positive. For example, Greenstone et al. (2012) find that while nonattainment of ozone concentrations (which triggers the policy responses associated with being in non-attainment) negatively affects productivity, nonattainment of carbon monoxide concentrations leads to statistically significant *increases* in productivity. However, the authors do not discuss reasons for these differences in outcomes across pollutants. Similarly, Alpay et al. (2002) find that the productivity of the Mexican food-processing industry *increased* with more stringent local environmental regulation, and that pollution regulations in the United States had no negative impact on the profitability or productivity of its domestic food manufacturing industry.

Berman and Bui (2001a) find that although refineries located in the Los Angeles (South Coast) Air Basin area experience a short-run fall in productivity due to increased regulatory stringency between 1979 and 1992, this effect appears to be temporary; after a few years, they enjoy

[28] See the seminal paper by Melitz (2003), who shows that only firms that are sufficiently productive can become exporters (as being more productive allows firms to secure a market share that is large enough to cover the fixed cost of exporting) and that trade raises average productivity by forcing the least productive firms to exit. See Balistreri and Rutherford (2012) for a discussion of the consequences of using the Melitz model for competitiveness in a computable general equilibrium (i.e., CGE) setting.

significantly *higher* productivity than other refineries in the United States despite the more stringent air pollution regulation. Similarly, Lanoie et al. (2008) find that the negative short-run effects of regulation on the Quebec manufacturing sector are outweighed by subsequent positive effects on multifactor productivity (MFP) growth.

In one of the few European studies to date, Rubashkina et al. (2015) find that environmental regulation (as proxied by PACE) negatively affects TFP, but the effects dissipate within two years. In a multi-level analysis using a dataset covering 60,000 companies across 23 OECD countries, 22 manufacturing sectors, and 21 years, Albrizio et al. (2014) find no evidence that a tightening of environmental policy has any permanent effects on MFP growth, at either the country or industry level. In fact, they find that an increase in environmental stringency is associated with a short-run increase in productivity growth, which translates into permanently higher MFP levels. However, all effects tend to fade away within less than five years. Albrizio et al. (2014) also find that the most productive industries and firms experience the highest gains in productivity, while less productive firms see negative effects, possibly because highly productive firms are better able to profit from changes required by environmental regulations.

In sum, the evidence indicates that environmental regulation has both negative, short-term impacts on productivity in some sectors and for some pollutants and positive productivity impacts in others.[29] However, more research is needed to investigate the longer run productivity impacts of environmental regulations.

Environmental Regulations and Innovation

From an economic perspective, **it is critical for environmental regulations to provide incentives for technological change because new technologies may substantially reduce the long-run cost of abatement** (Jaffe et al., 2003). From a political perspective, such policy-induced innovation may also improve the acceptability of environmental policies. Indeed, in today's knowledge-based economy, firms' competitiveness depends largely on innovation, which is considered to be a key component of productivity growth (Aghion and Howitt, 1992). Thus, there is a growing literature that seeks to quantify the link between environmental regulations and technological innovation.[30] The 'induced innovation hypothesis', dating back to Hicks (1932), suggests that when regulated firms face a higher price on polluting emissions relative to other costs of production, these firms have an incentive to develop new emissions-reducing technologies. **Many studies have clearly shown that environmental regulations encourage the development of pollution saving technologies**. For example, Jaffe and Palmer (1997) and Brunnermeier and Cohen (2003) show that stricter regulation (proxied by higher pollution control expenditures) leads to higher research and development expenditures and more environment-related patents, respectively. Similarly, higher energy prices have been shown to induce the development of energy efficient technologies (Newell et al., 1999; Popp, 2002). These results are confirmed in recent studies that use firm-level data, which allows them to control for macroeconomic factors that might affect both environmental regulation and innovation at the sector level. For example, using data on approximately 3,000 firms in the car industry, Aghion et al. (2016) show that firms tend to innovate more in clean technologies (electric, hybrid and hydrogen cars) in response to higher road fuel prices. Calel and Dechezleprêtre (2016) find that the EU ETS has increased innovation activity in low-carbon technologies among regulated companies by 30 percent relative to a control group.

From a policy perspective, **an important issue is determining which regulatory instruments provide the strongest incentives for innovation**. The theoretical literature suggests that market-based instruments provide stronger incentives for innovation than technology mandates and performance standards, and that among market-based instruments, emissions taxes and auctioned emission permits encourage more innovation than freely allocated emission permits

[29] See Kozluk and Zipperer (2013) for a review specifically focused on productivity.

[30] For recent surveys, see Carraro et al. (2010); Popp et al. (2010); and Ambec et al. (2013).

(Milliman and Prince 1989; Fischer et al. 2003; Parry et al. 2003). However, **the handful of empirical studies on this issue appear to at least partly contradict the hypothesis that market-based policies encourage more innovation than command-and-control regulations**. For example, Popp (2003) shows that following passage of the 1990 CAAA, which replaced command-and-control regulation with permit trading, innovation activity actually *decreased* in intensity. Taylor (2012) shows that for both the US SO_2 emissions cap-and-trade program and the U.S. Ozone Transport Commission NOx Budget Program, patenting activity collapsed when traditional regulation was replaced by a cap-and-trade. Thus, further research is needed on this issue.

Induced Innovation and Firms' Competitiveness

Can innovation induced by environmental regulations *more than fully* offset the costs of complying with them (Porter and van der Linde, 1995) and enhance firms' competitiveness? While there is evidence that the actual cost of achieving an environmental objective is usually smaller than anticipated because of induced innovation (see e.g., Harrington et al., 2000 and 2010; Simpson, 2014), the literature to date does not provide much empirical support for the Porter hypothesis in its so-called "strong" version.[31] Thus, **there is currently no empirical evidence that environmental regulation leads to an increase in firm competitiveness through its effect on innovation**.

In theory, environmental regulation can increase productivity growth (and hence competitiveness) if it leads to a permanent increase in the *rate* of innovation. There is some emerging evidence, however, that **regulation-induced environmental innovations tend to replace other innovations, leaving the overall *level* of innovation unchanged**. For example, in their study of paper mills in the United States, Gray and Shadbegian (1998) found that more stringent air and water regulations improved environmental innovation, but that the increased investment in emissions and water abatement technologies came at the cost of other types of productivity-improving innovation. Popp and Newell (2012) find that alternative energy patenting crowds out other types of patenting at the firm level. There seems to be a larger crowding out effect for small firms that are credit constrained (Hottenrott and Rexhaüser, 2013). Aghion et al. (2016) show that innovations in clean cars (electric, hybrid and hydrogen) occur almost completely at the expense of innovation in dirty vehicles (combustion engines). In contrast, Noailly and Smeet (2015) and Calel and Dechezleprêtre (2016) find no evidence of such substitution effects at the firm level, suggesting that some environmental regulations may raise the overall rate of innovation of regulated firms rather than simply redirecting innovation toward clean and away from polluting technologies.[32]

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).

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[31] The "weak" version of the Porter Hypothesis postulates that properly designed environmental regulation may spur innovation. The "strong" version of the Porter Hypothesis goes further, asserting that in many cases, this innovation more than offsets any additional regulatory costs— in other words, environmental regulation can lead to an increase in firm competitiveness (Ambec et al., 2013).

[32] To our knowledge, crowding out between firms, which could occur because the number of inventors in the economy is somewhat fixed in the short run, has not been analysed.

Porter and van der Linde (1995b) 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**.

While there is no evidence that regulated firms' competitiveness will increase due to policy-induced environmental innovation activities, global benefits appear to be more likely. Popp and Newell (2012) find that the social value of renewable energy patents, as measured by patent citations, is higher than the social value of patents in conventional fossil fuel technologies that are crowded out. Dechezleprêtre et al. (2014) confirm this finding in a comparison of knowledge spillovers from clean and dirty technologies in the transportation and energy production sectors. Thus, **regulation-induced innovation in clean technologies might increase the innovation activity (and possibly the competitiveness) of some unregulated companies through knowledge spillovers**. This would improve the net social benefit (or reduce the net cost) of the regulation without cancelling out the competitiveness effects on regulated companies.

Key conclusions

- Environmental regulations can have negative, short-term impacts on productivity in some sectors, but have also had positive impacts in others. Understanding this heterogeneity and linking it to policy design is a key avenue for future research. More research is also needed to investigate the productivity impacts of environmental regulations in the longer run.

- There is ample empirical evidence that environmental regulations induce innovation activity in clean technologies while discouraging R&D in conventional (polluting) technologies. Thus, environmental regulations can help the economy break away from lock-in to a polluting trajectory.

- At the firm level, green innovations developed to cope with regulations do not seem to increase firms' profits to the extent that the private costs of regulation are fully offset. This does not preclude the ability of environmental regulations to foster the development of global leaders in innovation, but for the average firm evidence that environmental regulations will lead to an increase in firms' competitiveness is lacking. An interesting question going forward is whether this is a consequence of poor policy design or of environmental regulation stringency per se.

- There is evidence that green innovations induce larger economic benefits than the dirty technologies they replace in terms of the knowledge they generate, which can be used by other innovators in the economy to develop further technologies. Thus, regulation-induced innovation in clean technologies might increase the innovation activity (and possibly the competitiveness) of some unregulated companies. In contrast with the direct effects of environmental regulations, these indirect effects are seldom studied. This is a clear knowledge gap.

6. Conclusions and priorities for future research

This issue note has reviewed the recent empirical literature on the impacts of environmental regulations on firms' competitiveness, as measured by trade, industry location, employment, productivity and innovation. The recent evidence shows that **taking the lead in implementing ambitious environmental policies can lead to small, statistically significant adverse effects on trade, employment, plant location and productivity in the short run, particularly in pollution- and energy-intensive sectors**. However, **the scale of these impacts is small compared to other determinants of trade and investment location choices** such as transport costs, proximity to demand, quality of local workers, availability of raw materials, sunk capital costs and agglomeration. Moreover, **the effects tend to be concentrated on a small group of basic industrial sectors** characterised by very energy intensive production processes; limited ability to fully pass through pollution abatement costs to consumers (whether due to regulation or international competition); and a lack of innovation and investment capacity to advance new production processes (Sato et al., 2014). For these sub-sectors, where pollution leakage and competitiveness issues represent a genuine risk, **a critical avenue for future research is to assess the various policy options available to prevent adverse impacts on trade and investment without dampening the incentives to develop cleaner processes and products** (Martin et al., 2014; Branger et al., 2015).

As this note has also shown, **there is strong evidence that environmental regulations induce innovation activity in cleaner technologies. However, the direct benefits from these innovations to the regulated entities do not appear to be large enough to outweigh the costs of regulations**. This suggests that the evidence for the most controversial interpretation of the Porter hypothesis (i.e., that environmental regulations can lead to an increase in firms' competitiveness) is so far lacking. However, the impact of environmental innovation induced by green policies on firms' economic performance is still poorly understood. The timing of environmental policies, in this respect, is critical. It is often argued that countries that implement environmental policies early on will benefit from a first-mover advantage when other countries catch up, because domestic firms will have developed the right technologies that they can then export to regulatory "laggards", giving them a key competitiveness advantage on the market. There is no empirical evidence to date on this first-mover advantage, and this is an important avenue for future research. Further research is also needed to identify the combinations of innovation and environmental policies that best encourage innovation in green technologies (Burke et al., 2016) while boosting firm productivity.

A limitation common to nearly all papers reviewed in this note is that the impact of environmental regulations on firm competitiveness are studied in isolation. However, in any ex-post cost-benefit evaluation of environmental regulations, these costs need to be weighed out by the benefits which justify the policy in the first place – less pollution, better health, etc. The benefits are often important and underestimated—for example, the estimated health benefits from the Clean Air Act are two orders of magnitude greater than the employment costs of the policy, so that including job loss in cost-benefit analyses of environmental regulations is unlikely to change their conclusions. **Future research should address the need for systematic comparison of the costs associated with environmental regulations with their benefits in terms of reduced pollution – by analysing the impact of environmental regulations on firm performance and environmental performance *jointly***.

This issue note raises the question of why the effects of environmental regulations on international industry relocation have been found to be so small and narrow given the strong concerns about competitiveness in public policy circles. One explanation could be that regulated companies have an incentive to overstate the potential competitiveness impacts of regulations as a strategy to lobby against stringent policies, by attributing unpopular offshoring decisions to public policy, rather than to underlying economic factors such as the shifting locus of supply and demand in global manufacturing or falling transport costs. An alternative explanation for the lack of empirical support for the large pollution haven effects discussed in the literature is that environmental policy is *endogenous* -- i.e., governments strategically set stringency levels to be low (high) where there is a high (low) risk of competitiveness distortions. This argument suggests that competitiveness concerns could trigger a 'race to the bottom' in global environmental protection efforts. To avoid such an outcome, **further research is needed to accurately measure and monitor the competitiveness effects of environmental regulations to help ensure that policy is based on robust evidence**.

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