The impacts of environmental regulations on competitiveness

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Executive summary

Environmental regulations make a small difference to productivity and employment

Environmental regulations can reduce employment and productivity by small amounts, in particular in pollution- and energy-intensive sectors, at least during the transitory period when the economy moves away from polluting activities and towards cleaner production processes. Job effects are more likely to occur within countries, where relocation barriers are low, than across borders. This suggests that government policies encouraging labour mobility, such as flexible labour markets, affordable housing and lifelong training, can help reduce or offset the costs of environmental regulations. Over the longer run, when macroeconomic adjustments, geographical and sectoral reallocation are factored in, job effects are even smaller than in the short run.

Environmental regulations only marginally affect international competitiveness

There is little evidence to suggest that strengthening environmental regulations deteriorates international competitiveness. The effect of current environmental regulations on where trade and investment take place has been shown to be negligible compared to other factors such as market conditions and the quality of the local workforce. However, the impact could increase in the future if efforts to control pollution diverge significantly across countries. Emerging research comparing environmental efforts in different countries will play a key role in being able to assess and prevent adverse impacts on trade and investment in the future.

The benefits of environmental regulations often vastly outweigh the costs

The costs of environmental regulations need to be weighed up against the benefits they provide and which justify those regulations in the first place. The benefits are often important and severely underestimated. For example, the estimated health benefits from the Clean Air Act in the United States are two orders of magnitude greater than the employment costs of the policy. This indicates that including job losses in cost-benefit analyses for environmental regulations is unlikely to make them unviable. Future research should systematically compare the costs of environmental regulations with their benefits.

Environmental regulations induce innovation in green technologies

There is ample evidence that environmental regulations induce innovation in clean technologies and discourage research and development in conventional (polluting) technologies. Thus, environmental regulations can help economies break away from a polluting economic trajectory and move to a ‘clean’ one.

Switching to green technologies can have economy-wide benefits

At the firm level, green innovations developed to reduce the cost of environmental regulations do not seem to increase firms' profits enough to fully offset the private costs of regulation. However, there is evidence that low-carbon innovations induce larger economic benefits than the 'dirty' technologies they replace because they generate more knowledge in the economy, which can be used by other innovators to further develop new technologies across various sectors of the economy. This makes it plausible that the switch from 'dirty' to 'clean' technologies could generate economic growth and justifies strong public support for clean technology development.

Advancing the competitiveness debate

A key area for future research is to identify where environmental regulations can be strengthened to deliver clear social benefits, in terms of health or new technologies, with little risk of reducing competitiveness. Because policies can affect sectors differently, this should be assessed on a sector-by-sector basis, depending on the abatement opportunities available and the level of competition the sector is exposed to. For each sector, policies will need to be fine-tuned to balance the policy goals with the multiple impacts of environmental regulations on pollution, employment, trade, productivity and innovation. A key challenge for research will be to better understand the link between policy design and these different dimensions of competitiveness. Policy design will also need to consider how environmental regulations should be adjusted as other countries' environmental regulations evolve. For this to happen, however, researchers will need better ways to measure the relative stringency of environmental regulations, and data from more countries. Currently, almost all of the existing data comes from developed countries, though the lessons can be applied more broadly.

1. Introduction

Ever since the first major environmental regulations[1] were enacted in the 1970s, there have been concerns about their potential impacts on businesses. Managing the balance between environmental constraints and economic impacts has been an ongoing dilemma. The recent economic downturn, combined with increased competition from emerging economies, has made the debate even more acute, particularly in relation to climate change policies.

Economists traditionally think environmental regulations add costs to companies and slow down productivity. Environmental regulations may thus affect the competitiveness of the domestic industry if the stringency of policies differs across countries, putting some firms at a disadvantage to their foreign competitors. An alternative view is that environmental regulations may foster innovation in environmentally-friendly technologies, help regulated firms achieve technological leadership and boost broader economic growth. These views have received a great deal of attention from policy makers, particularly in the context of the recent economic downturn.

The growing importance of this debate in policy circles has led to a large number of studies that attempt to quantify the impact of environmental regulations on businesses. These studies have analysed many aspects of the economic performance of regulated businesses, including productivity, innovation, employment, profitability, output and trade. This policy brief aims to provide an up-to-date assessment of the results from this vast and growing literature.

The policy brief asks questions that are of particular interest to policy makers. We start by discussing what competitiveness means, at the level of firms, sectors and countries. We explain how competitiveness effects occur, why it is important to assess them and how they are measured. We then turn to the heart of this policy brief: a review of the existing evidence. We focus on *ex post* evaluation studies. *Ex ante* modelling studies are not included. We discuss the impact of environmental regulations on productivity, employment, trade, industry location and innovation. We conclude by discussing what the literature teaches us about improving environmental regulations and identifying priorities for future research.

1 The discussion in this paper focuses on environmental regulations which impose costs on sectors, such as taxes or standards, and this term will be used to refer to such policies. In general, environmental policy can be categorised into six broad types. First, *economic instruments* include fiscal and financial incentives to reduce pollution (e.g. taxes, grants and feed-in tariffs), direct investment (infrastructure investments and procurement rules) and market-based instruments such as emissions trading or green certificates. Second, *information and education* policies include information provision, performance labelling and advice or aid in implementation. Third, *policy support* may include institutional creation or strategic planning. Fourth, *regulatory instruments* include codes and standards (e.g. building codes of vehicle fuel economy standards), monitoring or obligation schemes. Fifth, research, development and deployment includes demonstration projects and research programmes. Finally, *voluntary approaches* include negotiated agreements and public voluntary schemes.

2. What is competitiveness?

Competitiveness of firms, sectors or countries?

'Competitiveness' is a term that is often used but ill-defined. In general it refers to the effects of a policy on regulated entities' ability to compete in international markets. These effects can be felt at multiple levels.

At the level of the firm, a business is competitive if it can produce better or cheaper products or services than its domestic and international competitors. Competitiveness is synonymous with a firm's long-run profit performance and refers to its ability to compensate its employees and provide adequate returns to its owners. It can then be interpreted as firms' 'ability to sell', which reflects the capacity to increase market share and may be measured by trade volumes or domestic market share. Or it can be seen as the 'ability to earn', the capacity to increase profit measured by turnover, value added or market value.

Competitiveness at the sector level refers to how attractive different countries are for a particular industry and is often measured in terms of performance in international trade (net exports, investment flows). The main drivers of sector competitiveness include availability of production factors (including raw materials, labour and skills), industrial policy, supply chain linkages and economies of agglomeration.

Countries' competitiveness is a popular concept, measured for example by the World Economic Forum's Global Competitiveness Reports or the World Competitiveness Yearbook. These indices typically measure country-level drivers of attractiveness over the long term, such as standard of living, health, local pollution levels and employment, as well as economic growth and economic security. However, economists criticise the notion of national competitiveness. In his article 'Competitiveness: a dangerous obsession', Paul Krugman (1994) cautions against equating a country's competitiveness and a firm's. Whereas a firm or national sector becomes more competitive at the expense of rivals if competing for global market share, such a zero-sum view makes much less sense at the national level when the term is used as a synonym for national welfare or productivity. Mostly, higher productivity in one country does not come at the expense of other countries, but rather will benefit them by providing a bigger market for exports, greater opportunities for specialisation, and cheaper and more innovative inputs. For this reason, this policy brief is primarily concerned with competitiveness at the firm or sector level; not the national level.

How do competitiveness effects occur?

Environmental regulations tend to encourage firms to cut pollution by making it costly to pollute (for example via a pollution tax or a regulatory standard mandating adoption of costly pollution control equipment). There are two opposing views about the impacts of environmental regulations on production costs.

The conventional perspective suggests that environmental regulations damage the economic performance of regulated (usually pollution intensive) industries[2]because they increase production costs leading to lower productivity or profitability. Moreover, where there are *differences* in environmental regulations applied to firms competing for the same market; higher costs and lower productivity can impact market share. Proponents of this view suggest that polluting industries in open economies will tend to gravitate towards regions with lenient environmental policy.[3] In the short term, uneven environmental regulations could lead to reduced exports from regions with relatively ambitious policies. If businesses believe that some countries will always have more stringent environmental regulations, they may move manufacturing capacity to countries with relatively lax policies in the long run. These concerns are as old as environmental regulations themselves.

However, an alternative view was articulated by Michael Porter (1991). The 'Porter hypothesis' argues that environmental regulations might lead private firms and the economy as a whole to become more competitive internationally by providing incentives for environmentally-friendly innovation that would not have happened in the absence of policy. The Porter hypothesis originated primarily from analysing cross-border differences in the stringency of environmental regulation and economic performance. However, during the last 20 years, a vast literature has proposed many theoretical justifications for the Porter hypothesis. These include behavioural arguments (the interests of firms and managers might not align, and regulation forces managers to adopt innovations that are profitable for the firm but do not increase the manager's utility) or the existence of additional market failures such as market power or knowledge spillovers (see Ambec et al. 2013 for a recent review). Along with these theoretical developments, there has been a large amount of empirical research investigating the validity of the Porter hypothesis in practice.

Why is assessing competitiveness effects important?

Policy makers can use insights from empirical analysis to evaluate environmental regulations against their objectives. This information is particularly useful given the often intense political and lobbying pressures governments face when formulating environmental regulation.

Concerns about competitiveness, in particular carbon leakage,[4] have been paramount politically and are pivotal to the design of climate change policies. For example, the Kyoto Protocol states that "the Parties included in Annex I shall strive to implement policies and measures under this Article in such a way as to minimize adverse effects, including the adverse effects of climate change, effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties…" (UNFCCC, 1998).

2 Copeland (2012) argues that how environmental regulation impacts competitiveness can depend on factors such as whether pollution is generated during production or consumption, and on the extent to which environmental degradation destroys natural capital. For example, if environmental policy is targeting pollution which is generated by consumers, such as car emissions, the policy equally affects domestic and foreign car producers. If domestic producers are better able to cope with the regulation, they may increase their share of the domestic market.

3 Frequently, Ricardo's theory of comparative advantage is cited as the justification behind competitiveness impacts, but the pollution haven argument is more in line with the earlier principle of advantage argument put forward by Adam Smith.

4 'Carbon leakage' risk refers to the possibility that trade acts as a channel by which emissions 'escape' from regulated to non-regulated entities. It is most commonly perceived as the marginal emissions changes in firm B that are directly induced by policy implemented on firm A. Alternatively, Peters (2008) proposes a distinction between this conventional type of carbon leakage which is purely policy-induced ('strong carbon leakage'), and a broader definition of the term 'soft carbon leakage' which includes all trade embodied carbon, regardless of whether they are induced by climate policy or other underlying economic factors that influence trade patterns.

In the European Union Emissions Trading System (EU ETS), free allowances were generously allocated in Phases I and II to compensate firms for the potential competitiveness impacts, although the justification for free allowances in Phase III has shifted towards addressing carbon leakage for energy-intensive trade-exposed sectors (see Directive (2009/29/EC) (European Commission, 2010)). Similarly in the Californian cap-and-trade system that launched its first trading phase on 1 January 2012, potential leakage and competitiveness impacts are addressed by issuing free allowances for the first compliance period (2012 to 2015).

The design of provisions to mitigate potential competitiveness effects is politically sensitive. On the one hand, there is international pressure for industrialised nations to pursue more ambitious environmental regulations and in particular to lead mitigation efforts against climate change. On the other hand, policy makers face domestic pressure from industry lobby groups and the public to minimise the negative side effects of environmental regulations on jobs, profits, exports and so on. At the same time, there is also international pressure to ensure that environmental regulations are not a disguise for protectionist measures, or being used strategically in a globalising world, where there is fierce competition between countries to gain export share, attract foreign direct investment and retain manufacturing sector jobs. The EU ETS experience showed that the very measures designed to protect the profits of regulated firms can result paradoxically in large effective subsidies for European heavy industries if over-compensation occurs (for example, Phale et al., 2011). Such strategies to protect the economic performance of regulated firms may not directly affect the environmental performance of climate change policies, but they do affect how cost effective they are and who benefits. Assessing these implications is important, not only to help governments withstand the kinds of special-interest pressures and avoid the sorts of policy mistakes noted above, but also because economists have long cautioned that the gains environmental regulations bring to one sector or firm may be offset by losses in another.

How are competitiveness effects assessed empirically?

To be able to assess the competitiveness impacts of environmental regulations there must be some variation in the stringency of environmental regulation between firms, sectors, regions or countries. For example, some *firms* might be regulated while others are not, or some may receive more compensation than others; as they do under the EU ETS. Some *sectors* might face stricter regulation than others within a country, or the regulatory stringency may vary across *countries or regions*. If there are no differences, it is not possible to see what would have happened had the policy not been implemented.

Therefore, it is only the relative stringency differences of environmental policies that can be analysed, which is very difficult. Many methods have been tested but none are very robust. A popular choice has been regulatory compliance cost as a share of value added as a proxy for regulatory stringency, typically using data on pollution abatement cost expenditures (PACE). PACE data has been collected since the 1970s for the US and since the 1990s in Europe and Asia Pacific countries.[5] Others have used environmental or energy tax revenue, energy prices, renewable energy capacity, recycling rates, legislation counts, membership of international environmental agreements, other crude measures such as difference in GDP per capita, composite measures such as Yale University's Environmental Performance Index, and survey measures, for example from the World Economic Forum Executive Opinion Survey. However, recent analysis has demonstrated that they all have shortcomings and there is limited agreement about which countries have strict or lax environmental regulation (Brunel and Levinson, 2013).

5 Being a survey-based dataset, PACE suffers from reliability issues as well as endogeneity, as abatement cost is often normalized as a share of output.

Other variables suggested include the ratio between the actual emissions intensity of a sector and its predicted emissions intensity given its industrial composition (Brunel and Levinson, 2013) and sector energy prices (Sato et al., 2014). Some have also argued that different forms of regulation (see footnote 1) may be important in determining the nature of the competitiveness effects, and not only the stringency (Irlado et al., 2011).

Comparing the relative stringency level of price-based policies such as carbon taxes is seemingly simpler, as the price level is observable, but is complicated by factors such as differences in sector coverage, exchange rates and exemption rules, including the differences in free allowance allocation for market-based policies (Aldy and Pizer, 2013; Sato et al., forthcoming).[6] Indeed, many environmental regulations include some form of industry compensation such as rebates, exemptions or reduction in other payments (for example, employers' national insurance contributions). Such provisions not only affect the level of policy stringency but also alter incentives and influence the behaviour of firms.[7] Few measures of policy stringency take account of such compensation provisions, a clear shortcoming in the literature assessing the effects of environmental regulations on firm or sector performance.

As for how environmental regulations affect competiveness, while Jaffe et al. (1995) argue the ideal measure to study would be the effect of the policy on net exports (holding real wages and exchange rates constant),[8] many other indicators of competitiveness have been proposed and applied. In the context of climate change policies, studies have evaluated competitiveness impacts in terms of productivity, gross value added, profitability, employment, product prices, output, market share, investments, net imports and innovation activity, often measured by patent counts or research and development expenditures. Importantly, most studies have so far assessed these various dimensions *separately*. Yet the same policy can have opposing effects on different indicators. For example, it is possible that an energy intensive firm may react to a carbon price policy by pursuing technological advancement, increasing productivity, increasing product prices, reducing output, reducing employment and keeping trade constant, as Jaffe et al. (1995) point out: "Because the economic adjustment to regulation is highly complex, and because there are a multiplicity of issues wrapped up in the term 'competitiveness', it is not possible to combine estimates of these different aspects of the process into a single overall quantification of the effects of regulation on competitiveness. The best that can be done is to assess somewhat qualitatively the magnitude of estimated effects based on multiple indicators." Recently, some studies have jointly analysed several dimensions of competitiveness together, looking for example at innovation and trade (Constantini and Mazzanti, 2012) or technology and trade (Lovely and Popp 2011). These multi-dimensional studies are an important avenue for future research.

6 Although in theory the value or cost of emissions reductions is the same whether in the form of a real or opportunity cost, it has been repeatedly shown that firms in fact discount the value of potential emission saving if allowances are given for free (Neuhoff et al., 2014). While there is considerable variation in carbon prices internationally (Aldy and Pizer, 2013), most regulated sectors exposed to international trade currently receive free allowances such that the implicit carbon price differences are likely to be lower.

7 For example, the influence of different free allocation rules on operational, investment and trade decisions have been analysed by Branger et al. (2014).

8 As explained by Jaffe et al. (1995), this is a theoretical measure because it is impossible to measure the reduction in net exports 'before' adjustments in the exchange rates. Only the change after the adjustment is observed. However, it may be less of a problem for impacts on small sectors where the effects on trade are small and hence will not lead to adjustments to the exchange rate.

3. The empirical evidence

Do environmental regulations affect production costs?

While environmental regulations have proliferated globally over the past decades,[9] the general consensus is that, so far, the costs of complying with environmental regulations represent a relatively small share of production value for most sectors. A survey by Pasurka (2008) found that the proportion of manufacturing capital expenditure assigned to pollution abatement in 2000 ranged between 1 percent and 5 percent across OECD countries.

The introduction of carbon pricing in Europe generated wide concerns about the potential cost burden on industry. Model-based studies predicted that with carbon prices around €20-€30/tCO_2 the marginal cost impacts would be small for the large majority of industrial activities, but large impacts could occur in upstream segments within several energy intensive sectors, including fertilizers, iron and steel, aluminium, paper, basic organic chemicals or coke oven production (Sato et al., 2014). However, evidence suggests that most sectors did not see high cost increases due to a combination of generous free allocation and low carbon prices. In the electricity sector, where marginal costs were affected, high levels of carbon cost pass-through were observed, as theory would predict. Chan et al. (2013) compare 5,873 regulated and non-regulated firms between 2001 and 2009 across 10 European Union countries in the power, cement and iron and steel sectors. In the power sector, regulated firms on average experienced an increase in 'material costs' (including fuel) by 5 percent and 8 percent during Phase I and II of the European Union Emissions Trading System (EU ETS). This may be due also to the European Union renewable energy target. However, no such effects are found for the cement and steel sectors, because emissions trading permits were largely allocated to these sectors for free during this period.

As well as affecting marginal costs of production, environmental regulations can also affect entry and investment costs for companies. Ryan (2012) finds that the 1990 Amendments to the US Clean Air Act had no impact on the marginal (variable) costs of the Portland cement industry, but they made incumbent firms more competitive by increasing the average sunk costs of entry. Specifically, the costs of building a greenfield facility rose by $5 million to $10 million because they had to undergo rigorous environmental certification and testing.

Do environmental regulations affect productivity?

Because pollution control diverts some production factors away from production towards non-productive activities, theory predicts that environmental regulation should hamper productivity growth. Overall, there seems to be evidence for short-run negative impacts of environmental regulation on productivity, but there is no universal consensus on the issue (see Kozluk and Zipperer, 2013, for a recent review). The impact in the longer run seems smaller, with some evidence for positive productivity impacts after the initial transition period.

Many studies have found evidence for a significant but small effect of environmental regulation on productivity. Christiansen and Haveman (1981) estimate that around 10 percent of the slowdown in productivity growth observed in the United States between 1965 and 1980 can be attributed to environmental regulations, while Dufour et al. (1998) find that environmental regulation cut productivity growth in the Quebec manufacturing sector between 1985 and 1988.

9 See OECD database on instruments used for environmental policy, for example: http://www2.oecd.org/ecoinst/queries/Default.aspx

Gollop and Roberts (1983) estimate that sulphur dioxide (SO_2) regulations slowed down productivity growth in the United States in the 1970s by 43 percent. More recently, Gray and Shadbegian (1993, 2002, 2003) linked higher pollution-abatement operating costs with lower productivity in pulp and paper mills, steel mills, and oil refineries[10] (see also Boyd and McClelland, 1999). Greenstone et al. (2012) have conducted the most recent and largest plant-level study so far. Using detailed production data from nearly 1.2 million plant observations from the 1972-1993 Annual Survey of Manufactures they investigate the economic costs of air quality regulations (the 1970 Clean Air Act). They find that total factor productivity declines by 4.8 percent for polluting plants in strictly regulated counties compared to weakly or unregulated counties. This corresponds to an annual economic cost from the regulation of manufacturing plants of roughly $21 billion (in 2010 dollars), 8.8 percent of average manufacturing sector profits over the period of analysis.

However, a number of studies find that productivity is either unaffected or enhanced by environmental regulation. For example, Berman and Bui (2001a) report that refineries located in the Los Angeles (South Coast) Air Basin area enjoyed significantly higher productivity than other refineries in the United States despite the more stringent air pollution regulation in Los Angeles. They do find evidence for a short-run fall in productivity, but it appears that this effect is only *transitory*, and after a few years the net effect of the regulation becomes positive. Similarly, Alpay et al. (2002) find that the productivity of the Mexican food-processing industry actually increased with the pressure of local environmental regulation, while pollution regulations in the United States have had no impact on the profitability or productivity of its food manufacturing industry. This leads them to conclude that the Mexican food sector has become more competitive relative to that of the United States because of domestic environmental regulation, and that contrary to what was expected stricter environmental law in the United States did not provide Mexican companies with a cost advantage.

Do environmental regulations affect employment?

Discussions about the impacts of environmental regulations on competitiveness are often framed as 'jobs versus the environment', particularly in the United States, where falling employment in manufacturing has been an important political issue.[11] Many observers fear jobs will be lost because of higher costs related to environmental regulation. However, while there could definitely be significant *adjustment costs* as workers move from declining (polluting) to expanding (clean) sectors, in the long run, environmental regulations might simply induce a *substitution* between polluting and non-polluting activities. The impact of this substitution on net employment is undetermined (Brahmbhatt, 2014). The evidence so far has been mixed but, if anything, points to statistically insignificant or small effects on employment in regulated sectors.

Most studies focus on the impact of the US's Clean Air Act Amendments. Henderson (1996) and Kahn (1997) found relatively lower growth rates in manufacturing employment in counties with stringent air pollution regulations compared to less regulated counties. Using the same approach and a long panel of United States plant level data (1972-1987), Greenstone (2002) finds that the Clean Air Act Amendments of the 1970s led to a loss of around 590,000 jobs in (strictly regulated) nonattainment counties relative to attainment ones (subject to more lenient regulation). This represents 3.4 percent of manufacturing employment in the United States (and less than 0.5 percent of total employment). Part of this lost activity in nonattainment counties may have moved to attainment counties, so that the *net* national effect on employment is likely

10 However, when other commonly used measures of regulatory stringency are employed, like compliance status or the number of inspections by the regulatory agency, the estimated impacts are generally not statistically significant.

11 According to Kahn (2013), between 1998 and 2009, aggregate manufacturing jobs in the United States declined by 35 percent while the total production of this industry grew by 21 percent.

to be smaller. Moreover, many of these job losses are unlikely to be permanent as laid-off workers ultimately find other jobs. Walker (2013) estimates the costs to the workforce from the Clean Air Act Amendments. He finds that the average worker in a regulated sector experienced a total earnings loss equivalent to 20 percent of their pre-regulatory earnings. Almost all of the estimated earnings losses are driven by unemployment.[12] Overall, the total forgone wage bill associated with this regulation-induced sectoral shift in production is estimated to be more than $5.4 billion (in 1990 dollars). These estimates of forgone earnings are two orders of magnitude below most estimates of the health benefits of the 1990 Clean Air Act Amendments. The extent of transitional unemployment and related adjustment costs will depend on the degree of labour market imperfections and the quality of safety net policies to help workers make the transition. Kahn and Mansur (2013) also exploit variation among adjacent counties and use a relatively long panel (1998-2009). They find evidence that energy intensive sectors locate in low electricity-price areas and that polluting sectors seek out low regulation areas, reducing employment in high regulation areas. However, for the typical manufacturing industry, the effects are modest. An 8 percent increase in electricity price would result in a fall in employment of 3.8 percent in Ohio and 0.3 percent in California. Other recent studies have looked at the impact of energy prices on employment. Deschênes (2010) finds that employment rates are weakly related to electricity prices, a 1 percent increase in electricity prices leading to a change in full-time equivalent employment ranging from -0.16 percent to -0.10 percent. Aldy and Pizer (2011) also exploit the United States state-level variation in industry energy prices between 1990 and 2009 to estimate the price-employment relationship. They simulate the impact of a $15 per ton carbon tax corresponding to an 8 percent increase in electricity prices in the United States relative to the rest of the world and find that this would cut employment by 0.2 percent.

A range of studies, however, do not find evidence for such negative impacts of environmental regulation on employment. Morgenstern et al. (2002) use pollution abatement operating costs as a proxy for the stringency of environmental regulation and find that higher environmental spending generally does not cause a statistically significant change in employment. There are even statistically significant and positive effects in two industries, but total number of affected jobs remains quite small. These estimates suggest that, at most, environmental regulation accounted for 2 percent of the observed decline in employment from 1984 to 1994. Belova et al. (2013) also find no evidence of large negative effects from environmental regulations. Berman and Bui (2001b) compare petroleum refineries in the Los Angeles area, 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 allowing for induced plant exit and dissuaded plant entry. They actually find weak evidence that regulations may have resulted in a small net increase in employment, possibly because more labour is required for pollution control activities. The lower bound of their estimates implies fewer than 3,500 jobs lost due to regulation over 12 years, a number equivalent to the estimated deaths *every year* from pollution in counties not complying with national standards in the mid-1980s. Cole and Elliott (2007) use data for 1999-2003 for the United Kingdom and found no evidence that pollution abatement costs reduce employment. A number of recent studies have examined the impact of the EU ETS on employment, and no robust evidence has yet been found to support the link. Anger and Oberndorfer (2008) and Commins et al. (2011) find no statistically significant effect. Chan et al. (2013) find no effect on steel and cement sector jobs, but an ambiguous effect in the power sector. Abrell et al. (2011) also found ambiguous impacts on employment in the cement sector.[13]

12 However, earnings losses 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.

13 Martin et al. (2014) explain that the practice used in Abrell et al. (2011) to take 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. This problem is common with EU ETS studies that use matching estimators.

To sum-up, a few studies that use installation or state level data from the United States and long panels have found negative effects on employment in pollution intensive sectors from environmental regulations. This suggests that – in the United States at least – differences in environmental regulations between states or counties have led to small negative effects on employment in polluting sectors. However, because of wage adjustments and other factors (price of leisure, increased firm profits) the social costs of jobs lost due to environmental regulations are only a fraction of the associated lost earnings. Furthermore, the social costs of job losses are typically less than 10 percent of other social costs of regulations, so that including job losses in cost-benefit analyses of environmental regulations is unlikely to change their conclusions (Bartik, 2013). It also appears that employment effects are more likely to occur within national boundaries where relocation barriers are lower.

Do heterogeneous environmental regulations cause polluting activities to relocate internationally?

A central focus of the competitiveness debate and research has been on the impacts on international trade, capital flows and industry location. This literature tests the pollution haven effect[14] i.e. the hypothesis that countries with relatively lax regulation will specialise in the export of pollution intensive goods and services, which they produce at a lower cost, and countries with stringent policies will lose out in terms of industry and jobs. The pollution haven effect is one of the main arguments used against ambitious environmental regulations. However, the evidence is decidedly mixed.[15]

A key challenge in testing the pollution haven effect is that the most theoretically desirable test for competitiveness – identifying the effect of policies on net exports *holding real wages and exchange rates constant* – cannot be implemented because, in practice, cutting manufacturing net exports (if environmental policy is applied across the board) changes the exchange rate and net exports of other industries. Some studies nonetheless look at how net imports are affected by environmental regulations ignoring these adjustments (for example, Ederington, 2005), some look at a subset of industries (hence exchange rate adjustment can be ignored), while other papers test alternative outcomes. Studies have compared relative changes to net imports across sectors facing different regulatory costs (for example, Levinson and Taylor, 2008); where polluting industries are located (for example Mulatu et al., 2010) as well as the location of new investments (for example, Ben-Kheder and Zugravu, 2012). A new study by Cole et al. (2014) examines whether environmental regulatory costs make it more likely that companies will outsource parts of their production overseas. However, the equations for such alternative tests often lack theoretical foundations (Ben-Kheder and Zugravu, 2012).

Another key challenge is the lack of good measures for relative regulatory stringency, which means effects on trade or investment can only be explained as a function of industry characteristics (Ederington et al., 2005). In other words, what is often being tested is whether sectors subject to more stringent regulation, for example steel, undertake more or less trade or investment or outsourcing, relative to sectors subject to less environmental regulation, for example IT. Levinson and Taylor (2008) show that ignoring the level of foreign regulation and instead using indirect measures of environmental stringency such as pollution abatement and

14 The pollution haven effect can be distinguished from the bolder pollution haven hypothesis, which postulates that differences in environmental regulation is the most important determinant of industry location. Theoretical models of this hypothesis were formulated by Baumol and Oates (1988) and others. A related strand of literature investigates whether (liberalisation of) trade is good or bad for the environment (e.g. Taylor and Copeland, 2004; Antweiler et al., 2001).

15 The earlier studies are reviewed by Jaffe et al. (1995), a meta-analysis of studies on plant location is conducted by Jeppesen et al. (2002), and additional reviews are given in Mulatu et al. (2003), Brunnermeier and Levinson (2004), and Taylor and Copeland (2004).

control expenditures is theoretically problematic for a number of reasons,[16] and failing to account for these issues leads to biases and incorrect inference. As emerging economies such as China, India and Brazil become increasingly important in global trade, finding good measures of relative regulatory stringency will become key to the literature on pollution haven effect, which has thus far lacked a compelling multi-country test (Taylor, 2005).[17]

Given the major caveats, it is not surprising that strong consensus has yet to emerge from the body of empirical studies. A number of studies found limited evidence of pollution haven effect using cross-sectional data (for example, Grossman and Krueger, 1995) and various proxies of environmental policy gaps. For example, van Beers and van den Bergh (1997) construct their own regulatory gap indicator based mainly on energy intensity and recycling rates, Grether and de Melo (2004) use the difference in GDP per capita as a proxy and Grether et al. (2012) use two composite indexes from the World Economic Forum's Global Competitiveness Report and the environmental regulatory regime index from Esty and Porter (2005). These studies do not detect a systematic or robust regulatory gap effect.

The studies using panel data tended to support the pollution haven effect, but they also tended not to model the regulatory gap across countries for the same sectors, only the regulatory gap across sectors within one country (for example, Ederington et al., 2005 and Kellenberg, 2009). Based on a panel of 130 sectors for the years 1977 to 1986, Levinson and Taylor (2008) find some evidence that sectors with larger increases in clean-up costs tended to coincide with sectors that experience larger increases in net imports. They estimate that a 1 percent increase in pollution abatement cost expenditures in the United States is associated with a 0.4 percent increase in net imports from Mexico and a 0.6 per cent increase from Canada. Levinson (2010) instead examines the changes in composition of United States' imports and exports and finds that the composition of imports has become increasingly less polluting. He argues that this does not necessarily contradict the pollution haven effect, as the green shifts in imports may have been smaller without environmental regulations, but that if there has been a pollution haven effect it is likely to have been overwhelmed by other forces.

Aichele and Felbermayr (2012) investigate the effects of legally binding mitigation targets under the Kyoto Protocol on bilateral exports using a matching technique and find that Kyoto countries' exports are reduced by 13 percent to 14 percent. However, the validity of these results has been questioned. In particular, the signing of the Kyoto Protocol is a crude measure of environmental policy stringency and the results might be driven by factors other than the Kyoto Protocol commitments, most likely the effect of China joining the World Trade Organisation in 2002, which coincided with most Annex I countries' ratification of the Kyoto Protocol. Cole et al. (2014) use cross-sectional data for 12,335 Japanese firms and find that firms with more reported environmental protection efforts are 28 percent more likely to outsource parts of their production overseas than firms that report no effort, and they argue this gives support to the pollution haven effect. However, the robustness of the results is severely compromised by the poor definition of the regulatory variable, which is measured by a dummy variable that is equal to one if a firm answers positively to one of seven survey questions about environmental activities. The recent papers on the effects of the EU ETS on trade find limited empirical support (for example, Branger and Quirion, 2013). The combination of limited import penetration and the evidence of carbon cost pass-through suggests that measures designed to address competitiveness concerns (free allocation) may have prevented trade losses, but at the same time, European

16 For example, policy variables can capture differences across sectors other than the relative policy stringency and can lead to biases due to sector aggregation and the unobserved foreign regulation.

17 To this end, there may be scope to apply the approach of Aldy and Pizer (2011) – which involves using historic sector-level energy price as a proxy for relative policy stringency across American states – to international studies if sector level energy price information is available for key trading partners.

Union industries are protected by trade barriers to some degree, so that companies may have been over-compensated.

Studies examining environmental regulation as a determinant of industry location also find mixed results. A meta-analysis by Jeppsen et al. (2002) found that estimating the effects of environmental policy on new plant location is highly sensitive to empirical specification, data and the definition of the regulatory variable, and that no consensus emerges from the literature. Several studies found no statistically or economically significant effects (for example, Eskeland and Harrison, 2003; Smarzynska and Wei, 2001; Raspiller and Riedinger, 2008; and Dean et al., 2009). A study by Leiter et al. (2011) examines the impact of environmental regulation as measured by environmental protection expenditure and environmental tax revenue on four types of investment (including new investment) in 21 European countries and finds that greater stringency is associated with greater investment levels for all types. In contrast, a number of studies using state or county level data from the United States on inward foreign direct investment flows finds that environmental regulation has a statistically significant negative effect (for example, List and Co, 2000; Keller and Levinson, 2002). List et al. (2003) estimate that in the United States, the probability of hosting a new industrial plant decreases by 50 percent when a county changes from being a low environmental compliance cost region to a high one. Similarly, Wagner and Timins (2009) and Ben-Kheder and Zugravu (2012) find that environmental regulations affect outward foreign direct investment destinations for German chemical companies and French companies, respectively. The evidence from studies on developing countries is mixed.

While the pollution haven picture continues to be unclear, the possibility that trade and investment flows will be affected if countries pursue environmental regulations to significantly different degrees of ambition cannot be ruled out. Several avenues of emerging research will strengthen the empirical evidence base and give a better understanding of how potential adverse impacts on trade and investment from environmental regulations can be mitigated. These include emerging research on comparability of environmental effort (for example, Aldy and Pizer, 2013) and assessments of how effective alternative measures to address competitiveness impacts are. For example, a body of work evaluates the allowance allocation methods under emissions trading schemes (Fischer and Fox, 2007; Demailly and Quirion, 2008; Meunier and Ponssard, 2012); border carbon adjustments (Branger and Quirion, 2014; Boehringer et al., 2014); and consumption-based accounting (for example, Jakob et al., 2014). These studies are, of course, not empirical due to the lack of actual policy experiments.

Do environmental regulations encourage innovation activity?

In today's knowledge-based economy, firms' competitiveness is largely reliant on innovation so there is a growing body of research seeking to quantify the link between environmental regulations and technological change (see Popp et al., 2010; Popp, 2010; and Ambec et al., 2013, for recent surveys). When regulated firms face a higher price on polluting emissions relative to other costs of production, this gives them an incentive to make operational changes and investments that reduce the emissions intensity of their output. The 'induced innovation' hypothesis, dating back to Sir John Hicks (1932) and restated in the context of environmental regulation by Porter (1991) and Acemoglu et al. (2012), suggests that part of this new investment will be directed towards developing new emissions-reducing technologies. Indeed, a number of studies have shown unambiguously that environmental regulation affects the development of new green technologies. This result seems to hold across several measures of environmental regulation and different measures of innovation activity. For example, it has been shown that higher pollution control expenditures lead to higher research and development expenditures (Jaffe and Palmer, 1997) and to more environment-related patents (Brunnermeier and Cohen, 2003). Also, higher energy prices induce the development of energy efficient technologies (Popp, 2002; Verdolini and Galeotti, 2011).

Until recently, innovation has been mainly measured at the level of economic sectors or countries, but a few recent studies provide firm-level evidence. Aghion et al. (2014) examine innovation activity by around 3,000 firms in the car industry and show that they tend to innovate relatively more in clean technologies when they face higher fuel prices. Therefore, fuel taxes can help break the path dependence in the direction of low-carbon innovation. Calel and Dechezleprêtre (2014) explore the impact of the EU ETS on innovation by analysing low-carbon patenting activity of regulated firms. They show that the EU ETS has increased innovation activity in low-carbon technologies among regulated companies by 10 percent compared to a counterfactual scenario.

There is ample evidence that environmental regulations induce innovation in clean technologies and discourage research and development in conventional (polluting) technologies. Thus, environmental regulations can help economies break away from a polluting economic trajectory and move to a 'clean' one.

Does innovation induced by environmental regulations improve firms' competitiveness?

The Porter hypothesis (Porter, 1991; Porter and van der Linde, 1995) asserts that environmental regulations (in particular, market-based instruments) can "trigger innovation that may partially or more than fully offset the costs of complying with them". Economists, who find it hard to believe that environmental regulation would be needed to lead firms to make profit-increasing investments, were initially sceptical. However, this assumption has some theoretical justifications. Managers might be risk- or change-averse and thus overlook profitable opportunities. Countries may generate a first-mover advantage to domestic companies by regulating pollution sooner than others. Information asymmetries about the quality of 'greener' products can also lead environmental regulations to increase competitiveness (see Ambec et al., 2013, for an overview of these theories). The literature does not provide much empirical evidence for the Porter hypothesis.

For regulation-induced environmental innovations to improve competitiveness, an important question is whether they come at the expense of other innovations. In this respect, Gray and Shadbegian (1998) find that more stringent air and water regulations improved environmental innovation in paper mills in the United States, 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. Hottenrott and Rexhaüser (2013) find that regulation-induced environmental innovation crowds out research and development in other technologies, especially for small firms that are credit constrained. Aghion et al. (2014) show that innovations in clean cars (electric, hybrid and hydrogen) come at the expense of innovation in dirty vehicles (combustion engines). So there seems to be evidence for a crowding out effect, although Calel and Dechezleprêtre (2014) find no evidence that the increased innovation in low-carbon technologies after the introduction of the EU ETS damaged innovation in other technologies. Popp and Newell (2012) find that the social value of renewable energy patents, as measured by patent citations, seems to be higher than that of crowded out patents. This is confirmed by a systematic comparison of patents in clean and dirty technologies by Dechezleprêtre et al. (2014). Innovation in clean technologies induced by environmental regulation might be able to make unregulated companies more competitive because they benefit from this new knowledge. More work is needed, however, to understand the *social* impacts of clean technologies rather than just their *private* impacts on firms' profits.

A small number of studies have looked at the whole causality chain implied by the Porter hypothesis, from regulation to competitiveness, through to innovation – and thus the impact on firms' profitability. Lanoie et al. (2011) find that regulation-induced environmental innovation improves business performance but not enough to offset the costs of compliance. They conclude that the net effect is negative – that is, the positive effect of innovation on business performance does not outweigh the negative effect of the regulation itself. These results suggest that environmental regulation is costly, but less so than if one was to consider only the direct costs of the regulation itself, without the ability of innovation to mitigate those costs. Van Leeuwen and Mohnen (2013) provide evidence that regulation-induced green innovation does not increase labour productivity. Hence, the Porter hypothesis, whereby environmental regulation induces innovation which itself increases competitiveness, is not supported. Rexhauser and Rammer (2014) find that regulation-induced innovations which improve a firm's resource efficiency in terms of material or energy consumption have a positive impact on profitability, as measured by pre-tax profits over sales. In other words, the Porter hypothesis may not hold in general but does hold for some types of innovation.

In sum, green innovations developed to cut the cost of environmental regulations do not seem to increase firms' profits enough to fully offset the private costs of regulation. However, there is evidence that low-carbon innovations induce larger economic benefits than the 'dirty' technologies they replace because they generate more knowledge in the economy, which can be used by other innovators to further develop new technologies across various sectors of the economy. This makes it plausible that the switch from 'dirty' to 'clean' technologies could generate economic growth. This also justifies strong public support to clean technology development.

4. Conclusion: advancing the debate on competitiveness effects

Some 20 years ago, in their review of the literature on the competitiveness impacts of environmental regulation in the United States, Jaffe, Peterson, Portney and Stavins concluded that "there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness" and that "studies attempting to measure the effect of environmental regulation on net exports, overall trade flows, and plant location decisions have produced estimates that are either small, statistically insignificant, or not robust to model specification" (Jaffe et al., 1995). Since then, there have been hundreds of studies, using ever larger datasets at increasingly finer levels of disaggregation, employing up-to-date econometric techniques and covering a wider set of countries; but the overall conclusion has changed only slightly.

The recent evidence shows that environmental regulations can hit employment and productivity, in particular in pollution- and energy-intensive sectors. However, these effects appear to be small and transitory. Over the longer run, the effects tend to be smaller than in the short run, suggesting that government policies such as labour markets regulations can help reduce or offset the transitory impacts of environmental regulations on competitiveness. These effects seem more likely to occur within national boundaries where relocation barriers are low, than across borders. Internationally, the estimated effects of environmental regulations on trade and investment location so far are negligible in comparison to other determinants, such as market conditions and quality of local workers. Moreover, the social benefits of environmental regulations, in particular in terms of improved health, often seem to vastly outweigh their costs. The available evidence suggests that there is no case to cut back environmental regulations for competitiveness reasons, and seeking only 'win-win' solutions with no losers would risk leaving many socially beneficial policies off the table. The link between environmental regulations and innovation is perhaps where results from the recent literature differ most from the conclusions of Jaffe et al. (1995).[18] There is now ample evidence that environmental regulations induce innovation activity in clean technologies while discouraging research and development in conventional (polluting) technologies, as well as more recent evidence that low-carbon innovations induce larger economic benefits than the 'dirty' technologies that they replace in terms of knowledge spillovers, offering some support for the idea that directed technological change can help offset the costs of environmental regulations or even encourage economic growth.

The most obvious question arising from this synthesis is: why are the effects of environmental regulations found to be so small when competitiveness concerns are so high in public policy circles? A first possibility is that environmental policies are well designed so as to prevent competitiveness effects. A large number of key environmental regulations have compensation mechanisms in place, perhaps the most prominent example being the European Union Emissions Trading System (EU ETS) that has, until now, widely allocated emission permits for free. Another possibility is that the small effects identified thus far simply reflect the lack of stringency of most environmental policies. Yet it is likely that the threats posed by climate change and other environmental concerns will require environmental regulations that lie far outside the bounds of past experience.

18 Jaffe et al. (1995) concluded that "there is little or no evidence supporting the revisionist hypothesis that environmental regulation stimulates innovation and improved international competitiveness."

What, then, can we learn from the existing literature for future policies? By definition, ex post empirical evaluations conducted so far cover past or existing policies, but the possibility of larger effects on trade and investment in the future cannot be ruled out if efforts in pollution control diverge significantly across countries. There are stark divergences in the political will to tackle climate change among developed countries' governments, as exemplified by Australia's decision to abolish carbon taxes in 2014 and Germany's ambitious energy transition programme (Energiewende) which aims to reduce greenhouse gas emissions by 80-95 percent by 2050. The regulatory gap might also increase between some emerging economies such as China, Brazil, South Korea, Malaysia and India, which all play a key role in trade and global supply chains.

Key issues for future research include: establishing credible methods to compare relative policy stringency between regulatory regimes using different policy instruments; improving the identification of specific economic activities where pollution leakage and competitiveness issues represent a genuine risk; for these specific activities, assessing the various policy options available to prevent adverse impacts on trade and investment whilst avoiding the creation of new distortions; and determining how environmental policies should be adjusted as other countries' regulations evolve. Assessments should be conducted on a sector-by-sector basis, as the same policy can have different impacts depending on sector characteristics, such as the level of competition and the nature of technology innovation necessary to carry the sector towards achieving ambitious environmental goals. For each sector, fine-tuning of policy will be required to balance policy goals with the multiple impacts of environmental regulations on pollution, employment, trade, productivity and innovation. A key challenge for researchers analysing environmental regulations, therefore, will be to analyse the impact of policies along several indicators simultaneously. Almost all studies reviewed for this policy brief analyse the impact of environmental regulation on a single dimension, be it employment, trade or innovation. Analysing multiple indicators jointly will allow a more holistic vision of the consequences of environmental regulations and of their interactions.

Another important research area is how globalisation affects environmental regulations, in particular national governments' incentives to introduce environmental regulations. For these analyses to be carried out, however, improved measures of relative green policy stringency are required, and wider country coverage – including key developing countries. Currently, almost all of the existing evidence uses data from developed countries.

This paper focused on the impacts of environmental regulations on regulated companies, however, unregulated companies and sectors may also be affected through technology supply chain relationships, knowledge spillovers, health benefits, general equilibrium effects, etc. Analysing the cross-sectoral impacts of environmental regulations is a promising area for future research. However, there is a limit to what effects *ex post* studies can identify. For example, it is very difficult to identify the impact of environmental regulations on innovation activity of unregulated companies because it requires observing links between regulated companies and technology suppliers. *Ex ante* studies play a key role in assessing the macroeconomic impacts of environmental regulations on competitiveness, such as economy-wide technology development or double dividend effects through tax reform. They are also better suited to assessing the distributional and welfare implications of environmental regulations. We have only reviewed the *ex post* literature, purposely leaving *ex ante* studies aside. Since *ex ante* studies play a major role in policy development, it would be particularly useful to review the modelling literature with a view to assessing its accuracy in predicting the effects of environmental regulations by comparing *ex ante* with *ex post* assessment of the same regulations. This is left for future research.

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