

The Impacts of Environmental Regulations on Competitiveness

Antoine Dechezleprêtre* and Misato Sato†

Introduction

Ever since the first major environmental regulations were enacted in the 1970s, there has been much debate about their potential impacts on the competitiveness of affected firms. Businesses and policy makers fear that in a world that is increasingly characterized by the integration of trade and capital flows, large asymmetries in the stringency of environmental policies could shift pollution-intensive production capacity toward countries or regions with less stringent regulation, altering the spatial distribution of industrial production and the subsequent international trade flows. This has caused concern, particularly among countries that are leading the action against climate change, because their efforts to achieve deep emission reductions could put their own pollution-intensive producers at a competitive disadvantage in the global economy.

There are two different views in the environmental economics literature on the effects of asymmetric policies on the performance of companies competing in the same market: the pollution haven hypothesis and the Porter hypothesis. The pollution haven hypothesis, which is based on trade theory, predicts that more stringent environmental policies will increase compliance costs and, over time, shift pollution-intensive production toward low abatement cost regions, creating pollution havens and causing policy-induced pollution leakage (e.g., [Levinson and Taylor, 2008](#)). This is a particularly troubling problem for global pollutants such as carbon dioxide, because it means that on top of the economic impacts on domestic firms, abatement efforts will be offset to some extent by increasing emissions in other regions.

*Grantham Research Institute on Climate Change and the Environment, London School of Economics, Houghton Street, London WC2A 2AE, United Kingdom. Tel: +44 (0)207 852 3626; e-mail: A.Dechezlepretre@lse.ac.uk.

†Grantham Research Institute on Climate Change and the Environment, London School of Economics, Houghton Street, London WC2A 2AE, United Kingdom. Tel: +44 (0)207 107 5412; e-mail: m.sato1@lse.ac.uk.

We would like to thank Milan Brahmbhatt, Raphael Calel, Baran Doda, Damien Dussaux, Carolyn Fischer, Matthieu Glachant, Colin McCormick, and Dimitri Zenghelis for helpful comments on an earlier version of this article. We are grateful to three anonymous referees for very constructive comments and suggestions. Financial support has come from the Global Green Growth Institute, the Grantham Foundation for the Protection of the Environment, the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 308481 (ENTRACTE), and the UK Economic and Social Research Council through the Centre for Climate Change Economics and Policy.

Review of Environmental Economics and Policy, volume 11, issue 2, Summer 2017, pp. 183–206

doi: 10.1093/reep/rex013

Advance Access Published on July 27, 2017

© The Author 2017. Published by Oxford University Press on behalf of the Association of Environmental and Resource Economists. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

In contrast, the Porter hypothesis (Porter and van der Linde 1995b) 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 may help firms achieve international technological leadership and expand market share.

This article reviews the recent empirical literature that attempts to quantify the effects of asymmetric environmental regulations on key aspects of firms' competitiveness, including trade, industry location, employment, productivity, and innovation. The first major review on this topic (Jaffe et al. 1995) concluded that there is relatively little evidence that environmental policies lead to large losses in competitiveness. Over the last two decades, both the growth in the number of environmental policies worldwide and the availability of high-quality data, especially at the firm and facility level, have enabled researchers to improve their empirical analyses of the economic effects of asymmetric environmental policies. Our aim is to critically assess this evidence to ascertain whether the conclusions of Jaffe et al. (1995) still hold or should be updated. By synthesizing the evidence, we also hope to inform the political debate concerning the economic impacts of environmental regulations.

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

The article is organized as follows. We start by explaining how environmental regulation causes competitiveness effects and how these effects are measured. We then review the existing evidence, first discussing 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. We conclude with a summary and a discussion of priorities for future research.

How Does Environmental Regulation Affect Firms' Competitiveness?

In the context of environmental policies, competitiveness² effects result from *differences* or *asymmetries* in regulatory stringency³ applied across entities (e.g., firms or sectors) that

¹We do not include regulations on fishing, agriculture, forestry, mining, or waste, which are sometimes directed explicitly at protecting the environment and human health.

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 marketplace, 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).

³We use the term *policy stringency* here to describe a general level of policy ambition. As we will discuss, in practice, measuring relative policy stringency across different forms of regulation and enforcement regimes is far from straightforward.

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 United Nations Framework Convention on Climate Change 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 competing polluting firms.

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 and steel sectors by 5 percent to 8 percent (Chan, Li, and Zhang 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 paper, steel, and oil refining. In the United States, for example, in 2005 each of these sectors spent approximately 1 percent of their turnover to comply with environmental regulations, while the average for all manufacturing plants was 0.4 percent (Ferris and McGartland 2014). Importantly, differences in relative costs may arise not only from the stringency of the regulation, but also from its nature and design (Iraldo et al. 2011), in

⁴Note, 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.

⁵In 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 U.S. 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.

Table 1 Competitiveness Effects Due to Differences in the Stringency of Environmental Regulations

First-order effect	Second-order effect	Third-order effects			
		Cost impacts	Firm responses	Economic outcomes	Technology outcomes
Changes to relative costs (direct and indirect costs)	<ul style="list-style-type: none"> – Production volume – Product prices – Productive investments – Investment in abatement 	<ul style="list-style-type: none"> – Profitability – Employment – Market share 	<ul style="list-style-type: none"> – Product innovation – Process innovation – Input-saving technologies – Total factor productivity (TFP) 	<ul style="list-style-type: none"> – Trade flows – Investment location – Foreign direct investment (FDI) 	<ul style="list-style-type: none"> – Pollution levels and intensity – Pollution leakage

Source: Authors.

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 (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, technological, international, and environmental dimensions (third-order effects). These effects are not uni-directional, rather there are multiple linkages and dynamic feedbacks. Changes to technology outcomes, for example, may trigger cost impacts or firm responses to change.

The Pollution Haven Hypothesis

There are two opposing views on the likely competitiveness effects arising from asymmetric environmental policies worldwide, as noted earlier. 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 increase 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

⁶In 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.

more cheaply. If environmental regulatory differences are expected to last, companies' decisions regarding the location of new production facilities or foreign direct investment may also be affected, with pollution-intensive sectors, and thus manufacturing employment, possibly gravitating toward countries with relatively lax policies and creating pollution havens.

The Porter Hypothesis

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 that would not have occurred without the policy, they may offset part of the compliance costs. Porter and van der Linde (1995b) 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 feedback 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 toward international leadership in clean technologies that are increasingly in demand globally (Porter and van der Linde 1995a).

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 continues to use a variety of outcome measures linked to competitiveness (summarized in table 1).⁸ Estimates of the effect of policies on these different outcomes are usually derived using reduced form rather than structural equations. Despite some progress being made, there are still a number

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

⁸Jaffe et al. (1995) argue 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 of a single company are unlikely to affect exchange rates.

of challenges to conducting credible empirical analysis of the competitiveness impacts of environmental regulations.

Solving Endogeneity Concerns Through Disaggregated 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 analyzing 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 datasets 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.⁹ 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 U.S. context, the federal designation of counties into “attainment” or “nonattainment” status depends on local air quality for various pollutants, thus providing a convenient source of exogenous variation. Counties with nonattainment status then face much stricter environmental regulation.¹⁰

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.

⁹Omitted variable bias can occur when firms’ unobserved characteristics may be correlated with both regulatory stringency and the outcome measure (e.g., productivity).

¹⁰Being federally mandated, this status is unlikely to be related to differences in tastes, geographic attributes, or underlying economic conditions across counties. Moreover, local 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, List, and Syverson 2012).

Although the measurement of relative stringency is likely to be fraught with measurement error, a number of 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. 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. \(2015b\)](#), 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 setup 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 behavior of firms.¹¹ 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, which we do in the next two sections.

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.¹² In this section we examine the evidence concerning these impacts.

Environmental Regulation and International Trade

Much of the early literature tested the pollution haven hypothesis¹³ 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

¹¹For 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.

¹²Related to this are political economy concerns about governments' use of environmental policy as an implicit trade barrier to circumvent international free-trade agreements.

¹³Some 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.

on the scale of economic activity, sector composition, and technology adoption, and found limited empirical evidence that trade made developing countries dirtier.¹⁴ In a study of 43 countries, [Antweiler, Copeland, and Taylor \(2001\)](#) find that international trade is in fact beneficial to the environment (as measured by sulfur dioxide [SO₂] 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 U.S. imports following the adoption of environmental regulation. Taking account of intermediate inputs, he finds that between 1972 and 2001, U.S. 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, skilled labour availability, 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 variable¹⁵ and, for a panel of U.S. manufacturing industries, find that between 1978 and 1992, net imports rose with higher PACE, suggesting that differences in environmental regulation impact trade flows. Using the same data but taking account of factors that limit the geographic mobility of economic activity (e.g., transportation costs, fixed plant costs, and agglomeration economies of an industry), [Ederington, Levinson, and Minier \(2005\)](#) find that the pollution haven effect is difficult to detect in capital-intensive industries. They note that quantifying average effects on competitiveness across all sectors understates the effects of regulatory differences on “footloose” (i.e., geographically mobile) sectors. [Levinson and Taylor \(2008\)](#) use a panel for 1977–1986 and find that a 1 percent increase in PACE in the United States is associated with an increase in net imports of 0.4 percent from Mexico and 0.6 percent from Canada.¹⁶ [Levinson \(2010\)](#), however, argues that the result in [Levinson and Taylor \(2008\)](#) does not actually show that higher levels of PACE cause higher imports; rather, it shows that imports are rising in sectors where the gap in the stringency level across countries is increasing.

¹⁴For a review of such earlier studies, see [Jaffe et al. \(1995\)](#) and [Copeland and Taylor \(2004\)](#).

¹⁵The authors use political economy variables and factor intensities as instrumental variables for PACE. This analysis also finds that PACE is endogenous and suggests that policy stringency is determined strategically by governments.

¹⁶They use a fixed effects model that accounts for unobserved sector characteristics that are correlated with regulation and trade, unobserved foreign pollution regulation levels, and aggregation bias in sectoral data (due to changes in 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.

While carbon pricing policies are relatively new and coverage is limited, a number of recent studies conduct *ex post* analysis on their trade impacts.¹⁷ Branger, Quirion, and Chevallier (2016) examine the impact of the EU ETS—to date the world’s largest carbon market—using a time-series analysis for the period 2004–2012. 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 changed in response to energy prices between 1974 and 2005.¹⁸ 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, aluminum, cement, and bulk glass, but that the magnitude of the effect is small (a 0.1–0.8 percent increase in net imports from a hypothetical \$15 per ton CO₂ price). 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 percent increase in the energy price gap increases bilateral imports by 0.2 percent and that overall, energy price differences explain 0.01 percent of the variation in trade flows.¹⁹

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 a few sectors. Overall, the effect of relative stringency on trade flows is overwhelmed by other determinants of trade.

Environmental Regulation and Production and Investment Location

Addressing concerns that trade liberalization 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 exploration of the effects of environmental regulation on investment location as evidence of pollution havens.

This literature 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.

¹⁷There 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* modeling 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.

¹⁸They use a detailed panel of state-level manufacturing production data covering 450 sectors.

¹⁹The 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 industrialized countries and emerging economies such as China, as well as an increase in competitiveness concerns.

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 of environmental regulatory stringency,²⁰ [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 inflow of relocating plants by nearly 63 percent ([List et al. 2003](#)) and decreases the expected inflow of new dirty plants by 44–61 percent or 150–600 percent, depending on the estimator used ([List, McHone, and Millimet 2004](#)). A comparison of these inter- and intrastate studies of the United States suggests that studies with a smaller geographic 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 and List \(2004\)](#) finds that the effect of stricter regulation is spatially heterogeneous and varies systematically with location-specific attributes such as unemployment levels.

Impacts on inward FDI location

A number of studies use the within-country variation in environmental stringency and find inconclusive evidence on its impact on inward FDI location. [List, McHone, and Millimet \(2004\)](#) use U.S. 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, Lovely, and Wang \(2009\)](#) 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 U.S. state-level data, [Keller and Levinson \(2002\)](#) find that between 1977 and 1994, a 10 percent increase in relative manufacturing pollution abatement cost is associated with a 0.79 percent decrease in manufacturing FDI and, more specifically, a 1.98 percent decrease in FDI in the chemical industry. [Fredriksson, List, and Millimet \(2003\)](#) and [Millimet and Roy \(2016\)](#) 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, 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 relative environmental stringency across countries. [Xing and Kolstad \(2002\)](#) studied 22 countries between 1985 and 1990 using SO₂ emissions.²¹ The authors find a significant effect for

²⁰This is a state- and year-level industry-adjusted index of environmental stringency based on pollution abatement costs.

²¹This approach captures only one component of environmental stringency, namely the regulation of coal combustion, which likely biases estimates towards energy-intensive industries.

two of the six sectors studied – with a 1 percent decrease in SO₂ emissions associated with 0.27 and 0.20 million dollar increases, respectively, in new investments from U.S. multinational companies in the chemicals and primary metals sectors. However, this effect is small relative to the total outflow of U.S. 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 destinations 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,²² German FDI to that country would increase by €122,000 per year, which corresponds 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 lax stringency) attracted more U.S. 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 location choice.

Impacts on outward FDI location

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 behavior, 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 U.S. 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 percent and their foreign output by 9 percent.

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, [Jeppesen, List, and Folmer \(2002\)](#) find that the estimates are highly sensitive to the empirical specification, the data, the definition of the regulatory variable, the control variables, and geographic coverage. Our updated review of the new plant and FDI location literature here suggests that this conclusion still holds.

²²To give an idea of magnitude, this is exemplified by the difference in environmental stringency between Austria and neighbouring Slovakia.

²³More specifically, they find that for countries in the top twentieth percentile in terms of the value added of U.S. multinational affiliates from 1999 to 2003, 8.6 percent of the value added growth was attributed to lower environmental policy stringency.

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

Environmental Regulation and 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, Pizer, and Shih 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 nonpolluting 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.

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, Pizer, and Shih (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-U.S. 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 (2001a) 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 labor 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 labor is required for pollution control activities. This finding is similar to Morgenstern, Pizer, and Shih (2002), with the lower bound of the Berman and Bui (2001a) estimates implying that

²⁵For 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).

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 U.S. CAAA on employment. [Kahn \(1997\)](#) finds that the growth rate in manufacturing employment over the 1982–1988 period is 9 percent 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 percent slower growth rate in the chemicals, primary metals, industrial machinery, and instruments sectors. Interestingly, plants in nonattainment 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 CAAA 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 (even at the 10 percent level) 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 SO₂ emissions implemented under the 1990 CAAA, [Ferris and McGartland \(2014\)](#) provide evidence suggesting that the impact of environmental regulations on employment may be only temporary. Using a small panel dataset of 61 regulated and 109 unregulated plants, they find that employment is significantly lower in regulated plants than in nonregulated plants, but only in the first year of compliance.

[Walker \(2013\)](#) finds that the labor 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 equivalent to 20 percent of the worker's preregulatory 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 United States, [Deschenes \(2011\)](#) 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

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

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 percent increase in the price of electricity leads to a 16.5 percent decrease in employment in that sector. Based on these estimation results, [Kahn and Mansur \(2013\)](#) predict that the employment effect of a hypothetical \$15 per ton carbon tax would affect employment very differently across states, according to the carbon intensity of electricity production and the energy intensity of the industry, ranging 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 \(2017\)](#) 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 per tonne of CO₂ equivalent, the basic chemical manufacturing sector, one of the most emissions-intensive and trade-exposed industries, experiences the largest decline in employment (30 percent),²⁷ while the health care industry experiences a 16 percent 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 \(2017\)](#) finds that while there are clearly winners and losers, a revenue-neutral carbon tax may not adversely affect aggregate employment.

In summary, the most rigorous studies that use installation or county-level data from the United States and long panels provide evidence of a pollution haven effect within the United States. More specifically, they find that environmental regulations have negative effects on employment in pollution-intensive sectors. 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, it is important to keep in mind that employment effects might be larger within national boundaries (where relocation barriers are lower) than across countries.

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

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

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.

Evidence that environmental regulation hampers productivity

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 SO₂ regulations in the United States reduced productivity growth in 56 fossil-fuelled electricity utilities by an estimated 44 percent during the 1973–1979 period. More recently, [Gray and Shadbegian \(2003\)](#) 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, List, and Syverson \(2012\)](#) 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, List, and Syverson \(2012\)](#) 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.

Variation across pollutants and industries

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, List, and Syverson \(2012\)](#) find that while nonattainment of ozone concentrations 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, Kerkvliet, and Buccola \(2002\)](#) find that the productivity of the Mexican food processing industry *increased* with more stringent local environmental regulation and that pollution

²⁸See the seminal article 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 increases 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 (CGE) setting.

regulations in the United States had no negative impact on the profitability or productivity of its domestic food manufacturing industry.

Short-term impacts

Berman and Bui (2001b) find that although refineries located in the Los Angeles (South Coast) Air Basin area experience a short-run decrease in productivity due to increased regulatory stringency between 1979 and 1992, this effect appears to be temporary; after a few years they enjoy significantly *higher* productivity than other refineries in the United States despite the more stringent air pollution regulations. Similarly, Lanoie, Patry, and Lajeunesse (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 2 years. In a multilevel analysis using a dataset covering 60,000 companies across 23 Organization for Economic Cooperation and Development countries, 22 manufacturing sectors, and 21 years, Albrizio, Kozluk, and Zipperer (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 5 years. Albrizio, Kozluk, and Zipperer (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, Newell, and Stavins 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 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 can indeed encourage the development of pollution-reducing

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

³⁰For recent surveys, see Carraro et al. (2010), Popp, Newell, and Jaffe (2010), and Ambec et al. (2013).

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. Similarly, higher energy prices have been shown to induce the development of energy-efficient technologies ([Newell, Jaffe, and Stavins 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 ([Milliman and Prince 1989](#); [Fischer, Parry, and Pizer 2003](#); [Parry, Pizer, and Fischer 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 U.S. SO₂ emissions cap-and-trade program and the U.S. Ozone Transport Commission NO_x Budget Program, patenting activity collapsed when traditional regulation was replaced by 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, 1995b](#)) 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, Morgenstern, and Nelson 2000, 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,

³¹The “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](#)).

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 Rexhäuser 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 Smeets \(2015\)](#) 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 ([Rexhäuser and Rammer 2014](#)).

[Porter and van der Linde \(1995a\)](#) 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 analyzed 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, Martin, and Mohnen \(2014\)](#) 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.

Conclusions and Priorities for Future Research

Some 20 years ago, in their review of the literature on the competitiveness impacts of environmental regulation in the United States, [Jaffe et al. \(1995\)](#) concluded that “there is relatively

³²To 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 analyzed.

little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness.” Since then, through hundreds of studies that have used ever larger datasets with increasingly fine levels of disaggregation, employing up-to-date econometric techniques, and covering a wider set of countries, this conclusion has only become more robust.

This article 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 cost burden of environmental policies has often been found to be very small. 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 with 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 subset of sectors for which environmental and energy regulatory costs are significant—a small group of basic industrial sectors characterized 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., 2015a). For these subsectors, where pollution leakage and competitiveness issues represent a genuine risk, a critical avenue for future research is to assess and evaluate 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).

This article has also shown that there is strong evidence that environmental regulations induce innovation activity in cleaner technologies. Thus far the benefits from these innovations do not appear to be large enough to outweigh the costs of regulations for the regulated entities. Of course, this does not preclude the ability of environmental regulations to foster the development of global leaders in innovation, but it does suggest 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 lacking. As regulatory designs and combinations continue to be explored, further research will be needed to identify the combinations of research and development and environmental policies that best encourage innovation in green technologies (Burke et al. 2016).

This review 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 decreasing 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.

References

- Aghion, P., A. Dechezleprêtre, D. Hemous, R. Martin, and J. Van Reenen. 2016. Carbon taxes, path dependency and directed technical change: evidence from the auto industry. *Journal of Political Economy* 124(1):1–51.
- Aghion, P., and P. Howitt. 1992. A model of growth through creative destruction. *Econometrica* 60(2):323–51.
- Albrizio, S., T. Kozluk, and V. Zipperer. 2014. Empirical evidence on the effects of environmental policy stringency on productivity growth. OECD Economics Department Working Papers no. 1179. Paris: OECD Publishing.
- Aldy, J. E., and W. A. Pizer. 2015. The competitiveness impacts of climate change mitigation policies. *Journal of the Association of Environment and Resource Economists* 2(4):565–95.
- Alpay, E., J. Kerkvliet, and S. Buccola. 2002. Productivity growth and environmental regulation in Mexican and US food manufacturing. *American Journal of Agricultural Economics* 84(4):887–901.
- Ambec, S., M. Cohen, S. Elgie, and P. Lanoie. 2013. The Porter hypothesis at 20: can environmental regulation enhance innovation and competitiveness? *Review of Environmental Economics and Policy* 7(1):2–22.
- Antweiler, W., B. R. Copeland, and M. S. Taylor. 2001. Is free trade good for the environment? *American Economic Review* 91(4):877–908.
- Balistreri, E. J., and T. F. Rutherford. 2012. Subglobal carbon policy and the competitive selection of heterogeneous firms. *Energy Economics* 34(Suppl 2):S190–297.
- Ben-Kheder, S., and N. Zugravu. 2012. Environmental regulation and French firms location abroad: an economic geography model in an international comparative study. *Ecological Economics* 77:48–61.
- Berger, T. 2008. Concepts on national competitiveness. *Journal of International Business and Economy* 9(1):3–17.
- Berman, E., and L. Bui. 2001a. Environmental regulation and labor demand: evidence from the South Coast Air Basin. *Journal of Public Economics* 79(2):265–95.
- . 2001b. Environmental regulation and productivity: evidence from oil refineries. *Review of Economics and Statistics* 83(3):498–510.
- Branger, F., J. Ponsard, O. Sartor, and M. Sato. 2015. EU ETS, free allocations and activity level thresholds: the devil lies in the details. *Journal of the Association of Environment and Resource Economists* 2(3):401–37.
- Branger, F., and P. Quirion. 2014. Climate policy and the ‘carbon haven’ effect. *Wiley Interdisciplinary Reviews: Climate Change* 5(1):53–71.
- Branger, F., P. Quirion, and J. Chevallier. 2016. Carbon leakage and competitiveness of cement and steel industries under the EU ETS: much ado about nothing. *Energy Journal*, 37(3):109–35.
- Bristow, G. 2005. Everyone’s a ‘winner’: problematising the discourse of regional competitiveness. *Journal of Economic Geography* 5(3):285–304.
- Brunel, C., and A. Levinson. 2013. Measuring environmental regulatory stringency. OECD Trade and Environment Working Papers no. 2013/05. Paris: OECD Publishing.
- Brunnermeier, S. B., and M. A. Cohen. 2003. Determinants of environmental innovation in US manufacturing industries. *Journal of Environmental Economics and Management* 45(2):278–93.
- Burke, M., M. Craxton, C. D. Kolstad, C. Onda, H. Allcott, E. Baker, R. S. J. Tol. 2016. Opportunities for advances in climate change economics. *Science* 352(6283):292–93.

- Calel, R., and A. Dechezleprêtre. 2016. Environmental policy and directed technological change: evidence from the European carbon market. *Review of Economics and Statistics* 98(1):173–91.
- Carbone, J. C., and N. Rivers. 2017. The impacts of unilateral climate policy on competitiveness: evidence from computable general equilibrium models. *Review of Environmental Economics and Policy*. 11(1):24–42
- Carraro, C., E. De Cian, L. Nicita, E. Massetti, and E. Verdolini. 2010. Environmental policy and technical change: a survey. *International Review of Environmental and Resource Economics* 4(2):163–219.
- Chan, H. S., R. Li, and F. Zhang. 2013. Firm competitiveness and the European Union Emissions Trading Scheme. *Energy Policy* 63:1056–64.
- Cole, M., and R. J. R. Elliott. 2007. Do environmental regulations cost jobs? An industry-level analysis of the UK. *B.E. Journal of Economic Analysis & Policy* 7(1):1–27.
- Copeland, B. R., and M. S. Taylor. 2004. Trade, growth, and the environment. *Journal of Economic Literature* 42(1):7–71.
- Dean, J. M., M. E. Lovely, and H. Wang. 2009. Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China. *Journal of Development Economics* 90(1):1–13.
- Dechezleprêtre, A., R. Martin, and M. Mohnen. 2014. Knowledge spillovers from clean technologies: a patent citation analysis. Working Paper 135. Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy.
- Deschenes, O. 2011. Climate policy and labor markets. In *The Design and Implementation of US Climate Policy*, ed. D. Fullerton and C. Wolfram, 37–49. Chicago: University of Chicago Press.
- Ederington, J., A. Levinson, and J. Minier. 2005. Footloose and pollution-free. *Review of Economics and Statistics* 87:92–99.
- Ederington, J., and J. Minier. 2003. Is environmental policy a secondary trade barrier? An empirical analysis. *Canadian Journal of Economics/Revue canadienne d'économique* 36(1):137–54.
- Eskeland, G. S., and A. E. Harrison. 2003. Moving to greener pastures? Multinationals and the pollution haven hypothesis. *Journal of Development Economics* 70(1):1–23.
- Ferris, A. E., and A. McGartland. 2014. A research agenda for improving the treatment of employment impacts in regulatory impact analysis. In *Does Regulation Kill Jobs?*, ed. C. Coglianese, A. M. Finkel, and C. Carrigan, chap. 9. Philadelphia: University of Pennsylvania Press.
- Fischer, C., I. W. H. Parry, and W. A. Pizer. 2003. Instrument choice for environmental protection when technological innovation is endogenous. *Journal of Environmental Economics and Management* 45(3):523–45.
- Fredriksson, P. G., J. A. List, and D. L. Millimet. 2003. Bureaucratic corruption, environmental policy and inbound US FDI: theory and evidence. *Journal of Public Economics* 87(7–8):1407–30.
- Gollop, F. M., and M. J. Roberts. 1983. Environmental regulations and productivity growth: the case of fossil-fuelled electric power generation. *Journal of Political Economy* 9:654–74.
- Goulder, L. H., and I. W. H. Parry. 2008. Instrument choice in environmental policy. *Review of Environmental Economics and Policy* 2(2):152–74.
- Gray, W., and R. Shadbegian. 1998. Environmental regulation, investment timing, and technology choice. *Journal of Industrial Economics* 46:235–56.
- . 2003. Plant vintage, technology, and environmental regulations. *Journal of Environmental Economics and Management* 46:384–402.
- Greenstone, M. 2002. The impacts of environmental regulations on industrial activity: evidence from the 1970 and 1977 Clean Air Act Amendments and the Census of Manufacturers. *Journal of Political Economy* 110(6):1175–219.
- Greenstone, M., J. List, and C. Syverson. 2012. The effects of environmental regulation on the competitiveness of U.S. manufacturing. Working Paper 2012-013. MIT Centre for Energy and Environmental Policy Research.
- Grossman, G. M., and A. B. Krueger. 1995. Economic growth and the environment. *Quarterly Journal of Economics* 110(2):353–77.
- Hafstead, M. A. C., and R. C. I. Williams. 2016. Unemployment and environmental regulation in

- general equilibrium. NBER Working Paper no. 22269. National Bureau of Economic Research.
- Hanna, R. 2010. US environmental regulation and FDI: evidence from a panel of US-based multinational firms. *American Economic Journal: Applied Economics* 2:158–89.
- Harrington, W., R. D. Morgenstern, and P. Nelson. 2000. On the accuracy of regulatory cost estimates. *Journal of Policy Analysis and Management* 19(2):297–322.
- . 2010. How accurate are regulatory cost estimates? Policy brief. Resources for the Future, Washington, DC.
- Henderson, D. J., and D. L. Millimet. 2005. Environmental regulation and US state-level production. *Economics Letters* 87(1):47–53.
- Hicks, J. R. 1932. *The Theory of Wages*. Basingstoke: Palgrave MacMillan.
- Hottenrott, H., and S. Rexhäuser. 2013. Policy-induced environmental technology and inventive efforts: Is there a crowding out? ZEW Discussion Paper no. 13-115. Mannheim: ZEW.
- Iraldo, F., F. Testa, M. Melis, and M. Frey. 2011. A literature review on the links between environmental regulation and competitiveness. *Environmental Policy and Governance* 21(3):210–22.
- Jaffe, A. B., R. G. Newell, and R. N. Stavins. 2003. Technological change and the environment. In *Handbook of Environmental Economics*, ed. K.-G. Mäler and J. R. Vincent, 461–516. New York: Elsevier.
- Jaffe, A. B., and K. Palmer. 1997. Environmental regulation and innovation: a panel data study. *Review of Economics and Statistics* 79(4):610–19.
- Jaffe, A. B., S. R. Peterson, P. R. Portney, and R. N. Stavins. 1995. Environmental regulation and the competitiveness of US manufacturing: What does the evidence tell us? *Journal of Economic Literature* 33(1):132–63.
- Jeppesen, T., J. A. List, and H. Folmer. 2002. Environmental regulations and new plant location decisions: evidence from a meta-analysis. *Journal of Regional Science* 42(1):19–49.
- Kahn, M. E. 1997. Particulate pollution trends in the United States. *Regional Science and Urban Economics* 27(1):87–107.
- Kahn, M. E., and E. T. Mansur. 2013. Do local energy prices and regulation affect the geographic concentration of employment? *Journal of Public Economics* 101:105–14.
- Kellenberg, D. K. 2009. An empirical investigation of the pollution haven effect with strategic environment and trade policy. *Journal of International Economics* 78(2):242–55.
- Keller, W., and A. Levinson. 2002. Pollution abatement costs and foreign direct investment inflows to US. *Review of Economics and Statistics* 84(4):691–703.
- Kozluk, T., and V. Zipperer. 2013. Environmental policies and productivity growth – a critical review of empirical findings. OECD Economics Department Working Papers no. 1096. Paris: OECD Publishing.
- Lanoie, P., M. Patry, and R. Lajeunesse. 2008. Environmental regulation and productivity: new findings on the Porter hypothesis. *Journal of Productivity Analysis* 30:121–28.
- Lanoie, P., J. Laurent-Lucchetti, N. Johnstone, and S. Ambec. 2011. Environmental policy, innovation and performance: new insights on the Porter hypothesis. *Journal of Economics and Management Strategy* 20(3):803–42.
- Levinson, A. 1996. Environmental regulations and manufacturers' location choices: evidence from the Census of Manufacturers. *Journal of Public Economics* 62(1):5–29.
- . 2010. Offshoring pollution: Is the US increasingly importing pollution intensive production? *Review of Environmental Economics and Policy* 4(1):63–83.
- Levinson, A., and M. Taylor. 2008. Unmasking the pollution haven effect. *International Economic Review* 49(1):223–54.
- List, J. A., W. W. McHone, and D. L. Millimet. 2004. Effects of environmental regulation on foreign and domestic plant births: Is there a home field advantage? *Journal of Urban Economics* 56(2):303–26.
- List, J. A., D. L. Millimet, P. G. Fredriksson, and W. W. McHone. 2003. Effects of environmental regulations on manufacturing plant births: evidence from a propensity score matching estimator. *Review of Economics and Statistics* 85(4):944–52.

- Manderson, E., and R. Kneller. 2012. Environmental regulations, outward FDI and heterogeneous firms: Are countries used as pollution havens? *Environmental and Resource Economics* 51(3):317–52.
- Martin, R., M. Muûls, L. De Preux, and U. Wagner. 2014. Industry compensation under the risk of relocation: a firm-level analysis of the EU emissions trading scheme. *American Economic Review* 104:2482–508.
- McAusland, C., and D. L. Millimet. 2013. Do national borders matter? Intranational trade, international trade, and the environment. *Journal of Environmental Economics and Management* 65(3):411–37.
- McGuire, M. C. 1982. Regulation, factor rewards, and international trade. *Journal of Public Economics* 17(3):335–54.
- Melitz, M. J. 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica* 71(6): 1695–725.
- Milliman, S. R., and R. Prince. 1989. Firm incentives to promote technological change in pollution control. *Journal of Environmental Economics and Management* 17:247–265.
- Millimet, D. L., and J. A. List. 2004. The case of the missing pollution haven hypothesis. *Journal of Regulatory Economics* 26(3):239–62.
- Millimet, D. L., and J. Roy. 2016. Empirical tests of the pollution haven hypothesis when environmental regulation is endogenous. *Journal of Applied Econometrics* 31:652–677.
- Mohr, R. D. 2002. Technical change, external economies, and the porter hypothesis. *Journal of Environmental Economics and Management* 43(1):158–68.
- Morgenstern, R. D., W. A. Pizer, and J. S. Shih. 2002. Jobs versus the environment: an industry-level perspective. *Journal of Environmental Economics and Management* 43(3):412–36.
- Newell, R. G., A. B. Jaffe, and R. N. Stavins. 1999. The induced innovation hypothesis and energy-saving technological change. *Quarterly Journal of Economics* 114(3):941–75.
- Noailly, J., and R. Smeets. 2015. Directing technical change from fossil-fuel to renewable energy innovation: an application using firm-level patent data. *Journal of Environmental Economics and Management* 72:15–37.
- Parry, I. W. H., W. A. Pizer, and C. Fischer. 2003. How large are the welfare gains from technological innovation induced by environmental policies? *Journal of Regulatory Economics* 23(3):237–55.
- Pasurka, C. 2008. Perspectives on pollution abatement and competitiveness: theory, data, and analyses. *Review of Environmental Economics and Policy* 2(2):194–218.
- Peters, G. P., J. C. Minx, C. L. Weber, and O. Edenhofer. 2011. Growth in emission transfers via international trade from 1990 to 2008. *Proceedings of the National Academy of Sciences of the United States of America* 108(21):8903–8.
- Popp, D. 2002. Induced innovation and energy prices. *American Economic Review* 92(1):160–80.
- . 2003. Pollution control innovations and the Clean Air Act of 1990. *Journal of Policy Analysis and Management* 22(4):641–60.
- Popp, D., R. Newell, and A. Jaffe. 2010. Energy, the environment, and technological change. In *Handbook of the Economics of Innovation*, vol. 2, ed. B. H. Hall and N. Rosenberg, 873–937. Amsterdam: Elsevier.
- Popp, D., and R. Newell. 2012. Where does energy R&D come from? Examining crowding out from energy R&D. *Energy Economics* 34(4):980–91.
- Porter, M. E., and C. van der Linde. 1995a. Green and competitive: ending the stalemate. *Harvard Business Review* 73(5):120–34.
- . 1995b. Toward a new conception of the environment–competitiveness relationship. *Journal of Economic Perspectives* 9(4):97–118.
- Raspiller, S., and N. Riedinger. 2008. Do environmental regulations influence the location behavior of French firms? *Land Economics* 84(3):382–95.
- Rubashkina, Y., M., Galeotti, and E. Verdolini. 2015. Environmental regulation and competitiveness: Empirical evidence on the Porter Hypothesis from European manufacturing sectors. *Energy Policy* 83:288–300.
- Ryan, S. P. 2012. The costs of environmental regulation in a concentrated industry. *Econometrica* 80(3):1019–61.
- Rexhäuser, S., and C. Rammer. 2014. Environmental innovations and firm profitability:

- unmasking the Porter hypothesis. *Environmental and Resource Economics* 57:145–67.
- Sato, M., and A. Dechezleprêtre. 2015. Asymmetric industrial energy prices and international trade. *Energy Economics* 52(Suppl 1):S130–41.
- Sato, M., K. Neuhoff, V. Graichen, K. Schumacher, and F. Matthes. 2015a. Sectors under scrutiny: evaluation of indicators to assess the risk of carbon leakage in the UK and Germany. *Environmental and Resource Economics* 60(1):99–124.
- Sato, M., G. Singer, D. Dussaux, and S. Lovo. 2015b. International and sectoral variation in energy prices 1995–2011: How does it relate to emissions policy stringency? Working Paper no. 187, Grantham Research Institute on Climate Change and the Environment.
- Simpson, R. D. 2014. Do regulators overestimate the costs of regulation? *Journal of Benefit-Cost Analysis* 5(2):315–32.
- Taylor, M. R. 2012. Innovation under cap-and-trade programs. *Proceedings of the National Academy of Sciences of the United States of America* 109(13):4804–9.
- Wagner, U. J., and C. D. Timmins. 2009. Agglomeration effects in foreign direct investment and the pollution haven hypothesis. *Environmental and Resource Economics* 43(2):231–56.
- Walker, W. R. 2013. The transitional costs of sectoral reallocation: evidence from the Clean Air Act and the workforce. *Quarterly Journal of Economics* 128(4):1787–835.
- Xing, Y., and C. D. Kolstad. 2002. Do lax environmental regulations attract foreign investment? *Environmental and Resource Economics* 21(1):1–22.
- Yamazaki, A. 2017. Jobs and climate policy: evidence from British Columbia's revenue-neutral carbon tax. *Journal of Environmental Economics and Management* 83:197–216.
- Zeng, D.-Z., and L. Zhao. 2009. Pollution havens and industrial agglomeration. *Journal of Environmental Economics and Management* 58(2):141–53.