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Porter or Pollution Haven?

An analysis of the dynamics of competitiveness and environmental regulations

Abstract

This paper studies the effects of environmental regulations on the competitiveness of pollution intensive manufacturing industries in 48 U.S. states using data on pollution abatement costs and employment changes from 1999 and 2005. Regulatory impacts on competitiveness are measured by differences in industry employment developments between high-cost and low-cost states. The study is unique in that it uses recent, to my knowledge not previously analyzed, data and run regressions on the six most polluting manufacturing industries separately instead of pooling them all together. The results show that there is no robust proof for environmental regulations having any significantly negative or positive effect on the competitiveness in any of the industries studied, but that some industries are affected more than others which are evidence relevant for policymaking and further studies. The paper also presents supporting evidence for the theory that firms on average offset environmental compliance costs through innovation mechanisms and thereby maintains their international competitiveness.

The paper starts by introducing the reader to the trade and environment debate by presenting the Pollution Haven Hypothesis (PHH) and the Porter Hypothesis (PH). The empirical evidence so far is then presented and the theoretical background of the two hypotheses explained. The last part of the paper analyzes empirical data using a standard OLS model as well as a fixed effect model and ends with a discussion of the results and ideas for further research.

Abbreviations

EPA – Environmental Protection Agency
FDI – Foreign Direct Investment
LDCs – Least Developed Countries
NAICS – The North American Industry Classification System[1]
PAC – Pollution Abatement Cost
PACE Survey – Pollution Abatement Cost and Expenditures Survey[2]
PAOC – Pollution Abatement Operating Cost
PH – Porter Hypothesis
PHH – Pollution Haven Hypothesis
VA – Value Added

[1] http://www.census.gov/eos/www/naics/ [Accessed 2009-05-03]
[2] http://www.census.gov/econ/overview/mu1100.html [Accessed 2009-05-03]

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Introduction and motive

The trade and environment debate has been ongoing since the early 1970's and as its epicenter has been the notion that as countries liberalizes to trade, differences in environmental regulations will deteriorate comparative advantage for pollution intensive manufacturing industries in high-cost countries, affecting amongst other things industry location and FDI flows. Most empirical studies have had a hard time finding evidence for such an effect however, but interestingly enough the popular view outside of academia has for a long time been, and increasingly so, that the negative effect on competitiveness is a proven fact, likely because of the straightforward and intuitive appeal of the argument. In one 1999 U.S. study, 67% of respondents answered that international differences in environmental policies threatened American jobs through international trade (Coughlin 2002). This was also one of the main reasons why President Bush decided that the U.S. should not be a part of the global Kyoto climate change agreement, claiming that it would have cost as much as five million American jobs (Associated Press 2005).

This belief is highly relevant today as different forms of carbon taxes are discussed around the world. Congressman Bob Inglis from South Carolina commented on his proposed *Raise Wages, Cut Carbon Act of 2009* that if carbon taxes are imposed unilaterally; "then all we end up doing is decimating American manufacturing."[3] Senator James Inhofe of Oklahoma—one of the senate's most famous opponents to any form of legislation curbing greenhouse gas emissions—has opposed environmental regulations citing large and negative effects on employment (Inhofe 2008). Thus there is still a need to find out and communicate the objective facts of how environmental regulations affect industry competitiveness; indeed this is one of the most important policy issues of this decade as the world get ready to solve the climate change challenge and other environmental problems. The purpose of this study is to contribute to this task by trying to answer the question; how do environmental regulations affect the competitiveness of pollution intensive U.S. manufacturing?

The trade and environment debate

The debate surrounding trade and the environment started in the 1970's and became increasingly intense in the 1990's as a response to expanding international trade (e.g. through NAFTA and the GATT/WTO), increasing loss of manufacturing jobs to developing countries (see Table 1) and a fear that stringent environmental policies in one country could lead to comparative disadvantage relative to others (Brunnermeier and Levinson 2004). As international competition increased in pollution intensive manufacturing industries during the 1990's and early 2000, many consumer and industry groups, environmental organizations and political parties became increasingly worried about the effect that liberalization of trade had, and would continue to have in the future, on both the environment and on jobs, see Ederington (2007) for a discussion regarding NAFTA and Stonehouse (2000) regarding the WTO.[4]

[3] See http://inglis.house.gov/issues.asp?content=sections/issues/current/rnct/rnct_opening [Accessed on 2009-05-03]

[4] For specific disputes also see: http://www.wto.org/english/tratop_e/envir_e/envir_e.htm and particularly http://www.wto.org/english/tratop_e/envir_e/edis04_e.htm and http://www.wto.org/english/tratop_e/envir_e/edis08_e.htm [All accessed on 2009-05-03]

Table 1. Share of non-OECD in world manufacturing VA in ten pollution-intensive manufacturing industries

Industry	1980	1985	1990	1996
Leather	23.3	24.8	26.0	29.9
Paper	9.4	9.7	10.5	11.8
Industrial Chemicals	11.4	13.4	14.8	17.9
Other Chemicals	14.7	14.1	14.4	15.8
Petroleum Refineries	30.0	36.0	39.3	43.2
Rubber Products	15.4	16.1	18.5	21.5
Other Non-metallic Products	15.0	16.8	17.8	23.1
Iron and Steel	12.1	14.3	17.0	23.3
Non-ferrous Metals	15.4	16.5	17.0	20.3
Metal Products	8.2	9.0	9.5	11.0
Manufacturing Value Added	14.4	15.3	16.8	21.7

Source: Barton et al. (2007)

Two extremes have now developed in the trade and environment debate, offering two opposing theoretical explanations of the relevant dynamics. The first extreme is the "Pollution Haven Hypothesis" (PHH), see Taylor (2004) & Copeland and Taylor (2004) for theoretical reviews of the hypothesis, basically concluding that stringent environmental policies in the home country imposes compliance costs on businesses which, all other things equal, together with trade liberalization will lead to a comparative disadvantage in the competition with industries in foreign countries operating under less stringent environmental policies. Copeland and Taylor (1994)[5] shows that firms in pollution intensive sectors will respond by relocating production to the countries where the net cost of environmental compliance is the lowest and thereby create a strategic competition game in the international economy where offering "pollution havens" with low or no environmental regulations is a strategy that can be used to attract foreign investments. The consequence for developing countries, according to the hypothesis, is increased dirty exports, foreign investments and more environmental problems, and for developed counties a loss of pollution-intensive jobs, investments and exports. Brunnermeier and Levinson (2004) p. 9-10 suggest three basic defining principles of the PHH;

Definition 1: Economic Activity Shifts to Jurisdictions with Less Strict Environmental Regulations.

Definition 2: Trade Liberalization Encourages an Inefficient Race to the Bottom.

Definition 3: Trade Liberalization Shifts Polluting Economic Activity Toward Countries That Have Less Strict Environmental Standards.

The PHH can thus be used both to argue for trade restrictions (in quantities and/or quality) and/or for caution in regulating industries' environmental externalities.

The other extreme is called the "Porter Hypothesis" (PH) and suggests mechanisms through which stringent environmental policies in the home country can actually lead to increased efficiency and innovation, a net reduction in costs and an improved comparative advantage for domestic industries. Proposed by Porter (1991) and Porter and van der Linde (1995) the basic idea is that most negative environmental impacts stemming from an economic activity can be traced back to an inefficient use of resource inputs. If stringent environmental policies forces firms to reduce their pollution and is

[5] See Mehra and Das (2008) for an extension of the Copeland and Taylor analysis

designed in a flexible way (i.e. using economic instruments as opposed to command-and-control instruments – "clear goals, flexible approaches") that enables the companies to innovate and find the most efficient way possible to comply with the regulations, the authors argue that this induced innovation can lead to "innovation offsets" that by increasing resource productivity can save more money than the initial compliance cost imposed and thereby improve comparative advantage. Porter and van der Linde divide these offsets into two categories; "product offsets", leading to new and improved products and "process offsets" leading to more efficient use of inputs. The PH is thereby parting from economists' traditional arguments for environmental policy—which is that internalization of negative environmental externalities maximizes total social utility—by instead arguing in terms of increased firm level benefits. They use the famous *$10 bill on the street*[6] allegory and claim that in the real world, the streets are full with bills just waiting to be picked up. An obvious critique brought forward by for example Palmer and Oates (1995) is that if these opportunities really exists, firms don't need to be triggered by extra regulatory costs to grasp them but will always invest in worthwhile technologies anyway and an increase in the pollution abatement cost will therefore always leave the firms worse off.

The concepts of dynamic vs. static efficiency from Klein (1977) illustrates two key differences in the respective hypothesizes; the PHH explains the effects of environmental policy largely from the perspective of static efficiency—firms optimize given a static set of technologies and alternatives, inevitably leading to net costs of regulation given ex-ante optimality. Whereas the PH suggests that environmental regulation can stimulate unutilized dynamic efficiency where technological innovation is generated as a byproduct of regulation, creating a changing set of alternatives which can result in cost savings and a new and better (cheaper and more competitive) optimality for the polluting industry in question.

Most of the empirical studies so far have as the alternative explanation to the PHH used the idea that the costs of environmental regulations are too small to matter in comparison with other things such as factor endowments, technology and productivity. Copeland and Taylor (2004) p.30 calls this the "factor endowments hypothesis". I will part from this tradition and (while still recognizing that differences in factor endowments might be important) also look for evidence of the PH in the data.

Empirical findings so far

Pollution haven hypothesis

There has been quite a lot of empirical work done on the trade and environment topic and by far most studies have searched for evidence of the PHH, see Jaffe et al. (1995) and Brunnermeier and Levinson (2004) for reviews. The general result has been ambiguously pending between no-effect and the PHH predicted effects, but most often failing to find significant support for the PHH. The absence of empirical support is often explained with the factor endowment hypothesis and that compared to other factors affecting firms comparative advantage, the cost of environmental regulation compliance is simply too small to matter (see Table 2).

[6] Something in the lines of: "Two economists are walking down the street. One sees a 10-dollar bill lying on the sidewalk, and crouch down to pick it up. "Don't bother" says the other. "If it would really be there, someone would have picked it up already."

Table 2. Pollution abatement cost (PAC) as a percentage of total value added (VA) for the six most polluting manufacturing industries in the U.S. in 2005

Industry (NAIC:s code)	PAC/VA 2005
Petroleum & coal product mfg (324)	3.2%
Primary metal mfg (331)	3.0%
Paper mfg (322)	2.4%
Chemical mfg (325)	1.6%
Wood product mfg (321)	1.3%
Nonmetallic mineral product mfg (327)	1.1%

Source: U.S. Census Bureau (2008) & U.S. Census Bureau (2006)

Methodology-wise, studies on this topic can be divided into three broad categories: trade-flow, investment and production specialization studies. Studies in the first category tend to look for evidence that environmental regulation reduces the export/import ratio and is often based on Heckscher-Ohlin trade model like predictions. The second category look at FDI flows and whether investments in polluting industries concentrates towards countries will lax regulations. The third category looks at variables such as new plant openings, emissions and employment to see if industries expand and contract in response to environmental regulation.

Because of an advantage in availability of data, most studies have been centered on the U.S. where firms spent $27 billion complying with environmental regulations in 2005 (U.S. Census Bureau 2008). However, some international studies have been made by for example Cole and Elliott (2007), studying how environmental regulations affected 27 U.K. industries between 1999 and 2003 using data on environmental compliance costs as a measure of regulatory pressure. They perform a number of tests controlling for various workforce and industry characteristics as well as for possible endogeneity of environmental regulatory stringency, but fail to find support for the PHH in all of the tests. One weakness with the study is that it doesn't control for the possibility that firms substitute capital for labor when environmental regulations tightens up, i.e. use more labor relative to (supposedly polluting) capital which would obscure the effects of regulation in the study. It's also possible that, as highlighted by Millimet and List (2004), the effects on industry have large regional variances that country level studies fail to catch. This is obviously important from a policy point of view if one is concerned with the local effects on people and communities in addition to the aggregate economic effects.

In an input-output analysis of environment and trade in India Dietzenbacher and Mukhopadhyay (2007) finds that India during the 1990's—contrary to the PHH predictions—reduced the pollution intensity of their domestic industry by trading more. In fact, exports were found to be on average 25% less polluting than imports. A plausible explanation is that India is relatively well endowed with cheap and unskilled labor, which is primarily used in low-polluting production and that this, rather than differences in regulation, drives trade. Another international study by Javorcik and Wei (2004) looks at manufacturing industry investment flows from the U.S. to 25 economies in Eastern Europe and the former Soviet Union and asks whether investments in dirty industries are relatively more attracted to regions with weak environmental regulations. Their data show no support for the pollution haven effect and on the contrary points towards the same patterns as in the Dietzenbacher and Mukhopadhyay study.

Cagatay and Mihci (2006) uses a composite index for environmental stringency for a large number of countries to study international trade patterns in highly polluting—"environmentally sensitive"—industries. They find statistically significant deterring effects on trade and conclude that;

> "*the environmental stringency level differential between developing and developed nations is a crucial criteria in terms of explaining shifts in the trade patterns and international specialization of the countries*" Cagatay and Mihci (2006), p. 47

In a review containing many case studies Clapp (1998) argues along the same lines and claim that the cost of pollution control for hazardous industries are higher than previously believed and that relocation of production to developing countries is widespread. However, looking at U.S. industries Marchese and Zarrilli (2000) find no support for this claim and explain this by that polluting manufacturing is where U.S. comparative advantage is strong (capital, skilled-labor and technology intensive) and it's therefore not in the interest of companies to move abroad because of (relatively low) costs of pollution control.

Some U.S. studies (like this one) look at state-level differences in environmental regulations to study the effects on industrial activity. If states differ in environmental regulations the PHH predict that states with relatively more stringent regulations should see relatively more movements of production and investments out of the state – to other states as well as to other countries. If differences between states are very small however, it would not be possible to observe any effect even if there is one on the national level. Findings have been mixed but generally failing to find support for the PHH, Levinson (1996) reviews the literature.

Greenstone (2002) goes beyond states and look at country-level differences in the stringency of the Clean Air Act Amendments. He finds that over 15-years, between 1972 and 1987, countries with the toughest demands lost 590.000 jobs, $37 billion in capital stock and $75 billion in output in pollution-intensive industries.

In an interesting contribution to the literature Ederington et al. (2003) searches for explanations to the weak empirical evidence supporting the PHH and formulate two plausible theories. First of all, the pollution haven effect is probably greater between developed countries because of smaller differences in factor endowments. Whereas between developing and developed countries, endowments are the outweighing trade factors. But since developed countries tend to be relatively similar in their environmental regulations, the pollution haven effect will be small. Secondly they suggest that the most polluting industries are often the least "footloose", meaning they are the least mobile and less likely to migrate because of existing external economies of scale and high transportation and plant-level fixed costs. Van Beers & Van den Bergh (1997) finds that environmental regulations have a significant and negative effect on exports in industries that are relatively independent on local resources (i.e. high level of footlooseness) but no significant effect on resource based (non-footloose) industries, thus supporting this theory.

Copeland and Taylor (2004) (section 3) argue that it's important to separate the "pollution haven effect", i.e. an effect of environmental regulations on comparative advantage *on the margin* affecting plant locations and trade flows, from the "pollution haven hypothesis" – a systemic shift in industrial structure concentrating pollution intensive industry in countries with lax environmental standards. They argue that the theoretical and empirical support for a pollution haven effect is strong, while the evidence for the pollution haven hypothesis is weak. The explanation is that in practice the cost of complying with environmental regulations for businesses is outweighed by other factors that have greater importance for determining trade flows, like—as mentioned above—differences in factor endowments or technology. Their conclusions are thus in line with those of Ederington et al. (2003). The very same argument was also used by Grossman and Krueger (1994) in an influential paper showing that, in the context of NAFTA, Mexican comparative advantage in low-skilled labor (used in non pollution-intensive production) outweighed the importance of differences in the cost of complying with environmental regulations.

Brunnermeier and Levinson (2004) point out that many early studies who didn't find evidence for the PHH tended to use cross section data and argue that this led to biased results. They refer to more recent studies that use panel data to correct for time- and entity fixed effects and claim that these studies generally do find significantly negative effects on competitiveness. This seems to suggest that unobserved heterogeneity masked important information in early studies. A few such recent studies finding support for the PHH are: Keller and Levinson (2002) using an eighteen year (1977-1994) long panel for pollution abatement cost differences between U.S. states and regress that on foreign direct investments, Levinson and Taylor (2008) looking at data on U.S. regulation and trade with Canada and Mexico and List and Kunce (2000) as well as Greenstone (2002) finding support for a negative effect of regulation on polluting industries in the U.S.. However, other studies like Morgenstern et al. (2002) use the same method and fail to find support for the PHH.

Another critique of the conventional methods in the literature is brought forward by for example Ederington and Minier (2003) and concerns the possibility that environmental regulation is an endogenous variable in the estimated models. Most studies analyze environmental regulations as an exogenous variable, i.e. set independently outside of the model. However, if the trade variables also affect environmental regulations the variable is endogenous and the results in the conventional literature might be biased. The basis for treating environmental regulations as endogenous is mainly resting on two assumptions; that industries facing strong international competition will lobby for protection in the form of more lax regulations and that countries gain from imposing higher costs on export industries—raising prices on these goods, and lower costs on import industries—lowering prices on these goods, since this can improve the country's terms of trade. If the level of environmental regulation is an endogenous variable determined in this way, treating it as exogenous would underestimate the PHH predicted effects. In one study Van Beers & Van den Bergh (1997) uses a gravity-equation model of trade and finds that environmental regulation sometimes have a negative effect on exports, but they find no support for a positive effect on imports. This can be interpreted as evidence that regulated firms are "compensated" with trade protection. Compensation to regulated firms can also take the form of different kinds of direct transfers (Eliste and Fredriksson 2002).

Porter hypothesis

Empirical work on the PH is much scarcer and there is no empirical support for there being a general and unambiguously positive effect of regulation on competitiveness, even if some of the studies above have gotten occasional positive coefficients. Jaffe and Palmer (1997) separates the "weak", the "narrow" and the "strong" versions of the PH, where the weak simply implies that regulations will lead to cost-minimizing activities in firms, the narrow is a bit more specific stating that different kinds of regulations stimulate this process more or less (remember Porter's theory that flexible approaches yield larger gains) and the strong version where regulations lead to positive effects on firms competiveness. In their panel data study on U.S. industries they find support for regulations leading to innovation, i.e. the weak form, but the data is not detailed enough to say anything about whether the narrow or strong definitions hold or not.

Interpreting the hypothesis in this gradient way is useful and the strongest empirical support is found for the weak form, or the innovation inducing effect of regulation (see Jaffe et al. 2001, Table 2). Bhatnagar (1997) showed that environmental regulations had a significantly positive effect on environmental innovation in U.S. manufacturing, but that this didn't have a significantly positive or negative effect on industry profits, thus indicating that firms are dynamic in their response to regulation and can find ways to offset the costs, but not quite as to profit from the regulations. More specifically, a doubling of environmental compliance costs in the Chemical industry is expected to lead to a 17.5% increase in the number of environmental patents (ibid. p.22).

Greaker (2006) show that these cost savings can further be boosted by spillover effects as growing markets for environmental control technologies give firms downstream scale advantages and innovation effects, leading to reduced costs for their products even as demand increases. This can be interpret as evidence for a regulatory effect on a market failure and therefore a potential net gain of regulation, i.e. if expanding the market downstream is beneficial on the industry level, but means a first-mover disadvantage for early adopters of the control technology who will have to pay more than latecomers, regulation might lead to a more efficient equilibrium.

In a study on a large dataset containing information on 4 200 facilities in seven OECD countries Lanoie et al. (2007) looked at how different forms of environmental regulations affected firms technological innovation as well as environmental and commercial performance. They found that if firms perceive the environmental regulations to be stringent, they are also more likely than others to have a separate environmental R&D budget and as predicted by the PH the effect is greater the more flexible the regulations. Results from the increased R&D activity also have a positive effect on commercial performance in their model, but not quite large enough to totally offset the regulatory compliance costs; "innovation only partially offset the cost of complying with environmental policies" (p. 27). The authors also find some, but not fully robust, evidence that more flexible regulations increase the positive effects on commercial performance, i.e. weak support for the narrow version of the PH.

The process offsets – enabling firms to produce more with less – have also been studied, but with less clear results. There is some evidence that as regulations increases the price of environmental inputs (like energy and natural resources), firms' efficiency in using these inputs increases, albeit again perhaps not as much as to totally offset and turn around the regulatory costs. Boyd and McClelland (1999) studies the U.S. paper industry and finds that on average firm's can decrease their pollution and input intensity with 2-8% without it having a negative effect on output. But they also find that environmental compliance investments crowd out other (productive) investments and that overall, regulations harmed the firms in the sample. See Vollebergh (2007) and Jaffe et al. (2001) for reviews of the literature.

Theoretical model

Before studying empirical data I first present a theoretical background that can be used as a help to understand what we are looking for. The PHH model presented in this chapter is based on material from Copeland and Taylor (2004) and Levinson and Taylor (2008) and the PH material is from Xepapadeas and de Zeeuw (1999), Mohr (2002) and Ambeca and Barlac (2002).

Suppose a two goods (x = capital and pollution intensive and y = labor intensive and non-polluting), two country (Home and Foreign), two factor inputs (L - labor and K - capital) –model where each country's preferences and endowment ratios are identical, demand is homothetic (i.e. independent of income) and unaffected by environmental quality and where pollution policy is set independently in each country. The politically decided maximum level of pollution at home Z is set where the aggregate marginal savings for polluters equal the marginal damage to society (see Kolstad 2000, chapter 7) and a per unit pollution price τ is derived by either the government setting a Pigovian tax (equal to τ) or issuing Z amounts of tradable pollution permits and let the market clear at τ.

Each good is produced with constant returns to scale and the price of x is P while the price of y is one. The production of good x is pollution-generating (without abatement and with basic technology producing one unit of x emit one unit of pollution) and pollution harms consumers but not the productivity of other firms. It's now possible to specify two well behaved production functions, twice differentiable, increasing in both inputs and with diminishing marginal returns;

$$y = H(K_y, L_y) \qquad (1)$$

$$x = z^{\alpha}[F(K_x, L_x)]^{1-\alpha} \qquad (2)$$

Where (2) is the production function of X with pollution abatement (i.e. $z \leq$ F) and α ($0 < a < 1$) is the share of resources in production of X that goes to pollution abatement, $F(K_x, L_x)$ is the production of x without abatement. Note that pollution is here analyzed as an input in production; the intuition being that a firm needs to use pollution to produce and more or less so depending on abatement investments. The emission intensity of production of x is $e = \frac{z}{x}$ and firms chose e to minimize costs. Since the cost per unit of pollution is τ, the total cost of pollution abatement is τz. This means that $a = \frac{\tau z}{px}$, or the share of total value of production that is spent on pollution abatement. Combining these two equalities yields an expression for the firm's choice of pollution intensity with abatement;

$$e \equiv \frac{z}{x} = \frac{\alpha p}{\tau} \leq 1 \qquad (3)$$

As apparent by (3) the emission intensity falls with the price of pollution τ and increases in the price of x due to an increased opportunity cost of pollution abatement. Assuming a competitive equilibrium with full employment, production of both goods in the economy can now be written as;

$$x = x(p, \tau, K, L) \qquad (4a)$$

$$y = y(p, \tau, K, L) \qquad (4b)$$

From (4a) it's obvious that the only way production of x can be held constant while emissions are being reduced is if the production technology changes and/or more factors of production become available.

In both Home and Foreign a relative demand curve (RD) can be traced and under the assumptions of homothetic preference it will be identical in both countries. Each country will also have a relative supply curve (RS for home and RS* for foreign). Using equations (4a) and (4b) under constant returns to scale the general expression for the RS curve becomes;

$$RS(p, \tau, K/L) = \frac{x = x(p,\tau,K/L,1)}{y = y(p,\tau,K/L,1)} \quad (5)$$

In a case where the two countries differ only in terms of the stringency of their environmental policies, an increase in τ in Home will reduce their relative supply of the pollution generating good and raise its autarky price. In other words, Foreign has gained a comparative advantage in producing x relative to Home and consequently pollution intensive industry will migrate to Foreign from Home as the countries open up to trade (Fig. 1) – this is the PHH prediction.

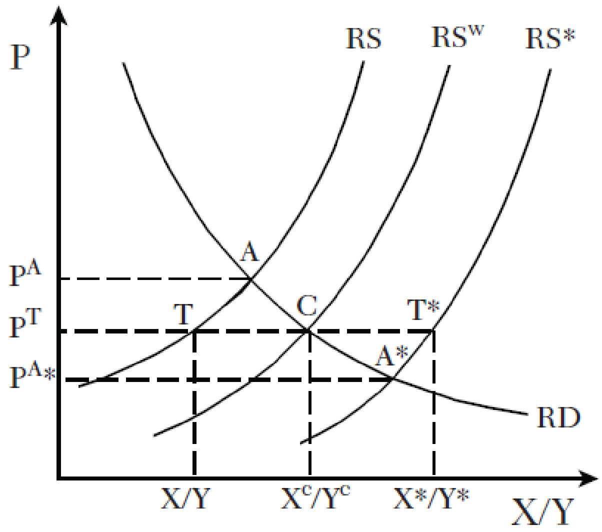

Fig.1 Trade and the PHH, from Copeland and Taylor (2004)

In the initial situation, both countries has equal τ so RS equals RS*, the world relative supply is RS^W and the equilibrium values are $\frac{X^c}{Y^c}$ and P^T. If policymakers decide to raise the pollution tax in Home the RS-curves will part, autarky price and relative supply of x will become different in the two countries and a trade pattern will emerge where Home export more products from the y sector and import more from the x sector and vice versa.

The model can now be extended to multiple sectors and within-sector industries. Let's denote output of industry ŋ in sector *i* by $x_i(\eta)$. Assume industries within a sector differ only in terms of their pollution intensity and that it's therefore possible rank them according to their e-value. To see the PHH effect on industries, assuming that at least some abatement is undertaken, this equation for the unit cost of industry ŋ in Home can then be used

$$c(\eta) = k(\eta)\tau^{\alpha(\eta)}(c^x)^{1-\alpha(\eta)} \quad (6)$$

where $k(\eta)$ is a constant, τ is the cost of emitting one unit of pollution, $c^x = c^x(w, r)$ is the cost of producing one unit of output and $\alpha(\eta)$ is the share of resources going to pollution abatement in industry ŋ. Imagine a similar cost function in Foreign denoted $c^*(ŋ)$ and industries can be ranked by production costs, it then follows that home will produce and export in industries where $c(ŋ) \leq c^*(ŋ)$. Since the cost function is increasing in τ, industries under more stringent environmental regulations is predicted to migrate abroad if regulations there are more lax.

Now let's move to the PH. It's challenging to find a solid theoretical argument for why the PH would hold in any general case (stable RS^W-equilibrium even after the change in τ, or even a gained comparative advantage for Home in the x sector) and no economist has successfully done this as to my knowledge. The best way to think about the PH is as an explanation of an *effect* that *might* counteract the cost of environmental regulation and in some cases perhaps even overweight it, rather than as a general rule. Porter & van der Linde (1995) used a set of case studies to explain the PH instead of a formal model, but since their paper was published numerous other academics have tried to set up theoretical models explaining the PH. Generally they rest on the assumption that some kind of market failure exist pre-regulation and is partly corrected by the regulation, which then leads to the positive net effect of regulation.

Xepapadeas and de Zeeuw (1999) show how environmental policy can lead to a capital modernization effect where firms get stronger incentives to upgrade their capital stock, which creates positive productivity effects. This model can't create a net benefit for firms, but a reduced cost of regulation. In a model with external economies of scale, developed by Mohr (2002), a second mover advantage effect is used to explain why—absent regulation—adoption of new and better technologies might be slower than optimal. The model rests on the assumption that a cleaner and more productive technology is available (but not widely adopted) and that environmental regulation encourages adoption of this technology. Ambeca and Barlac (2002) further shows, using a game-theory model, how regulation can force firms to "overcome organizational inertia" and lead to profitable R&D activities that would not otherwise have been undertaken. In the model, regulation reduces information rents for players within a firm that reports productivity of the polluting technology and decreases the firm's surplus from the polluting technology. This model also rests on the assumption that cleaner and more productive technologies are possible (but here they don't necessarily have to be already available).

Using these theories as a background I conclude that in order to reverse the PHH-model laid out above, and in an industry with some regulation and abatement in the initial position, the PH effect can work in two ways.

> [a)] Since τ increases and as a consequence of regulation firms have to, in order to cut costs, generate innovation that leads to cleaner technologies which counteracts the increase in τ (if the pollution price is set in the market, such in the case of marketable emission permits) and decrease z, both effects due to a downward shift in the marginal savings from pollution curve. Depending on the magnitude of the shift the new optimal a (let's call this a') can be either higher or lower than in the initial position. Combined, all effects can potentially reduce the unit cost of producing the good and leave firms more competitive.
>
> [b)] Regulation might increase the potential production, i.e. $F(K_x, L_x)$, under fix amounts of inputs. I propose two ways in which this can theoretically be achieved. [1)] Through increased factor productivity (the process offsets). If firms respond to regulation by getting more output per unit input (here labor and capital but can also be energy, materials, etc.) the net cost of

regulation can be negative. You can think of this as adding a technology variable $A > 1$ in front of the production function. 2) Income from new products (the innovation offsets). If firms generate additional income from new products generated by increased R&D, these incomes can be used to increase inputs in production of x (but of course does not have to be used to produce x) and can be large enough to yield a negative net cost of regulation.

With this background I specify a new production function for regulated firms under PH effects

$$x = z^{\alpha'} A[F(K_x, L_x)]^{1-\alpha'} \quad (7)$$

where ($\alpha' > 0$) and ($A > 1$). Together these variables theoretically make possible a situation where production under regulation can be greater than potential production before regulation and where firms thus would be made better off from regulation. In the multi-industry case this means that $c(\eta) \leq c^*(\eta)$ even when industry ŋ in Home is facing tougher regulations.

The lower costs can also be generated from technological innovation not connected to production in the ŋ industry, but created by firms in that industry. This can be understood as a *potential* lower cost where profits made from selling these regulation-generated innovations are large enough to lower $c(\eta)$ with a cash transfer. The effect on the trade model can run in both directions depending on how the innovation offsets affect comparative advantage[7], in any case the comparative advantage of regulated firms can improve, which is what I'm interested in here.

Empirical model

Antweiler et al. (2001) distinguishes three effects, or forces, relevant to the trade and environment debate; the "technique effect" capturing the pollution intensity per unit of output, the "composition effect" capturing changes in the industrial composition, i.e. if a region specializes in pollution intensive goods or not and the "scale effect" which measures the aggregate trade-induced growth of an economy and how it affects pollution levels. What this part of the paper does is employ econometric techniques to examine recent U.S. data for traces of a pollution-concentrating composition effect (the PHH) and/or a cost-saving/innovation-creating technique effect (the PH).

The data I'm analyzing is U.S. state level (all 48 contingent states) data for the six most pollution intensive manufacturing industries by 3-digit NAICS code. The industries are; Petroleum & coal product mfg (324), Primary metal mfg (331), Chemical mfg (325), Paper mfg (322), Wood product mfg (321) and Nonmetallic mineral product mfg (327). I'm using a panel dataset created by myself with recent (1999 and 2005) data. I've chosen to use non-pooled data, i.e. separated by 3-digit NAICS codes rather than study the manufacturing industry as a whole, which—as we will see—is crucial. I will regress a measure of competitiveness changes on a proxy for environmental regulatory stringency. It's likely that there will be a lag in the effects on industry of environmental regulations and I therefore lag the regulation proxy variable one year and assume that the proxy is also a good estimate for environmental regulations a few years before (as regulations doesn't completely change year on year) thus creating an effective lag of more than one year.

[7] Say a firm that is regulated initiates new R&D that leads to very successful products *in another industry*. It's then theoretically possible that the main effect on the comparative advantage of the country is positive in a different industry than the one that was regulated. This is certainly an extreme case but theoretically possible.

The models I will estimate are;

$$\Delta EMP_{\eta s} = \alpha_{\eta} + \beta_{\eta} PAOC_{\eta st} + \vartheta_{\eta n} X^{n}{}_{\eta st} + \varepsilon_{\eta st} \qquad (8)$$

$$\Delta EMP_{\eta s} = \alpha_{\eta s} + \beta_{\eta} PAOC_{\eta st} + \vartheta_{\eta n} X^{n}{}_{\eta st} + \theta_t + \varphi_s + \varepsilon_{\eta st} \qquad (9)$$

where (8) is a standard OLS model and (9) a fix effects model including state (φ_s) and year (θ_t) fix effects. Parameter α_{η} denotes an industry specific intercept (industry and state specific in model 9), β_{η} the incremental effect of pollution abatement operating costs (PAOC) in time t on employment changes from time t to t+1, $\vartheta_{\eta n} X^{n}{}_{\eta st}$ is a vector of control variables at time t with respective coefficients and $\varepsilon_{\eta st}$ is an assumed heteroskedastic (zero mean and non-constant variance) error term. The dataset is a panel dataset containing observations of PAOC for years 1999 and 2005, the employment change variable for 1999-2000 and 2005-2006 and control variables.

Key variables

The dependent variable to be explained $\Delta EMP_{\eta s}$ is the percentage change in employment in industry ŋ in state s between t and t+1. Going back to equation (6) the PHH-prediction is that $\Delta EMP_{\eta s} < \Delta EMP^{*}{}_{\eta s}$ if $c(\eta) > c^{*}(\eta)$ where now * denotes a different U.S. state, i.e. employment will drop more (or grow less) in a particular industry in a state if firms in that state face more stringent environmental regulations and holding other things equal. Changes in employment in this model should capture the effects of environmental regulations on the comparative advantage of each 3-digit NAICS industry in each state. If facing more stringent environmental regulations negatively affects the competitiveness of an industry in a state (as predicted by the PHH), we should see plants closing down, fewer investments in new plants and more imports relative to exports as prices go up when the cost of regulation is transferred into the price of goods. All this should then lead to a relative drop in employment in that state compared to states with less stringent regulations. If on the other hand stringent environmental regulation increases the competitiveness of an industry (as predicted by the PH) the reversed should happen. I thus predict the regression models to capture the relevant effects of changing trade and investment patterns as well as plant relocations within the U.S. and internationally. One critique of using employment changes is that a regulated industry might substitute labor for capital while at the same time reduce its total size (the scale effect) which would lead to no negative employment change even with an actual negative effect of the regulations, I will control for this potential problem (control variables are explained below).

The reason why I've chosen employment changes as the competitiveness measure rather than for example changes in industry GDP is that employment changes is better for capturing long-term trends in the data. Annual fluctuations in GDP year-on-year is substantial as input prices and market prices for goods changes. Firms tend to hoard labor in the short run and not lay off and hire people as GDP goes up and down in short cycles, hence the data on employment changes in my set has significantly less yearly fluctuations than does GDP. Therefore, if an industry in a state is losing competitiveness year over year as a result of environmental regulations, this trend would be cleaner in the employment data than in the GDP data. Another reason for using employment data is that this will be better at capturing the effects of outsourcing, which is also a potential effect that should be observed.

The regressor of interest $PAOC_{\eta s}$ is a proxy for environmental regulatory stringency that will explain differences in employment growth or contraction. $PAOC$ is a measure of the pollution abatement operating costs (PAOC) in state s at time t. In the language of the theoretical model I assume that $PAOC = f(\tau)$. Where the function is increasing in the cost of polluting τ, which is in turn increasing in regulatory stringency. The $PAOC$ data comes from the U.S. Census Bureau's Pollution Abatement Costs and Expenditures (PACE) Survey, which was an annual series of reports on the pollution abatement costs for U.S. manufacturing industries between 1973 and 1994 (excluding 1987) with subsequent reports for years 1999 and 2005 that used the new NAICS industry classification system. Both the 1999 and 2005 surveys include around 20.000 manufacturing industry plants. The data is obtained from a confidential mailout/mailback form that respondents are required by law to respond to. Costs of new capital expenditures and operating expenses for pollution prevention and treatment is collected and for the $PAOC$ variable I follow the convention in the literature and use only the operating expenses as they tend to be more accurately reported and stable over time, in contrast to the capital expenditures which are more dependent on factors other than regulatory stringency (see Levinson 1999, p. 18, List and Kunce 2000, p. 273 and Duffy-Deno 1992, p. 424). The operating expenses covers 67% of the reported costs in the 1999 survey and 78% in the 2005 survey.

An obvious problem with the PACE Survey data is that states differ in their industrial composition. States with a high concentration of dirty industries will have high costs of abatement regardless of their regulatory stringency. Levinson (1999) solves this problem by constructing an index of relative stringency that takes into account the difference in industrial composition. I've used the same three-stage method to construct the $PAOC$ variable;

$$S_{st} = \frac{P_{st}}{Y_{st}} \qquad \hat{S}_{st} = \frac{1}{Y_{st}} \sum_{\eta=311}^{339} \frac{Y_{\eta st} P_{\eta t}}{Y_{\eta t}} \qquad PAOC_{\eta s} = \frac{S_{st}}{\hat{S}_{st}}$$

S_{st} = unadjusted measure where P_{st} is the total pollution abatement operating costs in state s and time t and Y_{st} is the manufacturing sector's contribution to gross state product in state s and time t.

$\hat{S}_{st}$ = adjusted measure of predicted abatement costs where each state's industrial composition has been taken into account. The numbers 331 to 339 represent 19 manufacturing industries[8] by their 3-digit NAICS codes. $Y_{\eta st}$ is the contribution of industry ŋ to the gross state product in state s and time t. $P_{\eta t}$ is the nationwide pollution abatement operating expenses of industry ŋ in time t.[9] $Y_{\eta t}$ is the contribution to nationwide GDP from sector ŋ in time t. An industry adjusted index can then be computed by dividing S_{st} by $\hat{S}_{st}$.

The usefulness of the index is confirmed by regressing the S_{st} and the $PAOC_{\eta s}$ variables respectively on the share of dirty (the six most polluting) industries for all states and years in my dataset. S_{st} and the share of dirty industries are positively correlated, significant at the1% level and has an R-squared value of .4. Whereas the same relationship for the $PAOC_{\eta s}$ variable is positive but insignificant at all conventional levels (t-value = .38) and with an R-squared of .003.

Table 3 shows the $PAOC$ variable for all 48 states for 1999 and 2005, including each state's ranking (with 1 being the most high-cost state) for both years. The index is fairly stable but includes a few unrealistically large swings, like those of New Mexico (5 to 47), Delaware (7 to 44), Kansas (8 to 35)

[8] Codes: 311, 312, 313, 314, 321, 322, 323, 324, 325, 326, 327, 331, 332, 333 334, 335, 336, 337, 339
[9] It would obviously be better if we could use the expenses in each state and industry rather than the aggregated national values but unfortunately the data availability doesn't allow for this accuracy.

and Utah (43 to 11). However, these are all some of the smallest states and it's likely that the dramatic changes are due to noise in the data and a small number of respondents. There are also some significant methodological changes in the designs of the 1999 and 2005 surveys (see Gallaher et al. 2008) which might account for swings in small states, but which doesn't affect the general purpose of the index in this study – which is to create a solid inter-state ranking of relative costs each year and not between years. In any case the problematic small states are all outliers in the data and are removed from the regressions in order to get cleaner results.

What's perhaps most surprising about the index is the position of some individual states. Famous green states like California and Massachusetts ends up at the lower end of the ranking, while states less famous for green policies—like Texas and Alabama—is awarded a high index number, indicating relatively high pollution abatement costs for their industries. These results are consistent with the index ranking calculated in Levinson (1999) for earlier years and seem to suggest that there is a nontrivial difference between the objective $PAOC$ measure of environmental costs and the popular view about different state's environmental efforts. One possible explanation is that although I've adjusted for industrial composition, the numbers are still to some extent reflecting the share of dirty industries. States with a high concentration of dirty industries will have a high level of pollution and high costs of pollution abatement, since regulating to meet acceptable standards for the local population is in any case required. More stringent regulations at the federal level would be more costly for these states relative to others and they would be likely to oppose stronger regulations, giving the states a reputation for non-environmentalist policies. It's also important to note that this index only captures costs of polluting and doesn't try to reflect environmental quality at all, something that is generally taken into account in conventional environmental rankings.[10] In any case the index reflects the reported costs of pollution abatement and there is no substantial reason to believe that these costs have not been reported accurately, in fact the EPA ordered an independent validation of the PACE Survey responses, performed by RTI International, and concluded that;

> "*In the aggregate, RTI's independent cost estimates appear to confirm that PACE survey responses – within some margin of error – reflect actual pollution abatement capital expenditures and operating costs. ... In general, discrepancies appear to be largely offsetting and do not represent a significant source of bias at the aggregate level.*" (Gallaher et al. 2008, p. 39)

[10] See for example http://www.forbes.com/2007/10/16/environment-energy-vermont-biz-beltway-cx_bw_mm_1017greenstates.html [Accessed on 2009-05-03]. Also see Levinson (1999) part III

Table 3. Industry-adjusted PAOC-index for 48 U.S. states including ranking (1 being the highest cost state)

State	1999	2005	Rank 1999	Rank 2005
Alabama	1.5	1.26	15	14
Arizona	0.88	0.95	33	30
Arkansas	1.52	1.42	13	10
California	0.79	0.84	40	38
Colorado	0.74	0.53	42	45
Connecticut	0.43	0.42	47	48
Delaware	2.07	0.55	7	44
Florida	2.62	1.2	4	15
Georgia	0.81	0.98	39	28
Idaho	1.64	1.96	12	4
Illinois	1.08	0.93	28	32
Indiana	1.24	0.86	23	33
Iowa	1.04	0.86	29	34
Kansas	1.93	0.85	8	35
Kentucky	1.28	1.29	22	13
Louisiana	1.3	1.3	21	12
Maine	1.52	1.16	14	18
Maryland	1.1	0.99	26	27
Massachusetts	0.85	0.7	37	41
Michigan	1.03	1.13	30	19
Minnesota	1.9	1.01	9	23
Mississippi	1.85	1.0	10	25
Missouri	0.88	1.0	34	26
Montana	1.1	1.78	27	6
Nebraska	1.0	1.51	31	8
New Hampshire	1.12	0.5	25	46
New Jersey	0.35	0.63	48	43
New Mexico	2.59	0.45	5	47
New York	0.82	0.63	38	42
Nevada	3.6	1.67	2	7
North Carolina	0.6	0.85	45	36
North Dakota	8.73	1.99	1	3
Ohio	1.47	1.07	17	20
Oklahoma	1.13	1.19	24	17
Oregon	0.88	0.94	35	31
Pennsylvania	0.86	0.78	36	39
Rhode Island	0.52	0.74	46	40
South Carolina	1.47	1.84	18	5
South Dakota	0.77	1.04	41	22
Tennessee	1.43	1.01	20	24
Texas	1.71	1.2	11	16
Utah	0.74	1.31	43	11
Washington	1.45	0.84	19	37
Vermont	0.94	1.45	32	9
West Virginia	2.26	2.13	6	2
Virginia	1.5	1.05	16	21
Wisconsin	0.74	0.97	44	29
Wyoming	2.85	4.16	3	1

Data sources: Bureau of Economic Analysis (2009), U.S. Census Bureau (2002) & (2008)

Predictions

The theoretical predictions are;

1. Pollution haven hypothesis: $H_0: \beta_\eta = 0$ $H_1: \beta_\eta < 0$
   i.e. $PAOC$ negatively affects ΔEMP

2. Porter hypothesis: $H_0: \beta_\eta = 0$ $H_1: \beta_\eta > 0$
   i.e $PAOC$ positively affects ΔEMP

3. Models (8) and (9) can't separate the PHH and PH and in case $PAOC$ have no significant effect on ΔEMP ($\beta_\eta = 0$) it might be because of a situation of neither a Porter nor a Pollution Haven effect (i.e. the factor endowments hypothesis), or a case where the PH and PHH forces offset each other.

Table 4 shows a basic regression of ΔEMP on $PAOC$ with all states where data is available included in all industries. Table 5 shows the same regressions but with outliers removed.[11] From this point on I'll analyze all data with outliers removed. The regressions in Table 5 are inconclusive with Wood product mfg (321), Chemical mfg (325) and Primary metal mfg (331) showing a negative correlation and Paper mfg (322), Petroleum & coal product mfg (324) and Nonmetallic mineral product mfg (327) showing a positive correlation. All coefficients but the one on Chemical mfg (325) are insignificant.

Table 4. OLS results for six industries

	Wood product	Chemical	Primary metal	Paper	Petroleum & coal product	Nonmetallic mineral product
$PAOC$	.173	3.110*	-.789	-.412	.347	-1.643
	(.354)	(1.610)	(.696)	(.723)	(.335)	(1.483)
R^2	.002	.084	.013	.003	.007	.022
n	94	91	88	95	96	91

Robust standard errors in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions also include a constant.

Table 5. OLS results for six industries

	Wood product	Chemical	Primary metal	Paper	Petroleum & coal product	Nonmetallic mineral product
$PAOC$	-.856	2.428	1.585	-1.770**	.135	-.178
	(1.347)	(1.860)	(1.764)	(.796)	(.905)	(1.885)
R^2	.010	.040	.011	.055	.001	.001
n	81	82	79	82	82	81

Robust standard errors in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. All regressions also include a constant.

[11] All outliers have been removed because of unreliable values in the $PAOC$ variable, these include all states with a population of less than one million (Montana, Delaware, South Dakota, North Dakota, Vermont and Wyoming) plus Nevada which is an extreme outlier in all six industries.

Data issues and control variables

In addition to the dependent variable and the regressor of interest, model (8) also includes X—a vector of control variables. The fix effects model (9) in addition to that also includes fix effects variables θ_t and φ_s. I'll now explain and discuss all controls individually.

First of all, even though there is less variation in employment than in GDP there is still quite a lot of variability in the ΔEMP variable in my dataset and people might be concerned that business cycles mask the effects on employment that I'm looking for. In order to smooth out business cycles I include a variable ΔEMP_TOT containing the overall change in employment in each state over the same time period as ΔEMP. This will also control for the possibility that states who are experiencing a high loss of jobs relax the regulatory pressure in order to try and give relief to struggling firms, and vice versa.

The factor endowment theory discussed above (Copeland and Taylor 2004, Ederington et al. 2003 Grossman and Krueger 1994) and more generally the "unobserved heterogeneity" critique (Brunnermeier and Levinson 2004) presents potentially serious problems. E.g. some states might have a strong comparative advantage in a particular manufacturing industry – this industry would then emit a lot of pollution and possibly be strictly regulated as a consequence, not least because of regulatory pressure from the federal level. One such example is the attainment/non-attainment status[12] where polluters in areas that don't meet certain environmental quality levels are regulated tougher (see for example Greenstone 2002 for a relevant study). It might therefore be the case that in states with a strong comparative advantage in a particular industry, abatement costs and employment growth are positively correlated. To control for this and other unobserved factors I perform, in addition to standard OLS regressions, a full fix effects regression on all industries that include state fix effects φ, controlling for unobserved heterogeneity between states and year fix effects θ, that capture any year-specific effects that is constant between states but different each year, like changes in general technological development or national economic shocks.

Another potential issue is that firms in high-cost states might substitute capital for labor, assuming capital is more polluting than labor and it would then look like high-cost states increased employment and competitiveness in the model. To control for this I include a variable $WORK\_VA$ of log workers over value added for each state and industry. This variable also control for another possible and related source of bias, which is that firms within an industry in high-cost states might specialize in a particular type of production. For example specialize in segments with less machine production (i.e. more workers over value added) or high-tech segments with relatively high levels of low-polluting capital (i.e. less workers over value added). Using this control variable removes the potential effect of changing to within-industry segments with a different capital/labor ratio.

External economies of scale might also present bias if areas with a lot of existing activity within a particular industry offer well-developed infrastructure, reliable supplier networks, transportation services, labor competence and knowledge exchange. This would be attractive areas for new

[12] **Attainment Area:** An area considered to have air quality as good as or better than the national ambient air quality standards as defined in the Clean Air Act. An area may be an attainment area for one pollutant and a non-attainment area for others.
Non-Attainment Area: Area that does not meet one or more of the National Ambient Air Quality Standards for the criteria pollutants designated in the Clean Air Act.
(From: http://www.epa.gov/OCEPAterms/ [Accessed on 2009-05-04])

investments (see Friedman et al. 1992, p. 409) and affect employment positively. Concentrated industries could also wield substantial lobbying power and thus could convince policymakers to relax regulatory burdens. This would then present an endogeneity problem similar to the one discussed above (Ederington and Minier 2003) and the model would not yield unbiased results. Cole and Elliott (2007) control for this problem by including variables of gross value added and total level of employment. This would however be unsuitable for this study since the absolute size of an industry heavily depends on the size of the state, whereas the influence of an industry reasonably depends on its size in each state relative to the total economy in that state. I try to solve this by including a control variable $SHARE\_I$ of the log of each industry's share of gross state product in each state.

Lastly it might reasonably be suspected that there is a relationship between the wealth of a state and the environmental regulations as well as labor market developments and I therefore also add a variable $GDPCAP$ with the log GDP per capita in each state.

Table 6. Summary of control variables with descriptions and data sources

Variable	Description	Data source
$\boldsymbol{\Delta EMP\_TOT}$	Change in state-wide employment from t to t+1	Bureau of Economic Analysis (2009)
$\boldsymbol{WORK\_VA}$	Log share of workers over value added in each industry and state in time t	U.S. Census Bureau (2002) & U.S. Census Bureau (2007)
$\boldsymbol{SHARE\_I}$	Share of an industry of the gross state product in a state in time t	Bureau of Economic Analysis (2009)
$\boldsymbol{GDPCAP}$	Log GDP per capita in each state in time t	Bureau of Economic Analysis (2009)

Tables 7 to 12 presents regression results. For transparency reasons I include results from regressions of ΔEMP on $PAOC$ with each control variable independently, with all control variables together, with all relevant[13] control variables and lastly with all relevant control variables in the fix effects model. Regressions (1)-(4) presents the effect of adding each control variable, regression (5) present the interaction of all control variables together, regression (6) present what control variables can be removed without changing the resulting coefficient on $PAOC$ and regression (7) present the effect of adding fix effects to the model.

[13] Irrelevant controls that are removed are controls who doesn't affect the coefficient on the regressor of interest, i.e. on $PAOC$

Table 7. Regression results for Wood product mfg (321) using different combinations of control variables and fix effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$PAOC$	-.862	.461	-1.021	-1.708	-.328	-.333	-.392
	(1.290)	(1.102)	(1.520)	(1.604)	(1.138)	(1.111)	(3.532)
ΔEMP_TOT	1.111**				1.141***	1.160***	3.592***
	(.440)				(.430)	(.437)	(.729)
$WORK\_VA$		-.929			-2.564	-1.733	2.584
		(2.110)			(2.521)	(1.998)	(7.521)
$SHARE\_I$			.212		-.579		
			(.617)		(.653)		
$GDPCAP$				-4.075	-5.619	-3.361	-30.882
				(3.595)	(3.807)	(3.001)	(40.191)
Time fix	no	no	no	no	no	no	yes
State fix	no	no	no	no	no	no	yes
R^2	.116	.006	.012	.027	.159	.149	.667
n	81	79	81	81	79	79	79

Robust standard errors in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. Year 1999 dropped in the fix effects model and clustered robust standard errors in parenthesis

Table 8. Regression results for Paper mfg (322) using different combinations of control variables and fix effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$PAOC$	2.428	3.899*	2.410	1.759	3.860	3.769	3.759
	(1.867)	(2.266)	(1.858)	(2.242)	(2.763)	(2.717)	(6.530)
ΔEMP_TOT	.001				-.275		
	(.635)				(.641)		
$WORK\_VA$		-.753			-.934	-.700	-10.443*
		(2.532)			(2.772)	(2.691)	(5.560)
$SHARE\_I$			.242		-.266		
			(.765)		(.921)		
$GDPCAP$				-3.210	-.969		
				(4.118)	(4.932)		
Time fix	no	no	no	no	no	no	yes
State fix	no	no	no	no	no	no	yes
R^2	.037	.083	.038	.042	.086	.083	.692
n	82	78	82	82	78	78	78

Robust standard errors in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. Year 1999 dropped in the fix effects model and clustered robust standard errors in parenthesis

Table 9. Regression results for Petroleum & coal product mfg (324) using different combinations of control variables and fix effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$PAOC$	1.727	4.351*	2.436	1.054	5.304*	5.390*	8.347
	(1.826)	(2.514)	(1.708)	(2.267)	(3.054)	(2.845)	(8.422)
ΔEMP_TOT	1.208				.615		
	(.568)				(.711)		
$WORK\_VA$		-.329			.091	-.348	-1.939
		(1.162)			(2.065)	(1.163)	(2.761)
$SHARE\_I$			-1.589***		.403		
			(.594)		(1.160)		
$GDPCAP$				-2.496	5.833	5.508	
				(5.610)	(6.209)	(5.601)	
Time fix	no	no	no	no	no	no	yes
State fix	no	no	no	no	no	no	yes
R^2	.054	.085	.152	.014	.120	.103	.634
n	79	47	78	79	47	47	47

Robust standard errors in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. Year 1999 dropped in the fix effects model and clustered robust standard errors in parenthesis

Table 10. Regression results for Chemical mfg (325) using different combinations of control variables and fix effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$PAOC$	-1.798**	-1.858**	-1.826**	-1.190	-1.493*	-1.493*	.134
	(.753)	(.817)	(.737)	(.886)	(.820)	(.820)	(2.622)
ΔEMP_TOT	.668*				.421	.421	
	(.381)				(.381)	(.381)	
$WORK\_VA$		.398			-1.030	-1.030	2.909
		(.925)			(1.089)	(1.089)	(2.993)
$SHARE\_I$			-1.167**		-1.389**	-1.389**	
			(.463)		(.538)	(.538)	
$GDPCAP$				2.778	1.388	1.388	20.821
				(2.308)	(2.548)	(2.548)	(36.194)
Time fix	no	no	no	no	no	no	yes
State fix	no	no	no	no	no	no	yes
R^2	.107	.057	.141	.065	.187	.187	.561
n	82	81	82	82	81	81	81

Robust standard errors in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. Year 1999 dropped in the fix effects model and clustered robust standard errors in parenthesis

Table 11. Regression results for Nonmetallic mineral product mfg (327) using different combinations of control variables and fix effects

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
$PAOC$	.068	.787	.255	.307	.581	.596	-1.418
	(.777)	(.952)	(1.016)	(1.120)	(.940)	(.932)	(2.554)
ΔEMP_TOT	1.572***				1.658***	1.682***	2.335***
	(.389)				(.342)	(.352)	(.784)
$WORK\_VA$		-4.487**			-5.174***	-4.741***	-12.316*
		(1.889)			(1.806)	(1.674)	(7.028)
$SHARE\_I$			-.429		-.785		
			(.777)		(1.004)		
$GDPCAP$				.826	-2.308	-1.022	-34.082
				(2.457)	(2.755)	(2.135)	(32.956)
Time fix	no	no	no	no	no	no	yes
State fix	no	no	no	no	no	no	yes
R^2	.263	.094	.003	.001	.394	.389	.712
n	82	81	82	82	81	81	81

Robust standard errors in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. Year 1999 dropped in the fix effects model and clustered robust standard errors in parenthesis

Table 12. Regression results for Primary metal mfg (331) using different combinations of control variables and fix effects

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
$PAOC$	-.190	-.699	-.064	-2.680	-3.765**	-3.841**	-5.574
	(1.762)	(1.526)	(1.927)	(2.180)	(1.767)	(1.786)	(3.731)
ΔEMP_TOT	1.963***				1.100**		
	(.528)				(.455)		
$WORK\_VA$		-3.681***			-4.541***	-5.217***	-8.817**
		(1.136)			(1.146)	(1.121)	(3.562)
$SHARE\_I$			-1.299*		-2.014***	-2.606***	
			(.691)		(.664)	(.671)	
$GDPCAP$				-11.96***	-17.28***	-18.01***	
				(4.113)	(4.849)	(4.815)	
Time fix	no	no	no	no	no	no	yes
State fix	no	no	no	no	no	no	yes
R^2	.180	.119	.058	.080	.390	.337	.749
n	81	75	81	81	75	75	75

Robust standard errors in parenthesis. * significant at 10%; ** significant at 5%; *** significant at 1%. Year 1999 dropped in the fix effects model and clustered robust standard errors in parenthesis

Discussion of regression results and their robustness

Table 13 compares the raw regression results from Table 5 with the results from the two last regressions (OLS with relevant controls and the fix effects model with controls) from tables 7 to 12.

Table 13. Comparisons of results first from raw regressions without control variables, second with a set of control variables and third with control variables in the fix effects model

	Wood product	Chemical	Primary metal	Paper	Petroleum & coal product	Nonmetallic mineral product
$PAOC$	-.856	2.428	1.585	-1.770**	.135	-.178
	(1.347)	(1.860)	(1.764)	(.796)	(.905)	(1.885)
$PAOC$ & $X^n{}_{\eta s}$	-.333	3.769	5.295*	-1.308*	.596	-3.841**
	(1.111)	(2.717)	(3.305)	(.820)	(.932)	(1.786)
$PAOC, X^n{}_{\eta s}$ & FE	-.392	3.759	8.347	.134	-1.418	-5.574
	(3.532)	(6.530)	(8.422)	(2.622)	(2.554)	(3.731)

Robust standard errors in parenthesis (robust and clustered for fix effects regressions). * significant at 10%; ** significant at 5%; *** significant at 1%

As seen above the general OLS results are inconclusive with three negative and three positive coefficients, all industries maintain their coefficient signs after controls are added but significance levels now indicate robust negative effects in Chemical mfg (325) and Primary metal mfg (331) while Petroleum & coal product mfg (324) is significantly positive, but this result is based on only 47 observations and should not be seen as robust. After I control for unobserved heterogeneity by running the fixed effects model all coefficients turn insignificant, but for Primary metal mfg (331) where the coefficient is nearly significant at 14%. Also note that Chemical mfg (325) is now slightly positive and Nonmetallic mineral product mfg (327) negative. The coefficient on Petroleum & coal product mfg (324) is no longer significant (still 47 observations) and the coefficients on Wood product mfg (321) and Paper mfg (322) doesn't change to any meaningful extent.

Due to the low number of observations, drawing any conclusions about Petroleum & coal product mfg (324) should be done with caution, but one potential reason for why the industry has such a high coefficient is that it's very dependent on local natural resources and large investments in refineries and different types of infrastructure—resulting in a very low level of footlooseness (Ederington et al. 2003)—and is thus insensitive to pollution abatement costs. Regulators could be tempted to regulate such industries extra hard, which could result in a positive correlation. The likewise highly positive coefficient on Paper mfg (322) is consistent with this theory as this is also a particularly low footloose industry with large fixed costs (Ederington et al. 2003, p. 9). Both coefficients are though insignificant and I assume that the fix effects capture most of the time-invariant competitive advantages of the states so the sizes of the coefficients should be seen as indications at best.

The only real indication of a pollution haven effect after controlling for unobserved heterogeneity can be found in the Primary metal mfg (331) industry where the significance level is 14%. This is also one of the industries in my set most exposed to international trade, with exports plus imports equaling 38 percent of the total value of shipments (U.S. Census Bureau 2007 and U.S. ITA[14]). Most of the other industries have half of that. However, Chemical mfg (325) is also heavily exposed to trade (41 percent) but without a negative coefficient.

[14] See http://www.ita.doc.gov/td/industry/otea/industry_sector/tables_naics.htm [Accessed on 2009-05-04]

One potential problem with the results is that the time lag used is too short. All studies estimating similar models as this one uses time lags, but there is no way to define exactly what number of years is most appropriate to use. On the one hand, it certainly will take some time for the effects of regulations to reach the labor statistics, but on the other hand the PAC in a state at a certain year is probably also a pretty good proxy for the PAC in that state a few years back. But my time lag of one year can in any event be criticized for being too short, e.g. List and Kunce (2000) uses a four year lag. I therefore lagged $PAOC$ two years (maximum length the data allows for since 2007 is the latest year with available numbers) and re-ran the regressions. The results are virtually the same but with one major and one minor exemption. For Petroleum & coal product mfg (324) $PAOC$ is now no longer positive but negative at -.194 and highly insignificant with a robust standard error of 8.292. Since there is still only 47 observations this confirms the shakiness of the estimation but seems to indicate that there is no proof for any significant effect of $PAOC$ on competitiveness, neither negative nor positive. The minor exemption is that the coefficient on Nonmetallic mineral product mfg (327) is now slightly positive at .568 with robust standard error of 2.940, confirming the lack of evidence for any significant effect of $PAOC$ on competitiveness in this industry as well.

Regarding control variables, the business cycle captured by ΔEMP_TOT is expectedly positive and generally significant in all industries except for Paper mfg (322), which at first seems suspect. After examining the data the reason appears to be a strong industry cycle working across all states leaving the general state business cycles with no explanatory power. I tried to extend both employment variables one more year to get a second set of measures for Paper mfg (322) and got virtually the same results.

The $WORK\_VA$ control variable enters into all fix effects regressions and has a significant effect on the magnitude of the $PAOC$ coefficient. In Chemical mfg (325) and Nonmetallic mineral product mfg (327) the workers over value added ratio increases with $PAOC$ and as I control for this with $WORK\_VA$ the coefficient on $PAOC$ decreases (.732 to .134 and -.847 to -1.418 respectively), which can be interpret as support for the theory that firms in fact do substitute workers for polluting capital as regulations become more stringent and that this has to be controlled for. In the Paper mfg (322) industry, on the other hand, the workers over value added ratio decreases with $PAOC$ and the coefficient on $PAOC$ increases as I control for $WORK\_VA$, one potential explanation is that the workers over value added ratio reflects some within-industry specialization where high cost states specialize in cleaner hi-value segments. Without the $WORK\_VA$ control the $PAOC$ coefficient for the Paper mfg (322) industry is .766 and still insignificant.

Lastly I conclude that there also seems not to be any systematic interaction between the wealth of a state as measured by the log GDP per capita variable and the interplay between comparative advantage and environmental regulations. While including the control variable changes the coefficients on $PAOC$ in some industries, the change is not uniform in direction, small and doesn't affect significance levels in any meaningful way.

It seems like the most robust findings of this study is that even when the six most pollution intensive industries are studied and unobserved heterogeneity controlled for, it's difficult to find empirical support for the PHH or the extreme predictions of the PH (i.e. statistically significant and positive coefficients). There is some evidence in the data of a pollution haven effect in the Primary metal mfg (331) industry and also some support for the footlosseness-theory (see Van Beers & Van den Bergh

1997, table 2), but the coefficients are not significant and I would have wanted to find more clear-cut evidence in order to draw any conclusions about there being a direct causal and negative relationship. Indeed, since the fix effects model should control for most of the factor endowment variables (they are likely to be fairly constant over time) the evidence seem to suggest that $c(\eta)$ $= c^{*}(\eta)$ after regulation and a plausible explanation is that the PH and the PHH effects offsets each other.

You can also see that the effect of environmental regulations and the interaction between environmental control costs and other variables vary a lot between industries. Pooling together all manufacturing industries in an effort to make an overall judgment of the effect of environmental regulations on the sector must therefore be judged inappropriate and directly unproductive. From a policy point of view the results indicate that discussions about the effects of environmental regulations on the manufacturing sector as a whole, and legislations and programs targeting this problem, is misguided and must rather be conducted industry by industry.

Data critique and ideas for further research

While I've tried to control the results for potential weaknesses discussed in the previous literature there are some issues that deserve extra attention and discussion.

Van Beers & Van den Bergh (1997) found evidence suggesting that firms in states with stringent environmental regulations are compensated for this with trade protection and that these firms therefore will maintain or increase their competitiveness in the local market while losing competitiveness in the export market. If this is the case, employment might not suffer and we will not capture the negative impact of the environmental regulations in model (8) or (9). Industries in high costs states would now export less relative to firms in low costs states, but be protected in the local market and operate there with higher production costs. Prices of their products and services would hence be relatively high. This argument is more plausible if a whole country protected its industry at the expense of consumers having to pay more for goods and services, but it's less likely that individual states is able to protect its industries from competition from other states to such an extent that we would see no negative effect in the model if there really was one. Eliste and Fredriksson (2002) argues that industries are compensated by other kinds of transfers, which combined with the trade protection argument could enable firms to still keep their prices low, i.e. high costs states would protect firms and then subsidize them so that prices do not rise in the state. The reverse situation is also possible however; if industries that export a lot use this international pressure as an argument when lobbying policymakers against regulation, then high levels of exports would keep down the environmental regulations.

This is surely an interesting dynamic for future studies and highly relevant from a policy point of view, but I find it unlikely that this causes any serious systematic problems to the model estimated in this paper. To test if the level of export employment is an omitted variable in my model I added a control containing the percentage of workers employed in export related manufacturing at time t (data from U.S. Census Bureau 2007 & 2006[15]) to the fix effects regressions and re-ran all industries again, the coefficients on $PAOC$ didn't change in any significant or systematic way.

[15] Data from 1999 is not available so 2002 data was used as proxy for 1999.

Another data weakness is that even though I do the analysis on the 3-digit NAICS level, there might still be variation within industries. If for example high cost states specialize in a particular segment within each 3-digit industry, this would affect PACs as well as employment cycles. I try to control for this by adding the workers over value added variable and as discussed it generally didn't reveal any systematic bias. Theoretically a bias could here mean that low-cost states are in fact high-regulation states that have specialized in low-polluting segments within each industry. This is an interesting issue for further research; to look at the emissions intensity of different sub-segments and if there is a relationship between PAC and industry concentration, kind of like an intra-state PHH. One can argue though that for this analysis it's not very relevant, if regulations lead to specialization that maintains competitiveness we might see a shift in jobs – but no net job losses according to the results presented above, so the competitiveness of the industry as a whole is maintained.

Regarding the PAOC index it suffers from the problem that it's an industry adjusted average for each state and might not be accurate at the individual industry level. It's not unreasonable to assume however that environmental regulations cover emitters in these six pollution intensive industries more or less the same regardless of which industry they operate in. I.e. while mitigating one ton of a particular pollutant might imply different costs between industries, the ranking should hold out pretty well between the same industries in different states, since for example a pulp or iron mill in a state with a low index number (=high cost) should be relatively tougher regulated and thus more expensive compared to a pulp or iron mill in a high index number state. I consider this assumption reasonable but in the future, if more detailed data is made available, it would be interesting to create and use a more accurate index at the industry level.

Conclusions

This paper has studied the effects of environmental regulations on the competitiveness of six pollution intensive U.S. manufacturing industries in the 48 contingent states. The results, based on recent PAOC-data from 1999 and 2005, confirm earlier findings of no support for the PHH projections that high-costs states will see a competitiveness drop and heavy outflow of pollution intensive production. The study also didn't find support for the pure form of the PH. The results instead indicate that these are two opposing forces offsetting each other. This implies that firms respond dynamically to environmental compliance costs and find ways to offset the costs, likely both through internal innovation as well as due to downstream spillover effects.

Responding to the suggestions that unobserved heterogeneity biased early findings, this study estimates a fix effects model and although there seems to be unobserved factors creating bias in Chemical mfg (325) and Nonmetallic mineral product mfg (327), controlling for it doesn't lead to any stronger evidence for there being a systematic net effect of regulation. In one studied industry, Primary metal mfg (331), some evidence for a pollution haven effect was found and it seems very likely that amongst the six industries covered in this paper, this is the one facing the most negative effects on competitiveness from environmental regulations.

The estimated effects differ substantially between industries and two important additional findings were uncovered. First, industries with a low level of footlooseness, e.g. Paper mfg (322) and Petroleum & coal product mfg (324), are less sensitive to regulations than are more mobile industries. Second, firms also seem to differ in their ability to respond to regulations by altering their labor and capital ratios. This is an interesting area for further research.

From a policy point of view, if we for example want to help industries minimize regulatory costs and protect jobs and investments, maybe the most important message from this study is that effects will differ a lot even between seemingly homogenous industries and that understanding how each industry interacts with regulations are paramount. Simply stating that environmental regulations have a negative effect on manufacturing industry competitiveness is an oversimplification to say the least. The most important policy implication is that environmental regulations should be designed with maximum flexibility, for example by using market based mechanisms that give firms as much freedom as possible to innovate and mitigate costs. In this way costs can be minimized and regulatory stringency maximized at the same time.

Data appendix

General variables

	Mean	Std. dev	Min	Max
$PAOC$ (1999)	1.233	.536	.345	2.620
$PAOC$ (2005)	1.031	.372	.425	2.130
ΔEMP_TOT (1999)	2.119	.873	.290	3.860
ΔEMP_TOT (2005)	1.842	1.486	-.930	5.820
$GDPCAP$ (1999)	32570	5380	22562	47021
$GDPCAP$ (2005)	34744	5526	23546	49191

Same outliers removed as in regressions. Non-logged values.

Wood product mfg (321)

	Mean	Std. dev	Min	Max
ΔEMP (1999)	-.998	4.187	-13.1	7.36
ΔEMP (2005)	-1.412	4.143	-9.200	10.420
$WORK\_VA$ (1999)	.017	.003	.010	.027
$WORK\_VA$ (2005)	.013	.002	.010	.019
$SHARE\_I$ (1999)	.005	.005	.0005	.021
$SHARE\_I$ (2005)	.005	.004	.0004	.019

Same outliers removed as in regressions. Non-logged values.

Paper mfg (322)

	Mean	Std. dev	Min	Max
ΔEMP (1999)	-4.588	6.380	-14.900	14.520
ΔEMP (2005)	-5.897	6.907	-28.600	17.920
$WORK\_VA$ (1999)	.008	.002	.004	.014
$WORK\_VA$ (2005)	.006	.002	.002	.010
$SHARE\_I$ (1999)	.007	.008	.0004	.046
$SHARE\_I$ (2005)	.005	.006	.0003	.026

Same outliers removed as in regressions. Non-logged values.

Petroleum & coal product mfg (324)

	Mean	Std. dev	Min	Max
ΔEMP (1999)	.318	7.972	-18.230	19.670
ΔEMP (2005)	1.933	6.083	-11.300	25.000
$WORK\_VA$ (1999)	.003	.002	.001	.009
$WORK\_VA$ (2005)	.001	.0009	.0003	.004
$SHARE\_I$ (1999)	.002	.004	.00002	.024
$SHARE\_I$ (2005)	.006	.016	.00001	.112

Same outliers removed as in regressions. Non-logged values.

Chemical mfg (325)

	Mean	Std. dev	Min	Max
ΔEMP (1999)	-1.06	3.297	-9.220	8.690
ΔEMP (2005)	.956	4.433	-7.740	11.250
$WORK\_VA$ (1999)	.005	.002	.0006	.010
$WORK\_VA$ (2005)	.003	.001	.001	.006
$SHARE\_I$ (1999)	.017	.015	.001	.065
$SHARE\_I$ (2005)	.014	.013	.001	.056

Same outliers removed as in regressions. Non-logged values.

Nonmetallic mineral product mfg (327)

	Mean	**Std. dev**	**Min**	**Max**
ΔEMP (1999)	.828	3.557	-13.240	12.020
ΔEMP (2005)	2.519	4.689	-5.790	15.990
$WORK\_VA$ (1999)	.010	.002	.007	.016
$WORK\_VA$ (2005)	.007	.001	.004	.010
$SHARE\_I$ (1999)	.005	.002	.001	.010
$SHARE\_I$ (2005)	.004	.002	.001	.008

Same outliers removed as in regressions. Non-logged values.

Primary metal mfg (331)

	Mean	**Std. dev**	**Min**	**Max**
ΔEMP (1999)	-.430	5.340	-14.450	15.880
ΔEMP (2005)	1.387	5.794	-12.140	15.260
$WORK\_VA$ (1999)	.010	.003	.004	.023
$WORK\_VA$ (2005)	.006	.002	.001	.013
$SHARE\_I$ (1999)	.006	.007	.0004	.031
$SHARE\_I$ (2005)	.006	.006	.0005	.024

Same outliers removed as in regressions. Non-logged values.

References

Academic papers

Antweiler, W., Copeland, B.R. & Taylor, S.M. (2001). “Is free trade good for the environment?”, *The American Economic Review*, Sep 2001, 91(4)

Ambeca, S.B & Barlac, P. (2002). “A theoretical foundation of the Porter hypothesis*”, Economics Letters*, 75 (2002) 355–360

Bhatnagar, S. (1997). "The Impact of Environmental Regulation on Innovation: A Panel Data Study", Owen Graduate School of Management, JEL Codes: Q28, O31, L51, L60

Boyd, G.A. & McClelland, J.D. (1999). "The Impact of Environmental Constraints on Productivity Improvement in Integrated Paper Plants", *Journal of Environmental Economics and Management* (38)

Brunnermeier, B.S., & Levinson, A. (2004). “Examining the Evidence on Environmental Regulations and Industry Location”, *The Journal of Environment Development* 2004; 13; 6

Cagatay, S. & Mihci, H. (2006). “Degree of environmental stringency and the impact on trade patterns”, *Journal of Economic Studies*, Vol. 33 No. 1, 2006, pp. 30-51

Clapp, J. (1998). “Foreign direct investment in hazardous industries in developing countries: Rethinking the debate”, *Environmental Politics*, 7:4, 92 – 113

Clark, D.P., Marchese, S. & Zarrilli, S. (2000). “Do dirty industries conduct offshore assembly in developing countries?”, *International Economic Journal*, 75 Volume 14, Number 3, Autumn 2000

Copeland, B.R. & Taylor, M.S. (1994). “North-South trade and the environment”, *Quarterly Journal of Economics*, Aug 94, Vol. 109 Issue 3, p755

Copeland, B.R. & Taylor, M.S. (2004). “Trade, Growth, and the Environment”, *Journal of Economic Literature*, Vol. XLII (March 2004) pp. 7–71

Coughlin, C.C. (2002). “The controversy over free trade: The gap between economists and the general public”, Review, 1-21. St Louis, MO Federal Reserve Bank

Cole, M.A. & Elliott, R.J. (2007). “Do Environmental Regulations Cost Jobs? An Industry-Level Analysis of the UK”, *The B.E. Journal of Economic Analysis & Policy Topics*, Volume 7, Issue 1 2007 Article 28

Dietzenbacher, E. & Mukhopadhyay, K. (2007). “An Empirical Examination of the Pollution Haven Hypothesis for India: Towards a Green Leontief Paradox?”, *Environmental & Resource Economics*, 2007, 36:427–449

Duffy-Deno, K.T. (1992). “Pollution abatement expenditures and regional manufacturing activity”, *Journal of regional science*, Vol. 32, NO. 4

Ederington, J. (2007). “NAFTA and the Pollution Haven Hypothesis”, *The Policy Studies Journal*, Vol. 35, No. 2, 2007

Ederington, J. & Minier, J. (2003). “Is environmental policy a secondary trade barrier? An empirical analysis”, *Canadian Journal of Economics*, Vol. 36, No. 1 Feb 2003

Ederington, J., Levinson, A. & Minier, J. (2003). “Footloose and Pollution-Free”, NBER Working Paper No. W9718, May 2003

Eliste, P. & Fredriksson, P.G. (2002). “Environmental Regulations, Transfers, and Trade: Theory and Evidence”, *Journal of Environmental Economics and Management*, 43, 234-250

Friedman, J., Gerlowski, D.A. & Silberman, J. (1992). “What attracts foreign multinational corporations? Evidence from branch plant location in the United States”, *Journal of regional science*, Vol 32 No. 4

Gallaher, M.P., Morgan, C.L. & Shadbegian, R.J. (2008). “Redesign of the 2005 Pollution Abatement Costs and Expenditure Survey”, National Center for Environmental Economics, Working Paper Series (#08-01)

Greaker, M. (2006). "Spillovers in the development of new pollution abatement technology: A new look at the Porter-hypothesis", Journal of Environmental Economics and Management, 52 (2006) 411-420

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 Manufactures”, *Journal of Political Economy*, Dec2002, Vol. 110 Issue 6, p1175-1219

Grossman, G.M. & Krueger, A.B. (1994). “Environmental Impacts of a North American Free Trade Agreement”, NBER Working Papers Series, No. 3914

Jaffe, A.B. & Palmer, K. (1997). "Environmental regulation and innovation: A panel data study", *The review of economics and statistics*

Jaffe, A.B., Newell, R.G. & Stavins, R.N. (2001). "Technological change and the Environment", Resources for the Future, Washington D.C

Jaffe, A.B., Peterson, S.R., Portney, P.R. & Stavins, R.N. (1995). “Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?”, *Joumal of Economic Literature*, Vol. XXXIII (March 1995), pp. 132-163

Javorcik, B.S. & Wei, S. (2004). “The pollution haven hypothesis - Pollution Havens and Foreign Direct Investment: Dirty Secret or Popular Myth?”, *Contributions to Economic Analysis & Policy*, Volume 3, Issue 2 2004 Article 8

Keller, W. & Levinson, A. (2002). “Pollution abatement costs and foreign direct investment inflows to U.S. states”, *The Review of Economics and Statistics*, November 2002, 84(4): 691–703

Lanoie, P., Jeremy, L.L., Johnstone, N., Ambec, S. (2007). "Environmental Policy, Innovation and Performance: New Insights on the Porter Hypothesis", *Scientific Series*, Montreal

Levinson, A. (1999). “An industry-adjusted index of state environmental compliance costs”, NBER Working Papers Series, No. 7297

Levinson, A. & Taylor, S.M. (2008). “Unmasking the pollution haven effect*”, International economic review*, Vol. 49, No. 1, February 2008

List, J.A. & Kunce, M. (2000). “Environmental Protection and Economic Growth: What Do the Residuals Tell Us?”, *Land Economics*, May 2000, 76 (2): 267-282

Mehra, M.K. & Das, S.P. (2008). “North–South Trade and Pollution Migration: The Debate Revisited”, *Environ Resource Econ*, 2008, 40:139–164

Millimet, D.L. & List, J.A. (2004). “The Case of the Missing Pollution Haven Hypothesis”, *Journal of Regulatory Economics*, 26:3 239–262, 2004

Mohr, R.D. (2002). “Technical Change, External Economies, and the Porter Hypothesis”, *Journal of Environmental Economics and Management*, 43, 158-168

Morgenstern, R.D., Pizer, W.A. & Shih, J. (2002). “Jobs Versus the Environment: An Industry-Level Perspective”, *Journal of Environmental Economics and Management*, 43, 412–436 (2002)

Palmer, K. & Oates, W.E. (1995). “Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm?”, *Journal of Economic Perspectives*; Fall 95, Vol. 9 Issue 4, p119-132

Porter, M.E. (1991). “America's Green Strategy”, *Scientific American* April 1991, 264, 168

Porter, M.E., & van der Linde, C. (1995). “Toward a New Conception of the Environment-Competitiveness Relationship”, *Journal of Economic Perspectives* fall 1995, Volume 9, Number 4, Pages 97-118

Stonehouse, P.D. (2000). “A review of WTO and environmental issues*”, Journal of Agricultural and Environmental Ethics* 13: 121–144, 2000

Taylor, M.S. (2004). “Unbundling the pollution haven hypothesis”, *Advances in Economic Analysis & Policy* 2004, Volume 4, Issue 2, Article 8

Van Beers, C. & Van den Bergh, J.C.J.M. (1997). “An Empirical multi-Country Analysis of the Impact of Environmental Regulations on Foreign Trade Flows”, *The Kyklos*, Vol. 50

Vollebergh, H.R.J. (2007). "Differential Impact of Environmental Policy Instruments on Technological Change: A Review of the Empirical Literature", Tinbergen Institute Discussion Paper, TI 2007-042/3

Xepapadeas, A. & de Zeeuw, A. (1999). “Environmental Policy and Competitiveness: The Porter Hypothesis and the Composition of Capital”, *Journal of Environmental Economics and Management,* 37, 165-182

Books

Barton, J., Rhys, J., Anthony, B., Jan H., & Knutsen, H. (2007). “Environmental regulation and industrial competitiveness in pollution-intensive industries”, In Parto, S. & Herbert-Copley, B. (eds.), “Industrial Innovation and Environmental Regulation: Developing Workable Solutions”, *Institute on New Technologies* (United Nations University Press) & *International Development Research Centre.* Available [2009-04-27] for free at: http://www.idrc.ca/en/ev-105261-201-1-DO_TOPIC.html

Klein, B. (1977). “Dynamic Economies”, Cambridge, Mass.,Harvard University Press.

Kolstad, C.D. (2000). “Environmental Economics”, Oxford University Press, New York

Levinson, A. (1996). “Environmental regulations and industry location: international and domestic evidence”, in Bhagwati, J., Hudec, R.E. (Eds), “Fair Trade and Harmonization - Prerequisites for Free Trade?”, *The MIT Press*, Cambridge, MA, pp.429-57

Data

U.S. Census Bureau (2002). “Geographic Area Statistics: 2000 - Annual Survey of Manufacturers”, M00(AS)-3RV, U.S. Department of Commerce, Economics and Statistics Administration

U.S. Census Bureau (2002). “Pollution Abatement Costs and Expenditures: 1999”, MA200(99), U.S. Government Printing Office, Washington, DC, 2002

U.S. Census Bureau (2006). “Exports from Manufacturing Establishments: 2002”, AR(02)-1, U.S. Department of Commerce, Economics and Statistics Administration

U.S. Census Bureau (2006). “Geographic Area Statistics: 2005 - Annual Survey of Manufacturers”, M05(AS)-3, U.S. Department of Commerce, Economics and Statistics Administration

U.S. Census Bureau (2007). “Exports from Manufacturing Establishments: Preliminary Estimates for 2005”, ARP(05)-1, U.S. Department of Commerce, Economics and Statistics Administration

U.S. Census Bureau (2008). “Pollution Abatement Costs and Expenditures: 2005”, MA200(05), U.S. Government Printing Office, Washington, DC, 2008

Bureau of Economic Analysis (2009). “Regional economic accounts”, Statistics Database. [http://www.bea.gov/regional/index.htm] [accessed on 2009-04-27]

Other

Inhofe, J.M. (2008). “The Economics of America’s Climate Security Act of 2007: (S.2191, Lieberman-Warner Climate Bill)”, White Paper

Associated Press (2005). “Bush puts jobs ahead of Kyoto Treaty seen as not worth unemployment for millions”, Tues., Feb. 15, 2005. [http://www.msnbc.msn.com/id/6976284/] [accessed on 2009-04-27]