Trade liberalization and the environment: the pollution haven hypothesis

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1 Introduction

In a world where trade barriers tend to disappear with the growing amount of free trade agreements, new trade patterns arise. Whether those new patterns are desirable or harmful is at the heart of vivid debates, both among the scientific community and at the citizens level. Assessing the welfare gains from trade is probably one of the most important and yet difficult task for international trade economists, for it requires a bird's view to treat the immense amount of variables. Overall, the main takeaway from mainstream economics is that international trade is welfare-improving, although it has strong income distribution effects among countries and industries.

Assessing the welfare impacts of international trade certainly is a fascinating task; however, harnessing the complexity of the task is far beyond my own capacity. Nevertheless, it is my intention to narrow the focus on a specific feature underlying some of the new patterns of trade, namely the pollution haven hypothesis. The intuition behind this hypothesis is very simple: given the different levels in the stringency of environmental regulations between countries, trade liberalization might lead to a specialization in pollution-intensive products in the country with the most lax environmental regulations. In other words, those countries specialize in dirty products because they have a comparative advantage in producing them. Alternatively, countries with more stringent environmental standards will specialize in clean products since they face higher pollution costs. Trade liberalization is the binding ingredient necessary for those specializations to happen.

Since awareness about environmental issues permeates every layers of our society, the link between environment and international trade often gives birth to emotionally-charged discussions among citizens, scientists and policy makers, and so does the pollution haven hypothesis. The stakes are high for at least three reasons. First, the last decades have seen an impressive increase in FDI around the world. In 2017, the total worldwide FDI amounted to 1 527 869 million U.S. dollars, from which 1 073 214 U.S. dollars came from OECD countries[1]. With approximatively 70% of FDI from developed countries to developing countries, understanding the behaviour of multinational corporations (i.e. what drives their spatial distribution) is more important than ever. Second, if the pollution haven hypothesis is proved to be true, developing countries might want to set even lower regulations in order to increase their comparative advantage and attract international investments (i.e. race-to-the-bottom). Third, a validation of the pollution haven hypothesis might alter trade rules in order to limit environmental impacts. For example, combining international trade agreements with international environmental agreements, through

[1]Source: OECD data, Benchmark definition, 4th edition (BMD4): Foreign direct investment: financial flows, main aggregates.

restrictions on specific pollution-intensive goods, is a possible outcome.

The thesis is structured as follows: section 2 introduces the pollution haven hypothesis and its core basics; section 3 puts the pollution haven hypothesis in a chronological and theoretical perspective; section 4 critically assesses the causality chain behind the creation of pollution havens; section 5 covers the main empirical difficulties every economist faces when testing the pollution haven hypothesis; finally, section 6 presents future path to explore and section 7 concludes.

2 The pollution haven hypothesis: setting the scene

The aim of this introductory section is to cover some basic elements about the subject of interest of the thesis: what the pollution haven hypothesis is, and what it is not.

2.1 Definition

M. Scott Taylor[2] defines the pollution haven hypothesis as follows:

> *"The pollution havens hypothesis is the prediction that a reduction in trade barriers shifts pollution-intensive industries from countries with stringent environmental regulation to countries with weaker environmental regulation".* (Taylor, 2005, p. 4)

A few things need to be said first about some elements in the above-cited definition . First, the prediction is neutral, even if the pollution haven hypothesis is vastly used in anti-trade discourses and pro-environment speeches. The first theoretical work shows that under specific conditions, pollution havens can be pareto-improving (Copeland and Taylor, 1994). Second, trade barriers can take several forms: transport costs, tariffs (iceberg or ad-valorem), administrative costs, etc. The literature on pollution havens usually refers to a global reduction in tariffs following an event of trade liberalization. Third, the pollution-intensive industries are mostly manufacturing industries such as chemicals and metallurgy and do not vary significantly across countries. Fourth, the literature uses the 'developing countries' or 'South' terminologies to design countries with lax environmental regulation. In a similar fashion, the 'developed countries' or 'North' terminology refers to countries with stringent environmental regulation. I use the same terminology throughout my thesis for the sake of coherence and clarity.

[2] The Canadian economist is considered as the father of the pollution haven hypothesis.

It is also worth clarifying what the pollution haven hypothesis is not. There are several terminologies around trade, regulations and the environment, hence together with the fact that the pollution haven hypothesis has recently been popularized outside the academic world, misconceptions have inevitably emerged. Among others, the 'race-to-the-bottom' hypothesis, environmental dumping and toxic colonialism are the most common terms mistaken with the pollution haven hypothesis. First, the pollution haven hypothesis is often wrongly associated with the 'race-to-the-bottom' hypothesis. The latter refers to the calculated relaxation of regulations in order to attract jobs or industries. Racing to the bottom is thus a strategic, opportunistic behavior. In contrast, the former simply predicts specialization patterns given known differences in environmental regulation stringency and is silent on strategic or opportunistic policy adjustments. Thus, racing to the bottom can be seen as a possible *outcome* if the pollution haven hypothesis is verified. Second, another common hasty shortcut is made between the pollution haven hypothesis and 'environmental dumping'. Environmental dumping happens when environmental regulation would have been more stringent in the absence of strategic interactions, leading to sub-optimal (too high) pollution levels in the cooperative Nash equilibrium. Thus, by definition environmental dumping carries negative welfare outcomes, hence it is expressed in negative terms. In contrast, according to Taylor (2005), the pollution haven hypothesis is a positive prediction since it remains silent on the direction of the welfare change (if there is any). Third, toxic colonialism was introduced by Jim Puckett (Greenpeace) in 1992 based on the observation that developed countries export toxic wastes to developing countries[3]. The distinction between toxic colonialism and pollution havens can be difficult to grasp at first sight, since both terms involve trade patterns. The distinction lies in the very nature of the traded goods. On the one hand, toxic colonialism is about trading hazardous wastes. In the most extreme case, a poor country would typically be compensated by a rich country to bury undesired wastes (e.g. chemical wastes) on their territory. The toxicity lies in the traded good. On the other hand, pollution havens emerge in the process of producing a good. Pollution-intensive goods are not highly toxic *per se*. It is the very process of making them that refers to the pollution-intensiveness (e.g. involves greenhouse gas emissions).

2.2 The pollution haven effect

Attempts to prove the existence of the pollution haven *hypothesis* must necessarily show that trade flows variations are industry-specific. Put differently, the challenge is to show a specialization pattern within a relevant industry or sector (i.e. a dirty or clean sector) and to link this pattern to environmental regulation and trade liberalization. The pollution haven hypothesis is built upon the core assumption that regulations incur costs to the firms.

[3] see Kitt, 1995 "Waste Exports to the Developing World: A Global Response" for an overview

According to the pollution haven *effect*, tighter environmental regulation leads to higher production costs, which lowers output levels. However, the pollution haven effect itself does not predict any trade patterns. The pollution haven effect is a necessary but not sufficient condition for the validity of the pollution haven hypothesis. Therefore, simply failing to find a pollution haven effect is enough to refute the existence of the pollution haven hypothesis[4].

More specifically, according to Taylor (2005) the pollution haven effect "arises when a tightening of environmental regulation deters exports (or stimulates imports) of dirty goods" (p. 3). Thus, Taylor further extends the increase in production costs to the subsequent decrease in the firm's production of outputs. According to the Canadian economist, finding a small pollution haven effect should be taken as a warning sign against the pollution haven hypothesis "because it is reasonable to assume that a small measured pollution haven effect must surely be outweighed by other more conventional determinants of comparative advantage. (...) Therefore, estimating the strength of the pollution haven effect is of great value[5]". For example, Antweiler et al. (2001) and Cole and Elliott (2005) look at the interaction between environmental policy and capital abundance to determine comparative advantages. If North is capital abundant and pollution-intensive goods are capital-intensive, then North might specialize in the pollution-intensive goods (boosting dirty product exports) even if a pollution haven effect exists (reducing dirty product exports). Whether country endowment in capital or the pollution haven effect dominates, depends on their respective strength.

To sum up, the pollution havens hypothesis should not be reduced to the pollution haven effect which is nothing more than the causality chain from regulation to production costs and outputs. If such a chain exists, then trade patterns *might* arise (but there is no guarantee, because other motives for trade are at play). If they do, the pollution haven hypothesis is verified.

2.3 International trade and comparative advantages

As mentioned above, a comparative advantage is at the center of the pollution haven hypothesis. When does a comparative advantage arise? How is it different from the absolute advantage? Can the pollution haven effect be considered as an absolute advantage? Even though comparative and absolute advantage are well-known economic concepts, they often are misunderstood. Indeed, Paul Samuelson once described comparative advantage as the best example he knows that is undeniably true yet not obvious to intelligent people.

[4]Excepted if other motives for trade are absent, which is rarely the case.
[5]Taylor (2005), p. 4.

2.3.1 Why international trade?

According to classical economics, international trade happens for two very basic reasons. First, countries engage in trade because they are different. The second reason countries trade is because it allows them to achieve economies of scale[6]. Comparative advantages rest on these two basic reasons to engage in international trade[7].

2.3.2 A simple example

In order to fully grasp the concept, let's take a simple North-South textbook example modified with pollution costs. The example shows how pollution costs affect the economies' relative price structures that define a nation's comparative advantage. The example is built on a two-countries two-goods format. The two countries are North, a developed country, and South, a developing country. The goods used in the example are trees and concrete.

North

North can produce two types of good: a clean good, trees, and a dirty good, concrete. The production of 10 trees requires the same amount of resources than the production of 5 tons of concrete. But since North has high environmental standards, concrete faces a pollution tax equivalent to 2 trees for each ton of concrete produced. This small difference is of paramount importance. Now, the production of 5 tons of concrete requires the equivalent amount of resources needed to produce 20 trees. Stringent regulations in North changes the trade-off between trees and concrete. North must now produce fewer trees in order to produce 5 tons of concrete because concrete production costs has risen. In other words, North now faces a higher opportunity cost for concrete (i.e. the number of trees that could have been produced with the resources used to produce a given quantity of concrete).

South

Following the same logic, South produces two types of goods, trees and concrete with the only but crucial difference being the absence of pollution tax on concrete. (i.e. South has committed to no environmental regulation). Thus, the production of 10 trees requires the same amount of resources than the production of 5 tons of concrete.

[6]Krugman, Obstfeld and Melitz, International Economics, 9th ed

[7]In Krugman (1979) and Krugman (1980), two new motives for trade are presented: love for variety and increasing return to scale. These motives are typically not considered as sources of comparative advantages.

Comparative advantages

We now have two countries with different opportunity costs. Indeed, North faces a higher opportunity cost of producing concrete because they give up on more trees for each ton of concrete produced. This difference in opportunity cost is the essence of comparative advantages. In reality, comparative advantages can arise for many reasons. We will see later that the key driver of FDI in delevoping countries can be environmental regulations but also other factors such as capital endowment (Eliott and Cole, 2005). In this example, environmental regulation is the only driver of trade patterns and comparative advantages. North is said to have a comparative advantage in trees production, whereas South has a comparative advantage in concrete production. In theory, in a world without trade costs, all else equal, trade between North and South can benefit both countries if each country exports the goods in which they gave a comparative advantage and world welfare rises, as shown in the next paragraph.

Welfare implications

In our small example, if North stops producing concrete and instead uses the resources needed to produce those 5 tons of concrete for trees production, the country can produce a total of 20 trees. Similarly, if South specializes in concrete, they could produce 5 tons of concrete.

Table 1: Hypothetical changes in production

	Tons of concrete	Number of trees
North	- 5	+ 20
South	+ 5	- 10
Total	**0**	**+10**

As shown in Table 1, world production rises. This very simple yet powerful example shows how a more stringent environmental regulation can alter international trade patterns between North and South. Since more goods are produced, does world welfare rise? Not necessarily, because the pollution level increases via what the literature calls a "scale effect" explained in the next section.

2.4 Three widespread effects of international trade on the environment

The growing concerns about environmental consequences of international trade has led free trade advocates to examine whether trade inevitably raises world pollution. Some economists have showed that free trade can actually reduce world pollution under certain conditions. Three channels through which international trade can affect the environment are shown below.

Grossman and Krueger (1991) provide a useful distinction between the scale effect, the technique effect and the composition effect. In short, Cherniwchan, Copeland and Taylor (2016) summarize the three channels as follows: “first, trade raises the scale of economic activity which increases pollution. Second, trade raises real income and the demand for environmental quality. If governments are responsive, policies are strengthened and pollution falls via a technique effect. Third, controlling for incomes and scale, changes in the sectoral composition of clean and dirty industries affect emissions. These trade-created composition effects vary across countries depending on their comparative advantage[8]”. In light of this short description, the composition effect already clearly appears to be intimately linked with the pollution haven hypothesis.

2.4.1 The scale effect

The *scale effect* is the intuition that if the quantity of goods produced worldwide increases following an episode of trade liberalization (i.e. increased market access), or more generally if economic activity increases, then worldwide pollution increases. Of course, the scale effect assumes that the nature of production activities (covered in the composition effect below) remains unchanged. The scale effect includes emissions that arise from energy use or from the increased cross-border transportation, contributing the deterioration of air quality.

2.4.2 The technique effect

International trade increases competition among firms. Since competition drives innovation, firms are likely to adopt new, cleaner technologies. Any change in the process or in the production technique due to trade liberalization is called the *technique effect*. According to Grossman and Krueger (1991), the pollution intensity (i.e. pollution per unit of output) might fall for two main reasons. First, technology transfers is likely to happen between local and foreign firms, since foreign firms usually are multinationals with modern, cleaner technologies. However, the technology transfer should not be taken for granted. According to Eaton and Kortum (2002), those transfers depend on distance and size:

> "The percentage benefits decay dramatically with distance and size. With labor mobile the gain in nearby countries approaches that where the improvement occurred. Canada, for example, benefits almost as much as the United States from a U.S. technological improvement. Germany’s smaller neighbors experience more than half the gain from an improvement in German technology as Germany itself. At the other extreme, Japan, which is both distant and large, gets little from either Germany or the United States. The results point to the

[8] Cherniwchan, Copeland and Taylor (2016), p. 13.

conclusion that trade does allow a country to benefit from foreign technological advances. But for big benefits two conditions must be met. First, the country must be near the source of the advance. Second, the country needs to be able to reallocate its labor to activities outside of manufacturing[9]."

There is a second why pollution-intensity might fall. If income per capita increases with trade liberalization, and if environmental awareness increases with income, then demand for stricter environmental regulation is a natural consequence of economic growth. As environmental regulation increases, firms are whether required to upgrade their technology, or they receive incentives to do so.

2.4.3 The composition effect

Trade liberalization also shifts the patterns of trade. When trade barriers decrease, countries naturally tend to shift their production towards sectors for which they have a comparative advantage. Countries end up importing the goods for which they have a comparative disadvantage. In the case of environmental regulation, the composition effect means that North will replace its production of dirty goods with the production of clean goods and will start importing dirty goods to compensate the shortage in supply. The composition effect is the point of focus of the thesis since it is the very mechanism through which the pollution haven hypothesis predicts the trade patterns.

3 The pollution haven hypothesis: theoretical and chronological overview

3.1 The birth of the pollution haven hypothesis: Copeland and Taylor (1994)

The first studies to investigate the role of environmental policy in determining trade patterns date back to the 1970s. Pethig (1976) showed that in a Ricardian two-goods two-countries model, if country A exogenously allows for higher emissions than country B (i.e. lower standards), then country A will specialize in (i.e. export) the pollution-intensive good. Later, Siebert et al. (1980) and McGuire (1982) used the same framework with two primary factors. But none of those papers assumed policy endogeneity until Copeland and Taylor (1994) filled the gap in the literature with their influential paper "North-South

[9] Eaton and Kortum (2002), p. 1772.

Trade and the Environment". But more importantly, it was the first theoretical work to predict pollution levels and trade patterns based on environmental regulation stringency and income levels. It immediately gained notoriety, not only for its remarkable theoretical work, but also because it was published the same year as the North-American Free Trade Agreement (NAFTA) came into effect[10]. Indeed, its main predictions implied a massive relocalization of pollution-intensive industries towards Mexico, thus a job disaster for the US and an environmental disaster in Mexico. Given the importance of the theoretical foundations laid by Copeland and Taylor, a brief summary of their predictions is given in the next section.

3.2 Copeland and Taylor (1994)'s theoretical model

Setup

In their model, goods are differentiated by their pollution intensity and North has more human capital than South. In order to capture different realities, Copeland and Taylor designed their model with three key features. First, there is a large income disparity across countries. Second, this disparity comes from the unequal human capital endowment between North and South. Third, income differences result in different levels of pollution taxes, which in turn determine trade flows. With these three features in mind, the model allows to investigate whether trade induced by differences in environmental policy (since in the model the levels of pollution taxes alone determine trade flows) leads to higher overall level of pollution.

Results

With these assumptions, Copeland and Taylor are able to show that a movement from autarky to free trade affects both the level and distribution of world pollution. Pollution level rises in the lax regulation country (South) more that it falls in the tight regulation country (North), so that the aggregate world pollution level rises with trade. What is key to understand here is that income differences are of paramount importance in the model, since they have an impact on the technique, scale and composition effects:

> "We emphasize income effects because they determine the strength of the technique effect mentioned above, are tied to the scale of economic activity, and can determine how free trade affects the composition of national outputs and overall pollution levels[11]. (...) Our most important results are that income gains arising from an opportunity to trade can affect pollution in a different way than income gains obtained through economic growth and, moreover, that economic growth has different effects on pollution in a free trade regime than in autarky. If

[10] Clinton signed the trade agreement on december 8th 1993 which came into effect on January 1st 1994.
[11] Copeland and Taylor (1994), p. 756

environmental policy is set optimally, then potential increases in pollution generated by economic growth in autarky can be prevented by a policy-induced switch to cleaner methods of production. Given our assumption on substitution possibilities in production and consumption, growth in autarky has a neutral effect on pollution: the technique effect fully offsets the scale effect. However, international trade opens up a different channel that may nevertheless lead to an increase in world pollution. While trade, like growth, increases real incomes in both countries, it also creates a composition effect that is critical in determining the effect of trade on pollution. If differences in pollution taxes are the only motive for trade, and trade does not equalize factor prices, then a movement from autarky to free trade increases aggregate world pollution[12]."

Copeland and Taylor's paper's originality lies in the integration of these effects in a theoretical model. To wrap up, Copeland and Taylor were able to examine the role played by income differentials across countries in the patterns of trade, and the reason they succeeded to do so is because they endogenized the policy variable.

Trans-boundary pollution

In a companion paper, Copeland and Taylor study a trans-boundary pollution model. They make three main changes in comparison with the original paper. First, in their original paper, the authors examine environmental quality as a *local* public good, i.e. pollution only damages the emitting country. In the trans-boundary pollution setup, environmental quality is a *pure* public good, i.e. pollution affect all countries no matter where the source of pollution is located. Second, in order to isolate the effects of terms-of-trade motivations for pollution policy from purely environmental motives, they consider two cases: one with a small number of countries, and one with a large number of countries. In the first case, the terms-of-trade motivations for environmental policy cannot be ignored. In the second case, no country perceives a terms-of-trade effect from changes in its environmental policy. Third, in order to figure out how international income inequalities influence the effects of trade on the environment, their trans-boundary pollution model allows for factor price equalization. The main results are:

"(i) Free trade raises world pollution if incomes differ substantially across countries; (ii) if trade equalizes factor prices, human-capital-abundant countries lose from trade, while human-capital-scarce countries gain; (iii) international trade in pollution permits can lower world pollution even when governments' supply of permits is unrestricted; (iv) international income

[12]Copeland and Taylor (1994), p. 781-782.

transfers may not affect world pollution or welfare; and (v) attempts to manipulate the terms of trade with pollution policy leave world pollution unaffected[13]."

3.3 The pollution haven hypothesis after Copeland and Taylor (1994)

Following Copeland and Taylor (1994), and in the context of massive trade openness (mainly the North-American Free Trade Agreement, the Uruguay Round (1986) as a part of the GATT framework, followed by the commencement of the World Trade Organization in 1995), the debate became more and more intense as views began to diverge between two extremes: the pollution haven hypothesis on the one hand and the Porter hypothesis on the other.

The Porter hypothesis (Porter and Van der Linde, 1995) basically states that the technology effects dominate over the scale and composition effects. More precisely, tight environmental standards force firms to innovate and invest in more clean and efficient technologies. As a result, firms become more productive and gain in competitiveness, while reducing their emissions at the same time. By questioning the weight of the composition and scale effects against the technique effect, Porter's publication put serious doubts on the pollution haven hypothesis and contributed to the development of a new branch of the literature focusing on trade-induced innovation and the environment. Letchumanan and Kodama (2000) added that much of the theory had treated pollution havens with a too narrow cost-advantage neoclassical lens, ignoring dynamic factors such as trade-induced technology transfer, quality-upgrading and strategic partnerships that can possibly (i) have a greater impact than cost-induced advantages on competitiveness and (ii) spur eco-friendly consequences at the same time. During the 1990s, several empirical studies on the pollution haven hypothesis were conducted, but the results were mixed and confusing. Even though some results supported the existence pollution havens, they often lacked significance and failed to pass important robustness tests. This overall failure was attributed to many empirical challenges that supposedly have impeded the researcher's ability to assess the validity of the pollution haven hypothesis.

In the late 1990s, the literature started to take into account the endogeneity of regulation. Since the 2000s, new data, econometric tools, methods and estimators (such as fixed effect, instrumental variable and matching technique) gave a new breath to the empirical research and results gained significance since then, however evidence still remains mixed. In the late 2000s, Kellenberg (2009) states that "the empirical validity of pollution haven effects continues to be one of the most contentious issues in the debate regarding international trade, foreign investment, and the environment[14]". Ten years later, Gill et al.

[13] Copeland and Taylor (1995), p. 716.
[14] Kellenberg (2009), p. 242.

(2018) conclude in their literature review that "the pollution haven hypothesis has been theoretically and empirically reviewed in various previous studies with different specification and with different data set, yet no conclusive results can be drawn about the existence of the pollution haven hypothesis[15]".

3.4 Pollution havens: two main regression approaches

Different categories of studies can be defined according to the type of data used (cross section data or panel data). For example, until the end of the 1990s, cross section data was used in most studies. Panel data studies saw the light in the 2000s, allowing to solve for the unobserved heterogeneity across observations and for the endogeneity of environmental regulations. The level of data also matters (country-level, industry-level, firm-level, plant-level). The type and level of data mostly affects the precision of results. Ultimately, the type of data used depends on the empirical strategy adopted in order to prove the pollution havens hypothesis. Economists typically choose between two ways to examine the pollution haven hypothesis: using trade flows data, or using data on Foreign Direct Investments (FDI). Whatever the strategy adopted, Ederington et al. (2004) distinguish between two main regression approaches used in the literature.

3.4.1 The direct regression approach

The first type of regression approach studies how a given measure of economic activity (FDI or trade flows) depends on countries characteristics including the stringency of regulation and trade restrictions between countries. In their paper, Ederington et al. (2004) give an example of a typical regression where the direct effect of pollution regulations (P) on imports of a dirty good (M) is captured by the coefficient β_1 in equation (1):

$$M_{it} = \beta_1 P_{it} + \beta_2 T_{it} + \gamma X_{it} + \alpha d_i + \delta v_t + e_{it} \tag{1}$$

where P_{it} is a measure of pollution regulations, T_{it} is a measure of trade restrictions, X_{it} is a set of industry characteristics, and d_i and v_t are cross-section and time dummies[16]. Evidence for the existence of a pollution haven effect arises if the results show a positive coefficient on β_1, implying that an increase in the stringency of environmental regulation results in an increase in imports of the dirty goods. In the literature, β_1 is known as the "volume effect".

[15] Gill et al. (2018), p. 168, 169.
[16] Authors' specifications

3.4.2 The indirect regression approach

Although very simple to implement, this direct approach fails to study the effect of the interaction between trade restrictions and environmental stringency on the measure on economic activity. Indeed, β_1 in Equation 1 is not sufficient to prove the pollution haven hypothesis, i.e. how a reduction in trade barriers together with a difference in environmental regulations will affect the composition of the economic activity – in other words, what is the effect of a reduction in trade barriers on the direct pollution haven effect among sectors and industries? This is exactly what the indirect approach allows to prove:

$$M_{it} = \beta_1 P_{it} + \beta_2 T_{it} + \beta_3 \overline{\mathbf{P}}_{\mathbf{i}} \mathbf{T}_{\mathbf{it}} + \gamma X_{it} + \alpha d_i + \delta v_t + e_{it} \tag{2}$$

where $\overline{P}_i$, the average pollution abatement costs for industry i across all time periods, interacts with T_{it}, the variable on trade restrictions. By doing so, the regression allows to estimate how a given tariff change affects industries with more stringent average environmental regulations. According to Ederington et al. (2004), β_3 captures the indirect effect of pollution regulations on the sensitivity of trade to tariffs. In other words, "if a trade agreement lowers tariffs across the board, the environmental consequences will depend on whether the polluting industries or the clean industries are more responsive to the tariff reductions[17]". This "indirect" effect is similar to the "composition effect" defined by Grossman and Krueger (1991).

Finally, Ederington et al. (2004) indicate two other forms on interaction terms. First, one could interact T_{it} with P_{it} instead of $\overline{P}_i$. According to the authors, this equation allows to "estimate the degree to which tariffs have a larger effect on imports for industries whose pollution abatement costs rose more[18]" as represented in Equation 3 below:

$$M_{it} = \beta_1 P_{it} + \beta_2 T_{it} + \beta_3 \mathbf{P}_{\mathbf{it}} \mathbf{T}_{\mathbf{it}} + \gamma X_{it} + \alpha d_i + \delta v_t + e_{it} \tag{3}$$

Second, one could have interacted $\overline{T_i}$ with P_{it}, "which would estimate the degree to which increases in pollution abatement costs have a larger effect on industries with higher tariffs[19]":

$$M_{it} = \beta_1 P_{it} + \beta_2 T_{it} + \beta_3 \mathbf{P}_{\mathbf{i}} \overline{\mathbf{T}_{\mathbf{i}}} + \gamma X_{it} + \alpha d_i + \delta v_t + e_{it} \tag{4}$$

[17] Ederington et al. (2004), p. 10.
[18] Ederington et al. (2004), p. 10.
[19] Ederington et al. (2004), p. 10.

Pollution havens models applied to FDI

A similar regression approach can be used for FDI. In this case, regressions usually take the form of a logit or probit model. For example, Smarzynska and Wei (2001) define $Prob[FDI_{jk} = 1]$ as the independent variable, FDI_{jk} being a dummy for Foreign Direct Investments from multinational firm j to host country k. In their probit empirical model, the authors let FDI_{jk} take the value one if the multinational firm has undertaken FDI or if the firm is planning to invest in the host country; and zero otherwise. Smarzynska and Wei (2001)'s regression approach is represented in Equation 5 below:

$$Prob[FDI_{jk} = 1] = X_j\Gamma_j + H_k\Phi_k + Z_{jk}\Pi + \beta E_k + \gamma D_j E_k + e_{jk} \tag{5}$$

where X_j is a vector of variables describing the characteristics of firm j; H_k is a vector of variables describing the characteristics of host country k other than its environmental standards; Z_{jk} is a vector of variables describing the relationship between host country k and the source where firm j originates from; and Γ_j, Φ_k, and Π are vectors of parameters with corresponding dimensions. D_j is an index of firm j's pollution intensity, E_k is an index of host country k's environmental standards, and e_{jk} is an iid normally distributed error term[20].

The two parameters of interest are β and γ, capturing a *direct* pollution haven effect (i.e. volume effect) and an *indirect* effect (i.e. composition effect) respectively. Again, a negative and significant β estimate implies that a more stringent environmental regulation in host country k has a deterrent effect on inward FDI. A significant negative γ estimate implies that FDI in pollution-intensive sectors tend to be attracted to a host country k with lax environmental regulations. The pollution haven hypothesis states that $\gamma < 0$.

3.5 Examples of other methodologies used to test for pollution havens

This section looks at two original studies of the pollution haven hypothesis. The first is a recent paper from Cherniwchan (2017) who explains the overall clean-up of U.S. manufacturing plants by the implementation of the NAFTA and differences of environmental regulations between Mexico and the U.S. The second paper by Cole (2004) argues net exports should be looked at *as a proportion of consumption* when investigating for pollution havens.

[20] Authors' specifications.

3.5.1 Trade liberalization and the environment: evidence from NAFTA and U.S. manufacturing (Cherniwchan, 2017)

Cherniwchan (2017) studies the effects of a trade liberalization event on the pollution level in "Trade liberalization and the environment: Evidence from NAFTA and U.S. manufacturing". The study is a novel since it provides the first empirical evidence of how a trade agreement affects plant-level emissions[21] and to take into account geographic variation of trade frictions. Cherniwchan (2017) first identify three potential channels through which the NAFTA could have affected the emissions at U.S. plant level. First, U.S. plants should have enjoyed an increased market access due to the decrease in Mexican tariffs on U.S. exports. Second, U.S. plants should have suffered from a decreased protection from import competition due to the lower U.S. tariffs on Mexican imports. Third, U.S. plants should have enjoyed an increased access to intermediate inputs imported from Mexico, due to the lower tariffs.

Setup

The aim of the paper is to assess the effects of the three above-mentioned channels on pollution levels. In order to do so, the author begins by identifying NAFTA's effects on the environment, using the following empirical strategy:

$$\ln z_{ijst} = \beta_1 \left[\tau_{jt}^{Mex} \times \Phi_S\right] + \beta_2 \left[\tau_{jt}^{US} \times \Phi_S\right] + \beta_3 \left[\tau_{jt}^{Int} \times \Phi_S\right] + \rho_i + \mu_{jt} + \delta_{st} + \varepsilon_{ijst} \tag{6}$$

where $\ln z_{ijst}$ is the natural log of pollution emissions from plant i in industry j and state s at time t. ρ_i is a plant fixed effect that captures time-invariant plant heterogeneity, μ_{jt} are industry-year fixed effects that capture temporal variation in industry outcomes, δ_{st} are state-year fixed effects that capture state specific shocks, and ε_{ijst} is an error term that captures idiosyncratic changes in emissions. τ_{jt}^{Mex}, τ_{jt}^{US} and τ_{jt}^{Int} are measures of tariff preferences[22]. The author interacts the measures of tariff preferences with Φ_S (Equation 7), a normalized Head-Ries Index (HRI) measuring the state-specific trade frictions associates with bilateral trade between state s and Mexico. The interaction allows to account for the different effects of tariff reduction due to geographic variation in trade costs[23]. Φ_S varies inversely with the size of trade frictions, so that Φ_S increases as the costs of trade falls. Φ_S is shown in the equation

[21] Emissions are calculated on particulate matter (PM_{10}) and sulfur dioxide (SO_2).

[22] Author's specifications.

[23] According to Cherniwchan (2017), "If, for example, a plant faced prohibitively high geographic frictions prior to NAFTA, a reduction in domestic tariffs would not increase competition from Mexican imports because the plant remained protected by its location. On the other hand, if the plant was located in a state where trade was completely friction- less, it would be fully exposed to the change in trade policy. Thus, for any industry, only a fraction of plants could be affected by an increase in market access, an increase in access to imported inputs or an increase in import competition depending on their location." (p. 133)

below:

$$\Phi_s \equiv \frac{\phi_s^{Mex}}{\frac{1}{s}\sum_{s\in S}\phi_s^{Mex}} \tag{7}$$

The normalized HRI index derives from the equation below:

$$\phi_s^{Mex} = \sqrt{\frac{X_s^{Mex}}{X_s^s}\frac{X_{Mex}^s}{X_{Mex}^{Mex}}} \tag{8}$$

where ϕ_s^{Mex} approximates the trade frictions. X_s^{Mex} denotes total exports from state s to Mexico, X_{Mex}^s denotes Mexico's exports to state s, X_s^s denotes total production from state s that is consumed in state, and X_{Mex}^{Mex} denotes the value of Mexican production that is consumed domestically[24].

Coefficients of interest

Back to Equation 6, β_1, β_2 and β_3 are the coefficients of interest, measuring the effects on pollution of the three channels identified above. The authors defines the coefficients as follows[25]:

- β_1 measures the average percentage change in pollution emissions for plants that experience an increase in access to the Mexican market following trade liberalization relative to change in pollution for plants in the same industry or the same state that do not.

- β_2 measures the average percentage change in pollution from plants that experience an increase in Mexican competition following trade liberalization relative to the change in pollution for plants in the same industry or same state that do not.

- β_3 measures the average percentage change in pollution from plants that experience a decrease in the cost of obtaining intermediate inputs from Mexico following trade liberalization relative to the change in pollution for plants in the same industry or same state that do not.

Results

Robust evidence that NAFTA reduced US plant's emissions is found: a 1% decrease in Mexican tariffs for US final goods reduced the PM_{10} emissions by 1.30% and the SO_2 emissions by 1.46% approximately. The effects for intermediate inputs are found to be even larger: a 1% decrease in US tariffs on Mexican

[24]Author's specifications.
[25]Cherniwchan (2017), p. 137.

intermediate inputs reduced the PM_{10} emissions by 3.25% and SO_2 emissions by 13.19% approximately. Similar results were found by Shapiro and Walker (2016) who found a 60% decrease in emissions from the US manufacturing sector between 1990 and 2008. Over the same period, Levinson (2015) found an annual decrease in PM_{10} and SO_2 emissions by 3.55% and 3.61% respectively. In short, a clean-up of US manufacturing happened in the 1990s.

However, views differ on the reason of this fall in emissions. On the one hand, Cherniwchan (2017) claims that "the effects of NAFTA account for nearly two-thirds of these reductions on average; for the average affected plant, NAFTA reduced PM_{10} emissions by 1.69% per year and reduced SO_2 emissions by 3.06% per year[26]". On the other hand, Shapiro and Walker (2016) suggest that the fall in emissions is mainly due to a change in environmental regulation. Concerned that his estimates do not simply capture the change in environmental policies, Cherniwchan (2017) allows the effects of environmental regulation to differ between plants and finds no evidence that its estimates are capturing regulation effects. Up to this point, the two authors struggle on features of the *direct* regression approach, which can seem not relevant. In fact, Cherniwchan (2017) wants to first prove that the clean-up is due to trade liberalization and then show how lower barriers to trade have created these new pollution levels, as shown in the second step below.

The next step in Cherniwchan (2017)'s analysis consists in investigating whether the pollution decrease is due to a lower number of goods produced, or to a reduced amount of emissions per unit of good produced. After examining the effects of trade liberalization on the emission intensity of production, Cherniwchan (2017) concludes that the clean-up of US manufacturing mainly occurred via a change in emission intensity of production. Then, Cherniwchan (2017) investigates three likely reasons for this reduction in the emission intensity of production: (i) extensive margin changes due to plant entry and exit; (ii) changes in the mix of imported intermediate inputs; (iii) changes in the process innovation or technological upgrade.

The results are the following: (i) intensive margins, rather than extensive margins, play a role in the reduced emission intensity of production. This means that the clean-up in the U.S. most probably stems from changes in the firms' behavior, and not in the number of firms in the U.S.; (ii) after NAFTA, plants shifted their source of dirty intermediate inputs to Mexico because of existing differences in regulation-induced pollution costs. This result shows that plants changed their behavior due to trade liberalization coupled with differences in environmental regulations (cfr. the interaction term in the indirect regression approach); and (iii) the observed reduction in the emission intensity of production due to increased foreign

[26] Cherniwchan (2017), p. 131.

market access happens more in the upper quartile of plant size's distribution, thus consistent with the hypothesis of trade-induced technological change (i.e. the technique effect).

To sum up, Cherniwchan (2017) documents how the NAFTA decreased the emission intensity of the studied US plants. This happened mainly due to within-plant changes, suggesting intensive margin changes. Moreover, fragmentation of production is observed due to differences in environmental regulation. Finally, evidence on technology upgrading is found. Altogether, Cherniwchan (2017) finds evidence in favor of the pollution haven hypothesis.

3.5.2 Examining net exports as a proportion of consumption (Cole, 2004)

Cole (2004) suggests to examine specialization patterns using "net exports as a proportion of consumption" (NETXC), arguing that taking into account the consumption of a good allows to dissociate the increase in world consumption from the shift in the comparative advantage to produce a good. For example, a developing country might see his exports of dirty goods boosted by its environmental regulation-induced comparative advantage to produce that good, or by an increasing world demand for that good. Thus, Cole (2004) argues that "net exports alone cannot indicate whether specialization is occurring in line with the pollution haven hypothesis[27]".

Setup

He sketches the following equation for net exports as a proportion of consumption (NETXC):

$$\text{NET}XC_{ikt}^{j} = \frac{X_{ikt}^{j} - M_{ikt}^{j}}{C_{ikt}} \tag{9}$$

where

$$C_{ikt} = P_{ikt} - X_{ikt}^{W} + M_{ikt}^{W} \tag{10}$$

In Equation 9, X, M and P represent exports, imports and production, respectively, in developed country i, developing country/region j, sector k and for time period t. Superscript w denotes world[28].

This method consists in simply comparing NETXC from developed countries with their trade partners

[27] Cole (2004), p. 74.
[28] Author's specifications

from developing countries, for both clean and dirty industries. For instance, if the pollution haven hypothesis held, the results should show dirty industries' NETXC to fall over time for developed countries. Cole (2004) studies four pairs of trading partners (USA – Asia, USA – Latin America, UK – Asia and Japan – Asia[29]); in addition, he assumes the ISIC sectors 34 – 37 to be the dirty sectors (i.e. the sectors with the highest pollution intensity), while ISIC sectors 32, 38 and 39 represent the clean sectors (i.e. the sectors with the lowest pollution intensity).

Results

The author's results are shown in the two graphs below:

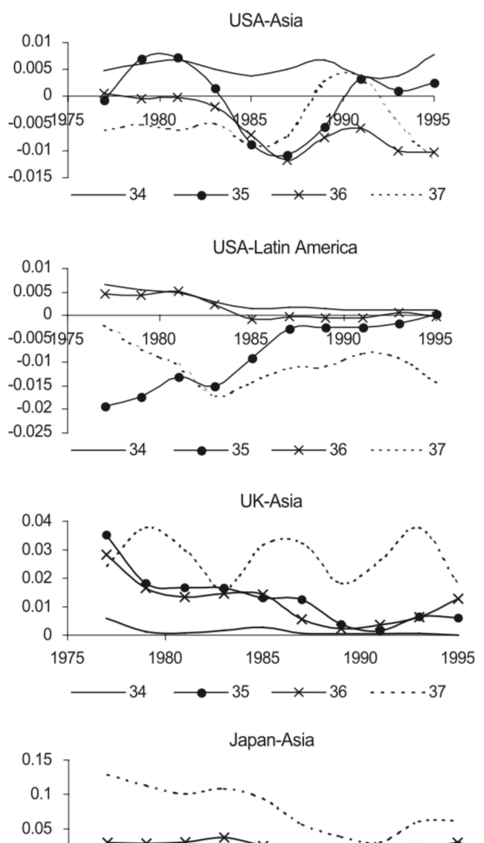


Figure 1: Specialization patterns for pollution intensive industries, 1977–1995.

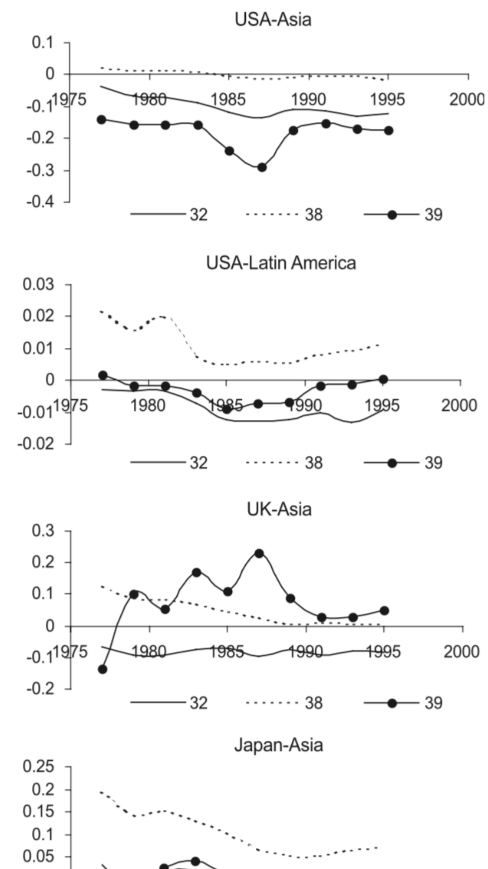


Figure 2: Specialization patterns for clean industries, 1977–1995.

[29] Asia excludes Japan

Looking at Figure 1, there is no global trend of a decrease in pollution intensive sectors' net exports. First, the USA-Asia pair exhibits cyclical movements for three out of four sectors; only the net exports of ISIC 36 (manufacture of non-metallic mineral products) seems to have decreased between 1975 and 1995. Second, the USA-Latin America couple exhibits a steep increase in the net exports of ISIC 35 (manufacture of chemicals and chemical products) and a light decrease of ISIC 37 (basic metal industries); the two other sectors remain constant. Third, concerning the UK-Asia country pair, ISIC 35 and ISIC 36 decrease over time while ISIC 37 is cyclical and ISIC 34 (manufacture of wood and wood products) remains constant. Fourth, looking at the Japan-Asia pair, only ISIC sector 37 (basic metal industries) decreases over time, the three others remaining constant. Overall, conclusions cannot be drawn since all country pairs exhibit mixed results. However, Cole (2004) argues that "We may be tempted to conclude that pollution havens have emerged between certain trading nations during certain periods[30]". Since he does not include any event trade liberalization nor tariff decreases in his analysis, it casts strong doubts on the validity of this affirmation.

Looking at Figure 2, most of the clean sectors appear to have decreased over time. Only one sector in one country-pair exhibits a growing NETXC over time: ISIC 39 (other manufacturing industries) for the UK-Asia pair. Cole (2004) concludes that "Since these sectors have very low pollution intensities this finding would obviously suggest that factors other than differences in environmental regulations must also be playing a role[31]". This is, in my opinion, a hasty conclusion. Indeed, the author *assumes* a difference in environmental regulations between the two countries in each country-pairs, but does not include any measure to support his claims. Moreover, if the pollution haven hypothesis held, NETXC for sectors with low pollution intensities would actually change over time because of differences in environmental regulations since North would specialize in these clean sectors.

4 Critical review of the pollution haven hypothesis' causality chain

Taylor (2005) suggests an interesting causality chain for the pollution haven hypothesis as presented in Copeland and Taylor (1994). The framework provided by Taylor in Figure 4 is the skeleton of a general equilibrium where trade, pollution and regulatory factors interplay. A loop between pollution, prices and incomes on the one hand and country characteristics on the other hand continuously feeds the logic

[30] Cole (2004), p. 75.
[31] Cole (2004), p. 76.

linkages between country characteristics, environmental regulation, production costs and trade or FDI flows.

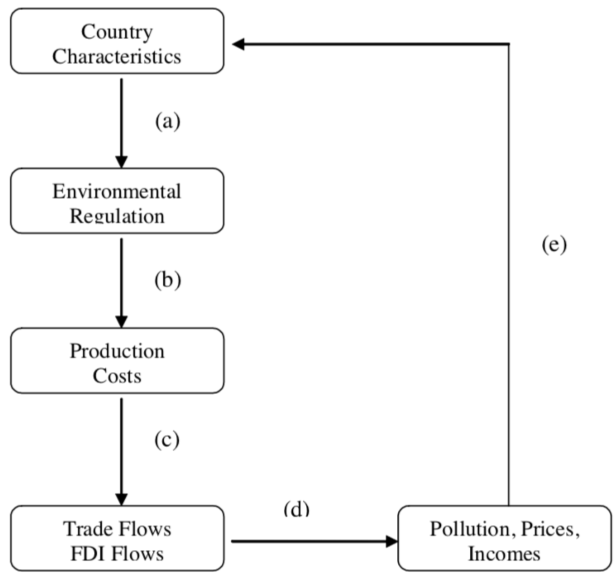


Figure 3: The pollution haven hypothesis unbundled (Taylor, 2005)

I use this framework as a tool to critically review each logical link leading to the formation of pollution haven. However, I deliberately make the choice to focus on the "pollution haven effect" part of the framework that I identify as the three first linkages in the causality chain: from country characteristics to regulation, from regulation to costs and from costs to trade flows. I do so because the framework is constructed in a very linear way, which, in my opinion is adequate for showing the causality chain of the pollution haven *effect* but too narrow for a clear understanding of the logic behind of pollution haven *hypothesis*. To be clear: I think Taylor (2005) made a great contribution with this framework, as it helps visualizing Copeland and Taylor (1994)'s model; however, I have some difficulties with the way the general equilibrium is represented.

First, as explained in the previous section, many empirical studies look at the coefficient of the interaction term between tariff reduction – which is not explicit here – and regulations on trade flows (i.e. indirect approach). Other studies only look at the effect of regulations on the pollution intensity of trade flows (i.e. direct approach). In my opinion, the frameworks exhibits something closer to the direct approach, which is not the best way to test the hypothesis (although I recognize that they contribute to the literature and should not be ignored).

Second, as in Copeland and Taylor (1994)'s original paper, the framework ignores other motives for trade that might influence the trade patterns. Although Taylor recognizes this flaw, and although I understand that models need simplicity, I believe they should be included or at least appear somewhere on the framework. This point is further discussed in the next section.

Third, the causality chain dissociates trade flows from pollution levels, however recent improvements in data collection and pollution tracking has made it possible to study the pollution intensity incorporated in imports and exports, yielding more robust results. Indeed, a country's pollution level is a broad aggregated measure, whereas looking at pollution intensity in trade flows narrows the focus and accurateness.

These reasons explain why I deliberately make the choice to focus on the pollution haven *effect* part of the framework that I identify as the three first linkages in the causality chain: from country characteristics to regulation, from regulation to costs and from costs to trade flows. I critically review each linkage in the next sub-sections, with the aim in mind to challenge and enrich Copeland and Taylor (1994)'s core assumptions.

4.1 Country characteristics to environmental regulation

According to Taylor (2005), "the hypothesis takes as given country characteristics such as access to production technologies, opportunities for abatement, and country specific endowments of productive factors. These country characteristics plus world prices determine national income which in turn maps into the stringency of environmental regulation at a)[32]". Copeland and Taylor (1994) make a host of assumptions such as factor immobility, zero tariff, and no strategic interaction. These strong assumption together with incomes as the sole determinant of environmental regulation led some researchers to investigate other mechanisms that can affect regulation. This branch of the literature is still very theoretical and criticises or enriches different angles of the original theory on the pollution haven hypothesis. What happens when factors become mobile? Can a country actually reduce its pollution-intensive imports while facing pollution abatement costs at the same time? What occurs if the model allows for strategic interactions between countries? We will see below that the link between country characteristics and environmental regulation is much more complex than expected. Income per capita surely plays an important role in shaping the environmental policies but other factors also have their share of importance.

[32]Taylor (2005), p. 5

4.1.1 The Environmental Kuznets Curve and the role of income growth

The Environmental Kuznets Curve (EKC) predicts that the level of environmental degradation is a concave function of income: in the first stages of economic development, pollution increases; as income increases, pollution progressively decreases; and at a certain level of income, pollution levels off and starts to slowly decrease. The result is a bell-shaped curve of pollution with respect to income. Evidence of the EKC is an argument in support of the pollution haven hypothesis because it means that North starts to shift the production of dirty products to the South, thus becoming cleaner as environmental regulations tighten.

Cole (2004) estimates an EKC model for ten air and water pollutants from 1980 to 1997, represented in Equation 11:

$$\ln E_{it} = \gamma + F_i + K_t + \delta \ln Y_{it} + \phi \left(\ln Y_{it}\right)^2 + \Psi \left(\ln Y_{it}\right)^3 + \sigma \ln M_{it} + \lambda \ln DX_{it} + \theta \ln DM_{it} + \eta \ln T_{it} + \epsilon_{it} \quad (11)$$

where E_{it} is a measure of pollution in country i at year t composed of six air pollutants and four water pollutants. F_i controls for country-specific effects, K_t controls for year specific-effects, Y_{it} represents income per capita, M_{it} represents the share of manufacturing in GNP, DX_{it} is the share of dirty exports to non-OECD countries in total exports, DM_{it} is the share of dirty imports from non-OECD countries in total imports, and T_{it} is the trade intensity[33].

Looking at the results (appendix A and appendix B), for 8 out of the 10 pollutants the estimated coefficients of Y_{it} and Y_{it}^2 are positive and negative, respectively; and they are statistically significant at 95% confidence levels. Thus, most of the pollutants exhibit an inverted U-shaped curve. Looking at Y_{it}^3, no evidence of a N-shaped relationship is found (i.e. the air and water pollution does not rise for high incomes). M_{it} is positive and significant for 8 out of 10 pollutants, suggesting that the declining manufacturing share of GNP for higher income per capita would partly explain the associated decline in emissions. Finally, DX_{it} (the share of dirty exports to non-OECD countries in total exports) and DM_{it} (the share of dirty imports from non-OECD countries in total imports) determine if pollution haven effects actually contribute to the concave shape of the EKC. One way to test it consists in testing whether the estimated turning points of the EKC differ if we exclude DX_{it} and DM_{it}. The 'simple' model (excluding DX_{it} and DM_{it}) should show lower turning points than the 'complete' model. Cole (2004)

[33] Author's specifications.

tests both models and his results show a lower turning point for 8 of the 10 pollutants, and therefore concludes: "The downturn in emissions experienced at higher income levels therefore appears to be a result of the increased demand for environmental regulations and increased investment in abatement technologies (both facilitated by higher income levels), trade openness, structural change in the form of a declining share of manufacturing output, and increased imports of pollution intensive output[34]".

Kearsley and Riddel (2010) criticize Cole (2004)'s empirical method, arguing that the use of aggregated measures of dirty imported and export shares to predict emissions "may be problematic if the marginal change in emissions varies across the dirty manufacturing sectors. If this is the case, then EKC estimation based on aggregated trade data may give a false picture of the EKC relationship[35]". They extends Cole (2004)'s regressions by estimating models based on disaggregated data on 2-digit and 3-digit ISIC that reflect pollution-intensive manufacturing. Their disaggregated sector trade shares are defined as in Equations 12 and 13 below:

$$DX_{it}^{k} = \frac{\sum_{j} \text{export}_{ijt}^{k}}{\sum_{K} \sum_{J} \text{export}_{iJt}^{K}} \tag{12}$$

$$DM_{it}^{k} = \frac{\sum_{j} \text{ import }_{ijt}^{k}}{\sum_{K} \sum_{J} \text{ import }_{iJt}^{K}} \tag{13}$$

where DX_{it}^{k} is the ratio of dirty exports to developing country j from OECD country i for dirty manufacturing sector k to total exports and DM_{it}^{k} is the ratio of dirty imports in manufacturing sector k from developing country j to OECD country i to total imports[36].

The next step in Kearsley and Riddel (2010)'s methodology is to include DX_{it}^{k} and DM_{it}^{k} in an EKC equation similar to Cole (2004)'s as represented in Equation 14:

$$E_{it} = \beta_0 + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 M_{it} + \beta_4 T_{it} + \sum_{k=1}^{n} \theta_k DX_{it}^{k} + \sum_{k=1}^{n} \delta_k DM_{it}^{k} + \gamma_i + \lambda_t + \varepsilon_{it} \tag{14}$$

where n is the number of dirty industries falling under ISIC codes 31 through 39; K is a superset of the n dirty industries and all other industry sectors; j are developing nations; J is a superset of j and all other nations, excluding country i. The coefficients θ_k and δ_k represent the marginal increase in emissions

[34] Cole (2004), p. 79.
[35] Kearsley and Riddel (2010), p. 905
[36] Authors' specifications.

resulting from dirty exports and imports in sector k, respectively[37].

Kearsley and Riddel (2010)'s aim is (i) to test whether Cole (2004)'s aggregated measures resulted in biased results and (ii) to test different model specifications in the hope to find a more rigorous test of the pollution haven hypothesis using an EKC model. They find that (i) using disaggregated data, their results show that only 8% of the dirty import sectors are positively and significantly correlated with higher emissions. Thus, they strongly reject the pollution haven hypothesis, therefore arguing against the validity of Cole (2004)'s results; (ii) Testing several model specifications, despite their efforts the authors only find very wide confidence intervals around the EKC turning points, offering "little support for the optimistic view that income growth naturally leads to reduced emissions after some peak emissions per capita is reached[38]".

Cascading pollution havens

Proof that the pollution haven hypothesis is responsible for the shape of the EKC has negative welfare implications. Indeed, if the reason countries' environmental quality increases with income is because they start importing pollution-intensive goods from foreign instead of producing them at home, it means they are passing over the burden of polluting industries to poorer countries, with all the related risks and consequences. Not only would such a situation be extremely costly in terms of pollution control, health, recycling etc. but also because the last countries in the chain will have no trading partner to handle over pollution to.

Such patterns of 'cascading' pollution havens were studied by Mani and Wheeler (1997) who argue that pollution havens are as transient as low-wage havens. They focus on Asia's three main economic regions: the Newly Industrializing Economies (NIE's – Hong Kong, Singapore, Korea, Taiwan); Developing East Asia (DEA – Malaysia, Indonesia, Thailand, Philippines and China); and South Asia (SA – India, Pakistan, Bangladesh, Sri Lanka). The authors argue that "the growth experience of pollution-intensive industries [across the three regions] seems to reflect these developments in a 'cascading' pattern[39]". More precisely, studying the changes in dirty-sector production shares and import/export ratios, Mani and Wheeler observe that "the dirty-sector share grew in all three regions during the 1970's; it levelled off in the NIE's and DEA, but continued rising in SA. The NIEs' dirty-sector import/export ratio fell sharply during the 1970's. When regulation tightened and the NIEs' ratio levelled off in the early 1980's, it began falling in DEA. As regulation tightened in DEA during the late 1980's, the import/export

[37] Authors' specifications.
[38] Kearsley and Riddel (2010), p. 919.
[39] Mani and Wheeler (1997), p. 14.

ratio began falling in SA[40]". The authors are optimistic about the developing countries' ability to solve environmental problems on their own. In their opinion, the "continuous, smooth relationship between income growth and environmental performance shows that developing countries are already making social choices which reflect the calculus of benefits and costs[41]". In the same spirit as Copeland and Taylor (1994), the authors argue that "rising incomes makes a cleaner environment more desirable and affordable[42]". The development of pollution control technologies, more frequent public campaigns about environmental issues and the stability of domestic institutions will most probably facilitate the transition. The authors' conclusion is clear: "ultimately, income growth will be the answer. As developing economies prosper and tighten their regulations, we are confident that the shadow of pollution havens will recede to insignificance[43]". Even if it happens to be true, one question remains: who will bear the costs of left behind pollution wastes, polluted lands or waterways, and cemeteries of toxic chemicals?

4.1.2 Location decision of factors and environmental standards

The mobility of factors can prevent countries to keep lax environmental regulation in the long run. While it is true that immobile factors will limit the agglomeration of factors in the polluting country with lax environmental standards because of the fixed available number of workers, relaxing this assumption does not necessarily imply a massive relocation of factors. In their paper "Environmental policy, population dynamics and agglomeration", Elbers and Withagen (2004) show that factor's mobility can affect how the social planner determines the optimal environmental regulation since it may actually create a dispersion force, i.e. skilled workers might flee the country if they care about the pollution level. Elbers and Withagen (2004)'s contribution is essential in understanding that increasing the factor mobility can boost pollution in the short run through the scale effect, while fostering the demand for environmental policies in the long run. Their results support the EKC.

4.1.3 Country's autonomy, strategic interactions and environmental regulation

A country's degree of autonomy in setting the tariffs can lead to different environmental policy outcomes. Regibeau and Gallegos (2004) develop a two-countries model in which North is "policy-active" through the use tariffs whereas South is "policy-inactive". Two firms produce pollution-intensive goods. One is located in the North, the other in the South. The firm located in the South has only access to a cheap

[40] Mani and Wheeler (1997), p. 16.
[41] Mani and Wheeler (1997), p. 21
[42] Mani and Wheeler (1997), p. 21
[43] Mani and Wheeler (1997), p. 21.

pollution-intensive production process. The firm located in the North can choose between the same cheap and highly polluting production process or a costly clean production process. The clean technology does not reduce the marginal cost of production. Finally, North's policy maker is committed to reduce pollution. The authors show that North will set up a higher optimal tariff in order to push the firm located in the North to adopt the clean technology. This protectionist behaviour can be compared with any environmental policy that aims to lower the national pollution level, and is called "tariff substitution" which is the focus of a specific branch of literature where tariffs replace other more effective instruments. The paper is provoking because it shows that in a well-defined context, free trade can run counter the pollution haven hypothesis according to which if pollution costs increase in the North then the quantity of pollution-intensive goods imported from the South should increase as well. Here, the import volume of pollution-intensive goods from the South is negatively correlated with the pollution reduction costs resulting from the costly clean technology adopted in the North. To conclude, this paper shed lights on the strategic interactions that might arise when a country retains a certain level of discretion in his own trade policy. Although trade indeed is never completely free, the model described above only works when the other country cannot set tariffs. While Broda et al. (2008) show that countries with greater market power set higher tariffs, it is hard to believe that low market power countries (typically small economies) have zero tariff setting power.

4.1.4 Linking political stability, corruption and trade openness with regulation

Another branch of the literature focuses on political stability, corruption and trade openness. Husted and Logsdon (1997) show that the NAFTA had a positive impact on the environmental regulation stringency and enforcement in Mexico. Using the year 1990 as baseline, they find an increase in plant inspections between 1990 and 1995 by a factor of 10. They also provide evidence that this trade-openness-induced change in environmental commitment was maintained along the 1995 financial crisis. The impact of openness to trade was further studied by Antweiler et al (2001) who showed that trade liberalization leads to higher incomes and more stringent regulation. Other studies allow for the presence of corruption. Using panel data between 1982 and 1992, Damania et al. (2003) show that "the effect of trade liberalization on the stringency of environmental policy depends on the level of corruption; and corruption reduces environmental policy stringency[44]". Political instability is studied by Brett and Keen (2000), Bohn and Deacon (2000) and Frederiksson and Svensson (2003), but no paper studied the joint interaction between trade openness, corruption and political stability on environmental policy.

[44] Damania et al. (2003), p. 490.

The gap is filled by Frederiksson and Mani (2004) in their paper "Trade integration and political turbulence: environmental policy consequences" who showed how openness to trade together with political stability leads to more stringent environmental regulation that trade openness alone. In their small open economy model, a lobby group from a pollution-intensive industry can bribe the policy maker in order to soften the environmental regulations. The policy maker has conflicting preferences: on the one hand, he values the environment through social welfare; on the other hand he also values bribes which degrade the environment quality. In other words, the policy maker faces a trade-off between environment conservation and bribes. Bribes and policies are decided and implemented in a three-stage model. In the first stage, the lobby group makes a bribe proposition to the policy maker. The level of the bribe is a function of (i) the the preference of the policy maker for environmental quality and (ii) the probability of the actual enforcement of the soft environmental policy to occur. In the second stage, the environmental policy choices are made and the policy maker receives a bribe proportional to the stringency of the regulation. The actual implementation of the policy happens in the third stage if and only if the policy maker remains in power (i.e. no political crisis occurs). Lastly, protectionist behaviour maintains high levels of pollution and output whereas trade openness lowers pollution and output. Frederiksson and Mani show that trade integration distorts the lobby's and the policy maker's incentives along the three-stage policy effort. The distortion is twofold. First, they find what they call a “bribery reduction effect”: since their model predicts a fall in output due to trade liberalization, the lobby finds it less profitable to bribe the policy maker. Second, they find a “welfare effect”: since output and pollution falls as the country lowers its tariffs, the policy maker's welfare maximizing incentive to tax pollution declines. Which effect dominates? The authors show that the bribery reduction effect dominates when the policy maker is very likely to accept bribes, and that the effects of trade integration depends on the level of political stability: on the one extreme, if the policy maker is fully stable, trade integration will unleash its full effects (bribery reduction effect and welfare effect) on environmental policy. On the other extreme, if the policy maker is totally unstable, trade integration will have zero effect on environmental policy since both above-mentioned effects become nonexistent.

4.1.5 Community characteristics and regulation

The role of community characteristics is studied by Becker (2004) in his paper “Pollution abatement expenditure by US manufacturing plants: do community characteristics matter?”. He finds empirical evidence that the local population can influence the pollution abatement level of plants located in their geographical zone. The study uses plant-level data from 1978 to 1988 from the U.S. Census Bureau's Pollution Abatement Costs and Expenditures (PACE) survey and the Annual Survey of Manufactures (ASM). The dependant variable is represented by the abatement costs, regressed against the quality of air at federal, state and local level as well as local characteristics. Becker finds that after controlling for plant characteristics and regulation, some local population characteristics have an additional effect. For example, the proportion of house owners has a positive and significant effect on the abatement costs. The same effect can be found when the county has a relatively high level of average per capita income, or when the county's relative proportion of Democrat voters is higher. On the opposite, the higher the proportion of manufacture workers or unemployed workers the lower the abatement costs. Similarly, Gray and Deily (1996) look at US steel mills and find that strict environmental policies are less likely to be adopted by the policy maker when many members of the local community are employed by the steel mills. To sum up, it seems that those who have much at stake regarding the environmental quality (Becker) or the environmental policies (Gray and Deily) actually thrive to make their views known at the plant (Becker) or at the political (Gray and Deily) level. Finally, according to Zheng and Shi (2017), the environmental awareness of Chinese citizens has significantly increased in the last decade. Partly due to their significant implication in the environmental regulatory framework (including multi-actor instruments such as letters of complaints on environmental problems), Zheng and Shi (2017) show that the public involvement of Chinese citizens have succeeded to influence both regulations and industry location decisions[45]. However, they show that national pollution has not decreased as polluting industries have simply moved inlands, to poorer regions. Anyway, this is an example of a national pollution haven story.

4.1.6 Closing remarks

This section teaches us an important lesson about economic theory and modelling in general. Although Copeland and Taylor (1994) have done a solid theoretical work, the mapping from country characteristics to environmental regulation is much more complex in reality. Which country characteristic dominates still remains an open question for further research. In the meantime, looking at the Appendix C, data shows a clear correlation between the economic and legal context index and the environmental regulatory regime index. We take this correlation as a satisfying evidence for the link between country characteristics and environmental regulation and move to the next logic link.

[45] The conclusions drawn by Zheng and Shi (2017) can easily be challenged since environmental complaints mainly come from Eastern provinces. According to the authors' calculations, in 2013, Eastern provinces' complaints accounted for 43% of total national complaints, which was 1.4 and 1.7 times the number of complaints from middle inland and west inland provinces respectively (Data source: China Environmental Yearbook (2014)). Note that Eastern provinces are richer but also more polluted.

4.2 Environmental regulation to production costs

Even though the link between environmental regulation and production costs intuitively is the least disputable in the pollution haven hypothesis' logic chain, some authors have argued that in some cases a more stringent regulation can break with the common beliefs by actually lowering production costs.

4.2.1 Evidence that environmental regulation increases costs

The literature studying the change in relative production costs due to regulatory differences distinguishes between direct and indirect costs.

On the one hand, direct costs can emerge from a cap and trade scheme, or pollution taxes for example. Evidence for direct costs was found, among others, by Chang, Li and Zhang (2013) who argue the European Union Emission Trading System (EU ETS) led to a 5 to 8% change in production costs for firms facing regulation in the power, cement, iron and steel industry. Pasurka (2008) shows regulation-induced pollution abatement costs range between 1 and 5% of the manufacturing capital expenditure. Moreover, Ferris and McGartland (2014) provide evidence of higher abatement costs for pollution-intensive industries in the manufacturing sector: in the US, those industries allocated approximately 1% of their 2005 financial year's turnover to abatement costs, while all manufacturing sectors spent on average 0.4%. In short, there is at least some evidence of sectoral variations in abatement costs.

On the other hand, indirect costs are caused by a additional, hidden burdens brought by environmental regulations. For example, a change in input costs due to a specific environmental policy: indeed, even if firm A does not face the specific environmental policy Y, firm A can bear the costs of policy Y if she buys intermediary inputs (e.g. electricity) from firm B (e.g. an electricity supplier) who faces policy Y (e.g. EU ETS applies to electricity). Other hidden costs can emerge if environmental regulations deter investments in new technologies. For example, the New Source Review (NSR) imposed higher standards for new plants or for modifications on old plants. Therefore, firms might want to delay investments that would decrease costs in the long run. In addition, firms might choose to operate old plants longer than expected even knowing the increasing costs such as maintenance costs. This view is supported by the 2003 Economic Report of the President[46]:

> *"The NSR permit process (...) might lead firms to delay or forgo plans to modernize their facilities in ways that would benefit the environment. To take just one example, a manu-*

[46] 2003; p. 172; coauthored by List

facturer that operates a process that includes a drying system determined that the system's energy efficiency could be improved if the existing drier nozzles were replaced with Teflon-coated nozzles. The firm found, however, that the replacement would be economical only if the expense of obtaining an NSR permit could be avoided. Since the firm could not readily discern whether the installation of new nozzles would be considered routine maintenance, repair or replacement, it decided not to proceed with the project. In this way, NSR deters firms from conducting needed repairs and often results in unnecessary emissions of pollutants. In this case NSR requirements actually made the environment worse off." (p. 172)

Strong empirical evidence requires not only panel data (before and after the policy implementation for each plant) but also solving the counterfactual issue (i.e. what would have happened without the policy). In "The Unintended Disincentive of the Clean Air Act", List, Millimet and McHone (2004) addressed these two empirical challenges using matching estimators in order to assess the rate of plant modification before and after the NSR. More precisely, they used the difference-in-differences semi-nonparametric propensity score matching estimator to analyze panel data on more than 2500 plant modification decisions in the New York State regions from 1980 to 1990. They found a significant effect of a tighter regulation on plant modification rates. To account for unobservable region-specific effects on the modification rate, the authors separate clean plants from the dirty ones and calculate the across-region difference in plant modification rates for clean plants only. By doing so, they capture the fraction of the modification rate that should not be affected by the NSR. The result obtained from the difference of the difference is the true effect of the NSR regulation on plant modification. Overall, they found that plants located in low NSR compliance costs regions are approximately 3 times more likely to undergo modifications than plants located in high NSR compliance costs regions. The same authors argued that other studies had largely underestimated the inverse relationship between environmental regulation and plant modifications, greenfield investment and the impact on location decision, because they used parametric estimates.

4.2.2 Asymmetries

There is a subtle underlying mechanism to understand in the pollution haven hypothesis' logic links in general, that is, differences are the main driver of each logic link. In theory the differences are proportional. Thus, the cost asymmetry between two countries should be proportional to the regulatory asymmetry at the source.

Golombek and Hoel (2004) challenge the logic link between regulatory and production costs differences. In "Unilateral emission reductions and cross-country technology spillovers", they show that a given asymmetry in two countries' regulation can lead to a smaller asymmetry in the abatement costs thanks to technological spillovers across countries. The model involves two countries, North and South. Both countries can choose between abatement and investment in RD which reduces abatement costs. Abatement technologies are endogenous, thus they can be affected by environmental policies. Given the difference in regulations between both countries, North abates and invests in RD relatively more than South. According to Hoel (1991), if North reduces its emissions then South would face lower marginal environmental costs and free-riding behaviours would appear. However, Golombek and Hoel argue that, allowing for RD spillovers, the free-riding effect are partially offset since it increases South's incentive to abate. In short, this contribution mitigates the logic link between environmental regulation differences and production costs differences.

4.2.3 Environmental regulation, innovation and cost reduction: the Porter hypothesis

From an economic point of view, the dynamic interactions between environmental regulation and innovation should not be overlooked for the following reason: if environmental regulation fosters innovation, then abatement costs might decrease in the long run through technological upgrading, improving firm competitiveness.

The "induced innovation hypothesis"[47] (Hicks, 1932) initiated the rise of an important branch of the literature that finally emerged around what is called the Porter hypothesis following the publication "The Competitive Advantage of Nations" by Michael Porter (1990). In short, the Porter Hypothesis states that tight environmental standards force firms to innovate and invest in more clean and efficient technologies. As a result, firms become more productive and gain in competitiveness, while reducing their emissions at the same time. This is an important caveat in our critical review of this logic link, since it predicts the exact opposite effect expected from a stringent environmental regulatory framework. Therefore, the views of the policy maker matters. In the Global Competitiveness Report (2001-2002), Porter and Esty identify two policy paths (Appendix D). On the one hand, a country may choose to follow a dirty growth path if the government believes in the pollution haven hypothesis – a famous case being the Delaware: in a series of deregulation, the State of Delaware aimed to attract jobs and industries through lower stringency, a practice also known as a "race-to-the-bottom" strategy. Racing to the bottom involves a sacrifice of the environmental quality against economic growth. On the other hand, a country can choose to follow a clean growth path if the government believes in the Porter hypothesis. This practice is also known as a "race-to-the-top" strategy, typically adopted by the State of California.

[47] According to the "induced innovation hypothesis", the more expensive the polluting emissions relative to costs of production, the higher the incentive to switch to less-polluting technologies: "a change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind - directed to economizing the use of a factor which has become relatively expensive". (Hicks, 1932, The Theory of Wages, p. 122)

In “Toward a New Conception of the Environment-Competitiveness Relationship”, Porter and Van der Linde (1995) argue that a well-thought set of environmental regulations can stir innovation and, in turn, partially or totally offset the compliance costs faced by firms. The authors add that “such ’innovation offsets’[48], as we call them, can not only lower the net cost of meeting environmental regulations, but can also lead to absolute advantages over firms in foreign countries not subject to similar regulations[49]”.

The authors propose different ways regulation can decrease *product-related* costs illustrated by real life examples. First, innovation to fulfill the environmental requirements often leads to better product quality or performance. For example, in 1990 a firm called Raytheon was compelled to eliminate the use of a toxic cleaner. They developed a technology that increased the product quality and lowered operating costs. The technology upgrade would not have happened without the regulation. Second, regulations can reduce costs by showing how to get rid of costly materials, reduce unnecessary packaging or make designs more simple. For example, facing a recycling law in 1991, Hitachi redesigned his products for improved recyclability. The new design involved less components and thus easier assembly. Third, innovation can reduce the disposal costs. For example, a law that requires product recyclability contributes to the easier recovery and / or reusability of valuable material afterwards.

The authors also give three examples of *process-related* cost reductions. First, regulations that put a price on pollutant wastes often leads to increased yield. For example, 3M improved quality controls in order to avoid environmental accidents at almost no cost. The average quantity of avoided toxic product disposal yielded the company more than 200 000 dollars per year. Second, regulation-induced process changes can also be profitable when it comes to reduced downtime, substitution for cheaper materials, or better utilization of materials in the process. Third, process-based innovation offsets can also appear when regulations turn firms’ wastes into more valuable forms. For example, a french nylon producer invested Fr 76 million in a machine capable to recover and sell the di-acids (they were incinerated before) for an annual yield of Fr 20,1 million.

The authors also mention other more subtle ways in which well-thought environmental regulations can indirectly benefit firms through innovation. First, in some cases regulations signal firms when resources

[48]“Innovation offsets can be broadly divided into product offsets and process offsets. Product offsets occur when environmental regulation produces not just less pollution, but also creates better-performing or higher-quality products, safer products, lower product costs (perhaps from material substitution or less packaging), products with higher resale or scrap value (because of ease in recycling or disassembly) or lower costs of product disposal for users. Process offsets occur when environmental regulation not only leads to reduced pollution, but also results in higher resource productivity such as higher process yields, less downtime through more careful monitoring and maintenance, materials savings (due to substitution, reuse or recycling of production inputs), better utilization of by-products, lower energy consumption during the production process, reduced material storage and handling costs, conversion of waste into valuable forms, reduced waste disposal costs or safer workplace conditions. These offsets are frequently related, so that achieving one can lead to the realization of several others.” (Porter and Van der Linde (1995), p. 101)

[49]Porter and Van der Linde (1995), p. 98.

are not efficiently used. Hence, regulations have the potential to help notify where there is room for technology improvements and costs reduction. Second, regulations on data collection sometimes bring interesting data insights helping firms achieve environmental improvements without increasing abatement, and sometimes at even lower costs. Third, regulations create pressure to innovate in the same way competition does. Fourth, and maybe the more subtle, regulations accompany innovation since they ensure that no other firm will have the possibility to improve their position during the transition period to innovation-based solutions by avoiding the costs of technology upgrading; in other words, regulations put everyone on the same page, therefore decreasing the possibilities for opportunistic behaviors.

Lanoie et al. (2011) conclude from several studies on the Porter hypothesis that the costs of environmental regulations are not totally offset by innovation. However, their conclusion should not be interpreted as a message against regulation, or that regulation has no positive outcomes. To the contrary, they implicitly suggest that offsets exist and one should not ignore the ability of innovation to reduce costs. Lanoie et al. do not provide a quantification of those offsets, but Rexhauser and Rammer (2014) provided further evidence from firm-level data that profitability from regulation-induced innovation exceeds profitability from voluntary innovation (with respectively 1.4 percentage point and 0.8 percentage point increase in profitability).

From a policy design perspective, Jaffe, Newell, and Stavins (2003) argue that incentive-based environmental policy are more effective in fostering cost-effective technologies than command-and-control approaches. The theoretical literature balances in favour of market-based instruments since many authors proved their enhanced potential to incentivise innovation more than performance standards (Fischer, Parry, Pizer, 2003). However, Popp (2003) found evidence of a decrease in innovation intensity after the 1990 Clean Air Act Amendment Summary was passed which triggered the implementation of a new permit trading system replacing a command-and-control standard-based approach. Since empirical research challenges the theory, further research is needed. A broad review of the literature on environmental regulations and international competitiveness was conducted by Jaffe (1995) who concluded that:

> *"International differences in environmental regulatory stringency pose insufficient threats to U.S. industrial competitiveness to justify substantial cutbacks in domestic environmental regulations. Nor does the evidence recommend enactment of stricter domestic environmental regulations in order to stimulate economic competitiveness."* (Jaffe, 1995, p. 159)

20 years later, after reviewing the new empirical and theoretical evidence, Dechezlepretre and Sato (2017) summarized the literature by quoting Jaffe et al. (1995):

> *"Some 20 years ago, in their review of the literature on the competitiveness impacts of environ-*

mental regulation in the United States, Jaffe et al. (1995) concluded that "there is relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on competitiveness. Since then, through hundreds of studies that have used ever larger data sets with increasingly fine levels of disaggregation, employing up-to-date econometric techniques, and covering a wider set of countries, this conclusion has only become more robust". (Dechezlepretre and Sato, 2017, p. 201)

To conclude, there is still no general consensus in the literature on environmental regulations and competitiveness, despite the massive amount of research in the field. Therefore, it remains unclear whether the Porter hypothesis should deserve full attention in the investigation of the pollution haven hypothesis; however one should keep an eye on the future research developments.

4.2.4 The California effect

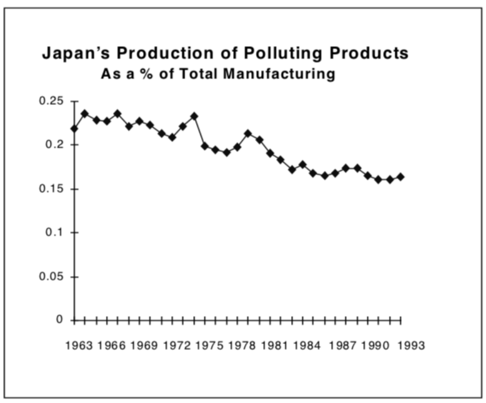
Another interesting point was made by David Vogel (1997), according to whom "a number of environmental regulations exhibit what can be described as the "California effect": they have moved in the direction of political jurisdictions with stricter regulatory standards[50]". More precisely, the California effect[51] owns its name to the historical leadership from the State of California in implementing high environmental standards and regulations. The upgrading of regulatory standards was followed by other states in the US and across borders. For example, Germany may have pushed the EU to adopt stricter rules because of its exposition in the highly regulated US market for cars[52]. Once the standards were adjusted, Germany was able to sell the same cars for both markets at a lower cost. To sum up, setting high regulations can reduce costs if a California effect exists, and cost reduction occurs thanks to increased market access and increasing economies of scale (Krugman, 1980). Vogel (1995) adds that domestic firms can benefit from a stricter regulatory standard if they know or anticipate better the costs of compliance of the new regulation. Perkins and Neumayer (2012) provide the first large scale, geographically disaggregated evidence of a trading-up effect.

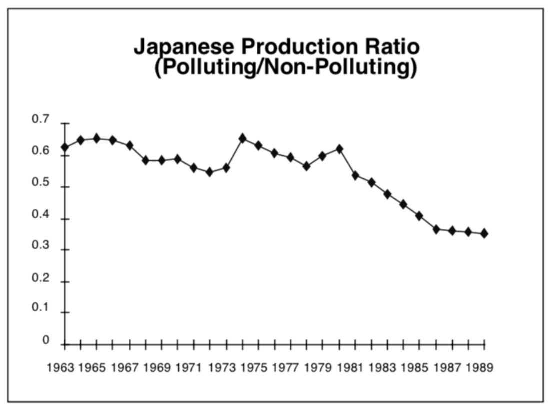
[50] David Vogel (1997), p. 561.
[51] The terminology was first used by David Vogel (1995) in his book "Trading Up: Consumer and Environmental regulation in a global economy".
[52] Half of the German cars exported to the US were sold in California

4.3 Production costs to trade flows and FDI

4.3.1 Pollution costs compared to other costs

Mani and Wheeler (1997) investigate the cost of pollution abatement on import-export ratios in Japan during the period 1963-1993. They start by noting that since pollution havens rest on comparative advantage, attention should be paid to other main costs factors specific to the dirty industries. Therefore, they first rank the most polluting industries: iron and steel, non-ferrous metals, industrial chemicals, pulp and paper, and non-metallic mineral products. These industries are both the most pollution-intensive (emissions per unit of output) and the most costly in terms of pollution abatement and control. They also compute and rank the five cleanest sectors. Their data shows that "as a proportion of clean-sector production, dirty-sector output dropped from nearly 70% in 1963 to about 30% in the mid-1990's. As a proportion of total manufacturing production, dirty-sector output dropped from about 25% in the early 1960's to about 15% in the mid-1990's[53]", as shown on the graphs (from the authors) below.

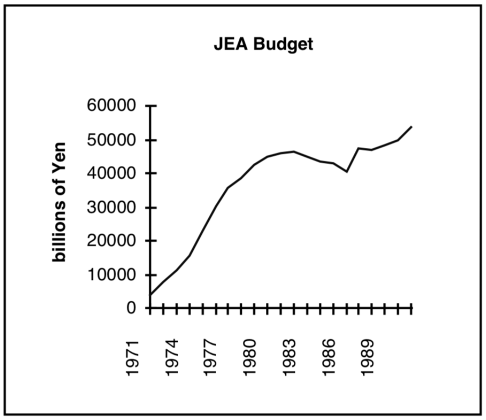


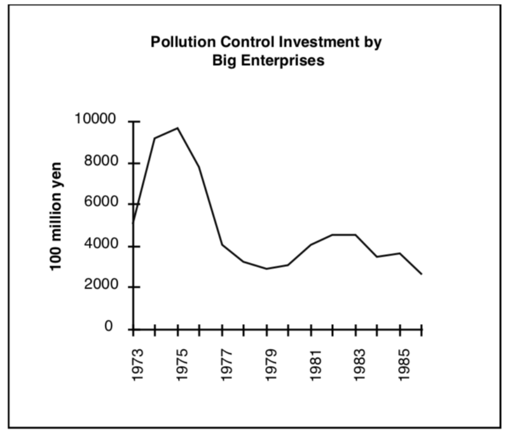


The second step consists in examining the causes of this decline. Mani and Wheeler investigate energy prices, land prices, and environmental regulation compliance costs. Looking at the energy-intensiveness, they find that the five dirtiest sectors outweigh the five cleanest sectors by a factor of three. The same pattern is observed for land-intensiveness. Therefore, the pollution haven hypothesis cannot be tested ignoring those costs of production. However, Mani and Wheeler argue that the rise of energy prices does not coincide with the decline in dirty goods production during the 1960s and 1980s, since relative energy prices stagnated during this period. The authors draw a similar conclusion after comparing land prices and the dirty sector share. What about the timing of the tightening of environmental regulations in Japan? Does it match with the relative decline in pollution-intensive production? Mani and Wheeler proxy the growing strictness in environmental regulation with the budget of the Japanese Environmental

[53] Mani and Wheeler (1997), p. 8.

Agency (JEA) and with the "pollution control investments by big enterprises" shown in the graphs (from the authors) below.





Mani and Wheeler (1997) conclude that "it is plausible to suppose that tightened regulation had an impact on the relative fortune of pollution-intensive production in Japan during in the 1970's and early '80's" and that "regulation probably led to both significant abatement by pollution-intensive industries in Japan, and displacement of some pollution-intensive production to Japan's trading partners[54]".

As a general conclusion, the magnitude of environmental regulation-induced costs is important in the link between production costs to trade flows and FDI. Some authors have argued that environmental regulation compliance costs were relatively small compared to other costs of production, despite their magnitude in absolute terms. The literature typically reports a 2% share of pollution costs in a firm's total production costs (e.g. Tobey, 1990; Dean, 1991), possibly explaining some author's arguments about the minimal loss in competitiveness. One should thus keep a critical view about those costs, because regulation does not necessarily means costs, and costs might be quite relatively small.

4.4 Concluding remarks on the critical review of the causality chain and extensions

As pointed out in the introduction of this section, some authors study the pollution haven hypothesis without explicitly using pollution costs. In addition, the causality chain dissociates trade flows from pollution levels, however recent improvements in data collection and pollution tracking has made it possible to study the pollution intensity of imports and exports. For example, some authors compute pollution intensity coefficients to examine emissions from imports, exports and production.

[54]Mani and Wheeler, p. 9.

4.4.1 Including pollution intensities in exports and imports

This method consists in (i) showing how a country became cleaner over time (for this, time series data is needed); and (ii) how this clean-up can be attributed to a shift of pollution-intensive goods from exports to imports (i.e. domestic production of dirty goods decreases).

Ederington, Levinson and Minier (2004) address the pollution haven hypothesis using trade data from U.S. manufacturing industries at the 4-digit level during the period 1978–1994. First, they document the U.S. manufacturing shift towards cleaner industries: the manufacturing sectors' real value added rose by 51% while the emissions of 14 pollutants tracked by the World Bank's IPPS rose by much less than 51%, sometimes even declining over the same period. At the same time, the U.S. went through a series of trade barriers reductions (for instance, successful negotiations on the GATT). At first sight, one could take this as a supporting evidence of the pollution haven hypothesis. However, a decomposition of trade flows suggests a more cautious interpretation: while import volumes increased by 344%, their composition shifted to cleaner goods. The change in the value of U.S. imports outweighed the change in pollution content by a factor of three. Looking at U.S. exports, they grew by 268% while their pollution content grew by 200%. Thus, the change in value of the U.S. exports slightly dominated the change in pollution content of the U.S. exports, which means that U.S. exports became cleaner over time. To sum up, U.S. imports and exports both got cleaner during the period 1978-1994. If the pollution haven hypothesis held, U.S. imports should be getting dirtier and U.S. exports should be getting cleaner. Since the U.S. imports became proportionately more clean over time than U.S. exports, it does not support the pollution haven hypothesis. In my opinion, this study does not provide robust results since environmental regulation is not accounted for explicitly. However, this example is useful to understand how comparing pollution intensities in imports and exports can be helpful in the context of pollution havens. Of course, it is not sufficient since even those trade patterns can be influenced by other factors, as explained below.

4.4.2 Capital abundance as a source of comparative advantage?

Copeland and Taylor (1994)'s model can be criticized in that it ignores the role of relative factor endowment in shaping the patterns of international trade. Attributing all motives for trade to regulatory differences is a very strong assumption. Indeed, as Copeland and Taylor stated in their influencing publication "North-South trade and the environment" (1994), "In reality, of course, trade is influenced by many conflicting factors... To make inferences about the actual pattern of trade, one would have to weigh the influences derived from environmental policy against other determinants of trade[55]". Since then, the literature highlighted the importance of other variables likely to outplay the effects of environmental regulations on trade flows and location decisions. The literature has mainly focused on capital abundance since pollution intensive sectors are also capital intensive. The Heckscher-Ohlin model of factor endowment states that a country will specialize in in the sector intensive in the factor in which the country is abundant. Since developing countries are less capital abundant than developed countries, why would they specialize in pollution intensive sectors?

The ideal setup to test the pollution haven hypothesis would require equal levels of capital endowment between two countries, but this is rarely (if not never) the case. Some studies therefore focused on inward FDI in U.S. States since most of them have their own environmental policy. Keller and Levinson (2002) exploit differences in pollution abatement costs among U.S. states and they employ panel data over a eighteen years period in order to control for unobserved characteristics across states. They find a robust and significant effect of differences in pollution abatement costs on FDI[56].

In "FDI and the Capital Intensity of "Dirty" Sectors: A Missing Piece of the Pollution Haven Puzzle", Cole and Elliott (2005) explore the possibility that pollution havens are not widespread because economists have neglected the role capital endowment. Their starting point is to show the relationship between capital intensity and pollution intensity for U.S. industries in the graph below:

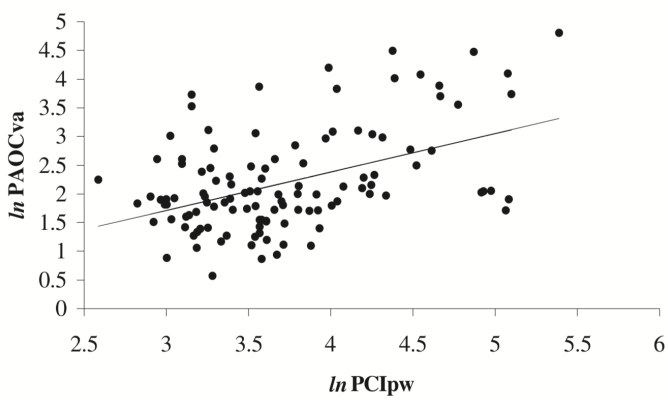


Figure 4: The Relationship Between Physical Capital Intensity and Pollution Abatement Costs (Cole and Elliott (2005)

Then, the authors show that capital abundant countries are more likely to have more stringent environmental regulations. Combining capital, pollution and regulations, they add: "if comparative advantage is determined by both differences in factor endowments and environmental regulations, then pollution

[55]Copeland and Taylor (1994), p. 757.
[56]Similar studies include List et al. (2001) and Fredriksson et al. (2003)

intensive FDI will be drawn to countries with a high level of capital endowment relative to the stringency of their environmental regulations.[57]" With this in mind, Cole and Eliott (2005) choose to study two potential pollution havens for U.S. outward FDI: Brazil and Mexico. They choose these two countries because they have a relatively high capital to labour ratio coupled with low environmental regulations. In addition, according to the authors both countries have received a fair share of FDI during the period covered (1989-1994), ranking second and third countries that have received the most FDI worldwide through the 1990s[58]. That being said, Cole and Eliott (2005) state that "if pollution havens exist anywhere, Brazil and Mexico are two of the more likely contenders.[59]" Then, Cole and Eliott (2005) estimate the following equation:

$$USFDI^{i}_{jt} = \alpha_i + \delta_t + \beta_1 PCIpw_{it} + \beta_2 PAOCva_{it} + \beta_3 MKT_{it} + \beta_4 WAGE_{it} + \beta_5 RD_{it} + \beta_6 EMPL_{it} + \beta_7 IMP_{it} + \beta_8 TRANS_{it} + \varepsilon_{it} \quad (15)$$

where $USFDI^{i}_{jt}$, the dependent variable, is US FDI in sector i, for country j in year t; country j is Brazil or Mexico. Each sector's FDI stocks are expressed as a share of total US FDI stocks in country j in that year. $PCIpw_{it}$ is the physical capital intensity of sector i in the US, measured as non-wage value added per worker; $PAOCva$ is a measure of sector i's pollution abatement costs as a share of value added (in the US); MKT_{it} is a measure of market size for each sector, within Brazil or Mexico under the assumption that US FDI will be attracted to a large domestic market; $WAGE_{it}$ is a measure of the wage differential between Brazil/Mexico and the US within each sector. RD_{it} is research and development expenditure as a share of value added within each sector, in the US; $EMPL_{it}$ measures the number of employees per firm within each sector in Brazil or Mexico as a proxy for economies of scale in that sector; IMP_{it} denotes the import penetration within each sector in the host country, defined as imports within the sector as a share of the sector's production; Finally, $TRANS_{it}$ is the unit value of the output from each sector defined as price per kilogram[60].

The results show positive and significant estimates for $PCIpw_{it}$ and $PAOCva$, the two variables of interest. Interestingly, $PCIpw_{it}$ has a greater effect than $PAOCva$ on outwards US FDI to both Mexico and Brazil (the estimates of $PCIpw_{it}$ are more than two times larger than the estimates of $PAOCva$). Thus, the authors conclude that capital matters more than environmental regulations, however the role of the latter should not be undermined since the results support the existence of a pollution haven *effect*.

[57]Cole and Eliott (2005), p. 541.
[58]China is first.
[59]Cole and Eliott (2005), p. 535.
[60]Authors' specifications

A similar result was found by Antweiler et al.. (2001) who concluded that "international trade is in fact beneficial to the environment (as measured by sulfur dioxide [SO2] concentration) because the increase in economic activity (scale effect) is offset by changes in both technology and the composition of output in the economy. One explanation for this result is that in low income countries, the higher price of capital offsets their "advantage" of having lax environmental policies because pollution intensive industries are also capital intensive.[61]"

5 Empirical difficulties

Empirical researchers face the over-simplified models developed by theorists. While simplifying assumptions are needed in order to isolate specific mechanisms, the same cannot be done when working with data. Indeed, empiricists must take into account the complexity contained in numbers. For instance, the amount of FDI is influenced by many factors besides environmental regulations. If an unobserved variable influences FDI and environmental regulation, then researchers face an endogeneity issue. Sometimes, even finding the right data is challenging.

5.1 Measurement difficulties

As for any empirical research, data collection is of utmost importance. For many studies, simply gathering data can be challenging. For example, pollution data in developing countries is not as widespread as for developed countries, hence economists often have no other alternative than to assume similar levels of pollution intensities among sectors across countries. Another challenge lies in the measurement of stringency, which includes conceptual and methodological challenges as documented below.

5.1.1 Measuring pollution levels

According to Cole (2004), there is a general consensus that amongst the most pollution intensive sectors are ISIC 34, manufacture of wood and wood products, ISIC 35, manufacture of chemicals and chemical products, ISIC 36, manufacture of non-metallic mineral products and ISIC 37, basic metal industries[62]. According to Hettige et al. (1995), the sectors with the lowest pollution intensities are ISIC 32, textile,

[61] Antweiler et al.. (2001), p. 908.
[62] Cole, 2004 p. 74.

wearing apparel and leather industries, ISIC 38, manufacture of fabricated metal products and ISIC 39, other manufacturing industries.

However, pollution data from developing countries is often incomplete or absent. As a consequence, researchers can take a dangerous shortcut by assuming that the data found in developed countries applies in the South. Some studies have suggested this possibility for pollution intensities. Hettige et al. (1995) are the authors of the famous Industrial Pollution Projection System (IPPS) that can be used to estimate industrial pollution across countries, regions, and on new projects. The estimation model is built on U.S. industrial data, although according to the authors "even if there is considerable international variation in the absolute level of sectoral pollutant intensities, the relative ranking of intensities across sectors may be expected to remain more constant. Thus, one might reasonably expect the Fertilizers and Pesticides sector to be found near the top of all national rankings of toxic release intensity indices, and the Soft Drinks and Carbonated Waters sector to be found near the bottom[63]". They add: "it is clear that many country-specific factors will affect the accuracy of prototype IPPS projections outside the US. For particular sectors such as wood pulping, average pollution intensity is likely to be higher in developing countries. However, the pattern of sectoral intensity rankings may be similar. For example, wood pulping will be more water pollution- intensive than apparel manufacture in every country[64]".

Smarzynska and Wei (2001), who use pollution indices in order to compute pollution intensities, recognize that "the main drawback of both indices is that they are based on U.S. data. Thus, we are assuming that pollution intensity of facilities set up by American investors overseas is the same as that of U.S. facilities, or (perhaps a weaker assumption that) the pollution intensity of the overseas production of two firms is proportional to their pollution intensity at home[65]". They back their assumption with a survey made ten years earlier reporting that in 62% of cases the development of environment, health and safety laws and regulations in the home country had motivated changes in company-wide environmental policies and programs[66].

Hansen (1999)'s survey of environmental management practices in 154 Trans-National Corporations (TNC) further supports the importance of foreign ownership's environmental policies for their affiliates in the host countries[67] through a relatively high level of cross border integration of environmental management. First, he observes that headquarters play a much more important role in environmental protection than media pressure, NGO or market specific factors. He finds similar figures than the UNCTAD, with

[63] IPPS report, 1995, p. 66.
[64] IPPS report, 1995, p. 2.
[65] Smarzynska and Wei (2001), p. 7.
[66] UNCTAD, 1992, p. 38.
[67] The author focuses on NTC affiliates in China, India and Malaysia

roughly 2/3 of the TNC affiliates' written environmental policies being formulated by the headquarter. However, this figure is substantially inflated by U.S. and EU firms, since it drops to only 40% if the focus is narrowed to Asian firms. Second, Hansen observes that headquarters tend to set environmental standards according to the type of affiliate (e.g. old affiliates and brownfield plants) and to the industry (e.g. chemical and pharmaceutical industry). Again, the author warns us that "conclusions regarding environmental management practice cannot be extrapolated to environmental performance in general. Moreover, the sample is probably to be biased toward companies having more elaborate environmental practices as environmental 'laggards' are likely to have declined to participate. Finally, the survey relies solely on affiliate managers' responses to a questionnaire[68]".

5.1.2 Linking pollution to firm-level production

We have seen that using disaggregated data enhances precision. For example, Kearsley and Riddel (2010) challenge Cole (2004)'s methodology and results arguing that aggregated data on trade flows have hampered the author's ability to rigorously prove the existence of pollution havens. Other authors study a similar analytical challenge that may have prevented researchers from identifying a statistically significant effect of regulation on the location choice of multinationals. The existing literature that focuses on location decisions has paid little attention to the firm level where production stages occur (Zarsky, 1999). Indeed, facing the difficulty of assigning pollution intensity measures to production activities of different multinational firms, researchers have been content to rely on aggregated data about industry choices (Smarzynska and Wei, 2001), for it requires less detailed data. Not only is finding firm-specific data on pollution emissions laborious, but it also requires merging the data with a firm-level data set which is a labor-intensive task. To my knowledge, the earliest comprehensive report of that kind is the IPPS described above, merging pollution data of approximately 200 000 U.S. facilities with their respective economic data[69] using the Toxic Release Inventory (TRI) maintained by the US Environmental Protection Agency (EPA) on the one hand, and the Longitudinal Research Database (LRD), an establishment-level database provided by the Census Bureau (CS) on the other hand (Hettige et al., 1995).

[68]Hansen (1999), p. 25.

[69]The IPPS spans approximately 1,500 product categories, all operating technologies, and hundreds of pollutants. It can separately project air, water, and solid waste emissions, and incorporates a range of risk factors for human toxic and ecotoxic effects. It can also project emissions of some greenhouse gases and several compounds which are hazardous to the ozone layer. (from the report)

5.1.3 Measuring stringency

The literature also faces difficulties to measure the varying strength of environmental protection among countries, especially in developing economies where the actual law enforcement might substantially diverge from the laws on the book (Smarzynska and Wei, 2001). Shadbegian and Wolverton (2010) state that "measuring the level of environmental stringency in any meaningful way is quite difficult, whether at the national, state, or local level[70]". Levinson et al. (2008) highlight that merely finding data on environmental stringency is not an overwhelming challenge, but rather the conception of data that would represent environmental stringency is difficult. Almost a decade later, Brunel and Levinson (2016) argue that many studies were conducted with the shared idea that data collection constitutes the main challenge, naively thinking that gathering the right data thanks to the appropriate resources would solve the issue. According to Brunel and Levinson,

> "The challenges to using such information as measures of stringency for policy analysis actually derive from a much deeper set of conceptual (and econometric) problems: (1) *multi-dimensionality* — environmental regulations cannot easily be captured by a single measure of "stringency"; (2) *simultaneity* — regulations are meant to affect emission levels, but emissions levels can be a factor in determining the stringency of a regulation because, for example, jurisdictions with the most serious pollution problems may impose the most stringent regulations; (3) *industrial composition* — in places where the mix of industries is more pollution-intensive, the average business automatically faces more stringent regulations; and (4) *capital vintage* — regulatory standards are typically stricter for new sources of pollution, which may result in firms keeping older plants in operation longer, thus affecting the environment, the economy, and measures of regulatory stringency." (Brunel and Levinson, 2016, p. 47)

Smarzynska and Wei (2001) employ three types of measures: first, they use a composite index reflecting the degree of participation in four different international environmental protection treaties. The second measure is an index of the strength of the air and water ambient and emission standard system as rated by European Bank of Reconstruction and Development (1997), a direct assessment of the regulation itself. Third, the authors exploit the reductions in emissions of carbon dioxide, lead and water pollutants as a proxy for the actual enforcement of environmental laws. Of course, although the measure proposed by Smarzynska and Wei is a novel in the literature, other authors have explored different equally clever paths. For example, Brunel and Levinson (2016) add abatement costs and public sector expenditures or

[70] Shadbegian and Wolverton (2010) p. 13.

enforcement as measures of stringency. In their quest to prove the effects of environmental regulatory stringency on competitiveness, Porter and Esty (2002) computed what they called the Environmental Regulatory Regime Index (ERRI). The authors present the ERRI as a "summary performance measure of the quality of the environmental regulatory system in a country" (p. 93). The ERRI is a combination of 6 sub-indexes that the authors called stringency of standards, regulatory structure, information, subsidies, regulatory enforcement and environmental institutions.

5.2 Dealing with the endogeneity of regulation

The previous section exposes the difficulties of producing an accurate measure of environmental stringency. Overcoming this challenge, economists face a new empirical difficulty: there is a broad consensus that research failed because environmental policy is endogenous. Briefly, endogeneity is a well-known statistical issue that occurs when an explanatory variable is correlated with a variable in the error term (in our case, unobserved determinants of trade flows or location choice). As a consequence, the explanatory variable's coefficient is biased upwards or downwards. In other words, we under- or overestimate the effect of the explanatory variable on the variable of interest. For example, in the case of pollution haven hypothesis, specific characteristics of developing countries (such as corruption and political instability) might deter foreign direct investments while affecting environmental policy. Since the pollution haven hypothesis predicts a comparative advantage based on variations in the stringency of environmental regulations, empirical research must take explicit account of the endogeneity of this variable.

5.2.1 Trade policy

Until the end of the 1990s, economists struggled with a very weak effect of environmental regulation found on trade flows. Prior to the 2000s, most (if not all) studies took environmental regulation as exogenous. One of the main advances in the literature was to treat environmental regulation as endogenously determined. Many economists shared the intuition that trade considerations might play a role in setting environmental regulation. The theory behind this intuition derives from second-best models. Such models originate from the fact that international trade policies limit the countries' power to set trade barriers. Facing international competition, countries use their "second-best" tools to protect their industries: domestic regulation. For example, if a country faces strong import competition in a given industry due to a recent trade agreement, the policy maker might be tempted to (endogenously) set a weaker environmental regulation for this specific industry, i.e. lower pollution costs in order to boost domestic production, and reduce net imports. There are two underlying mechanisms: on the one hand, the political economy theory, and on the other hand, the terms-of-trade theory. First, the literature about the political economy theory states that each industry has different political strength due to its size (Caves, 1976), its opportunity cost of lobbying (Magee, Brock, and Young, 1989), and the strength of its unions (Trefler, 1993). Second, the literature about the terms-of-trade theory states that countries have a strategic incentive to lower the taxes on the import-competing industry since the tax increases the price of the goods produced by this industry, thus worsening the terms-of-trade of the importing country (Markusen, 1975). Thus, foreign competition might affect the stringency of pollution taxes (i.e. lowering the level of environmental standards). To sum up, both the political economy theory and the terms-of-trade theory suggest that industries facing stronger import competition may induce the policy maker to relax the stringency of environmental regulations. Such endogenous environmental policy setting weakens the correlation between environmental regulation and net imports across industries.

Ederington and Minier (2003) find a significantly larger effect of environmental regulation on trade flows when the level of environmental regulation is taken as an endogenous variable rather than an exogenous variable. The authors proxy the stringency of environmental regulation with time-series data on pollution abatement costs from 1978 to 1992 (provided by the Census Bureau's Pollution Abatement Costs and Expenditures (PACE) survey). According to the authors, "both the political economy and the terms-of-trade theories suggest that higher levels of net imports may result in the relaxation of environmental regulations. However, relaxed environmental regulations in an industry would result in lower levels of net imports. These two effects can be isolated by simultaneously estimating an import equation and an environmental regulation equation[71]". Both equations are described below. Their empirical strategy is inspired by Grossman and Krueger (1994)'s methodology. They regress net imports scaled by domestic production[72] (M_{it}) on pollution abatement costs (t_{it}) and trade barriers (τ_{it}), and a vector of factor intensity variables (F_{it}). Finally, μ_i and μ_t control for industry and time fixed effects.

$$M_{it} = \mu_i + \mu_t + \beta_1 \cdot t_{it} + \beta_2 \cdot \tau_{it} + \beta_3 \cdot F_{it}^n + \eta_{it} \tag{16}$$

In addition, they define environmental regulation stringency as a function of net imports:

$$t_{it} = \alpha_i + \alpha_t + \delta_1 \cdot \tau_{it} + \delta_2 \cdot M_{it} + \delta_n \cdot P_{it}^n + \epsilon_{it} \tag{17}$$

Where α_i controls for industry-specific differences in abatement and pollution control costs (fixed effects) since for a given pollution tax rate the most polluting industries will face higher costs, α_t controls for

[71] Ederington and Minier (2003), p. 144.
[72] U.S. shipments in industry i at time t

country-wide trends in environmental regulation over time, and P_{it} is a vector of political economy. Based on the theory of endogenous regulation (recall the political economy and terms-of-trade theories), the authors expect that "higher levels of imports and lower levels of exports in an industry will be correlated with less stringent environmental regulations[73]" (i.e., $\delta_2 < 0$).

The results are in line with the author's expectations. First, the OLS estimation of equation (1) alone (where the environmental regulation variable is determined endogenously) generates a positive and significant estimate of β_1, meaning that higher pollution and control costs increases net imports. However, the estimate of β_1 (0.531) means that an industry in which environmental costs rose by 1 percentage point could expect net imports to increase by only 0.53 of a percentage point - which is not very convincing (similar to what was found in the literature through the 1990s). In a second step, the authors estimate equation (1) and equation (2) simultaneously, now taking into account the endogenous nature of the environmental policy variable. The results are striking: a 1 percentage point increase in the pollution abatement and control costs in a given industry with respect to otherwise identical industries leads to a 30 percentage point increase in net imports.

Ederington and Minier (2003) conclude that "environmental policy has a much stronger impact on net import levels than had previously been reported". (...) This result, they add, "is important, since this previous research has often been used to justify the claim that a country's environmental regulations are not a valid area of international negotiation[74]".

5.2.2 Corruption

Corruption is undeniably more present in developing countries. If we believe that corruption is likely to be correlated with a lax environmental policy, then the environmental policy variable might be endogenous and corruption should not be omitted. Many studies report a significant negative correlation between corruption in a host country and inward FDI (see Wei, 2000b).

Wei (2000b) summarizes three ways to measure corruption: first, using surveys like in the GCR or in the WDR. Second, via ratings given by the big consulting firms in their reports. Third, using an average of existing indexes. In order to solve the endogeneity issue, Smarzynska and Wei (2001) control for bureaucratic corruption using a composite measure. More precisely, the authors combined a survey from the 1997 Global Competitiveness Report (GCR) with a survey from the 1997 World Development Report (WDR). Both surveys asked respondents to scale corruption based on their exposure to irregular

[73] p. 145.
[74] p. 149

or additional payments. Using this measure for corruption, the authors hope to find a significant effect of environmental standards on inward FDI[75]. However, controlling for corruption, environmental standard remains insignificant. The regression results support the existence of a composition effect. The authors further try to estimate their model with another measure of corruption in host countries called the "Neumann index", but the coefficient of environment standards remain insignificant. Therefore, the inclusion of a measure of corruption is disputable.

Finally, corruption is not a one-way street. Even though the evidence presented above views corruption as a deterrent factor for FDIs, it can attract multinational corporations looking for easy-to-bribe governments. This is especially the case for multinationals whose production generates consequent amounts chemical wastes. Indeed, the illegal disposal of hazardous wastes is more likely to happen highly corrupted countries via illegal practices such as bribes for instance.

6 Future challenges and possible path to explore

6.1 Economic Geography

Different ingredients of economic geography are worth to investigate. Distance, transport costs and spillovers are the main topics covered in this section.

First, globalization and international trade is often associated with decreasing transport costs. In the early 2000s, the literature on the gravity model of trade[76] faced what was called the "distance puzzle". In short, the "distance puzzle" derived from the observation that, for a given distance, the estimated coefficient of distance on trade appeared to be *increasing* over time. In other words, transport costs might not be decreasing after all.[77] Here is the bottom line: if transport costs did not decrease as much

[75] Smarzynska and Wei (2001) design the following empirical model:

$$Prob[FDI_{jk} = 1] = X_j\Gamma_j + H_k\Phi_k + Z_{jk}\Pi + \beta E_k + \gamma D_j E_k + \delta Corr + e_{jk} \tag{18}$$

Where X_j is a vector of variables describing the characteristics of firm j; H_k is a vector of variables describing the characteristics of host country k other than its environmental standards; Z_{jk} is a vector of variables describing the relationship between host country k and the source where firm j originates from; and Γ_j, Φ_k, and Π are vectors of parameters with corresponding dimensions. D_j is an index of firm j's pollution intensity, E_k is an index of host country k's environmental standards, and e_{jk} is an iid normally distributed error term. The parameters of interest are β and γ, the "volume" and "composition" effects respectively.

[76] In the gravity model of trade and, more specifically, the gravity equation, distance (an explanatory variable) plays a central role in determining the amount of trade (the variable of interest) between two countries. Not surprisingly, distance is negatively correlated with trade.

[77] However, in "Has Distance Died? Evidence From a Panel Gravity Model" Brun et al. (2002) use a panel gravity model to address the "distance puzzle" for 130 countries between 1962 and 1996 and found evidence that using to an "augmented" trade barrier function actually yields a 11% decrease of the coefficient of distance on trade.

as expected *and* transport costs vary across dirty and clean industries, then distance matters in the estimation of trade flows.

Second, Grether and Melo (2003) argue that the most pollution-intensive industries are typically intermediate goods producers. The authors give the example of the newspaper industry: the production of paper can be delocalized in the South; however the final good is sold in the North. Moreover, pollution-intensive goods are typically heavy and are slow to ship from port to port (logistic costs). Thus, pollution-intensive industries face higher costs, possibly affecting the trade patterns. If those results are true, proximity to users should be taken into account in any empirical study attempting to test the pollution haven hypothesis. They conclude that "taking into account political economy determinants of multinational behavior in host countries and the internal trade-offs between leveling up emission standards (to avoid dealing with multiple technologies) and cutting abatement expenditures, overall this literature finds no evidence of havens, but rather of 'halos'.[78]"

Third, recent developments in the field of economic geography teach us important lessons about the dynamics of location decisions. Among them, spillovers have largely proved their share of importance. Millimet et al. (2011) raised concerns about biased results if spillovers are not taken into account. For example, it can be that weak environmental regulations attract a first wave of multinational firms and the second wave consists firms attracted by the hub of multinational firms that has formed for lower regulatory standards in the first place. Typical economic geography arguments for the agglomeration of firms include knowledge spillovers, sharing shipping costs of intermediate inputs, etc. In such situation, the coefficient of environmental regulation will be biased. In addition, the number of multinationals established in a country raises their lobbying power and efficiency (Cole and Fredriksson, 2009). Since developing countries are often associated with high levels of corruption, and corrupted governments are easy targets for lobbys, then corruption contributes to firms agglomeration and should be taken into account.

6.2 Anticipation of trade liberalization

Looking at the trade flows also present risks of bias. Comparing the import – export ratio of clean and dirty products before and after trade liberalization should face intense scrutiny. For example, Iacovone and Javorcik (2012) show that Mexican firms underwent quality upgrade of their goods in anticipation of the upcoming NAFTA back in the 90s (one year before a product starts being exported). The process of quality upgrading is not continuous since the authors find no evidence of quality upgrading after the

[78] Grether and Melo (2003), p. 21.

variety starts being exported. If those quality upgrade concern dirty products, since the authors proxy quality with domestic price premium, the value of Mexican exports would increase. Therefore, the mere anticipation of a trade agreement would decrease the difference between pre and post liberalization import – export ratios. For example, manufacturing sector A upgrades its quality, proxied by a price increase. Consequently, the value of Mexican exports increases and the ratio of import – export decreases. This already happens before trade liberalization, implying less liberalization-induced difference in pre and post NAFTA import – export ratios. One question remains: why did Mexican firms improve product quality? If they did it in order to meet the US environmental standards, it would be an argument against the pollution haven hypothesis.

7 Conclusion

The increasing environmental awareness has led policy makers to design pollution abatement schemes in order to tackle the pollution problems, considered by economists as an externality. These schemes typically consist in market based instruments (e.g. pollution taxes) or classic environmental standards. The pollution haven hypothesis is built on the assumptions that both types of regulations incur costs to firms. Since developed countries exhibit more stringent environmental regulations than developing countries, the pollution haven hypothesis predicts that the developed countries will stop producing pollution-intensive goods, but rather specialize in clean industries and import pollution-intensive goods from developing countries costs.

The pollution haven hypothesis has gained attention in the 1990s, at the time the NAFTA was implemented, since it predicted a relocalization of U.S. polluting industries towards Mexico, thus an economic disaster for the U.S and an environmental disaster for Mexico. Despite the fairly intuitive impact of environmental regulations on trade patterns, until now the empirical literature has failed to significantly prove the validity of the pollution haven hypothesis. Early studies surveyed by Dean (1992), Levinson (1996) and Copeland and Taylor (2004) found either no (or, in some cases, counter-intuitive) effects of environmental regulation costs on outputs or exports. When found, evidence of a causal effect was weak. Some took this weakness as a proof against the pollution haven hypothesis since the existing evidence of strong causal effects for other determinants of trade would have dominated over the pollution haven hypothesis anyway. For instance, capital abundance might play a role in shaping the international trade patterns, since pollution-intensive industries are capital-intensive. Therefore, countries with low capital endowment – typically found in the developing economies – would *not* specialize in pollution-intensive industries.

The critical review of the pollution havens causality chain has shed light on more subtle mechanisms that might add to the difficulties to prove the pollution haven hypothesis. First, looking at the link between country characteristics and environmental regulation, we have seen that income growth does not immediately translate into more stringent regulations. Indeed, the environmental Kuznets curve states that environmental quality is a bell-shape function of income per capita. Some authors take the declining slope of the environmental Kuznets curve as the proof that pollution havens exist. Second, we have also seen how factor mobility can reduce regulation in the short run. Third, strategic interactions might arise when a country retains a certain level of discretion in his own trade policy. Fourth, we saw how openness to trade together with political stability leads to more stringent environmental regulation than trade openness alone. Finally, evidence was presented on the role of local communities in shaping environmental regulation. Looking at the link between environmental regulation and production costs, we have covered some evidence that environmental regulation increases both direct and indirect costs. However, another branch of the literature argues that environmental regulation is a vector of profitability and competitiveness. According to the Porter hypothesis, the costs of regulation are offset by innovation and technological upgrading. Recent literature reviews reveal that negative effects of environmental regulation on competitiveness should definitely not be taken for granted. Looking at the link between production costs and trade flows or FDI, we have seen that the relative magnitude of environmental regulation-induced costs compared to other costs is important to take into account, rather than looking at numbers alone. Finally, we recommended to study the pollution-intensiveness embodied in trade flows instead of trying to link pollution levels with trade flows for more reliable results.

The last section covered two main empirical difficulties that every researcher faces when looking into pollution havens. First, measuring pollution is not an easy task since data on pollution is poorly recorded in developing countries. Moreover, linking pollution to firm-level production is challenging given the disaggregated level of data. Measuring pollution stringency faces another problem, that is, how to conceive and define pollution stringency from a methodological point of view. The second main difficulty with pollution havens is that the variable for environmental policy was proved to be endogenous. Advances in economic geography have also added complexity to the task.

Overall, there is still no consensus on the pollution haven hypothesis. It seems like the more economic science evolves, the more complex proving the pollution haven hypothesis becomes. Therefore, it is not my intention to take a side in the debate. However, I hope that the originality of the different path explored have enriched the debate.

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