

Foreign direct investment and environmental policy: have location factors been neglected?¹

by

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Abstract:

This paper analyses the effect of asymmetric environmental policies on the international strategies of firms, when countries differ in terms of market size and barriers to trade and FDI have been removed. It contributes to the debates on the Pollution Haven Hypothesis and on the risk of “carbon leakage” in the EU. A simple model with endogenous plant location is presented, considering both a symmetric and an asymmetric scenario. It is shown that, if countries have the same size and there are no other sources of asymmetry, a more stringent pollution tax unilaterally adopted will always lead to some form of delocalisation. However, in an asymmetric context, if the more stringent environmental policy is introduced by the larger country, and unit transport cost is high with respect to the pollution tax, it is possible that the firm’s location choice will not change. The model suggests that environmental taxes should be industry-specific, accounting for the geographical mobility of the industry. In addition, the analysis implies that environmental rules should not be uniform worldwide, but should take account of differences in countries’ market size and thus ability to attract production.

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1. Introduction

The impact of globalisation on the level of pollution is at the centre of a hot debate, involving experts from different disciplines, politicians and NGOs. There is disagreement on various issues. It is not clear which are the instruments of environmental policy to be preferred in the present context of highly integrated economies, and whether a uniform environmental policy should be applied in all countries or instead country-specific environmental policies should be adopted². There is no agreement thus on the degree of flexibility to be introduced in a possible future international agreement on the environment. Furthermore, there is a great deal of uncertainty on the repercussions of different forms of environmental policies on the competitiveness of firms. The issue is of great importance, both for the negative effect of pollution on the population, and for the impact of such policies on economic growth and income distribution. An analytical approach, helping to understand the complex chain of effects and the possible trade-offs, may contribute to dispel some of these uncertainties, thus offering useful suggestions for devising environmental policies both at the national and international level.

Globalisation, due to market integration via trade and foreign direct investment (FDI), may influence the level of pollution in a country through various channels (effects on growth, on the composition of income, technological effects, effects on environmental policy). On the other hand, countries' environmental policies may influence firms' location decisions, thus affecting trade and FDI.

An important aspect of the interaction between globalization and environment is the interplay of environmental policy and FDI. A key issue in the literature is whether globalization will lead to the emergence of "pollution havens". This issue is inherently linked with firms location decisions and thus with the effect of environmental measures on the choice of international strategy. On the other hand, national governments may be influenced by firms' international mobility when setting environmental standards.

The pollution haven hypothesis (PHH) predicts that firms active in sectors with high pollution intensity, and operating in countries adopting more restrictive policies, after the liberalisation of trade and FDI, will transfer production abroad, and will serve the domestic markets from these new foreign plants (see e.g. Copeland and Taylor, 1994, 1995, 2003, 2004; Fullerton, 2006). As environmental policy becomes more restrictive with economic growth (being the environment a normal good), it is expected that in highly polluting sectors

production will move from developed to developing countries. Thus, due to globalisation and asymmetries in environmental policy, it is foreseen that developing countries will become the dustbin of the world, and on the other side developed countries will loose entire production sectors with negative repercussions on employment.

The PHH debate began in the 1990s, when NAFTA was launched (Grossman and Kruger, 1995). The discussion at that time centred on the possibility that firms in pollution intensive sectors will migrate from US and Canada, moving production to Mexico. The debate has been revived recently when the EU has adopted unilaterally more restrictive environmental policies. The Spring 2007 European Council decided that the EU should maintain the international leadership in facing climate change challenges, agreeing upon binding targets to reduce greenhouse gas emissions by 20% by 2020 compared to 1990, and adopting targets on renewable energy and energy efficiency. In January 2008 an action plan (Climate Action, Energy for a Changing World) was introduced to implement such decisions.³ These policies create a more stringent environmental regime in EU as compared to other geographical areas, and thus may have important repercussions on the competitiveness of European firms, particularly in energy-intensive industries, and potentially stimulate European firms to delocalize production (the so called “carbon leakage” problem)^{4,5}.

A vast literature has dealt with the possibility of “pollution havens”. Most of these studies analyze the interaction of trade and environment (Copeland and Taylor, 1994, 1995, 2003, 2004; Fullerton, 2006), without taking into account the issue of firms’ geographical mobility. The emphasis rests on international trade, and the analysis of firms’ location strategies is set aside. In other words, the phenomenon of FDI is ignored, although it represents an essential part of the PHH debate. Moreover, while theoretical works converge in predicting a shift in production from developed to developing countries in pollution intensive sectors, empirical research has not supported such predictions. In fact we may talk of a “pollution havens” paradox.

In this paper we will contribute to the PHH and “carbon leakage” debates analysing the effect of asymmetric environmental policies on the international strategies of firms, when countries differ in terms of market size. In section 2, we will discuss what the formal literature

² The World Bank is debating whether a uniform global tax or a country-specific tax should be adopted.

³ See Commission EC (2008).

⁴ The term “carbon leakage” is used to indicate the possibility of EU firms relocating their factories, jobs and thus emissions to third countries with less strict emission regulations.

⁵ In the case of pollution havens (and “carbon leakage”), we are dealing with pollution related to production. Measures aiming to emissions related to consumption (such as in transport) do not affect firms’ location choices.

suggests on the interaction between FDI and environmental policy, highlighting some important aspects of the phenomenon which have been largely overlooked. In section 3, we will discuss what are the main characteristics of pollution intensive sectors, and thus the stylized facts on which to build a model. In section 4, a simple model endogenizing location will be presented, considering both a symmetric and an asymmetric context. The role of market size asymmetries will be explored. The impact of asymmetries in environmental policies on firms location in different scenarios will be considered in section 5. We will maintain that empirically grounded models endogenizing location may give an important contribution to explain the pollution haven paradox. Section 6 presents some implications for empirical research and section 7 draws the main conclusions and policy implications.

2. Formal literature on FDI and environmental policy

When addressing the interaction between FDI and environmental policy, we have two main actors: governments choosing environmental policy and firms deciding where to locate production. We have a vast literature endogenizing one or both of these decisions, in some case accounting for, and in other ignoring, strategic aspects in these decisions (see Table 1).

Table 1 Formal literature on FDI and environmental policy

	Exogenous Env Policy One Country	Exogenous Env Policy Two Countries	Endogenous Env Policy One Country	Endogenous Env Policy Two Countries
Exogenous Location One Firm				
Exogenous Location Two Firms			Cole et al (2006)	Bayindir-Upmann (2003)* Kayalica & Lahiri (2005)**
Endogenous Location One Firm		Motta & Thisse (1994)		Markusen et al (1995) Rauscher (1995)*** Hoel (1997)*
Endogenous Location Two Firms		Markusen et al.(1993) Markusen (1997)		Ulph & Valentini (2001)**

Notes: * Integrated markets, no transport costs
 ** Third country model, no transport costs
 *** No transport costs

A first generation of models⁶, which appeared in the 1990s (e.g. Markusen et al 1993, 1997; Motta and Thisse, 1994), focused on explaining the effect of environmental measures on location decisions, and only the location decision was endogenized (see Table 1). These models were outgrowths of previous works on firms' international strategies, and thus framed to capture the major determinants of this choice.

The first model to account for the impact of environmental policy on firms' location decisions is Markusen et al (1993). This model is built to capture the direct and indirect –via induced changes in plant location - effects of environmental measures on welfare. The analysis is carried out considering environmental policy as exogenous and only one active government, focusing on local pollution. The model is an extension of work devoted to analyse firms' international strategy (Horstman and Markusen, 1992). Thus most of the key factors entering in firms' location decisions are considered: the model allows for plant and firm fixed costs and for transport costs connected with export. It is a two stage game with two countries of equal size and two firms. Firms decide at the first stage their location strategy (no entry, exporting, investing abroad), and at the second stage game they play a Cournot output game. The case in which a firm serves the world market only by producing abroad is ruled out by assumption. If a firm controls only one plant, that is assumed to be located in the home market. However, the pollution haven debate focuses exactly on the possibility that all production is moved abroad. The attention is on pollution tax when abatement is not possible, although the conclusions can be easily adapted to environmental restrictions leading to increasing marginal cost of pollution when abatement is possible. It is shown that the effects of an environmental tax are heavily context-dependent. The possible induced changes in market structure, which have major welfare repercussions, are a function of the parameters considered.

The main conclusion is that, in order to define optimal environmental measures (that is measures which maximize the country's social welfare), it is crucial to endogenize market structure. Environmental policy, due to plant location shifts, may result in major discontinuous changes in welfare. If environmental policy ignores the induced effects on plant location, major mistakes can be done, with high costs in terms of welfare. A tax, which would be optimal with unchanged plant location (optimal “exogenous” tax), may instead lead to a fall in welfare due to unpredicted shifts in market structure.

⁶ The international business literature offers interesting contributions on FDI and environment (Dunning and Lundan, 2008; Brewer and Lundan, 2006; Lundan, 2004; Lundan, 2003). In the future, this paper will be extended to integrate contributions from the IB literature.

Also Motta and Thisse (1994) try to understand the conditions under which strict environmental regulations lead domestic firms to relocate their activities and, more generally, to identify the welfare effect of such a policy. They consider two countries and two firms; however the setting is simplified as only one firm chooses location and only one government may change environmental policy. The main difference with Markusen et al (1993) is that, when the game begins, firms are already established in their home country, which implies that plant costs in the home market are sunk. One of the two countries (country A) introduces a more restrictive environmental policy which increases variable costs in country A. It is shown that “in the presence of large fixed sunk costs, delocation is probably not the most natural outcome of such a policy. Furthermore, delocation does not necessarily imply a fall in domestic welfare.” (p. 574).

As to market size differences, the authors show that an increase in the size of the country imposing the restrictive environmental policy raises the likelihood that the firm based in that country will move production abroad. The authors however do not clarify that this counterintuitive result depends on the specific scenario considered. In fact they take into account the case in which the increase in marginal cost of production due to the environmental policy is higher than unit trading cost. In section 4 we will show that the relationship between the unit cost increase due to more stringent environmental regulations, such as a pollution tax, and unit transport cost is a key determinant of whether stricter environmental standards will result in production shifts, as suggested by the PHH.

In the FDI and environment literature the interest shifted quite early from endogenous location towards endogenizing environmental policy and analysing the strategic interaction between governments. During the last ten years, strategic environmental policy has been the main focus in this literature. In all the most recent studies the choice of environmental policy is endogenized considering a non-cooperative game amongst governments, while often taking the international strategy of firms as exogenous (Bayindir-Upmann, T., 2003; Kayalica M. Ö. and S. Lahiri, 2005; Cole, M.A., R.J.R. Elliot and G. Fredriksson, 2006). In a few papers both governments and firms decisions are treated as endogenous (Markusen, J.R., E.R. Morey and N. Olewiler, 1995; Rauscher, M., 1995; Hoel, 1997; Ulph and Valentini, 2001).

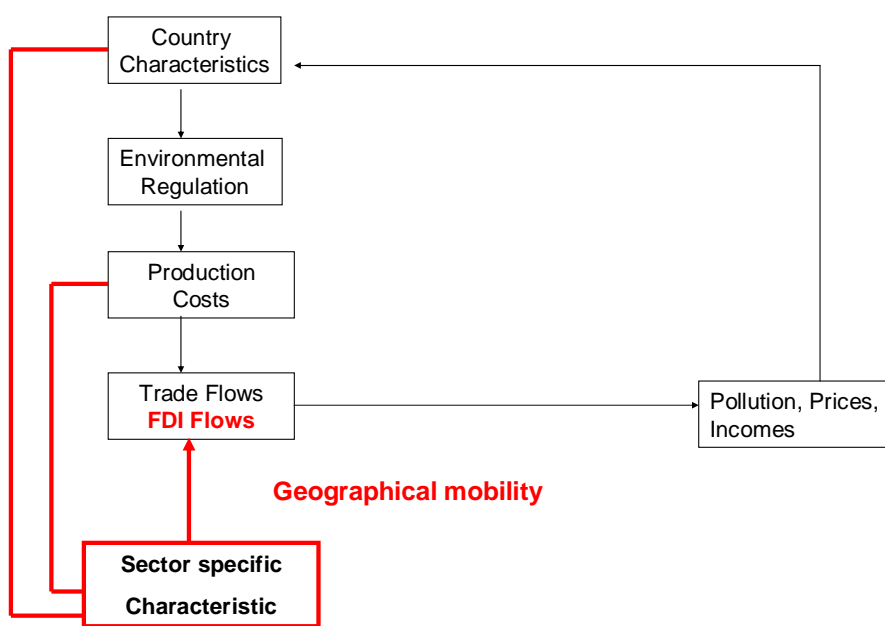
Models endogenizing both policy and location have become increasingly stylized, to the extent of losing many of the essential ingredients of the location decision. It is generally assumed that there are no transport costs, that firms serve only a third market, that firm profits

are not a component of welfare, that all countries have the same size, etc. (see Table 1). Thus, such models loose much of their interest for empirical work or policy decisions.

In this paper we will argue that key location factors should be put back in the front stage, in order to understand the logic of firms' reaction to the unilateral introduction of environmental measures, thus pointing to key factors to be considered in assessing the verisimilitude of the PHH and the risk of "carbon leakage" in EU.

Let us consider what are, according to Taylor (2006), Copeland and Taylor (1993, 2003, 2004), the logic steps behind the PHH, as illustrated in Fig. 1. The black (thin) arrows represent the causation mechanism highlighted by Taylor (2006). As environmental regulations become tighter with economic growth, country characteristics influence environmental policy, which in turn affects trade and FDI by increasing production costs. Environmental regulations

Figure 1 Unbundling the Pollution Heaven Hypothesis: the FDI story



Source: adaptation from Taylor (2006)

are considered in many studies as the sole determinant of location.

We will instead maintain that Taylor (2006) scheme loses some essential ingredients and thus should be enriched adding the links denoted by the red (thick) arrows. In order to understand the effect of environmental regulations on trade and FDI flows, we should account for sector-specific characteristics and furthermore for the interaction of sector-specific and

country characteristics which determine the extent of firms' geographical mobility (as indicated by the red (thick) arrows).

The literature shows that the effect of environmental measures on plant location is highly context-dependent. A large array of possibilities may emerge, depending on the parameters considered. The starting point is thus to identify the main features of pollution-intensive sectors, in order to define key stylised and empirically grounded facts on which to build a model.

3. Stylized facts and neglected location factors

The impact of industries on the environment may be measured by different indicators. Mani and Wheeler (1997) show that if the level of abatement expenditure per unit of output is considered, five sectors emerge as "dirty industries": Iron and Steel, Non-Ferrous Metals (such as aluminium), Industrial Chemicals, Pulp and Paper, and non Metallic Mineral Products (such as cement). On the other hand, if actual emission intensity (emission per unit of output) is considered the ranking is indicated in Table 2.

Table 2 Ranking of Pollution-Intensive Industries

Rank	Air	Water	Metals	Overall
1	371 Iron and Steel	371 Iron and Steel	372 Non-Ferrous Metals	371 Iron and Steel
2	372 Non-Ferrous Metals	372 Non-Ferrous Metals	371 Iron and Steel	372 Non-Ferrous Metals
3	369 Non-Metallic Min. Prd.	341 Pulp and Paper	351 Industrial Chemicals	351 Industrial Chemicals
4	354 Misc. Petroleum, Coal Prd.	390 Miscellaneous Manufacturing	323 Leather Products	353 Petroleum Refineries
5	341 Pulp and Paper	351 Industrial Chemicals	361 Pottery	369 Non-Metallic Min Prd.
6	353 Petroleum Refineries	352 Other Chemicals	381 Metal Products	341 Pulp and Paper
7	351 Industrial Chemicals	313 Beverages	355 Rubber Products	352 Other Chemicals
8	352 Other Chemicals	311 Food Products	383 Electrical Products	355 Rubber Products
9	331 Wood Products	355 Rubber Products	382 Machinery	323 Leather Products
10	362 Glass Products	353 Petroleum Refineries	369 Non-Metallic Min. Prd.	381 Metal Products

Source: Mani and Wheeler, 1997

These sectors have some common features. Mani and Wheeler (1997) find that dirty industries are relatively intensive in capital, energy and land. The importance of capital intensity (and thus fixed plant costs) in these sectors is underlined in several other studies (e.g.

McKinsey & Company (2006); Lundan, 2004; Cole and Elliot, 2005). In fact firms in these sectors produce bulk commodities with a high weight/value ratio and are thus characterized by large transportation costs (see Anderson and Wincoop, 2004; Hummels, 2007).

Let us consider as an illustration the case of cement production. This is a key industry, both from an economic and an environmental perspective. Cement is an essential input for the construction industry (highways, residential and commercial buildings, tunnels and dams) and cement plants account for 5% of global emissions of carbon dioxide (CO₂), the main cause of global warming⁷. This industry is very energy intensive⁸ and it is included in the EU Emission Trading Scheme (ETS)⁹. It is characterized by large capital start-up costs estimated by McKinsey (2006) to amount to 120 million Euro for a 1 million ton plant.¹⁰ Cement production is also characterized by high transport costs as compared to unit value. Transport costs from Northern Africa or the Eastern European countries outside the EU to Antwerp have been estimated to reach 36% of unit variable production costs.¹¹ Markets are served largely via local production. In 2006 trade of cement and clinker (the primary input to cement) represented only 7% of world cement consumption.¹²

Thus fixed plant costs and transport costs are essential components of a model analyzing firms' responses to environmental policies. In the model presented below the focus will be on the role of plant economies of scale (as different from firm economies of scale) and transport costs. The interplay of these factors with market size asymmetry in influencing firms' location strategies, and thus in influencing the probability of outcomes in line with the pollution haven hypothesis, will be discussed .

⁷ The New York Times, "Cement industry is at center of climate change debate", October 29, 2007. Cement manufacturing leads to CO₂ emissions both because CO₂ is released in the process of turning limestone into clinker as well as in the combustion of fuels (see Jacott, Reed, Taylor and Winfield, 2003).

⁸ Energy costs may represent 30-40% of production costs (Cembureau, Competitiveness of European cement industry, www.cembureau.be).

⁹ EU ETS, launched in 2005, is a cap-and-trade scheme. It covers energy-intensive industries such as power generation, mineral oil refineries, coke ovens, ferrous metal processing, cement, glass ceramics and pulp and papers. See McKinsey (2006).

¹⁰ It is classified as a capital intensive industry in European Commission (2007). It is thus not surprising that five large multinationals (Holcim, Lafarge, Cemex, HeidelbergCement, Italcementi) control around 58% in the EU25 market and 30% of the global cement market. See The Global Cement Report (7th edition), www.CemNet.com.

¹¹ McKinsey, 2006, p. 37. Jacott et al (2003) also indicate that transport of cement and clinker is extremely expensive providing data on Mexican exports to the US.

¹² See The Global Cement Report (7th edition), www.CemNet.com. However the trade intensity varies considerably within sub-sectors. See the "Commission services paper on Energy Intensive Industries exposed to significant risk of carbon leakage" available at <http://EurActiv.com> "EU considers industries exposed to "carbon leakage" 22 September 2008.

4. The model

We want to analyze the impact that a unilateral increase in the stringency of environmental policy has on the location strategy of the local firms. The focus will be on the role of different location factors, in particular on the interplay of transport costs, relative market size and plant specific costs. In order to highlight the essential economic mechanisms, the simplest case will be considered: a two country and one firm model, with endogenous location.

Let us consider an international monopolist based in country I, which can serve the foreign market via export. Then assume that country I introduces a pollution tax,¹³ creating more stringent regulations on pollution emissions as compared to country II. Such policy may have different repercussions on Firm 1's location strategy, as illustrated in Figure 2.

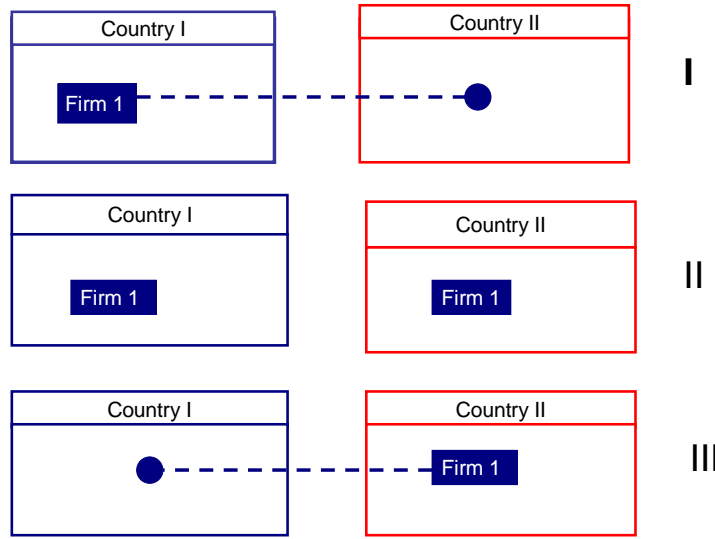
A first possibility is "no delocalisation" (case I in Figure 2). In such setting, the pollution tax will have no impact on Firm 1 location choice, as it will continue to produce in the home country and serve the foreign market via export. If, on the contrary, there is a shift of production abroad, this may be partial or total. We may have "partial delocalisation" (case II in Figure 2) if the environmental measures stimulate the local firm to substitute export with foreign production, leading to a partial shift of production abroad. The firm will undertake a market oriented FDI and have a plant in each country. The third case is "total delocalisation" (case III in Figure 2). Firm 1 will move all production abroad, and will export back to the home market. This is the case implicitly assumed in the pollution haven debate.¹⁴ A model should allow for all these possibilities, in order to understand under which conditions the different outcomes are more likely. It will thus be possible to identify which are the key factors driving firms' international choices and then which independent variables should be included in empirical analysis.

Market size asymmetries may play an important role. The studies analyzing the interaction of FDI and environmental policy generally assume that countries have equal market size. There are only a few exceptions (see Motta and Thisse, 1994; Mc Ausland, 2006). In

¹³ If many industries pollute and the firm considered is a price taker in a competitive market for permits, the pollution tax is equivalent to the price of a permit per unit of output, and the analysis can be extended to an emission trading system. See Markusen et al. (1993) and Alexeeva-Talebi et al. (2008).

¹⁴ It is not clear whether "carbon leakage" implies partial or total delocalisation. Moreover, there is no agreement yet on how to measure "carbon leakage". See "Report of the ad hoc meeting on the EEC working group on emission trading on carbon leakage and auctioning". See <http://www.ec.europa.eu/environment/climat/emission/pdf/finrep.pdf>

Figure 2: Possible effects on firms' location due a pollution tax unilaterally introduced by country I



Note: Firm 1 = local production; ● = export

Motta and Thisse (1994) the effect of relative market size is analysed only within very restrictive assumptions leading to counterintuitive results. It would be interesting instead to enquire how market size asymmetries influence the effects of environmental policy on firms' location strategy in different scenarios, in order to highlight their impact on the welfare implications of pollution policy.

4.1 Assumptions of the model

Let us consider an international monopoly. Before the introduction of the pollution tax, the producer (firm 1) is based in country I and exports to country II. Domestic and foreign inverse demand functions are assumed to be linear:

$$P_I = a_I - b_I q_{1,I} \quad (1)$$

$$P_{II} = a_{II} - b_{II} q_{1,II} \quad (2)$$

where $q_{1,K}$ denotes the output sold in country K (with $K = I, II$). The parameters a_K, b_K measure market size in the respective country. It is assumed that $b_I = b_{II}$, and thus the country index will be omitted. It follows that market size differences will be measured only by a_I versus a_{II} .

Production technology is characterized by a constant marginal cost c and a fixed cost G_K (with $K=I, II$ and $I=h$ while $II=f$) necessary to install a manufacturing plant. There is also a fixed cost at the firm level F which captures firm-specific activities such as advertising, marketing, distribution and managerial services. Transport costs per unit of export are indicated by the parameter s , while the pollution tax by t_I . We are considering industrial pollution and it is assumed that emissions are proportional to output.

As to the international strategy, the firm may choose to serve a foreign market via export or FDI. While export implies additional marginal (and unit) transport cost s , FDI involves additional plant specific fixed costs G_f (associated to the new plant in the foreign market).¹⁵ Thus export is the high marginal cost and low fixed costs option, while the reverse is the case for FDI. When total delocalisation takes place, Firm 1 will have to bear transport costs to transfer the goods produced in country II to the home market.

Profits of the firm depend on the market configuration, which is characterized by the number of plants controlled in the home and foreign markets. The notation $\pi^{n,m}$ indicates the firm profits in a given market structure, where $n \in \{0, 1\}$ indicates the number of plants in the home market (country I), and $m \in \{0, 1\}$ the number of plants owned in the foreign market (country II).

The objective functions in the different scenarios are:

Case I: no delocalisation, that is (1,0)

$$\pi_1^{1,0} = (a_I - bq_{1,I})q_{1,I} + (a_{II} - bq_{1,II})q_{1,II} - cq_{1,I} - (c + s)q_{1,II} - t_I(q_{1,I} + q_{1,II}) - F - G_h \quad (3)$$

Case II: partial delocalisation, that is (1,1)

$$\pi_1^{1,1} = (a_I - bq_{1,I})q_{1,I} + (a_{II} - bq_{1,II})q_{1,II} - c(q_{1,I} + q_{1,II}) - t_I q_{1,I} - F - G_h - G_f \quad (4)$$

Case III: total delocalisation, that is (0,1)

$$\pi_1^{0,1} = (a_I - bq_{1,I})q_{1,I} + (a_{II} - bq_{1,II})q_{1,II} - (c + s)q_{1,I} - cq_{1,II} - F - G_f \quad (5)$$

4.2 Optimal sales and equilibrium profits

¹⁵ This parameter also accounts for other additional fixed costs associated to FDI.

With "no delocalisation" (case (1,0)), which implies that Firm 1 produces only in country *I* and exports to the other country, we obtain that optimal sales and profits are given by the following equations:

$$\hat{q}_{1,I}^{1,0} = \frac{a_I - c - t_I}{2b} \quad (6)$$

$$\hat{q}_{1,II}^{1,0} = \frac{a_{II} - c - s - t_I}{2b} \quad (7)$$

$$\hat{\pi}_1^{1,0} = \frac{(a_I - c - t_I)^2}{4b} + \frac{(a_{II} - c - s - t_I)^2}{4b} - F - G_h \quad (8)$$

With "partial delocalisation" (case (1,1)), that is if Firm 1 chooses to serve the foreign market via local production opening a plant also in country *II*, we obtain that optimal sales and profits are as follows:

$$\hat{q}_{1,I}^{1,1} = \frac{a_I - c - t_I}{2b} \quad (9)$$

$$\hat{q}_{1,II}^{1,1} = \frac{a_{II} - c}{2b} \quad (10)$$

$$\hat{\pi}_1^{1,1} = \frac{(a_I - c - t_I)^2}{4b} + \frac{(a_{II} - c)^2}{4b} - F - G_h - G_f \quad (11)$$

With "total delocalisation" (case (0,1)), when Firm 1 moves all production abroad and the home market is served by the foreign subsidiary, we obtain that optimal sales and profits are given by:

$$\hat{q}_{1,I}^{0,1} = \frac{a_I - c - s}{2b} \quad (12)$$

$$\hat{q}_{1,II}^{0,1} = \frac{a_{II} - c}{2b} \quad (13)$$

$$\hat{\pi}_1^{0,1} = \frac{(a_I - c - s)^2}{4b} + \frac{(a_{II} - c)^2}{4b} - F - G_f \quad (14)$$

5. Effects of environmental policy in different scenarios

Three scenarios will be defined taking into account different possible sources of asymmetry. The effect of the introduction of a unilateral pollution tax in country *I* on the local firm's location strategy will be assessed within each scenario.

5.1 The full symmetry scenario ($a_I = a_H$, $G_f = G_h$, G_h not sunk)

We are considering here the case in which the two countries have the same size ($a_I = a_H$). In addition, fixed plant costs are equal in both markets, which implies that there are no additional fixed costs to enter a foreign market, such as for instance additional costs due to language difference or costs of controlling production from a distance. Furthermore, this scenario requires that the fixed costs associated to the home plant are not sunk; in other words either the firm is not yet established in the home market, or the economic life of the home plant has reached termination.

Comparing Eqs. (8), (11), (14) we can state:

Proposition I: *With full symmetry a more stringent environmental tax imposed by country I ($t_I > 0$) will always lead to some form of delocalisation (total or partial).*

Proof:

It can be easily shown that

$$\hat{\pi}_1^{0,1} - \hat{\pi}_1^{1,0} = \frac{1}{4b}[(a_I - c - s)^2 - (a_H - c - s - t_I)^2] + \frac{1}{4b}[(a_H - c)^2 - (a_I - c - t_I)^2] + (G_h - G_f) > 0$$

$\forall s$ given that $a_I = a_H$ and $G_h = G_f$. □

Thus, with symmetry in market size and plant costs, the profits associated to total delocalisation are always larger than the profits associated to no delocalisation. Therefore, transport costs do not influence the choice between home production and delocalisation.

However, transport costs do influence the characteristics of the process of delocalisation. In order to illustrate this point, it is necessary to consider the relative importance of transport costs as compared to the environmental costs faced by the firm. Thus we define as “low transport costs” the case with $s < t_I$, that is if unit transport costs are lower than the pollution tax; on the contrary we call “high transport costs” the case with $s > t_I$, that is if unit transport costs are higher than the pollution tax.

We can state:

Proposition II : *With full symmetry and low transport costs (i.e. $s < t_I$) delocalisation is total, that is all production is moved abroad when country I enacts unilaterally a more stringent environmental policy.*

Proof:

It is straightforward to show that $\hat{\pi}_1^{0,1} - \hat{\pi}_1^{1,1} = \frac{1}{4b} [(a_I - c - s)^2 - (a_I - c - t_I)^2] + G_h > 0$.

Since $G_h > 0$, a sufficient condition for this inequality to hold is that $s < t_I$ □

With full symmetry and low transport costs, there are no centripetal forces to compensate for the effect of the pollution tax which, by rising unit variable costs, stimulates the local firm to move production abroad

In addition we obtain:

Proposition III *With full symmetry and high transport costs ($s > t_I$) delocalisation may be total or partial.*

Proof:

It is easily found that

$$\hat{\pi}_1^{1,1} > \hat{\pi}_1^{0,1} \quad \text{iff} \quad \frac{(s - t_I)}{4b} [2(a_I - c) - (s + t_I)] > G_h \quad (15)$$

□

Note that the probability of partial versus total delocalisation is increasing in unit transport costs s , as the LHS of Eq. (15) is increasing in s .

Corollary

With high transport costs, economic growth makes the partial delocalisation equilibrium more likely. In fact the LHS of (15) is increasing in a_I , and with $a_I = a_{II}$ a rise in a_I may be interpreted as indicating a larger world market, with relative market size unchanged.

5.2 Market size asymmetry and plant costs symmetry scenario ($a_I > a_{II}$, $G_f = G_h$, G_h not sunk)

We introduce now market size asymmetry, with country I been larger than country II (i.e. $a_I > a_{II}$). At the same time, plant fixed costs are the same in both countries ($G_f = G_h$), thus plant fixed costs at home are not sunk.

We obtaine that, if the environmental tax ($t_I > 0$) is imposed by the large country ($a_I > a_{II}$), it is not anymore the case that some form of delocalisation will take place for all transport costs values. In other words, although with full symmetry delocalisation will take place whichever is the value of s , i.e. the (1,0) option can be ruled out, when the country with the more stringent environmental policy is the largest ($a_I > a_{II}$), the level of transport costs is crucial in determining whether or not market structure will change.

We could show that:

Proposition IV *With low transport costs ($s < t_I$), a more stringent pollution tax by country I will always result in all production shifting abroad (total delocalisation), as in the case of market size symmetry.*

Proof:

We have that

$$\hat{\pi}_1^{0,1} - \hat{\pi}_1^{1,0} = \frac{1}{4b} \left\{ [(a_I - c - s)^2 - (a_I - c - t_I)^2] + [(a_{II} - c)^2 - (a_{II} - c - s - t_I)^2] \right\} + (G_h - G_f)$$

and

$$\hat{\pi}_1^{0,1} - \hat{\pi}_1^{1,1} = \frac{1}{4b} [(a_I - c - s)^2 - (a_I - c - t_I)^2] + G_h$$

For these inequalities to be strictly positive a sufficient condition is that $s < t_I$,

given that $G_f = G_h$. □

To summarize, with low transport costs, market asymmetry does not play any role.

We have also found that:

Proposition V *With high transport costs ($s > t_I$), if the more stringent environmental policy is imposed by the large country, we may have that neither partial nor total delocalisation takes place.*

Proof:

Straightforward, as

$$\hat{\pi}_1^{1,0} > \hat{\pi}_1^{0,1} \quad \text{iff} \quad \frac{1}{2b} [a_I(s - t_I) - a_{II}(s + t_I) + t_I(t_I + s + 2c)] > 0 \quad (16)$$

$$\text{with } \frac{\partial(\hat{\pi}_1^{1,0} - \hat{\pi}_1^{0,1})}{\partial s} = \frac{1}{2b}(a_I + t_I - a_H) > 0 \quad (17)$$

$$\text{and } \frac{\partial(\hat{\pi}_1^{1,0} - \hat{\pi}_1^{0,1})}{\partial a_H} = -\frac{(s + t_I)}{2b} < 0 \quad (18)$$

while:

$$\hat{\pi}_1^{1,0} > \hat{\pi}_1^{1,1} \quad \text{iff} \quad G_f > \frac{(s + t_I)}{4b}[2(a_H - c) - (s + t_I)] \quad (19)$$

$$\text{with } \frac{\partial(\hat{\pi}_1^{1,0} - \hat{\pi}_1^{1,1})}{\partial s} = -\frac{1}{4b}[2(a_H - c) - 2s] < 0 \quad (20)$$

$$\text{and } \frac{\partial(\hat{\pi}_1^{1,0} - \hat{\pi}_1^{1,1})}{\partial a_H} = -\frac{(s + t_I)}{4b} < 0 \quad (21)$$

□

If both Eqs. (16) and (19) are verified, a more stringent pollution tax in the large country (country I) will not modify the local firm's location strategy. Note that both conditions (16) and (19) are decreasing in a_H (see (18) and (21)). Thus with a decrease in a_H , that is when the gap in market sizes becomes larger, the probability of choosing the no delocalisation strategy increases.

As to the effect of transport costs, we find that an increase in s , while decreasing the probability of total delocalisation due to Eq. (17), increases the likelihood of partial delocalisation due to Eq. (20).

We may conclude that total delocalisation is an unlikely outcome in sectors characterized by high transport costs, when environmental policy is enacted by the large country ($a_I > a_H$). The results in fact show that the probability of total delocalisation is decreasing in relative home market size and in s . Even if G_h is not sunk, market asymmetry associated to high transport costs may explain why a unilateral increase in the stringency of environmental policy by the large country may not result in local firms moving abroad, that is why it may not lead to outcomes in lines with the PHH.

In this setting, plant economies of scale (specifically the size of the foreign plant G_f) play a key role only in the choice between not changing location strategy and serving each market by local production ((1,0) vs (1,1)). With $G_f = G_h$, plant economies of scale instead do not influence the choice between producing only at home and total delocalisation ((1,0), vs (0,1)).

5.3 Plant costs asymmetry with market size symmetry scenario ($G_f > G_h$, $a_I = a_{II}$).

We now consider higher fixed costs abroad due for instance to additional costs of control or to the fact that the domestic plant is sunk and its economic life has not yet reached termination. We will focus on the case in which domestic plant costs are sunk ($G_h = 0$).¹⁶ The two markets are assumed instead to be symmetric.

We find that:

Proposition VI *When fixed plant costs are higher abroad, no delocalisation may be the optimal strategy both with low and high transport costs, even in the case of two symmetric markets.*

Proof:

It is straightforward to show that

$$\hat{\pi}_1^{1,0} > \hat{\pi}_1^{0,1} \text{ iff } G_f - G_h > \frac{1}{4b} [(a_I - c - s)^2 - (a_{II} - c - s - t_I)^2] + \frac{1}{4b} [(a_{II} - c)^2 - (a_I - c - t_I)^2]$$

and $\hat{\pi}_1^{1,0} > \hat{\pi}_1^{1,1}$ if Eq.(19) holds. □

Higher fixed plant costs abroad, as in the case when domestic plant costs are sunk, represent a powerful centripetal force and thus should be taken into account when assessing the probability that restrictive environmental measures unilaterally adopted will induce domestic firms to move production abroad. The key role of asymmetry in plant costs instead does not seem to be fully acknowledged in the “carbon leakage” debate currently undergoing in the EU.

Moreover, we can restrict the set of feasible outcomes, ruling out the possibility that some forms of delocalisation may become an equilibrium location strategy in different scenarios. We find that:

Proposition VII *When fixed plant costs are higher abroad, with low transport costs ($s < t_I$) partial delocalisation is never an optimal strategy, while with high transport costs ($s > t_I$) total delocalisation is never an optimal strategy.*

Proof:

¹⁶ The conclusions may be easily extended to $G_f > G_h$ with $G_h > 0$.

It is easily found that

$$\hat{\pi}_1^{1,1} - \hat{\pi}_1^{0,1} = \frac{1}{4b} [(a_I - c - t_I)^2 - (a_I - c - s)^2] - G_h. \text{ With } G_h = 0, \text{ we have that}$$

$$\text{sign}(\hat{\pi}_1^{1,1} - \hat{\pi}_1^{0,1}) = \text{sign}(s - t_I). \quad \square$$

We thus find that in the low transport costs scenario the only feasible outcomes are no delocalisation and total delocalisation, while in the high transport costs scenario the only feasible outcomes are no delocalisation and partial delocalisation

5.4 Market size and plant costs asymmetry scenario ($a_I > a_{II}$, $G_f > G_h$ or G_h sunk).

Let us consider both asymmetries jointly, and assume that at the same time country I is larger and it is more expensive to create a plant in the foreign market, thus fixed plant costs are higher in country II. In this scenario, the centripetal forces discouraging the firm from moving production abroad are stronger. Therefore the range of parameters for which unilateral environmental policy will result in firms delocalising production abroad is further reduced.

The possible outcomes in terms of the firm's location strategy are summarized in Table 3. It is interesting to notice that in two key scenarios, which capture crucial features of the present economic reality, total delocalisation can be ruled out as a feasible outcome, i.e. is never an optimal location strategy. In addition it emerges that no delocalisation is a feasible outcome in most cases.

6. Implications for empirical analysis

Theoretical and empirical research on the interplay of FDI and environmental policy seem to be moving in different directions. On one hand, the formal literature is shifting emphasis from location factors (and thus endogenous market structure) to endogenous environmental policy in a strategic context. At the same time, empirical research seems to be devoting greater emphasis to the role of location factors, although the role of plant economies of scale, transport costs and market size asymmetries has not been fully accounted for.

Table 3 The effect of a unilateral pollution tax on the local firm's location strategy under different scenarios

	$s < t_1$	$s > t_1$
Full symmetry	Total D	Partial D Total D
Market size asymmetry	Total D	No D Partial D Total D
Plant costs asymmetry	No D Total D	No D Partial D
Market size & plant costs asymmetry	No D Total D	No D Partial D

Note: D = delocalisation

Several recent papers have dealt with the “pollution havens paradox”. Some of these studies use trade data (considering net imports by industry as dependent variable). Interesting results are found by Ederington, Levinson and Minier (2005) on the role of the geographical mobility of industries (captured by low fixed plant costs and trade costs).

Studies using FDI data at the firm level (Smarzynska and Wei (2004); Spatareanu, (2007)) find evidence of an effect of stricter environmental policy on the volume but not on the composition of FDI. In other words, there is no indication that firms operating in more polluting industries are more attracted to countries with relatively weaker environmental standards than firms in less polluting industries. These studies however do not include among the independent variables plant economies of scale and transport costs.

There is no agreement in the literature that the issue of geographical mobility plays a key role. Several authors suggest that other factors than industry mobility may be critical in understanding whether the stringency of environmental regulation has a significant impact on local firms’ competitiveness. Thus Levinson and Taylor (2008) believe that several econometric and data issues are responsible for the mixed results so far obtained on the PHH and move forward in their empirical analysis in this direction.

The present analysis offers two main messages to empirical research on the pollution haven hypothesis. To start with, what matters are not transport costs in absolute terms, but

transport costs as compared to environmental costs (i.e. compared to the increase in unit variable costs due to the environmental measure). Secondly, if transport costs are higher than environmental costs (thus in a high transport costs setting), market size asymmetry plays a key role in determining the effect of an unilateral introduction of stringent environmental measures.

7. Conclusions and future research

This paper analyzes the impact of asymmetries in environmental policy on the international strategy of firms, when countries differ in terms of market size and barriers to trade and FDI have been removed. The analysis is set within the wider context of the debate on the pollution haven hypothesis, which predicts that firms active in sectors with high pollution intensity, and operating in countries adopting more restrictive policies, after the liberalisation of trade and FDI, will transfer production abroad, and will serve the domestic market from these new foreign plants. This discussion also focuses on the effect of unilaterally introduced environmental measures, when barriers to trade and FDI have been removed. The debate began in the 1990s, when NAFTA was launched and has been revived in 2007 when EU Heads of State agreed to the unilateral adoption of more restrictive environmental policies. The discussion in the EU centres on how real is the “carbon leakage” threat, i.e. the risk that such measures will stimulate European firms to delocalize production.

The aim of the paper is to show that the FDI perspective may contribute to the pollution haven and “carbon leakage” debates, calling attention on how plant fixed costs and transport costs, interacting with relative market size, affect the probability of shifts in firms’ international location strategy. In order to highlight the essential economic mechanisms, a very simple model has been presented, with two countries and one firm.

It is shown that, to understand whether environmental policy results in the shifting of production abroad, what matters is not transport cost in absolute terms, but unit transport cost as compared to the pollution tax. It also results that, if countries have the same size and there is no other asymmetry (full symmetry scenario), a more stringent environmental tax will always lead to some form of delocalisation, independently of the level of transport costs. On the other hand, in this scenario transport costs influence the characteristics of the process of delocalisation, that is whether partial or total delocalisation will take place. When countries differ in size and the more stringent environmental policy is introduced by the large country, if unit transport cost is high as compared to the pollution tax, it is possible that firms’ location will not change. It emerges that total delocalisation is an unlikely outcome in sectors

characterized by high transport costs, when environmental policy is enacted by the large country. We also show that when domestic plant costs are sunk, in the high transport costs scenario, total delocalisation cannot be an optimal strategy. Even if the home plant fixed costs are not sunk, market asymmetry associated to high transport costs may explain why a unilateral increase in the stringency of environmental policy by the large country does not result in local firms moving abroad.

The analysis, by calling attention on the role of the geographical mobility of industry and on the role of market size asymmetries, has several policy implications. It suggests that environmental taxes should be industry-specific, accounting for the key industry characteristics influencing geographical mobility. Furthermore, as relative market size is important in the high transport costs scenario, it implies that countries with different size should be allowed to adopt different environmental policies. Since the incentive to move abroad created by a pollution tax is greater in the case of a small country, small countries should be allowed to implement less restrictive environmental provisions. The analysis thus suggests that environmental rules should not be uniform worldwide, but should take account of differences in countries' market size and thus of the ability to attract production, allowing smaller countries to implement lower pollution taxes.

As to future research, the next step is to consider an international oligopoly. Then the model will be extended to take account of the effect of environmental measures not only on firms' international strategy but also on their innovative activities.

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