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Do International Environmental Agreements Affect Tax and Environmental Competition among Asymmetric Countries?

Thierry Madiès *, Ornella Tarola † & Emmanuelle Taugourdeau ‡§

Abstract

Developed and developing countries compete using various instruments including corporate taxes and environmental regulations in order to attract firms. They also commit to international environmental agreements with "common but differentiated responsibilities" (CBDR). We investigate how the principles of CBDR and of "in a position to do so" embedded in global environmental agreements affect optimal corporate taxes and environmental standards. We find that the latter depend only on the mitigation burdens imposed by international agreements. In other words, the burden of competition between countries is carried by corporate taxes, which depend among others on the level of firms' mobility costs and on production cost differentials. Interestingly, we find that developed countries are not necessarily worse-off in terms of payoffs under CBDR, while emerging countries "in a position to do so" are not necessarily harmed by assuming responsibilities.

Keywords: Tax Competition, Capital Integration, Global Pollution, Environmental agreements

JEL classification: H2, R3, R5, Q5.

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1 Introduction

Foreign direct investment (FDI) is one of the main drivers of globalization. FDI inflows to developing countries have increased much more rapidly than those to developed countries, with the share of worldwide FDI inflows going to developing countries increasing from 25.5% in 1982-1987 to 31.1% in 1994-1999, and developing countries accounting for more than 50% of inflows in 2007-2018 (UNCTAD, 2019)[1]. The governments of competing countries use different instruments, including corporate taxes and environmental standards in order to gain an advantage and attract FDIs[2]. Corporate tax rates have decreased in both high and low income countries by almost 20 percentage points over the last two decades and there is a long-standing literature, which shows that corporate taxation has a negative effect on FDI location and that tax competition is mainly responsible for the decline of corporate tax rates (Overesch and Rincke, 2011). There is also a long line of research dealing with the effects of environmental regulations on FDI with mixed results (**??**). Environmental regulations differ between countries depending on their level of development. Surveys generally show that policy makers and the general public have greater environmental awareness in high-income countries than in developing and transition countries (Standard Eurobarometer survey, 2019). The latter are also often accused of acting as pollution havens, although the evidence of this actually being the case is not clear-cut (see (Cole, 2004; Kheder and Zugravu, 2012; Dou and Han, 2019) for an in-depth discussion of this issue.). There is also some evidence of an inverted-U shaped income-pollution relationship, the so called environmental Kuznets curve (see Grossman and Krueger (1995) and Cole (2004) for a short survey): there is a turning-point income level for a variety of environment indicators, below which an increase in income deteriorates the environment, and above which economic growth improves the environment. Arrow et al. (1995) argue that policies that respond to changing preferences in the population are the underlying cause of these empirical observations, as environmental improvements are driven by increasing public attention to environmental amenities.

Countries do not only behave competitively however; they are also involved in international environmental agreements – among which agreements on greenhouse gas reduction – however difficult these are to enforce in practice. Examples of environmental agreements include the UNFCCC Framework Convention on Climate Change (1992), the Kyoto Protocol (1997) and the Paris Agreement (2015). The aim of our paper is to understand the effects of competition between developed and developing countries for FDI. We consider that the countries differ in terms of production costs and the initial number of firms present. More specifically, we

[1]UNCTAD. World Investment Report; United Nations: New York, NY, USA, 2019

[2]Studies using political economy arguments point out that that FDI can affect the degree of stringency of local environmental policy (**?**)

assume that countries strategically choose their corporate tax and environmental regulations to attract (imperfectly) mobile firms in the context of environmental agreements. An important sticking point is that international agreements generally consider developed countries to have contributed more to global warming and thus have a greater responsibility to reduce emissions than developing countries do. More specifically, our model accounts for the effects of so-called "common but differentiated responsibilities and respective capabilities" (CBDR) on tax and environmental competition between developed and developing countries. We also consider how the controversial phrase including "countries in a position to do so" to pollution mitigation efforts (see below for more details) may affect international competition for FDI. Finally, we identify the circumstances under which some countries win and others lose in terms of the payoffs of international competition for FDI.

The UNFCCC Framework Convention on Climate Change (1992) refers to so-called "common but differentiated responsibilities" (CBDR) and describes the social and economic conditions that underlie this criterion. The convention classifies countries into Annex I and non-Annex I, the former generally referring to developed countries and the latter to developing countries since historically, developed countries have emitted more carbon dioxide than developing countries.[3] Accordingly, countries tend to act according to their CBDR status.

At the 2011 United Nations Climate Change Conference (COP17), countries agreed that the next climate treaty should be applicable to all parties. The parties confirmed this principle three years later at COP20 in Lima, namely that countries "in a position to do so" should take action. However, this principle of differentiation was called into question at the Paris COP. While a number of Non-Annex I countries, represented by the Group of 77 and China stated their wish to maintain the 1992 division, industrialized countries pointed out that global emissions were increasingly originating from emerging nations such as China and India. China's per capita emissions are equivalent to the EU's. Moreover, rich states such as Singapore and oil-producing countries in the Arabian gulf are considered developing nations in the 1992 classification despite having high per capita emissions and considerable financial means. Developed countries, including the EU, argue that the world has changed since 1992 and that countries' responsibilities for, and capacities to mitigate pollution have evolved accordingly.

Surprisingly, the combination of tax competition with the strategic setting of environmental standards has mostly been studied in the field of public finance. The existing literature on emissions regulation and capital tax competition introduces pollution into Zodrow and Mieszkowski's (1986) and Wilson's (1986) workhorse model of capital tax competition. In their seminal paper, Oates and Schwab (1988)

[3] Despite its weak formal legal status, the effectiveness of the principle should not be dismissed. Its vision is reflected in two operational paragraphs in the FCCC (Article 3 and Article 7), in Principle 23 of the Stockholm Declaration, in the Paris Agreement and in the Preamble to the Kyoto Protocol.

model emissions “as if they are an input” along with capital in the production of a final good. They find that small countries refrain from taxing capital and set efficient emissions caps. Alternatively, Ogawa and Wildasin (2009) assume that a final good is produced with perfectly mobile capital, and emissions are proportional to capital use. They find that small countries set emissions taxes efficiently, regardless of whether pollution is local or transboundary. Applying Oates and Schwab (1988)'s modeling of emissions and the assumption of local pollution, Eichner and Pethig (2018) show that large asymmetric countries choose inefficient capital taxes and emissions caps. Taking up Ogawa and Wildasin's assumption of ”dirty” capital, Eichner and Runkel (2012) point out that capital taxes are inefficiently low when the capital supply is elastic rather than inelastic as in Ogawa and Wildasin (2009). Fell and Kaffine (2014) demonstrate that Ogawa and Wildasin's efficiency result depends on the assumption of no retirement of capital and fixed environmental damages per unit of capital. However, the latter result has recently been put into question by Yamagishi (2019), who points out that Ogawa and Wildasin's efficiency result crucially depends on the assumption that the level of environmental standards is exogenous (or to put it differently, that governments have no say in environmental regulations). Relaxing this assumption leads back to the more intuitive result that competition between countries or regions leads to weak environmental standards at equilibrium.

Our paper deviates from the literature on pollution and capital taxation in several respects. First, in contrast with the existing tax competition literature, we focus on imperfectly mobile firms (costly mobility) rather than perfectly divisible and mobile capital. This allows us to discuss the effects of one dimension of globalization, namely the increasing mobility of firms. Second, we assume that countries are asymmetric – one country is endowed with more firms and has higher production costs than the other – while most of the tax competition literature assumes symmetry (with the exception of Bucovetsky (1991), Wilson (1991), Cai and Treisman (2005) and more recently Mongrain and Wilson (2018)). More specifically, we assume that some countries are “developed” in the sense that they have more firms and higher production costs, while other, ”developing” countries host a smaller share of firms. Furthermore, rather than only dealing with the interactions between tax policy and environmental regulations resulting from international competition for FDI, our paper also (and mainly) focuses on how the (differentiated) implementation of CBDR and the principle of being “in a position to” share the burden of fighting pollution affects optimal tax policies, environmental standards, and ultimately countries' payoffs. To the best of our knowledge, this point has not been considered to date either in the environmental economics literature or the public finance literature. Note that we share with Ogawa and Wildasin (2009), Eichner and Runkel (2012) and Fell and Kaffine (2014) the assumption of transboundary pollution, but these studies focus on one-instrument policies, whereas we investigate strategic two-instrument policies.

Our paper lays out a non-cooperative game where a developed country and a developing country compete over their environmental standards (the laxer the environmental standards, the lower the fixed costs for firms are) and corporate taxes to attract internationally (imperfectly) mobile firms. Firms pollute when they produce and we focus on global pollution. The richer, more industrialized country hosts more firms than the poorer country, while the later has lower production costs than the former. Governments are assumed to maximize corporate tax revenues net of the environmental damage caused by firms' pollution. Developed and developing countries both have some leeway when choosing their environmental regulations. However, we account for the fact that they do not have the same level of environmental responsibility. We introduce the principle of CBDR in a very simple way through a parameter that weights pollution damage in the pay-off function differently for the developing and the developed country. Our model also accounts for the fact that emerging countries face increasing pressure to contribute to emissions abatement as they become "in a position to do so".

Optimal tax policies, environmental standards, and pay-offs result from three main forces. The principle of CBDR implies that environmental standards are tighter in the developed country than in the developing country. However, the developed country may have an incentive to reduce its corporate tax to offset its loss of attractiveness for mobile firms. This downward force is counterbalanced by the fact that the developed country, which initially hosts a larger number of firms, has lower tax-base elasticity than the developing country, which initially hosts fewer firms. Furthermore, tax-base elasticities and then the optimal tax gap between countries ultimately depend on mobility costs. Finally, the fact that the production cost gap favors the developing country also contributes to explaining the optimal corporate tax levels.

Our main results are the following. *First,* the optimal environmental standards set by the developed and the developing country depend only on the mitigation burden imposed on each country by international agreements. Interestingly, environmental standards are not affected by mobility costs. It is as if countries compete exclusively over corporate taxes, without using environmental regulations as a strategic device to attract firms. *Second,* the interaction between tax policies and environmental regulations (together with the production cost differential) implies that the developed country's optimal corporate tax is not necessarily higher than the developing country's as is generally the case in the literature on asymmetric tax competition. It is higher when the production cost differential is moderate and mobility costs are high. In particular, under CBDR, there is generally no need for the developing country to undercut the developed country on corporate tax at equilibrium, except when its comparative cost advantage is weak and mobility costs are high (to ensure the tax incentive to relocate to the developing country is high enough to make it attractive). By the same token, the developing country sets a lower corporate tax and laxer environmental standards than the developed country when cost differences are small and firms face high mobility costs. However, in this case, the developing

country loses out in terms of pay-offs. The developing country is generally a winner (in terms of pay-offs) and a net importer of capital but the developed country is less likely to lose when the the developing country's mitigation burden is above a certain threshold. If responsibilities are shared more equally with the developing country considered "in a position to do so", the developing country is always a net importer of capital; however, the rich country is more likely than under CBDR to do better than the developing country (even without being a net importer of firms).
The paper proceeds as follows. In the next section, we describe the main features of the model. Section 3 presents the non-cooperative equilibrium with two instruments. Section 4 deals with the payoff analysis and section 5 concludes.

2 The model

We consider an economy composed of two countries 1 and 2, with different numbers of firms, s_i $\forall i = 1, 2$, and $s_1 + s_2 = 1$[4]. We assume that country 1 has a higher number of firms, so that $s_1 \geq \frac{1}{2}$. The governments of each country levies a corporate tax t_i and set environmental standards α_i.
Firms produce a homogeneous good. Each firm is run by a worker-entrepreneur and is endowed with one unit of capital. The fixed quantity q produced by each firm is sold on a competitive world market at a given price. Without loss of generality, we normalize the price to one.
The production process is polluting. When producing output q in country i, a firm incurs a cost, $C_i(q, \alpha_i)$, with

$$C_i(q, \alpha_i) = c_i(q) + \frac{\mu}{2}(1 - \alpha_i)^2$$

The above function includes a variable cost of production, $c_i(q)$, with $\frac{\partial C_i(q,\alpha_i)}{\partial q} = \frac{\partial c_i(q)}{\partial q} > 0$, and a convex fixed cost, $\frac{\mu}{2}(1 - \alpha_i)^2$. The costs of production are lower in country 2 than in country 1 $c_1(q) > c_2(q)$.
The two sources of asymmetry (a higher initial number of firms and higher costs of production in country 1) imply that country 1 represents a developed (or industrialized country) and country 2 a developing (or emerging) country, and in the rest of the paper the two countries are referred to as such. As far as the fixed cost is concerned, $\alpha_i \in [0, 1]$ quantifies the *environmental policy stringency index* of country i.[5] When $\alpha_i = 1$, firms can pollute freely and are not required to make any green investments. When $\alpha_i < 1$, environmental regulations require firms to make costly

[4] Mongrain and Wilson (2018), for instance, uses the same source of asymmetry.

[5] The OECD Environmental Policy Stringency Index (EPS) is a country-specific measure of the stringency of environmental policies: "The OECD's environmental policy stringency (EPS) indicator aggregates information on selected environmental policies to create a composite measure of relative policy stringency across countries and over time (Botta and Kozluk, 2014)" - see https://www.oecd.org/economy/greeneco/How-stringent-are-environmental-policies.pdf, page 4.

efforts to reduce emissions, either via end-of-pipe measures or cleaner production techniques.[6] The higher α_i is, the less green firms are required to be in country i and the lower the fixed cost they face in this country is. In the fixed cost term, μ is the monetary cost per unit of effort that the firm has to bear to become greener. Without loss of generality, we set $\mu = 1$.

2.1 Firm location decisions

Firms are mobile and distributed over the interval $[0, 1]$ in decreasing order of their willingness to invest abroad. The willingness to invest abroad of firm l, initially located in country i, is denoted $x_{i,l}$. Following Pieretti and Zanaj (2011), we assume that relocating abroad costs firms a unit cost, $k > 0$. This mobility cost can be viewed as quantifying restrictions on international movements of capital (or firms): the higher this cost is, the more difficult it is for firms to relocate abroad. If firm l remains in country i, its profits are given by:

$$\pi^i_{i,l} = q - C_i(q, \alpha_i) - t_i \quad \forall i = 1, 2$$

where t_i is the corporate tax in country i.

Conversely, if firm l relocates from country i to country j, its profits are given by:

$$\pi^j_{i,l} = q - C_i(q, \alpha_i) - t_j - kx_{i,l} \; \forall i = 1, 2 \quad j = 1, 2 \quad \text{and} \quad i \neq j.$$

We assume that q is high enough to guarantee that should firm l relocate from i to j, its profits remain non-negative, i.e. $q \geq C(q, \alpha_j) + t_j + kx_{i,l}$.

The marginal willingness to relocate abroad x_i verifies the following indifference condition:

$$q - \frac{1}{2}(1-\alpha_i)^2 - c_i(q) - t_1 = q - \frac{1}{2}(1-\alpha_j)^2 - c_j(q) - t_j - kx_i \; i = 1, 2 \; j = 1, 2 \; and \; i \neq j \tag{1}$$

Thus, firms with $x_{i,l} < x_1$ are willing to relocate from i to j while firms with a $x_{i,l} > x_i$ prefer not to.

To simplify the notation for the rest of the paper, we denote by x the net flow of firms and $\Delta c = c_1(q) - c_2(q) > 0$ the cost differential with:

$$x = \frac{1}{k}\left(\frac{1}{2}(\alpha_2 - \alpha_1)(2 - (\alpha_1 + \alpha_2)) - (t_2 - t_1) + \Delta c\right) \tag{2}$$

and $x > 0$ when the net flow of firms is from 1 to 2 and $x < 0$ in the way reverse.

[6] Incineration plants for waste disposal are a typical example of end-of-pipe technologies. In contrast, cleaner technologies reduce the environmental impact of production by fully or partially replacing polluting technologies. The use of environmentally friendly materials is an example of cleaner production measures (Frondel et al., 2007; Mantovani et al., 2017).

2.2 Governments

Governments are assumed to maximize a payoff function that depends on tax revenues net of the pollution disutility induced by firms. Note that the payoff function allows for governments to be self-interested and concerned with the environment.

Formally, the payoff functions G_1 and G_2 of the two public authorities are:

$$G_i = R_i(\alpha_1, t_1, \alpha_2, t_2) - D_i(\alpha_1, t_1, \alpha_2, t_2),\ i = 1, 2$$

with

$$\begin{aligned} R_i &= s_i(1 - x_i)t_i \text{ when } i \text{ faces a net outflow of firms } (x > 0) \\ R_j &= ((1 - s_i) + s_i x_i)t_j \text{ when } i \text{ benefits from a net inflow of firms } (x < 0) \end{aligned}$$

and

$$D_1 = \phi_1 P_x; \qquad D_2 = \phi_2 P_x$$

with

$$\begin{aligned} P_x &= (s_1(1 - x))\alpha_1 + ((1 - s_1 - x s_1))\alpha_2 \text{ when } x > 0 \\ P_x &= (s_1 - (1 - s_1)x)\alpha_1 + (1 - s_1)(1 + x)\alpha_2 \text{ when } x < 0 \end{aligned}$$

The first component in the payoff function, R_i, represents the revenue from source-based taxation of firms located in country i with tax t_i. This component increases the payoff through the *tax base driver*, $s_i(1-x_i)$ in the country that attracts firms and $((1 - s_i) + s_i x)$ in the country that loses firms) and the *level driver*, t_i. The second component in the payoff function, D_i measures environmental damage: P_x represents the global emissions generated by firms. Global emissions can be decomposed in local emissions generated by firms located in the country and the environmental damage incurred locally due to foreign pollution. The parameters $0 < \phi_1 < 1$ and $0 < \phi_2 < 1$ represent the *mitigation burdens* of the corresponding countries, i.e. the different levels of pollution mitigation efforts imposed by international agreements on developed and developing countries. Since each country's payoff depends on global pollution, the only difference in terms of pollution between the two countries' payoff functions comes from the mitigation burden.

3 The equilibrium analysis

The two governments play a simultaneous game when choosing their level of environmental stringency, α_i, and the corporate tax t_i. We assume that mobility costs are not prohibitive, so that $x \neq 0$ for asymmetric countries.

Definition 1. *The Nash equilibrium is given by:*

$$(t_1^*(k, s_1, \Delta c), t_2^*(k, s_1, \Delta c), \alpha_1^*(k, s_1, \Delta c), \alpha_2^*(k, s_1, \Delta c))$$

Definition 2. *Country i is:*
i) a tax haven when firms move from j to i ***and*** $t_i^* < t_j^*$,
ii) a pollution haven when firms move from j to i ***and*** $\alpha_j^* < \alpha_i^*$.

In the following subsection, we first analyze the equilibrium assuming that countries follow the principle of *common but differentiated responsibilities* (CBDR), and therefore that the burden of emissions abatement is mainly carried by developed countries. In a second subsection, we will investigate how the equilibrium configuration changes when developing countries assume a greater share of responsibility (ϕ_2 increases), as they become "in a position to do so".

3.1 Common but differentiated responsibilities: $\phi_1 > \phi_2$

Before deriving the properties of the equilibrium under CBDR, let us state the conditions under which an interior equilibrium exists.

Lemma 1. *For $x > 0$, the two following conditions must be fulfilled to guarantee the existence of an interior solution:*
(i) $\Delta c \in [\Delta c_x, \Delta c^*]$
(ii) $k > k^*$
For $x < 0$, the two following conditions must be fulfilled to guarantee the existence of an interior solution:
(i) $\Delta c < min[\Delta c_{x<0}, \Delta c^*_{x<0}]$.
(ii) $k_x > k > k^*$

with $\Delta c^* \equiv \frac{k(1+s_1)}{s_i} + 3\phi_1\phi_2 - \frac{5\phi_1^2+\phi_2^2}{2}$; $\Delta c_x \equiv \frac{(\phi_1^2-\phi_2^2)}{2} - \frac{k(2s_1-1)}{s_i}$; $k^* \equiv \frac{(\phi_1-\phi_2)(5\phi_1-\phi_2)s_i}{2(s_1+1)}$; $k^x = \frac{(\phi_1^2-\phi_2^2)s_i}{2(2s_1-1)}$ *and,* $s_i = s_1$ *for* $x > 0$ *and* $s_i = 1 - s_1$ *for* $x < 0$.

Proof. See Appendix 1 for technical details. □

Condition (i) guarantees that $t_1^* > 0$ ($t_2^* > 0$ is verified for any Δc) and that x belongs to either $[0, 1[$ or $]-1, 0]$. Condition (ii) guarantees that condition (i) can be satisfied for some $\Delta c > 0$. Note that under CBDR, $k^* > 0$.

The previous lemma leads to the following corollary.

Corollary 1. *When $\phi_1 + \phi_2 < 1$, it does not exist any set of positive parameters $(\Delta c, k)$ which leads to an equilibrium characterized by a net flow of firms from country 2 to country 1 ($x < 0$).*

Proof. From condition (ii) for $x < 0$, $k^*_{x<0} < k_{x<0} \iff s_1 < \frac{2\phi-1}{3\phi_1-\phi_2}$ and when $\phi_1 + \phi_2 < 1$, we have $\frac{2\phi-1}{3\phi_1-\phi_2} < \frac{1}{2}$ which implies $k^*_{x<0} > k_{x<0}$. □

The policy instruments at the interior equilibrium are given by:

$$\begin{aligned}\alpha_1^* &= 1-\phi_1 \quad \text{and} \quad t_1^* = \frac{1}{6}\left(\frac{2k(1+s_1)}{s_i} - (\phi_1-\phi_2)(5\phi_1-\phi_2) - 2\Delta c\right)\\ \alpha_2^* &= 1-\phi_2 \quad \text{and} \quad t_2^* = \frac{1}{6}\left(\frac{2k(2-s_1)}{s_i} - (\phi_1-\phi_2)(\phi_1-5\phi_2) + 2\Delta c\right), \end{aligned} \tag{3}$$

with $s_i = s_1$ when $x > 0$ and $s_i = s_2 = 1-s_1$ when $x < 0$.

We immediately derive the following Lemma:

Lemma 2. *For all values of k and Δc, whenever $\phi_1 > \phi_2$, $\alpha_1^* < \alpha_2^*$.*

The equilibrium flow of firms is given by

$$x^* = \frac{1}{6k}\left(\frac{2k(2s_1-1)}{s_i} + 2\Delta c - (\phi_1^2-\phi_2^2)\right) \tag{4}$$

with

$$\begin{aligned} x^* > 0 &\Longrightarrow \Delta c > \Delta c_{x>0} \equiv \frac{(\phi_1^2-\phi_2^2)}{2} - \frac{k(2s_1-1)}{s_1}\\ x^* < 0 &\Longrightarrow \Delta c < \Delta c_{x<0} \equiv \frac{(\phi_1^2-\phi_2^2)}{2} - \frac{k(2s_1-1)}{1-s_1} \end{aligned}$$

with $\Delta c_{x>0} > 0$ for $k < k_{x>0} \equiv \frac{s_1(\phi_1^2-\phi_2^2)}{2(2s_1-1)}$ and $\Delta c_{x<0} > 0$ for $k < k_{x<0} \equiv \frac{(1-s_1)(\phi_1^2-\phi_2^2)}{2(2s_1-1)}$ and $k_{x>0} > k_{x<0}$.

Under CBDR therefore, environmental regulation policies depend only on the mitigation burden attributed to each country, regardless of mobility costs and the initial number of firms in either country. Environmental standards are not affected either by the asymmetry in production costs that contributes to the attractiveness of country 2. This is because the tax competition mechanism fully internalizes the effects of mobility costs, the production cost differential, and of the initial endowment of firms, isolating environmental regulations from these parameters at equilibrium. Indeed, the equilibrium corporate taxes t_1^* and t_2^* increase with the mobility costs k, although t_1^* increases more rapidly than t_2^*: when mobility costs increase, a tax increase is less penalizing for the developed country because the increase in tax revenues from firms initially located in the country outweighs the loss of tax revenue due to firms relocating to the developing country. Moreover, for a set of parameters $(\Delta c, k)$ leading to an equilibrium with $x > 0$, the equilibrium corporate taxes are decreasing functions of the initial number of firms in country 1 (s_1), and the reaction is twice as high in country 2 than in country 1 ($\frac{\partial t_2^*}{\partial s_1} = 2\frac{\partial t_1^*}{\partial s_1} < 0$). Indeed, in the case where more firms are initially located in country 1, country 2's is willing to be very aggressive to increase its tax base and encourage firms to relocate. Conversely, for given $(\Delta c, k)$ leading to an equilibrium with $x < 0$, the equilibrium corporate taxes are increasing functions of the initial number of firms in country 1 (s_1), and the reaction is twice as high in country 1 than in country 2 ($\frac{\partial t_1^*}{\partial s_1} = 2\frac{\partial t_2^*}{\partial s_1} < 0$).

Finally, the equilibrium corporate tax in country 1 is a decreasing function of the production cost asymmetry whereas the equilibrium corporate tax in country 2 increases with the cost asymmetry. On the one hand, higher mobility costs make international tax competition less and less fierce, enabling governments to increase taxes without causing an outflow of firms. On the other hand, since the production cost asymmetry pulls firms toward the developing country, the greater this asymmetry is, the lower the equilibrium tax set by country 1 has to be to avoid firm relocation. Symmetrically, the greater the asymmetry is, the higher country 2 can set its corporate tax without any decrease in its tax base.

The following Lemma describes how tax competition develops depending on the production cost differential Δc.

Lemma 3. *At the equilibrium, it holds that*

$$t_1^* \gtreqless t_2^* \Longleftrightarrow \Delta c \lesseqgtr \Delta\tilde{c},$$

with $\Delta\tilde{c} \equiv \frac{k(2s_1-1)}{2s_1} + \phi_2^2 - \phi_1^2$ *and* $\Delta\tilde{c} > 0$ *iff* $k > \tilde{k} \equiv 2\frac{s_1}{2s_1-1}\left(\phi_1^2 - \phi_2^2\right)$.

Proof. Immediately derived from the difference between the equilibrium corporate taxes: $(t_1^* - t_2^*) = \frac{k(2s_1-1)-2s_1(\Delta c+\phi_1^2-\phi_2^2)}{3s_1}$ when $x^* > 0$ while $t_1^* < t_2^*$ when the equilibrium implies $x^* < 0$ (See appendix 2 for more details). □

To understand the ranking of the taxes, let us decompose the three terms in the numerator of Expression (4): $2k(2s_1 - 1)$ captures the *tax base driver* whereby country 2 has a greater incentive to cut its corporate tax to attract firms than country 1 does. The second term $2s_1\Delta c$ represents the *production cost driver*, which makes the developing country more attractive than its rival, all other things being equal. Finally, the third term $s_1(\phi_1^2 - \phi_2^2) > 0$ captures the effect of the *mitigation burden*. This term enters negatively in the expression for x^*, meaning that CBDR tends to push firms toward country 1. This seems counterintuitive: more stringent regulations in country 1 (due to $\phi_1 > \phi_2$) should limit the attractiveness of this country, because they imply higher costs. However, given that $\phi_1 > \phi_2$, the higher ϕ_1 is, the lower the gap in corporate taxes $(t_1^* - t_2^*)$ is and the more attractive country 1 is. This attractiveness outweighs the environmental regulation differential in favor of country 2.

The interplay between the three forces described above leads to the following Lemma.

Lemma 4. *Whenever the production cost asymmetry is such that $\Delta c < \Delta c'_x$ and mobility costs are low, i.e. $k < k'_x$, country 1 sets a lower corporate tax than country 2, and this is sufficient to make country 1 a net importer of firms at equilibrium ($x^* < 0$).*
When $\Delta c > \Delta c_x$ and mobility costs are sufficiently high, i.e. $k > k_x$, firms relocate from country 1 to country 2 ($x^* > 0$), regardless of the respective levels of corporate taxes.

Combining the three Lemmas with the expression of the equilibrium flows of firms leads to the following Proposition.

Proposition 1. *Under CBDR, the developing country is a pollution haven if and only if the production cost asymmetry is sufficiently high ($\Delta c > \Delta c_{x>0}$,). It is also a tax haven iff $\Delta\tilde{c} > \Delta c$. The developed country is never a pollution haven, but it is a tax haven iff $\Delta c_{x<0} > \Delta c$.*

Proof. First, note that for $x > 0$ we have: $\Delta\tilde{c} > \Delta c_x$ for $k > \tilde{k}_x \equiv \frac{s_1(\phi_1^2 - \phi_2^2)}{2s_1 - 1}$ with $\tilde{k} > \tilde{k}_x$ and $\tilde{k}_x > k_x$. Thus, when $k > \tilde{k}$ it always holds that $\Delta c_x < \Delta\tilde{c}$. Symmetrically, when mobility costs are low, i.e. $k < k_x$, $\Delta\tilde{c} < \Delta c_x$. Thus

- $\Delta c > \max[\Delta c_x, \Delta\tilde{c}]$, then $t_1^* < t_2^*$ and $x^* > 0$
- when $\Delta\tilde{c} > \Delta c_x$, implying that $\Delta c_x < 0$, then $\Delta\tilde{c} > \Delta c > \Delta c_x$. In this case, $t_1^* > t_2^*$ and $x^* > 0$.

For $x < 0$, when an equilibrium exists it leads $t_1^* < t_2^*$. Thus for $\Delta c < \Delta c_x$ we have $t_1^* < t_2^*$ and $x^* < 0$.

□

Figure 1 depicts the different equilibrium configurations obtained as a function of the cost differential, Δc, and the mobility costs k [7]. The equilibrium only exists in the colored areas. The blue and grey areas are situations in which the developing country is a pollution haven ($\alpha_1^* < \alpha_2^*$ and $x^* > 0$); however, the grey zone is the only one where country 2 is both a pollution and a tax haven. The pink area represents the configuration in which country 1 is a tax haven ($t_1^* < t_2^*$ and $x^* < 0$) and country 2 adopts laxer environmental regulations. Areas are disconnected because the initial tax base determining the flow of firms from country i to country j is not symmetric when firms move from 1 to 2 or 2 to 1.

The economic intuition for these configurations can be expressed as follows: Above a certain cost differential, $\Delta c > \max[\Delta c_{x,x>0}, \Delta\tilde{c}]$ (blue area), country 2 can attract firms and become a net importer of capital just by relaxing its environmental regulations. It does not need to undercut its rival on corporate tax. When the cost

[7] We set $s_1 = 0.75$, $\phi_1 = 0.75$ and $\phi_2 = 0.6$ for the graph.

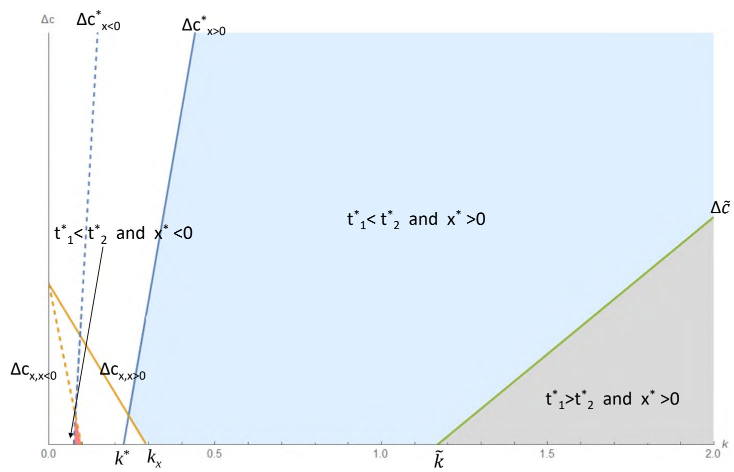


Figure 1: Equilibrium configurations for $\phi_1 > \phi_2 \iff \alpha_1^* < \alpha_2^*$

differential is such that $\Delta\tilde{c} > \Delta c > \Delta c_{x,x>0}$ (grey area), country 2 is forced to be more aggressive in reducing its corporate tax to attract firms, since the combined effects of its environmental policy, the cost differential and the tax base driver are no longer sufficient to generate an inflow of firms. This configuration arises if mobility costs are high, i.e. $k > \tilde{k}$, making firms less willing to move. It is worth noting that, when ϕ_2 is very much lower than ϕ_1, $\tilde{k}$ can be larger than 1. In this case, the grey area disappears and $t_1^* < t_2^*$ always holds.[8]

Finally, when the cost differential is such that $\Delta c < \Delta c_{x,x<0}$ (in the pink area), country 1 can attract firms by cutting its corporate tax, despite having more stringent environmental regulations. This outcome is the result of two drivers. First, the tax gap between t_2^* and t_1^* is a decreasing function of the mobility costs, and therefore widens when the latter decrease. This in turn makes firms' choice of location more sensitive to corporate taxes than to environmental standards (which are not affected by k). Second, the attractiveness of country 2 due to its lower production costs tends to shrink significantly. Overall, the much lower taxes in country 1 and the weak production cost advantage of country 2 mean that the latter cannot prevent firms from relocating to the developed country.[9]

Some remarks are in order. First, note that more stringent environmental standards do not always go hand-in-hand with a lower corporate tax. The developing country only chooses to reduce its corporate tax and relax its environmental stan-

[8]Notice that the threshold value of ϕ_2 for $\tilde{k} < 1$ is $\phi_2 > \sqrt{\phi_1^2 - \frac{(2s_1-1)}{2s_1}}$ with $\phi_1^2 - \frac{(2s_1-1)}{2s_1} > 0$ if and only if $s_1 < \frac{1}{2(1-\phi_1^2)}$.

[9]Note that the cost differential has to be very low for an equilibrium to exist.

dards when (i) mobility costs are very high and (ii) the production cost differential is small. Under these circumstances, country 2 attracts firms from country 1 even if the latter also behaves more aggressively in terms of its tax.

In contrast, even if mobility costs are high, country 2 does not need to adopt an aggressive tax policy to attract firms when its production costs are a sufficient amount lower than country 1's. The production cost advantage together with the initial tax base driver and the laxer environmental regulations bring about a net inflow of firms into country 2 at equilibrium .

3.2 The mitigation burden under the principle of CBDR

The above analysis shows that the strategic choice of environmental standards by policy-makers only depends on the allocation of the mitigation burden that stems from the principle of CBDR: $\partial\alpha_i/\partial\phi_i < 0$.

In addition to this direct effect of the mitigation burden on environmental policies, there are some indirect effects on the equilibrium configurations. The parameter ϕ_2 affects both $(\alpha_2^* - \alpha_1^*)$ and $(t_1^* - t_2^*)$[10]. In particular, when ϕ_2 increases, *(i)* the gap between the environmental standards $(\alpha_2^* - \alpha_1^*)$ decreases, which reduces the attractiveness of country 2. (ii) Moreover, when $t_1^* > t_2^*$, if ϕ_2 increases, the tax gap $(t_1^* - t_2^*)$ becomes wider, increasing the attractiveness of country 2. Following the same rationale, in the alternative case where $t_1^* < t_2^*$, a higher ϕ_2 reduces the tax gap $(t_2^* - t_1^*)$ and thus also reduces country 2's tax disadvantage. *(iii)* Third, a higher ϕ_2 means a lower $\tilde{k}$ and k_x, thereby increasing the range of k values with $k > \tilde{k} > k_x$ and the need for country 2 to engage in aggressive tax behavior $(t_2^* < t_1^*)$[11]. Finally, the higher ϕ_2 is, the higher $\Delta\tilde{c}$ and the lower Δc_x are (see Figure 2). This expands the range of $\Delta c-$ values for which $\Delta\tilde{c} > \Delta c > \Delta c_x$. At the extreme value of $\phi_2 = \phi_1$, $k_x = \tilde{k} = k^* = 0$ and $\Delta\tilde{c} > 0$ but $\Delta c_x < 0$ for all admissible values of k.

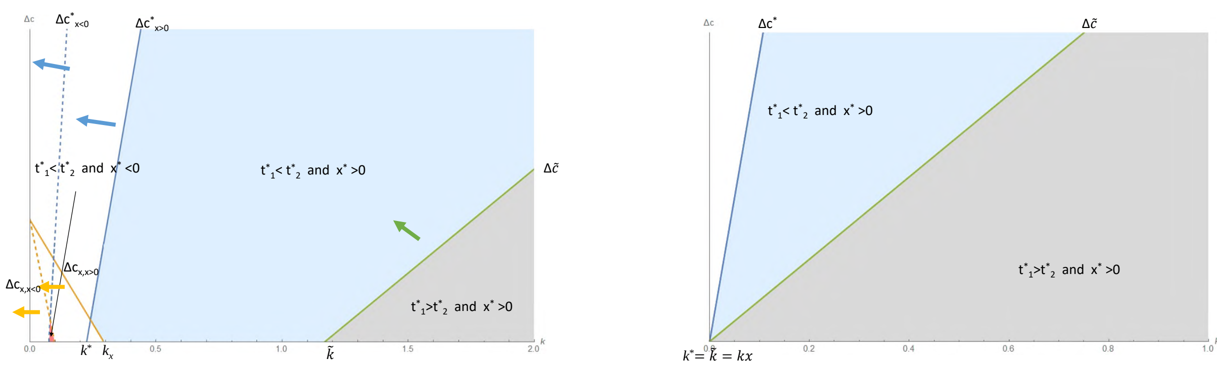
Accordingly, when the developing country takes on more of the environmental mitigation burden, i.e. ϕ_2 increases, the tax gap $(t_1^* - t_2^* > 0$ (resp. $t_1^* - t_2^* < 0))$ decreases (resp. increases). The attractiveness of the developing country is then further increased by the production cost advantage, which becomes more important, all other things being equal, since $\partial\Delta\tilde{c}/\partial\phi_2 > 0$ but $\partial\Delta c_x/\partial\phi_2 < 0$. More precisely, the set of conditions under which the developing country is a tax haven without being a pollution haven becomes increasingly broad as the mitigation burden for developing countries increases. The question that naturally arises is then what happens when the principle of CBDR is relaxed to such an extent that $\phi_2 \geq \phi_1$?[12] The equilibrium values of the policy instruments $(\alpha_1^*, \alpha_2^*, t_1^*, t_2^*)$ and the flow of firms

[10] See appendix 2 for more details

[11] See Appendix 1 for the effects of ϕ_2 on the difefrent thresholds of k

[12] The principle of CBDR is controversial and two reasons have been put forward by the EU and other industrialized nations in calling for a common effort based on *local abilities*. First, many countries classified as developing have or are experiencing considerable economic growth; and second, as a result, the contribution of developing countries to global emissions is increasing.

x^* are still given by equations (3) and (4)[13]. When $\phi_2 = \phi_1$, it is immediately clear that whatever the corporate taxes chosen by country 1 and country 2, $\alpha_1^* = \alpha_2^*$ and $x^* > 0$ always holds. The economic intuition behind this result follows from what we have already observed, namely the interplay between the tax base driver and the production cost driver.[14] Indeed, the asymmetry between country 1 and country 2 in terms of firm endowments makes country 2 more inclined to attract firms in order to enlarge its tax base (*tax base driver*). Accordingly, country 2 reduces its corporate tax more aggressively the higher ϕ_2 is. This in turn encourages firms to relocate from country 1 to country 2. In contrast, when country 1 undercuts country 2 (i.e. $t_1^* < t_2^*$), the tax gap $(t_2^* - t_1^*)$ decreases as ϕ_2 increases, meaning that the higher tax in the developing country does not deter firms from relocating to the developing country to benefit from lower production costs asymmetry (*production cost effect*). These effects are magnified by an increase in ϕ_2, all other things being equal.



(a) $\phi_1 > \phi_2$ (b) $\phi_1 = \phi_2$

Figure 2: Increase of ϕ_2

We can summarize the above findings in the following proposition:

Proposition 2. *When $\phi_2 \geq \phi_1$,:*
Firms always relocate from 1 to 2. The developed country is not a pollution haven or a tax haven at equilibrium.
The developing country is a tax haven when mobility cost are rather high($k > \tilde{k}$) while cost differential are rather low ($\delta c < \Delta\tilde{c}$).

Proof. Immediately derived from Lemma 5 and Expression (4). □

[13] The selection of the interior equilibrium and the parameter conditions ensuring the existence of the equilibrium are presented in Appendix 1.

[14] The competition driver term is zero in the expression for x^* when $\phi_1 = \phi_2$.

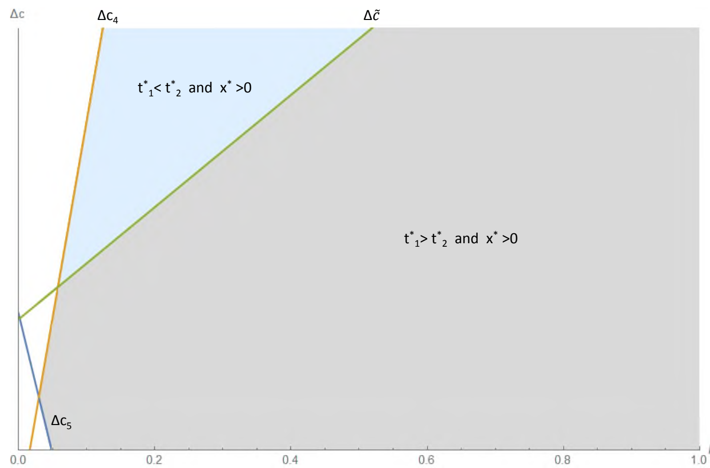


Figure 3: Equilibrium configurations for $\phi_2 > \phi_1 \Longleftrightarrow \alpha_1^* > \alpha_2^*$

Figure 3 depicts the equilibrium configuration when the developed country becomes "in a position to" contribute to pollution mitigation ($\phi_2 > \phi_1$ with $\phi_2 = 0.8$ and $\phi_1 = 0.75$). Lines Δc_4 and Δc_5 define the combinations of $(k, \Delta c)$ that guarantee the existence of an interior equilibrium. As explained above, if $\phi_1 = \phi_2$, an increase in ϕ_2 does not lead to firms relocating from 2 to 1. Indeed, at a given production cost differential, the two drivers of firm relocation (the difference in mitigation burdens and in tax bases), favor country 2. [15] When ϕ_2 becomes bigger than ϕ_1, the developing country has to be much more aggressive in terms of tax policy to attract firms (the grey area is larger in Figure 2(b) than in Figure 2(a)).

4 Payoff analysis

Let us now consider the equilibrium payoffs for different values of the mitigation parameters.[16]

Remember that the payoff function consists of two components: a *revenue component* and an *environmental damage* term[17]. When $\phi_i > \phi_j$, environmental damage reduces the equilibrium payoff of country i more than it does country j's. Thus,

[15]The mitigation burden gap attracts firms toward country 2, rather than being a disincentive, because as explained above, the tax response to the mitigation burden has a greater effect than the environmental standards themselves do.

[16]To avoid cumbersome details, we relegate the calculation of the equilibrium values of G_1^* and G_2^*. to Appendix B

[17]The revenue component accounts for the tax revenue generated by the set of firms located in country i and is driven by two effects: i.e. the *tax level driver* and the *tax base driver*. Note that the level of emissions does not depend on which country is considered since we consider global pollution.

under CBDR, global pollution is always perceived as more damaging in the developed country. To rank the equilibrium payoffs G_1^* and G_2^*, we need to consider the impact of the revenue component.

To this end, let us consider the payoff gap:

$$G_1^* - G_2^* = \frac{1}{3}\left(\frac{k(2s_1-1)}{s_i} + \phi_1^2 + 3\phi_2 - \phi_2^2 - 2\Delta c - 3\phi_1\right) \gtreqless 0 \tag{5}$$
$$\iff \Delta c \lesseqgtr \frac{1}{2}\left(\frac{k(2s_1-1)}{s_i}\right) + 3(\phi_2 - \phi_1) + (\phi_1^2 - \phi_2^2) \equiv \Delta c_G$$

with $\frac{\partial \Delta c_G}{\partial \phi_2} > 0$ and $\frac{\partial \Delta c_G}{\partial \phi_1} < 0$. Moreover, $\Delta c_G > 0 \iff k > \frac{s_i(3-\phi_1-\phi_2)(\phi_1-\phi_2)}{2s_1-1} \equiv k_G$. Since Δc_G increases with k, when $\Delta c_G > 0$, $\Delta c_G > 0 > \Delta c_x$.
Recall that $\Delta\tilde{c}$ is the threshold production cost differential that equalizes the corporate taxes of the two countries, while Δc_x is the threshold differential that stops the flow of firms between countries. Comparing with Δc_G leads to the following lemma:

Lemma 5.
- *When $\phi_1 \geq \phi_2$, $\Delta c_G \gtreqless \Delta\tilde{c} \iff \phi_1 \gtreqless 1 - \phi_2$.*
- *When $\phi_1 \leq \phi_2$, $\Delta c_G \gtreqless \Delta\tilde{c} \iff \phi_1 \lesseqgtr 1 - \phi_2$.*

Proof. Directly from $\Delta c_G - \Delta\tilde{c} = \frac{3}{2}(\phi_1 - \phi_2)(\phi_1 + \phi_2 - 1)$ □

Moreover, under CBDR, the analysis of Δc_G and Δc_x leads to the following proposition:

Proposition 3. *At any equilibrium with $x^* < 0$, it holds that $G_1^* < G_2^*$*

Proof. See Appendix 3 □

For low levels of k and Δc such that at the equilibrium, country 1 undercut country 2 and firms move from 2 to 1, country 1 is always worse off than country 2. Indeed, for country 1 the low level of the tax is very detrimental for the payoff that, in addition to a higher mitigation burden foe global pollution implies a lower level of payoff compared to country 2. For the rest of the analysis, we will concentrate of the equilibrium configurations with $x^* > 0$.

Figures 4 (for the CBDR scenario) and 5 (for the "in a position to do so" scenario) shows how the payoffs are ranked under several configurations[18]. The pink line representing Δc_G shifts leftward when ϕ_2 increases. It is then clear that an increase in ϕ_2 for a given ϕ_1 (comparing Figures 4(a) and 5(a), and 4(b) and 5(b)) makes country 1 more likely to do better than country 2. A rise in ϕ_2 makes

[18]the full taxonomy of payoff rankings is presented in Appendix 2

country 2 less attractive than country 1 in terms of environmental regulations. As a result, country 1 does not need to engage in a race to the bottom that would be harmful for its tax revenues. However, a more interesting point is that ϕ_2 is not the only key parameter. The payoff ranking also depends on the combination of ϕ_1 and ϕ_2 as stated in the following Proposition:

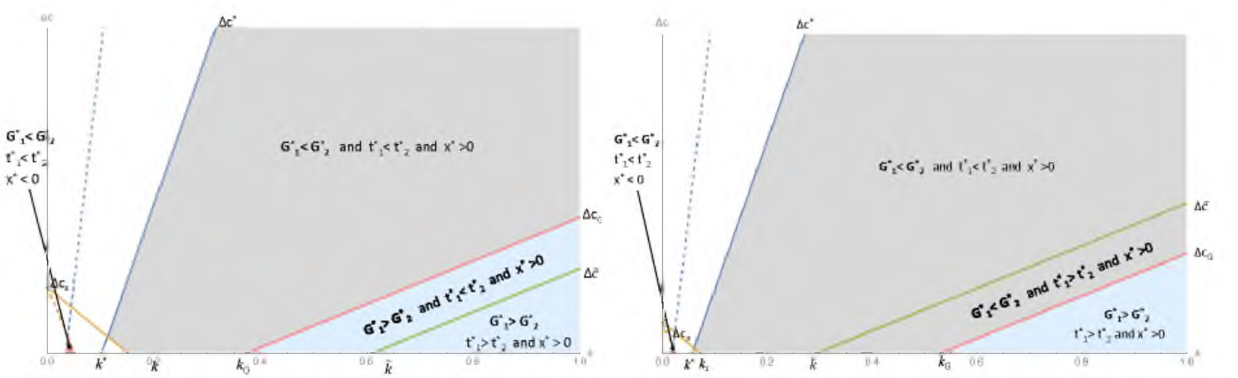
Proposition 4. *When the mitigation burden of the developed (resp. developing) country is sufficiently high ($\phi_i > Max[\phi_j, \frac{1}{2}]$ with $i = 1$ (resp. 2)), its equilibrium payoff is more likely to be higher than its rival's.*

Proof. Derived from Expression (5) and Lemma 5. □

As parts (a) and (b) of Figure 4 show, under CBDR, country 1 is more likely to have a higher payoff than country 2 if ϕ_1 is above a certain threshold, i.e. $\phi_1 > 1 - \phi_2$ (cf Lemma 5), which is the case for any $\phi_1 > Max[\frac{1}{2}, \phi_2]$. The economic explanation for this counterintuitive result comes from the impact of ϕ_1 on tax competition. Indeed, when the difference $(t_1^* - t_2^*)$ is positive, it decreases when ϕ_1 increases, while, when the difference is negative, it increases with ϕ_1. In both cases, a high ϕ_1 makes country 2 less attractive for firms, which has a positive effect on country 1's payoff, all other things being equal. Intuitively, when $\phi_1 > \phi_2$, the developed country has a greater incentive than the developing country to minimize environmental damage because it has a negative effect on its payoff. It therefore sets more stringent environmental regulations. All other things being equal, this pushes firms to leave country 1 and therefore has a negative effect on the revenue component of the payoff. To compensate for a potential loss of firms, country 1 either sets a lower corporate tax $t_1^* < t_2^*$ to increase the tax base effect, or it sets a higher corporate tax $t_1^* > t_2^*$ to increase the tax level effect. As a result, in spite of the greater environmental damage suffered by country 1, G_1^* may nevertheless be greater than G_2^*. Country 2's payoff is higher than country 1's, i.e. $G_2^* > G_1^*$, under two sets of circumstances. First, $G_2^* > G_1^*$ when country 2 is a net importer of capital ($x^* > 0$) while nevertheless having a higher corporate tax. In this case, the corporate tax effect and the tax base effect reinforce each other. Second, $G_2^* > G_1^*$ when country 2 is a net exporter of capital but the tax gap $(t_2^* - t_1^* > 0)$ is sufficiently large to offset the effect of firm relocation on tax revenues $(x^* < 0)$[19]. In this case the positive impact of the corporate tax effect on G_2^* is stronger than the negative impact of the tax base effect. Even in the alternative case with $t_2^* < t_1^*$, $G_1^* > G_2^*$. In this case, the effects of environmental damage and of the outflow of firms from country 1 to country 2 are outweighed by the higher tax in country 1. The tax level component dominates the tax base effect due to the relocation of firms from country 1 to country 2. Of course, as ϕ_2 increases, G_2^* tends to decrease because of the environmental damage term.

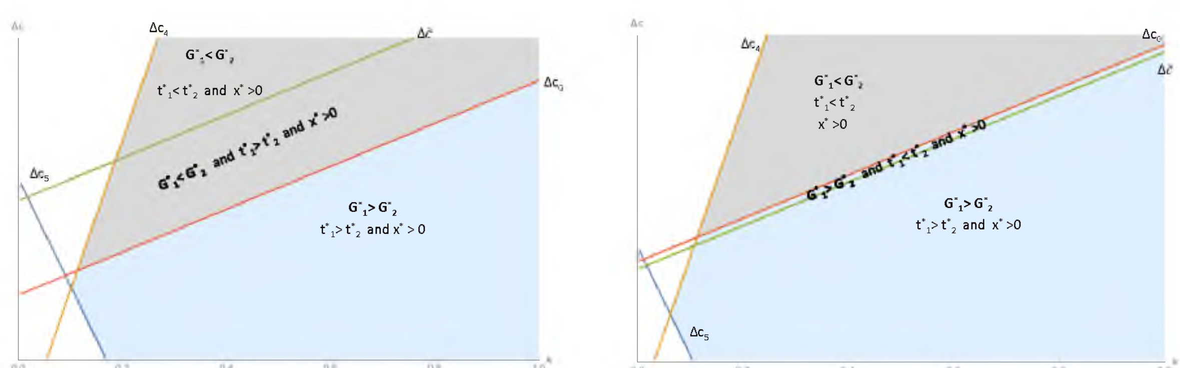
[19] for $\Delta c_x > \Delta c_G > \Delta c > \Delta \tilde{c}$

Symmetrically, when $\phi_2 > \phi_1$, the developing country's incentive to minimize environmental damage is greater than the developed country's. The payoff difference $G_1^* - G_2^*$ increases with ϕ_2, so when $G_1^* > G_2^*$, an increase in ϕ_2 increases the difference between G_1^* and G_2^* but when $G_1^* < G_2^*$, an increase in ϕ_2 reduces the difference between G_1^* and G_2^*. This is intuitive because the relative importance of the environmental damage term in country 2's payoff increases when ϕ_2 increases. Interestingly, in this scenario, country 2 is a net importer of capital, in spite of its more stringent environmental regulations, not only when $t_2^* < t_1^*$ but also when $t_2^* > t_1^*$. This is because the parameters Δc and k make firms less responsive to the tax gap. Under these conditions and for the reasons described above, G_2^* is more likely to be greater than G_1^* when $\phi_2 > 1 - \phi_1$, which occurs when $\phi_2 > Max[\phi_1, \frac{1}{2}]$.



(a) $\phi_1 + \phi_2 > 1$ ($\phi_1 = 0.75$ and $\phi_2 = 0.6$) (b) $\phi_1 + \phi_2 < 1$ ($\phi_1 = 0.4$ and $\phi_2 = 0.25$)

Figure 4: Ranking of payoffs when $\phi_1 > \phi_2$[20]



(a) $\phi_1 + \phi_2 > 1$ ($\phi_1 = 0.75$ and $\phi_2 = 0.9$) (b) $\phi_1 + \phi_2 < 1$ ($\phi_1 = 0.4$ and $\phi_2 = 0.55$)

Figure 5: Ranking of payoffs when $\phi_2 > \phi_1$[21]

5 Conclusion

This paper has shown that the fears of developed and of developing countries regarding the effects of international environmental agreements on their attractiveness for FDI are not necessarily justified. Indeed, the principle of CBDR does not always make developed countries less attractive, while assuming responsibilities when "in a position to so" does not always undermine the attractiveness of developing countries. Interestingly, the competition between developing and developed countries does not involve environmental standards, but rests mainly on corporate taxes, whose level depends on firms' mobility costs (i.e. economic integration). This may explain why there is little empirical evidence supporting the pollution haven hypothesis, except in the special case of very dirty industries.

The model could be extended in several directions. First, by considering firms operating in more or less polluting sectors. Some countries can be expected to "specialize" in dirty industries while others adopt a "not in my backyard" policy. Second, there is ample evidence that developing countries use tax incentives, such as tax holidays for certain industries, much more than developed countries do. Our model does not account for this possibility because it only considers positive corporate taxes. Tax incentives would of course help developing countries be more aggressive from a tax perspective, which would limit their loss of competitiveness when considered "in a position to" contribute to emissions abatement.

6 Appendix

6.1 Appendix 1

Maximisation program for $x > 0$

Maximizing the payoff function G_i with respect to the policy tools t_i and α_i leads to the following best response function:

$$t_1 = \frac{1}{4}\left(2k\frac{s_1}{s_i} + 2t_2 + \alpha_1(2 - \alpha_1 + 2\phi_1) - \alpha_2(2\alpha - \alpha_2 + 2\phi_2) - 2\Delta c\right)$$

$$t_2 = \frac{1}{4s_1}\left(2k\frac{1 - s_1}{s_i} + s_1(2t_1 + \alpha_2(2 - \alpha_2 + 2\phi_2) - \alpha_1(2 - \alpha_1 + 2\phi_1) + 2\Delta c\right)$$

with $s_i = s_1$ for $x > 0$ and $s_i = 1 - s_1$ for $x < 0$,

$$\alpha_i = \begin{cases} \frac{t_i + 2\phi_i + \alpha_j\phi_i + \sqrt{t_i^2 + 2(3k + 3t_j + 2(1-\alpha_2)^2 - 3\Delta c)\phi_i^2 - 2t_i\phi_i(1-\alpha_j+3\phi_i)}}{3\phi_i} \\ \frac{t_i + 2\phi_i + \alpha_j\phi_i - \sqrt{t_i^2 + 2(3k + 3t_j + 2(1-\alpha_2)^2 - 3\Delta c)\phi_i^2 - 2t_i\phi_i(1-\alpha_j+3\phi_i)}}{3\phi_i} \end{cases}$$

$$\alpha_j = \begin{cases} \frac{s_h(t_j + 2\phi_i + \alpha_i\phi_j) + \sqrt{s_h(t_j^2 + 2(3k + 3t_i + 2(1-\alpha_i^2) + 3\Delta c)\phi_j^2 - 2t_j\phi_j(1-\alpha_i+3\phi_j)}}{3\phi_j s_h} \\ \frac{s_h(t_j + 2\phi_i + \alpha_i\phi_j) - \sqrt{s_h(t_j^2 + 2(3k + 3t_i + 2(1-\alpha_i^2) + 3\Delta c)\phi_j^2 - 2t_j\phi_j(1-\alpha_i+3\phi_j)}}{3\phi_j s_h} \end{cases}$$

with $i=1$, $j=2$ and $s_h = s_1$ for $x<0$ and $i=2$, $j=1$ and $s_h = 1-s_1$ for $x<0$. We drop solutions which exhibit corner solutions ($x=1$ or $x=-1$) and those which do not fit with the initial conditions ($x>0$ or $x<0$). This equilibrium must satisfy the following conditions:

1. Concavity
2. $1 > x \geq 0$ or $0 \geq x > -1$
3. $t_1^A > 0$ and $t_2^A > 0$

The only interior equilibrium (t_i, α_i) is given by:

$$\alpha_1^* = 1-\phi_1 \quad \text{and} \quad t_1^* = \frac{1}{6}\left(\frac{2k(1+s_1)}{s_i} - (\phi_1-\phi_2)(5\phi_1-\phi_2) - 2\Delta c\right)$$
$$\alpha_2^* = 1-\phi_2 \quad \text{and} \quad t_2^* = \frac{1}{6}\left(\frac{2k(2-s_1)}{s_i} - (\phi_1-\phi_2)(\phi_1-5\phi_2) + 2\Delta c\right).$$
$$x^* = \frac{1}{6}\left(\frac{k(4s_1-2)}{s_i} + \left(\phi_2^2-\phi_1^2+2\Delta c\right)\right) \geq 0 \Leftrightarrow \Delta c \geq \Delta c_x$$

with $\Delta c_x \equiv \frac{1}{2}\left(\phi_1^2-\phi_2^2-2k\frac{2s_1-1}{s_i}\right)$
Also $\frac{\partial \Delta c_x}{\partial k} < 0$ and $\Delta c_x > 0 \iff k < \frac{(\phi_1^2-\phi_2^2)s_i}{2(2s_1-1)} \equiv k^x$. Moreover $\frac{\partial k^x}{\partial \phi_2} < 0$.
Let us denote :
$\Delta c_{x>0} \equiv \frac{1}{2}\left(\phi_1^2-\phi_2^2-2k\frac{2s_1-1}{s_1}\right)$ for $x>0$
$\Delta c_{x<0} \equiv \frac{1}{2}\left(\phi_1^2-\phi_2^2-2k\frac{2s_1-1}{1-s_1}\right)$ for $x<0$.
and $\Delta c_{x>0} > \Delta c_{x<0}$

Conditions $0<\phi_1<1$ and $0<\phi_2<1$ ensure that $0<\alpha_1^*<1$ and $0<\alpha_2^*<1$

1. At the equilibrium, local concavity is derived from:

$$\frac{\partial^2 G_1^A}{\partial \alpha_1^2} = \frac{-2k(1+s_1)+s_i(2\Delta c+\phi_2^2-13\phi_1^2)}{6k} < 0 \Longleftrightarrow \Delta c < \frac{k(1+s_1)}{s_i} + \frac{13\phi_1^2-\phi_2^2}{2}$$
$$\frac{\partial^2 G_2^A}{\partial \alpha_2^2} = \frac{2k(s_1-2)+s_i(\phi_1^2-13\phi_2^2-2\Delta c)}{6k} < 0 \Longleftrightarrow \Delta c > \frac{(s_1-2)k}{s_i} + \frac{\phi_1^2-13\phi_2^2}{2}$$
$$\frac{\partial^2 G_1^A}{t_1^2} = \frac{\partial^2 G_2^A}{t_2^2} = -\frac{2s_i}{k} < 0$$

So that local concavity holds for $\Delta c \in [\Delta c_1, \Delta c_2]$, with

$$\Delta c_1 \equiv \frac{(s_1-2)k}{s_i} + \frac{\phi_1^2-13\phi_2^2}{2} \quad \text{and} \quad \Delta c_2 \equiv \frac{k(1+s_1)}{s_i} + \frac{13\phi_1^2-\phi_2^2}{2}$$

2. For $x \leq 0$, $0 \geq x > -1$ holds for $\Delta c \in [\Delta c_3, \Delta c_{x<0}]$, with

$$\Delta c_3 \equiv \frac{k(s_1 - 2)}{1 - s_1} + \frac{\phi_1^2 - \phi_2^2}{2}$$

and $\Delta c_3 > 0 \iff k < \frac{\phi_1^2 - \phi_2^2}{2} \frac{1-s_1}{2-s_1} = k_3$.
For $x \geq 0$, $1 > x \geq 0$ holds for $\Delta c \in [\Delta c_{x>0}, \Delta c_4]$, with

$$\Delta c_4 \equiv \frac{k(1 + s_1)}{s_1} + \frac{\phi_1^2 - \phi_2^2}{2}$$

and $\Delta c_4 > 0 \iff k > \frac{s_1}{2(1+s1)}(\phi_2^2 - \phi_1^2) = k_4$

3. $t_1^A > 0$ and $t_2^A > 0$ hold for $\Delta c \in [\Delta c_5, \Delta c_6]$ with:

$$\Delta c_5 \equiv \frac{(s_1 - 2)k}{s_i} - 3\phi_1\phi_2 + \frac{\phi_1^2 + 5\phi_2^2}{2} \quad \text{and} \quad \Delta c_6 \equiv \frac{k(1 + s_1)}{s_i} + 3\phi_1\phi_2 - \frac{5\phi_1^2 + \phi_2^2}{2}$$

with
$\Delta c_6 > 0 \iff k > \frac{s_i}{2(1+s_1)}(5\phi_1 - \phi_2)(\phi_1 - \phi_2) = k^*$ and $\frac{\partial \Delta c_6}{\partial k} > 0$ and

$$\frac{\partial k^*}{\partial \phi_2} = \frac{s1(-3\phi_1 - \phi_2)}{1 + s1} < 0$$

Maximisation program for $x \geq 0$ ($s_i = s_1$)

Ranking the Δc_k terms, we have $\Delta c_x > \Delta c_1$ and $\Delta c_2 > \Delta c_4$, such that the interior equilibrium exists for any:

$$\Delta c \in [max[\Delta c_x, \Delta c_5], min[\Delta c_4, \Delta c_6]]$$

with $\Delta c_x > \Delta c_5 \iff k > \frac{s_1 \Phi_2(\Phi_2 - \Phi_1)}{1 - s_1}$ and $\Delta c_4 > \Delta c_6 \iff \phi_1 > \phi_2$.
then,

- For $\phi_1 > \phi_2$, the interior equilibrium exists for any:

$$\Delta c \in [\Delta c_x, \Delta c_6]$$

- For $\phi_2 > \phi_1$, the interior equilibrium exists for any:

$$\Delta c \in [\Delta c_5, \Delta c_4]$$

  since $\Delta c_x < 0$. Moreover, $\Delta c_4 > \Delta c_5 \iff k > s_1\phi_2(\phi_2 - \phi_1)$.

Maximisation program for $x < 0$ ($s_i = s_2 = 1 - s_1$)

Ranking the Δc_k terms, we have $\Delta c_3 > \Delta c_1$ and $\Delta c_2 > \Delta c_x$, such that the interior equilibrium exists for any:

$$\Delta c \in [max[\Delta c_3, \Delta c_5], min[\Delta c_x, \Delta c_6]]$$

with $\Delta c_3 > \Delta c_5 \iff \phi_1 > \phi_2$ and $\Delta c_x > \Delta c_6 \iff k < \frac{(1-s_1)\phi_1(\phi_1-\phi_2)}{s_1}$.
then

- For $\phi_1 > \phi_2$, the interior equilibrium exists for any:

  $$\Delta c \in [\Delta c_3, min[\Delta c_x, \Delta c_6]]$$

  Since Δc_x is decreasing in k while Δc_6 is increasing in k, an equilibrium exists for a pair of $(\Delta c, k)$ positive when $k \in [k^*, k^x]$. Indeed, when $k^x < k^*$, $\Delta c_6 < 0$ when Δc_x and conversely. Moreover, since $k^x > k_3$ then $\Delta c_3 < 0$ when $k^x > k^*$.
  Then, for $\phi_1 > \phi_2$, the interval for an interior equilibrium to exist reduces to:

  $$\Delta c < min[\Delta c_x, \Delta c_6]$$

  when $s_1 < \frac{2\phi-1}{3\phi_1-\phi_2}$ which ensures $k_{x<0} > k^*_{x<0}$. When $s_1 > \frac{2\phi-1}{3\phi_1-\phi_2}$, there is no equilibrium with $x < 0$.

- For $\phi_2 > \phi_1$, an interior equilibrium does not exist since $\Delta c_{x<0}$ is negative.

For the rest of the paper, we denote $\Delta c_6 \equiv \Delta c^*$

Finally, based on the conditions on existence of an equilibrium when $x \geq 0$ or $x \leq 0$, since $\Delta c_{x,x<0} < \Delta c_{x,x>0}$, there is only one possible interior equilibrium for each set of parameters $(\Delta c, k)$ positive when it exists.

6.2 Appendix 2: tax rates ranking

At the equilibrium, we have

$$t_1^* - t_2^* = \frac{1}{3}\left(\frac{k(2s_1-1)}{s_i} - 2(\Delta c + \phi_1^2 - \phi_2^2)\right) > 0$$

and whatever the ranking of ϕ_1 and ϕ_2, we have:

$$t_1^* - t_2^* > 0 \iff \Delta c < \frac{k(2-s_1)}{2s_i} + \phi_2^2 - \phi_1^2 \equiv \Delta\tilde{c}$$

with $\frac{\partial \Delta\tilde{c}}{\partial k} > 0$ and $\Delta\tilde{c} > 0 \iff k > \frac{2s_i(\phi_1^2-\phi_2^2)}{2-s_1} \equiv \tilde{k}$
and

$$\frac{\partial \tilde{k}}{\partial \phi_2} = \frac{2s_1\phi_1}{1-2s_1} > 0$$

Moreover,

$$\frac{\partial (t_1^* - t_2^*)}{\partial \phi_2} = \frac{4}{3}\phi_2 > 0$$

Finally,

$$\Delta\tilde{c} > \Delta c_x \iff k > \frac{s_i}{2s_1 - 1}(\phi_1^2 - \phi_2^2) = \tilde{k}_x$$

- For $\phi_1 > \phi_2$, $\Delta c^* > \Delta\tilde{c} \iff k > s_1(\phi_1 - \phi_2)^2$ so that $\Delta c^* > \Delta\tilde{c}$ for any $\Delta\tilde{c} > 0$;
- For $\phi_2 > \phi_1$, $\Delta\tilde{c} > 0$.

  Finally, since for $\phi_1 > \phi_2$ and $x < 0$, we have $\tilde{k}_{x<0} > k_{x<0}$. Then, for any equilibirum with $x^* < 0$ we have $t_1^* < t_2^*$.

6.3 Appendix 3: Taxonomy of the payoff rankings

The expression of the payoff are :

$$G_1^* = \frac{1}{36}\left(\frac{4k(s_1+1)^2}{s_i} - 8(s_1+1)\Delta c + 4(s_1+1)(\phi_1^2 - \phi_2^2) + 36\phi_1(\phi_2 - 1) + \frac{s_i\left(\phi_2^2 - \phi_1^2 + 2\Delta c\right)^2}{k}c\right)$$

$$G_2^* = \frac{1}{36}\left(\frac{4k(s_1-2)^2}{s_i} - 8(s_1-2)\Delta c + 4(s_1-2)(\phi_1^2 - \phi_2^2) + 36\phi_2(\phi_1 - 1) + \frac{s_i\left(\phi_2^2 - \phi_1^2 + 2\Delta c\right)^2}{k}c\right)$$

Taxonomy under CBDR ($\phi_1 > \phi_2$)

When $\phi_1 > \phi_2$, we know that we may observe equilibria with $x > 0$ or $x < 0$.

1. For a set of $(\Delta c, k)$ implying $x^* > 0$, we have$\Delta c_x \gtreqless \Delta c_G$ if and only if $k \lesseqgtr \frac{s_1(\phi_1-\phi_2)}{(2s_1-1)} \equiv k_{xG}$ with $k_G > k_{xG} > k_x$.
   Thus, when $k < k_{xG}$, then $\Delta c_x > 0 > \Delta c_G > \Delta\tilde{c}$. Under these conditions we have,
   - for $\Delta c > \Delta c_x$, we observe that $t_2^* > t_1^*$ and $x^* > 0$. Unsurprisingly, G_1 $^* < G_2^*$: the higher tax imposed by this country ($t_2^* > t_1^*$) magnifies the benefit of having a large tax base ($x^* > 0$);

- for $\Delta c_x > \Delta c$, it still holds that $G_1{}^* < G_2^*$ since the higher tax imposed by country 2 $t_2^* > t_1^*$ outweighs the effect of the smaller tax base in country 2 (i.e. $x^* < 0$).

Otherwise, when $\phi_1 > \phi_2$ but $k > k_{xG}$ and $1 < \phi_1 + \phi_2$, then $\Delta c_G > \Delta \tilde{c}$ and $\Delta c_x < \Delta c_G$. Thus, $\Delta c_G > \Delta \tilde{c} > 0 > \Delta c_x$.

- For $\Delta c > \Delta c_G$, we have $t_2^* > t_1^*$ and $x^* > 0$ and $G_1{}^* < G_2^*$
- for $\Delta c_G > \Delta c > \Delta \tilde{c} > 0 > \Delta c_x$, we have $t_2^* > t_1^*$ and $x^* > 0$ but $G_1^* > G_2^*$
- for $\Delta c_G > \Delta \tilde{c} > \Delta c > 0 > \Delta c_x$ we have $t_1^* > t_2^*$ and $x^* > 0$ but $G_1{}^* > G_2^*$

Finally, when $\phi_1 > \phi_2$ but $k > k_{xG}$ and $1 > \phi_1 + \phi_2$, then $\Delta c_G < \Delta \tilde{c}$ and $\Delta c_x < \Delta c_G$. Thus, $\Delta \tilde{c} > \Delta c_G > 0 > \Delta c_x$.

- For $\Delta c > \Delta \tilde{c}$, we have $t_2^* > t_1^*$ and $x^* > 0$ and $G_1{}^* < G_2^*$
- for $\Delta \tilde{c} > \Delta c > \Delta c_G > 0 > \Delta c_x$, we have $t_1^* > t_2^*$ and $x^* > 0$ but G_1 $^* < G_2^*$
- for $\Delta \tilde{c} > \Delta c_G > \Delta c > 0 > \Delta c_x$ we have $t_1^* > t_2^*$ and $x^* > 0$ but $G_1{}^* > G_2^*$

2. **Proof of lemma 10:: For a set of $(\Delta c, k)$ implying $x^* < 0$, we have $\Delta c_x \gtreqless \Delta c_G$ if and only if $k \lesseqgtr \frac{3(1-s_1)(\phi_1-\phi_2)}{(2s_1-1)}$ with $\frac{3(1-s_1)(\phi_1-\phi_2)}{(2s_1-1)} > k_x$ which immediately implies that whenever $\Delta c_x > 0$ then $\Delta c_G < 0$ and for any $\Delta c_{<}[\Delta c < min[\Delta c_x, \Delta c^*]$ then $t_1^* > t_2^*$ and $G_1^* < G_2^*$.**

Taxonomy under $\phi_2 > \phi_1$

When $\phi_2 > \phi_1$, we know that there is no possible equilibrium with $x < 0$. Then we restrict our analysis to the case $x > 0$:
When $\phi_1 + \phi_2 > 1$, we have $\Delta \tilde{c} > \Delta c_G > 0 > \Delta c_x$. In this scenario,

- for $\Delta c > \Delta \tilde{c}$, then $t_2^* > t_1^*$ and $x^* > 0$ and $G_1{}^* < G_2^*$.
- for $\Delta \tilde{c} > \Delta c > \Delta c_G$ then $t_2^* < t_1^*$ and $x^* > 0$ and $G_1{}^* < G_2^*$
- for $\Delta \tilde{c} > \Delta c_G > \Delta c$, then $t_2^* < t_1^*$ and $x^* > 0$ and $G_1{}^* > G_2^*$.

When $\phi_1 + \phi_2 < 1$, we have $\Delta c_G > \Delta \tilde{c} > 0 > \Delta c_x$. In this scenario,

- for $\Delta c > \Delta c_G$, then $t_2^* > t_1^*$ and $x^* > 0$ and $G_1{}^* < G_2^*$.
- for $\Delta c_G > \Delta c > \Delta \tilde{c}$ then $t_2^* > t_1^*$ and $x^* > 0$ and $G_1{}^* > G_2^*$
- for $\Delta c_G > \Delta \tilde{c} > \Delta c$, then $t_2^* < t_1^*$ and $x^* > 0$ and $G_1{}^* > G_2^*$.

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