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# Tax haven, pollution haven or both ?

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**Abstract**

This paper studies the interplay between a poor and a rich country when they sequentially compete over corporate taxes and environmental regulations to attract imperfectly mobile firms. Countries have also different environmental awareness. We show that the poor country generally undercuts the corporate tax set by the rich country. The poor country chooses to be both a tax and pollution haven when it is less environmentally concerned than the rich country and capital integration is low. The rich country has never an incentive to be both a tax haven a pollution haven. Interestingly, at equilibrium, the poor country rarely does better in terms of welfare than the rich country. Finally we find that higher capital mobility narrows the tax gap between the rich and the poor country but does not affect the optimal environmental policy: tax competition immunizes countries against the detrimental effect of globalization on environmental standards.

**Keywords**: Tax Competition, Capital Integration, Cross-border Pollution, Environmental Standards

**JEL classification:** H2, R3, R5, Q5.

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# 1 Introduction

Globalization enhances competition between countries and regions to attract firms, secure jobs, and over time, sustain economic development. Competition between countries and states is multifaceted and public authorities can act through fiscal instruments and regulations such as environmental standards. Policy-makers in high-income countries and in intermediate or low-income countries have a strategic incentive to cut their business taxes and relax environmental standards to attract footloose firms at the expense of their competitors. However, the benefits of economic development have increasingly been brought into question over the last decades, especially in developed countries, on the grounds that a concentration of industrial activities pollutes, not only in the same jurisdiction as the polluting activities, but also in neighboring ones and even in more distant countries, since pollutants can be transported over hundreds, even thousands of kilometers. More generally, global warming, air pollution and acid rain, which are extremely damaging to the environment, are characterized by cross-border spillovers.[1]

The purpose of our paper is to present a simple model of competition between a rich (high-income) country and a poor (intermediate or low-income) country. The two countries compete over corporate tax rates and environmental standards in the context of increasing capital mobility and concerns over globalization and cross-border pollution. Policy-makers differ in their environmental awareness. The political trade-off between business- and environmentally-friendly policies depends on a country's level of development. The pressure on environmental issues is higher in high-income countries than in developing or transition countries. For instance, the Standard Eurobarometer survey (2019) clearly shows that public concern about climate change and environmental protection is much lower in Eastern European countries than in EU15 member states. More generally, there is some evidence of an inverted U-shaped income–pollution relationship, the "environmental Kuznets curve" (Chen et al. (2019) for a short survey). More specifically, our paper aims to address the following questions: Are poor countries more likely than rich countries to be tax and pollution havens? Are rich countries able to attract capital investment without cutting taxes or relaxing environmental standards? How does international capital mobility affect tax policies and environmental standards? How do differences in environmental awareness between countries affect tax and environmental policies?

To answer these questions, we set up a sequential non-cooperative game in which a rich country and a poor country first set their environmental standards and then compete over corporate taxes to attract internationally (imperfectly) mobile firms. In producing, the firms pollute domestically and generate cross-border pollution spillovers: environmental standards affect pollution and environmental quality both locally and in the competing country. Countries have some leeway when choosing their environmental standards but they have to comply with international environmental agreements. Non-cooperative environmental standard setting does not mean that countries do not cooperate at all on environmental issues. On the contrary, countries often invest considerable efforts into finding cooperative agreements on environmental issues involving transboundary pollution (e.g. the Convention on Long-Range Transboundary Air Pollution and the Kyoto Protocol). However, signatories have a certain level of discretion and strategic room for maneuver in defining their environmental policies

[1] There is ample evidence of cross-border pollution between US states (see Millimet (2013) for a comprehensive survey). Transboundary pollution is also well documented in Asia: Japan and South Korea regularly complain that the acid rain they suffer is caused by emissions of sulfur and nitrogen oxides from coal-burning plants in northern China (Abu Sayed, "Cross-border pollution : A growing international problem. The Daily Star, February 19, 2011.). Transboundary air pollution also occurs between European Union member states despite the emission reduction measures adopted under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and EU legislation (European Environment Agency, 2020).

(see the above mentioned empirical evidence).
The structure of the game follows from the widely accepted rule that decisions taken in the first stage are irreversible (Pieretti and Zanaj, 2011). This is the case for environmental regulations, which are more binding in the middle-to-long term than tax decisions, which are subject to frequent, sometimes yearly changes. As a result, when setting their environmental standards, countries anticipate that they will also be engaging in corporate tax competition in the second stage of the game. Firms are supposed to bear the mobility costs of relocating from one country to another. In our model, countries maximize tax revenues by imposing a corporate tax that is inversely related to the tax-elasticity of mobile firms. It is straightforward to show that the corporate tax base is less elastic in rich countries than in poor countries. Besides, the lower mobility costs that come with greater economic integration drive corporate taxes down, and richer countries tend to have more integrated economies than poorer ones do. Furthermore, social attitudes towards the environment and pollution differ between countries. A key feature of the model is that by relaxing its environmental standards in the first stage of the game to attract firms, a country may trigger a backlash from the competing country in the form of a corporate tax cut in the second stage. In this model therefore, relaxing environmental standards may not necessarily be the best strategy for the competing countries. Of course, policy-makers can decide to relax their environmental standards and/or cut corporate taxes to attract firms and increase tax revenue. However, this may come at the expense of increased domestic pollution. Indeed, the trade-off depends not only on the relative (political) weights of tax revenues and domestic pollution, but also on pollution spillovers between countries and the extent to which policy-makers are concerned by the latter.
Our main results are the following. The equilibrium environmental standards depend both on domestic concerns about pollution and on concerns for cross-border pollution in the competing country (through a strategic effect). The higher the concern for both types of pollution is, the more stringent the environmental standards are. Interestingly, international capital mobility does not affect the equilibrium environmental standards because governments fully internalize the effects of the latter on firms' location when choosing their corporate taxes in the second stage of the game. Our paper also shows that the poor country generally undercuts the large country and acts as a tax haven because it is more sensitive to corporate inflows. At equilibrium however, the poor country almost always does worse than the rich one. The balance ultimately depends on the level of capital integration and the respective degrees of environmental awareness. Under some circumstances moreover, the rich country may have incentives to undercut the poor one. We also find that higher capital mobility narrows the tax gap between the rich and the poor country. The effect on the respective payoffs ultimately depends on the level of economic integration. Finally, the rich country never acts as both a tax and a pollution haven at equilibrium while the poor country can act as both. Indeed, when both capital mobility and domestic environmental awareness are low, the poor country can benefit from cutting corporate taxes to increase its attractiveness.
The paper is organized as follows. The next section outlines the related literature. Section 3 presents the main characteristics of the model. Section 4 defines the subgame perfect Nash equilibria of the sequential game. Section 5 provides some comparative statics. Section 6 deals with extensions of our model. Section 7 discusses the model and its policy-making implications.

## 2 Related literature

To the best of our knowledge, our paper is the first to jointly tackle tax and environmental competition between a rich and a poor country in a very simple framework where firms are imperfectly mobile and countries differ in their levels of environmental concern. However, there is a long-standing strand of the theoretical public finance literature in which fiscal competition is modeled as a non-cooperative game where public authorities tax mobile capital and provide public goods. One of the main results is that equilibrium tax rates are too low to adequately finance public goods. The standard model of tax competition has been extended in various directions (see Keen and Konrad (2013) for a comprehensive survey), including through the combination of tax and environmental competition between identical countries. This small section of the literature dates back to the seminal paper by Oates and Schwab (1988), which showed that governments set inefficiently low capital taxes at equilibrium and relax their environmental standards. In an influential paper, Ogawa and Wildasin (2009) challenge this result and find that tax competition for mobile capital leads to a first-best outcome regardless of transboundary pollution and hence, that there is no need for international environmental policy coordination. However, the latter result has recently been put into question by Yamagishi (2019), who emphasizes that Ogawa and Wildasin (2009)'s efficiency result crucially depends on the assumption that the level of environmental standards is exogenous – or put 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. Neither paper considers differently sized or differently developed countries. Nor do they consider the effects of economic integration on equilibrium levels of corporate taxes and environmental standards, since standard tax competition models assume that capital is perfectly mobile and boils down to a continuum of investors of insignificant size. Finally, countries are assumed to have the same environmental preferences, which of course is quite a stretch.[2]

Most of the tax competition literature deals with symmetric agents. Bucovetsky (1991) and Wilson (1991) are exceptions. They show that small countries, in terms of population, set lower capital tax rates than larger countries do. However, these models do not deal with environmental issues and assume that per capita endowments do not vary between countries. We, in contrast, assume that the countries are different: the density of firms is higher in the rich country than in the poor one. Other papers have looked beyond simple population asymmetry. For instance, Cai and Treisman (2005) model fiscal competition over productivity-enhancing infrastructure between a richly endowed country and a poorly endowed country. They show that international capital mobility leads to a situation in which the poor country drops out of the competition and the rich country becomes unconstrained. Capital mobility exacerbates initial inequalities and hinders economic development. However, their model assumes perfect capital mobility and does not consider environmental policies. Models that include new economic geography factors such as increasing returns to scale and transportation costs in a tax competition framework generally show that core (high market potential) countries set higher taxes than peripheral ones do, but that trade integration tends to reduce the tax gap (Baldwin and Krugman, 2004; Haufler and Wooton, 2010; Exbrayat and Geys, 2014). Once again, to the best of our knowledge, this literature ignores the interactions between tax and environmental competition. The framework of our model is closer to the literature in which fiscal competition is modeled as a two-stage game where governments compete in the first stage over a productivity-enhancing public infrastructure and, in the second stage, over a corporate tax (Justman et al., 2005; Bénassy-Quéré et al., 2007; Pieretti and Zanaj, 2011). This literature shows that the productivity-enhancing infrastructure mitigates the intensity of tax competition. Besides, Pieretti and Zanaj (2011) interestingly find that for intermediate

[2]Environmental preferences are shaped by a variety of factors such as social norms, the economic and social development of a region, and green advocacy. See Glaeser (2014) for a deep analysis of the supply of environmentalism and to Bowles (1998) for the endogenous formation of environmental preferences. See also Elhadj and Tarola (2015) for a recent analysis of the relationship between economic and environmental preferences.

mobility costs, the smaller jurisdiction can attract foreign capital by providing a higher level of public goods than the larger one, rather than undercutting it.

The environmental economics literature has likewise mostly ignored the interactions between tax and environmental competition, focusing mainly on the optimal environmental policy in a strategic setting to address the issues of carbon leakage and pollution havens (Naegele and Zaklan, 2019). Some of these papers endogenize firms' choice of location as a reaction to exogenous unilateral pollution reduction measures (Markusen et al., 1993; Motta and Thisse, 1994; Petrakis and Xepapadeas, 2003; Sanna-Randaccio and Sestini, 2012; Sanna-Randaccio et al., 2017), while a different strand of the literature endogenizes both the environmental policy and the choice of location. However, most of these models assume that countries are perfectly symmetric, that pollution is local and that there are no transport costs (Ulph and Valentini, 2001; Abe and Zhao, 2005; Ikefuji et al., 2016). The key argument in this literature is that when jurisdictions compete for FDI, this leads to a race to the bottom in terms of environmental standards. The ongoing process of globalization encourages governments to attract multinational firms from elsewhere by lowering environmental standards (Kayalica and Lahiri, 2005). Polluting firms thereby move from countries with stricter regulations to countries with weaker environmental standards, leading to the formation of pollution havens. Of course, this disregards the effect of market size asymmetry, which may be a factor in attracting firms (Böhringer et al., 2014; Sanna-Randaccio et al., 2017).

From an empirical perspective, several studies have documented the detrimental effect of high corporate taxes on FDI (De Mooij et al., 2006; Feld and Heckemeyer, 2011). Furthermore, empirical estimates of tax reaction functions have found that countries mimic each other's corporate taxation policies (Devereux et al., 2008; Overesch and Rincke, 2011; Redoano, 2014). As far as environmental regulations are concerned, some empirical studies have found a negative and potentially causal effect of the stringency and enforcement of environmental regulations on FDI decisions. However, this effect is small and often concentrated in the most pollution-intensive industries. Recently, Kellenberg (2009), Shahbaz et al. (2015), Sarkodie and Strezov (2019) and Yuan et al. (2019) confirmed the validity of the pollution haven hypothesis. However, other studies still question the fact that more stringent environmental standards really do lead to an outflow of firms (Kirkpatrick and Shimamoto, 2008; Kheder and Zugravu, 2012; Dou and Han, 2019).

The empirical literature has also revealed strategic interactions and mimicking behavior in the adoption and enforcement of environmental regulations between US States (Fredriksson et al., 2004) and between countries (Davies and Naughton, 2014). Note finally that in our model, countries compete over a bundle of instruments. Fredriksson et al. (2004) identify strategic interactions between US states on tax policy, productive public expenditures, and environmental regulations. More specifically, their results show strong evidence of interstate strategic interactions both within the scope of a given instrument and between different instruments. In other words, states may react to lax environmental standards in neighboring states by cutting taxes.

# 3 The model

We consider an economy composed of two countries, 1 and 2, with different densities of firms, $s_i$ $\forall i = 1, 2$, and $s_1 + s_2 = 1$, so that $s_1 \geq \frac{1}{2}$. The countries can be nations, regions or sub-national jurisdictions. In the rest of the paper, we call the country with the higher initial density of firms (country 1) the "rich" country and country 2 the "poor" country. Our model can also be interpreted in terms of differences in population if we assume that the number of capital owners who are also entrepreneurs and workers is proportional to population size.

As size can also be taken to mean geographical size, we describe the countries as "poor" and "rich" as this more clearly conveys the notion of wealth. The countries have tax autonomy and levy a corporate tax $t_i$. They also set environmental standards through the emissions cap $\alpha_i$.

### 3.1 Firms

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.
Production of the output $q$ is polluting. When producing in $i$, a firm incurs a cost, $C(q, \alpha_i, \bar{\alpha})$, with

$$C(q, \alpha_i, \bar{\alpha}) = c(q) + (F(\bar{\alpha}) + \mu(\bar{\alpha} - \alpha_i))$$

where $\alpha_i$ is the emissions cap in $i$, while $\bar{\alpha}$ represents the internationally-set emissions cap. The international limit is not controlled by country $i$ but comes for example from an international agreement or from a higher level of government.[3]

The above function includes a variable cost of production, $c(q)$, with $\frac{\partial C(q,\alpha_i,\bar{\alpha})}{\partial q} = \frac{\partial c(q)}{\partial q} > 0$, and a fixed cost of compliance with the emissions cap, $(F(\bar{\alpha}) + \mu(\bar{\alpha} - \alpha_i))$, which satisfies $\frac{\partial C(q,\alpha_i,\bar{\alpha})}{\partial \alpha_i} < 0$. The cost of compliance consists of two components: the first, $F(\bar{\alpha})$, with $\frac{\partial F(\bar{\alpha})}{\partial \bar{\alpha}} > 0$, captures firms' efforts to comply with the international cap, given their current technological capabilities. This could be investment in end-of-pipe measures or the implementation of cleaner production techniques.[4] When the international and local emission caps coincide, the second part of the compliance cost $\mu(\bar{\alpha} - \alpha_i)$ disappears. However, when $\bar{\alpha} \neq \alpha_i$, the cost of compliance for firms located in country $i$ is no longer fully captured by $F(\bar{\alpha})$. In particular, when the emissions cap in country $i$ is higher than the international one, i.e. when environmental regulations in country $i$ are laxer than the international norm $((\bar{\alpha} - \alpha_i) < 0)$, the cost for firms located in country $i$ of complying with the local cap, $\alpha_i$, is reduced by $\mu |\bar{\alpha} - \alpha_i|$. In contrast, in the case of more stringent local standards, the cost of compliance is increased by the same amount $\mu |\bar{\alpha} - \alpha_i|$. Without any loss of generality, we normalize $\mu$ to 1.

### 3.2 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 by $x_{i,l}$. Following Pieretti and Zanaj (2011), we assume that relocating abroad costs firms a unit cost, $k < 1$.

Thereby, if firm $l$ remains in country $i$, its profits are given by:

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

where $t_i$ is the profit tax in country $i$.

[3] While the Kyoto protocol defined legally binding emission caps for developed countries, in the Paris Agreement, countries are no longer constrained by a globally shared cap. In particular, caps can be set at the regional or national level, so emissions are reduced on a voluntary basis.

[4] 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 a typical example of cleaner production measures (Frondel et al., 2007; Mantovani et al., 2017).

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

$$\pi_{i,l}^{j} = q - C(q, \alpha_i, \bar{\alpha}) - t_j - kx_{i,l} \quad \forall i = 1,2 \quad j = 1,2 \quad \text{and} \quad i \neq j.$$

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

Defining $x_1$ as a neutral attitude toward relocating abroad from country 1, namely that firms with $x_{1,l} < x_1$ are willing to relocate from 1 to 2 while firms with a $x_{1,l} > x_1$ prefer not to, this threshold is defined as follows:

$$q - \bar{\alpha} + \alpha_1 - c(q) - F(\bar{\alpha}) - t_1 = q - \bar{\alpha} + \alpha_2 - c(q) - F(\bar{\alpha}) - t_2 - kx_1. \tag{1}$$

Symmetrically, considering a firm initially located in country 2 and indifferent to staying in 2 or relocating to 1 leads to $x_2 = -x_1$. To simplify the notation for the rest of the paper, we denote by $x = x_1 = -x_2$ the cut-off between staying put and relocating abroad. From (1) we obtain

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

When $(t_1 - t_2) > (\alpha_1 - \alpha_2)$, namely $x > 0$, there is a positive flow of firms from 1 to 2, while on the contrary, $(t_1 - t_2) > (\alpha_1 - \alpha_2)$ $(x < 0)$ entails a flow of firms from 2 to 1. It immediately follows from (2) that

$$\frac{\partial x}{\partial t_1} = -\frac{\partial x}{\partial t_2} = \frac{1}{k} \quad \text{and} \quad \frac{\partial x}{\partial \alpha_1} = -\frac{\partial x}{\partial \alpha_2} = -\frac{1}{k}.$$

Any change in either the profit tax or the emissions cap in country $i$, has an effect on the number of firms relocating to country $j$, i.e. on $x$, which, unsurprisingly, is inversely related to the mobility cost $k$.[5]

### 3.3 Governments

The countries are assumed to maximize their tax revenues net of pollution-related disutility. Note that the payoff function allows the government to be both benevolent toward the environmental preferences of entrepreneur-workers and selfish through tax revenues.[6]

Formally, the payoff functions $G_1$ and $G_2$ of the public authorities in the two countries are written:

$$\begin{aligned} G_1(\alpha_1, t_1, \alpha_2, t_2) &= R_1 - e_1 = s_1(1-x)t_1 - e_1, \\ G_2(\alpha_1, t_1, \alpha_2, t_2) &= R_2 - e_2 = ((1-s_1) + s_1 x)t_2 - e_2, \end{aligned}$$

with[7]

$$e_1 = \frac{1}{2}\left(\gamma_1 s_1(1-x)\alpha_1^2 + \phi_1(1 - s_1 + xs_1)\alpha_2^2\right)$$

and

$$e_2 = \frac{1}{2}\left(\gamma_2(1 - s_1 + s_1 x))\alpha_2^2 + \phi_2 s_1(1-x)\alpha_1^2\right).$$

[5]Note that $x$, which represents a neutral attitude to staying put and relocating, also corresponds to the proportion of firms willing to relocate abroad.

[6]This payoff corresponds to a purely benevolent government objective in the case where tax revenues are redistributed through transfers to citizens. Our paper falls within the literature on governments that are neither purely benevolent nor purely Leviathan. See Edwards and Keen (1996) and Cai and Treisman (2005)

[7]Introducing the disutility of environmental damage as a convex function of the pollution level in the payoff function is in line with the standard literature on environmental economics. See for instance Baksi (2014), Bárcena-Ruiz (2006), Ulph (1996) and Falk and Mendelsohn (1993) for quadratic functions.

where $s_1(1-x)$ and $1-s_1+s_1x$ are respectively the numbers of firms in country 1 ($N_1$) and country 2 ($N_2$).
In the payoff function $G_i$, $e_i$ represents the disutility of environmental damage in country $i$. This damage consists of a *domestic component* (the first term in the brackets) and a *foreign component* (the second term in the brackets).[8]

*The domestic component* is proportional to the *emissions* generated in country $i$. In particular, it is determined (i) by the number of firms located in $i$ at equilibrium and (ii) by the emissions cap in country $i$: the higher the value of $\alpha_i$ is, the laxer the environmental regulations are in this country and thus the higher the emissions generated by firms per unit of production are. Finally, the parameter $\gamma_i$ captures the level of environmental concern in country $i$ for local pollution, which depends on the specific set of environmental norms and values in that country.[9]

*The foreign component*, i.e. *transboundary pollution*, by symmetry with the above, is determined by (i) the number of firms located in the foreign country and (ii) the emissions cap in the foreign country, $\alpha_j$. All other factors being equal, the impact that this component has on the environmental disutility, $e_i$, depends on $\phi_i$, which reflects both the environmental awareness of country $i$ and the type of transboundary pollution. Indeed, the impact of the transboundary pollution depends on the form it takes, for example acid rain, marine pollution or air quality degradation.

We do not make any assumptions about the relative strengths of the concerns about local and foreign pollution $\left(\gamma_i \gtreqless \phi_i\right)$. At first sight, it may seem that an environmentally aware country should suffer more from domestic emissions than from cross-border pollution since the former have a direct impact while the latter only affects the country indirectly. Still, it could be that a country is bothered by a polluting neighbor to such an extent that transboundary pollution becomes a greater concern than domestic emissions (Unteroberdoerster, 2001).

The disutility of environmental damage depends on the flow of firms as follows:

$$\frac{\partial e_1}{\partial x} = \frac{1}{2}s_1(\phi_1\alpha_2^2 - \gamma_1\alpha_1^2) \gtreqless 0 \Longleftrightarrow \frac{\phi_1}{\gamma_1} \gtreqless \left(\frac{\alpha_1}{\alpha_2}\right)^2 \tag{3}$$

$$\frac{\partial e_2}{\partial x} = \frac{1}{2}s_1(\gamma_2\alpha_2^2 - \phi_2\alpha_1^2) \gtreqless 0 \Longleftrightarrow \frac{\phi_2}{\gamma_2} \lesseqgtr \left(\frac{\alpha_2}{\alpha_1}\right)^2 \tag{4}$$

Accordingly, a reduction in the number of firms in country 1 (i.e. an increase in $x$) increases the environmental disutility for any $\frac{\phi_1}{\gamma_1} > \left(\frac{\alpha_1}{\alpha_2}\right)^2$ *i.e.* when the concern for transboundary pollution relative to local pollution is higher than a threshold that depends on the ratio of the emissions caps in the two countries. A decrease in the number of firms in country 1 leads, all other factors being equal, to lower local emissions and higher transboundary emissions. If the level of environmental concern in jurisdiction 1 for transboundary pollution is far higher than it is for local pollution, it may well be that the environmental disutility suffered by country 1 actually increases when the number of firms it hosts decreases. This is undoubtedly the case when the environmental standards in 2 are lower than in 1: a laxer environmental policy in the foreign country combined with a higher concern for transboundary over local pollution means that the environmental disutility increases when firms leave the country. This corresponds to a *"yes in my backyard"* (YIMBY) mechanism, the opposite of the well-known NIMBY ("not

[8]For country 1, the domestic component is $\gamma_1\left(s_1(1-x)\alpha_1^2\right)$ while the foreign component is $\phi_1\left((1-s_1+xs_1)\alpha_2^2\right)$.
[9]The policy-maker's concerns about pollution may be driven by pure or impure altruism. The environment can be considered a public good to be protected (Andreoni, 1990). Alternatively, emissions reduction can be seen as a reputational driver (Benabou and Tirole, 2006) or be motivated by moral concerns (Frey, 1999).

it my backyard") phenomenon, whereby the presence of firms in the country is considered environmentally favorable.
Conversely, when $\phi_1 < \gamma_1$, if the environmental regulations in country 1 are weaker than in country 2, i.e. $\alpha_1 > \alpha_2$, the environmental disutility in country 1 always decreases as $x$ increases. Indeed, if country 1 sets a higher emissions cap than country 2 and is highly intolerant of local pollution, an outflow of firms is environmentally beneficial from country 1's perspective. The relocation of firms from country 1 to country 2 leads to a decrease in the disutility due to domestic pollution that is not completely offset by the effects of transboundary pollution from country 2. This corresponds to a NIMBY mechanism, since an outflow of firms from the country is considered environmentally beneficial.[10] This generates opposition to the presence of firms in this country, since they are considered undesirable.

By following the same argument, any decrease in $x$, meaning an increase in the number of firms in country 1, increases the environmental disutility if the concern for local pollution is substantially higher than it is for transboundary pollution.

The above analysis only concerns the effects of $x$ on environmental disutility. For the sake of completeness, it is worth noting that although firms do generate domestic pollution, they also determine the tax base of a country, and the larger the tax-base, the higher the corporate tax revenue (all other things being equal). The *net impact* of hosting firms in a country accounts for these two competing effects.

# 4 Sequential game

The two governments play a two-stage game. First, they choose an emissions cap $\alpha_i$ and second, they set their corporate tax rate. This sequence of decisions reflects the fact that environmental standards are long term decisions whereas taxes can vary from on year to another.

We assume that the mobility costs are not prohibitive, so that $x \neq 0$ for asymmetric countries. Solving the sequential game backward, we first solve the tax competition subgame.

**Definition 1.** *The subgame perfect Nash equilibrium is defined as* $(t_1^*(k, s_1), t_2^*(k, s_1), \alpha_1^*(k, s_1), \alpha_2^*(k, s_1))$.

## 4.1 Tax competition subgame

The second stage is solved under the assumption that equilibrium emissions caps have been defined in the first stage by the two countries. Maximizing $G_1(\alpha_1, t_1, \alpha_2, t_2)$ and $G_2(\alpha_1, t_1, \alpha_2, t_2)$ w.r.t $t_1$ and $t_2$ yields

$$\frac{dG_i}{dt_i} = \frac{dR_i}{dt_i} - \frac{de_i}{dt_i} = 0$$

with

$$\frac{dR_1}{dt_1} = \overbrace{s_1}^{\text{tax level effect}} \overbrace{- s_1\left(x + \frac{t_1}{k}\right)}^{\text{tax base effect}} = \frac{1}{k} s_1 \left(k + \alpha_1 - \alpha_2 - 2t_1 + t_2\right)$$

and

$$\frac{\partial e_1}{\partial t_1} = \frac{1}{k}\frac{\partial e_1}{\partial x} = \frac{1}{k}\frac{1}{2} s_1 (\phi_1 \alpha_2^2 - \gamma_1 \alpha_1^2)$$

[10]NIMBY projects are all undertakings that increase the overall payoff (tax revenues) but impose net costs on individuals in the host community (a private bad, such as pollution).

and for country 2

$$\frac{dR_2}{dt_2} = \overbrace{1-s_1}^{\text{tax level effect}} + \overbrace{s_1\left(x-\frac{t_2}{k}\right)}^{\text{tax base effect}} = 1-\frac{1}{k}s_1\left(k+\alpha_1-\alpha_2-t_1+2t_2\right)$$

and

$$\frac{\partial e_2}{\partial t_2} = -\frac{1}{k}\frac{\partial e_2}{\partial x} = -\frac{1}{k}\frac{1}{2}s_1(\gamma_2\alpha_2^2-\phi_2\alpha_1^2)$$

which respectively give the following best response functions:

$$t_1(t_2) = \frac{1}{4}\left(2(k+t_2)+2(\alpha_1-\alpha_2)+\gamma_1\alpha_1^2-\phi_1\alpha_2^2\right)$$

$$t_2(t_1) = \frac{\left(2k(1-s_1)+2s_1t_1+s_1\left(2(\alpha_2-\alpha_1)+\gamma_2\alpha_2^2-\phi_2\alpha_1^2\right)\right)}{4s_1}$$

The slopes of the two tax response functions are positive and lower than 1. In line with the tax competition literature, the corporate tax rates are strategic complements.[11] There is thus a single set of subgame equilibrium tax rates, i.e.

$$\begin{bmatrix} t_1^*(\alpha_1,\alpha_2) = \frac{2k+2ks_1+2s_1(\alpha_1-\alpha_2)+\alpha_1^2s_1(2\gamma_1-\phi_2)+\alpha_2^2s_1(\gamma_2-2\phi_1)}{6s_1}, \\ t_2^*(\alpha_1,\alpha_2) = \frac{4k-2ks_1+2s_1(\alpha_2-\alpha_1)+\alpha_1^2s_1(\gamma_1-2\phi_2)+\alpha_2^2s_1(2\gamma_2-\phi_1)}{6s_1}. \end{bmatrix}$$

Moreover, we observe that

$$\frac{\partial t_i^*(\alpha_i,\alpha_j)}{\partial\alpha_i} = \frac{1}{3}\left(\alpha_i(2\gamma_i-\phi_j)+1\right) \gtreqless 0 \Leftrightarrow \gamma_i \gtreqless \frac{1}{2}\left(\phi_j-\frac{1}{\alpha_i}\right) \tag{5}$$

and

$$\frac{\partial t_i^*(\alpha_i,\alpha_j)}{\partial\alpha_j} = \frac{1}{3}\left(\alpha_j(\gamma_j-2\phi_i)-1\right) \gtreqless 0 \Leftrightarrow \phi_i \lesseqgtr \frac{1}{2}\left(\gamma_j-\frac{1}{\alpha_j}\right) \tag{6}$$

Expressions (5) and (6) account for the effects of the emissions caps on the tax competition subgame.

The effect of $\alpha_i$ on $t_i^*(\alpha_i,\alpha_j)$, measured by Equation(5), is driven by two factors: an environmental factor and a tax-revenue factor. First, an increase in $\alpha_i$, for a given number of firms in $i$, directly increases domestic pollution. A higher $\alpha_i$ also makes country $i$ more attractive for firms, lowering $x$ and further increasing local emissions. To limit this increase, country $i$ has the incentive to increase its corporate tax rate to limit the inflow of firms, which is environmentally beneficial for a sufficiently high value of $\gamma_i$, i.e. $\gamma_i > \frac{1}{2}\left(\phi_j-\frac{1}{\alpha_i}\right)$. Still, this limits the tax base, with a negative effect on tax revenue, all other things held equal. Compensating for this loss of revenue is a further incentive for country $i$ to increase its corporate tax rate. As a result, $t_i^*(\alpha_i,\alpha_j)$ increases with $\alpha_i$. Note that there is no incentive to limit the inflow of firms from country $j$ if $\gamma_i$ is low, i.e. $\gamma_i \leq \frac{1}{2}\left(\phi_j-\frac{1}{\alpha_i}\right)$. In these circumstances, since country $i$ is less intolerant of local pollution, it has no reason to increase its corporate tax rate to limit the inflow of firms: the equilibrium tax $t_i^*$ decreases as $\alpha_i$ increases, with a positive effect on the tax base.

[11] Most papers in both the theoretical and the empirical literature show that tax rates are strategic complements. For a recent survey on whether taxes are strategic complements or strategic substitutes, see for instance Vrijburg and de Mooij (2016).

Equation (6) shows that $t_i^*(\alpha_i, \alpha_j)$ and $\alpha_j$ can be substitutes or complements depending on the value of $\phi_i$. This relationship stems from the fact that the presence of firms in a country has *two environmental effects*: one through *local* emissions and the other through *transboundary* pollution. If the concern for transboundary emissions ($\phi_i$) is high, country $i$ has an incentive to attract firms from $j$ to both mitigate transboundary pollution and increase its corporate tax base. However, this increases domestic pollution in country $i$. The higher $\phi_i$ is, the lower the opportunity cost is for country $i$ to attract firms in terms of environmental disutility (*yes in my backyard* effect). In this case, $t_i$ and $\alpha_j$ are strategic substitutes. In contrast, if $\phi_i$ is low, $t_i$ and $\alpha_j$ turn out to be complements. Indeed, when $\phi_i$ is low, transboundary pollution from country $j$ is of little consequence. Accordingly, if country $j$ relaxes its environmental standards, country $i$ has no incentive to cut its corporate tax rate to attract firms (*not in my backyard* effect). Attracting firms in this way would increase the tax base but at the expense of increasing local pollution and possibly, of reducing tax revenue if the increase in the tax base does not compensate for the lower tax rate.

It is worth noting that

$$\frac{\partial t_i^*(\alpha_i, \alpha_j)}{\partial \gamma_i} = \frac{1}{3}\alpha_i^2 > 0 \quad \text{and} \quad \frac{\partial t_i^*(\alpha_i, \alpha_j)}{\partial \gamma_j} = \frac{1}{6}\alpha_j^2 > 0 \tag{7}$$

$$\frac{\partial t_i^*(\alpha_i, \alpha_j)}{\partial \phi_i} = -\frac{1}{3}\alpha_j^2 < 0 \quad \text{and} \quad \frac{\partial t_i^*(\alpha_i, \alpha_j)}{\partial \phi_j} = -\frac{1}{6}\alpha_i^2 < 0. \tag{8}$$

The equilibrium tax rate $t_i^*(\alpha_i, \alpha_j)$ increases with the level of concern about domestic pollution: a greater concern for domestic pollution reduces the incentive to attract firms, limiting government $i$'s ability to increase its corporate tax rate without suffering from an outflow of firms. The loss of tax revenue is compensated by the decrease in pollution. Since $t_i$ and $t_j$ are strategic complements, $t_i$ also increases with the level of concern for domestic pollution in country $j$.

Conversely, increases in $\phi_i$ and $\phi_j$ both decrease the equilibrium rates in the tax game. Let us first consider the effect of $\phi_i$ on $t_i^*(\alpha_i, \alpha_j)$: all other things being equal, an increase in $\phi_i$ increases the negative impact in country $i$ of transboundary pollution from country $j$. If country $i$ cuts its own tax rate to attract firms from country $j$, thereby limiting transboundary pollution, the inflow of firms will increase local emissions. Still, this negative environmental effect is weaker than the positive effect of increasing the tax base. Overall, this combination of factors leads to a "*yes in my backyard effect*".

The effect of $\phi_j$ on $t_i^*(\alpha_i, \alpha_j)$ is indirect. It is mediated by $t_j^*(\alpha_i, \alpha_j)$, which decreases as $\phi_j$ increases as described above. Since $t_i^*(\alpha_i, \alpha_j)$ and $t_j^*(\alpha_i, \alpha_j)$ are strategic complements, $t_i^*(\alpha_i, \alpha_j)$ also decreases.

### 4.2 Emissions caps

We can now move to the first stage of the game. Plugging $t_1^*(\alpha_1, \alpha_2)$ and $t_2^*(\alpha_1, \alpha_2)$ into the payoff functions $G_1$ and $G_2$, and maximizing $G_i(\alpha_i, \alpha_j)$ w.r.t. $\alpha_i$, we obtain

$$\alpha_1^* = \frac{1}{\phi_2 + \gamma_1} \quad \text{and} \quad \alpha_2^* = \frac{1}{\phi_1 + \gamma_2},$$

with

$$\alpha_1^* \gtreqless \alpha_2^* \Longleftrightarrow (\gamma_1 + \phi_2) \lesseqgtr (\gamma_2 + \phi_1) \tag{9}$$

Interestingly, at equilibrium, the emissions cap $\alpha_i^*$ chosen by country $i$ depends on its level of concern for domestic pollution ($\gamma_i$) and country $j$'s level of concern for transboundary pollution ($\phi_j$). In contrast, the concern in country $i$ about foreign pollution does not alter its equilibrium choice of emissions cap $\alpha_i^*$. Contrary to the situation in a purely non-cooperative game, the sequential game involving taxes and emissions caps leads the two countries to internalize the effects of both their environmental policy and their rival's in the tax competition stage. While the effect of concerns about domestic pollution is quite intuitive (higher $\gamma_i$ means lower $\alpha_i$), the effect of the competing country's concerns about foreign pollution is less obvious (higher $\phi_j$ means lower $\alpha_i$). When choosing $\alpha_i$, country $i$ takes into account the fact that its own emissions cap will trigger a reaction from country $j$. This reaction comes in the form of tax competition. From (8), a higher concern $\phi_j$ for transboundary emissions leads country $i$ to reduce its corporate tax rate $t_i^*(\alpha_i, \alpha_j)$. This attracts firms, thereby reducing transboundary pollution, and enlarges country $i$'s tax base, with a positive effect on the tax revenue. On the other hand, it increases the level of local emissions. To reduce the disutility due to local pollution, country $i$ decreases its environmental standards $\alpha_i^*$. The magnitude of the strategic effect of $\alpha_i^*$ on $t_i^*(\alpha_i, \alpha_j)$ is captured by (5): the greater the concern about transboundary pollution ($\phi_j$) is, the weaker the interplay between environmental and tax policies ($\alpha_i$ and $t_i$) is.

We can immediately derive the following result:

**Proposition 2.** *When $\Delta_i > \Delta_j$, country $j$ is a pollution haven ($\alpha_j^* > \alpha_i^*$), with $\Delta_i = \gamma_i - \phi_i$ $\forall i$ and $i \neq j$.*

*Proof.* Immediately from (9). □

Let us recall that when setting their environmental standards, the two countries take into account the corresponding domestic and foreign emissions.[12] This occurs through the only transmission channel between the two countries which is the flow of firms, $x$. A net outflow of firms from a country reduces domestic emissions but increases cross-border pollution. What matters then is the difference between the two pollution concern parameters, let us call this the *concern gap for domestic/transboundary pollution*: $\Delta_i = \gamma_i - \phi_i$ $\forall i$. When $\Delta_i > \Delta_j$, the pollution concern gap is more damaging in country $i$ than in country $j$. This pushes country $i$ to set a lower emissions cap than country $j$'s, discouraging firms from producing in country $i$ but limiting domestic pollution. Since country $j$ has a smaller pollution concern gap, it is more inclined to set a higher emissions cap, which attracts firms and enlarges the tax base, but also increases domestic pollution.

### 4.3 Subgame perfect Nash equilibrium

The subgame perfect Nash equilibrium, defined as $(t_1^*(k, s_1), t_2^*(k, s_1), \alpha_1^*(k, s_1), \alpha_2^*(k, s_1), x_1^*(k, s_1))$ is given by,

$$\begin{aligned} t_1^* &= \frac{s_1+1}{3s_1}k + \Phi_1 \text{ and } t_2^* = \frac{2-s_1}{3s_1}k + \Phi_2 \\ \alpha_1^* &= \frac{1}{\phi_2+\gamma_1} \text{ and } \alpha_2^* = \frac{1}{\phi_1+\gamma_2} \end{aligned}$$

where $\Phi_i \equiv \frac{1}{6}\left(\frac{4\gamma_i+\phi_j}{(\gamma_i+\phi_j)^2} - \frac{4\phi_i+\gamma_j}{(\gamma_j+\phi_i)^2}\right)$ $i, j = 1, 2$ and $i \neq j$.

This configuration yields the equilibrium flow of firms:

$$x^*(s_1, \gamma_1, \phi_1) = \frac{1}{6}\left(\frac{2(2s_1-1)}{s_1} + \frac{(\gamma_1-\phi_1)-(\gamma_2-\phi_2)}{k(\phi_1+\gamma_2)(\phi_2+\gamma_1)}\right) \tag{10}$$

[12] For the sake of simplicity, let us call the country that strategically sets a higher emissions cap than its rival a pollution haven, and the country that sets the lower corporate tax rate a tax haven.

with $x^* < 1$ iff $k > k_{Min} \equiv \frac{s_1((\gamma_1-\phi_1)-(\gamma_2-\phi_2))}{2(s_1+1)(\phi_2+\gamma_1)(\phi_1+\gamma_2)}$, whereas $x^* > -1$ if and only if $k > k_{Max} \equiv \frac{1}{2}s_1\frac{(\gamma_2-\phi_2)-(\gamma_1-\phi_1)}{(\phi_2+1)(\phi_1+1)(5s_1-1)}$.[13]

Note that the equilibrium flow of firms $x^*$ depends on the two sources of asymmetry we consider in our model. The first source, captured by the term $\frac{2(2s_1-1)}{s_1}$ is the asymmetry in firm densities between the two countries. The higher density of firms in country 1 ($s_1 \geq \frac{1}{2}$) implies that at equilibrium, firms flow from the rich country to the poor one. Because of its initially larger tax base, the former benefits more from increasing its tax rate than the latter does. The countries are also asymmetric in their levels of concern about pollution, captured by $\gamma_i$ and $\phi_i$, $i = 1, 2$. When the pollution concern gap is higher in the rich country than in the poor one, $(\gamma_1 - \phi_1) > (\gamma_2 - \phi_2)$, then the equilibrium standards chosen by country 1 are lower than country 2's, increasing the a net flow of firms towards country 2.
At equilibrium, the number of firms in country 1 is:

$$N_1^* = s_1(1-x^*) = \frac{s_1((\gamma_2-\phi_2)-(\gamma_1-\phi_1))}{6ks_1(\phi_1+\gamma_2)(\phi_2+\gamma_1)} + \frac{s_1+1}{3s_1} \tag{11}$$

and in country 2:

$$N_2^* = 1 - s_1 + s_1x^* = \frac{s_1((\gamma_1-\phi_1)-(\gamma_2-\phi_2))}{6ks_1(\phi_1+\gamma_2)(\phi_2+\gamma_1)} + \frac{2-s_1}{3s_1} \tag{12}$$

Finally, the difference in payoffs at equilibrium is

$$G_1^* - G_2^* = \frac{k(2s_1-1)}{3s_1} + \frac{2\gamma_1+5\phi_2}{6(\gamma_1+\phi_2)^2} - \frac{2\gamma_2+5\phi_1}{6(\gamma_2+\phi_1)^2} \tag{13}$$

Equations (10) to (13) characterize the perfect subgame equilibrium as a function of the mobility costs $k$ and the pollution concern gaps $\Delta_i$ $\forall i$. Table 1 in the appendix sums up the different cases, and we can derive the following propositions.

**Proposition 3.** *The poor country is unambiguously a tax haven if $\Delta_2 > \Delta_1$. If $\Delta_2 < \Delta_1$, the poor country is a tax haven if and only if capital mobility is sufficiently low ($k \geq \tilde{k}$).*

In line with the standard literature on tax havens, the poor country is inclined to lower its corporate tax rate to attract firms and increase its tax revenue. Indeed, the rich country suffers less from an outflow of firms than the poor one does. This argument is in line with Kanbur and Keen (1993) and Pieretti and Zanaj (2011), among others. When $\Delta_2 > \Delta_1$, since the pollution concern gap is larger in the poor country, it sets stricter environmental regulations (proposition 2) thereby weakening the incentive for firms to leave country 1. To mitigate this effect, the poor country decreases its corporate tax rate as a means of attracting firms. This result does not hold when the poor country's pollution concern gap is smaller than its rival's, i.e. when $\Delta_2 < \Delta_1$. In this case, the poor country sets a higher emissions cap than its rival's (see proposition 2), increasing the outflow of firms from the latter. Which of the two countries sets the lower tax rate depends on capital mobility. When capital mobility is low, i.e. $k \geq \tilde{k}$, firms are less responsive to weak environmental policies and the poor country has to increase its attractiveness by ensuring its corporate tax rate is lower. On the contrary, when capital mobility is high, i.e. $k < \tilde{k}$, firms are more responsive to an asymmetry in environmental policies and the outflow of firms from country 1 is high enough that the poor country does not need a generous tax policy to be attractive. The poor country can set a higher corporate tax rate than the rich country's ($t_1^* < t_2^*$).

The following corollary of Propositions 2 and 3 completes this specific case:

[13] Note that $k_{Max} < 0$ for $\phi_2 > \phi_1$ and $k_{Min} < 0$ for $\phi_1 > \phi_2$.

**Corollary 4.** *The rich country only chooses to be a tax haven if the poor country acts as a pollution haven.*

This corresponds to the case in which international mobility costs are low ($k < \tilde{k}$). Indeed, when countries are highly integrated (low capital mobility costs), firms are highly reactive to any gap in environmental standards and the rich country has to cut its tax rate to limit the relocation of firms to the poor country.

In the more restrictive case of very low mobility costs ($k < \hat{k} < \tilde{k}$), the high outflow of firms from 1 to 2 leads to there being more firms in 2 than in 1 at equilibrium: $N_2^* > N_1^*$. This finding holds in spite of the lower initial density of firms in the poor country.

Combining Propositions 2 and 3, we also obtain the conditions under which the poor country acts as both a tax and a pollution haven:

**Corollary 5.** *The poor country is both a tax haven and a pollution haven when $\Delta_2 < \Delta_1$ and international capital mobility is low ($k > \tilde{k}$).*

If the poor country is less concerned about generating pollution than the rich country is ($\Delta_2 < \Delta_1$), it relaxes its environmental standards to attract firms (Proposition 2). Moreover, if capital mobility is low, this relaxes tax competition and corporate tax rates increase in both countries. However, the tax rate is higher in country 1 because it can afford a small outflow of firms from its larger initial tax base: the negative effect of this outflow is outbalanced by the higher tax revenues levied on the remaining firms. In contrast, the poor country's interest is always to undercut the rich country's corporate tax rate, even when mobility costs are high and few firms relocate, to generate tax revenue. The high mobility costs restrict the flow of firms so that even though the poor country is a capital importer, the stock of firms remains higher in country 1: $N_1^* > N_2^*$.

**Corollary 6.** *The rich country is never both a pollution haven and a tax haven.*

This follows directly from Propositions 3 and 4. This corollary emphasizes the fact that the poor country is the only one with the incentive to be both a tax and a pollution haven. Indeed, because of its high initial density of firms, the rich country is less affected by an outflow of firms than the poor country is. When the rich country is a pollution haven, its environmental standards are attractive to firms and the country does not need to reinforce its attractiveness by setting a lower corporate tax rate. The holding force of the environmental policy is high enough to enable country 1 to set a higher corporate tax rate than country 2's. The previous propositions and corollaries have depicted the strategic positions of the two countries (tax or pollution haven) and the consequences in terms of the flow and density of firms at equilibrium. We now turn to the the payoffs ($G_1^*$ and $G_2^*$).

**Proposition 7.** *Whatever the equilibrium configuration, the poor country's payoff can only ever be higher than the rich country's if the two economies are highly integrated ($k < \check{k}$).*

As shown in the appendix, the expression for $\check{k}$ is rather complex and cannot be ranked intuitively with respect to the other thresholds.[14] Notice that $\check{k}$ can be negative, in which case it is impossible for the poor country to do better than the rich one.
In particular, Proposition 7 does not exclude the possibility, when capital mobility is low, that even when the poor country acts simultaneously as a tax haven and a pollution haven,

[14] The relative value of $\check{k}$ with respect to the other thresholds ($\tilde{k}$, $\hat{k}$, and $\bar{k}$) depends on the values of $(\gamma_1 + \phi_2)$ relative to $(\gamma_2 + \phi_1)$, of $\phi_1$ relative to $\phi_2$, and of $\gamma_1$ relative to $\gamma_2$.

it still has a lower payoff than the rich country. The efforts undertaken to attract firms are so strong in terms of tax competition and pollution that they prevent the poor country from doing better than the rich one. A higher payoff for the poor country is even more unlikely if the poor country is less concerned about pollution (net effect).[15] This result contradicts the commonly held idea that being a tax haven is beneficial for countries. Conversely, when mobility costs are low, being either a tax haven or a pollution haven allows the poor country to obtain the higher payoff at equilibrium. Hence, capital mobility is the key element that determines which country does better; a rich country that is a capital exporter and not a tax or a pollution haven can have the higher payoff when capital mobility is low.

## 5 Comparative statics

As a natural continuation of the above analysis, we now investigate how the configuration of the market changes with the parameters of the model.

First of all, it is easy to see that the initial density of firms in the rich country, $s_1$, has an unambiguously negative effect on the corporate tax rates,

$$\frac{dt_1^*}{ds_1} = -\frac{1}{3}\frac{k}{s_1^2} < 0 \qquad \frac{dt_2^*}{ds_1} = -\frac{2}{3}\frac{k}{s_1^2} < 0$$

and no effect on the emissions caps at equilibrium. When the density of firms in country 1 increases (with a symmetric reduction in the density of firms in country 2), this directly decreases the tax base in country 2. Country 2 is induced to cut its tax rate to attract firms. Through a standard tax competition mechanism (taxes are strategic complements), country 1 reacts by cutting its own tax rate. However, because of the lower density of firms in country 2, the decrease is more substantial in 2 than it is in 1. This explains the positive effect of $s_1$ on $x^*$, which describes either an increase in the outflow of firms from 1 ($x^* > 0$) or a decrease in the inflow of firms to 1 ($x^* < 0$):

$$\frac{\partial x^*}{\partial s_1} = \frac{1}{3s_1^2} > 0.$$

Moreover, we observe that:

**Proposition 8.** *As international capital mobility increases,*
*i) the tax gap between the rich and the poor country becomes narrower if $t_1^* > t_2^*$;*
*ii) the environmental standards set at equilibrium are not affected;*
*iii) the difference in payoffs between the rich and the poor country decreases when $G_1^* > G_2^*$.*

*Proof.* Differentiating the equilibrium values with respect to $k$ yields: $\frac{\partial t_1^*}{\partial k} = \frac{s_1+1}{3s_1} > 0$ and $\frac{\partial t_2^*}{\partial k} = \frac{2-s_1}{3s_1} > 0$. Moreover, $\frac{\partial t_1^*}{\partial k} - \frac{\partial t_2^*}{\partial k} = \frac{1}{3}\frac{2s_1-1}{s_1} > 0$ and $\frac{\partial(G_1^*-G_2^*)}{\partial k} = \frac{2s_1-1}{3s_1} > 0$ for any $s_1 \geqslant \frac{1}{2}$. □

Note that this result is analogous to the effect of trade costs in trade models: when trade costs increase (decrease), the tax gap increases (decreases).

Both $t_i^*$ and $t_2^*$ increase with $k$ but to a different extent. Because of the larger initial density of firms in country 1, the flow of firms is more sensitive to the level of capital integration ($k$) in country 1 than in country 2, and the corporate tax $t_1^*$ is more responsive to

[15]This happens when mobility costs are neither too low nor too high : $\tilde{k} < k < \check{k}$.

changes in mobility costs. This stronger reaction means that the payoff of the rich country is more strongly affected by a change in $k$ than the poor country's payoff is. More precisely, an increase in capital mobility reduces the difference in payoffs if the rich country has the higher payoff, but increases the difference if the rich country has the lower payoff at equilibrium (i.e. when mobility costs are already low: $k < \check{k}$). Finally, the level of capital integration does not affect the optimal emissions caps since capital mobility costs are fully integrated into the tax choices in this sequential game.

Note moreover that an increase in capital integration leads the rich country to become a larger capital exporter (when $x^* > 0$) or the poor country to become a smaller capital exporter (when $x^* < 0$) when $\Delta_2 > \Delta_1$, i.e. when the pollution concern gap is larger in the poor country than in the rich one:

$$\frac{\partial x^*}{\partial k} = \frac{1}{6}\frac{(\gamma_2 - \phi_2) - (\gamma_1 - \phi_1)}{k^2(\phi_2 + \gamma_1)(\phi_1 + \gamma_2)} \gtreqless 0 \Leftrightarrow \Delta_2 \gtreqless \Delta_1.$$

As already mentioned, the concern for pollution leads to NIMBYism or YIMBYism depending on the concern gap for domestic/foreign pollution. When both countries have the the same pollution concern gap, the equilibrium flow of firms no longer depends on capital integration ($k$) since the flow's response to a change in capital integration is already taken into account in setting the corporate tax rate.

Finally, analyzing the effect of the levels of concern about pollution yields:

$$\frac{\partial t_i^*}{\partial \phi_i} = \frac{(2\phi_i - \gamma_j)}{3(\phi_i + \gamma_j)^3} \gtrless 0 \Rightarrow \phi_i \gtrless \frac{\gamma_j}{2} \quad \text{and} \quad \frac{\partial t_i^*}{\partial \phi_j} = -\frac{1}{6}\frac{\phi_j + 7\gamma_i}{(\phi_j + \gamma_i)^3} < 0$$

$$\frac{\partial t_i^*}{\partial \gamma_j} = \frac{1}{6}\frac{\gamma_j + 7\phi_i}{(\phi_j + \gamma_i)^3} > 0 \quad \text{and} \quad \frac{\partial t_i^*}{\partial \gamma_i} = \frac{(\phi_j - 2\gamma_i)}{3(\phi_j + \gamma_i)^3} \gtreqless 0 \Rightarrow \gamma_i \lesseqgtr \frac{\phi_j}{2}$$

whereas

$$\frac{dx^*}{d\phi_2} = \frac{dx^*}{d\gamma_1} = \frac{1}{6k(\phi_2 + \gamma_1)^2} > 0 \quad \text{and} \quad \frac{dx^*}{d\phi_1} = \frac{dx^*}{d\gamma_2} = -\frac{1}{6k(\phi_1 + \gamma_2)^2} < 0$$

To grasp the economic rationale for this, recall that whenever $\gamma_i$ and/or $\phi_i$ increase, all other factors being equal, this increases the disutility of local and/or transboundary pollution in country 1.

If the poor country's level of concern about the rich country's pollution is less than half what it is about its own pollution ($\phi_2 < \frac{\gamma_1}{2}$), country 2 reduces its tax rate $t_2^*$ in response to a rise in $\phi_2$ to attract firms. Indeed, an increase in $\phi_2$ for a given $\gamma_2$ reduces the relative disutility of domestic pollution in country 2. Moreover, the benefit for country 2 of hosting firms, in terms of tax revenue, outbalances the disutility of the environmental damage these firms create. Country 1 reacts in two ways. On the one hand, it reduces its tax rate to limit the outflow of firms, and on the other, to reduced the aggressiveness of country 2's tax policy, it reduces its emissions cap. The emissions cap $\alpha_1^*$ is a means of reducing the disutility of transboundary pollution.
If $\phi_2$ is high (i.e. $\phi_2 > \gamma_1/2$), any further increase substantially increases the disutility of transboundary pollution in country 2, which increases its tax rate ($t_2^*$) because the benefit of increasing its share of firms in terms of tax-revenue does not outbalance the environmental disutility it would suffer otherwise. In line with the above, country 1 reacts in two ways: it reduces its corporate tax rate to limit the outflow of firms and makes its environmental regulations more stringent to soften the reaction of country 2. The role of $\gamma_i$ follows from the same argument.

# 6 Particular cases and discussion

We have derived our results in a general framework allowing for mobile firms and several kinds of asymmetries. In this section, we investigate the specific cases of symmetric countries and immobile firms. Finally, we extend our framework by considering asymmetric productivities.

## 6.1 Case of symmetric countries

The results for symmetric countries follow naturally from those with asymmetric countries. The countries can be partially or perfectly symmetric, i.e. symmetric in their firm densities, environmental awareness, or both.

When their levels of environmental concern are symmetric, i.e. $\gamma_i = \gamma_j = \gamma$ and $\phi_i = \phi_j = \phi$, it holds that $\alpha_1^* = \alpha_2^* = \frac{1}{\gamma+\phi}$ and $t_1^* \geq t_2^*$.[16] Thus, the two countries set the same emissions cap at equilibrium and the poor country always acts as a tax haven. Moreover, at equilibrium, the flow of firms depends only on the countries' tax policies. The poor country is a capital importer but does worse than the rich country ($G_1^* > G_2^*$ because $\tilde{k} = 0$). Thus, for identical levels of environmental concern (both countries suffer the same disutility from one unit of emissions, both for domestic and transboundary pollution), the poor country acts as a tax haven to attract firms and benefits from an increase in tax revenue that outbalances the negative effects of increased domestic pollution.

The following proposition describes the outcome when the countries have the same initial density of firms:

**Proposition 9.** *If the two countries have the same density of firms ($s_1 = s_2 = 1/2$) but different pollution concern gaps ($\Delta_i \neq \Delta_j$), at equilibrium, with $\Delta_i < \Delta_j$, country $i$ is a pollution haven and country $j$ a tax haven.*

Notice that this result does not depend on the mobility costs $k$ even though $x^*$ depends on $k$. At equilibrium, the value of the policy tool depends on the relative levels of environmental concern. The country with the small pollution concern gap (country $i$) acts as a pollution haven, but its rival (country $j$) acts as a tax haven. The difference in emissions caps ($\alpha_i^* > \alpha_j^*$) drives the firms toward the country with the laxer environmental standards. The other country sets its tax rate lower than its rival's to limit the outflow of firms.

Obviously, when $\phi_i = \phi_j$ and $s_1 = s_2 = 1/2$, it follows that $\alpha_i^* = \alpha_j^* = \frac{1}{\gamma+\phi}$, $t_i^* = t_j^* = k + \frac{\gamma-\phi}{2(\gamma+\phi)^2}$ and $x^* = 0$. Stronger concerns about pollution generate more stringent environmental standards but lower corporate taxes because of more intense tax competition to attract firms.

## 6.2 Case of immobile firms

The case of immobile firms can be treated by assuming that the mobility costs $k$ tend to $+\infty$. Thus, the condition expressed by (1) boils down to $x = 0$. With no capital mobility, the payoff function $G_i$ is monotonically increasing in $t_i(\alpha_i, \alpha_j)$ since there is no tax competition mechanism with which to attract firms. This implies that taxes are set to the maximum level, i.e. the level at which profits are zero:[17]

[16] The threshold mobility cost for tax equality is zero: $\tilde{k} = 0$ (see appendix).

[17] Remember that we have set $\mu = 1$.

$$t_i^*(\alpha_i) = q - c(q) - (K(\bar{\alpha}) + (\bar{\alpha} - \alpha_i)) \quad \forall i = 1, 2$$

In the second stage, the optimal emissions cap is determined by two opposite drivers. On the one hand, the higher $\alpha_i$ is, the higher profits are, and the higher the corporate tax rate $t_i$ and tax revenue are. On the other hand, a higher $\alpha_i$ also increases the disutility of environmental damage since in spite of the very stringent regulations in country $i$, this does not lead to an outflow of firms. At equilibrium, the optimal standards are:

$$\alpha_i^* = \frac{1}{\gamma_i} \quad \forall i = 1, 2.$$

The equilibrium is thus given by

$$(\alpha_1^*, t_1^*, \alpha_2^*, t_2^*) = \left(\frac{1}{\gamma_1}, q - c(q) - \left(K(\bar{\alpha}) + \left(\bar{\alpha} - \frac{1}{\gamma_1}\right)\right), \frac{1}{\gamma_2}, q - c(q) - \left(K(\bar{\alpha}) + \left(\bar{\alpha} - \frac{1}{\gamma_2}\right)\right)\right)$$

The equilibrium value $\alpha_i^*$ is easily derived because the profit function is linear with respect to the environmental standards. Nonetheless, the above equilibrium configuration provides interesting insights when compared with the one that emerges when firms are mobile. When firms are immobile, the emissions caps are not affected either by the tax rate in the competing country or by transboundary pollution, since environmental regulations no longer influence the allocation of firms between the countries. The only trade-off for public authorities is the arbitrage between the benefits of tax revenue (the corporate tax rate and environmental standards are complements) and the disutility of domestic pollution. The result is that in the absence of an internalization mechanism for the effects of transboundary pollution through the flow of firms, environmental regulations are weaker and the corporate tax rate is maximal for the chosen level of environmental standards.

### 6.3 Asymmetric productivities

For the sake of simplicity, the model considered so far assumes that the countries differ in wealth (density of firms) but not in productivity. We now extend our model by including the fact that country 1's output is greater than country 2's ($q_1 > q_2$). This market power does not affect the environmental regulations in the two countries because the latter only depend on the levels of concern for pollution (because of the sequence of the game). Contrary to the environmental policies, the corporate tax rates are affected by the production gap so that $t_1^{*\prime} = t_1^* + \frac{Q}{3}$ and $t_2^{*\prime} = t_2^* - \frac{Q}{3}$, denoting the new equilibrium values with a prime and setting $Q = q_1 - c(q_1) - (q_2 - c(q_2))$ (calculations available on request from the authors). When $Q > 0$, which is the case for $c'(q_i) < 1$, the higher level of production in country 1 enables the government to set a higher tax rate without increasing the outflow of firms because at equilibrium, the capital outflow from 1 to 2 (or inflow from 2 to 1) is lower (higher) than when the countries have equal productivities: $x' = x - \frac{Q}{3k}$. Unsurprisingly, the equilibrium number of firms in country 1 is larger than with symmetric productivities ($N_1^{*'} = N_1^* + \frac{s_1}{3k}$) while it is lower in country 2 ($N_2^{*'} = N_2^* - \frac{s_1}{3k}$), which increases the rich country's payoff at the expense of the poor country's $\left(G_1^{*'} - G_2^{*'} = G_1^* - G_2^* + \frac{2Q}{3}\right)$.

## 7 Concluding remarks and policy-making implications

Our main finding is the following: when setting their environmental standards, countries internalize the effect of their own pollution on the corporate tax rate set by the competing country. As a result, the equilibrium environmental standards depend on the levels of concern for both domestic and cross-border pollution. Furthermore, while equilibrium environmental standards are not affected by capital integration, corporate tax rates are .

The mechanisms governing our model may help explain several stylized facts about the interactions between interjurisdictional tax competition and environmental awareness. The following discussion must be considered suggestive. First, our model shows that poor or small countries have incentives to undercut rich and large countries and to some extent act as tax havens. This is in line with both the standard tax competition literature and the literature on tax competition and new economic geography. There is also evidence that on average, industrialized (OECD) countries have higher corporate income tax rates than non-OECD countries, although the difference has been narrowing over the past decade (Crivelli et al., 2015; Asen, 2019). On the same note, in the European Union (EU), the average statutory corporate tax rate is lower in Central and Eastern European Countries (CEEC) than in the EU15 as a whole, with mean tax rates of respectively 17% in the CEEC and 24% in the EU15 in 2019.

Second, our paper explicitly models interactions between corporate taxation and environmental standards in a competitive setting, which seems a plausible assumption as there is empirical evidence that governments compete on several fronts and that they may react strategically via one instrument, say by cutting taxes, when faced with lax regulations in a competing state. More interestingly, our model shows that cutting corporate taxes and relaxing environmental standards is not the only possible strategy to attract firms, especially for large and industrialized countries. Developed countries can do better even if they have higher corporate taxes and high environmental standards. Because they are less sensitive to tax-induced offshoring than less developed countries, they can enjoy both high tax revenues and high environmental quality. Interestingly, it seems that economic integration may help bring developing countries closer to this situation as it narrows the tax gap between rich and poor countries. More generally, our model illustrates and explains the wide range of strategies available to governments (Figure 1 displays these strategies for EU-27 member states and the UK).[18] Transition and developing countries are not all pollution havens and tax havens even if they are more likely to be pollution havens than industrialized countries are (Koźluk and Timiliotis, 2016).

Third, our model also suggests that even if stringent environmental standards may negatively affect firms' profits and dissuade them from basing operations in countries with a high environmental awareness, policy-makers choose pollution standards independently from international mobility costs and, more generally, from the degree of economic integration. This finding contrasts with the traditional view that globalization is likely to lead to a race-to-the bottom for corporate taxes and to a general relaxation of environmental standards. In our model, policy-makers set environmental standards based only on concerns about pollution. To some extent, policy-makers set environmental standards in keeping with their own environmental preferences while adjusting corporate tax rates to attract firms. This result is along the lines of Ogawa and Wildasin's 2009, even if our model differs from theirs in many respects. Our analysis suggests that coordination efforts should focus on tax rather than environmental policies, or at least, that leaving governments some leeway in setting their environmental regulations is possible. Our result is also in line with the large empirical literature that finds that corporate taxation is a strong factor in FDI decisions while the host country's environmental norms have a much smaller effect.

[18] The same kind of exercise can be carried for OECD and non-OECD countries.

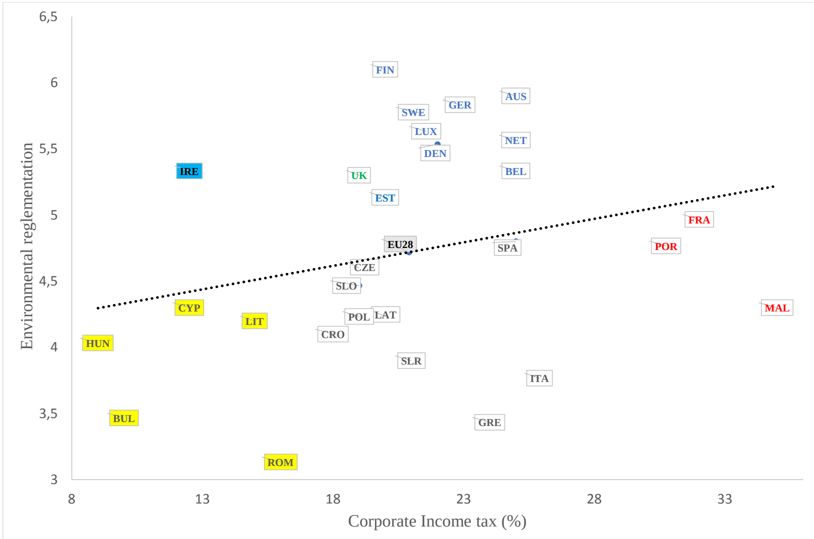


Figure 1: Interplay between tax policies and environmental regulations in a sample of EU member states (Source: OECD and World Economic Forum)

# 8 Appendix

## 8.1 Environmental standards

Plugging $t_1^*(\alpha_1, \alpha_2)$ and $t_2^*(\alpha_1, \alpha_2)$ into the payoff functions $G_1$ and $G_2$, we get

$$\frac{dG_i}{d\alpha_i} = \frac{\partial G_i}{\partial \alpha_i} + \overbrace{\frac{\partial G_i}{\partial t_i^*(\alpha_1, \alpha_2)}}^{=0} \frac{\partial t_i^*(\alpha_1, \alpha_2)}{\partial \alpha_i} + \frac{\partial G_i}{\partial t_j^*(\alpha_1, \alpha_2)} \frac{\partial t_j^*(\alpha_1, \alpha_2)}{\partial \alpha_i} = 0$$

which reduces to:

$$\frac{dG_i}{d\alpha_i} = \frac{(\alpha_i(\phi_j + \gamma_i) - 1)\left(s_i\left(2(\alpha_j - \alpha_i) + \alpha_i^2(\phi_j + \gamma_i) - \alpha_j^2(\phi_i + \gamma_j)\right) - 2k(s_i + 1)\right)}{9k} = 0$$

Checking for the second order condition (i.e maximum), we obtain:

$$\frac{d^2 G_i}{d\alpha_i^2} = \frac{1}{9k}\left(3s_i(\gamma_i + \phi_j)^2\alpha_i^2 - 6s_i(\gamma_i + \phi_j)\alpha_i - 2(\phi_j + \gamma_i)k(s_i + 1) - s_i\alpha_j^2(\phi_j + \gamma_i)(\phi_i + \gamma_j) + 2\alpha_j(\phi_j + \gamma_i)s_i + 2s_i\right)$$

Let us define the polynomial $P_1(\alpha_i) = a\alpha_i^2 + b\alpha_i + c$ with

$$a = \frac{(\phi_j + \gamma_i)^2 s_i}{3k} > 0$$
$$b = -\frac{2(\phi_j + \gamma_i)s_i}{3k} < 0$$
$$c = \frac{-2(\phi_j + \gamma_i)k(s_i + 1) - s_i\alpha_j^2(\phi_j + \gamma_i)(\phi_i + \gamma_j) + 2\alpha_j(\phi_j + \gamma_i)s_i + 2s_i}{9k}$$

To ensure that the solution to the FOC is a maximum, we first have to check that the discriminant is positive. We can easily derive that the discriminant is positive for $c < \frac{s_i}{3k}$, otherwise, the polynomial $P_1(\alpha_i)$ is positive for any $\alpha_i$ (since $c > \frac{s_i}{3k} > 0$) and the solution is a minimum.

Let us consider the case in which the discriminant is positive:

$$c < \frac{s_i}{3k} \iff k > \frac{2\alpha_j(\phi_j+\gamma_i)s_i - s_i\alpha_j^2(\phi_j+\gamma_i)(\phi_i+\gamma_j) - s_i}{2(\phi_j+\gamma_i)(s_i+1)}$$

We obtain the two following roots for the polynomial :

$$\overline{\alpha}_i = \frac{s_i + \sqrt{\frac{s_i\left(2(\phi_j+\gamma_i)k(s_i+1)+s_i\left(\alpha_j^2(\phi_j+\gamma_i)(\phi_i+\gamma_j)-2\alpha_j(\phi_j+\gamma_i)+1\right)\right)}{3}}}{(\phi_j+\gamma_i)s_i}$$

$$\underline{\alpha}_i = \frac{s_i - \sqrt{\frac{s_i\left(2(\phi_j+\gamma_i)k(s_i+1)+s_i\left(\alpha_j^2(\phi_j+\gamma_i)(\phi_i+\gamma_j)-2\alpha_j(\phi_j+\gamma_i)+1\right)\right)}{3}}}{(\phi_j+\gamma_i)s_i}$$

Since $P_1\left(\frac{1}{\gamma_i+\phi_j}\right) = c - \frac{s_i}{3k} < 0$ we have the following condition:

$$\text{For } k > \frac{2\alpha_j(\phi_j+\gamma_i)s_i - s_i\alpha_j^2(\phi_j+\gamma_i)(\phi_i+\gamma_j) - s_i}{2(\phi_j+\gamma_i)(s_i+1)}, \quad P_1(\alpha_i) < 0 \iff \alpha_i \in [\underline{\alpha}_i, \overline{\alpha}_i].$$

From Equation 8.1, we obtain 3 solutions:

$$\begin{aligned}
\alpha_{i1} &= \frac{1}{\phi_j+\gamma_i} \quad \textit{with} \quad \overline{\alpha}_i > \alpha_{i1} > \underline{\alpha}_i \\
\alpha_{i2} &= \frac{s_i + \sqrt{s_i\left(2(\phi_j+\gamma_i)k(s_i+1)+s_i\left(\alpha_j^2(\phi_j+\gamma_i)(\phi_i+\gamma_j)-2\alpha_j(\phi_j+\gamma_i)+1\right)\right)}}{(\phi_j+1)s_i} > \overline{\alpha}_i \\
\alpha_{i3} &= \frac{s_i - \sqrt{s_i\left(2(\phi_j+\gamma_i)k(s_i+1)+s_i\left(\alpha_j^2(\phi_j+\gamma_i)(\phi_i+\gamma_j)-2\alpha_j(\phi_j+\gamma_i)+1\right)\right)}}{(\phi_j+\gamma_i)s_i} < \underline{\alpha}_i
\end{aligned}$$

The concavity condition excludes solutions 2 and 3, which are minima, and solution 1 is the only maximum: $\alpha_i = \frac{1}{\phi_j+\gamma_i}$ for $k > \dfrac{s_i((\gamma_i-\phi_i)-(\gamma_j-\phi_j))}{2(\gamma_j+\phi_i)(\gamma_i+\phi_j)(1+s_i)}$.

## 8.2 Equilibrium configurations

The values of the threshold mobility costs are:

$\tilde{k} \equiv \frac{5((\gamma_1-\phi_1)-(\gamma_2-\phi_2))s_1}{2(2s_1-1)(\gamma_2+\phi_1)(\gamma_1+\phi_2)}$, and $t_1^* - t_2^* = \frac{2k(2s_1-1)(\gamma_2+\phi_1)(\gamma_1+\phi_2)+5s_1(\phi_1-\phi_2)}{6s_1(1+\phi_1)(1+\phi_2)} > 0$ iff $k > \tilde{k}$.
$\bar{k} \equiv \frac{s_1((\gamma_2-\phi_2)-(\gamma_1-\phi_1))}{(\phi_2+\gamma_1)(\phi_1+\gamma_2)2(2s_1-1)}$, and $x^* > 0 \iff k > \bar{k}$ from (10),
$\hat{k} = \frac{s_1((\gamma_1-\phi_1)-(\gamma_2-\phi_2)}{(2s_1-1)(\gamma_2+\phi_1)(\gamma_1+\phi_2)}$ and $N_1^* > N_2^* \iff k > \hat{k}$.
Finally, $\check{k} \equiv \frac{3s_1}{(2s_1-1)}\left(\frac{2\gamma_2+5\phi_1}{6(\gamma_2+\phi_1)^2} - \frac{2\gamma_1+5\phi_2}{6(\gamma_1+\phi_2)^2}\right)$ and $G_1^* - G_2^* > 0 \iff k > \check{k}$.

Note that:

$\tilde{k} \equiv \frac{5((\gamma_1-\phi_1)-(\gamma_2-\phi_2))s_1}{2(2s_1-1)(\gamma_2+\phi_1)(\gamma_1+\phi_2)} > 0 \Leftrightarrow (\gamma_1-\phi_1) > (\gamma_2-\phi_2)$.
$\bar{k} \equiv \frac{s_1((\gamma_2-\phi_2)-(\gamma_1-\phi_1))}{(\phi_2+\gamma_1)(\phi_1+\gamma_2)2(2s_1-1)} > 0 \Leftrightarrow (\gamma_2-\phi_2) > (\gamma_1-\phi_1)$

<table>
<tr><td></td><td colspan="2">$\mathbf{\Delta_2 > \Delta_1}$</td><td colspan="3">$\mathbf{\Delta_1 > \Delta_2}$</td></tr>
<tr><td></td><td colspan="2">$\bar{k} > 0$<br>$\tilde{k} < 0$ and $\hat{k} < 0$</td><td colspan="3">$\tilde{k} > \hat{k} > 0$<br>$\bar{k} < 0$</td></tr>
<tr><td>$\forall k$</td><td colspan="2">$\alpha_1^* > \alpha_2^*$<br>$t_1^* > t_2^*$<br>$N_1^* > N_2^*$</td><td colspan="3">$\alpha_1^* < \alpha_2^*$<br>$x^* > 0$</td></tr>
<tr><td rowspan="3">$k > \check{k}$</td><td rowspan="2">$k > \bar{k}$<br>$x^* > 0$</td><td rowspan="2">$k < \bar{k}$<br>$x^* < 0$</td><td rowspan="2">$k > \tilde{k}$<br>$t_1^* > t_2^*$<br>$N_1^* > N_2^*$</td><td colspan="2">$k < \tilde{k}$<br>$t_1^* < t_2^*$</td></tr>
<tr><td>for $\tilde{k} > k > \hat{k}$<br>$N_1^* > N_2^*$</td><td>for $\tilde{k} > \hat{k} > k$<br>$N_1^* < N_2^*$</td></tr>
<tr><td colspan="2">$G_1^* > G_2^*$</td><td colspan="3">$G_1^* > G_2^*$</td></tr>
<tr><td rowspan="3">$k < \check{k}$</td><td rowspan="2">$k > \bar{k}$<br>$x^* > 0$</td><td rowspan="2">$k < \bar{k}$<br>$x^* < 0$</td><td rowspan="2">$k > \tilde{k}$<br>$t_1^* > t_2^*$<br>$N_1^* > N_2^*$</td><td colspan="2">$k < \tilde{k}$<br>$t_1^* < t_2^*$</td></tr>
<tr><td>for $\tilde{k} > k > \hat{k}$<br>$N_1^* > N_2^*$</td><td>for $\tilde{k} > \hat{k} > k$<br>$N_1^* < N_2^*$</td></tr>
<tr><td colspan="2">$G_1^* < G_2^*$</td><td colspan="3">$G_1^* < G_2^*$</td></tr>
</table>

Table 1: Sets of equilibria depending on the level of capital integration and the ranking of pollution concern gaps for $k > k_{Max}$ and $k > k_{Min}$ with $\Delta_i = \gamma_i - \phi_i$.

$\hat{k} = \frac{s_1((\gamma_1-\phi_1)-(\gamma_2-\phi_2))}{(2s_1-1)(\gamma_2+\phi_1)(\gamma_1+\phi_2)} > 0 \Leftrightarrow (\gamma_1 - \phi_1) > (\gamma_2 - \phi_2)$

The sign of $\check{k}$ is much more complicated to determine and depends on the ranking of $(\gamma_1 - \phi_1)$ and $(\gamma_2 - \phi_2)$ and on the ranking of $\phi_1$ and $\phi_2$

Let us rank the threshold values $\hat{k}, \check{k}$ and $\tilde{k}$, when positive:

$$\begin{aligned}
\tilde{k} - \check{k} &\equiv \frac{3}{2} s_1 \frac{\gamma_2(\gamma_1+\phi_2)^2 - \gamma_1(\gamma_2+\phi_1)^2}{(\phi_2+1)^2(\phi_1+1)^2(2s_1-1)} \gtreqless 0 \Leftrightarrow \gamma_2(\gamma_1+\phi_2)^2 \lesseqgtr \gamma_1(\gamma_2+\phi_1)^2 \\
\hat{k} - \check{k} &\equiv \frac{3}{2} s_1 \frac{\phi_1(\gamma_2+\phi_1)^2 - \phi_2(\gamma_1+\phi_2)^2}{(\phi_2+1)^2(\phi_1+1)^2(2s_1-1)} \gtreqless 0 \Leftrightarrow \phi_1(\gamma_2+\phi_1)^2 \gtreqless \phi_2(\gamma_1+\phi_2)^2 \\
\tilde{k} - \hat{k} &= 3s_1 \frac{(\gamma_1-\phi_1)-(\gamma_2-\phi_2)}{(2s_1-1)(\phi_2+1)(\phi_1+1)} \gtreqless 0 \Leftrightarrow \gamma_1+\phi_2 \lesseqgtr \gamma_2+\phi_1 \\
\bar{k} - \check{k} &= \frac{3s_1}{2(2s_1-1)} \left( \frac{\gamma_1+2\phi_2}{(\phi_2+\gamma_1)^2} - \frac{\gamma_2+2\phi_1}{(\phi_1+\gamma_2)^2} \right) \gtreqless 0 \Leftrightarrow \frac{\gamma_1+2\phi_2}{(\phi_2+\gamma_1)^2} \gtreqless \frac{\gamma_2+2\phi_1}{(\phi_1+\gamma_2)^2}
\end{aligned}$$

So whenever
(i) $\gamma_2 - \phi_2 > \gamma_1 - \phi_1$, it follows $\bar{k} > 0$, $\hat{k} < 0$ and $\tilde{k} < 0$
(ii) $\gamma_1 - \phi_1 > \gamma_2 - \phi_2$, it holds that $\tilde{k} > \hat{k} > 0$ and $\bar{k} < 0$.

Moreover, we know that $k_{Max} < 0$ for $\gamma_1 - \phi_1 > \gamma_2 - \phi_2$ and $k_{Min} < 0$ for $\gamma_2 - \phi_2 > \gamma_1 - \phi_1$. Let us check the ranking of $k_{Max}$ and $\bar{k}$ when $\gamma_2 - \phi_2 > \gamma_1 - \phi_1$ and the ranking of $k_{Min}$ and $\hat{k}$ when $\gamma_1 - \phi_1 > \gamma_2 - \phi_2$:

- Let us compare $\bar{k}$ and $k_{Max}$:

$$\bar{k} - k_{\max} = \frac{3s_1^2}{2(2s_1 - 1)(5s_1 - 1)} \frac{(\gamma_2 - \phi_2) - (\gamma_1 - \phi_1)}{(\gamma_1 + \phi_2)(\gamma_2 + \phi_1)}$$

  Then $\bar{k} > k_{Max}$ when $\gamma_2 - \phi_2 > \gamma_1 - \phi_1$.

- Now let us compare $\hat{k}$ and $k_{Min}$:

$$\hat{k} - k_{Min} = \frac{(\gamma_1 - \phi_1) - (\gamma_2 - \phi_2)}{(\gamma_2 + \phi_1)(\gamma_1 + \phi_2)} \left( \frac{3s_1}{2(s_1 + 1)(2s_1 - 1)} \right)$$

  Then $\hat{k} > k_{Min}$ when $\gamma_1 - \phi_1 > \gamma_2 - \phi_2$.

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