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# Leading and losing the tax competition race[1]

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# Leading and losing the tax competition race.[1]

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## Abstract

In this paper we extend the standard approach of horizontal tax competition by endogenizing the timing of decisions made by the competing jurisdictions. Following the literature on the endogenous timing in duopoly games, we consider a pre-play stage, where jurisdictions commit themselves to move early or late, i.e. to fix their tax rate at a first or second stage. We highlight that at least one jurisdiction experiments a second-mover advantage. We show that the Subgame Perfect Equilibria (SPEs) correspond to the two Stackelberg situations yielding to a coordination problem. In order to solve this issue, we consider a quadratic specification of the production function, and we use two criteria of selection: Pareto-dominance and risk-dominance. We emphasize that at the safer equilibrium the less productive or smaller jurisdiction leads and hence loses the second-mover advantage. If asymmetry among jurisdictions is sufficient, Pareto-dominance reinforces Risk-dominance in selecting the same SPE. Three results may be deduced from our analysis: (*i*) the race to the bottom is less severe than predicted; (*ii*) the smaller jurisdiction leads; (*iii*) the 'big-country-higher-tax-rate' rule does not always hold.



JEL Codes: H30, H87, C72.

Key-words: Endogenous timing; tax competition; first/second-mover advantage; strategic complements; Stackelberg; Risk dominance.

# 1 Introduction

Tax competition is often seen as characterized by a “race-to-bottom” phenomenon, leading to under-provision of public goods. This result has been obtained using models that formalize tax competition through a Nash equilibrium with simultaneous moves and highlight a downward pressure on tax rates (see Zodrow and Mieszkowski (1986), Wilson (1986) or Wildasin (1988)).[1]

In this paper, we challenge this result by endogenizing the timing of decisions by fiscal authorities. We extend a standard model of capital tax competition with asymmetry among countries through a timing game used in the Industrial Organization literature. We first prove that moving sequentially will always lead to higher tax rates in both countries due to the strategic complementarity characteristics of these rates. In addition, we establish that there is a second-mover advantage for at least one country. The Subgame Perfect Equilibria (SPEs) correspond to the two Stackelberg situations, inducing a coordination issue. Specifying a quadratic form for the jurisdiction’s production functions, we apply two criteria of selection: Pareto dominance and risk dominance. We show that at the safer equilibrium, not only the less productive or equivalently smaller country leads, but also that the tax rate of the smaller country may be superior to the rate in the larger country. If asymmetry among countries is sufficient, the smaller country experiments a first-mover advantage, and Pareto-dominance reinforces risk-dominance in selecting the same SPE.

Very few works have focused on the nature itself of tax competition. The assumption of simultaneous moves of countries when deciding their tax policy, is largely accepted. As remarked by Schelling (1960), the viability of the equilibrium with simultaneous moves is dubious as soon as countries’ commitment is considered. An obvious way to commit is to decide before the others. Very few articles in the literature on international tax

[1] This approach has been extended in many directions by taking into account the difference among countries in their size or their initial endowments, by studying several tax instruments, by considering Leviathan governments, and so on. See for instance the surveys of Wilson (1999) or Wilson and Wildasin (2004) among the most recents.

competition consider the case where tax decisions are sequential:[2] Gordon (1992), Wang (1999) and to a smaller extent Baldwin and Krugman (2004). The first author considers double-taxation conventions between countries. He establishes that capital income taxation can be sustained if the dominant capital exporter country acts as a Stackelberg leader by choosing first its tax policy. Following Kanbur and Keen (1993) who focus on commodity taxation, Wang (1999) assumes that the larger country behaves as a Stackelberg leader. Baldwin and Krugman (2004) highlight the role of economies of agglomeration to explain why tax rates remain higher in the core country than in the periphery, by assuming that the core country moves first. In the empirical literature on tax competition too, few papers deviate from the simultaneous tax competition assumption (see Altshuler and Goodspeed (2002) or Redoano (2007)).

The preceding theoretical works which consider a Stackelberg configuration assume an exogenous timing, each jurisdiction or country having its predetermined role as leader or follower.[3] Given this background, the aim of this paper is twofold: firstly, going beyond the study of the Stackelberg equilibrium, we analyze the endogenous timing of tax setting and its consequences on the final equilibrium, which becomes a Subgame Perfect Equilibrium (SPE); secondly, since there are several SPEs, we solve the coordination issue that appears by using the notions of Pareto and risk dominance. This allows us to identify the leader respectively at the efficient equilibrium and at the safest one.

Our analysis is grounded on the standard approach to horizontal tax competition proposed by Wildasin (1988), as formalized by Laussel and Le Breton (1998). This model presents the advantage of focusing exclusively on strategic interactions. Moreover, Laussel and Le Breton (1998) rigorously establish the condition of existence and uniqueness of a Nash equilibrium in the canonical tax competition game.[4] Following the literature on

[2] Several recent papers on fiscal federalism consider a Stackelberg game where the central government leads. However, the induced vertical tax competition is not encompassed in the definition of tax competition by Wilson and Wildasin (2004). Moreover, the sequence of moves is assumed to be given.

[3] For instance, Wang (1999) writes (p. 974):

> "It is natural and conceivable that, in a real-world situation of tax-setting, the large region moves first and the small region moves second."

[4] The issue of equilibrium existence, *a fortiori* uniqueness, is seldom tackled in the tax competition

endogenous timing in duopoly games initiated by d'Aspremont and Gerard-Varet (1980) and Gal-Or (1985), we consider the two-period action commitment game proposed by Hamilton and Slutsky (1990): each country has to move in one of two periods; if one player chooses to move early, *i.e.* to fix its tax rate at the first period, while the other moves late, the latter behaves as a Stackelberg follower, the former as a leader; otherwise, choices of tax rates are simultaneous, and countries play the standard tax competition game. This kind of game, which has been called "leadership game" or "commitment game" has been mainly developped in Industrial Organization.[5] Our approach is close to van Damme and Hurkens (2004) and Amir and Stepanova (2006), who develop models of endogenous moves in Bertrand duopoly game where firms' strategies, i.e. prices, are complements.

We consider three "basic games" depending on the sequence of moves: one static and two Stackelberg games. In these games inspired from Wildasin (1988) and Laussel and Le Breton (1998), tax rates are strategic complements.[6] This property has been widely documented in empirical works on countries' reaction functions (see Devereux, Lockwood, and Redoano (2008) for instance). Morever, besides its realism, this property involves the supermodularity of the standard tax competition game, which insures the existence of equilibria. We rank the equilibrium tax rates obtained for the three basic games, and show that the standard tax competition equilibrium (simultaneous moves) leads to the lowest rates. We highlight a second-mover advantage for at least one of the two countries, which is consistent with the strategic complementarity of the tax rates. We turn into the timing game proposed by Hamilton and Slutsky (1990). The Subgame Perfect Equilibria

literature. Bucovetsky (1991), Wildasin (1991) or Wilson (1991) specify their respective model so as to have simple (generally linear) best reply curves. More recently, except Laussel and Le Breton (1998), we can mention the works of Bayindir-Upmann and Ziad (2005), Rothstein (2007) or Petchey and Shapiro (2009): Bayindir-Upmann and Ziad (2005) use the concept of a second order locally consistent equilibrium, which is less general than the Nash equilibrium; Rothstein (2007) considers ad valorem taxes instead of unit taxes; Petchey and Shapiro (2009) develop a dual approach, where countries minimize their policies' costs.

[5]This framework is also used in the international trade literature (Syropoulos (1994), Raimondos-Møller and Woodland (2000)) and in public economics (Kempf and Rota-Graziosi (2009), where we propose a taxonomy of international interactions depending on the sign of the spillovers and the nature of interactions).

[6]Bulow, Geanakoplos, and Klemperer (1985) coined the terms "strategic substitutes" and "strategic complements" to define the cases of downward- and upward-sloping reaction functions, respectively.

(SPEs) correspond to the two Stackelberg situations. These equilibrium tax rates are unambiguously superior to these determined in the simultaneous Nash game. The race to the bottom, if it exists, is less strong than predicted in the standard tax competition analysis.

Since we obtain two SPEs, a new issue appears which concerns the coordination among equilibria: which country chooses to move first? To answer, we determine the conditions under which Pareto (or payoff) dominance of one SPE is garanteed. However, this criterion fails to apply for all possible situations. It requires sufficient asymmetry among countries. Beyond the Pareto criterion, we consider the notion of risk-dominance as defined by Harsanyi and Selten (1988) to establish which equilibrium is the more secure.[7] Both the Pareto- and risk-dominance criteria support the view that the smaller (less productive) country leads the tax competition, thus losing the "second-mover advantage". In other words, leading the competition does not translate into a "small country" advantage (see Wellisch (2000)). Indeed, we establish that the "big-country-higher-tax-rate" rule does not always hold, that is the smaller country may fix an higher tax rate. Our findings are direct implications of the existing strategic complementarity in the tax competition race.

The rest of the paper is organized as follows: section 2 presents the basic framework and the three simple games depending on the simultaneity or sequentiality of country's moves; in section 3, we determine the SPEs by ranking the tax rates in the different games, highlighting a second-mover advantage in the extended game, and solving this; in section 4, we consider the coordination issue among the two possible SPEs, and we use the Pareto-dominance and risk-dominance criteria to go beyond this issue; section 5 concludes.

[7]We consider quadratic production functions usually used in the literature, because the use of the risk-dominance criterion requires the specification of the payoff functions.

# 2 Basic Framework

We consider a two-country economy where capital is mobile and the two fiscal authorities set capital taxes. The model is similar to the one proposed by Laussel and Le Breton (1998) as these authors provide a rigorous analysis of the existence and the uniqueness of a Nash equilibrium in a tax competition game inspired from Wildasin (1988). Our main results (PROPOSITIONS 1 and 2) are based on the strategic complementarity of tax strategies, or in other terms on the supermodularity of the tax competition game.

## 2.1 The model

The two jurisdictions, or countries, are denoted by $A$ and $B$. A single homogeneous private good is produced locally. This good can either be consumed or used as an input into the provision of the local public good. We define $F_i(K_i)$ the production function of private goods in Country $i$ as a function of employed capital, denoted by $K_i$, with $F_i'(K_i) > 0 > F_i''(K_i)$. Following Laussel and Le Breton (1998), we assume:

$$F_i'''(.) \geq 0. \tag{1}$$

This assumption insures the existence of a Nash equilibrium.

In contrast to Laussel and Le Breton (1998) who restrict themselves to the symmetric case, we introduce some asymmetry among countries by considering different production functions ($F_A(.) \neq F_B(.)$). Several other formalizations of asymmetry are available in the literature: Bucovetsky (1991) assumes that countries differ by their size; Peralta and van Ypersele (2005) consider different individual capital endowments. However, the choice of the nature of asymmetry would not affect our results, which are based on the property of strategic complementarity of tax rates. In section 4, we establish a parallel between the less productive country and the smaller country on the ground of the arguments of capital elasticity or *ex ante* lowly endowed country.

Each country finances its public expenditure by means of a per unit tax on capital at rate $t_i$ and a per unit tax on labor or land (a fixed production factor) at rate $\tau_i$. The availability of a non-distorting tax ($\tau_i$) on an immobile factor which is supplied inelastically, allows countries to optimally provide the public good ($g_i$). We do not consider the underprovision issue of the public good in order to focus exclusively on the nature of competition. The household in Country $i$ may be described by the following utility function: $U_i(x_i, g_i) = x_i + g_i$, where $x_i$ denotes the consumption of private goods and corresponds to the net income. As Laussel and Le Breton (1998) we assume that the net income derives from the fixed factor only. Thus, we have: $x_i = (1 - \tau_i) w_i$, where $w_i$ denotes the earned wage, equal to the marginal productivity of labor. We define the welfare function of Country $i$ as the sum $W_i$ of the fixed factor income and the capital tax income:[8]

$$W_i(t_i, t_j) = F_i(K_i) - K_i F_i'(K_i) + t_i K_i. \tag{2}$$

The capital is perfectly mobile between the jurisdictions and we assume an initial level of total capital equal to $\overline{K}$. The market clearing conditions involve:

$$\begin{cases} F_A'(K_A) - t_A = F_B'(K_B) - t_B \\ K_A + K_B = \overline{K} \end{cases} \tag{3}$$

In order to turn down the "pathological" case, where there is a continuum of Nash equilibria satisfying $F_i'(K_i) - t_i = 0$, we assume that the following inequality always holds:

$$F_i'(K_i) - t_i > 0 \quad \text{for} \quad i = A, B \tag{4}$$

This second condition means that the net capital return is strictly positive. Combined with condition (1), it guarantees the uniqueness of the studied Nash equilibrium.

[8] This assumption which is also advanced by Hindriks, Peralta, and Weber (2008) is restrictive, since it means that the capital owners are absent in the objective function of the government. However, Laussel and Le Breton (1998) provide two possible interpretations of a such restriction, which are consistent with Wildasin (1988): it can be justified as a partial equilibrium, or it corresponds to a political economy view, focusing on the median voter. This second view is supposed to reflect the high concentration of countries' capital distribution.

From (3), it is immediate to get that:

$$\frac{\partial K_i}{\partial t_i} = \frac{1}{F_A''(K_A) + F_B''(K_B)} = \frac{\partial K_j}{\partial t_j} = -\frac{\partial K_i}{\partial t_j} < 0. \tag{5}$$

The stock of capital in Country $i$ is decreasing in its tax rate $(t_i)$ and increasing in the tax rate of the other country $(t_{j\neq i})$.

Further, we can prove the following

**Lemma 1** *Under assumption (1), tax rates are strategic complements.*

**Proof.** See Appendix A.1. ■

The explanation is simple: when government $j$ increases its rate, it alleviates the competitive pressure on governement $i$ as this decision reduces the incentive of capital to migrate from $i$ to $j$. Therefore the marginal utility derived from an increase of the tax rate set by governement $i$ is increasing since it generates more revenues and finances more additional public good. In other words, the cross-derivatives of $W_i(t_i, t_j)$ are positive.

The strategic complementarity property of tax setting functions is crucial for our analysis. Several recent works focusing on the estimation of the fiscal reaction functions in an international or federal context support the view that fiscal interactions exist and highlight positive slope reaction functions among countries or jurisdictions (see for instance Revelli (2005), Devereux, Lockwood, and Redoano (2008)).

In the following subsections, we will study three different games, depending on the sequence of the countries' tax-setting. We denote $G^N$ the game where both countries choose simultaneously their tax rate; $G^A$ the game where Country $A$ leads and Country $B$ follows; and $G^B$ the game where Country $B$ leads.

## 2.2 Simultaneous game $\left(G^N\right)$

At the simultaneous non-cooperative equilibrium each country chooses its own tax rate without taking into account the externalities on the other country. We denote by $\left(t_A^N, t_B^N\right)$ the Nash equilibrium of this game. This pair must satisfy the following set of definitions:

$$\begin{cases} t_A^N \equiv \underset{t_A \in [0,1]}{\arg\max} W_A(t_A, t_B), & t_B \text{ given} \\ t_B^N \equiv \underset{t_B \in [0,1]}{\arg\max} W_B(t_A, t_B), & t_A \text{ given} \end{cases}$$

Let us define the function $\Phi_i(t_i, t_j)$ by:

$$\Phi_i(t_i, t_j) = t_i + K_i F_j''(K_j), \quad j \neq i \tag{6}$$

The first-order conditions (FOCs) obtain:

$$\begin{cases} \Phi_A\left(t_A^N, t_B^N\right) \frac{\partial K_A}{\partial t_A} = 0 \\ \Phi_B\left(t_B^N, t_A^N\right) \frac{\partial K_B}{\partial t_B} = 0 \end{cases}$$

or equivalently, since $\frac{\partial K_A}{\partial t_A} \neq 0$ from (5),[9]

$$\begin{cases} \Phi_A\left(t_A^N, t_B^N\right) = 0 \\ \Phi_B\left(t_B^N, t_A^N\right) = 0 \end{cases} \tag{7}$$

Under assumption (1), Laussel and Le Breton (1998) establish the existence of the Nash equilibrium. Condition (4) involves the uniqueness of this equilibrium by ruling out the "pathological" case. In Appendix A.1, we show that $\frac{dt_j}{dt_i} < 1$, which means here that the best-reply correspondences are contractions. This is another way to guarantee the existence and the uniqueness of a Nash equilibrium (see Vives (1999), p. 47).

## 2.3 Stackelberg games $G^A$ and $G^B$

There are two Stackelberg games depending on the identity of the leader. In the game $G^i$, we assume that Country $i$ "leads", that is fixes first its tax rate, and Country $j$ chooses

[9] The second-order conditions (SOCs) are satisfied at $\left(t_A^N, t_B^N\right)$:

$$\frac{\partial^2 W_i(t_i, t_j)}{\partial t_i^2} = \frac{\partial \Phi_i(t_i, t_j)}{\partial t_i} \frac{\partial K_i}{\partial t_i} + \Phi_i(t_i, t_j) \frac{\partial^2 K_i}{\partial t_i^2} < 0,$$

since $\frac{\partial \Phi_i(t_i,t_j)}{\partial t_i} > 0$ and $\Phi_i\left(t_i^N, t_j^N\right) = 0$.

its own level $t_j$.

Applying backward induction, we first consider the maximization program of Country $j$ when it acts as the follower. It is given by:

$$t_j^F(t_i) \equiv \arg\max_{t_j \in [0,1]} W_j(t_j, t_i)$$

The FOC of the follower obtains

$$\Phi_j\left(t_j^F(t_i), t_i\right) = 0 \tag{8}$$

We turn into Country $i$'s maximization program, when it acts as the leader. It is given by:

$$t_i^L \equiv \arg\max_{t_i \in [0,1]} W_i\left(t_i, t_j^F(t_i)\right)$$

The corresponding FOC obtains

$$\Phi_i\left(t_i^L, t_j^F\left(t_i^L\right)\right) + \left(K_i F_i''(K_i) - t_i^L\right)\frac{dt_j}{dt_i} = 0. \tag{9}$$

From the strategic complementarity of tax rates, we deduce that the second term of equation (9) is negative. The first term is positive. This property will allow us to rank the equilibrium tax rates in the next subsection.

## 2.4 Comparison of the equilibrium tax rates

We show that these equilibria generate different solutions and the tax rates obtained in a game with leadership are higher than the rates obtained in the Nash game, when the two authorities play simultaneously. This comes from the fact that tax rates are strategic complements: an increase in the rate fixed by the other government leads a government to increase its own rate.

Given the property of strategic complementarity, we are able to rank the equilibrium tax rates.[10]

**Lemma 2** *There are three possible rankings of the levels of tax rates:*

$$\begin{cases} t_A^N < t_A^F < t_A^L \\ t_B^N < t_B^F < t_B^L \end{cases}, \quad \begin{cases} t_A^N < t_A^F < t_A^L \\ t_B^N < t_B^L < t_B^F \end{cases} \quad or \quad \begin{cases} t_A^N < t_A^L < t_A^F \\ t_B^N < t_B^F < t_B^L \end{cases}$$

**Proof.** See APPENDIX A.2. ■

Consistent with the strategic complementarity property, tax rates in any Stackelberg equilibrium are higher than the rates obtained at the Nash equilibrium. When the leader, say $A$, increases its tax rate relative to the Nash equilibrium value, it induces the follower, $B$, to increase its own tax rate because of the strategic complementarity property. In turn, this increases the leader's payoff because of the positive externality induced by tax decision, and captured by the sign of $\partial W_i(t_i, t_j)/\partial t_j\ (>0)$. Hence we get $t_A^L > t_A^N$ and $t_B^F > t_B^N$. In other words, the presence of a leader in the tax competition race mitigates the "race-to-the-bottom" feature obtained in Nash equilibrium.

However it may happen that $t_A^F > t_A^L$. This comes from the differences in the $\Phi_i(t_i, t_j)$ functions, hence in the production functions. For a sufficient degree of asymmetry in the production functions, the interaction effects are much stronger from $B$ to $A$, than from $A$ to $B$. Then $t_A^L$ is very close to $t_A^N$ and $t_B^L$ is very far from $t_B^N$ as well as $t_A^F$ from $t_A^N$. This explains the obtained possible rankings. In the Appendix, we provide a graphical illustration of this LEMMA for quadratic production functions.

# 3 Identifying the leader in the tax competition race.

These results imply that the existence and identity of a leader matter a lot in the tax competition race. Hence we would like to know the identity of the leader if it exists: is it Country A or B? To answer this question, we turn to the endogenization of moves,

[10] For the rest of the paper, we will use the following notation: $t_i^F \equiv t_i^F\left(t_j^L\right)$.

using a timing game. In the first stage of the timing game, the two players, here the two authorities of the jurisdictions, decide on their preferred role. They may decide they want to play “Early” or “Late”. Depending on the outcome of this stage, one of the three games described above is selected and processed. Following Hamilton and Slutsky (1990) and Amir and Stepanova (2006) we study the Subgame Perfect Equilibria of this timing game. First, we highlight the presence of a second-mover advantage. This allows us to deduce the Subgame Perfect Equilibria.

## 3.1 Second-mover advantage

We define the notions of “first-” and “second-mover advantage” as follows:

**Definition 1** *Country $i$ has a first (second)-mover advantage if its equilibrium payoff in the Stackelberg Game in which it leads (follows) is higher than in the Stackelberg Game in which it follows (leads).*

Using this definition, we establish the following PROPOSITION:

**Proposition 1** *At least one country has a second-mover advantage in the tax competition race.*

**Proof.** See APPENDIX A.3. ■

When $t_i^N < t_i^F < t_i^L$ for both countries, there is a second-mover advantage for both countries as both prefer to follow: a country optimally benefits from the higher tax rate decided by the leader. Being a follower allows a country both to benefit from higher tax rates compared to the Nash equilibrium and to have the lower tax rate, thus attracting more capital. In other terms it free-rides the leader even though this free-riding is less important than in the simultaneous Nash game. In case of identical countries, both countries have a second-mover advantage.[11] When $t_i^N < t_i^L < t_i^F$ and $t_j^N < t_j^F < t_j^L$, only Country $i$ prefers to follow.

[11] When the two countries are identical, that is when $F_i(K) = F_j(K)$, it is immediate to derive from the previous Lemma the comparison between the tax rates under this assumption: $t^N < t^F < t^L$.

## 3.2 A Timing Game

In order to address the existence and identity of a leader, we shall endogenize the sequence of moves by resorting to a timing game, following the seminal study of Hamilton and Slutsky (1990).

This game, which we denote by $\widetilde{G}$, is defined as follows. At the first or "preplay" stage, players simultaneously and non-cooperatively decide whether to move "early" or "late". The players' commitment to this choice is perfect. The timing choice of each player is announced at the end of the first stage. The second stage corresponds to the relevant tax competition game studied in the previous section, which is deduced from the timing decision at the first stage: the game $\left(G^N\right)$ if both players choose to move early or late; the Stackelberg game $\left(G^A\right)$ if Country $A$ chooses to move early (strategy *Early*) while Country $B$ chooses to move late (strategy *Late*); the Stackelberg game $\left(G^B\right)$ if Country $B$ chooses to move early (strategy *Early*) while Country $A$ chooses to move late (strategy *Late*).[12] The game $\widetilde{G}$ may be reduced to a single-stage game, which has the following normal form:

| | | Country $B$ | |
|---|---|---|---|
| | | *Early* | *Late* |
| Country $A$ | *Early* | $W_A^N, W_B^N$ | $W_A^L, W_B^F$ |
| | *Late* | $W_A^F, W_B^L$ | $W_A^N, W_B^N$ |

where $W_i^N \equiv W_i\left(t_i^N, t_j^N\right)$, $W_i^L \equiv W_i\left(t_i^L, t_j^F\left(t_i^L\right)\right)$ and $W_i^F \equiv W_i\left(t_i^F\left(t_j^L\right), t_j^L\right)$.

From the preceding normal form of the game $\widetilde{G}$, we obtain the following Proposition:

**Proposition 2** *The Subgame Perfect Equilibria (SPEs) of the timing game are the Stackelberg Equilibria.*

**Proof.** See Appendix A.4. ■

[12] An other option exists in the literature on endogenous timing when both players choose to lead. Indeed, Dowrick (1986) and more recently van Damme and Hurkens (1999) consider a Stackelberg warfare, where both countries would choose their strategy as leader. In contrast, Hamilton and Slutsky (1990) or Amir and Stepanova (2006) apprehend this situation as the static Nash game. Hamilton and Slutsky (1990) emphasize that Stackelberg warfare can occur only through error, since the underlying strategy of one player is not consistent with the other player's strategy.

Since tax rates are strategic complements, there are two possible Stackelberg equilibria corresponding to the timing game $\widetilde{G}$. This comes from the fact that in any case, both the first- and second-movers are better off than under a Nash equilibrium. At the SPEs, the tax rates are in both countries superior to those established at the simultaneous Nash equilibrium, *i.e.* in the standard tax competition game.[13] From PROPOSITION (2), we deduce the following COROLLARY:

**Corollary 1** *Moving sequentially instead of simultaneously is Pareto-improving for both countries.*

**Proof.** Immediate. ■

We highlight that the SPEs are Pareto-superior to the simultaneous Nash Equilibrium ($W_i^{F,L} > W_i^N$). The "race-to-bottom" is weaker as it is predicted in the standard tax competition model since tax rates are always higher in the sequential games: both countries have a common interest in avoiding the Nash tax rates, and they can do so by resorting to non-synchronous moves, that is by accepting that one of them leads the tax competition race.

# 4 A coordination issue

A new issue appears due to the multiplicity of SPEs of $\widetilde{G}$: how to select one of the two possible solutions? There is a coordination issue. To solve this issue, we can resort to two criteria in order to rank the SPEs: the Pareto-dominance and the risk-dominance criteria. Harsanyi and Selten (1988) define the latter criterion as follows:

**Definition 2** *An equilibrium risk-dominates another equilibrium when the former is less risky than the latter, that is the risk-dominant equilibrium is the one for which the product of the deviation losses is the largest.*

[13] Notice that the equilibria studied in the literature on tax competition is not *commitment robust*. Extending the approach of Rosenthal (1991), van Damme and Hurkens (1996) establish that a Nash Equilibrium is commitment robust if and only if no player has a first-mover incentive, that is no player prefers to lead than to play the simultaneous game. In APPENDIX A.2, we highlight that both countries always have a first-mover incentive.

In our framework, equilibrium $(Early, Late)$ (Country $A$ leads, Country $B$ follows) risk-dominates equilibrium $(Late, Early)$ if the former is associated with the larger product of deviation losses, denoted by $\Pi$. More formally, the equilibrium $(Early, Late)$ risk-dominates $(Late, Early)$ if and only if

$$\Pi \equiv \left(W_A^L - W_A^N\right)\left(W_B^F - W_B^N\right) - \left(W_A^F - W_A^N\right)\left(W_B^L - W_B^N\right) > 0. \tag{10}$$

As stressed by Amir and Stepanova (2006), a resolution for risk-dominance does not appear possible without using a precise specification of the problem.[14] To apply this criterion to the tax competition problem, we consider a quadratic production function, already used in the relevant literature:[15]

$$F_i(K) = (a - b_i K) K. \tag{11}$$

Without loss of generality, we assume $b_A < b_B$: firms in Country $A$ are more productive than in Country $B$. We can also interpret this assumption as Country $A$ is better endowed than the other. Under this assumption on the production functions, the tax rates and the capital stocks at the equilibria of the three studied games are presented in the

[14] Analysing the competition among firms, these authors use a linear demand function as van Damme and Hurkens (1999).

[15] See for instance, Bucovetsky (1991), Grazzini and van Ypersele (2003), Peralta and van Ypersele (2005), Devereux, Lockwood, and Redoano (2008).

following table:

Table 1 : Tax rates and capital stocks in $G^N$, $G^A$ and $G^B$.

| | $G^N$ | $G^A$ | $G^B$ |
|---|---|---|---|
| Country $A$ | | | |
| $t_A$ | $b_B\overline{K}$ | $\frac{2(b_A+b_B)^2}{3b_A+2b_B}\overline{K}$ | $\frac{2b_B(b_A+2b_B)}{2b_A+3b_B}\overline{K}$ |
| $K_A$ | $\frac{\overline{K}}{2}$ | $\frac{b_A+b_B}{3b_A+2b_B}\overline{K}$ | $\frac{b_A+2b_B}{2b_A+3b_B}\overline{K}$ |
| Country $B$ | | | |
| $t_B$ | $b_A\overline{K}$ | $\frac{2b_A(2b_A+b_B)}{3b_A+2b_B}\overline{K}$ | $\frac{2(b_A+b_B)^2}{2b_A+3b_B}\overline{K}$ |
| $K_B$ | $\frac{\overline{K}}{2}$ | $\frac{2b_A+b_B}{3b_A+2b_B}\overline{K}$ | $\frac{b_A+b_B}{2b_A+3b_B}\overline{K}$ |

From the preceding table, we can make several observations. First, if each region has the same capital endowment before tax competition occurs, we observe that no country exports capital at the simultaneous Nash equilibrium, while the leading country is always a capital exporter. Second, at the simultaneous Nash equilibrium, the more productive country has the higher tax rate: $b_A < b_B \Leftrightarrow t_A^N > t_B^N$. This point results from the difference in the capital elasticities: $\varepsilon_{K_A^N/t_A^N} = -\frac{b_B}{b_A+b_B} < \varepsilon_{K_B^N/t_B^N} = -\frac{b_A}{b_A+b_B}$. Here we echo the analysis of Bucovetsky (1991) and Wilson (1991) who establish that small jurisdictions[16] tend to set lower tax rates than large ones. On the basis of capital elasticity, we can draw a parallel between size and productivity, when we consider that the smaller country corresponds to the less productive one, which we also call the *ex ante* lowly endowed country.

Given the definition (10) of risk-dominance, we obtain the following PROPOSITION:

**Proposition 3** *(i) The SPE, where the less productive country leads, risk-dominates the other equilibrium.*

*(ii) If the asymmetry between countries is sufficient, the safer SPE becomes Pareto-dominant.*

[16] Small jurisdictions or counties may be considered as *ex ante* lowly endowed, since their size in population explains directly their initial stock of capital under the assumption that each inhabitant has the same individual endowment in capital.

**Proof.** See APPENDIX A.5. ■

This proposition implies that Country $B$ is always selected as the leader, according to the risk-dominance criterion as long as $b_A < b_B$.[17] When the difference in productivity is sufficiently pronounced ($b_A/b_B < 0.25$ or $b_A/b_B > 4$, see APPENDIX A.5.3), one country has a first-mover advantage, while the other still has a second-mover advantage. The risk-dominant equilibrium becomes Pareto-dominant. The following table summarizes the results of the preceeding PROPOSITION:[18]

Table 2: Risk and Pareto dominance

| $b_A$ | $[\beta_0, \beta_1[$ | $[\beta_1, b_B[$ | $[b_B, \beta_3[$ | $[\beta_3, \beta_4]$ |
|---|---|---|---|---|
| $W_{i,j}^k$ | $W_A^F > W_A^L$ <br> $W_B^F < W_B^L$ | $W_A^F > W_A^L$ <br> $W_B^F > W_B^L$ | $W_A^F > W_A^L$ <br> $W_B^F > W_B^L$ | $W_A^F < W_A^L$ <br> $W_B^F < W_B^L$ |
| Pareto-dominance | $(F, L)$ | none | none | $(L, F)$ |
| Risk-dominance | $(F, L)$ | $(F, L)$ | $(L, F)$ | $(L, F)$ |

At the safer SPE, the less productive country has to move early ($B$ for $b_A \in [\beta_0, b_B[$, $A$ for $b_A \in [b_B, \beta_4[$) since it has more to loose in playing the simultaneous game than the other country. For instance, if $b_A \in [\beta_0, b_B[$, Country $B$ increases its own tax rate compared to the Nash level, which will trigger a larger increase in Country $A$ tax rate because of the complementarity effect; on the other hand, if $A$ is a leader (*Early*), given that $B$ as a follower (*Late*) will not tend to act much, the gain of $A$ as a leader with respect to the Nash solution, is not that large.

When the asymmetry is sufficient ($b_A \in [\beta_0, \beta_1[$ or $b_A \in [\beta_3, \beta_4]$), the SPE where the less productive country leads, becomes Pareto-superior to the other SPE. Indeed, for low values of $b_A$ with respect to $b_B$ ($b_A \in [\beta_0, \beta_1[$), the less productive country (namely $B$) experiments a first-mover advantage, while the other has a second-mover advantage.

[17] This result is a straight criticism of the assumption made by Wang (1999) or Baldwin and Krugman (2004) that the larger country or the core country behaves as a leader.

[18] See the APPENDIX A.5 for the definition of $\beta_k$. A graphical illustration of these results is provided in the APPENDIX (Graph 2).

By leading and fixing a higher tax rate $\left(t_B^L > t_B^F\right)$, Country $B$ encourages Country $A$ to increase its tax rate since we have $t_A^F > t_A^L$.[19] Thus, Pareto-dominance reinforces risk-dominance when countries' asymmetry is sufficient.

In brief, the sequential-move outcome is mutually beneficial relative to the simultaneous-move (see COROLLARY 1), and risk-dominance attributes a role to each country that involves a sharing of the surplus among them, with an advantage given to the follower over the leader. By choosing to lead the tax competition race, a country gives up the second-mover advantage to its competitor.

Finally, our analysis invites to reconsider the "big-country-higher-tax-rate" rule, which was emphasized first by Bucovetsky (1991).[20] Indeed, while at the simultaneous Nash equilibrium, the more productive, or equivalently, the larger country always sets a higher tax rate due to its relatively low elasticity of capital to the tax rate, it may set the lower tax rate at the safer SPE. More formally, if $b_B > b_A > \frac{\sqrt{5}-1}{2} b_B$, we obtain $t_A^F < t_B^L$.[21] The less productive (equivalently, the smaller) country may tax at a higher rate than the other country. In other terms, the *ex ante* advantage (in productivity or in size) is reinforced through the second-mover advantage.

# 5 Conclusion

Our analysis revisits tax competition by relaxing one implicit assumption generally made in the relevant literature: the simultaneity of decisions on tax rates. Inspired by several works in Industrial Organization, we developed a model where the timing of move, i.e. the tax-setting, is endogenous. Our main results hold for any form of the government's

[19] From TABLE 1, we have $t_A^F > t_A^L$ for $b_A < \beta_1 < \alpha_1 b_B$, where $\alpha_1$ is solution of $-1 + 4\alpha^2 + 2\alpha^3 = 0$, $\alpha_1 \approx 0.451606$.

[20] In an asymmetric model of international trade Raimondos-Møller and Woodland (2000) also establish the existence of situations in which the small country leads, fixing its tariff rate first and yielding to improve the welfare of both countries.

[21] Moreover, the elasticity of capital is higher in the follower country:

$$\varepsilon_{K_A^F/t_A^F} = -\frac{b_B}{b_A + b_B} > \varepsilon_{K_B^L/t_B^L} = -1.$$

objective function as long as tax rates are strategic complements. We established that: the tax rates are higher when countries move sequentially than when they move simultaneously; at least one country experiments a second mover-advantage; moving sequentially is Pareto- improving; the SPEs correspond to the two Stackelberg situations yielding to a coordination issue. By specifying quadratic production functions, we solve it by applying the notions of Pareto and risk dominance. At the safer SPE, the *ex ante* well endowed country follows, reinforcing its *ex ante* advantage through the second-mover advantage. When countries' asymmetry is sufficient, Pareto-dominance confirms risk-dominance in selecting the same SPE.

In addition to the empirical studies which would explicitly consider the dynamics of tax-setting decisions,[22] further research could be considered. An immediate development is to introduce the capital owners in the welfare function. New conditions for existence and uniqueness of the Nash equilibrium would be needed before the analysis of Stackelberg games could proceed.[23] An other development would be to to consider the issue of underprovision of public goods when the timing of moves is endogenized.

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[22] Very few empirical studies have considered the order of tax-setting: Altshuler and Goodspeed (2002) established that European countries follow the United States when they set their tax rate; focusing on European countries only, Redoano (2007) show that large countries behave as leader. We established an inverse sequence of tax decisions at the safer equilibrium. This contradiction invites to further empirical and theoretical developments.

[23] See footnote (3) on the issue of the existence of Nash equilibrium in tax competition models.

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# A Appendix

## A.1 Proof of Lemma 1: strategic complementarity of the tax rates

We have

$$\begin{aligned}\frac{\partial \Phi_i (t_i, t_j)}{\partial t_i} &= 1 + F_j'' (K_j) \frac{\partial K_i}{\partial t_i} + K_i F_j''' (K_j) \frac{\partial K_j}{\partial t_i} \\ &= 1 + \left[F_j'' (K_j) - K_i F_j''' (K_j)\right] \frac{\partial K_i}{\partial t_i} > 0,\end{aligned}$$

and

$$\begin{aligned}\frac{\partial \Phi_i (t_i, t_j)}{\partial t_j} &= F_j'' (K_j) \frac{\partial K_i}{\partial t_j} + K_i F_j''' (K_j) \frac{\partial K_j}{\partial t_j} \\ &= \left[-F_j'' (K_j) + K_i F_j''' (K_j)\right] \frac{\partial K_j}{\partial t_j} < 0.\end{aligned}$$

Under assumption (1), we deduce

$$\frac{\partial \Phi_i (t_i, t_j)}{\partial t_i} > 0 \quad \text{and} \quad \frac{\partial \Phi_i (t_i, t_j)}{\partial t_j} < 0.$$

Applying the Envelop theorem to (7) or equivalently to (8), we obtain[24]

$$\frac{dt_j}{dt_i} = -\frac{\frac{\partial \Phi_j (t_j, t_i)}{\partial t_i}}{\frac{\partial \Phi_j (t_j, t_i)}{\partial t_j}} > 0 \text{ and } \frac{dt_j}{dt_i} < 1.$$

□

## A.2 Proof of Lemma 2: ranking of the equilibrium tax rates

From the definition of the Stackelberg equilibrium, we always have:

$$W_i \left(t_i^L, t_j^F \left(t_i^L\right)\right) \equiv \max_{t_i} W_i \left(t_i, t_j^F (t_i)\right) \geqslant W_i \left(t_i^N, t_j^F \left(t_i^N\right)\right) = W_i \left(t_i^N, t_j^N\right), \tag{12}$$

since $t_j^F \left(t_i^N\right) = t_j^N$ by definition of the follower's maximisation program. Inequality (12) involves that each country has a first-mover incentive.

If $t_j^N \geqslant t_j^F \left(t_i^L\right)$, since $\frac{\partial W_i(t_i,t_j)}{\partial t_j} = -\frac{\partial K_i}{\partial t_j} K_i F_i'' (K_i) + t_i \frac{\partial K_i}{\partial t_j} > 0$, the definition of the Nash equilibrium yields

$$\begin{aligned}W_i \left(t_i^N, t_j^N\right) &\equiv \max_{t_i} W_i \left(t_i, t_j^N\right) \\ &\geqslant W_i \left(t_i^L, t_j^N\right) \\ &> W_i \left(t_i^L, t_j^F\right),\end{aligned}$$

which contradicts (12). Thus we always have:

$$t_i^F > t_i^N, \quad i = A, B. \tag{13}$$

[24] Note that $\frac{\partial K_i}{\partial t_i} = \frac{\partial K_j}{\partial t_j}$.

Since $\frac{\partial K_i}{\partial t_i} < 0$ and $\frac{dt_i}{dt_j} > 0$, we establish from the FOCs of the different games $\left(G^{N,A,B}\right)$ that

$$\Phi_i\left(t_i^L, t_j^F\right) > \Phi_i\left(t_i^N, t_j^N\right) = \Phi_i\left(t_i^F, t_j^L\right) = 0. \tag{14}$$

Since $\frac{\partial \Phi_i(t_i,t_j)}{\partial t_j} < 0 < \frac{\partial \Phi_i(t_i,t_j)}{\partial t_i}$, the inequalities (13) and (14) involve that we always have

$$t_i^L > t_i^N, \quad i = A, B. \tag{15}$$

Moreover, inequality (14) involves

$$\begin{array}{rcl} t_i^L & < & t_i^F \Rightarrow t_j^F < t_j^L \\ t_j^F & > & t_j^L \Rightarrow t_i^L > t_i^F. \end{array}$$

We have three possible rankings of the levels of public goods: $\forall (i,j) \in \{A,B\}^2$ and $i \neq j$,

$$\left\{ \begin{array}{l} t_i^N < t_i^F < t_i^L \\ t_j^N < t_j^F < t_j^L \end{array} \right. \quad \text{or} \quad \left\{ \begin{array}{l} t_i^N < t_i^F < t_i^L \\ t_j^N < t_j^L < t_j^F \end{array} \right.$$

Under symmetry, we have: $t_A^L = t_B^L = t^L$, $t_A^F\left(t_B^L\right) = t_B^F\left(t_A^L\right) = t^F$ and $t_A^N = t_B^N = t^N$. We obtain one possible ranking only:

$$t^N < t^F < t^L.$$

□

## A.3 Proof of Proposition 1: second-mover advantage

- When $\forall i = A, B, \quad t_i^N < t_i^F < t_i^L$, we have

$$\begin{array}{rcl} W_i\left(t_i^F, t_j^L\right) & \geqslant & W_i\left(t_i^L, t_j^L\right) \\ & > & W_i\left(t_i^L, t_j^F\right), \end{array}$$

  where the first inequality results from the definition of the Stackelberg equilibrium when Country $i$ follows, and the second from the facts that $t_j^F < t_j^L$ and $\frac{\partial W_i(t_i,t_j)}{\partial t_j} > 0$. Each country has a second-mover advantage.

- When $t_i^N < t_i^L < t_i^F$ and $t_j^N < t_j^F < t_j^L$, we have

$$W_i\left(t_i^F, t_j^L\right) > W_i\left(t_i^L, t_j^F\right),$$

  as in the precedent case since $t_j^F < t_j^L$. Country $i$ has a second-mover advantage.□

## A.4 Proof of Proposition 2: Subgame Perfect Equilibria

For each country $i$, we always have by definition

$$W_i^L > W_i^N.$$

Moreover, we know that

$$\begin{array}{rcl} W_i^F & = & W_i\left(t_i^F\left(t_j^L\right), t_j^L\right) \geqslant W_i\left(t_i^N, t_j^L\right) \\ & > & W_i\left(t_i^N, t_j^N\right) = W_i^N. \end{array}$$

where the first inequality results from the definition of the Stackelberg equilibrium when Country $i$ follows, and the second from the facts that $t_i^L > t_i^N$ and $\partial W\left(t_i, t_j\right)/\partial t_j > 0$. Thus, there are two SPEs which correspond to the two Stackelberg situations.□

## A.5 Proof of Proposition 3: Risk and Pareto-dominance with a quadratic production function

### A.5.1 Definition of the relevant interval on $b_B$

$\beta_0$ and $\beta_4$ define the interval of values for $b_A$ for which: $\forall i = A, B$, $\left(t_i^N, t_i^L, t_i^F\right) \in [0,1]^3$. Without lost of generality, we assume that $b_B = \gamma b_A$, with $\gamma > 0$. We have

$$\left(t_i^N, t_i^L, t_i^F\right) \in [0,1]^3 \Leftrightarrow \beta_0 \leqslant b_A \leqslant \beta_4,$$

where $\beta_0 = \min\left\{\frac{3+2\gamma}{2\overline{K}(1+\gamma)^2}, \frac{2+3\gamma}{\overline{K}^2(1+\gamma)^2}\right\}$ and $\beta_4 = \max\left\{\frac{3+2\gamma}{2\overline{K}(2+\gamma)}, \frac{(2+3\gamma)^2}{\overline{K}^2(1+2\gamma)^2}\right\}$.[25]

### A.5.2 Risk-dominance

We obtain the following expression of the deviations product:

$$\Pi\left(b_A, b_B, \overline{K}\right) = (b_A - b_B)\, Q\,(b_A, b_B)\, \overline{K}^4,$$

where

$$Q\,(b_A, b_B) = \frac{(b_A + b_B)\left(14b_A^6 + 78b_A^5 b_B + 180b_A^4 b_B^2 + 231b_A^3 b_B^3 + 180b_A^2 b_B^4 + 78b_A b_B^5 + 14b_B^2\right)}{2\left(6b_A^2 + 13b_A b_B + 6b_B^2\right)^3}.$$

Since $Q\,(b_A, b_B) > 0$ for every $b_A$ and $b_B$, we deduce that: $sign\left\{\Pi\left(b_A, b_B, \overline{K}\right)\right\} = sign\left\{(b_A - b_B)\right\}$. We obtain:
If $b_A < b_B = \beta_2$,

*(A moves Late, B moves Early)* Risk-dominates *(A moves Early, B moves Late).*

If $b_A > b_B$,

*(A moves Early, B moves Late)* Risk-dominates *(A moves Late, B moves Early).*

### A.5.3 Pareto-dominance

We define the parameter $\alpha$ as $b_A = \alpha b_B$, with $\alpha > 0$. If $\alpha < 1$(respectively $> 1$), Country $A$ is more (respectively less) productive than country $B$. We have:

$$\begin{aligned} W_B^F - W_B^L &= \frac{-1 + \alpha^2(1+\alpha)(11+7\alpha)}{(3+2\alpha)(2+3\alpha)^2} b_B \overline{K}^2 > 0 \quad \text{if and only if} \quad \alpha > \alpha^* \approx 0.250419. \\ W_A^F - W_A^L &= \frac{7 + 18\alpha + 11\alpha^2 - \alpha^3}{(3+2\alpha)^2(2+3\alpha)} b_B \overline{K}^2 > 0 \quad \text{if and only if} \quad \alpha < \alpha^{**} \approx 3.99331. \end{aligned}$$

$If \quad b_A < \beta_1 = \alpha^* b_B,$

*(A moves Late, B moves Early)* Pareto-dominates *(A moves Early, B moves Late).*

$If \quad b_A > \beta_3 = \alpha^{**} b_B,$

*(A moves Early, B moves Late)* Pareto-dominates *(A moves Late, B moves Early).*

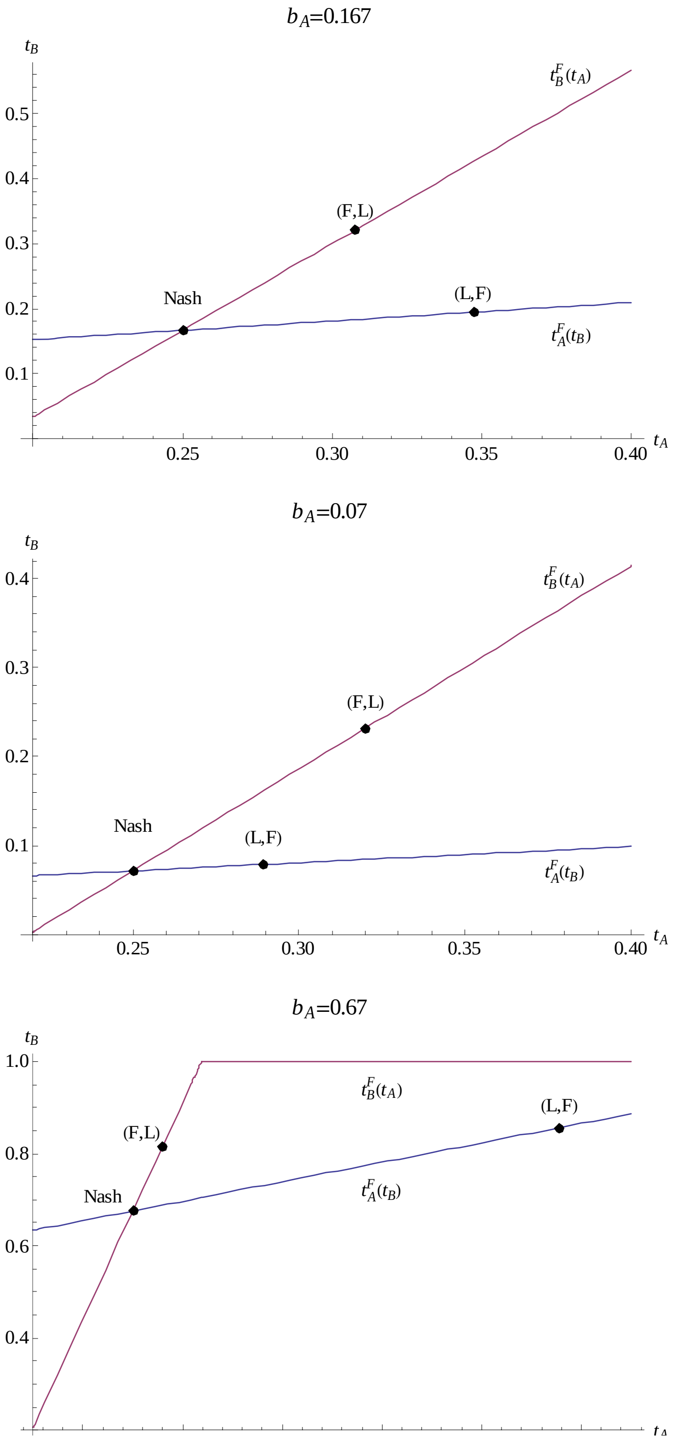
□

[25] These values are determined by solving the following equations: $t_i^k = 1$ for $\forall i \in \{A, B\}$ and $\forall k \in \{N, L, F\}$.

# B Graphs

## B.1 Graph 1: Reactions functions

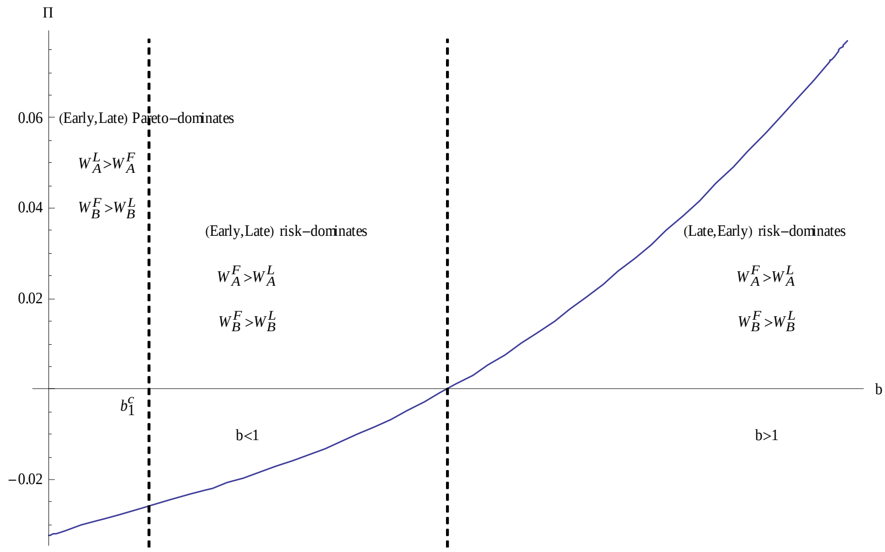
The following graphs present the reaction functions in the case of quadratic production functions with a normalized worldwide capital ($\overline{K} = 1$ and $b_B = 0.25$). These reaction functions are denoted $t_i^F(t_j)$, since they are established with the follower's maximization program, but correspond also to the simultaneous Nash maximization program. $(F, L)$ denotes the Stackelberg equilibrium where Country $A$ leads and $B$ follows.




Graph 1: Reaction functions and equilibria for different values of the degree of asymmetry ($b_A$)

## B.2 Graph 2: Pareto and Risk-dominance

The following graph illustrates Proposition 3.




Graph 2: Pareto and Risk-dominance depending on $b_A$ with $b_B = 1$, $a = 1$ and $\overline{K} = 1$.