An ACE Model of International Tax Competition

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Abstract:
This paper develops and simulates a multi-period, multi-firm, two-country, agent-based computational economics (ACE) model of international tax competition. The ACE model is constructed in such a way to allow the analysis of tax competition over time and includes some factors that are important for firm location, such as agglomeration economies and positive externalities arising from public infrastructure, as well as some other features that give a more real-world picture. We take into account, location and de-location procedures, time delays-lags in the cross-border movement of firms, and firms dynamic decisions taken in an evolutionary perspective.
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1. Introduction

Initiated by the traditional tax competition literature[1], there is an extensive and ever-growing line of theoretical and empirical research, which analyzes the effects of corporate taxation on firm location in an international setting. This interest of the recent empirical literature in the effects of tax differentials on capital flows is mainly due to the increasing economic integration and capital mobility world wide that eases and intensifies the conduct of tax competition – the act of undercutting national tax rates in order to attract capital from abroad.

Tax competition theory investigates the effects of international capital mobility on national corporate tax rates and on the flows of productive capital among competing national governments, and thus it deals with (and makes predictions regarding) the effects of corporate tax differentials on firm location. The main theoretical result of the basic tax competition model is that corporate (capital) tax rates will be inefficiently low, leading to an underprovision of public goods.[2] This happens because capital or firms respond immediately to tax differentials and governments engage in a "race to the bottom" of tax rates (corporate taxation is competed downward). This theoretical framework clearly stresses the importance of corporate taxation for firm location. In fact, it is the only effective location determinant, even in models that allow for country asymmetries (different sizes or different endowments of capital and other production factors-resources) the basic result holds (corporate tax differentials determine capital outflows and inflows). According to the theoretical predictions of the tax competition literature a high and increasing degree of economic integration should lead to severe pressures on national tax policies. Additionally, corporate taxation should become increasingly more important as a determinant of firm location as the extent of international economic integration increases (capital is supposed to become more sensitive-elastic to tax differentials).

On the other hand, the "new economic geography" can be described as a theoretical framework of industry location that encompasses elements of international trade theory, economic geography and urban economics, and it emerged as a response to explain the core-periphery structure across countries. In this framework, countries (or regions) are assumed to be identical in all aspects and the core-periphery pattern is determined endogenously. The main story is that an initial "symmetric

[1] This literature has its origins from the so-called basic tax competition models of Zodrow and Mieszkowski (1986) and Wilson (1986). For an excellent presentation and review of the theoretical tax competition literature see, for instance, Wilson (1999).

[2] The extended tax competition literature (building on the basic model) makes further predictions. For instance, labour and other less internationally mobile tax bases will have an increased tax burden as international capital mobility increases (Bucovetsky and Wilson 1991). Other tax competition models (with more realistic assumptions) focus on specific features (e.g. country asymmetries), but in all models we have the same qualitatively result.

equilibrium" can result in a new locational equilibrium, where production and demand structures across regions are no longer identical. Industrial location becomes entirely endogenous, because of either market size spillovers (Krugman, 1991a,b) or vertical (input-output) linkages between industries (Venables, 1996), which can induce circular and self-reinforcing processes of agglomeration. The implication of the former model is that economic integration can lead two identical countries to become differentiated into an industrial core and an agricultural periphery, while the latter predicts the concentration of vertically linked industries in one location.

Using the theoretical framework of the NEG, the models of Baldwin and Krugman (2004), Andersson and Forslid (2003), and Ludema and Wooton (2000), which explicitly analyze international corporate taxation issues and their effects on industry location, point out that tax differentials are counterbalanced by other factors and mechanisms that are important for agglomeration and that a "race to the bottom" of tax rates (as the conventional tax competition models predict) must not necessarily take place. The main point of this literature is that tax differentials among countries can exist, even in a highly integrated world economy. More specifically, the industrial core can impose a higher tax rate than the periphery without inducing a capital outflow towards the low tax (peripheral) countries.

Though the theoretical tax competition models (based either on neoclassical or on NEG assumptions), especially the more recent and more advanced, provide an analytical analysis, they have to some extent a limited framework of analysis with many simplifying assumptions. More specifically, the evolutionary aspects and the time dynamics of the competition game are not considered, and usually a one-shot game analysis is undertaken.

Approaching this issue using an agent-based computational economics (ACE) framework provides the advantage to consider the above aspects. Therefore, in this paper we develop and simulate a multi-period, multi-firm, two-country, ACE model of international tax competition. The model is constructed in such a way to allow the analysis of tax competition over time and includes some factors that are important for firm location, such as agglomeration economies and positive externalities arising from public infrastructure, as well as some other features that give a more real-world picture. We take into account, location and de-location procedures, time delays-lags in the cross-border firms movement, and firms dynamic decisions taken in an evolutionary perspective.

The rest of the paper proceeds as follows. Section 2 presents the theoretical ACE model that is simulated. Section 3 describes the model and simulation implementation. Section 4 presents the

simulation results for a number of different policy scenarios. Finally, section 5 summarizes and concludes.

2. The Model

There are two countries (A and B) which compete over firms, since capital is internationally mobile. The government in each country has two policy variables, namely the corporate tax rate (T) and investment in productive public infrastructure (G), which creates external productivity benefits to firms. The government, which is a country-level agent, uses those two policy variables to attract firms. The behavior of the government is given by the different policy scenarios we run. The governments get revenues (R) by taxing the firms' profits ($Y_{Tf.}$):

$$R=f(T) \quad (1)$$

R is used only to generate G:

$$R=G \quad (2)$$

More specifically, revenues spent for infrastructure in period t are transformed into G in period t:

$$R_t=G_t \quad (3)$$

Additionally, we assume that governments have always to spend some R for G, because there is depreciation of G in each period at a rate d. So, G in each period is:

$$G_t= (1-d)G_t \quad (4)$$

We have an equal number of firms of the same size, which have the same initial amount of capital (therefore of equal size), in both countries. The only production factor is capital (K). Each firm has a constant-returns to scale production function (there are no internal scale and agglomeration economies to the firms), essentially it is a linear function:

$$Y=f(K)=bK,\ 0<b<1 \quad (5)$$

In the model we have agglomeration economies which arise (are generated) from the accumulation-agglomeration of capital in one location-country and external public infrastructure benefits. We represent the agglomeration economies and infrastructure benefits with an aggregate country-level production function, which has increasing returns (the agglomeration economies are represented in that way), that is the more capital flows to the country the more productive is the production process in that country. In the aggregate country-level production function G is also a production factor (the infrastructure benefits are represented in that way).
Thus country-level production (Y_A) depends on K and on G:

$$Y_A=f(K, G)=a[(1+me^{-k/t})/(1+ne^{-k/t})]+(K/G) \quad (6)$$

Agglomeration and infrastructure productivity benefits are external to the firms' production functions. This means that the production-output (Y_f) of each firm is given by the firm-level production function plus the external benefits received. So, total production-output of each firm (Y_{Tf}) is:

$$Y_{Tf}= Y_f+Y_{Af}+Y_{Gf}, \quad (7)$$

where Y_f=output of firm depending only on the firm's production function
Y_{Af}= additional output from external benefit of agglomeration economies that spills over to the firm
Y_{Gf}= additional output from external benefit of infrastructure that spills over to the firm

Therefore, each firm takes into account these external agglomeration and infrastructure benefits, when it comes to make a location decision (moving to county B or remaining in country A). More specifically, the firms maximize profits (P) which depend on Y_{Tf} and T:

$$P = Y_{Tf} – T \quad (8)$$

The firms and capital cannot relocate to the other country instantaneously. It needs some time for firms to relocate their capital (productive units). We assume in the first periods only a small fraction of the total capital of the firms (production plants) can be moved, whilst as time passes (that is as we go more

to the longer-run) an increasingly fraction of capital can be deployed to the other country (for more details on this see next section). Finally, the firms in each period decide where (in which country) to produce, by calculating and taking into account the external agglomeration and infrastructure benefits in each country and the tax rates in each country. The whole behavior of the firms is given by this calculation and comparison of the country which determines if the firm moves or not. The dynamics of the tax competition game are determined by this firm behavior and on the choice variables of the government (T, G) and its particular policy behavior-strategy (which we assume with alternative policies and simulation scenarios), and finally on the importance of the agglomeration economies and of the infrastructure benefits (for more details on this see next section).

3. Model and Simulation Implementation

Our dynamic model was implemented in Java, using the REPast framework (REcursive Porous Agent Simulation Toolkit) (Collier 2003). REPast gives us an environment with functionalities like Graphs, Parameters Setting, Play, Stop, Pause, etc. The model itself, with all the behavior and functionalities had to be programmed from the scratch using Java language. We will present a diagrammatic model of this simulation using UML language, according to Cesar and Hwang (2007) suggestion. In order to understand the conventions and symbols used in the different diagrams, we recommend that the reader must be familiar with UML (Booch et, al. 1999).

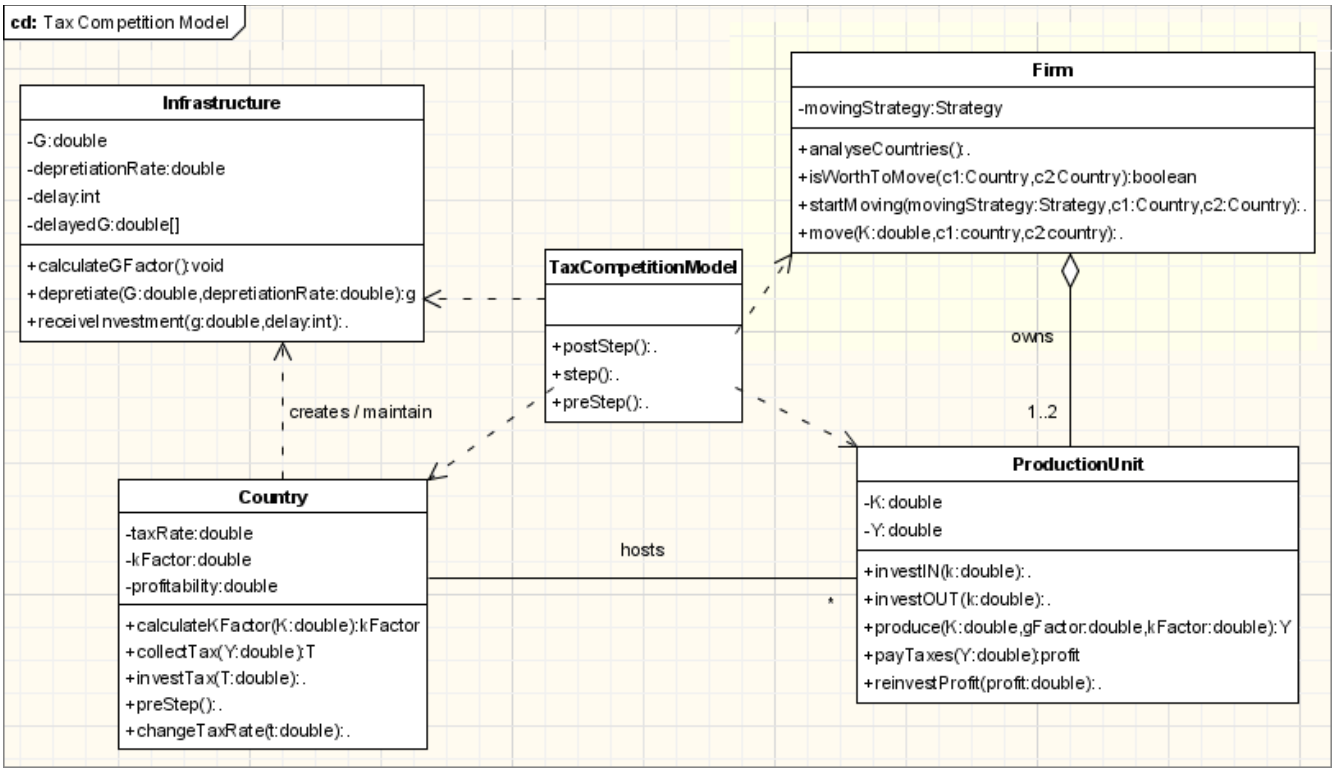

Figure 1 – Class diagram

The model is composed by agent classes (Country, Firm, Infrastructure and ProductionUnit) and a main controller class, named TaxCompetitionModel, which is responsible to orchestrate the simulation, initialize parameters, create agents and interact with the graph display environment. This class have basic operations (methods) that fire agents operations to run before (preStep), after (postStep) and during (step) each iteration (that we called period).

The model agent classes are as follow:

Country - The class Country encapsulates the behavior of the agent which represents governments. As our model defines two countries, there are two instances of this class: country A and country B. For each country, there are a number of attributes such as: taxRate, a floating point number (defined in the diagram as double) assigned as the fraction of firms output that goes to the government (tax); kFactor, a calculated number which represents the benefit of agglomeration economies on the country; and the average profitability of firms in that country. A government also act in the model executing the operations defined in the lower part of the class representation (calculateKFactor, collectTax, and so on.). The sequence, timing and behavior of each of these operations are better understandable when we introduce sequence diagrams further in this session.

Infrastructure – Represents the infrastructure generated from the government investment of collected taxes. The value of the total investment is represented by the attribute G, which suffers from depreciation at each period according to certain depreciationRate. Infrastructure may not be instantaneously available when government invests money. There may be some delay between the time government collects taxes, invests and this value become available to firms as an enhancing productivity factor as established by our model. There is one instance of this class for each Country.

Firm – A number of firms (100, for example) are instantiated by the model and, in the beginning, they are located in either country A or country B and they don't have production units in more than one country. The class Firm, represents the entity which decides where to place their production plants (represented by ProductionUnit class). On the beginning of the simulation, each firm has only 1 ProductionUnit. As periods iterate, firms may move part of their capital from country to country, searching for a better profitability. Therefore, a Firm may have 1 or 2 ProductionUnit's. Each firm may have a different movingStrategy – there is – firms' decisions may take time and their moving speeds are different as well. We defined some different types of strategies (super-fast, fast, medium-fast, slow-movers, lazy-movers, etc…) and firms are created with these intrinsic behaviors.

ProductionUnit – This class represents the production plants of firms. Firms invest their capital (K) in production units located at country A or country B. This capital is used on the production process, represented by the operation produce, to generate output Y. The production function uses K and the external benefits kFactor and gFactor, which are defined based on their location. After generating output Y, firms pay taxes to governments and the remaining net profits are reinvested in the same production unit, causing K to increase. Units may also increase (or decrease) K through capital movements from country to country.

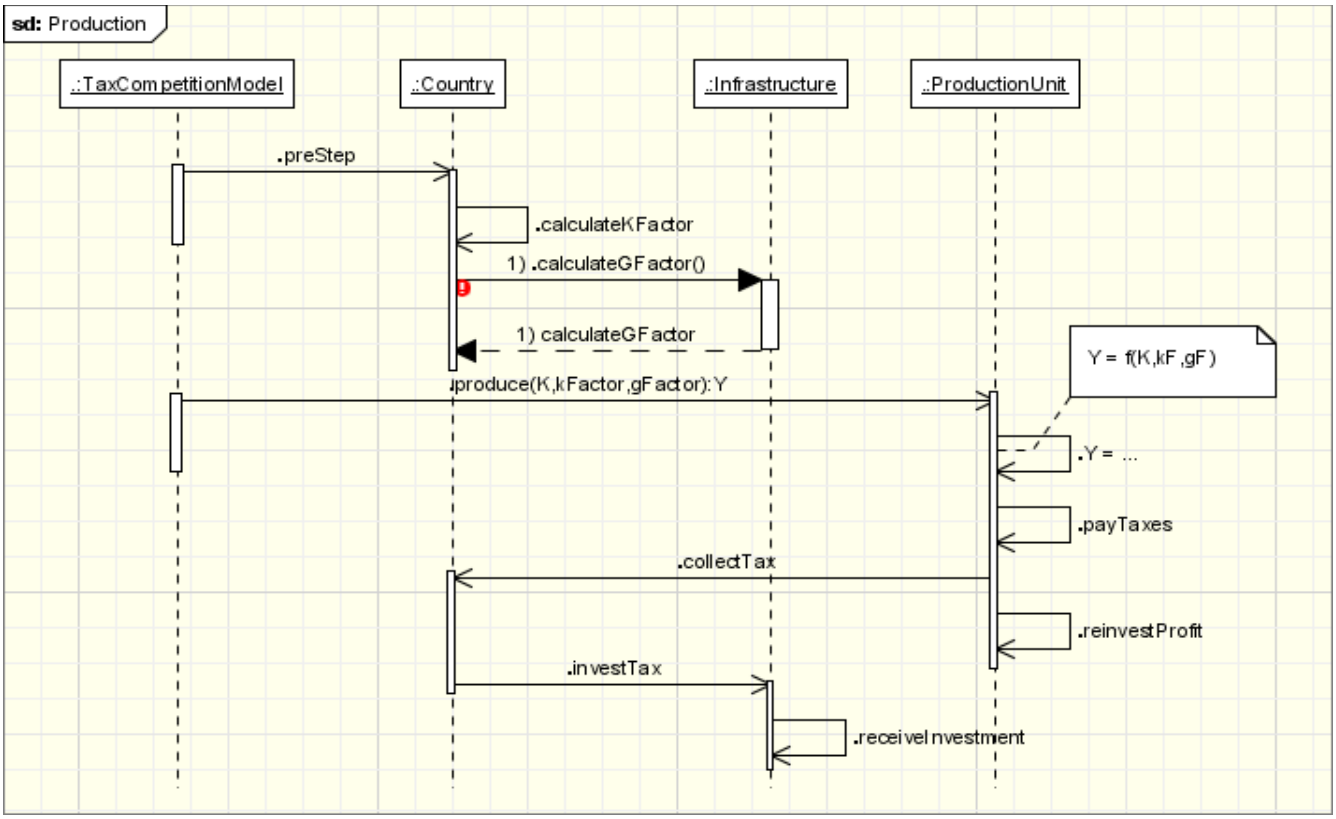

Figure 2 – Production sequence diagram

The production process is fired on each iteration. However, a prior step is run for calculating the G and K factors based on countries' total amount of hosted capital and infrastructure investment. These values are used on firms production function as benefits that will increase the output (Y). After producing output, firms collect taxes and reinvest the remaining profits, increasing its capital. Countries invest the collected taxes in infrastructure. Some delay on infrastructure availability may occur, depending on simulation parameters and G will increase after some parameterized number of periods.

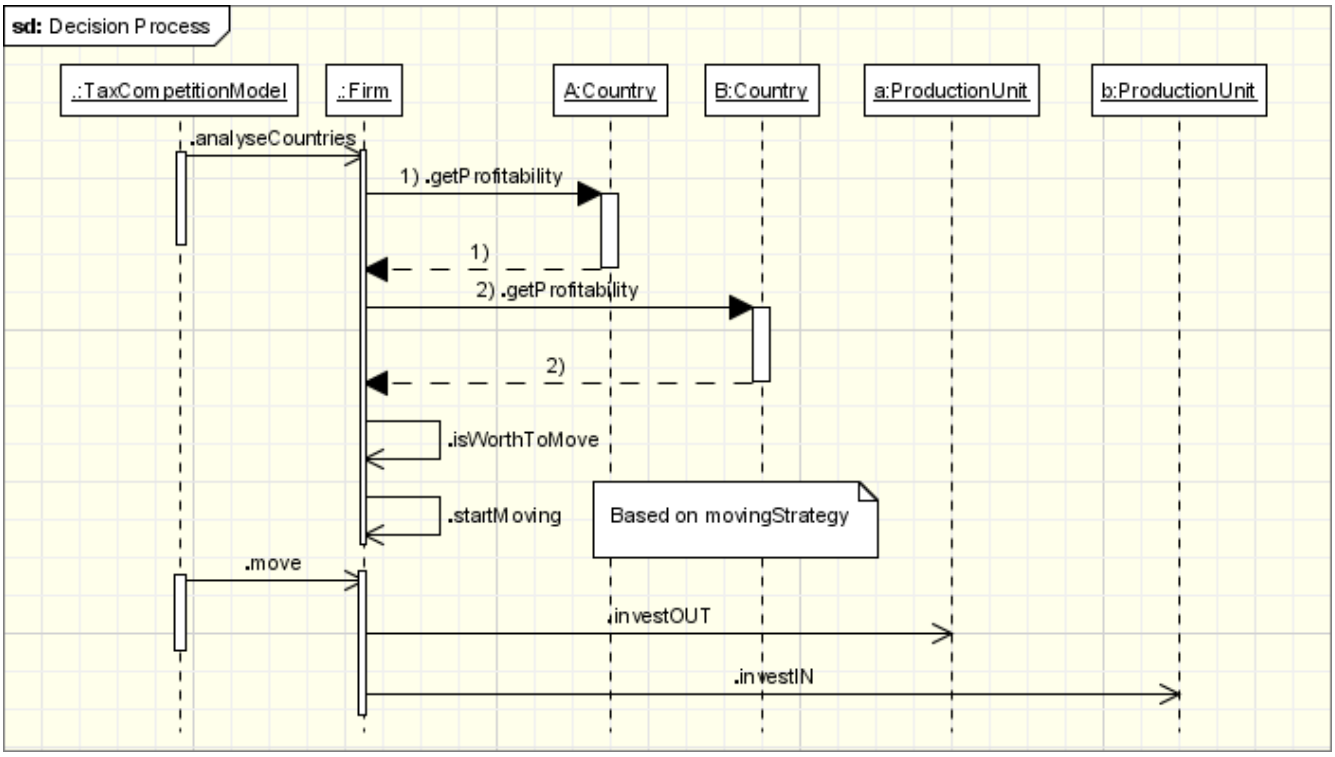

Figure 3 – Firms decision process sequence diagram

Each firm decides whether move or not based on the profitability of firms in each country. Once a firm decides that is worth to move, it starts a moving process based on its strategy which may have different levels of delay and capital percentage. Firms are constantly analyzing countries profitability but it only effectively move part of its capital obeying its moving strategy. It may take several periods to start and only some assigned percentage of the capital will be moved in each period. Moving from country to country means establishing a new ProductionUnit (on the first move) or moving capital from one ProductionUnit to another.

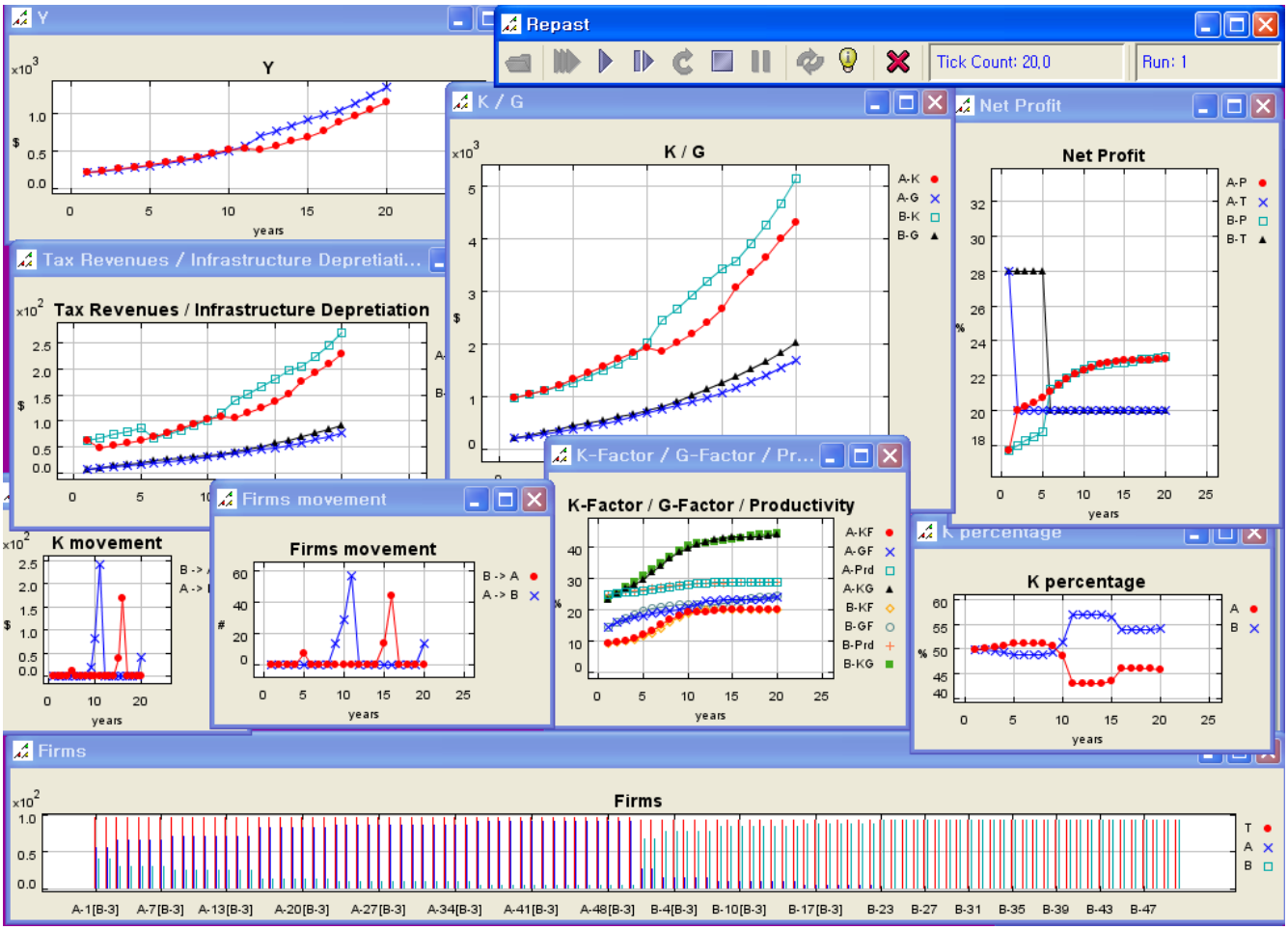

Figure 4 – Simulation program

The simulation program draws several different graphs that allow us to observe firms capital and output, countries K and G factors, profitability, firms' movements, etc. Parameters are saved and restored from files in order to allow multiple simulations with different parameters, in order to observe agents behavior in each different situation.

4. Simulation Results and Discussion

Our methodological approach involves the simulation of various scenarios regarding the government strategies for different levels of importance of agglomeration economies and public infrastructure benefits that spill-over to the firms and for different parameter values (moving delays and strategies, generation and depreciation of public infrastructure, production functions, etc.). We have run various simulations representing different government strategies-policies with a number of different parameter

values of the model for checking the sensitivity and robustness of our simulation results. Here, we present the three base cases.

Simulation scenario 1

Country A decreases tax and B does not response

The result is the conventional tax competition scenario, which is that firms move to country A (see Figure 5). Though it takes time for this to happen, so B looses firms substantially after 7 periods (especially after 10 periods), but looses not all firms (keeps about 5% of total capital in both countries).

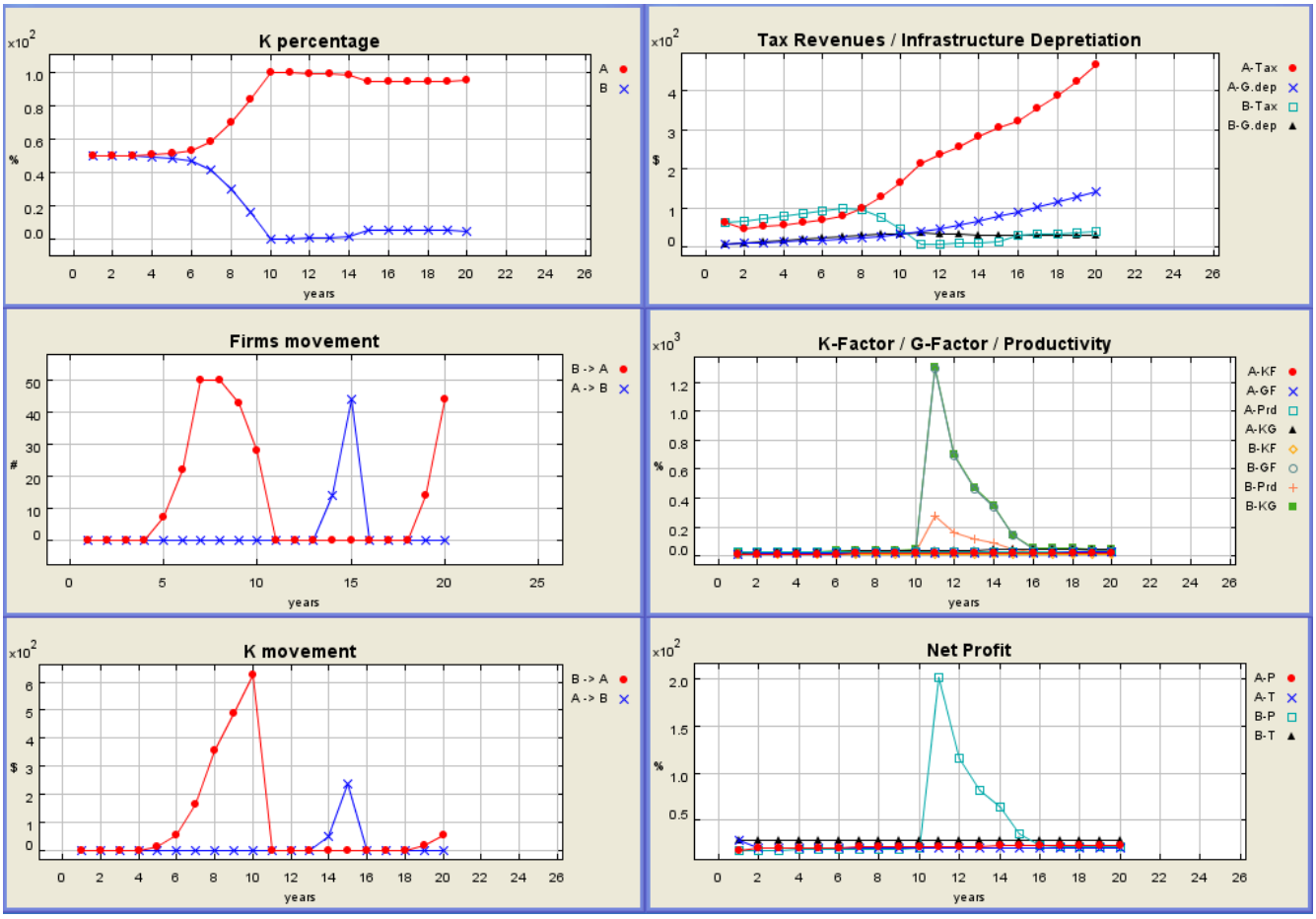

Figure 5 – Results of Simulation Scenario 1

In the beginning (up to 7-8 periods) B does more tax revenues and A has increasing infrastructure depreciation. There is no linear development in the cross-border movement in the firms (firms, capital move from B to A but also some from A back to B), because we have changes in the external benefits arising from G and agglomeration. Specifically, when B looses some firms the (ratio – relation) infrastructure compared to the number of firms (amount of capital) improves resulting in increased external productivity benefits from those improved infrastructure ratio and increased net profitability for firms in B, and thus some firms remain and some come back from A, but eventually it is not enough to revert the process (firms all coming back to B), because the tax cut is more important for the net profitability.

Simulation scenario 2

Country A decreases tax and B responses not immediately but after 5 periods with a tax cut equal to A

Here in this case we have an unconventional result, since eventually most of the firms and capital (K in B=54% and K in A=46%) move to B and this result is stable after 20 periods if there is no change in the policy of either country (see Figure 6). Thus, though at the end both countries have the same lower tax rate (20%), the country (A) that initiated that tax cut (tax competition) ended up with loosing some firms, whilst the country (B) that responded after 5 periods ended up with more firms, attracting them from A without the need for a tax cut below the tax rate of A. This happens mainly because country A by cutting its tax rate, whilst country B retaining it in its initial level, makes less tax revenues and builds up less infrastructure than country B for the first periods of up to 6 years because there is no substantial firm movement due to the time required for firms to relocate their productive capital (plants) from B to A.

Thus, B does not loose firms at all in the first periods and afterwards it looses slightly (after 6 periods). The crucial point is after that period, in which an increased outflow of firms from B to A can be realized, due to the necessary time that has passed to increasingly move their productive capital, and as time passes even the following the leader strategy firms (firms which are not first movers but wait a little longer and move only when some firms already left and established plants in the other country) eventually relocate their production. If B at that point does not respond with a tax cut (which does not have to be equal to the tax rate of A, it can be slightly above) firms will increasingly move to A because the tax rate cut becomes more important for their net profit than the external productivity gains from the productive public infrastructure (benefits), and as more firms move to A it becomes

increasingly more profitable for other firms to follow and relocate their production to A due to the increased net profit to be gained in A from the decreased tax rate and from the agglomeration economies. Even in the longer run, if B continues to not responding, A has so much tax revenues and more than B (even it has a lower tax rate than B) due to the increased number of firms and amount of capital that it attracted, that it builds up much more infrastructure than B, resulting in increased external infrastructure benefits for firms moving into A.

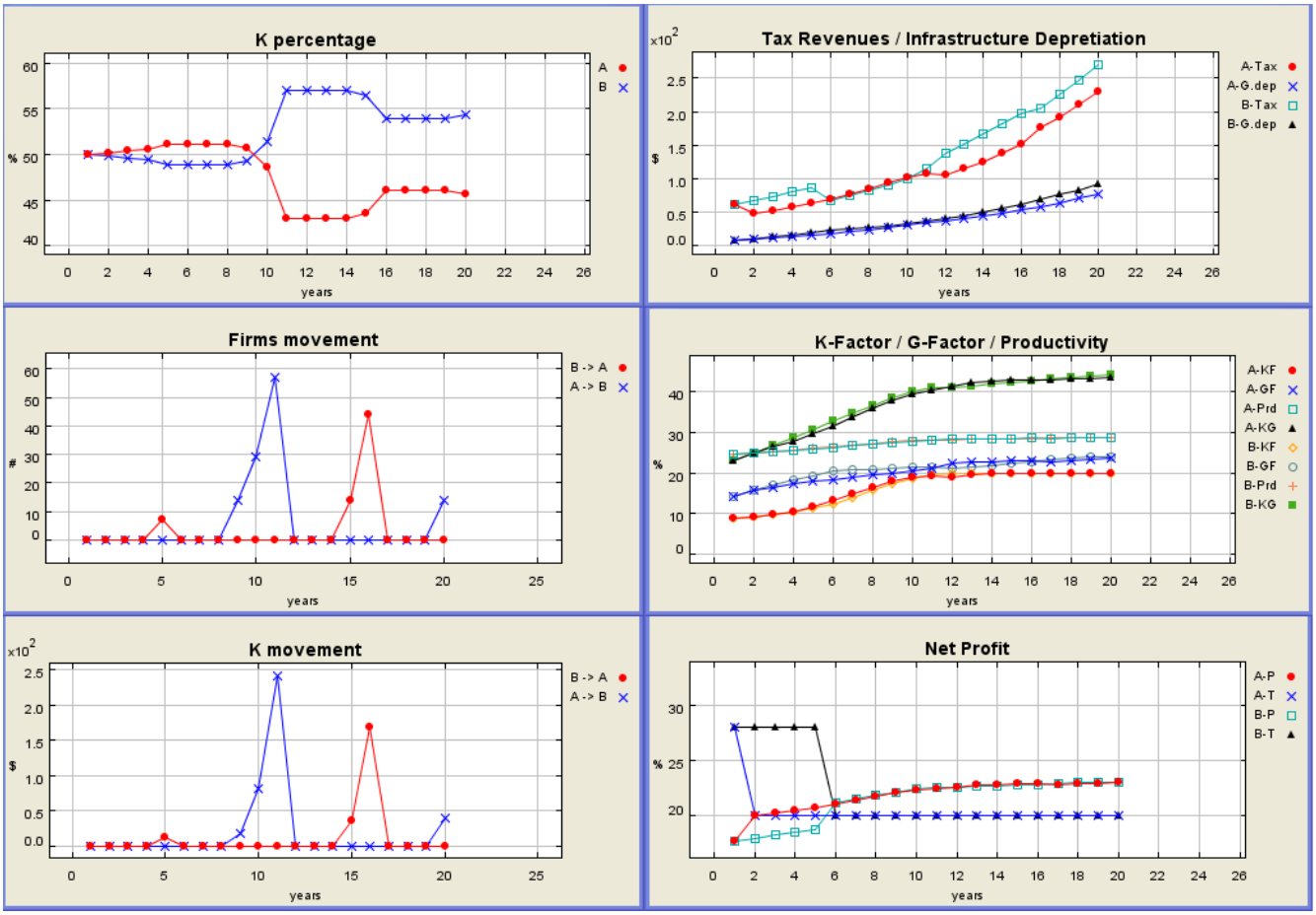

Figure 6 – Results of Simulation Scenario 2

So, in the case of country B not responding with a tax cut (even a small one), which is of course represents tax competition scenario 1), B looses the initial advantage of having more external productivity gains to the firms due to the increased infrastructure benefits, and thus retaining and attracting more firms. However, if at that crucial point at which an ever increased outflow of firms

from B to A is being realized country B decreases its tax rate (which can be slightly higher than the new tax rate of A) it takes advantage of this initial increased infrastructure productivity gains due to a larger amount of public infrastructure investment and together with the decreased tax rate, which ensures its taxation disadvantage to be smaller, the country achieves to attract more firms from A, increasing thereby its overall advantage due to increased agglomeration economies and increased infrastructure benefits.

The main policy implication of this simulation scenario is that due to the simultaneous presence of public infrastructure benefits, agglomeration economies, and the firm movement and relocation time dynamics, a country has not to immediately respond and engage in a tax competition (especially in a race to the bottom), but can initially for a period of time invest in public infrastructure, resulting in more external infrastructure benefits for firms in that country than in the other country which has reduced its tax rate. Then in a second stage it can reduce its tax rate, which due to the increased productivity gains for firms from the increased infrastructure stock has not to be below or equal to the tax level of A but to some extent above that level. In that way the country reduces it tax disadvantage, but without engaging in tax competition, and creates more infrastructure, attracting firms from the other country. Once some firms move to that country, it can increasingly attract more firms also due to the agglomeration economies.

Simulation scenario 3

Country A increases tax initially and then decreases at its original level, B does not respond

Here we have a scenario which could be called anti-tax competition, in the sense that a country instead of reducing its tax rate it increases it (see Figure 7). More specifically, the strategy of country A is to increase initially its tax rate, so that it can have higher tax revenues for building up more productive public infrastructure, with the aim of attracting firms from the increased external infrastructure benefits. Then in a second stage it reduces its tax rate to its initial level which is equal to the tax rate of the other country. The basic mechanisms in work here are similar to the tax competition scenario 2. The act of increasing the tax rate is completely unconventional and runs against the usual theoretical tax competition literature.

However, in our model where we simultaneously take into account the time dynamics of the firm movement and relocation and the generation of productive public infrastructure, and the presence of agglomeration economies, such a policy makes sense and is indeed effective. By increasing its tax rate,

country A makes initially more tax revenues than B (up to five periods) and more infrastructure investment and infrastructure productivity benefits for the firms. However, the tax increase is relatively more important for the firms' profitability, and if this tax disadvantage does not disappear in the long-run, then firms will increasingly move out of country A to country B. Thus, initially country A builds up more infrastructure, creating the basis for more infrastructure benefits for firms in the future, and looses a small amount of capital in the first periods. Then the country decreases again its tax rate to the original level (removing the tax disadvantage compared to B), resulting in the attraction of firms and capital in A due to the increased infrastructure benefits with same taxation level as in country B.

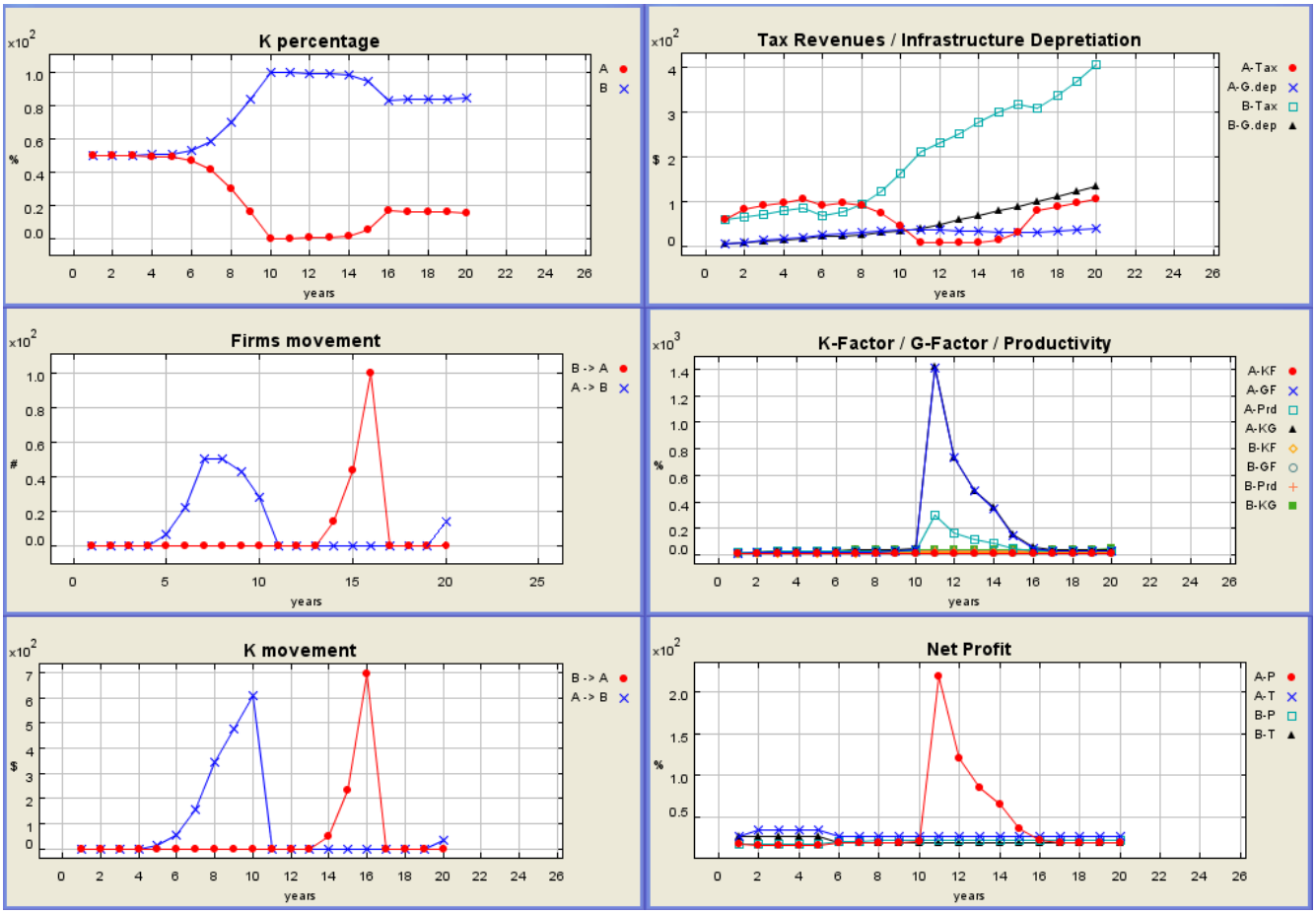

Figure 7 – Results of Simulation Scenario 3

The basic policy implication is that it is possible for a country to increase for a period of time it corporate taxation above the level of the other countries in order to increase infrastructure investment without loosing firms (only a slight outflow of capital). Then by setting the same original tax rate (tax reduction) it can actually attract firms from other countries due to the significant advantage of more productive public infrastructure. It is also possible (though the result is very sensitive to parameter specification) that the country after increasing the tax rate does not to have to set it at the initial level but can be slightly above the original tax rate (before the increase) which also the other country has.

5. Conclusions

This paper analyzed tax competition by developing and simulating a multi-period, multi-firm, two-country, agent-based computational economics (ACE) model of international tax competition. The paper's results show that game becomes more complex and the agents' (governments) strategies have a different degree of effectiveness in different periods. This depends on game's conditions at each time due to the simultaneous presence of public infrastructure benefits, agglomeration economies, and the time required for firms to move part or all of their productive capital.

In general, our simulation results confirmed the possibility of a positive tax differential for a country (higher tax rate) without having firm and capital outflows, as shown in theoretical tax competition models of the NEG framework. The above possibility also arises, in our model, from the public infrastructure benefits that spill-over to the firms in the form of increased productivity. A particularly interesting observation is that, with the evolutionary approach, we can get some different and more insightful results that in some cases go in opposite direction of the basic and simplified findings of the traditional tax competition models. The paper's results have provided important implications regarding the effectiveness of different government policies and strategies within a more realistic framework. Particularly, it has been demonstrated through the various simulation scenarios that time itself is a significant factor which affects the impact of various policies or strategies.

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