Competition for FDI with vintage investment and agglomeration advantages*

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Abstract

Countries compete for new FDI investment, whereas stocks of FDI generate agglomeration benefits and are potentially subject to extortionary taxation. We study the interaction between these aspects in a simple vintage capital framework with discrete time and an infinite horizon, focussing on Markov perfect equilibrium. We show that the equilibrium taxation destabilizes agglomeration advantages. The agglomeration advantage is valuable, but is exploited in the short run. The tax revenue in the equilibrium is substantial, and higher on "old" FDI than on "new" FDI, even though countries are not allowed to use discriminatory taxation. If countries can provide fiscal incentives for attracting new firms, this stabilizes existing agglomeration advantages, but may erode the fiscal revenue in the equilibrium.

Keywords: Dynamic tax competition, vintage capital, agglomeration, foreign direct investment, bidding for firms

JEL classification code: F21, H71

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1 Introduction

Host countries of foreign direct investment (FDI) face an important trade-off. They compete in attempting to attract new FDI, and at the same time they would like to extract revenue from their acquired stock of FDI. We study the dynamics of this trade-off, taking into account that old capital depreciates slowly, new investment in each period is determined as the outcome of fiscal competition, and the location of old capital may offer agglomeration benefits to new capital. We analyse both uniform taxation and differential treatment between old capital and new investment and ask whether tax competition will generally preserve and perpetuate existing patterns of capital agglomeration or whether intensified tax competition may cause deagglomeration and make agglomeration of capital a transitory state.

The main findings are as follows. First, uniform taxation of old (immobile) and new (still mobile) capital causes old FDI to have a strategic effect on competition. The country with substantial amounts of old FDI is reluctant to choose a low tax. The country without a stock of old capital is more "lean and hungry". It does not sacrifice tax revenue on immobile old capital when choosing a low tax. The strategic implications are similar in nature to those analysed in the context of tax competition for mobile and immobile tax bases in a static framework (as in Janeba and Peters, 1999, and Marceau, Mongrain and Wilson, 2007). Our dynamic framework raises additional issues, as attracting the new FDI in a given period will alter the incentives for competition in future periods, but the intuition from a static analysis carries over: the country with the high stock of old (immobile) capital chooses a higher expected tax rate than its competitor. Moreover, both countries win the new investment in a given period with positive probability. Even though countries cannot choose discriminatory taxes and must choose the same tax rate to apply to old capital and new investment, the expected tax burden on old capital tends to be higher than the expected tax burden on new investment. Moreover, the vintage property of capital prevents tax competition between the countries from becoming a race to the bottom.[1]

Second, and less anticipated by previous static considerations, our analysis facilitates an examination of agglomeration advantages: new FDI may have a cost advantage if the investment occurs in a country which has a high stock of old FDI

[1] We also generalize this framework to competition between more than two countries and consider finite relocation cost for old capital instead of perfect immobility.

already. We find that this cost advantage will generally stabilize the role of being the country with the higher stock of FDI, but that the agglomeration of capital remains a transitory state. A country could perfectly prevent a shift of the agglomeration to a competitor and could perpetuate the agglomeration advantage by way of its tax policy. However, such behavior does not emerge in the MPE. Instead, a country is too tempted to extract revenue from the existing stock of capital. In the mixed strategy MPE that emerges the country that accumulated FDI previously is more likely to lose it in the next period than it is to keep it. The greater the agglomeration advantage enjoyed by the country with the high stock of old FDI, the lower the tax rates of both countries in equilibrium and the lower the expected discounted value of tax revenues accruing to the two countries. Hence, an agglomeration advantage may intensify tax competition.

A third aspect considered is the interaction between tax competition and subsidies for new FDI. Political arguments are often advanced that agglomeration advantages need to be nurtured to be sustained. In our framework, an agglomeration advantage is beneficial for the country that has it. However, in the equilibrium the country is willing to risk losing this advantage for benefits in the short run. Historically, agglomeration and technology leadership sometimes shifted but not very frequently.[2] Recent changes in international openness and fiscal competition may make the question more relevant. The new member states of the European Union choose taxes on corporate income that are far below the average rates that apply to the European Union as a whole. Also, these new accession countries do not have a large stock of old FDI. Hence, they do not pay a high price in terms of reducing the tax rates on the previously attracted FDI or their capital base more generally if they reduce their tax rates. Intensified fiscal competition may shift agglomeration away from the "old" location in the capital rich member states towards the new member states in the future. We show that whether this is the case or not generally depends on whether countries can separate the fiscal burden on old capital from the fiscal burden on new investment via subsidies paid to new investors. We show that such

[2] A famous example is the shift of technology leadership in the context of the Dyestuffs Industries and the emergence of leadership in Germany in the late 19th century. Historians describe the success of the Dyestuffs industry in Germany as being brought about by several factors, including lenient patent laws, the interaction between research and industry and considerable public investment in chemical laboratories (see Murmann and Homburg, 2001, and Harhoff, 2007).

subsidies should make agglomeration more stable, but should erode the amount of fiscal revenue (net of subsidies) that emerges in the MPE.

Our analysis proceeds as follows. In Section 2 we survey related literature. In Section 3 we describe the framework of our formal analysis. Section 4 solves for an MPE and its comparative static results. Section 5 considers investment subsidies as an additional instrument of competition. Section 6 concludes.

2 Related literature

Several analyses of FDI focus on the long-term relationship between the investor and the host country in the absence of inter-country competition. They focus on the implications of the host country's opportunistic incentives to expropriate the investment once it is made, and on the lack of investment that may result if investors anticipate this behavior. Eaton and Gersovitz (1983) were first to address this problem formally and showed that equilibria with tacit collusion can solve the problem if the government is sufficiently patient.[3] The aspect of inter-country competition comes into play in Janeba (2000) who shows that building up excess capacity in different countries may allow a multinational enterprise to react elastically to extortionary taxation by shifting its production and profits to the locations with low taxes. Janeba's intriguing mechanism is related in spirit to Kehoe (1989) who argues that tax competition between regions may resolve the hold-up problems in the context of time consistent capital taxation. In our framework the FDI and the profits it generates become perfectly immobile once the investment is in place, but a country that attracted the FDI in the past must decide how much tax to extract from this immobile base, knowing that a choice of a high tax makes it less likely that it will win the ongoing competition for new FDI.

Three other lines of literature are closely related to our analysis. First, Kind,

[3]This paper initiated much further research on this issue. Further contributions containing brief surveys are Thomas and Worrall (1994) and Konrad and Lommerud (2001). A recent empirical study of outright expropriation or nationalization of FDI and a brief literature overview is provided by Duncan (2006). Our focus is more on the "cold" expropriation that occurs via extortionary taxation, as in Schnitzer (1999) who considers the role of control rights of the investor. The potential profitability loss that results from a transfer of control rights in connection with expropriation may deter such expropriation, but is less effective in limiting "cold expropriation" by extortionary taxation.

Midelfart Knarvik and Schjelderup (2000) and Baldwin and Krugman (2004) study tax competition if capital is initially agglomerated in one of the countries. In their frameworks the country with the agglomeration advantage may preserve this advantage by applying 'limit taxes'. We show that, in a dynamic context with new FDI in each period, the vintage nature of investment may cause the agglomeration advantage of a country to be transitory. Our analysis therefore leads to a different prediction about the intertemporal sustainability of agglomeration advantages and may provide an explanation for why regions or countries may lose their agglomeration advantages over time. The vintage structure of investment in our framework is similar to the 'overlapping generations' structure in the multi-period finite horizon model of Holmes (1999). He shows that agglomeration at a geographic location that has a natural disadvantage compared to another location may exhibit a drift and move to the geographic location that has the natural advantage, if this advantage is high enough. However, he does not address tax policy or the strategic dynamic interaction and competition between governments.

Second, more recently, a small literature on tax competition with stocks of capital and flows of investment has emerged. Wildasin (2003) and Hatfield (2006) consider dynamic capital taxation as an optimal control problem. Countries try to extract tax revenue from an imperfectly mobile capital stock that is partially owned by foreigners. These approaches are in continuous time. This literature does not consider a time structure of invested capital that results in the strictly positive tax revenues of our Markov perfect equilibrium, and does not allow for the vintage dynamics, temporary asymmetries and random oscillation of capital agglomeration.

Third, our analysis is related to problems that have been studied in Bertrand markets with subsets of price sensitive and loyal or uninformed customers, building on the fundamental insights in Varian (1980). Narasimhan (1988) examines a version of the static Varian model with asymmetric loyal customer bases.[4] Padilla (1995) extends this framework to an infinite horizon allowing for overlapping generations of customers and finite switching costs.[5] In the absence of agglomeration advantages,

[4] See also Baye, Kovenock and de Vries (1992) who extend the Narasimhan analysis to n firms. Wang (2004), Andersson and Konrad (2001) and Marceau, Mongrain and Wilson (2007) consider tax competition in finite horizon games with mobile and immobile tax bases, leading to equilibria similar to those in Narasimhan (1988).

[5] Farrell and Shapiro (1988) construct a dynamic model similar to that of Padilla (1995) but examine sequential, rather than simultaneous, price setting. See Deneckere, Kovenock and Lee

our equilibria are similar to those specified by Padilla for switching costs above a critical value.[6] Anderson, Kumar and Rajiv (2004) correct Padilla's analysis for switching costs below this critical value.[7, 8] Although the nature of the pricing equilibrium in mixed strategies that emerges from Padilla's analysis is similar to the mixed strategies that result in our problem of FDI competition in the absence of agglomeration advantages, to our knowledge, there is no corresponding work in the industrial organization literature that combines both lock-in and the type of network or agglomeration effects that arise in this paper.[9] In this sense, our analysis is novel not just to the literature on tax competition but also to the analogous problem of price setting with switching costs and network effects.

3 The formal framework

We consider a dynamic framework with an infinite number of periods $t = 1, 2, ...$ There are two countries, A and B, each with an infinite life span. In each period one foreign investor i_t arrives and decides whether to locate a unit of FDI in country A or in country B. We denote this decision as $i_t \in \{A, B\}$. The investment exists for two periods and cannot relocate. If $i_t = B$ in period t, this investment is also located in B in period $t+1$. The investment depreciates and disappears at the end of period $t+1$. Accordingly, in each period there is one old unit of FDI that is located either in A or in B, and one newly arriving unit of FDI that is perfectly mobile between A and B. A unit of FDI generates profit in each of the two periods and completely depreciates after that. The profits in each period are exogenously given for each investment.

(1992) for a critique of the claimed endogeneity of sequential price setting in the Farrrell-Shapiro model.

[6] These correspond to the equilibria of Padilla's (1995, p. 525) Theorem 1, part b.

[7] The analysis by Anderson, Kumar and Rajiv (2004) pertains to the incorrect specification of equilibria in Padilla's Theorem 1, part a.

[8] Chen and Rosenthal (1996) consider a dynamic duopoly in which each firm has loyal customers in a given period, but the low-price firm in that period gains a loyal customer in the next period at the expense of its rival. Although the equilibria examined in this model exhibit qualitative similarities to those in Padilla (1995) and Anderson, Kumar and Rajiv (2004), the model differs in that there are no price sensitive (mobile) consumers always willing to purchase from the lower price firm in a given period.

[9] See Farrell and Klemperer (2007) for a very recent survey of competition with switching costs and network effects.

Moreover, there is a cost of investment in the first period of FDI. This cost may depend on the choice of location. We assume that the cost is lower if the FDI locates in the country in which there is already one active unit of FDI, and the cost saving that occurs in this case, compared to investing in the other country, is equal to $\Delta \geq 0$. This cost saving is called the *agglomeration advantage*. If $\Delta = 0$, then there is no agglomeration advantage. The FDI's profit is then fully independent of the location choice. If $\Delta > 0$, then the country which attracted the investment i_{t-1} in period $t-1$ has an agglomeration advantage in period t: everything else equal, the firm making the investment decision prefers to invest in the country which attracted the investment in the previous period, due to the cost savings. This cost saving can refer to a number of factors that are typically associated with agglomeration advantages, including technological spillovers from the investment in place to the newly arriving investment.[10] Given these assumptions, in the absence of governmental policy, FDI is attracted by the region which attracted investment in the past. However, the governments in both regions are active players and we turn to their action space next.

Countries simultaneously choose taxes $T_A(t)$ and $T_B(t)$, respectively, at the beginning of each period t, prior to the location choice of newly arriving FDI. These taxes are constrained from above by $T_j \in [0, r]$ with r sufficiently small compared to the profits from FDI to make FDI always attractive and the investor's participation constraint non-binding. These taxes are non-discriminatory in the sense that the tax $T_j(t)$ that is chosen by country j for period t applies to all FDI which resides in j in this period, both old FDI that located in j already in period $t-1$, and new FDI that locates in j in period t.

Investors' payoffs are determined by their exogenous profits in the two periods of their activity, by the set-up costs for FDI in the first period of activity, by the taxes they have to pay, and by their discount rate that makes first and second period payments comparable. We assume that all investors and governments have the same common discount rate, expressed by a common discount factor equal to $\delta \in [0, 1)$, which is taken as time invariant and exogenous. Accordingly, if i_t locates in A, then

[10] Several microfoundations for Δ could be given, based on trade cost, knowledge spillovers, labor market externalities and others. For a short survey and further references see Devereux, Griffith and Simpson (2007). Strange, Hejazi and Tang (2006) emphasize coping with uncertainty as a common denominator of several agglomeration advantages that have been identified.

investor i_t's payoff is

$$\pi_{i_t}(A) = \begin{cases} G - T_A(t) + \Delta - \delta T_A(t+1) & \text{if} \quad i_{t-1} \text{ located in } A \\ G - T_A(t) - \delta T_A(t+1) & \text{if} \quad i_{t-1} \text{ located in } B, \end{cases} \tag{1}$$

with G exogenously given. Investor i_t's payoff of locating in B is obtained analogously.

The determination of the objectives of governments in tax competition frameworks is a more delicate matter. Within our restricted framework, we assume that a government's payoff is equal to the present value of its revenues from taxing FDI. The normative basis for this assumption is that even a government that aims at maximizing the social welfare in the respective country would like to extract tax revenue from FDI, because foreigners bear the burden of these taxes, and their utility should not enter the objective function of a government that aims to maximize the welfare of its citizens. Accordingly, country j's objective function at a given period t is

$$\theta_{t-1}(T_j(t)) + \sum_{k=t}^{\infty} \theta_k(T_j(k) + \delta T_j(k+1))\delta^{k-t} \tag{2}$$

with $\theta_k = 1$ if $i_k = j$ and $\theta_k = 0$ otherwise.

Before characterizing and restricting the players' sets of strategies, we characterize the set of histories of the game in different periods. Assuming that, in period $t = 1$, one investor had already chosen its location i_0, the sequence of actions that is described in section 3 establishes possible histories at any point in time. When countries make their tax choices at the beginning of period t, a history is a sequence of actions $h_t = \{i_0, (T_A(1), T_B(1), i_1), ..., (T_A(t-1), T_B(t-1), i_{t-1})\}$, and all feasible histories at period t constitute the elements of the set H_t. Accordingly, a pure local strategy of country j at period t is a mapping $T_j(h_t, t)$ from H_t into $[0, r]$. Similarly, when the investor who arrives at the beginning of period t chooses its investment location, the mapping i_t is a mapping from $H_t \times [0, r] \times [0, r]$ into $\{A, B\}$ that assigns a location choice to each feasible $(h_t, T_A(t), T_B(t))$. In this framework the set of possible equilibrium outcomes is typically very large. However, it is natural to restrict the strategy space and to look at Markov perfect equilibria (MPE). For this purpose we restrict the set of behavioral strategies of countries and investors to those which employ local strategies in each period t as follows. Countries choose $T_j(i_{t-1}) \in [0, r]$, solely as a function of the location decision of investor i_{t-1} in period $t-1$, who either invested in country A or in country B. We allow countries to employ local randomization, described by their cumulative distribution functions $F_j(i_{t-1}), j = A, B$, with support $[0,r]$. Note that, by construction, these mappings are not dependent on the historical time period and these restrictions require that all histories that lead to the same investment decision i_{t-1} are mapped into the same tax choices by countries (with possible mixing) in period t. Similarly, we restrict the set of behavioral strategies of investors as follows. The investor who chooses the location of FDI at the beginning of period t makes its location choice as a function of $(i_{t-1}, T_A(t), T_B(t))$. These restrictions require that all histories that lead to the same investment decision i_{t-1} and tax rate choices $T_A(t)$ and $T_B(t)$ are mapped into the same investment choices by the investor i_t that chooses the location of FDI in the respective period t. By construction, these mappings are also not dependent on the time period.

4 Markov perfect equilibrium

We now consider the equilibrium tax choices of the governments. We determine the net fiscal burden that is imposed on FDI, and whether the tax choices stabilize or destabilize a given agglomeration advantage. In order to make this comparison, we note that the agglomeration advantage is sustained in a laissez-faire equilibrium forever: If $\Delta > 0$ and $T_i(t) \equiv 0$, the new FDI would always be invested in the country which has the stock of old FDI. This is an efficient investment path and is also the benchmark for evaluating whether equilibrium tax policy destabilizes or strengthens an existing agglomeration of capital.

We now turn to the equilibrium with endogenous tax policy and state our main result:

Proposition 1 *Let $r > 2\Delta(1+\delta)$. (i) A MPE in stationary strategies with positive taxes $T_A(i_{-1})$ and $T_B(i_{-1})$ exists in which, if $i_{-1} = j$,*

$$F_j(T) = \begin{cases} \frac{(\delta+2)T + \delta\Delta - r}{(\delta+2)T + (\delta-2)\Delta + r\delta} \text{ for } T \in (\frac{r-2\Delta(1+\delta)}{\delta+2} + \Delta, r) \end{cases}, \tag{3}$$

$F_j(T) = 0$ for $T < \frac{r-2\Delta(1+\delta)}{\delta+2} + \Delta$, and $F_j(T) = 1$ for $T \geq r$; if $i_{-1} \neq j$,

$$F_j(T) = \begin{cases} 2\frac{(\delta+2)T + 2\Delta(1+\delta) - r}{(\delta+2)T + \Delta(3\delta+2) + r\delta} \text{ for } T \in [\frac{r-2\Delta(1+\delta)}{\delta+2}, r-\Delta) \end{cases}, \tag{4}$$

$F_j(T) = 0$ for $T < \frac{r-2\Delta(1+\delta)}{\delta+2}$, and $F_j(T) = 1$ for $T \geq r - \Delta$. (ii) In this equilibrium,

the continuation value for the country with the stock of old FDI in a given period is

$$v_1 = 2\frac{r - \delta\Delta}{(2+\delta)(1-\delta)} \tag{5}$$

and the continuation value for the other country is

$$v_0 = \frac{r(1+\delta) - 2\Delta}{(2+\delta)(1-\delta)}. \tag{6}$$

The proof of Proposition 1 is relegated to a Supplementary Appendix. Figure 1 depicts the equilibrium mixed strategies in period t for $r = 1$, $\Delta = 0.1$ and $i_{t-1} = B$ both for $\delta = 0$ (solid lines) and for $\delta = .9$ (dashed lines). For intuition consider the case $\delta = 0$. The problem reduces to a sequence of static games. Each of these is equivalent to Bertrand pricing games with loyal and non-loyal customers as in Narasimhan (1988). For $r > 2\Delta$ there are no deterministic values of T_A and T_B that are mutually optimal replies and hence no equilibrium in pure strategies. An equilibrium is in mixed strategies. The equilibrium cumulative distribution functions in t for $i_{t-1} = B$ can be obtained from (3) and (4) and $\delta = 0$. The maximum tax charged by country B is $T_B = r$ (which is the exogenously given maximum). Country A does not have a stock of old FDI in this period. It will not charge a tax higher than $r - \Delta$: given the agglomeration advantage of country B, with a tax that exceeds $r - \Delta$ country A will not attract the new FDI. This determines the upper limit of the support for country A and explains the flat part of F_A in Figure 1. Consider the lower limit. If country B charges $T_B = r$ on its immobile tax base (the old FDI that located in country B), this yields tax revenue equal to r. For this reason, B is not willing to reduce its tax to a level arbitrarily close to zero. There is a smallest positive tax such that B is indifferent between charging $T_B = r$ on the old FDI but not attracting the new FDI in this period, and charging this minimum tax but also attracting the new FDI in this period with probability 1. This minimum tax yields the lower limit of the support from which B chooses T_B. Denote this limit as $q + \Delta$. Country A will never undercut this smallest tax by more than Δ. Hence, the lower bound of A's support is $\frac{1}{2} - \Delta$ in Figure 1. Within the interval $[\frac{1}{2} - \Delta, r - \Delta]$, country A randomizes as described by (4), which makes B just indifferent between all possible choices in its support. Similarly, B randomizes on the interval $[\frac{1}{2}, r)$ as described by (3) in a way that makes A just indifferent between taxes in its support. In addition, since probabilities sum to 1, B needs to place a mass point at $T_B = r$.

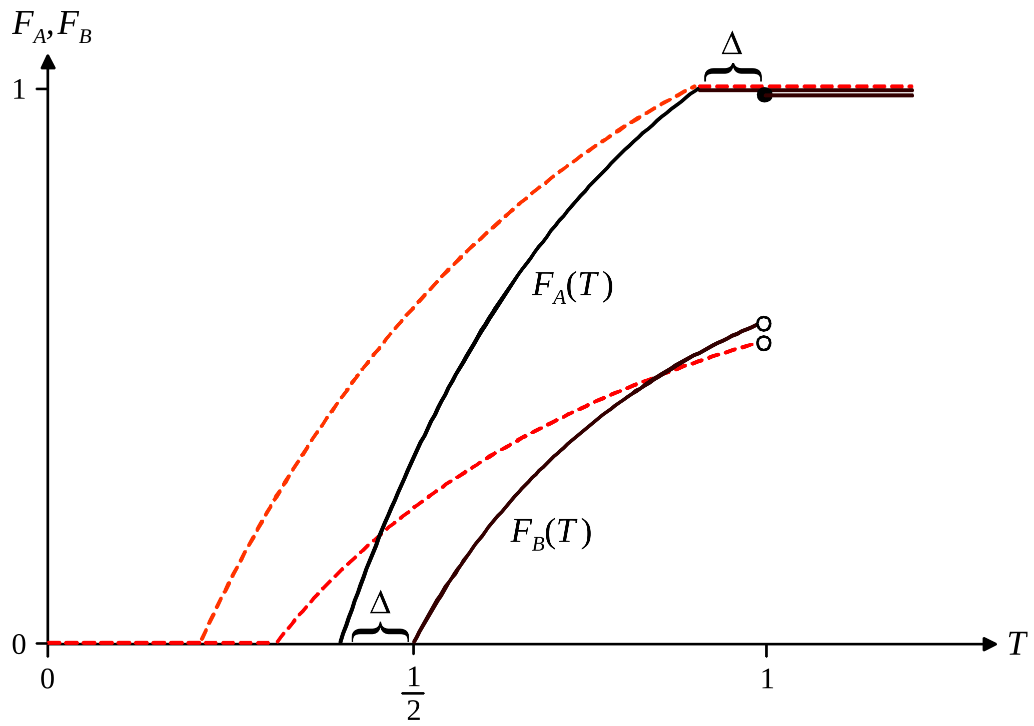

Figure 1: Cumulative distribution functions F_A and F_B for T_A and T_B for a period t with $r = 1$, $\Delta = 0.1$, $i_{t-1} = B$, $\delta = 0$ (solid lines) and $\delta = .9$ (dashed lines).

Note that existence of this equilibrium requires that $r \geq 2\Delta(1 + \delta)$. If this condition is violated the equilibrium support for the country that does not host the old FDI requires negative tax rates, which are ruled out.[11]

For a wide range of parameters only a mixed strategy equilibrium exists[12], so

[11] A MPE in pure strategies with persistent agglomeration with $T_I(t) = 0$ for the country I without a stock of old FDI in period t, and $T_J(t) = \Delta$ for the country which hosts the old FDI in period t exists in the range $r \leq 2\Delta/(1 - \delta)$. Hence, for the range $2\Delta/(1 - \delta) \geq r \geq 2\Delta(1 + \delta)$ a multiplicity of equilibria exists. It can be shown that this range with multiple equilibria disappears if we allow for negative choices of T, with the dividing line between pure-strategy equilibrium with persistent agglomeration and equilibrium with transitory agglomeration as in Proposition 1 being defined by $r = 2\Delta/(1 + \delta)$. (A proof can be obtained from the authors upon request.)

[12] Consider, for instance, $i_{t-1} = B$, and $\Delta = 0$. Country A would like to attract the investment in period t, and is willing to undercut any positive tax rate chosen by country B. However, for resulting high tax rates T_A, country B would like to undercut A likewise, making T_A suboptimal for A. For tax rates sufficiently smaller than r, country B does not undercut T_A and prefers to choose $T_B = r$. But given $T_B = r$, a T_A that is discretely smaller than T_B is, again, not an optimal reply for A.

such an equilibrium appears to be a reasonable prediction for the outcome of rational choice by default. Active randomization of players according to the equilibrium strategy has been advocated based on the insight that anticipated deviations from the strategy may be exploited by the co-players. A second justification is Harsanyi's (1973) approach using Bayesian equilibria to justify equilibria in mixed strategies.[13]

Some additional qualitative properties of the MPE in Proposition 1 are characterized in the next proposition.

Proposition 2 *The following properties hold for the MPE with cumulative distribution functions (3) and (4): (i) The period tax burden on "old" FDI is higher in expectation than the period tax burden on "new" FDI. (ii) The expected tax revenue on total FDI per period is higher than r. (iii) The probability that $i_t = i_{t-1}$ is smaller than $1/2$ for small Δ and equal to $1/4$ for $\Delta = 0$.*

The proof of Proposition 2 is in the Supplementary Appendix, but the proposition has a clear intuition. In the MPE, investment is taxed more heavily when it matures. Tax policies under which investors receive a preferential tax treatment in early periods of investment are known as "tax holidays" and are widely studied in the tax competition literature. The usual assumption in this context is that countries may be able to commit to a lower tax for some time, but their commitment power does not stretch into the indefinite future. In our framework "tax holidays" result endogenously from the equilibrium outcome in which countries with a stock of old FDI have a tendency to choose higher taxes than countries with no such stock when competing for new FDI. It is based here on a reversion-to-the-mean effect: new FDI can choose the country which exhibits the superior fiscal conditions in the period of investment. Old FDI has to accept the conditions chosen in the respective country in which it is located.

The putty-clay nature of FDI causes two different effects regarding the location choice of future FDI: an incumbency effect and an agglomeration benefit effect. To

[13]See, e.g., Fudenberg and Tirole (1991, pp. 230-234). An alternative to the mixed strategy MPE with simultaneous choices is sequential timing, as has been discussed in Farrell and Shapiro (1988). See also Deneckere, Kovenock and Lee (1992), who critique the timing game employed by Farrell and Shapiro. In such a game of timing the country with locked-in investment sets tax first at rate r and the country with no old investment follows and undercuts by Δ. The payoffs in this equilibrium are higher than in Proposition 1 but, if applied to our model, relocation of the agglomeration would also occur in the equilibrium.

study the incumbency effect, let $\Delta = 0$. In this case the country which attracted FDI in the previous period has an immobile tax base in the current period. Let this country be B. If B chooses a high tax, it is likely that the tax chosen by A is lower and the FDI goes to A. A high tax rate therefore is likely to make country B lose the mobile tax base in this period, and this is a twofold loss: the country loses the tax revenue on this tax base in the current period and it loses the advantage of having an immobile tax base in the next period. The competing country A has a twofold gain from attracting FDI in the current period, and this is a reason why country A has a strong incentive to undercut the tax rate chosen by B: first, A does not have an immobile tax base from previous FDI; hence, it does not lose tax revenue on this tax base by reducing its own tax rate in a given period. Second, a lower tax rate makes it more likely that the tax rate is sufficiently low to attract the new investment in that period, which can then be taxed in the current period, and is an immobile tax base that can be taxed by A also in the next period. The nature of this competition makes it likely that a country which attracted FDI in the previous period will not attract it in the current period. Hence, investment alternates stochastically over time. A country that attracted the investment in the previous period has an incentive to exploit this immobile investment, and this makes the country disadvantaged vis-a-vis the competitor without such a stock of tax base that can be exploited. Following Fudenberg and Tirole (1984), one may say that the country which currently has a stock of investment is a "fat cat", whereas its competitor has the "lean and hungry look". This analysis reveals that the country that attracted much past investment has a strategic disadvantage. Capture of previous investment, hence, is not only a benefit, but equilibrium forces drive future investment away from saturated countries and towards lean and hungry countries.

An agglomeration effect comes into play if investments exhibit positive spillovers towards each other (or towards new investment in our case), i.e., if there are technological benefits from agglomeration, which are measured in our framework by Δ. With agglomeration ($\Delta > 0$) it is most efficient for investment to always locate in the same country. Consequently, for $\Delta > 0$ the equilibrium described in Proposition 1 is characterized by inefficient investment. Due to the mixed strategies employed, with probability greater than $1/2$ new FDI does not locate in the country with the old FDI, and the cost saving of Δ is sacrificed. Because of the stationarity of the problem, this happens in all periods. Accordingly, using the equilibrium cumulative distribution functions we can denote the present value of the efficiency loss at period $t = 1$ with $i_0 = j$ as

$$\frac{\Delta}{1-\delta}\int_{\Delta}^{r} F'_{-j}(x-\Delta)(1-F_j(x))dx, \tag{7}$$

which typically does not provide a solution that is easily interpreted.

For the equilibrium characterized in Proposition 1 it holds that the higher the agglomeration advantage Δ enjoyed by the country with old FDI, the lower the tax rates of both countries in equilibrium and the lower the expected discounted value of tax revenues accruing to the two countries. However, the difference between the present discounted value of the tax revenues of the country possessing an agglomeration advantage and the country competing with it for new investment, increases in the agglomeration advantage Δ. Consequently, when such advantages exist, they are valuable assets that yield benefits to the country possessing them. More formally, we state and prove the following

Proposition 3 *Suppose $r > 2\Delta(1+\delta)$ and consider the equilibrium in Proposition 1. (i) The higher the agglomeration advantage Δ the lower the equilibrium tax rate of each country in the sense of first order stochastic dominance. (ii) The continuation value v_1 is decreasing in Δ for $\delta > 0$ and v_0 is decreasing in Δ for $\delta \geq 0$. (iii) The difference $v_1 - v_0$ is increasing in Δ.*

Again, the proof of the proposition is in the Supplementary Appendix. The intuition for Proposition 3 is as follows. Recall that for $\Delta = 0$ the country with the old FDI has a strategic disadvantage in the competition for new FDI. This makes the competition asymmetric, which causes comparatively higher tax rates. Setting $\Delta > 0$ introduces an effect that is advantageous for the country with the old FDI. Overall, these strategic advantages and disadvantages are countervailing forces, so that $\Delta > 0$ makes competition more even. This generally reduces equilibrium taxes in expectation and even the country which initially hosts the old FDI suffers from this, as it will find itself in a different role in the future.

In the remainder of this section we consider two modifications of the general set-up.[14] First, we discuss what happens if old capital is not completely immobile

[14] One modification that we do not treat in detail in this paper is the case of $\Delta < 0$, which may be interpreted as the case in which old FDI leads to negative congestion effects on new FDI. Intuition for this case is provided by assuming $\delta = 0$. If congestion is severe, i.e., $r \leq 2(-\Delta)$, then an equilibrium

and can relocate at a relocation cost c. Second, we consider the competition between more than two countries.

Suppose first that old capital can relocate, and that this involves a relocation cost $c \geq 0$. The MPE in Proposition 1 is sustained if c is sufficiently large, for instance, $c \geq r$ being a sufficient condition. For some values of $c < r$, the analysis becomes more involved. In particular, assumptions are needed about the role of the agglomeration advantage, in particular in the case in which tax choices in a given period may make the old capital move to the other country. Several reasonable assumptions can be made for this case, depending on the nature of the agglomeration advantage.[15]

For this reason, we focus on the case with $\Delta = 0$ which becomes structurally equivalent to the problem studied by Padilla (1995) and Anderson, Kumar and Rajiv (2004). They show that the nature of the equilibrium depends on the size of c relative to r. We illustrate the nature of the problem focussing on the case with c small compared to r, making r non-binding in the equilibrium. We focus again on the case with $\delta = 0$, which is the limit of the more general problem for $\delta \to 0$ and transforms the local decision problems in each period into a static problem for investors and the governments. Then, for $c < r/2$ an MPE exists which is characterized by the following mixed strategies in period t: If $i_{t-1} = B$, then

$$F_B(T) = \left\{ \frac{T-c}{T} \quad \text{and } F_A(T) = \left\{ \frac{2(T-c)}{T} \quad \text{for } T \in [c, 2c) \right.\right. , \tag{8}$$

with $F_A(T) = F_B(T) = 0$ for $T < c$ and $F_A(T) = F_B(T) = 1$ for $T \geq 2c$. For $i_{t-1} = A$, all subscripts A and B need to be interchanged.[16]

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emerges in which FDI alternates between the two countries. In this equilibrium, both countries set the tax rate equal to r. If $r > 2(-\Delta)$, a mixed strategy equilibrium emerges that is derived similarly to that in Proposition 1, although its properties are somewhat different. Specifically, in this mixed strategy equilibrium the country with old FDI randomizes its tax continuously in $(r/2, r + \Delta)$, and places a masspoint at r. The country without old FDI randomizes continuously in $((r/2) - \Delta, r)$ and also places a masspoint at r.

[15] The issue of coordination between the investors becomes potentially relevant in this case. The decisions about new investment and about relocation of old investment become interdependent and governed by expectations.

[16] This can be confirmed either by considering $\delta \to 0$ in the more general results in Padilla (1995) and Anderson et al. (2004), or directly, as follows: given $F_A(T)$, the period payoff for B is equal to $2c$ for all $T_B \in [c, 2c]$ and lower than that for all other T_B. Similarly, given $F_B(T)$, the period payoff for A is equal to c for all $T_A \in [c, 2c)$ and lower than that for all other T_A. Note that $T = 2c$

The MPE for this set of parameters is only a special case. However, the example shows that mobility of old capital with a finite cost of mobility may induce similar processes of stochastic relocation of agglomeration. Also, the lock-in of old capital leads to a similar strategic disadvantage of its host country in the competition for new FDI. Further, as $c \to 0$, the equilibrium converges towards Bertrand cut-throat competition for two units of perfectly mobile capital in each period.

We return now to the general analysis with immobile old capital as described in Section 3 and consider more than two countries.

Proposition 4 *Let there be $n \geq 3$ identical countries denoted $A_1, A_2, ..., A_n$. Let $r > \Delta$ and define $\alpha \equiv (n-1)^{-1}$. (i) If $r \leq 2\Delta/(1-\delta) \equiv \overline{r}$ then, for $i_{t-1} = A_j$, $T_j(t) = \Delta$ and $T_i(t) = 0$ $\forall i \neq j$, $\forall t > 0$ constitute a MPE of the game. (ii) If $r \geq \frac{2\Delta(1+\delta\alpha)}{1+\delta\alpha-\delta} \equiv \underline{r}$ then for $i_{t-1} = A_j$ taxes $T_j(t) = r$ and $T_i(t) = 0$ $\forall i \neq j$ and $\forall t > 0$ constitute a MPE of the game.*

The proof is again relegated to a Supplementary Appendix. In the MPE in (i) the country in which the capital is agglomerated uses 'limit taxes' and this makes the agglomeration of capital permanent. This case is reminiscent to the results in Baldwin and Krugman (2004). In the MPE in (ii) the agglomeration is transitory. There are several countries which are in a situation similar to standard Bertrand competition. This competition drives the smallest tax rate down to zero. The country with the old capital cannot benefit from taking part in this competition and is better off if it extracts the maximum tax from old FDI.

Note that

$$\underline{r} \equiv \frac{2\Delta(1+\delta\alpha)}{1+\delta\alpha-\delta} < 2\Delta/(1-\delta) \equiv \overline{r}. \tag{9}$$

Hence, there is a range of values of r for which both types of equilibria exist, $\underline{r} \leq r \leq \overline{r}$. Intuitively, if there are several countries without old capital, these countries are willing to compete very strongly. This can lead to two types of MPE. If the agglomeration advantage is large compared to the maximum tax, the country with old investment does not lose much in the current period if it chooses a 'limit tax' that is sufficiently small to attract also the new investment rather than choosing a maximum tax r, and

is the upper end of the equilibrium support, which requires $c < r/2$. If capital can relocate at some cost and there is a binding upper limit r (i.e., $c \in (r/2, r)$), this additional constraint will induce a modified equilibrium in mixed strategies.

the country gains in the future by keeping the agglomeration of capital. In the other MPE the agglomeration is again transitory: the country which has the stock of old capital is better-off by extracting revenue in the present even if this implies that the agglomeration of capital locates for some time in another country. As a result, new investment always pays zero taxes in the first period, and is maximally taxed in the second period when it turns into old capital. Moreover, the agglomeration of capital always relocates to another country in this MPE. Hence, an increase in the number of countries can intensify competition for the agglomeration and can make a relocation of the agglomeration even more likely.

From a policy perspective, we should note that Proposition 4 considers a rather extreme case in which there are several countries without any capital. We would expect that Proposition 1 characterizes a situation that is empirically more relevant.

5 Bidding for firms

We assumed so far that countries have to tax old and new FDI according to the same rules. A country which attracted FDI in the past, hence, sacrifices the opportunity to levy a high tax on this immobile investment if it chooses to compete seriously for the new investment, and this caused considerable fiscal revenues in the equilibrium in Proposition 1. When competing for FDI, countries are often not allowed to use discriminatory taxation with respect to old and new investment. However, they may use an additional instrument in the competition for new investment. As has been highlighted in the literature (e.g., Black and Hoyt, 1989, Besley and Seabright, 1999, and Kessing, Konrad and Kotsogiannis, 2009), countries may make upfront transfers to new FDI, and may bid for FDI much like in a standard auction.[17] This second instrument will generally change the nature of the equilibrium and may erode the fiscal net revenue that remains to countries.

To analyse this more formally, we enlarge the set of actions of countries in each period. Each country chooses the tax $T_j(t) \in [0, r]$ that applies to any old and

[17] In the industrial economics literature, Chen (1997) employs a duopoly model with locked-in customers to compare uniform pricing and discriminatory pricing policies that offer a discount to new customers switching from the other firm. Chen's model differs from that examined in this section in that it is a two-period model in which all customers are locked into one or the other firm and customer switching costs are drawn from a nondegenerate distribution.

new FDI that is located in country j in the given period, and also it makes a bid $S_j(t) \in [0, k]$ to the new investor in the respective period t. Here, k is an exogenous constant, sufficiently large to be non-binding, but finite. For instance, any $k \geq 2r + \Delta$ is a suitable limit. This changes the period payoffs of countries. Let, e.g., $i_{t-1} = B$. Then the payoff of country B in period t is $T_B(t)$ if $i_t = A$, and $2T_B(t) - S_B(t)$ if $i_t = B$, and the period payoff of A is $T_A(t) - S_A(t)$ if $i_t = A$ and zero otherwise.

Moreover, given $i_{t-1} = B$, a foreign direct investor's total payoff is equal to $G + \Delta + S_B(t) - T_B(t) - \delta T_B(t+1)$ if $i_t = B$, and it is equal to $G + S_A(t) - T_A(t) - \delta T_A(t+1)$ if $i_t = A$. Accordingly, anticipating the future tax burden in the country of location, the investor will locate the FDI in the country with the higher payoff. For equal payoffs we apply here a more specific tie-breaking rule and assume that, if the payoffs are equal, the investor locates in the country which has the agglomeration advantage.

Strategy sets, histories, and a restriction to Markov perfect strategies follow straightforwardly from these assumptions, and we can state the following proposition

Proposition 5 *Suppose $r > 2\Delta(1 + \delta)$ and let $i_0 = B$. Then a Markov perfect equilibrium exists in which $T_A^*(t) = T_B^*(t) = r$, and $S_j^*(t) = \delta(r + \Delta) + r - \Delta$ if $i_{t-1} = j$, and $S_j^*(t) = \delta(r + \Delta) + r$ if $i_{t-1} \neq j$, for all $t = 1, 2, ...$ The payoffs in this equilibrium are $v_A^* = 0$ and $v_B^* = r + \Delta$.*

The proof of Proposition 5 is in the Supplementary Appendix. The proposition shows that the high tax revenue outcome in the tax competition equilibrium of Proposition 1 is a consequence of a lack of a sufficient number of fiscal instruments. If the countries have as many instruments as there are types of tax bases, then the competition between countries again becomes cut-throat in nature. This result is not unexpected and confirms the intuition that differential taxation of tax bases with different elasticities tends to strengthen tax competition, as, for instance, in Janeba and Peters (1999) and Haupt and Peters (2005).

Contrasting this result with piecemeal evidence in the European Union on tax and subsidy competition shows that further aspects need to be taken into consideration to explain the success of new member states in attracting new FDI. A possible explanation for this success, despite the forces which are described in Proposition 5, is the co-funding of infrastructure investment that takes place inside the European Union as part of their development and cohesion objectives.

Proposition 5 also highlights the interaction between the number of available fiscal instruments and the agglomeration effect. In the absence of subsidization, from Proposition 4 we know that an increase in the agglomeration effect Δ lowers the present discounted value of tax revenues for both countries in the equilibrium that is characterized in Proposition 1. Proposition 5 shows the reverse; an increase in the agglomeration effect Δ raises the discounted value of net revenues of the country with old FDI and has no effect on the value of net revenues for the competing country, which are zero. This arises because, in the presence of two instruments, competition for new FDI is decoupled from revenues extracted from old FDI. Due to the immobility of old FDI, the host country can reap the complete hold-up benefit, r. At the same time, perfect Bertrand-like tax competition for new FDI drives the return from that FDI to Δ for the host country with agglomeration advantages and zero for its rival.

The result shows that the restrictions on subsidies paid to new FDI may moderate tax competition for FDI within Europe and may prevent a 'race to the bottom'. It reveals a possible channel by which tax competition that is complemented by countries' bidding for FDI may lead to higher average tax revenues but lower fiscal net revenues than if such bids are not feasible. The aggregate tax revenues in the equilibrium in Proposition 5 are equal to $2r$ in each period, and are smaller than $2r$ in the equilibrium that is characterized in Proposition 1. However, the present value of all aggregate fiscal net revenues of all future periods is equal to $r + \Delta$ in the equilibrium with bidding for FDI, and it is equal to $v_1 + v_0$ as given in (5) and (6) in Proposition 1. An immediate implication of the comparison of the present value of aggregate fiscal net revenues under the two regimes is the following proposition:

Proposition 6 *Suppose $r > 2\Delta(1 + \delta)$. The present discounted value of aggregate fiscal net revenues is higher with a single instrument ($T_j(t)$) (in the equilibrium characterized in Proposition 1), than with two instruments ($T_j(t)$ and $S_j(t)$) (in the equilibrium characterized in Proposition 5), if and only if $r > \frac{\Delta(4+\delta(1-\delta))}{(1+\delta)^2}$.*

This observation is interesting from an empirical point of view. Empirically the relationship between capital mobility, effective marginal tax rates, and fiscal net revenues is not straightforward. For instance, sustained or even increasing tax revenue has been observed jointly with a reduction in marginal tax rates.[18] If the increased

[18] Devereux, Griffith and Klemm (2002), for instance, address the puzzle that corporate tax revenue did not decrease, despite decreases in tax rates.

competition for FDI has been complemented with a change in the number or composition of instruments, sustained or even increasing tax revenue does not preclude a drop in fiscal net revenue. As shown in Proposition 6, for δ or r sufficiently large or Δ sufficiently small, two instruments generate less fiscal revenue than one. At the same time, the average statutory tax rates are higher than in the case with only one tax instrument.

6 Discussion

We considered fiscal competition for FDI in a dynamic framework. We accounted for a number of properties: FDI is mobile ex-ante and can react to the fiscal conditions that apply in different countries. It becomes immobile and potentially subject to extortionary taxation once it is in place while it depreciates over time. We also allowed for a cost advantage from investing in the country that hosts earlier investment.

Our main findings are the following. First, we confirm an insight from static analysis: a country's acquired stock of immobile FDI is a mixed blessing. On the one hand, the country can extort this immobile tax base. On the other hand, such extortionary taxes will affect newly acquired FDI. The temptation to extort the immobile tax base is a strategic disadvantage in the tax competition for new FDI. As a result, the country which has accumulated a stock of immobile FDI at the beginning of a period will, on average, charge a higher tax, and is likely to lose the agglomeration advantage to a country without a stock of immobile FDI. Second, in the dynamic equilibrium a frequent change in the agglomeration advantage between countries will be observed along the equilibrium path. These theoretical results appear to be consistent with empirical results by Dumais, Ellison and Glaeser (2002). They recognize (p. 193) that "...concentration is the outcome of a life cycle process in which new plants are constantly being born, existing plants are expanding and contracting at different rates, and a substantial number of businesses are failing" and consider empirically what drives agglomeration and deagglomeration. They find that (p. 200) "...new firm births and expansions of existing plants have a deagglomerating effect...". We provide a fiscal competition argument that can explain this effect. Third, we find that the agglomeration advantage can intensify both countries' incentives to charge lower taxes.

Countries are innovative in finding arrangements to circumvent any rule against discriminatory taxation. For instance countries often promise tax holidays to foreign direct investors where this is legally feasible, provide investing firms with public infrastructure without charging an adequate user fee, or sell them property or other production inputs at below market value.[19] We also considered competition that includes subsidies to new FDI. If discriminatory taxation is feasible, it changes the nature of the equilibrium. A Markov perfect equilibrium emerges in which each country taxes the stock of investment that has previously been invested in this country at its maximum. Independently of this time consistent treatment of old FDI, the countries compete in attracting new FDI. This was analysed in section 5. As a result, agglomeration may perpetuate itself, but the economic advantage of agglomeration may be very small.

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[19] This motivates the study of the acquisition process of FDI as an auction, as in Black and Hoyt (1989), Besley and Seabright (1999) and Oman (2000).

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8 Supplementary Appendix

This supplementary appendix has the proofs of Propositions 1 to 5 that appear in the main part of the paper.

Proof of Proposition 1. Consider property (i). An investor who locates his FDI in period t anticipates that the actual FDI location in t will lead to the same expected tax burden in $t+1$ on this investment, because the respective host country will choose the same local tax strategy in period $t+1$, irrespective of whether this host country is A or B. The location decision can, hence, be made on the basis of returns in period t only. In period t the agglomeration benefit matters: investing in the country in period t that hosts the FDI made in $t-1$ has a cost advantage of size

Δ. Therefore, if $i_{t-1} = B$, then $i_t = B$ if

$$T_B(t) < T_A(t) + \Delta. \quad (10)$$

The FDI is made in A if the reverse inequality holds, and FDI may be located in either country with equal probability if equality holds in (10). It is important for this result that each investor appears and decides only once. An investor whose FDI has expired its two periods of activity disappears and will not re-appear with new FDI in the future.

Turn now to the tax choices made by countries. Note that the one-stage deviation principle applies. To see this note that the lowest aggregate payoff for a country is bounded from below by zero. Also, the highest payoff (2) of a country is bounded from above by

$$\frac{2r}{1-\delta}. \quad (11)$$

Maximum feasible payoff differences between arbitrary action profiles are therefore bounded from above.

Suppose now that all future investors and countries A and B follow the candidate equilibrium choices in all periods $t+1, \ldots.$ This allows us to calculate the continuation value v_1 at $t+1$ that applies for the country j for which $i_t = j$ and the continuation value v_0 that applies for the country j for which $i_t \neq j$ as follows: if $T_j(t+1) = r$, the investor i_{t+1} locates FDI not in j, but in the other country with probability 1. As this tax choice has a positive probability mass in the candidate equilibrium strategy for j with $i_{t-1} = j$, it must hold that

$$r + \delta v_0 = v_1. \quad (12)$$

Second, given the equilibrium candidate strategies, country j with $i_t = j$ is indifferent in period $t+1$ between choosing $T_j = r$ and $T_j = q + \Delta$ with

$$q = \frac{r - 2\Delta(1+\delta)}{\delta + 2} \quad (13)$$

being the lower bound of the equilibrium support for the country without old FDI. As $T_j(t) = q + \Delta$ will attract FDI in period t with probability 1, it must hold that

$$\left(\frac{r - 2\Delta(1+\delta)}{\delta + 2} + \Delta\right)2 + \delta v_1 = v_1. \quad (14)$$

These two equations can be used to calculate the continuation values as

$$v_1 = 2\frac{r - \delta\Delta}{(\delta + 2)(1 - \delta)} \tag{15}$$

and

$$v_0 = \frac{r(1 + \delta) - 2\Delta}{(\delta + 2)(1 - \delta)}. \tag{16}$$

Consider now period t. It remains to show that the local strategies F_A and F_B are mutually optimal replies. Consider first country B. Given the candidate equilibrium choices of A, country B's payoff as a function of $T_B(t)$ can be written as

$$F_A(T_B - \Delta)(T_B + \delta v_0) + (1 - F_A(T_B - \Delta))(2T_B + \delta v_1) \tag{17}$$

Inserting (4), (15) and (16) shows that the value of (17) is equal to v_1 in (15) for all $T_B \in [q + \Delta, r]$. Moreover, all $T_B \notin [q + \Delta, r]$ yield a lower payoff. This makes any mixed strategy F_B that has $[q+\Delta, r]$ as its support an optimal reply to F_A. Turn now to the tax choices of country A, anticipating that country B chooses F_B as in (3), and the continuation values v_1 and v_0 as in (15) and (16). Country A's payoff as a function of $T_A \in [q, r - \Delta]$ is

$$F_B(T_A + \Delta)\delta v_0 + (1 - F_B(T_A + \Delta))(T_A + \delta v_1). \tag{18}$$

Inserting (3), (15) and (16) shows that the value of (18) is equal to v_0 in (16) for all $T_A \in [q, r - \Delta)$ and smaller than v_0 for any feasible $T_A \notin [q, r - \Delta]$.

Note for completeness that (3) and (4) are cumulative distribution functions, and the lower bound of taxes, q, is positive if $r > 2\Delta(1 + \delta)$ holds.

Consider (ii). The payoffs v_1 and v_0 for the country with and without the old FDI were derived already as (16) and (15), respectively.

Proof of Proposition 2. The proof of property (i) uses a revealed preference argument. Let, without loss of generality, $i_{t-1} = B$. This "old" FDI is taxed by $T_B(t)$ in period t. The "new" FDI in period t is taxed by $T_B(t)$ if $i_t = B$, and by $T_A(t)$ if $i_t = A$. Moreover, $i_t = A$ if $T_B(t) - \Delta > T_A(t)$. Hence, the tax burden is the same on "old" and "new" FDI if $i_t = i_{t-1}$, and is lower (or at most the same, which happens only if $T_A(t) = T_B(t)$ and $\Delta = 0$) if $i_t \neq i_{t-1}$. Because both countries randomize their tax rates independently according to (3) and (4), outcomes with $T_A(t) < T_B(t) - \Delta$ happen with positive probability.

Consider (ii). The sum v_0+v_1 is the present value of the sum of both countries' tax revenue at any given t. This sum can be written as

$$v_0 + v_1 = \frac{r}{(1-\delta)} + \frac{r - 2(1+\delta)\Delta}{(2+\delta)(1-\delta)}. \tag{19}$$

It exceeds $\frac{r}{(1-\delta)}$ if $r > 2\Delta(1+\delta)$. However, $\frac{r}{(1-\delta)}$ is the present value of tax revenue that emerges if, on average, the total tax revenue is equal to r in each period, and $r > 2\Delta(1+\delta)$ is the condition stated in the proposition that is required to make the country that has no agglomeration advantage choose a positive minimum tax in the equilibrium.

Consider (iii). Suppose $i_{t-1} = B$. Then using $F_A(T)$ and $F_B(T)$ from Proposition 1 yields

$$P_{A \text{ wins}} = \int_{\Delta}^{r} F_A'(x-\Delta)(1-F_B(x))dx. \tag{20}$$

It is not straightforward to find a closed form solution to this integral using (3) and (4) in general. For $\Delta = 0$ the probability reduces to $P_{A \text{ wins}} = 3/4$. Hence, $P_{A \text{ wins}} < 1/2$ for sufficiently small Δ follows by continuity.

Proof of Proposition 3. (i) Let $i_{t-1} = j$ and write the equilibrium distribution of country j given in (3) as a function of Δ,

$$F_j(\Delta) = \frac{(\delta+2)T + \delta\Delta - r}{(\delta+2)T + (\delta-2)\Delta + r\delta} \equiv \frac{N}{D} \tag{21}$$

where N stands for numerator and D for denominator. Note that

$$dF_j(\Delta)/d\Delta = \frac{\delta}{D} - \frac{(\delta-2)N}{D^2} = \frac{\delta}{D} - \frac{(\delta-2)}{D}F_j(\Delta) \tag{22}$$

It is easily verified that D is positive over the relevant range, so that $sgn\ (dF_j(\Delta)/d\Delta) = sgn\ \ [\delta - (\delta-2)F_j(\Delta)] > 0$. Hence, the effect of an increase in the agglomeration parameter Δ is to raise the probability that the country with old FDI sets its tax rate below any given level T in the support of its distribution. A similar result holds for the country with no vintage FDI. If $i_{t-1} \neq j$, then from (4)

$$F_j(\Delta) = 2\frac{(\delta+2)T + 2\Delta(1+\delta) - r}{(\delta+2)T + \Delta(3\delta+2) + r\delta} \equiv 2\frac{N}{D} \tag{23}$$

where again N stands for numerator and D for denominator. Since

$$dF_j(\Delta)/d\Delta = \frac{4(1+\delta)}{D} - \frac{2(3\delta+2)N}{D^2} = \frac{4(1+\delta)}{D} - \frac{(3\delta+2)}{D}F_j(\Delta) \tag{24}$$

and D is positive, $sgn\ (dF_j(\Delta)/d\Delta) = sgn\ [4(1+\delta) - (3\delta+2)F_j(\Delta)] > 0$.

(ii) From (16) and (15) it is easily verified that v_1 is decreasing in Δ for $\delta > 0$ and v_0 is decreasing for all $\delta \geq 0$. (iii) From (16) and (15) it also follows that $v_1 - v_0 = \frac{r+2\Delta}{(\delta+2)}$, which is increasing in Δ.

Proof of Proposition 4. (i) The one-stage deviation principle applies. We consider deviations in a single period t. With a nonnegativity constraint on taxes no country $i \neq j$ has an incentive to deviate from $T_i(t) = 0$, as any higher tax does not attract FDI and also does not yield positive tax revenue. Consider one-stage deviations from $T_j(t) = \Delta$ for country j. A deviation to $T_j \in [0, \Delta)$ is not profitable. It reduces the payoff in period t by $2(\Delta - T_j)$ and does not affect the continuation game. A deviation to $T_j > \Delta$ in period t generates a discounted payoff of $T_j + \delta 0$, which takes its maximum for $T_j = r$ which is lower than $2\Delta/(1-\delta)$ if $r \leq 2\Delta/(1-\delta) \equiv \overline{r}$.

To show (ii), consider the continuation values in the candidate equilibrium. The continuation value of the country with the old FDI in t in this equilibrium is

$$r + \delta v_0 = v_1. \tag{25}$$

The continuation value of a country i with no old FDI in t is

$$v_0 = 0 + \delta(\alpha v_1 + (1-\alpha)v_0)\,, \text{ where } \alpha \equiv (n-1)^{-1}. \tag{26}$$

Here we assume a symmetric random tie-breaking rule: if several countries without old capital choose the same $T_i < T_j(t) - \Delta$, the new FDI goes to each of them with the same probability α. Rearranging (26) we obtain

$$v_0 = \frac{\delta \alpha v_1}{1 - \delta(1-\alpha)}. \tag{27}$$

Using (27) to replace v_0 in (25) and solving for v_1 yields

$$v_1 = \frac{r}{1-\delta}[\frac{1+\delta\alpha-\delta}{1+\delta\alpha}]. \tag{28}$$

By the one-stage deviation principle it is necessary and sufficient that any single deviation from $T_j(t) = r$ and $T_i(t) = 0\ \forall i \neq j$ does not increase the player's payoff. Countries $i \neq j$ have no incentive to deviate at period t. Country $j's$ optimal deviation from $T_j(t) = r$ is to the highest tax at which j attracts both units of capital, which is $T_j(t) = \Delta$ (giving ties to j). The payoff from doing so given that all countries conform to the equilibrium strategies thereafter is $2\Delta + \delta v_1$. For this deviation to be deterred the following inequality must hold: $2\Delta + \delta v_1 \leq v_1$ or, inserting the right hand side of (28) in place of v_1,

$$r \geq \underline{r} \equiv \frac{2\Delta(1+\delta\alpha)}{1+\delta\alpha-\delta}. \tag{29}$$

Consequently, a MPE in which $T_j(t) = r$ and $T_i(t) = 0$ for all $i \neq j$ exists when r satisfies (29).

Proof of Proposition 5. Note first that the one-stage deviation principle applies also for the augmented framework for analogous reasons. Consider now the decision of an investor at t. As both countries charge the same tax in period $t+1$, regardless of i_t, the investor can base the location decision on a comparison of period t payoffs. There are savings in investment of Δ from investing in i_{t-1}. Let $i_{t-1} = B$. Then $i_t = B$ if and only if $S_B(t) - T_B(t) + \Delta \geq S_A^*(t) - T_A^*(t)$. Continuation play in periods $t+s$ for $s = 1, 2, \ldots$ as in the candidate equilibrium in Proposition 5 yields continuation values for the countries as $v_A = 0$ and $v_B = r + \Delta$ if $i_t = B$, and $v_A = r + \Delta$ and $v_B = 0$ if $i_t = A$. Let $i_{t-1} = B$. Suppose that B anticipates $T_A^*(t) = r$ and $S_A^*(t) = \delta(r+\Delta) + r$. Then the payoff of B becomes equal to $T_B(t)$ if $S_B(t) - T_B(t) + \Delta < S_A^*(t) - T_A^*(t)$, and equal to $2T_B(t) - S_B(t) + \delta v_1$, if $S_B(t) - T_B(t) + \Delta \geq S_A^*(t) - T_A^*(t)$. Among the latter choices, the payoff maximizing choice is $S_B(t) - T_B(t) = \delta(r+\Delta) - \Delta = \delta(r+\Delta) + r - r - \Delta = S_B^*(t) - T_B^*(t)$. We now turn to country A. The payoff of A is equal to zero for all $S_A(t) - T_A(t) \leq S_B^*(t) - T_B^*(t) + \Delta$. Moreover, the payoff for A is negative for all $S_A(t) - T_A(t) > \delta v_1 = \delta(r+\Delta) = \delta(r+\Delta) + r - \Delta - r + \Delta = S_B^*(t) - T_B^*(t) + \Delta$. This completes the proof.