

Corporate Tax Games with International Externalities from Public Infrastructure

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Abstract

We construct a model of corporate tax competition in which governments also use public infrastructural investment to attract foreign direct investment, thus enhancing their tax bases. In doing so, we allow for inter-regional infrastructural externalities. Depending on the externality, governments are shown to strategically over- or under-invest in infrastructure. We examine how tax cooperation influences investment in infrastructure and find that welfare may be lower under tax cooperation than under tax competition; this is, in fact, the case when infrastructure is sufficiently effective in raising the tax base and generates a sufficiently large negative interregional externality.

Key Words: Tax competition, Tax cooperation, Public infrastructure investment, Externalities.

JEL Codes: F23, H40.

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1 Introduction

As economic globalisation deepens, countries tend to compete fiercely with each other to attract foreign direct investment (FDI). Often countries use favourable tax rates to compete for multinational investment. This is not only suggested by the vast literature on tax competition but also emphasised by the often heated political debate on corporate taxes.¹ While the tax rate in the prospective host location matters for a firm's location decision, its actual location choice typically hinges on a combination of host location characteristics that best suits the specific needs of that firm.² Hence, any government policy that helps to create a more profitable environment for multinational firms, such as investment in local public infrastructure, potentially attracts mobile capital into a region. Following the literature, we will interpret investment in public infrastructure widely as any government investment that increases locally producing firms' productivity.³

This paper focuses on two questions. First, we examine how governments' investment decisions in public infrastructure interact with their policy of corporate taxation. Second, we explore how tax harmonisation between two competing host countries affects those countries' investment in public infrastructure and their welfare. The possibility of tax harmonisation has been on the political agenda for a long time now and seems even more pressing as globalisation deepens and discussions on this matter between the major trading blocks and even within trading blocks (for instance, among EU member states) seem to re-occur with increased frequency.

In addressing these issues, we explicitly model some of the innate characteristics of public infrastructure investment. Investment in public infrastructure is typically a medium-run or even long-run decision, implying that it is –at least to a large extent– irreversible. In addition, because of its public good character, public infrastructure investment may affect the attractiveness of neighbouring host countries as a result of potential interregional or international spillover effects.

Indeed, there is a good deal of evidence that such interregional spillovers exist. However, the nature of the spillovers and in particular whether they are beneficial or harmful to neighbouring regions, seems to depend on the specific regions involved as well as on the type of public infrastructure. For instance, in a number of empirical studies, Cohen and Morrison (2004) present evidence of positive spatial spillovers of public infrastructure between US-states. By contrast, Boarnet (1998) and López-Bazo (2003) find evidence of public infrastruc-

¹Recent surveys on tax competition include Zodrow (2010) and Baskaran and Lopes da Fonseca (2013). The debate on tax competition also often features in the economic press (see, for instance, "Heard that countries should .compete.on tax? Wrong", The Guardian, 18 April 2013).

²An important determinant of multinationals' responsiveness to a particular location's fall in tax rate depends on the market potential of that location (see Davies and Voget (2009)). The higher the location's market potential, the more likely it is that multinationals will respond by locating there.

³Among many others, Pieretti and Zanaj (2011) use a similar interpretation.

tural investment having harmful effects on surrounding regions for Canada and Spain, respectively. Yu et al. (2012) present evidence for China, suggesting that public infrastructure spillovers are positive between some regions, negative between others and zero for yet other regions. In our theoretical set-up, we allow for both positive and negative interregional spillovers from a region’s investment in public infrastructure.

In our model, two jurisdictions, “Home” and “Foreign”, choose public infrastructure independently and also have profit tax raising power. Each region’s profit tax base depends negatively on local tax rates, but positively on local public infrastructure. Jurisdictions play a two-stage game: they commit to public infrastructure levels in stage one, which captures the long-term nature of this investment decision, and compete for FDI with corporate taxes in stage two. Importantly, we incorporate the possible existence of interregional externalities associated with public infrastructure investment. Public infrastructural investment in one country may directly reduce the FDI going to the other location, as it potentially makes the rival location relatively less attractive (e.g., public investment in domestic roads). However, when investment in public infrastructure has a positive interregional spillover effect (e.g., investment in interregional transport routes), FDI to both locations may increase.⁴ We examine how these interregional or international spillovers affect the tax competition game between the jurisdictions. Subsequently, we examine how tax harmonisation, in particular tax cooperation, affects governments’ optimal choice of public infrastructure. We then explore the welfare effects of tax harmonisation and show that, under some conditions, its effects on the welfare of the countries that take part can be negative, even if the countries involved are symmetric.

Our results have important policy implications. First, even if tax rates are chosen cooperatively and the countries involved are similar, a welfare improvement is not guaranteed. Second, if investment in public infrastructure is chosen by individual countries, one can expect excessive public infrastructure investment, which may reduce welfare below the level reached under tax competition if cross-border externalities generated by public infrastructure investment are sufficiently negative. The main reason why public infrastructure investment may have a negative external effect on other regions is due to a competition effect that reduces the multinational investment into the other region and thus harming that region’s tax base. So, in a federal context, if the federal government aims to eliminate a race to the bottom in tax rates between its states by setting a common tax rate at the federal level, it may inadvertently lower national welfare if its states have autonomous decision power on regional public infrastructure investment and use it to attract multinationals from abroad. Similarly, in a trading block, such as the European Union, tax cooperation at EU-level may, in the presence of negative cross-border externalities from public infrastructure, lead to a drop in welfare when individual member states use

⁴Martin and Rogers (1995) distinguish between a country’s investment in domestic and international infrastructure in a theoretical model that examines firm location and integration (without tax competition) and emphasise the different effects of the two types of public infrastructure for agglomeration.

public infrastructure investment as a means to attract FDI from outside the EU.

The relationship between public infrastructure and tax competition has been previously addressed in the literature. Notable examples are Baldwin et al (2003), Baldwin and Krugman (2004), Zissimos and Wooders (2008) and Pieretti and Zanaj (2011). The last two papers examine the link between public infrastructure and tax competition in a two-stage game in a Hotelling set-up. Our paper differs from previous work in three important ways. First, our model setup is more general than a Hotelling framework and for many of our results we are able to dispense with specific functional forms. Second, focussing on the possible externalities associated with public infrastructure investment, we allow for the possibility of positive as well as negative interregional spillovers. Third, we examine a form of tax harmonisation that should not just eliminate the harmful race-to-the-bottom property but allows similar countries to set their taxes to maximise joint welfare.

Section 2 presents the building blocks of our framework. In section 3, we solve a simple model that captures the essence of our results. In section 4 we abandon the specific functional forms used in section 3 to generalise our results and formalise them in propositions. In section 5 we discuss the welfare effects of tax harmonisation. Section 6 presents some extensions. Section 7 concludes.

2 The Model Set-up

Consider two jurisdictions, “Home” and “Foreign” (denoted by H and F, respectively), which are both prospective host locations for multinational firms from other countries. The jurisdictions can be different countries or different regions of the same country with independent tax raising authority as well as public infrastructure decision making power. The jurisdictions compete for third-country FDI as this generates benefits for each region. One obvious benefit is the tax revenue the government collects from multinationals. Naturally, these tax revenues increase in the actual amount of FDI attracted into the country. Low corporate tax rates and high investment levels in local public infrastructure are two ways of achieving this. Tax revenues from multinationals located in H are represented by tB , where t is H’s profit tax rate and B denotes the aggregate pre-tax profits of multinational firms located in H. For brevity, we will refer to B as H’s (multinational) tax base and B^* as F’s (multinational) tax base. These mobile tax base functions can be written as:

$$B = B(t, t^*, x, x^*), \tag{1a}$$

and

$$B^* = B^*(t, t^*, x, x^*). \tag{1b}$$

We assume $B_t < 0$, where subscripts here and elsewhere denote partial derivatives. This captures the idea that a higher tax rate reduces the tax base

as it reduces the inward FDI into H. We have $B_{t^*} > 0$ because the countries are substitute locations for multinational investment. The partial derivatives of B^* are analogous. Local infrastructure can be expected to both make a location more attractive for multinational investment and to raise the profitability at that location. Both of these effects work towards raising the aggregate pre-tax profits of multinationals in the region that invests in public infrastructure, hence $B_x > 0$ and $B_{x^*} > 0$. Signing the cross effects B_{x^*} and B_x^* is less straightforward as they depend on whether the externality that one region's public infrastructure investment generates for the other is negative or positive. A rival host region's investment in public infrastructure may reduce a region's relative attractiveness to multinationals and therefore its multinational tax base. This could, for instance, be the case when the rival host location invests in education. However, some types of public infrastructure investment could be beneficial to regions other than the investing region itself. For example, a region's investment in a major local port may increase the attractiveness of other nearby prospective host regions as well. In that case, the investment in public infrastructure by one region entails a positive interregional spillover to the nearby region. We define the ratios $\lambda(t, t^*, x, x^*) \equiv \frac{B_x}{B_x^*}$ and $\lambda^*(t, t^*, x, x^*) \equiv \frac{B_{x^*}}{B_{x^*}^*}$; $\lambda > 0$ implies that the spillover is positive ($B_x^* > 0$), while $\lambda < 0$ indicates the spillover is negative ($B_x^* < 0$).⁵ We assume $-1 \leq \lambda \leq 1$ and $-1 \leq \lambda^* \leq 1$, which implies that the effect of a region's infrastructural investment is always stronger on the own region than its effect –whether positive or negative– on the competing region.

Of course, FDI can provide many different benefits to a region. However, for now, to avoid the analysis becoming unnecessarily complicated, we will just focus on the gains in tax revenue.⁶ Welfare for H and F, respectively, are given by:

$$W(t, t^*, x, x^*) = tB - \Omega(x) \tag{2a}$$

and

$$W^*(t, t^*, x, x^*) = t^*B^* - \Omega^*(x^*) \tag{2b}$$

where $\Omega(x)$ and $\Omega^*(x^*)$ stand for the costs of infrastructural investment in H and F respectively. We assume these are increasing convex functions of public infrastructure ($\Omega''(x) > 0$ and $(\Omega^{*''}(x^*) > 0)$).

We will consider two two-stage games. In one game, jurisdictions choose taxes non-cooperatively; in the other, they set tax rates cooperatively. In the first stage of each game, governments simultaneously choose investment levels in public infrastructure and subsequently, in the second stage, they set corporate tax rates. We solve each game by backward induction.

We first solve a specific case of our model, using a linear function for each region's multinational tax base and a quadratic function for the regional cost of public infrastructure investment. The use of these special functional forms allows us to side-step the technicalities involved in solving the general model

⁵ Naturally, it is possible that $B_{x^*} < 0$ while $B_x^* \geq 0$ and vice versa.

⁶In section 6, we extend the analysis to take account of other, non-tax benefits.

and thus present our results in as transparent a way as possible. We will refer to this case as the "Linear Quadratic" (LQ) case. Subsequently, we generalise the model and formulate our results in propositions.

3 The "Linear-Quadratic" case

In the Linear-Quadratic case, the multinational tax bases in H and F are respectively given by:

$$B = \alpha - \beta(t - \varepsilon t^*) + \gamma(x + \lambda x^*) \quad (3a)$$

and

$$B^* = \alpha - \beta(t^* - \varepsilon t) + \gamma(x^* + \lambda x) \quad (3b)$$

In expressions (3a) and (3b), α , β and γ are positive, $0 < \varepsilon < 1$ and $-1 < \lambda < 1$, so that the sign of the partial derivatives of B and B^* are as discussed in the previous section. The respective public infrastructure investment cost functions for H and F are respectively given by $\Omega(x) = (\omega/2)x^2$ and $\Omega^*(x^*) = (\omega/2)x^{*2}$, with $\omega > 0$. As indicated by our expressions, we assume for now that the two regions are completely symmetric.⁷

3.1 Tax competition

First consider the game in which taxes are set non-cooperatively.

3.1.1 Stage two: Non-cooperative tax setting

The governments simultaneously and non-cooperatively choose taxes given infrastructural investment levels x and x^* . The Home government maximises Home welfare with respect to t , which yields its tax reaction function, $\psi(t^*; x, x^*)$:

$$\psi(t^*; x, x^*) = \frac{\alpha + \gamma(x + \lambda x^*)}{2\beta} + \frac{\varepsilon}{2}t^* \quad (4)$$

The tax reaction function for the Foreign government is analogous. From expression (4) we can see that taxes are strategic complements. The tax reactions shift outward in the region's own public infrastructure investment and in the competing region's public infrastructure investment if the latter generates a positive externality.

The equilibrium tax rate for Home, denoted by t^N , is:

$$t^N = [(2 + \varepsilon)\alpha + \gamma((2 + \varepsilon\lambda)x + (2\lambda + \varepsilon)x^*)]/[\beta(4 - \varepsilon^2)] \quad (5)$$

Given symmetry, the equilibrium tax rate in Foreign, t^{*N} , takes the same form with the role of x and x^* reversed.

⁷We examine the effect of asymmetry between the regions in section 6.

Let us now examine how investment in public infrastructure affects equilibrium tax rates. A region's tax rate is always increasing in its own investment in public infrastructure ($dt^N/dx > 0$ from expression (5)). The effect of a region's investment in public infrastructure on the other host region's corporate tax rate (dt^N/dx^*) is ambiguous and depends on the externality on the rival region. When a region's infrastructure investment generates a positive or not too negative externality for the rival host region (i.e., $\lambda > \bar{\lambda} \equiv -\varepsilon/2$), it raises the latter's tax rate, but the opposite is true when the negative externality is negative and sufficiently strong (i.e., $\lambda < \bar{\lambda} \equiv -\varepsilon/2$).

3.1.2 Stage one: Investment in public infrastructure under tax competition

We now determine optimal regional investment levels in infrastructure. For ease of exposition, we focus on H's choice. F's choice of investment is completely analogous. Home maximises welfare with respect to x , taking $t^N = t^N(x, x^*)$ (see expression (5)) and $t^{*N} = t^{*N}(x, x^*)$ into account. This yields the first-order condition for x :

$$\frac{dW}{dx} = W_x + W_t \frac{dt}{dx} + W_{t^*} \frac{dt^*}{dx} = 0 \quad (6)$$

Here and henceforth we use subscripts to indicate partial derivatives. Using the envelope theorem, $W_t = 0$ from the second stage. When discussing expression (6), it proves helpful to use the "strategic investment" terminology pioneered by Fudenberg and Tirole (1984). The first term in expression (6) is the direct effect of x on Home welfare, with $W_x = t\gamma - \omega x$. Let us focus on this term first. If governments were to choose public infrastructure investment simultaneously to setting taxes, H would choose x such that $W_x = 0$, implying that the marginal direct benefits of public infrastructure investment would be equal to its marginal costs (i.e., $t\gamma = \omega x$). We will henceforth refer to this hypothetical case, in which $W_x = 0$, as the "non-strategic simultaneous-move benchmark". The last term in expression (6) is the "strategic" term ($W_{t^*} \frac{dt^*}{dx}$). The sign of this term determines whether the Home government will—in the terminology of Fudenberg and Tirole (1984)—"over"- or "under"-invest, relative to the hypothetical non-strategic benchmark, in order to manipulate the tax rates set in the rival jurisdiction. If the strategic term is positive, then the first term in expression (6) has to be negative ($W_x < 0$) and we say that the Home government "over"-invest in public infrastructure relative to the non-strategic benchmark. If the strategic term is negative, then the opposite holds ($W_x > 0$) and the government "under"-invest relative to the non-strategic benchmark.

To determine which of these cases will occur, we need to examine the strategic term in detail. The term can be decomposed into W_{t^*} and dt^*/dx . We have $W_{t^*} = t\beta\varepsilon > 0$, implying that the Foreign tax rate is "friendly", which means that a rise in Foreign's tax rate increases Home welfare.⁸ The sign of

⁸Brander (1995) was the first to refer to cross derivatives such as this as the "friendliness" term.

the strategic term therefore depends on the sign of dt^*/dx , which, as shown earlier, depends on the sign of $2\lambda + \varepsilon$. So, if λ is above the threshold $\bar{\lambda} = -\varepsilon/2$ ($dt^*/dx > 0$), then Home will “over”-invest in public infrastructure ($W_{t^*} \frac{dt^*}{dx} > 0$, hence $W_x < 0$). However, when $\lambda < \bar{\lambda} = -\varepsilon/2$, it will “under”-invest ($W_{t^*} \frac{dt^*}{dx} < 0$, hence $W_x > 0$). Again, the first-order condition for the Foreign government is analogous to the one for Home given by expression (6), and the characterisation of Foreign’s optimal investment in public infrastructure is similar to the one given for the Home government.

Intuitively, governments wish to avoid a race to the bottom in corporate tax rates and will act strategically when choosing their investment levels in public infrastructure. When a region’s investment in public infrastructure raises the rival region’s tax rate, it will choose to augment its investment, since a high tax rate in the rival host region will allow the investing region to set a high tax rate itself. When its investment does the opposite, the investing region will avoid low tax rates by limiting its investment in public infrastructure.

The equilibrium level of public infrastructure investment in H is:

$$x^N = [2\gamma\alpha(2 + \varepsilon\lambda)]/D^N \quad (7)$$

with $D^N \equiv \beta(2 - \varepsilon)(4 - \varepsilon^2)\omega - 2\gamma^2(1 + \lambda)(2 + \varepsilon\lambda) > 0$. Again, the optimal public infrastructure investment in Foreign is analogous.

3.2 Tax cooperation

Here, we continue to assume that the regions independently choose their public infrastructure investment levels, x and x^* , in stage one, before the common tax rate, τ , is set in stage two. The expressions for the multinational tax base in Home is now given by:

$$B = \alpha - \beta(1 - \varepsilon)\tau + \gamma(x + \lambda x^*) \quad (8)$$

and, again, given symmetry, the multinational tax base in Foreign, B^* , takes the same form with the role of x and x^* reversed. The common tax rate is chosen to maximise the sum of Home and Foreign welfare, $W + W^*$, taking account of the fact that, at this stage, public infrastructure has already been chosen. The first-order condition for the jointly optimal tax rate is:

$$W_\tau + W_\tau^* = \tau(B_\tau + B_\tau^*) + B + B^* = 0 \quad (9)$$

implying that the common tax rate under tax cooperation is given by:

$$\tau = \frac{2\alpha + \gamma(1 + \lambda)(x + x^*)}{4\beta(1 - \varepsilon)} \quad (10)$$

Investment in public infrastructure in either region raises the common tax rate ($d\tau/dx = d\tau/dx^* = \gamma(1 + \lambda)/[4\beta(1 - \varepsilon)] > 0$).

In stage one, Home and Foreign choose their public infrastructure investment levels non-cooperatively, taking account of the effect of this on the future

cooperatively set corporate tax. The first-order condition for Home welfare maximisation with respect to infrastructural investment is:

$$W_x + W_\tau \frac{d\tau}{dx} = 0. \quad (11)$$

with $W_x = \gamma\tau - \omega x$ and $W_\tau = B - \beta(1 - \varepsilon)\tau$. The first-order condition for Foreign welfare maximisation is similar. Since $d\tau/dx = d\tau/dx^* > 0$, the sign of the strategic term in expression (11) depends on the friendliness term, W_τ . Since expression (9) can, given symmetry, be rewritten as $W_\tau + W_\tau^* = 2W_\tau = 0$, it implies $W_\tau = 0$. This means that the strategic term in expressions (11) vanishes and hence neither region invests strategically: they both invest the same level of public infrastructure as in the hypothetical benchmark. Optimal public infrastructure investment levels under tax cooperation (denoted by x^C and x^{*C}), are then given by:

$$x^C = x^{*C} = \alpha\gamma/D^C \quad (12)$$

with $D^C = 2\beta\omega(1 - \varepsilon) - \gamma^2(1 + \lambda) > 0$ to guarantee stability.

We now depict the first-order conditions for infrastructure and taxes in symmetric (x,t) -space; these are drawn for tax competition ($x^N(t)$ and $t(x)$) and for tax cooperation ($x^C(\tau)$ and $\tau(x)$) (see Figure 1). In both Figure 1a and 1b, the equilibrium under tax competition is indicated by point N and the equilibrium under tax cooperation by point C. Figure 1a shows the two equilibria for $\lambda > \bar{\lambda}$, while Figure 1b represents the two equilibria when $\lambda < \bar{\lambda}$.

[Insert Figure 1 about here]

Before discussing the welfare effects of tax cooperation, we will generalise the model in the next section and formulate our results in propositions.

4 The general model

In this section we generalise our results obtained for the LQ case. For this purpose, we use the general function forms specified in section 2. Note that we do not impose symmetry. We do, however, rule out corner solutions.

4.1 Tax competition

Again, we first consider the game in which taxes are set non-cooperatively.

4.1.1 Stage two: Non-cooperative tax setting

In stage two, governments simultaneously and non-cooperatively choose taxes given infrastructural investment levels x and x^* . First-order conditions associated with welfare maximisation yield H's and F's tax reaction functions, given by $t = \psi(t^*; x, x^*)$ and $t^* = \psi^*(t; x, x^*)$, respectively. The slope of H's tax best response functions is given by $\psi_{t^*} = -W_{tt^*}/W_{tt}$. The second-order conditions require $W_{tt} < 0$. Hence, the sign of ψ_{t^*} is the same as that of W_{tt^*} , with $W_{tt^*} = B_{t^*} + tB_{tt^*}$. The term B_{t^*} is positive. The intuition is that an increase in the tax in F makes H a relatively more attractive location and, since this increases Home's tax base, it raises the marginal benefit of the tax. The sign of B_{tt^*} is ambiguous. However, provided that B_{tt^*} is not too negative, we have $W_{tt^*} > 0$. Although it is straightforward to extend the analysis to cases in which $W_{tt^*} < 0$ and $W_{t^*t}^* < 0$, we henceforth assume that the following condition holds to avoid excessive taxonomy:

Assumption 1 $W_{tt^*} > 0$ and $W_{t^*t}^* > 0$.

This implies that the tax best-response functions are positively sloped and that corporate tax rates are strategic complements. The following assumption ensures that these cross effects do not dominate the direct effects and thus guarantees the stability of the tax game:

Assumption 2 $W_{tt} + W_{tt^*} < 0$ and $W_{t^*t^*}^* + W_{t^*t}^* < 0$.

Investment affects the equilibrium taxes by shifting the tax reaction functions. The impact on H's reaction function is captured by $\psi_x = -W_{tx}/W_{tt}$ (with $W_{tx} = B_x + tB_{tx}$) and, similarly, $\psi_{x^*} = -W_{tx^*}/W_{tt}$ (with $W_{tx^*} = B_{x^*} + tB_{tx^*}$). Since $W_t = B + tB_t = 0$ and hence $t = -B/B_t$, we can rewrite W_{tx} and W_{tx^*} as $W_{tx} = B_x - B_{tx}(B/B_t)$ and $W_{tx^*} = B_{x^*} - B_{tx^*}(B/B_t)$. Defining $R \equiv 1 - (B/B_t)(B_{tx}/B_x)$ and $r \equiv 1 - (B/B_t)(B_{tx^*}/B_{x^*})$, we can write $W_{tx} = RB_x$ and $W_{tx^*} = rB_{x^*}$. Let R^* and r^* be analogously defined for the Foreign jurisdiction. We will assume the following reasonable restriction holds:

Assumption 3 $R > 0$, $r > 0$, $R^* > 0$ and $r^* > 0$.⁹

This condition is guaranteed to hold in many special cases including the LQ case discussed in the previous subsection. From Assumption 3 $\psi_x > 0$, but the sign of ψ_{x^*} depends on that of B_{x^*} and so is ambiguous. However, we also,

⁹ $R > 0$ implies that the tax elasticity of the region's multinational tax base ($-B_t(t/B)$) is decreasing in public infrastructure investment; that is $-\partial(B_t t/B)/\partial x = tB_t B_x R/B^2 < 0$. The idea here is that inflows of FDI become less sensitive to corporate taxes when the region is more attractive due to higher infrastructural provision. This implies $R > 0$ since $B_t < 0$ and $B_x > 0$. Likewise, $r > 0$ implies the elasticity of the H's multinational tax base does not decrease if F's investment tends to reduce the gross pre-tax profits in H. The assumption implies that if F's investment makes H's location less attractive on infrastructural grounds then H's multinational tax base becomes more sensitive to taxes.

assume that the absolute impact of own investment on the tax reaction function is at least as large as the impact of rival investment on the reaction function so that:

$$\textbf{Assumption 4} \quad |\psi_x| \geq |\psi_x^*|.$$

Equilibrium tax rates depend on the levels of public infrastructure governments invested in period one and can be written as $t = t(x, x^*)$ and $t^* = t^*(x, x^*)$.

Assumption 5 For given infrastructural investment levels, the tax equilibrium $\{t(x, x^*), t^*(x, x^*)\}$, is unique.

Note that Assumptions 1 to 5 hold automatically in the LQ version of the model.

To determine the effect of x on equilibrium tax rates, we totally differentiate the first-order conditions for welfare maximisations and obtain:

$$\frac{dt}{dx} = \frac{W_{t^*x}^* W_{tt^*} - W_{t^*t^*}^* W_{tx}}{\Delta} \quad (13a)$$

and

$$\frac{dt^*}{dx} = \frac{W_{tx} W_{t^*t}^* - W_{tt} W_{t^*x}^*}{\Delta} \quad (13b)$$

with $\Delta \equiv W_{tt} W_{t^*t^*}^* - W_{t^*t}^* W_{tt^*} > 0$, which follows from Assumption 2.

Proposition 1 *Under non-cooperative tax setting an increase in public investment increases the optimal tax in the investing country.*

Proof: See Appendix.

Using the expressions for $W_{tx}, W_{tx^*}, W_{t^*x^*}^*$ and $W_{t^*x}^*$ we can rewrite expressions (13b) and the analogous expression dt/dx^* as:

$$\frac{dt^*}{dx} = A(\lambda - \bar{\lambda}) \quad (14a)$$

and

$$\frac{dt}{dx^*} = A^*(\lambda^* - \bar{\lambda}^*) \quad (14b)$$

with $A \equiv -r^* B_x W_{tt} / \Delta > 0$, $A^* \equiv -r B_{x^*}^* W_{t^*t^*}^* / \Delta > 0$, $\bar{\lambda} \equiv \frac{W_{t^*t}^* R}{W_{tt} r^*} < 0$ and $\bar{\lambda}^* \equiv \frac{W_{tt^*} R^*}{W_{t^*t^*}^* r} < 0$. This gives us the following result.

Proposition 2 *Under non-cooperative tax setting,*

- (a) *an increase in public investment in Home increases (decreases) the optimal tax in the Foreign country if $\lambda > \bar{\lambda}$ ($\lambda < \bar{\lambda}$);*
- (b) *an increase in public investment in Foreign increases (decreases) the optimal tax in Home if $\lambda^* > \bar{\lambda}^*$ ($\lambda^* < \bar{\lambda}^*$).*

If the Home region’s investment in public infrastructure raises the multinational tax base in the other host region (i.e., $B_x^* > 0$), $dt^*/dx > 0$ is guaranteed (from expression (14a)): a region’s investment in public infrastructure increases the other host region’s corporate tax rate.

However, if $B_x^* < 0$ (and hence $\lambda < 0$), the sign of dt^*/dx is ambiguous (see expression (14a)). If H’s investment in public infrastructure only causes a “modest” reduction in the multinational tax base in F (i.e., $\lambda < 0$ but $|\lambda| < |\bar{\lambda}|$), Home’s investment will raise Foreign’s corporate tax rate. But, if H’s investment in public infrastructure generates a “dramatic” reduction in multinational tax base in F (i.e., $\lambda < 0$ with $|\lambda| > |\bar{\lambda}|$), Home’s investment will reduce Foreign’s corporate tax rate ($dt^*/dx < 0$).¹⁰

4.1.2 Stage one: Investment in public infrastructure under tax competition

We now determine the regions’ optimal investment in infrastructure. For ease of exposition we will focus on H’s choice. F’s choice of investment is completely analogous. The first-order condition for Home welfare maximisation is given by expression (6) with $W_t = 0$ from the second stage. The first term in expression (6), the direct effect of x on Home welfare, is now equal to $W_x = tB_x - \Omega'$. The sign of the strategic term, the last term in expression (6), determines whether the Home government will over- or under-invest relative to the hypothetical non-strategic benchmark, in order to manipulate the tax rates set in the rival jurisdiction.

Proposition 3 *Under non-cooperative tax setting, Home government will*
 (a) *strategically overinvest in public infrastructure relative to the non-strategic benchmark benchmark if $\lambda > \bar{\lambda}$;*
 (b) *strategically underinvest in public infrastructure relative to the non-strategic benchmark benchmark if $\lambda < \bar{\lambda}$.*

Proof: To determine which of these cases will occur, we need to examine the strategic term in detail. The term can be decomposed into W_{t^*} and dt^*/dx . We have $W_{t^*} = tB_{t^*} > 0$, implying that the Foreign tax rate is “friendly”, which means that a rise in Foreign’s tax rate increases Home welfare. The sign of the strategic term therefore depends on the sign of dt^*/dx , which, as Proposition 2 showed, depends on the sign of $\lambda - \bar{\lambda}$.

4.2 Tax cooperation

In this subsection we restrict attention to symmetric regions.

¹⁰The thresholds $\bar{\lambda}$ and $\bar{\lambda}^*$ are negative but they need not always be greater than -1 . If they are not larger than -1 , then there is no λ and λ^* values for which taxes fall in rival investment. However, if the B and B^* functions are additively separable in taxes and infrastructure, then $R = R^* = r = r^* = 1$ and then $\bar{\lambda} > -1$ and $\bar{\lambda}^* > -1$ follow from Assumption 2.

Assumption 6 The regions are identical: they have symmetric tax base functions and identical public infrastructure cost functions.

This assumption will facilitate comparison with the first best, which we will discuss in the next section. The first-order condition for the jointly optimal tax is given by expression (9), with

$W_\tau = W_\tau^*$ in a symmetric equilibrium and so $2W_\tau = 0$ (from expression (9)), implying $W_\tau = 0$. To compare the harmonised and non-harmonised taxes note that $W_\tau = 0$ can be written as $W_t + W_{t^*} = 0$. Since $W_{t^*} > 0$, this implies $W_t < 0$, meaning that, at given (symmetric) public infrastructure investment levels, the cooperative taxes are higher than those under non-cooperation.

In stage one, the Home jurisdiction chooses its public infrastructural investment non-cooperatively, for which the first-order condition is given by expression (11). Since the equilibrium in public infrastructure is symmetric, $W_\tau + W_\tau^* = 2W_\tau = 0$. In turn, this implies $W_x = 0$ (from expression (11)) and, as discussed in the previous section, this means that investment is set according to the non-strategic simultaneous-move benchmark.

Proposition 4 *When countries are symmetric, tax cooperation eliminates strategic investment in public infrastructure.*

5 Tax competition versus tax cooperation: A welfare comparison

In this section, we compare welfare levels under tax competition and tax cooperation. It is *a priori* not certain that cooperative tax setting alone will yield higher welfare levels than tax competition since, even under tax cooperation, jurisdictions set their infrastructure independently. First, we prove that tax cooperation typically does not yield the "first-best" outcome, where the "first-best" refers to the jointly optimal outcome in which the regions set both taxes and infrastructure levels to maximise their total welfare. Second, we argue that tax cooperation may not even be the second-best and determine the conditions under which tax competition actually yields an outcome that is welfare superior to the outcome under tax cooperation.

5.1 The first best

The first-best outcome is reached when a social planner, maximising joint welfare of Home and Foreign, decides on the tax rate and each region's investment in public infrastructure.¹¹ This outcome is replicated by the regions jointly setting both the tax rate *and* public infrastructure levels to maximise their total welfare. Assuming that the optimisation problem has a unique interior

¹¹Clearly, this is not the full global first-best as it ignores among other things the welfare of the FDI source countries.

solution, the first-order condition for the first-best tax is given by expression (9), whereas the optimal choice of infrastructure is given by:

$$W_x + W_x^* = 0 \tag{15}$$

where $W_x = \tau B_x - \Omega'$ and $W_x^* = \tau B_x^*$. The following proposition does not rely

on special functional forms.

Proposition 5 *The cooperative tax outcome coincides with the first-best joint optimum only when $\lambda = 0$.*

Proof. At $\lambda = 0$, $W_x^* = 0$, which implies that expression (15) is reduced to $W_x = 0$. In addition, the first-order condition for the first-best tax is given by expression (9). Hence, at $\lambda = 0$, both first-order conditions for the first best are identical to those for the case with tax cooperation alone ■

At the first-best, unlike at the cooperative harmonised tax equilibrium, each region's public infrastructural investment is chosen taking full account of the external effect on the other region's welfare. Hence, tax cooperation alone will not yield the first-best outcome when regional public infrastructure investment generates cross-regional externalities.

5.2 Tax competition versus tax cooperation

After having demonstrated that tax cooperation alone typically does not yield the first-best outcome, we now show that tax cooperation may even yield a lower welfare level than tax competition when regional public infrastructure investment generate externalities for the other potential host region. Since a welfare comparison between tax cooperation and tax competition requires specific functional forms, we use the LQ version of our model.

In Figures 2a-c, we again depict the first-order conditions for infrastructure and taxes in symmetric (x, t) -space; these are now not only shown for tax competition $(x^N(t)$ and $t(x))$ and for tax cooperation $(x^C(\tau)$ and $\tau(x))$, but also for the first-best $(x^O(\tau)$ and $\tau(x))$, where the first-best outcome is represented by point O. In Figure 2a, there is no externality from public infrastructure investment ($\lambda = 0$). In that case—as shown by Proposition 5—, tax cooperation actually yields the first-best outcome and hence the first-best welfare level, whereas tax competition clearly attains a lower welfare level (represented by the fact that it lies on the W^N -isowelfare contour, with $W^N < W^O$). When there is a spillover—positive or negative—, welfare under tax cooperation always falls below the first-best welfare level. Nevertheless, for positive externalities ($\lambda > 0$), tax cooperation always yields a higher welfare level than tax competition, which is illustrated in Figure 2b ($W^C > W^N$). However, this is not always the case when the externality is negative ($\lambda < 0$). Why is this so? With tax cooperation equilibrium tax rates are higher than with tax competition. This

implies that levels of public infrastructure investment are higher with tax cooperation than with competition. However, with each jurisdiction investing in public infrastructure that is harmful to the other host jurisdiction, the externality will lower welfare in each jurisdiction. Furthermore, when investment in public infrastructure is relatively effective (i.e., when η is high), investment under tax cooperation will be a lot higher than with tax competition, thereby magnifying the negative welfare effect of public infrastructure investment on each jurisdiction.

[Insert Figure 2 about here]

Next, we consecutively calculate welfare levels under tax competition and tax cooperation in order to determine the conditions under which welfare under tax competition is higher than under tax cooperation.

Under tax competition, the first-order condition for welfare maximisation $W_t = B + tB_t = 0$ implies $B = -tB_t = \beta t^N$. Also, since $W_x = t\gamma - \omega x$, $W_{t^*} = t\beta\varepsilon$ and $dt^*/dx = (2\lambda + \varepsilon)\gamma$ in expression (6), we can write $x^N = (\eta/\gamma)[1 + 2\varepsilon\frac{(\lambda - \bar{\lambda})}{4 - \varepsilon^2}]t^N$, where $\eta \equiv \gamma^2/\omega$ is a measure of the relative effectiveness of public infrastructure investment. Hence, each region's welfare level under tax competition is given by:

$$W^N = \beta[1 - \frac{\eta}{2\beta}(1 + 2\varepsilon\frac{(\lambda - \bar{\lambda})}{4 - \varepsilon^2})^2](t^N)^2 = W^{*N} \quad (16)$$

$$\text{with } t^N = t^{*N} = \frac{\alpha}{\beta(2 - \varepsilon) - \eta(1 + \lambda)(1 + 2\varepsilon\frac{\lambda - \bar{\lambda}}{4 - \varepsilon^2})}.$$

With tax cooperation and symmetric jurisdictions, expression (9) implies $2W_\tau = 0$, hence $B = -\tau B_\tau = \beta(1 - \varepsilon)\tau$. Furthermore, $W_x = \tau\gamma - \omega x$ and $d\tau/dx = (1 + \lambda)\gamma/[4\beta(1 - \varepsilon)]$ from expression (10). Hence, welfare in each jurisdiction under tax cooperation is equal to:

$$W^C = \beta[(1 - \varepsilon) - \frac{\eta}{2\beta}]\tau^2 = W^{*C} \quad (17)$$

with $\tau = \alpha/[2\beta(1 - \varepsilon) - \eta(1 + \lambda)]$.

Even in the LQ case, the welfare expressions (expressions 16 and 17) are not easy to compare. It is helpful to illustrate the welfare comparison diagrammatically. We use two figures to do this. Figure 3a depicts welfare under tax competition and tax cooperation (as well as in the first best) as functions of λ . In the diagram, when λ is sufficiently negative, welfare under tax competition is higher than under tax cooperation. Obviously, this diagram is drawn for specific parameter values. While it is true that when externalities from public infrastructure are positive, tax cooperation always yields higher welfare than tax competition, tax cooperation does not necessarily give lower welfare than tax competition when externalities are negative. In fact, it is also necessary that, at the same time as the externality being negative, the relative effectiveness

of public infrastructure (η) is high. Figure 3b demonstrates this by showing welfare under the three regimes (tax competition, tax cooperation and the first best) as a function of η ; note that in this figure $\lambda < 0$). At the threshold $\tilde{\eta}$, welfare under tax competition and cooperation are equal. For low levels of η ($\eta < \tilde{\eta}$), tax cooperation generates higher welfare than tax competition. However, for η -levels beyond $\tilde{\eta}$ ($\eta > \tilde{\eta}$), the welfare level attained under tax competition is higher than under tax cooperation.

Proposition 6 *In the LQ-case, there exists a critical η -threshold, $\tilde{\eta}(\lambda)$, with (i) $W^C(\tilde{\eta}) = W^N(\tilde{\eta})$ and (ii) $d\tilde{\eta}/d\lambda > 0$.*

Proof See Appendix.

[Insert Figure 3 about here]

6 Extensions

In this section we look briefly at some extensions of our basic model. We consider, in turn, a modified welfare function that includes non-tax benefits of FDI, regional asymmetries, and another form of tax harmonisation, i.e., a minimum tax.

6.1 Non-tax revenue benefits of inward FDI and public infrastructure

To keep the analysis simple, we have assumed so far that the only benefit of public infrastructure is that it enhances the multinational profit tax base. However, public infrastructure clearly has many different direct social and economic benefits. So does inward FDI: it also may generate benefits in addition to increasing the multinational tax base, such as providing technological spillovers to domestic firms. Furthermore, there may be beneficial interaction effects between public infrastructure and FDI; for instance, a more developed public infrastructure may allow a country to benefit to a greater extent from any spillovers from inward FDI. In this subsection we will extend our analysis to take account of these additional benefits. We will represent these additional benefits to Home and Foreign by g and g^* , respectively, and assume that g is increasing in both Home infrastructure, x , and inward FDI, denoted by k . Furthermore, as argued earlier, inward FDI is decreasing in t and increasing in t^* and x .

The volume of FDI may also depend on x^* , though as discussed earlier, the sign is ambiguous. Taking all these effects into account we can write the non-tax benefits of inward FDI and public infrastructure in compact form as $G(t, t^*, x, x^*) = g[k(t, t^*, x, x^*), x]$ and $G^*(t, t^*, x, x^*) = g^*[k(t, t^*, x, x^*), x]$ for Home and Foreign respectively. The partial derivatives of $G(t, t^*, x, x^*)$ are $G_t < 0$, $G_{t^*} > 0$, $G_x > 0$ and G_{x^*} ambiguous where here and henceforth we use

subscripts to indicate partial derivatives. The partial derivatives of $G^*(t, t^*, x, x^*)$ are analogous. Home and Foreign welfare can now be written as:

$$W(t, t^*, x, x^*) = tB(t, t^*, x, x^*) + G(t, t^*, x, x^*) - \Omega(x) \quad (18a)$$

and

$$W^*(t, t^*, x, x^*) = t^*B^*(t, t^*, x, x^*) + G^*(t, t^*, x, x^*) - \Omega^*(x^*) \quad (18b)$$

Compared to the case without G and G^* , it remains the case that welfare can be written as a function of the taxes and infrastructure in the two countries. So, apart from complicating the analysis, what difference does the inclusion of G and G^* make? First, additional benefits to FDI clearly work towards reducing the optimal corporate tax rates. The first-order condition for the Home tax is now $tB_t + B + G_t = 0$. Hence, the optimal tax can be written as $t = -(B/B_t) - (G_t/B_t)$ where the new second term on the right-hand side is negative and works towards a lower tax.

Second, there is a more subtle effect on the strategic incentive to invest in public infrastructure. When additional benefits of FDI and public infrastructure are taken into account, investment in infrastructure could in some cases shift a region's tax reaction function inwards rather than outwards. Since taxes are strategic complements such an inward shift in the reaction function will typically lead to both taxes falling. If the presence of G and G^* does have this effect, it will change the strategic incentive to invest in infrastructure. As we saw earlier, the impact on H's reaction function of an increase is captured by $\psi_x = -W_{tx}/W_{tt}$ with $W_{tt} < 0$. Hence the sign of ψ_x depends on that of $W_{tx} = B_x + tB_{tx} + G_{tx}$. Without G_{tx} , this is positive and it will remain so provided G_{tx} is not too negative. In that case, our analysis of the strategic effect of public infrastructure is qualitatively unaffected.

However, Assumption 3 does not guarantee that $W_{tx} = B_x + tB_{tx} + G_{tx}$ is positive and a negative effect G_{tx} works towards ψ_x being negative. When would G_{tx} be negative? Suppose public infrastructure increases the marginal return to FDI. For instance, a country with a more developed education system may have a greater capacity to absorb and make productive use of spillovers from foreign multinationals. Algebraically, in the case of the Home country, this can be captured by $g_{kx} > 0$. Such an "absorptive capacity" effect works towards G_{tx} and ψ_x being negative. To see this as clearly as possible, consider the case in which infrastructure only affects $g(k, x)$ directly but does not directly affect the level of FDI so that $k(t, t^*)$ is independent of x . In this case, $G_{tx} = g_{kx}k_t$. Then, G_{tx} has the opposite sign to g_{kx} . Intuitively, if public infrastructure increases the marginal return to FDI then it is more likely that a higher x leads a country to set a lower corporate tax to encourage now more beneficial FDI. If this is the case, then $\psi_x < 0$ and, since taxes are strategic complements, an increase in Home infrastructure works towards a reduction in both taxes, provided ψ_x^* is not too positive.

6.2 Asymmetric regions

So far, we assumed the regions involved are symmetric. In this subsection we discuss the effects of tax cooperation when regions are asymmetric. Again, as a welfare comparison between tax cooperation and tax competition requires specific functional forms, we use the LQ version of our model.

The multinational tax base functions for Home and Foreign are respectively given by expression (3a) and by:

$$B^* = \alpha^* - \beta(t^* - \varepsilon t) + \gamma(x^* + \lambda x) \quad (19)$$

Thus, we introduce regional asymmetry in the most straightforward way, i.e., by assuming that one of the regions, Home, has, *ceteris paribus*, a higher multinational tax base than Foreign, which is captured by $\alpha > \alpha^*$. The reasons why this might be the case could be varied and have a historical, geographical, cultural or even a linguistic basis. Henceforth, we will refer to Home as the "naturally more attractive" region for short. In the equilibrium with tax competition, Home will now charge a higher tax rate than Foreign, while also investing more in public infrastructure. When the regions cooperate and set a common tax rate, τ , the expression for Foreign's multinational tax base is given by:

$$B^* = \alpha^* - \beta(1 - \varepsilon)\tau + \gamma(x^* + \lambda x) \quad (20)$$

while Home's tax base is given by expression (8). The common (harmonised) tax rate is chosen to maximise the sum of Home and Foreign welfare, $W + W^*$. However, the first-order condition for the jointly optimal tax rate, $W_\tau + W_\tau^* = 0$, now implies $W_\tau = -W_\tau^*$, implying that the strategic term in expressions (11) and the strategic term in the analogous expression for Foreign will have opposite signs. This, in turn, means that, if one region strategically over-invests relative to the non-strategic hypothetical benchmark, then the other one strategically under-invests. In fact, Home, the "naturally more attractive" region will over-invest in public infrastructure, thus attempting to drive up the tax rate, whereas Foreign will under-invest, thereby attempting to keep the common tax rate low.

We now discuss the welfare effects of tax cooperation, using a diagrammatic approach. (The derivations have been relegated to Appendix B.) Figure 4 shows welfare for each country as a function of λ , where the dashed curves indicate welfare under tax competition and the solid curves represent welfare with tax cooperation (with the starred ones representing Foreign welfare). The level of η is chosen such that the point at which $W^N = W^C$ and the point at which $W^{*N} = W^{*C}$ can both be depicted in the diagram. Clearly, welfare is always higher in Home, i.e., the country that is "naturally more attractive" for FDI; so, $W^N > W^{*N}$ and $W^C > W^{*C}$. Like with symmetric regions, whether a region gains or loses from tax cooperation depends on the relative effectiveness of public infrastructure investment and on the level of the spillover. When the spillover parameter is high ($\lambda > \tilde{\lambda}^*$ in Figure 4, with $W^{*C}(\tilde{\lambda}^*) = W^{*N}(\tilde{\lambda}^*)$), both regions gain from tax cooperation and will agree to harmonise taxes. However,

when spillovers are sufficiently negative ($\lambda < \tilde{\lambda}$ in Figure 4 with $W^C(\tilde{\lambda}) = W^N(\tilde{\lambda})$), tax cooperation harms both regions and there will be no incentive to set taxes cooperatively. For intermediate spillover levels ($\tilde{\lambda}^* < \lambda < \tilde{\lambda}$ in Figure 4), the "naturally more attractive" region (Home) prefers tax cooperation to tax competition, while the opposite is true for the "naturally less attractive" region. This may even occur for small positive values of λ . In that case, regions may wish to bargain over side-payments to make tax cooperation sustainable.

[Insert Figure 4 about here]

6.3 Other forms of tax harmonisation

We now consider an alternative form of tax harmonisation. Suppose regional taxes are constrained not to fall below a minimum tax, \underline{t} . Given \underline{t} , the jurisdictions play a non-cooperative two-stage game, setting infrastructure in stage one and taxes in stage two. We discuss the effect of the minimum tax on public infrastructure investment, using Figure 5. In Figure 5, t^N and t^{*N} represent equilibrium tax rates when governments choose infrastructural investment levels strategically.

When the minimum tax is sufficiently low, i.e., $\underline{t} < t^N$, it will have no effect. Each region still has an incentive to push the tax rate beyond the legal minimum and hence do so by choosing public infrastructure investment strategically. Equilibrium taxes remain t^N and t^{*N} and investment levels in public infrastructure are the same as in the situation before the minimum tax rate was imposed. This case is depicted in Figure 5a.

However, when the minimum tax rate is higher than the strategically chosen tax rate in the symmetric equilibrium ($\underline{t} > t^N$), the equilibrium tax rate in each region is \underline{t} . Figure 5b represents this case. There is no longer any need to choose public infrastructure investment levels strategically as the legally imposed minimum tax rate effectively pushes the tax rates beyond the level that would prevail when governments are unconstrained in choosing taxes. This implies that when public infrastructure has positive (or not too negative) interregional spillovers (i.e., $\lambda > \bar{\lambda}$), a minimum tax can, if effective, be expected to curtail investment in public infrastructure (since governments strategically "over-invest" when unconstrained). However, one can expect a minimum tax again, if effective, to increase investment in public infrastructure when the latter has sufficiently negative interregional spillovers ($\lambda < \bar{\lambda}$) or when public infrastructure purely enhances the regional benefits of FDI.

[Insert Figure 5 about here]

7 Conclusion

A country's ability to attract inward FDI and the profitability of that investment depends, among other things, on corporate tax rates and on the level and quality

of local public infrastructure. Since a potential host country can attract more multinational firms by increasing its investment in public infrastructure, the multinational firm component of its tax base thus depends in part on the level of local public infrastructure. What is more, public infrastructural investment in one country can also affect the tax base of a competing host country, and may do so either positively or negatively.

To study these issues we have constructed a two-country model of corporate tax competition for inward FDI, in which governments also invest in public infrastructure. When the externality generated by one country's investment in public infrastructure is positive or not too negative, then governments strategically increase their investment in infrastructure in order to raise the rival host country's corporate tax rate. This softens tax competition and therefore benefits the investing host country indirectly. However, if the externality is very negative so that infrastructure in one country strongly reduces the rival host country's tax base through the business stealing effect, then the strategic effect of public infrastructure is negative and the investing country has an incentive to lower its public infrastructure investment.

The external effect of public infrastructure on the other country also affects the gains from tax harmonisation. Although tax cooperation often raises the welfare of countries, we have found that this is not always the case. In fact, when infrastructure is sufficiently cost effective in raising a country's own tax base but at the same time generates a sufficiently large negative interregional externality, then tax cooperation, without infrastructure coordination, actually reduces welfare.

The reason for this lies in the fact that, although resulting in higher equilibrium taxes and hence avoiding a race to the bottom in tax rates, tax cooperation also leads to higher investment in public infrastructure. When countries coordinate taxes but not infrastructure, they ignore the business stealing negative externality that their infrastructure imposes on other countries and they engage in excessive (mutually damaging) investment. When this effect is strong enough, tax cooperation results in lower welfare levels than tax competition.

Our results are cautionary as they imply that policy makers may inadvertently make matters worse by signing up to tax harmonisation programmes that involve cooperation in taxes without consideration of regional public infrastructure investment schemes. Thus, those assessing tax harmonisation initiatives at both the national level –in federal states– and at the supranational level –such as the EU– should take into account the effects on regional public infrastructure investment. Since our model has identified negative externalities in infrastructure as a potential reason for welfare losses from tax harmonisation, more empirical work in this area would help to guide policymakers.

8 Appendices

8.1 Appendix A

Proof of Proposition 1:

Under non-cooperative tax setting an increase in public investment increases the optimal tax in the investing country. Here we will examine the the case of the home country.

From $\frac{dt}{dx} = \frac{W_{t^*x}^* W_{tt^*} - W_{t^*t^*}^* W_{tx}}{\Delta}$ we know that the sign depends on that of

the numerator since $\Delta > 0$ from Assumption 2. To determine the sign of the numerator not that the derivative $W_{t^*t^*}^*$ negative from the foreign second-order condition for foreign country, the derivative W_{tt^*} is positive from Assumption 1 and W_{tx} is positive from Assumption 3. Hence $\frac{dt}{dx}$ is guaranteed to be positive

if $W_{t^*x}^* \geq 0$, so we will focus on the case in which $W_{t^*x}^* < 0$. When $W_{t^*x}^* < 0$, Assumption 4 which states that $|\psi_x| \geq |\psi_x^*|$ implies $-W_{tx}/W_{tt} \geq W_{t^*x}^*/W_{t^*t^*}^*$ and so $W_{tx} \geq -W_{tt} \frac{W_{t^*x}^*}{W_{t^*t^*}^*} > 0$. Hence the numerator $-W_{t^*t^*}^* W_{tx} + W_{t^*x}^* W_{tt^*}$ is at least as large as $W_{tt} \left(\frac{W_{t^*x}^*}{W_{t^*t^*}^*} \right) W_{t^*t^*}^* + W_{t^*x}^* W_{tt^*} = W_{t^*x}^* (W_{tt} + W_{tt^*}) > 0$ from Assumption 2. Hence we can conclude that $\frac{dt}{dx} = \frac{W_{t^*x}^* W_{tt^*} - W_{t^*t^*}^* W_{tx}}{\Delta} > 0$.

Analogous derivations can be used to show $\frac{dt^*}{dx^*} > 0$.

Proof of Proposition 6

The threshold $\tilde{\eta}$ is defined by $W^N(\tilde{\eta}) = W^C(\tilde{\eta})$. Using expressions (16) and (17), we obtain the following quadratic function in $\tilde{\eta}$:

$$A\tilde{\eta}^2 + Z\tilde{\eta} + E = 0 \quad (\text{A.1})$$

with $A \equiv -2(1+\lambda)[(1-\varepsilon)(1-\lambda)S^2 - (2-\varepsilon)S + (1+\lambda)]$, $Z \equiv 4(1-\varepsilon)^2 S^2 + 4(1-\varepsilon)(1+\lambda)[2 - (2-\varepsilon)S] - (2-\varepsilon)^2$, $E \equiv 2(1-\varepsilon)\varepsilon^2$ and $S \equiv 1 + 2\varepsilon \frac{\lambda - \bar{\lambda}}{4 - \varepsilon^2}$. Solving expression (A.1) for $\tilde{\eta}$, selecting the relevant root, yields $\tilde{\eta} = -\frac{Z + \sqrt{Z^2 - 4AE}}{2A} > 0$.

8.2 Appendix B

We define $\mu \equiv \alpha^*/\alpha$, hence $\mu < 1$. In stage two, equilibrium tax rates with tax competition are given by

$$t^N = [(2 + \varepsilon\mu)\alpha + \gamma((2 + \varepsilon\lambda)x + (2\lambda + \varepsilon)x^*)]/[\beta(4 - \varepsilon^2)] \quad (\text{B.1a})$$

for Home and by

$$t^{*N} = [(2\mu + \varepsilon)\alpha + \gamma((2 + \varepsilon\lambda)x^* + (2\lambda + \varepsilon)x)]/[\beta(4 - \varepsilon^2)] \quad (\text{B.1b})$$

for Foreign. Home and Foreign's public infrastructure best response functions are:

$$x = 2\gamma(2 + \varepsilon\lambda)[(2 + \mu\varepsilon)\alpha + 2(\lambda - \bar{\lambda})\gamma x^*]/H \quad (\text{B.2a})$$

and

$$x^* = 2\gamma(2 + \varepsilon\lambda)[(2\mu + \varepsilon)\alpha + 2(\lambda - \bar{\lambda})\gamma x]/H \quad (\text{B.2b})$$

respectively, with $H \equiv \beta\omega\Delta^2 - 2\gamma^2(2 + \varepsilon\lambda)^2$ and $H > 0$ from the second-order conditions. Hence, Home and Foreign equilibrium investment levels in public infrastructure are respectively given by:

$$x^N = [2\gamma(2 + \varepsilon\lambda)\alpha(H(2 + \varepsilon\mu) + J(2\mu + \varepsilon))]/\nabla^N \quad (\text{B.3a})$$

and

$$x^{*N} = [2\gamma(2 + \varepsilon\lambda)\alpha(H(2\mu + \varepsilon) + J(2 + \mu\varepsilon))]/\nabla^N \quad (\text{B.3b})$$

with $J \equiv 4\gamma^2(2 + \varepsilon\lambda)(\lambda - \bar{\lambda})$ and $\nabla^N \equiv H^2 - J^2$.

Under tax cooperation, the common tax rate set cooperatively by the regions is:

$$\tau = \frac{\alpha(1 + \mu) + \gamma(1 + \lambda)(x + x^*)}{4\beta(1 - \varepsilon)} \quad (\text{B.4})$$

where equilibrium levels of x and x^* are given by:

$$x^C = \frac{\alpha\gamma}{\nabla^C} [(3 + \lambda)(K + \mu L) + (1 - \lambda)(\mu K + L)] \quad (\text{B.5a})$$

and

$$x^{*C} = \frac{\alpha\gamma}{\nabla^C} [(3 + \lambda)(\mu K + L) + (1 - \lambda)(K + \mu L)] \quad (\text{B.5b})$$

with $K \equiv 8\beta\omega(1 - \varepsilon) - \gamma^2(1 + \lambda)(3 - \lambda)$, $L \equiv \gamma^2(1 + \lambda)^2$ and $\nabla^C \equiv K^2 - L^2 > 0$. With $K > L$ (to guarantee stability) and $\mu < 1$, we indeed have $x^C > x^{*C}$. Furthermore, we know that from expression (11) that Home over-invests in public infrastructure –relative to the hypothetical non-strategic benchmark– when $W_\tau = B - \beta(1 - \varepsilon)\tau > 0$. Using expression (B.4), this condition can, after some rearranging, be rewritten as $(1 - \lambda)\gamma x > +\lambda x^* > -\alpha(1 - \mu) + (1 - \lambda)\gamma x^*$. Since $\mu < 1$ and $x^C > x^{*C}$, this condition is met; hence, Home strategically over-invests in public infrastructure, whereas Foreign strategically under-invests.

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Figure 1: Symmetric first-order conditions under tax competition and tax cooperation

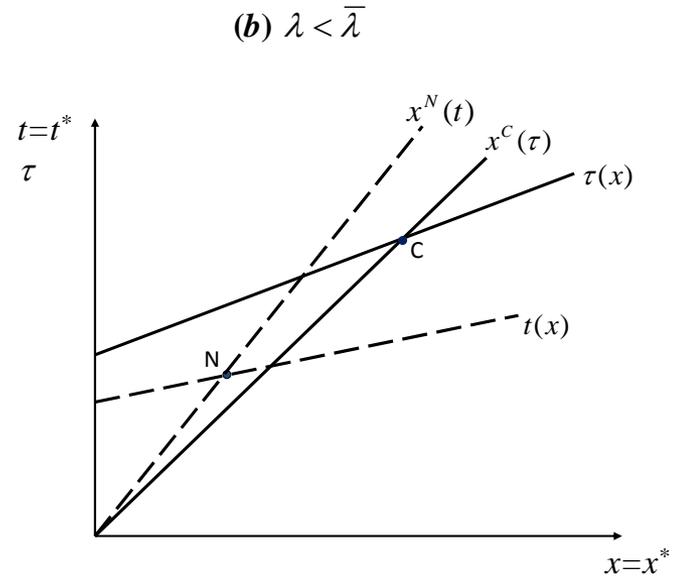
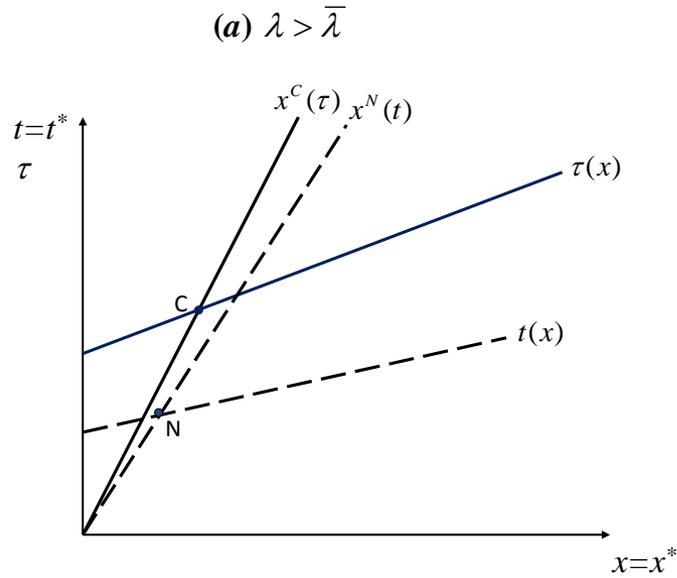
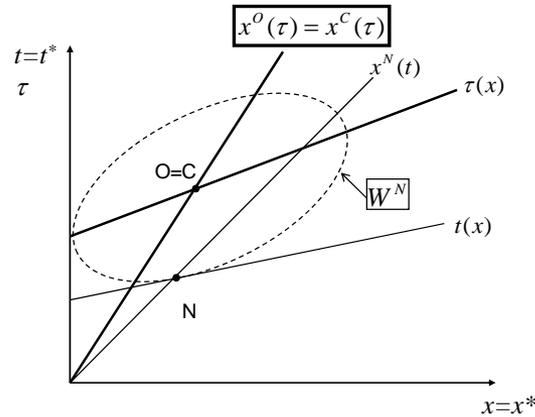
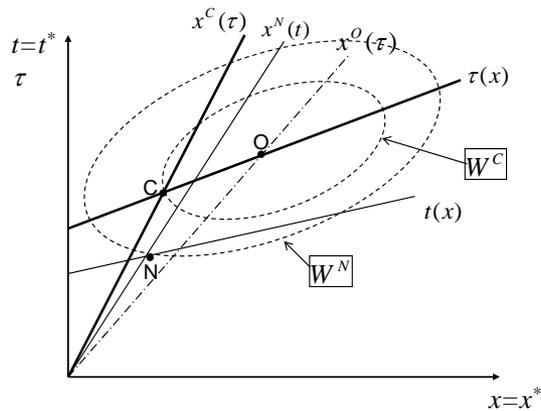


Figure 2: Tax rates and public infrastructure investment levels under symmetry – Tax competition vs. cooperation

(a) $\lambda = 0$



(b) $\lambda > 0$



(c) $\lambda < 0$

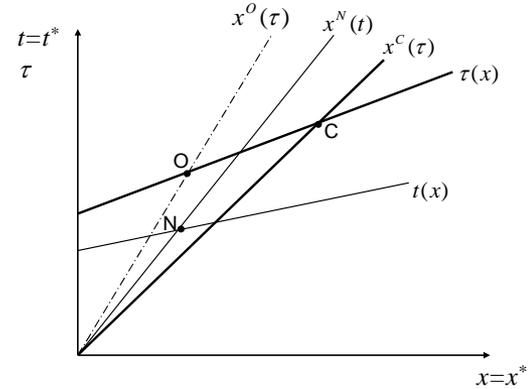
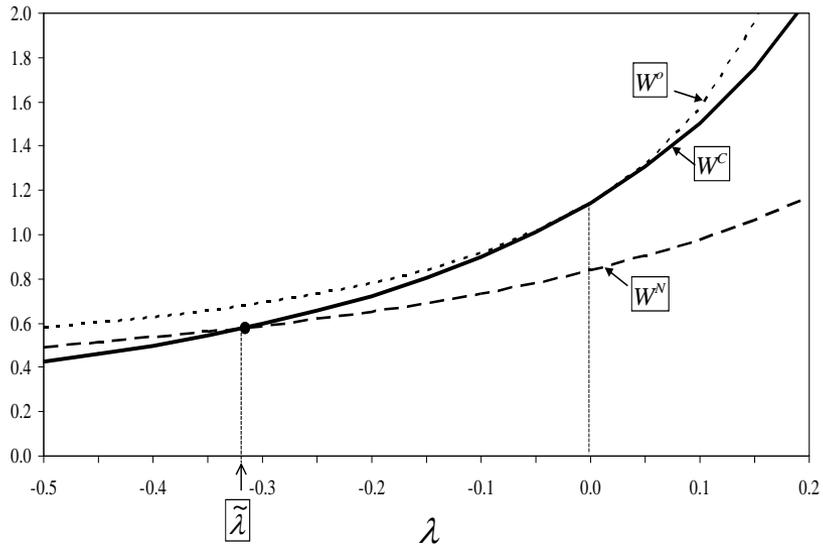


Figure 3: Welfare under tax competition and tax cooperation

(a) Welfare and externalities from public infrastructure



(b) Welfare and relative effectiveness of public infrastructure

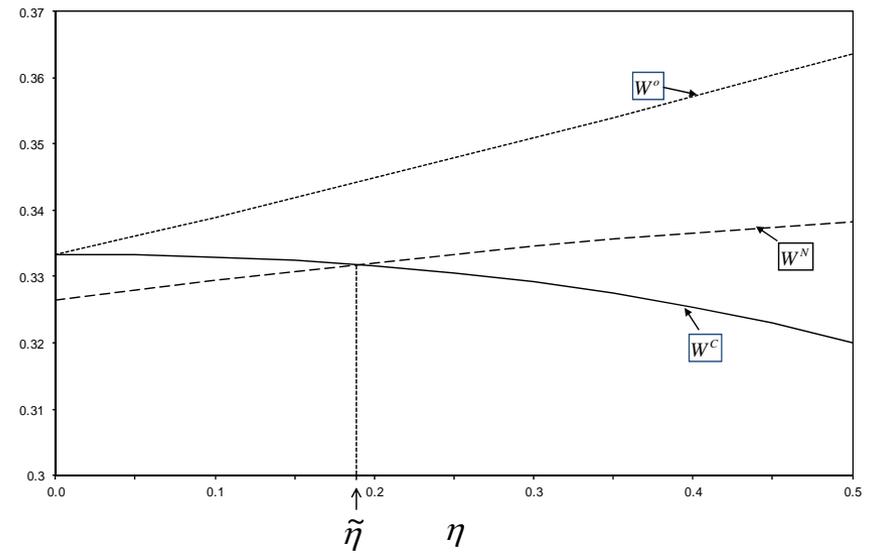


Figure 4: Welfare under tax competition and tax cooperation
– Asymmetric jurisdictions

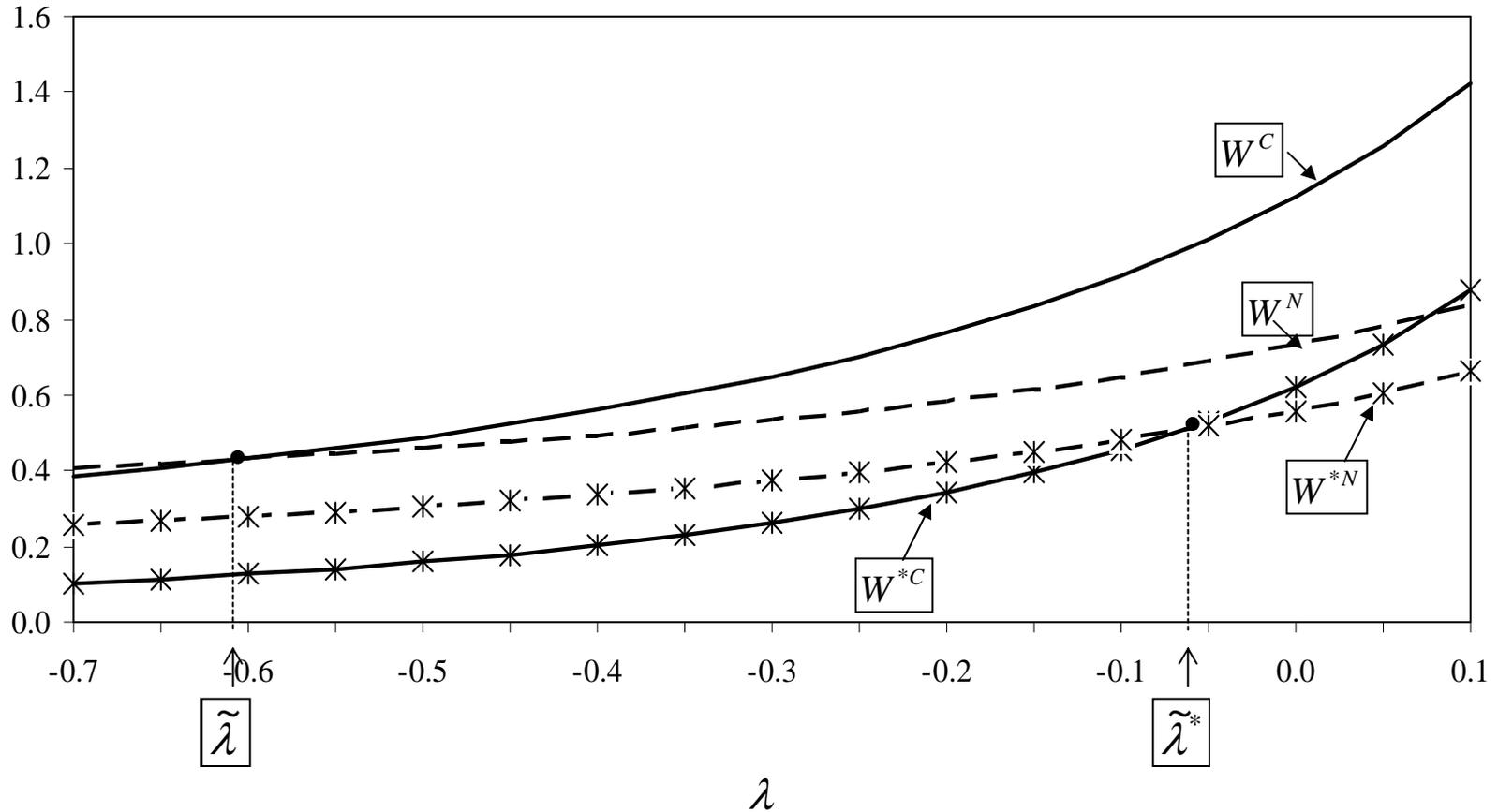


Figure 5: The effect of tax harmonisation – A minimum tax

