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Partial tax harmonization through infrastructure coordination

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Abstract

In this article we analyze the role that infrastructure coordination plays to in achieving partial tax harmonization in a coalition of asymmetric jurisdictions. We find that infrastructure coordination with different investment levels can facilitate partial tax harmonization between asymmetric jurisdictions when asymmetries are not too large. Furthermore, agreeing on a common investment level can be even more effective in facilitating partial tax harmonization between asymmetric jurisdictions. Our results explain the harmonization of corporate tax rates observed in the EU between 1995 and 2006 where there was simultaneous convergence of public infrastructure investments facilitated via EU structural funds.

Keywords: Partial Tax Harmonization; Infrastructure Coordination

JEL Classification Numbers: F15, F38, H20, H87

1 Introduction

Since the 1980s processes of economic integration have increased the international mobility of capital to an extent never observed before. This has led governments to engage in fiscal competition in order to attract more capital and to maintain investment levels. As a result, we have observed an ongoing reduction of tax rates on corporate income to inefficiently low levels (Zodrow and Mieszkowski, 1986; Wilson, 1986; Bucovetsky and Wilson, 1991). A major concern that this process has raised in developed countries is that tax competition has caused a transfer of the tax burden from capital towards labor. For example, the European Commission stated in 1996 that the implicit average tax on capital had decreased from 44% to 35% at the expense of an increase in the implicit tax on labor from 34% to 40.5% in European Union (EU) member countries from 1980 to 1994

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(European Commission, 1996). As a response to inefficiently low capital tax competition several authors have advocated the coordination of tax rates (Bucovetsky, 1991; Kanbur and Keen, 1993; Fuest and Huber, 2001; Devereux and Fuest, 2010; Keen and Konrad, 2012). Although it is generally recognized that the global harmonization of capital taxes is almost impossible to achieve, recent research has nevertheless paid increasing attention to the conditions that would allow for partial tax harmonization between a coalition of countries (Burbidge et al, 1997; Konrad and Schjelderup, 1999; Beaudry et al, 2000; Brøchner et al, 2007; Conconi et al, 2008; Bucovetsky, 2009; Bettendorf et al, 2010; Vrijburg and de Mooij, 2010; Eichner and Pething, 2013).[1] This is especially the case in the EU where different proposals for the coordination of capital taxation have been made.[2] Indeed, in Figure 1 we observe that corporate taxation in the EU, while following the global tendency of declining tax rates, experienced a convergence of tax rates during the period 1995 to 2006 between high and middle income countries to around 30%. After the 2003 enlargement of the EU, we have yet to observe a further convergence of corporate taxation between low income countries on the one hand and high and middle income countries on the other hand. The results in the literature hardly explain this harmonization of capital taxation during the 1995-2006 period because the different productivity levels between EU countries render (partial) tax harmonization more difficult (Keen and Konrad, 2012). Interestingly, if we take a look at the per capita investment in infrastructure in EU member countries in the same period, as displayed in Figure 2, we observe that the period of convergence of tax rates between high and middle income countries is accompanied by a more intensive increase in the middle income countries which surpassed per capita infrastructure investment in high income countries in 2001. It should be noticed that this convergence of infrastructure investments is not accidental but is directed by the EU as a major part of public infrastructure investments financed via EU structural funds that amounted to a total of 100.5 billion euro during the period 2000-2006. Thus, in Figure 3 we observe that in middle and low income countries a substantial number of total infrastructure investments were financed by the EU. For example, in Greece more than 70% of infrastructure investments were financed by the EU.

In this article we analyze the role that infrastructure coordination has played in achieving fiscal harmonization between a coalition of asymmetric countries. For this purpose, we use the tax competition model developed by Zodrow and Mieszkowski (1986) and Wilson (1986) in which, as in Konrad and Schjelderup (1999), we allow a subset of jurisdictions to form a tax coalition. We modify the framework of Konrad and Schjelderup (1999) by allowing for asymmetries in productivity levels between jurisdictions and by assuming that governments make infrastructure investments that enhance the productivity of private firms. In our three jurisdiction model, jurisdictions differ in their productivity levels. Jurisdictions 1 and 2 decide whether to form a coalition in which commitments

[1] Keuschnigg et al. (2014) define tax coordination and harmonization in the EU as follows: "*tax coordination refers to a cooperative tax setting, where countries or a group of them build on domestic tax systems to render them compatible with the aims of the Union as formulated the Treaty on the European Union. Consequently, countries deliberately give up parts of their autonomy in tax matters*". Moreover, "*harmonization is viewed as tighter coordination, leading to almost identical or at least similar tax systems, tax bases and tax rates within a Union*".

[2] See Dankó (2012) for further information about the proposals for corporate tax harmonization.

are credible. We analyze a three stage game. In stage 1, jurisdictions 1 and 2 decide whether to coordinate tax rates and infrastructure investments. Once a decision is taken, the levels of infrastructure investments are decided in stage 2. Finally, in stage 3, for a given level of infrastructure the tax rates are chosen. All decisions at each stage are taken simultaneously by all jurisdictions (and the tax coalition). Once the stage 2 subgames are solved, our analysis leads to the comparison of the following cases: 1) No coordination, 2) partial tax harmonization without infrastructure coordination; 3) partial tax harmonization with infrastructure coordination where we distinguish between: a) infrastructure coordination with different investment levels, and b) infrastructure coordination with a common investment level. The main findings of our analysis are that, first, partial tax harmonization is welfare enhancing if jurisdictions are not too different in their productivity levels. Second, infrastructure coordination with different investment levels can facilitate partial tax harmonization between asymmetric jurisdictions. Third, while infrastructure coordination with a common investment level uses fewer instruments than in the former case, it can be even more effective in facilitating partial tax harmonization between asymmetric jurisdictions. We believe that especially this last result can give an explanation for the convergence of corporate tax rates observed in the EU in the decade before the economic crisis in 2008.

Our analysis is related to several studies. The general model of tax competition was developed by Zodrow and Mieszkowski (1986) and Wilson (1986) and has shown that the Nash equilibrium capital tax rates chosen by each jurisdiction are not socially optimal.[3] Asymmetries between jurisdictions that allowed them to differ in population size were first introduced by Bucovetsky (1991). He finds that these kinds of asymmetries exacerbate inefficiencies in capital taxation. As simultaneous tax coordination by all countries is unlikely to be established, the literature has focused on tax coordination of a subset of countries that might be able to create mechanisms or institutions that allow a credible commitment to maintaining jointly agreed tax rates. Konrad and Schjelderup (1999) have shown that such partial tax coordination can increase the welfare of the participating jurisdictions. This depends on the response of jurisdictions from outside the tax coalition and the relative size of the tax union. Thus, a necessary condition for a welfare enhancing effect is that tax rates are strategic complements and that jurisdictions are not too different. Brøchner et al. (2007) study partial tax coordination in the EU, using a general equilibrium model. Their conclusions suggest that corporate tax coordination would generate moderate welfare growth and that all schemes for coordination leave some EU member states as winners and others as losers, thus meaning that the elaboration of compensation mechanisms is required in order to maintain the coordination agreement. Conconi et al. (2008) analyze the three alternative scenarios of tax coordination (non-coordination, partial coordination, and harmonization) in a specific context of two distortions on capital taxation: tax competition (downward pressures) and time-consistent confiscatory taxation (upward pressures when governments have incentives to levy corporate taxes that are too high once capital is installed). They find that partial tax coordination benefits all jurisdictions if capital is sufficiently mobile, so it is more desirable and sustainable in such a situation when compared to harmonization or non-cooperative equilibrium. Vrijburg

[3]See Keen and Konrad (2012) for an overview on the literature regarding this matter.

and de Mooij (2010) generalize the analysis of Konrad and Schjelderup (1999), comparing welfare levels and equilibrium tax rates in the three alternative scenarios of tax coordination and asymmetric jurisdictions. They analyze the case in which the coalition acts as a leader so it foresees the strategic tax reaction by the last jurisdiction when deciding its own tax policy. Their analysis determines that the improvement of welfare in the coalition formation depends on the strategic complementarity of tax rates which is not fully guaranteed. Under partial tax coordination, if the union acts as leader, the coalition tends to increase tax rates more if tax rates are strategic complements. Coalitions between large countries are more likely than coalitions between small countries due to a larger common gain from internalized tax spillovers. Additionally, small jurisdictions are better off under no-coordination than under harmonization, so they would never agree to coordinate their taxes (although they prefer the partial tax coordination agreement over harmonization). A model in which governments do not choose only capital tax rates but also infrastructure investment levels has been developed by Keen and Marchand (1997). They show that simultaneous capital and infrastructure competition not only yields inefficiently low tax rates but also inefficiently high infrastructure investments. Becker and Fuest (2010) analyze the effects of infrastructure coordination using a model in which countries compete for the location of profitable firms. They find that the coordination of infrastructure investments between two countries can mitigate tax competition between these countries. While our model is based on the capital tax competition literature as opposed to the literature on interjurisdictional competition for profitable firms, the main differences between their and our model is that we focus on tax harmonization and allow for asymmetries between countries and, most importantly, policy responses of third countries. This last aspect is especially relevant if the results are to be used to analyze tax harmonization policies in the EU which, due to market globalization and increased international capital mobility, depend more and more on tax policies of countries outside the EU. Finally, Han (2013) analyzes how infrastructure investments affect partial tax harmonization between symmetric jurisdictions and finds it can harm both tax coalition members and nonmembers, which is in contrast to the classical result that partial tax harmonization is Pareto improving in such a case. The main difference from our paper is that infrastructure investments in his analysis are not subject to coordination between jurisdictions as he focuses exclusively on the coordination of tax rates.

The rest of the paper is organized as follows. Section 2 sets up the model. Section 3 focuses on the benchmarks without infrastructure coordination. Section 4 and Section 5 include the main results in which infrastructure coordination with different investment levels and with a common investment level is analyzed, respectively. Finally, Section 6 contains the conclusion. The proofs are in the Appendix.

2 The model

Consider the tax competition model developed by Zodrow and Mieszkowski (1986) and Wilson (1986) in which, as in Konrad and Schjelderup (1999), we allow a subset of jurisdictions to form a tax coalition. In this article their framework is modified by allowing for asymmetries in productivity between jurisdictions and by assuming that governments provide local public goods that enhance the productivity of private firms. To be precise, consider $N = 3$ jurisdictions, indexed by $i = 1, 2, 3$, each inhabited by an identical number of immobile residents with mass one who each supply one unit of labor. The total amount of capital is fixed and normalized to 1. The initial capital stock per worker in each jurisdiction is assumed to be symmetric, i.e., $\overline{k}_i = \frac{1}{3}$. Output is produced using capital and labor and the production function is written in intensive form, $f_i(k_i)$, with the standard assumptions of $f_i' > 0$, $f_i'' < 0$, where k_i denotes the capital per worker employed in jurisdiction i. Following the literature (Hindriks et al., 2008; Hauptmeier, 2012; Han, 2013; Eichner and Pething, 2013; among others), we assume a linear quadratic production function

$$f_i(k_i) = (\alpha + \epsilon_i + g_i) k_i - k_i^2, \quad i = 1, 2, 3, \tag{1}$$

where g_i is the level of infrastructure investment provided by the government in jurisdiction i at cost $c_i(g_i) = g_i^2/2$ and $\alpha > 0$. Eq. (1) implies that jurisdictions even with equal infrastructure investments differ in the level of their productivity levels. Without loss of generality we assume $\epsilon_1 = 0$. Furthermore, to guarantee nonnegative equilibrium values we restrict the analysis to $(\epsilon_2, \epsilon_3) \in R = \left\{\epsilon_2 \geq 0,\ \frac{1}{2}\epsilon_2 - \frac{19}{18} < \epsilon_3 < \frac{19}{9} - \frac{28}{5}\epsilon_2\right\}$.

Countries compete in choosing a unit per capital tax rate t_i to attract mobile capital from the rest of the world. Capital is mobile between jurisdictions such that the net return to capital, ρ, is determined by the following arbitrage condition:

$$\rho = f_i'(k_i) - t_i \qquad \text{for} \quad i = 1, 2, 3.$$

The arbitrage condition together with the market clearing condition ($\sum k_i = 1$) implies that the amount of capital invested in jurisdiction i is given by:

$$k_i = \frac{1}{3} + \frac{(2\epsilon_i - \epsilon_j - \epsilon_h) + (2g_i - g_j - g_h) - (2t_i - t_j - t_h)}{6}, \tag{2}$$

where $i, j, h = 1, 2, 3$; $j \neq i$; $h \neq i, j$.[4]

The tax rates in jurisdiction i are chosen by governments to maximize the welfare W_i of its residents:[5]

$$W_i = f_i(k_i) - f_i'(k_i) k_i + t_i k_i - g_i^2/2 = k_i^2 + t_i k_i - g_i^2/2, \tag{3}$$

where $f_i(k_i) - f_i'(k_i) k_i$ is labor income, and $t_i k_i$ are tax revenues used to finance public goods.

We assume that jurisdictions 1 and 2 will be able to credibly commit to a common tax rate and, therefore, are able to form a tax coalition. If it is beneficial for both jurisdictions to form a tax union, our assumptions imply that jurisdiction 2 is the more productive jurisdiction in the tax coalition, while the jurisdiction outside the tax coalition, jurisdiction 3, can be either more productive than both members of the tax coalition ($\epsilon_3 \geq \epsilon_2$), less productive than both jurisdictions ($\epsilon_3 < 0$), or more productive than jurisdiction 1 but less

[4] When not stated otherwise, we assume these conditions for all of our further expressions.

[5] For example, this corresponds to the assumption that tax rates are determined by the median voter and that the median voter has no capital endowment (see Borck, 2003).

productive than jurisdiction 2 ($0 \leq \epsilon_3 < \epsilon_2$). The timing of the game is as follows. First, in stage 1, jurisdictions 1 and 2 decide whether to coordinate tax rates and infrastructure investments. Once a decision is taken, infrastructure investments are decided in stage 2. Finally, in stage 3, for a given level of infrastructure, tax rates are chosen. All decisions at each stage are taken simultaneously by all jurisdictions (and the tax coalition).

3 No infrastructure coordination

3.1 No tax harmonization

First, consider the noncooperative game in which each jurisdiction chooses its infrastructure investment and capital tax rate separately. In stage 3, the rate t_i that maximizes welfare in Eq. (3) is:[6]

$$t_i = \frac{1}{4} + \frac{(2\epsilon_i - \epsilon_j - \epsilon_h) + (2g_i - g_j - g_h) + t_j + t_h}{8}. \tag{4}$$

From Eq. (4) we see that tax rates are strategic complements. Furthermore, the optimal tax rate is increasing in the jurisdiction's infrastructure investment and decreasing in the infrastructure investments of other jurisdictions. The stage 3 Nash-equilibrium tax rates are given by:

$$t_i = \frac{1}{3} + \frac{2\epsilon_i - \epsilon_j - \epsilon_h + 2g_i - g_j - g_h}{9} \tag{5}$$

where the condition $\partial t_i / \partial t_j < 1$ in Eq. (4) guarantees the stability of the equilibrium.

In stage 2, jurisdiction i chooses the optimal level of infrastructure g_i that maximizes welfare, which after substitution of the expressions in Eqs. (5) and (2) into (3) writes as:

$$W_i = 2\left(\frac{1}{3} + \frac{2\epsilon_i - \epsilon_h - \epsilon_j + 2g_i - g_j - g_h}{9}\right)^2 - \frac{g_i^2}{2}. \tag{6}$$

The best-response function of jurisdiction i is:[7]

$$g_i = \frac{8}{65}\left(3 + 2\epsilon_i - \epsilon_j - \epsilon_h - g_j - g_h\right) \tag{7}$$

which means that infrastructure investments are strategic substitutes. The stage 2 Nash-equilibrium infrastructure investments are given by:

$$g_i^N = \frac{8}{27} + \frac{8}{57}\left(2\epsilon_i - \epsilon_j - \epsilon_h\right). \tag{8}$$

Substituting Eq. (8) into Eq. (5) yields the equilibrium tax rates:

$$t_i^N = \frac{1}{3} + \frac{3}{19}\left(2\epsilon_i - \epsilon_j - \epsilon_h\right). \tag{9}$$

[6] Notice that from substitution of Eq.(2) in Eq.(3) we have that W_i is concave in t_i.

[7] Concavity of W_i is given as $\frac{\partial^2 W_i}{\partial g_i^2} = -\frac{65}{81} < 0$.

Using this expression we obtain for infrastructure investments $g_i^N = \frac{8}{9} t_i^N$ such that the welfare in jurisdiction i is:

$$W_i^N = \frac{130}{81} \left(t_i^N\right)^2 . \tag{10}$$

Regarding the tax rates and infrastructure investments in the different jurisdictions we obtain from Eqs. (8) and (9) that infrastructure investments and tax rates are higher in the more productive jurisdiction (i.e., $g_i^N > g_j^N$, $t_i^N > t_j^N$ iff $\epsilon_i > \epsilon_j$). From the literature we know that the Nash equilibrium outcome yields inefficiently low tax rates and an underprovision of public goods. Furthermore, when jurisdictions can choose their infrastructure investments freely, in the Nash equilibrium, infrastructure investments are too high (Keen and Marchand, 1997). We state this as a first result:

Lemma 1 *Under no coordination, in all jurisdictions, the Nash equilibrium tax rates and the provision of public goods are inefficiently low and infrastructure investments are inefficiently high.*

3.2 Partial tax harmonization

Now, following Konrad and Schjelderup (1999), consider that jurisdictions 1 and 2 form a coalition subgroup which jointly maximizes the welfare of this group (i.e., $W_1 + W_2$) to choose a common tax rate, t_c, on which both jurisdictions agree publicly and can credibly commit. Jurisdiction 3, simultaneously, determines its tax rate t_3. The level of infrastructure in stage 2 is decided separately by all jurisdictions. The stage 3 equilibrium tax rates are:

$$t_c = 1 + \frac{\epsilon_1 + \epsilon_2 - 2\epsilon_3 + g_1 + g_2 - 2g_3}{6}, \tag{11}$$

$$t_3 = \frac{1}{2} - \frac{\epsilon_1 + \epsilon_2 - 2\epsilon_3 + g_1 + g_2 - 2g_3}{12}. \tag{12}$$

In stage 2, as in the previous case, the three jurisdictions choose their infrastructure noncooperatively. The equilibrium infrastructure investments are given by:

$$g_i^T = \frac{23}{45} + \frac{43}{105}\epsilon_i - \frac{4}{21}\epsilon_j - \frac{23}{105}\epsilon_3,\ i,j = 1,2; i \neq j, \tag{13}$$

$$g_3^T = \frac{14}{45} - \frac{8}{105}\epsilon_1 - \frac{8}{105}\epsilon_2 + \frac{16}{105}\epsilon_3. \tag{14}$$

Substituting Eqs. (13) and (14) into Eqs. (11) and (12) yields the equilibrium tax rates:

$$t_c^T = \frac{16}{15} + \frac{8}{35}\left(\epsilon_1 + \epsilon_2 - 2\epsilon_3\right), \tag{15}$$

$$t_3^T = \frac{7}{15} - \frac{4}{35}\left(\epsilon_1 + \epsilon_2 - 2\epsilon_3\right). \tag{16}$$

Using these expressions and noting that $\epsilon_1 = 0$, equilibrium values of infrastructure can be written as $g_1^T = \frac{23}{48}t_c^T - \frac{3}{10}\epsilon_2$, $g_2^T = \frac{23}{48}t_c^T + \frac{3}{10}\epsilon_2$, and $g_3^T = \frac{2}{3}t_3^T$. Social welfare levels are:

$$W_i^T = \left(\frac{5}{4}t_c^T + \frac{(-1)^i 2}{5}\epsilon_2\right)\left(\frac{1}{4}t_c^T + \frac{(-1)^i 2}{5}\epsilon_2\right) - \frac{1}{2}\left(\frac{23}{48}t_c^T + \frac{(-1)^i 3}{10}\epsilon_2\right)^2, i = 1,2 \tag{17}$$

$$W_3^T = \frac{16}{9}\left(t_3^T\right)^2 . \tag{18}$$

Jurisdictions 1 and 2 will choose a common tax rate when both jurisdictions obtain a higher welfare, i.e., when $W_i^T > W_i^N$ for $i = 1, 2$. The following result shows when this is the case.

Lemma 2 *For given ϵ_3, $\exists(\epsilon_2, \epsilon_3) \in R$ partial tax harmonization takes place when the jurisdictions in the tax coalition are not too different, i.e., when ϵ_2 is small. The welfare gains from partial tax harmonization for jurisdiction 2 are larger than for jurisdiction 1.*

The result obtained in Lemma 2 allows R to be separated into two areas which are displayed in Figure 4A. Partial tax harmonization is beneficial for jurisdictions 1 and 2 if they are not too different in their efficiency levels (i.e., in Area T). If jurisdiction 2 is much more efficient than jurisdiction 1, partial tax harmonization is not beneficial for jurisdiction 1. This is even more the case when the jurisdiction outside the tax coalition is more productive (see Area N). Regarding the effect of partial tax harmonization, as expected, we find that the jurisdictions that form part of the tax coalition increase their tax rates ($t_c^T > t_i^N$ for $i = 1, 2$), while jurisdiction 3 increases (decreases) its tax rate when its productivity is low (high).[8] Accordingly, in Area T, while jurisdictions 1 and 2 gain from tax harmonization, the jurisdiction outside the tax coalition obtains higher (lower) welfare when its productivity is low (high).[9] Finally, while jurisdictions 1 and 2 increase their infrastructure investments after tax harmonization, jurisdiction 3 increases (decreases) its infrastructure investments when its productivity is low (high).[10] In light of the result in Lemma 1, this implies that while partial tax harmonization allows the inefficiencies in tax rates to be reduced it increases the inefficiencies in infrastructure investments which are now even higher than under no coordination.

4 Infrastructure coordination

4.1 No tax harmonization

As shown in Lemma 1, all jurisdictions would benefit from a joint reduction of infrastructure investments. To see if this will also be the case when a subgroup of them coordinate their infrastructure investments, consider that jurisdictions 1 and 2 coordinate their infrastructure investments in stage two by choosing g_1 and g_2 to maximize joint welfare. Jurisdiction 3, simultaneously, determines its own level of infrastructure. In stage 3, first, we consider that all jurisdictions choose their capital tax rate separately. Thus, the stage 3 Nash equilibrium tax rates are given by Eqs. (5). In stage 2, joint welfare maximization of jurisdictions 1 and 2 yields the following Nash equilibrium values:

$$g_i^I = \frac{76}{549} + \frac{4}{305}\left(33\epsilon_i - 28\epsilon_j - 5\epsilon_3\right), \; i, j = 1, 2; i \neq j, \tag{19}$$

$$g_3^I = \frac{184}{549} - \frac{8}{61}\left(\epsilon_1 + \epsilon_2 - 2\epsilon_3\right). \tag{20}$$

[8] To be precise, we have that $t_3^T > t_3^N$ for $\epsilon_3 < \frac{1}{2}\epsilon_2 + \frac{133}{87}$, and $t_3^T < t_3^N$ for $\epsilon_3 > \frac{1}{2}\epsilon_2 + \frac{133}{87}$.

[9] However, notice that the region in $\Re$ where $W_3^T < W_3^N$ is very small ($\epsilon_3 > \frac{1}{2}\epsilon_2 + 2.0980$). For example, $W_3^T < W_3^N$ when $\epsilon_1 = \epsilon_2 = 0$, and $\epsilon_3 = 2.1$.

[10] We have $g_3^T > g_3^N$ for $\epsilon_3 < \frac{1}{2}\epsilon_2 + 0.1155$, and $g_3^T < g_3^N$ for $\epsilon_3 > \frac{1}{2}\epsilon_2 + 0.1155$.

Substituting Eqs. (19) and (20) into Eqs. (5) yields the equilibrium tax rates:

$$t_i^I = \frac{19}{61} + \frac{1}{305}(114\epsilon_i - 69\epsilon_j - 45\epsilon_3), \ i,j = 1,2; i \neq j, \quad (21)$$

$$t_3^I = \frac{23}{61} - \frac{9}{61}(\epsilon_1 + \epsilon_2 - 2\epsilon_3). \quad (22)$$

Again, using these expressions and noting that $\epsilon_1 = 0$, equilibrium values of infrastructure can be written as $g_1^I = \frac{4}{9}t_1^I - \frac{4}{15}\epsilon_2$, $g_2^I = \frac{4}{9}t_2^I + \frac{4}{15}\epsilon_2$, and $g_3^I = \frac{8}{9}t_3^I$. Social welfare levels are:

$$W_i^I = 2\left(t_1^I\right)^2 - \frac{1}{2}\left(\frac{4}{9}t_1^I - (-1)^i \frac{4}{15}\epsilon_2\right)^2, \ i = 1,2 \quad (23)$$

$$W_3^I = \frac{130}{81}\left(t_3^I\right)^2. \quad (24)$$

Jurisdictions 1 and 2 will coordinate their infrastructure investments when both jurisdictions obtain a higher welfare, i.e., when $W_i^I > W_i^N$ for $i = 1,2$.

Lemma 3 *For given ϵ_3, $\exists(\epsilon_2, \epsilon_3) \in R$ where partial infrastructure coordination takes place. This is the case when the jurisdictions in the tax coalition are not too different, i.e., when ϵ_2 is small. The welfare gains from partial infrastructure coordination for jurisdiction 2 are larger than for jurisdiction 1.*

From Lemma 3 we see that partial infrastructure coordination will take place when jurisdictions 1 and 2 are sufficiently symmetric (Area I in Figure 4B), while in case of large asymmetries there will be no infrastructure coordination (Area N). The consequences of a partial coordination of infrastructure investments are a reduction in infrastructure investments in jurisdictions 1 and 2 while investments in jurisdiction 3 increase.[11] Capital tax rates in jurisdictions 1 and 2 decrease after infrastructure coordination in order to compensate the loss of attractiveness of their jurisdictions because of lower infrastructure investments. Jurisdiction 3 increases its capital tax rate.[12]

4.2 Partial tax harmonization

Now, consider that jurisdictions 1 and 2 form a coalition subgroup which chooses both, a common capital tax rate t_c and the level of infrastructure investments g_1 and g_2 that maximize the joint welfare of this group. Jurisdiction 3, determines its own level of infrastructure and capital tax rate. The stage 3 equilibrium tax rates are the same as in the partial tax coordination case and, thus, are given by Eqs. (11) and (12). In stage 2, joint welfare maximization of jurisdictions 1 and 2 yields the following equilibrium infrastructure investments:[13]

[11] Notice that $g_i^I - g_i^N = -0.1579 + 0.1521\epsilon_i - 0.2269\epsilon_j + 0.0748\epsilon_3 < 0$ for $\Delta W_1^{I-N}(\epsilon_2, \epsilon_3) > 0$, $i = 1,2$, and $g_3^I - g_3^N = \frac{32}{31\,293}(9\epsilon_2 - 18\epsilon_3 + 38) > 0$.

[12] We have: $t_i^I - t_i^N = \frac{4}{17385}(45\epsilon_3 + 252\epsilon_i - 297\epsilon_j - 95) < 0$, $i = 1,2$, and: $t_3^I - t_3^N = \frac{4}{3477}(9\epsilon_2 - 18\epsilon_3 + 38) > 0$.

[13] Notice that sufficiency is guaranteed as $\frac{\partial^2(W_1+W_2)}{\partial g_1^2} = -\frac{103}{144} < 0$ and $\frac{\partial^2(W_1+W_2)}{\partial g_1^2}\frac{\partial^2(W_1+W_2)}{\partial g_2^2} - \left(\frac{\partial^2(W_1+W_2)}{\partial g_1 \partial g_2}\right)^2 = \frac{67}{144} > 0$.

$$g_i^{TI} = \frac{35}{177} + \frac{32\epsilon_i - 27\epsilon_j - 5\epsilon_3}{59}, \; i,j = 1,2; i \neq j, \tag{25}$$

$$g_3^{TI} = \frac{62}{177} - \frac{4(\epsilon_1 + \epsilon_2 - 2\epsilon_3)}{59}. \tag{26}$$

Substituting Eqs. (25) and (26) into Eqs. (11) and (12) yields the equilibrium tax rates:

$$t_c^{TI} = \frac{56}{59} + \frac{12}{59}(\epsilon_1 + \epsilon_2 - 2\epsilon_3), \tag{27}$$

$$t_3^{TI} = \frac{31}{59} - \frac{6}{59}(\epsilon_1 + \epsilon_2 - 2\epsilon_3). \tag{28}$$

Under the assumption that $\epsilon_1 = 0$ equilibrium values of infrastructure can be written as $g_1^{TI} = \frac{5}{24}t_c^{TI} - \frac{1}{2}\epsilon_2$, $g_2^{TI} = \frac{5}{24}t_c^{TI} + \frac{1}{2}\epsilon_2$, and $g_3^{TI} = \frac{2}{3}t_3^{TI}$ such that social welfare levels in the different jurisdictions are:

$$W_i^{TI} = \left(\frac{5}{4}t_c^{TI} + \frac{(-1)^i}{2}\epsilon_2\right)\left(\frac{1}{4}t_c^{TI} + \frac{(-1)^i}{2}\epsilon_2\right) - \frac{1}{2}\left(\frac{5}{24}t_c^{TI} + \frac{(-1)^i}{2}\epsilon_2\right)^2, \; i = 1,2, \tag{29}$$

$$W_3^{TI} = \frac{16}{9}\left(t_3^{TI}\right)^2. \tag{30}$$

The results in Lemmas 2 and 3 have shown that jurisdictions 1 and 2 gain from both tax harmonization and infrastructure coordination when asymmetries are not too large. This leads us to expect that partial tax harmonization is easier to achieve when jurisdictions in the tax coalition coordinate their infrastructure investments. The following result states this formally.

Proposition 1 *Infrastructure coordination between asymmetric jurisdictions that form a tax coalition can facilitate (hinder) partial tax harmonization when the productivity level of the jurisdiction outside the coalition is low (large).*

From Lemma 3 we know that both jurisdictions gain from infrastructure coordination when their productivity levels are not too different. Comparing cases A and C in Figure 4, we observe that these additional gains enlarge the area in which partial tax harmonization is welfare enhancing for both jurisdictions (area TI compared to area T). Therefore, we have that infrastructure coordination allows partial tax harmonization agreements to be reached between asymmetric jurisdictions when this would not be possible without the coordination of infrastructure investments. A comparison of tax rates and infrastructure investments under no coordination and partial tax harmonization with infrastructure coordination shows that the jurisdictions that form the tax coalition increase tax rates and decrease infrastructure investments when jurisdiction 3's productivity is not too high. This means that both kinds of inefficiency (too low tax rates and too high infrastructure investments) are reduced inside the tax coalition in this case. When jurisdiction 3's productivity is large, the only difference is that jurisdiction 2 increases its infrastructure investments instead of decreasing them.[14] Regarding the jurisdiction outside the tax

[14] From Eqs. (9) and (27): $t_c^{TI} - t_1^N = \frac{1}{3363}(2071 + 1215\epsilon_2 - 837\epsilon_3) > 0$ for all $(\epsilon_2, \epsilon_3) \in R$ and $t_c^{TI} - t_2^N = \frac{1}{3363}(2071 - 378\epsilon_2 - 837\epsilon_3) > 0$ for all $(\epsilon_2, \epsilon_3) \in R$. From Eqs (8) and (25) we have: $g_1^{TI} - g_1^N = \frac{-1}{30\,267}(2983 + 9603\epsilon_2 - 1683\epsilon_3) < 0$ for all $(\epsilon_2, \epsilon_3) \in R$ and $g_2^{TI} - g_2^N = \frac{-1}{30\,267}(2983 - 7920\epsilon_2 - 1683\epsilon_3)$.

coalition we find that its behavior crucially depends on its productivity level. When jurisdiction 3's productivity is low (high), it increases (decreases) capital tax rates and infrastructure investments.[15]

5 Infrastructure coordination through common investment levels

5.1 No tax harmonization

The former analysis has shown that asymmetries between jurisdictions are an obstacle to achieving capital tax harmonization or the coordination of infrastructure investments. Therefore, as an alternative to the type of coordination analyzed before, consider that jurisdictions 1 and 2 decide to reduce asymmetries between jurisdictions by agreeing on a common level of investments, g_c. This will allow the difference in investments to be reduced and, consequently, should facilitate tax coordination. Formally, in stage 2, jurisdictions 1 and 2 choose the common level of investments g_c to maximize joint welfare. Simultaneously, jurisdiction 3 determines its own level of infrastructure. In stage 3, all jurisdictions choose their capital tax rate separately. Thus, the stage 3 Nash equilibrium tax rates are given by Eq. (5) and welfare levels by Eq. (6). In stage 2, joint welfare maximization of jurisdictions 1 and 2, and welfare maximization of jurisdiction 3 yields the following Nash equilibrium values:

$$g_c^{IC} = \frac{2}{61}\epsilon_1 + \frac{2}{61}\epsilon_2 - \frac{4}{61}\epsilon_3 + \frac{76}{549}, \tag{31}$$

$$g_3^{IC} = \frac{16}{61}\epsilon_3 - \frac{8}{61}\epsilon_2 - \frac{8}{61}\epsilon_1 + \frac{184}{549}. \tag{32}$$

Substituting Eqs. (31) and (32) into Eq. (5) yields the equilibrium tax rates:

$$t_i^{IC} = \frac{19}{61} + \frac{1}{183}\left(44\epsilon_i - 17\epsilon_j - 27\epsilon_3\right), \; i = 1, 2 \tag{33}$$

$$t_3^{IC} = \frac{23}{61} - \frac{9}{61}\left(\epsilon_1 + \epsilon_2 - 2\epsilon_3\right). \tag{34}$$

Noting that $\epsilon_1 = 0$, equilibrium values of infrastructure can be written as $g_c^{IC} = \frac{4}{9}t_1^{IC} + \frac{2}{27}\epsilon_2 = \frac{4}{9}t_2^{IC} - \frac{2}{27}\epsilon_2$, and $g_3^{IC} = \frac{8}{9}t_3^{IC}$. Social welfare levels are:

$$W_i^{IC} = 2\left(t_2^{IC}\right)^2 - \frac{1}{2}\left(\frac{4}{9}t_2^{IC} - \frac{(-1)^i 2}{27}\epsilon_2\right)^2, \; i = 1, 2 \tag{35}$$

$$W_3^{IC} = \frac{130}{81}\left(t_3^{IC}\right)^2. \tag{36}$$

Lemma 4 *For given ϵ_3, $\exists(\epsilon_2, \epsilon_3) \in R$ where partial infrastructure coordination with common investment levels takes place. This is the case when the jurisdictions in the tax*

[15] This can be observed immediately from Eqs. (9) and (28) as $t_3^{TI} - t_3^N = \frac{1}{3363}(189\epsilon_2 - 378\epsilon_3 + 646)$ and from Eqs. (8) and (26) as $g_3^{TI} - g_3^N = \frac{2}{30\,267}(1098\epsilon_2 - 2196\epsilon_3 + 817)$.

coalition are not too different, i.e., when ϵ_2 is small. The welfare gains from partial infrastructure coordination with common investment levels for jurisdiction 1 are larger than for jurisdiction 2.

Comparing Lemmas 3 and 4, we observe that both kinds of infrastructure coordination (i.e., with different investment levels and with a common investment level) are welfare enhancing when the jurisdictions inside the coalition have similar productivity levels (i.e., in areas I and IC in cases B and D, respectively, in Figure 4). However, whereas under infrastructure coordination with different investment levels larger welfare gains are obtained by the more productive jurisdiction (in this case jurisdiction 2), under infrastructure coordination with a common investment level it is the less productive jurisdiction (jurisdiction 1) that obtains larger welfare gains. This stems from the fact that agreeing upon a common investment level eliminates the difference between the infrastructure investments of jurisdictions 1 and 2 and, therefore, makes jurisdiction 1 more and jurisdiction 2 less attractive for capital investments. Infrastructure coordination allows jurisdictions 1 and 2 to reduce infrastructure investments and, thus, to reduce inefficiencies in these investments; however, at the same time tax rates decrease, which increases inefficiencies.[16] In contrast, the jurisdiction outside the tax coalition increases infrastructure investments and tax rates.[17]

5.2 Partial tax harmonization

Finally, consider that jurisdictions 1 and 2 form a coalition subgroup which chooses both a common capital tax rate t_c and a common level of infrastructure investments g_c that maximize the joint welfare of this group. Again, jurisdiction 3 determines its infrastructure investment and capital tax rate independently. The stage 3 equilibrium tax rates are the same as under partial tax coordination and, thus, are given by Eqs. (11) and (12). The equilibrium infrastructure investments are given by:

$$g_c^{TIC} = \frac{35}{177} + \frac{5(\epsilon_1 + \epsilon_2 - 2\epsilon_3)}{118}, \tag{37}$$

$$g_3^{TIC} = \frac{62}{177} - \frac{4(\epsilon_1 + \epsilon_2 - 2\epsilon_3)}{59}. \tag{38}$$

Substituting Eqs. (37) and (38) into Eqs. (11) and (12) yields the equilibrium tax rates:

$$t_c^{TIC} = \frac{56}{59} + \frac{12}{59}(\epsilon_1 + \epsilon_2 - 2\epsilon_3), \tag{39}$$

$$t_3^{TIC} = \frac{31}{59} - \frac{6}{59}(\epsilon_1 + \epsilon_2 - 2\epsilon_3). \tag{40}$$

[16] From Eqs. (9) (8), (33) and (31) we have: $t_1^{IC} - t_1^N = \frac{2}{3477}(-38 + 113\epsilon_2 + 18\epsilon_3) < 0$, $t_2^{IC} - t_2^N = \frac{2}{3477}(-38 - 131\epsilon_2 + 18\epsilon_3) < 0$ $g_c^{IC} - g_1^N = \frac{2}{31\,293}(-2470 + 2709\epsilon_2 + 1170\epsilon_3) < 0$, and $g_c^{IC} - g_2^N = \frac{2}{31\,293}(-2470 - 3879\epsilon_2 + 1170\epsilon_3) < 0$
$\forall(\epsilon_2, \epsilon_3) \in IC$ in Figure 4D.

[17] From Eqs (9), (8), (32) and (34) we have: $t_3^{IC} - t_3^N = \frac{4}{3477}(9\epsilon_2 - 18\epsilon_3 + 38) > 0$, and $g_3^{IC} - g_3^N = \frac{32}{31\,293}(9\epsilon_2 - 18\epsilon_3 + 38) > 0$, $\forall(\epsilon_2, \epsilon_3) \in IC$ in Figure 4D.

Under the assumption that $\epsilon_1 = 0$ equilibrium values of infrastructure can be written as $g_c^{TIC} = \frac{5}{24}t_c^{TIC}$, and $g_3^{TIC} = \frac{2}{3}t_3^{TIC}$ such that social welfare levels in the different jurisdictions are:

$$W_i^{TIC} = \left(\frac{5}{4}t_c^{TIC} + \frac{(-1)^i}{4}\epsilon_2\right)\left(\frac{1}{4}t_c^{TIC} + \frac{(-1)^i}{4}\epsilon_2\right) - \frac{1}{2}\left(\frac{5}{24}t_c^{TIC}\right)^2, \; i = 1, 2, \quad (41)$$

$$W_3^{TIC} = \frac{16}{9}\left(t_3^{TIC}\right)^2. \quad (42)$$

Proposition 2 *Infrastructure coordination through the choice of a common investment level allows partial tax harmonization between asymmetric jurisdictions that cannot be achieved by infrastructure coordination with different investment levels. This is the case when jurisdiction 2's productivity is large and the productivity of the jurisdiction outside the tax coalition is low.*

A comparison of cases C and E in Figure 4 shows that partial infrastructure coordination in which jurisdictions agree upon a common investment level allows an agreement to be reached on partial tax harmonization that cannot be achieved under infrastructure coordination with different investment levels. This is the case when jurisdictions 1 and 2 are fairly asymmetric and jurisdiction 3's productivity is high (i.e., in area TIC). This result is obtained because under partial tax harmonization with infrastructure coordination through *a common* investment level, even when jurisdictions are asymmetric, jurisdiction 1 gains from infrastructure coordination (see Lemma 4) while jurisdiction 2 gains from tax coordination (see Lemma 2). Under partial tax harmonization with infrastructure coordination through different investment levels only the more productive jurisdiction (i.e., jurisdiction 2) gains from the formation of a tax coalition when asymmetries in the tax coalition are high. Comparing both kinds of infrastructure coordination we also observe from Eqs. (27) and (39) that tax rates are the same in both cases ($t_c^{TIC} = t_c^{TI}$) while jurisdiction 1 (jurisdiction 2) inverts more (less) in infrastructures in the case of infrastructure coordination through a common investment level.[18] The jurisdiction outside the tax coalition chooses the same capital tax rate and infrastructure investment in both cases.[19]

6 Conclusions

Tax harmonization has become an important concern in most developed economies because tax competition has constantly decreased capital tax rates over recent decades and has led to a shift of the tax burden from capital towards labor. As the global harmonization of capital taxation is unlikely to be achieved, the literature has focused on the conditions that allow tax harmonization in a coalition of countries. In this article we analyze how such a partial tax harmonization is influenced by a simultaneous coordination of infrastructure investments. Two kinds of infrastructure coordination are considered:

[18] As $t_c^{TIC} = t_c^{TI}$, from Eqs. (25) and (39) it follows that $g_1^{TI} = \frac{5}{24}t_c^{TI} - \frac{1}{2}\epsilon_2 < \frac{5}{24}t_c^{TIC} = g_c^{TIC}$, and $g_2^{TI} = \frac{5}{24}t_c^{TI} + \frac{1}{2}\epsilon_2 > \frac{5}{24}t_c^{TIC} = g_c^{TIC}$.

[19] See Eqs. (28), (26), (40) and (38).

infrastructure coordination with different investment levels, and infrastructure coordination with a common investment level. We obtain that infrastructure coordination can facilitate partial tax harmonization. This is the case when the coalition partners are not too different in their productivity levels. Furthermore, we find that infrastructure coordination with a common investment level enables partial tax harmonization even when asymmetries between coalition members are substantial. This result explains the harmonization of corporate tax rates observed in the EU between 1995 and 2006 where there was a simultaneous convergence of public infrastructure investments facilitated via EU structural funds.

Our result has an important policy implication. As asymmetries between jurisdictions are an important handicap to accomplishing tax harmonization, a primary objective of policy makers should be to reduce these asymmetries. The coordination of infrastructure investments can be an instrument to achieve this objective. Our analysis has shown that even a reduction of public infrastructure investments in some jurisdictions can be welfare enhancing for all coalition members when this finally leads to a harmonization of tax rates in the tax coalition.

Our analysis also opens up interesting lines for further research. As our analysis has been limited to three jurisdictions it would be interesting to study how our results generalize with more jurisdictions. Furthermore, our analysis could be complemented by considering other forms of public tax decision making. For example, as in Borck (2003) the choice of the tax structure could be considered in a majority voting model in which jurisdictions compete in tax rates. Finally, our analysis is based on a horizontal coordination of tax rates and infrastructure levels. As tax decisions are taken both at the state level and at regional and local levels, it would be interesting to analyze how the interplay of horizontal and vertical coordination of tax rates and infrastructure levels would change our results.

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Appendix

Proof of Lemma 1. Suppose all jurisdictions increase tax rates by an amount λ, $\lambda > 0$. Then welfare becomes:

$$W_i(t_i^N + \lambda, t_j^N + \lambda, t_h^N + \lambda, g_i^N, g_j^N, g_h^N) = \frac{130}{81}\left(t_i^N\right)^2 + \lambda t_i^N > 0$$

which proves that a joint tax increase by all jurisdictions increases welfare compared to the no cooperation case (N). As the provision of public goods equals tax revenues $t_i k_i$ and k_i does not change when all jurisdictions increase tax rates by the same amount, it follows immediately that public goods provision is too low. Finally, consider a reduction of infrastructure investments of the amount μ in all jurisdictions ($0 < \mu < g_i^N$, $\forall i$). Then welfare becomes:

$$W_i(t_i^N, t_j^N, t_h^N, g_i^N - \mu, g_j^N - \mu, g_h^N - \mu) = \left(t_i^N\right)^2 + \left(g_i^N - \frac{1}{2}\mu\right)\mu > 0$$

which proves the last statement. ■

Proof of Lemma 2. From Eqs. (10) and (17) we have:

$$\begin{aligned}\Delta W_2^{T-N}(\epsilon_2,\epsilon_3) &\equiv W_2^T - W_2^N = \frac{1699}{36\,450} + \frac{61\,527}{884\,450}\epsilon_2^2 + \frac{13\,207}{53\,865}\epsilon_2 \\ &\quad - \frac{23\,837}{265\,335}\epsilon_2\epsilon_3 + \frac{3457}{2653\,350}\epsilon_3^2 - \frac{6427}{269\,325}\epsilon_3 \\ &> 0 \quad \text{for } \forall(\epsilon_2,\epsilon_3)\in R.\end{aligned}$$

Jurisdiction 2 is always better off under partial tax harmonization. Regarding jurisdiction 1, from Eqs. (10) and (17) we have:

$$\begin{aligned}\Delta W_1^{T-N}(\epsilon_2,\epsilon_3) &\equiv W_1^T - W_1^N = \frac{1\,699}{36\,450} - \frac{25\,166}{1\,326\,675}\epsilon_2^2 - \frac{59\,608}{269\,325}\epsilon_2 \\ &\quad + \frac{38\,576}{442\,225}\epsilon_2\epsilon_3 + \frac{3\,457}{2\,653\,350}\epsilon_3^2 - \frac{6\,427}{269\,325}\epsilon_3\end{aligned}$$

with $\Delta W_1^{T-N}(0,0) = 0.0466 > 0$, $\Delta W_1^{T-N}(\frac{95}{252},0) = -0.0395 < 0$ and $\partial \Delta W_1^{T-N}/\partial\epsilon_2 = 0.0872\epsilon_3 - 0.0379\epsilon_2 - 0.2213 < 0$ for $(\epsilon_2,\epsilon_3)\epsilon R$. Thus, there is a unique function $f_{T-N}(\epsilon_2) = \frac{854\,791}{93\,339} - \frac{115\,728}{3457}\epsilon_2 - \sqrt{\frac{13\,566\,967\,708}{11\,950\,849}\epsilon_2^2 - \frac{143\,033\,254\,000}{322\,672\,923}\epsilon_2 + \frac{418\,981\,654\,000}{8712\,168\,921}}$ defined by $\Delta W_1^{T-N}(\epsilon_2,\epsilon_3) = 0$ which separates R in two areas with $\Delta W_1^{T-N}(\epsilon_2,\epsilon_3) > 0$ for $\epsilon_2 < f_{T-N}(\epsilon_2)$ and $\Delta W_1^{T-N}(\epsilon_2,\epsilon_3) < 0$ for $\epsilon_2 > f_{T-N}(\epsilon_2)$. Finally, notice that

$$\begin{aligned}\Delta W_2^{T-N}(\epsilon_2,\epsilon_3) - \Delta W_1^{T-N}(\epsilon_2,\epsilon_3) &= \left(\frac{33\,559}{379\,050}\epsilon_2 - \frac{33\,559}{189\,525}\epsilon_3 + \frac{5983}{12\,825}\right)\epsilon_2 \\ &> 0 \quad \text{for } \forall(\epsilon_2,\epsilon_3)\in R.\end{aligned}$$

Thus, the welfare gains from partial tax harmonization are larger for jurisdiction 2. ■

Proof of Lemma 3. From Eqs. (10) and (23) we obtain

$$\begin{aligned}\left(W_2^I - W_2^N\right) - \left(W_1^I - W_1^N\right) &= \frac{10\,168}{2972\,835}\left(9\epsilon_2 - 18\epsilon_3 + 38\right)\epsilon_2 \\ &> 0 \quad \text{for } \forall(\epsilon_2,\epsilon_3)\in R.\end{aligned}$$

Thus, jurisdiction 2 always gains from infrastructure coordination when jurisdiction 1 gains. Therefore, it is sufficient to analyze when this is the case. We have that:

$$\begin{aligned}\Delta W_1^{I-N}(\epsilon_2,\epsilon_3) &\equiv W_1^I(\epsilon_2,\epsilon_3) - W_1^N(\epsilon_2,\epsilon_3) \\ &= \frac{16\,616}{2\,712\,609} - \frac{61\,360}{12\,089\,529}\epsilon_2^2 - \frac{1\,777\,664}{28\,633\,095}\epsilon_2 \\ &\quad + \frac{16\,616}{12\,089\,529}\epsilon_3^2 - \frac{33\,232}{5\,726\,619}\epsilon_3 + \frac{1\,777\,664}{60\,447\,645}\epsilon_2\epsilon_3\end{aligned}$$

with $\Delta W_1^{I-N}(0,0) = 0.0061 > 0$, $\Delta W_1^{I-N}(\frac{95}{252},0) = -0.0180 < 0$ and $\partial \Delta W_1^{I-N}/\partial\epsilon_2 = 0.0294\epsilon_3 - 0.0102\epsilon_2 - 0.0621 < 0$ for $(\epsilon_2,\epsilon_3)\epsilon R$. Thus, there is a unique function $f_{I-N}(\epsilon_2) = \frac{19}{9} - \left(\frac{3477}{10\,385}\sqrt{31}\sqrt{34} + \frac{3584}{335}\right)\epsilon_2$ defined by $\Delta W_1^{I-N}(\epsilon_2,\epsilon_3) = 0$ which separates R in two areas with $\Delta W_1^{I-N}(\epsilon_2,\epsilon_3) > 0$ for $\epsilon_2 < f_{I-N}(\epsilon_2)$ and $\Delta W_1^{I-N}(\epsilon_2,\epsilon_3) < 0$ for $\epsilon_2 > f_{I-N}(\epsilon_2)$. ■

Proof of Proposition 1. First, consider jurisdiction 2. We have:

$$\begin{aligned}\Delta W_2^{TI-T}(\epsilon_2,\epsilon_3) &\equiv W_2^{TI}-W_2^{T}=\frac{5951\,819}{153\,512\,100}\epsilon_2^2-\frac{467\,779}{7675\,605}\epsilon_2\epsilon_3+\frac{467\,779}{3289\,545}\epsilon_2\\ &+\frac{261\,092}{38\,378\,025}\epsilon_3^2-\frac{522\,184}{16\,447\,725}\epsilon_3+\frac{261\,092}{7049\,025}\\ &> 0 \quad \text{for } \forall(\epsilon_2,\epsilon_3)\in R.\end{aligned}$$

Jurisdiction 2 is always better off under partial tax harmonization with infrastructure coordination (TI) than under partial tax harmonization (T) (and under no coordination (N), as shown in the proof of Lemma 2).

Second, for jurisdiction 1 we have:

$$\begin{aligned}\Delta W_1^{TI-T}(\epsilon_2,\epsilon_3) &\equiv W_1^{TI}(\epsilon_2,\epsilon_3)-W_1^{T}(\epsilon_2,\epsilon_3)\\ &= -\frac{2359\,393}{153\,512\,100}\epsilon_2^2+\frac{1816\,711}{38\,378\,025}\epsilon_2\epsilon_3-\frac{1816\,711}{16\,447\,725}\epsilon_2\\ &+\frac{261\,092}{38\,378\,025}\epsilon_3^2-\frac{522\,184}{16\,447\,725}\epsilon_3+\frac{261\,092}{7049\,025}\end{aligned}$$

with $\Delta W_1^{TI-T}(0,0)=0.0370>0$, $\Delta W_1^{TI-T}(\frac{95}{252},0)=-0.0068<0$ and $\partial\Delta W_1^{T-N}/\partial\epsilon_2 = 0.0473\epsilon_3-0.0307\epsilon_2-0.1105<0$ for $(\epsilon_2,\epsilon_3)\epsilon R$. Thus, there is a unique function $f_{TI-T}(\epsilon_2)=\frac{7}{3}-\frac{548\,877}{522\,184}\sqrt{13}\epsilon_2-\frac{139\,747}{40\,168}\epsilon_2$ defined by $\Delta W_1^{TI-T}(\epsilon_2,\epsilon_3)=0$ which separates R in two areas with
$\Delta W_1^{TI-T}(\epsilon_2,\epsilon_3)>0$ for $\epsilon_2<f_{TI-T}(\epsilon_2)$ and $\Delta W_1^{TI-T}(\epsilon_2,\epsilon_3)<0$ for $\epsilon_2>f_{TI-T}(\epsilon_2)$. Furthermore, we have:

$$\begin{aligned}\Delta W_1^{TI-N}(\epsilon_2,\epsilon_3) &\equiv W_1^{TI}(\epsilon_2,\epsilon_3)-W_1^{N}(\epsilon_2,\epsilon_3)\\ &= -\frac{1553\,449}{45\,239\,076}\epsilon_2^2+\frac{1521\,943}{11\,309\,769}\epsilon_2\epsilon_3-\frac{1777\,417}{5357\,259}\epsilon_2\\ &+\frac{183\,355}{22\,619\,538}\epsilon_3^2-\frac{297\,925}{5357\,259}\epsilon_3+\frac{424\,555}{5075\,298}\end{aligned}$$

with $\Delta W_1^{TI-N}(0,0)=0.0837>0$, $\Delta W_1^{TI-N}(\frac{95}{252},0)=-0.0463<0$ and $\partial\Delta W_1^{T-N}/\partial\epsilon_2 = 0.1346\epsilon_3-0.0687\epsilon_2-0.3318<0$ for $(\epsilon_2,\epsilon_3)\epsilon R$. Thus, there is a unique function $f_{TI-N}(\epsilon_2)=\frac{113115}{330039}-\frac{1521943}{183355}\epsilon_2-\frac{1121}{1100130}\sqrt{2}\sqrt{35218557\epsilon_2^2-7712640\epsilon_2+696800}$ defined by $\Delta W_1^{TI-N}(\epsilon_2,\epsilon_3)=0$ which separates R in two areas with $\Delta W_1^{TI-N}(\epsilon_2,\epsilon_3)>0$ for $\epsilon_2<f_{TI-N}(\epsilon_2)$ and $\Delta W_1^{TI-N}(\epsilon_2,\epsilon_3)<0$ for $\epsilon_2>f_{TI-N}(\epsilon_2)$.

Finally, notice that functions $f_{T-N}(\epsilon_2)$, $f_{TI-N}(\epsilon_2)$ and $f_{TI-T}(\epsilon_2)$ have a single intersection point in R at $(\epsilon_2,\epsilon_3)=(0.1711,1.0892)$ which separates R in three areas (displayed in Figure 4C):

1. Area TI: ($\epsilon_2<f_{TI-T}(\epsilon_2)$ and $\epsilon_2<f_{TI-N}(\epsilon_2)$) where $W_i^{TI}(\epsilon_2,\epsilon_3)>W_i^{N}(\epsilon_2,\epsilon_3)$ and $W_i^{TI}(\epsilon_2,\epsilon_3)>W_i^{T}(\epsilon_2,\epsilon_3)$, $i=1,2$, such that the equilibrium outcome is TI which is preferred by all jurisdictions.

2. Area T: ($f_{TI-T}(\epsilon_2)<\epsilon_2<f_{T-N}(\epsilon_2)$) where $W_1^{T}(\epsilon_2,\epsilon_3)>W_1^{TI}(\epsilon_2,\epsilon_3)$, $W_2^{TI}(\epsilon_2,\epsilon_3)>W_2^{T}(\epsilon_2,\epsilon_3)$ and $W_i^{T}(\epsilon_2,\epsilon_3)>W_i^{N}(\epsilon_2,\epsilon_3)$, $i=1,2$. The equilibrium outcome is T as jurisdiction 1 does not agree to coordinate infrastructure investments which is the preferred outcome for jurisdiction 2.

3. Area N: ($\epsilon_2 > f_{T-N}(\epsilon_2)$ and $\epsilon_2 > f_{TI-N}(\epsilon_2)$) where $W_1^N(\epsilon_2,\epsilon_3) > W_1^{TI}(\epsilon_2,\epsilon_3)$, $W_1^N(\epsilon_2,\epsilon_3) > W_1^T(\epsilon_2,\epsilon_3)$. The equilibrium outcome is N as jurisdiction 1 loses from both partial tax harmonization and partial tax harmonization with infrastructure coordination.

■

Proof of Lemma 4. From Eqs. (10) and (35) we obtain

$$\begin{aligned}\left(W_1^{IC}-W_1^N\right)-\left(W_2^{IC}-W_2^N\right) &= \frac{24\,452}{93\,879}\epsilon_2-\frac{6}{61}\epsilon_2^2+\frac{7268}{198\,189}\epsilon_2\epsilon_3\\ &\quad -\frac{260}{1539}\epsilon_3+\frac{130}{3249}\epsilon_3^2\\ &> 0 \quad \text{for } \forall(\epsilon_2,\epsilon_3)\in R,\end{aligned}$$

which proves the second statement. Jurisdiction 2's welfare gains are:

$$\begin{aligned}\Delta W_2^{IC-N}(\epsilon_2,\epsilon_3) &\equiv W_2^{IC}(\epsilon_2,\epsilon_3)-W_2^N(\epsilon_2,\epsilon_3)\\ &= \frac{16\,616}{2712\,609}-\frac{543\,626}{12\,089\,529}\epsilon_2^2-\frac{245\,440}{5726\,619}\epsilon_2\\ &\quad +\frac{16\,616}{12\,089\,529}\epsilon_3^2-\frac{33\,232}{5726\,619}\epsilon_3+\frac{245\,440}{12\,089\,529}\epsilon_2\epsilon_3\end{aligned}$$

with $\Delta W_2^{IC-N}(0,0)=0.0061>0$, $\Delta W_2^{IC-N}(\frac{95}{252},0)=-0.0164<0$ and $\partial\Delta W_2^{IC-N}/\partial\epsilon_2 = 0.0203\epsilon_3-0.0899\epsilon_2-0.0429<0$ for $(\epsilon_2,\epsilon_3)\epsilon R$. Thus, there is a unique function $f_{IC-N}(\epsilon_2)=\frac{19}{9}-\frac{1159}{4154}\sqrt{19}\sqrt{59}\epsilon_2-\frac{15\,340}{2077}\epsilon_2$ defined by $\Delta W_2^{IC-N}(\epsilon_2,\epsilon_3)=0$ which separates R in two areas with $\Delta W_2^{IC-N}(\epsilon_2,\epsilon_3)>0$ for $\epsilon_2<f_{IC-N}(\epsilon_2)$ and $\Delta W_2^{IC-N}(\epsilon_2,\epsilon_3)<0$ for $\epsilon_2>f_{IC-N}(\epsilon_2)$.

■

Proof of Proposition 2. First, consider jurisdiction 1. From Eqs (10), (17), (29), and (41) we have that jurisdiction 1 is always better off under tax harmonization with infrastructure coordination with common investment levels (TIC) than under no coordination (N), tax harmonization (T), and tax harmonization with infrastructure coordination with different investment levels (TI):

$$\begin{aligned}\Delta W_1^{TIC-N}(\epsilon_2,\epsilon_3) &\equiv W_1^{TIC}-W_1^N=\frac{424\,555}{5075\,298}-\frac{7555\,633}{180\,956\,304}\epsilon_2^2-\frac{800\,537}{10\,714\,518}\epsilon_2\\ &\quad +\frac{551\,903}{22\,619\,538}\epsilon_2\epsilon_3+\frac{183\,355}{22\,619\,538}\epsilon_3^2-\frac{297\,925}{5357\,259}\epsilon_3\\ &> 0 \quad \text{for } \forall(\epsilon_2,\epsilon_3)\in R,\\ \Delta W_1^{TIC-T}(\epsilon_2,\epsilon_3) &\equiv W_1^{TIC}-W_1^T=\frac{261\,092}{7049\,025}-\frac{13\,990\,897}{614\,048\,400}\epsilon_2^2+\frac{4822\,753}{32\,895\,450}\epsilon_2\\ &\quad -\frac{4822\,753}{76\,756\,050}\epsilon_2\epsilon_3+\frac{261\,092}{38\,378\,025}\epsilon_3^2-\frac{522\,184}{16\,447\,725}\epsilon_3\\ &> 0 \quad \text{for } \forall(\epsilon_2,\epsilon_3)\in R,\\ \Delta W_1^{TIC-TI}(\epsilon_2,\epsilon_3) &\equiv W_1^{TIC}-W_1^{TI}=\left(\frac{91}{354}-\frac{13}{118}\epsilon_3-\frac{7}{944}\epsilon_2\right)\epsilon_2>0 \quad \text{for } \forall(\epsilon_2,\epsilon_3)\in R.\end{aligned}$$

Second, consider jurisdiction 2. From Eqs. (10) and (41) we have that jurisdiction 2 is always better off under tax harmonization with infrastructure coordination with common investment levels (TIC) than under no coordination (N):

$$\begin{aligned}\Delta W_2^{TIC-N}(\epsilon_2,\epsilon_3) &\equiv W_2^{TIC} - W_2^{N} = \frac{424\,555}{5075\,298} - \frac{1673\,569}{180\,956\,304}\epsilon_2^2 + \frac{1396\,387}{10\,714\,518}\epsilon_2 \\ &\quad - \frac{918\,613}{22\,619\,538}\epsilon_2\epsilon_3 + \frac{183\,355}{22\,619\,538}\epsilon_3^2 - \frac{297\,925}{5357\,259}\epsilon_3 \\ &> 0 \quad \text{for } \forall(\epsilon_2,\epsilon_3) \in R.\end{aligned}$$

Thus, as both jurisdictions are better off under TIC than under N, No harmonization (N) is not an equilibrium. Furthermore, from Eqs. (17) and (41) we have:

$$\begin{aligned}\Delta W_2^{TIC-T}(\epsilon_2,\epsilon_3) &\equiv W_2^{TIC} - W_2^{T} = \frac{261\,092}{7049\,025} - \frac{48\,395\,449}{614\,048\,400}\epsilon_2^2 - \frac{755\,677}{6579\,090}\epsilon_2 \\ &\quad + \frac{755\,677}{15\,351\,210}\epsilon_2\epsilon_3 + \frac{261\,092}{38\,378\,025}\epsilon_3^2 - \frac{522\,184}{16\,447\,725}\epsilon_3\end{aligned}$$

with $\Delta W_2^{TIC-T}(0,0) = 0.0371 > 0$, $\Delta W_2^{TIC-T}(\frac{95}{252},0) = -0.0175 < 0$ and $\partial \Delta W_2^{TIC-T}/\partial\epsilon_2 = 0.0492\epsilon_3 - 0.15763\epsilon_2 - 0.11486 < 0$ for $(\epsilon_2,\epsilon_3)\epsilon R$. Thus, there is a unique function $f_{TIC-T}(\epsilon_2) = \frac{7}{3} - \frac{1239}{1044\,368}\sqrt{13}\sqrt{1348\,521\epsilon_2} - \frac{290\,645}{80\,336}\epsilon_2$ defined by $\Delta W_2^{TIC-T}(\epsilon_2,\epsilon_3) = 0$ which separates R in two areas with $\Delta W_2^{TIC-T}(\epsilon_2,\epsilon_3) > 0$ for $\epsilon_2 < f_{TIC-T}(\epsilon_2)$ and $\Delta W_2^{TIC-T}(\epsilon_2,\epsilon_3) < 0$ for $\epsilon_2 > f_{TIC-T}(\epsilon_2)$.

From Eqs. (29) and (41) we have:

$$\begin{aligned}\Delta W_2^{TIC-TI}(\epsilon_2,\epsilon_3) &\equiv W_2^{TIC} - W_2^{TI} = -\frac{1}{2832}\epsilon_2\left(333\epsilon_2 - 312\epsilon_3 + 728\right) \\ &< 0 \quad \text{for } \forall(\epsilon_2,\epsilon_3) \in R.\end{aligned}$$

This result implies that of the two forms of tax harmonization with infrastructure coordination, jurisdiction 2 prefers infrastructure coordination with *different* investment levels while jurisdiction 1 prefers infrastructure coordination with *a common* investment level.

Finally, notice that the intersection point of functions $f_{T-N}(\epsilon_2)$, $f_{TI-N}(\epsilon_2)$ and $f_{TI-T}(\epsilon_2)$ lies on the right of function $f_{TIC-T}(\epsilon_2)$. Thus, again we have three areas in R (displayed in Figure 4E):

1. Area TI, TIC: ($\epsilon_2 < f_{TI-T}(\epsilon_2)$ and $\epsilon_2 < f_{TI-N}(\epsilon_2)$) where $W_i^{TI}(\epsilon_2,\epsilon_3) > W_i^{N}(\epsilon_2,\epsilon_3)$, and $W_i^{TI}(\epsilon_2,\epsilon_3) > W_i^{T}(\epsilon_2,\epsilon_3)$, $i = 1, 2$, $W_1^{TIC}(\epsilon_2,\epsilon_3) > W_1^{TI}(\epsilon_2,\epsilon_3)$ and $W_2^{TI}(\epsilon_2,\epsilon_3) > W_2^{TIC}(\epsilon_2,\epsilon_3)$ such that the equilibrium outcome is either TI or TIC which are preferred by all jurisdictions to T and N.

2. Area T: ($f_{TI-T}(\epsilon_2) < \epsilon_2 < f_{T-N}(\epsilon_2)$ and $f_{TIC-T}(\epsilon_2) < \epsilon_2$) where $W_1^{TIC}(\epsilon_2,\epsilon_3) > W_1^{T}(\epsilon_2,\epsilon_3) > W_1^{TI}(\epsilon_2,\epsilon_3)$, $W_2^{TI}(\epsilon_2,\epsilon_3) > W_2^{T}(\epsilon_2,\epsilon_3) > W_2^{TIC}(\epsilon_2,\epsilon_3)$ and $W_i^{T}(\epsilon_2,\epsilon_3) > W_i^{N}(\epsilon_2,\epsilon_3)$, $i = 1, 2$. The equilibrium outcome is T as jurisdiction 1 does not agree to coordinate infrastructure investments with different investment levels which is the preferred outcome for jurisdiction 2, and jurisdiction 2 does not agree to coordinate infrastructure investments with a common investment level which is the preferred outcome for jurisdiction 1.

3. Area TIC: ($\epsilon_2 > f_{T-N}(\epsilon_2)$ and $\epsilon_2 > f_{TI-N}(\epsilon_2)$) where $W_i^{TIC}(\epsilon_2, \epsilon_3) > W_i^N(\epsilon_2, \epsilon_3)$, $i = 1, 2$, $W_1^N(\epsilon_2, \epsilon_3) > W_1^T(\epsilon_2, \epsilon_3)$. The equilibrium outcome is TIC as both jurisdictions prefer partial tax harmonization and infrastructure coordination with a common investment level to no coordination, and jurisdiction 1 prefers partial tax harmonization without infrastructure coordination to no coordination.

$\blacksquare$

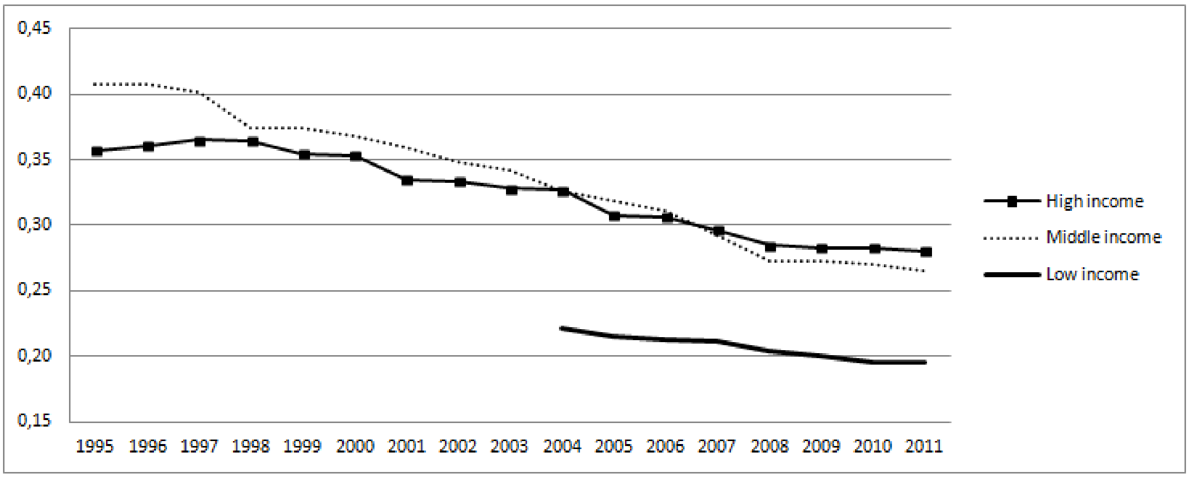

Figure 1: Combined corporate income tax rate of EU countries (period 1995-2011). Countries are classified into high, middle and low income countries. High income countries comprise Austria, Belgium, Denmark, Finland, France, Germany, Netherlands, Sweden, and United Kingdom. Middle income countries include Greece, Italy, Spain, and Portugal. Low income countries encompass Czech Republic, Estonia, Hungary, Slovak Republic, Slovenia, and Poland. Source: Own calculation based on OECD (2015).

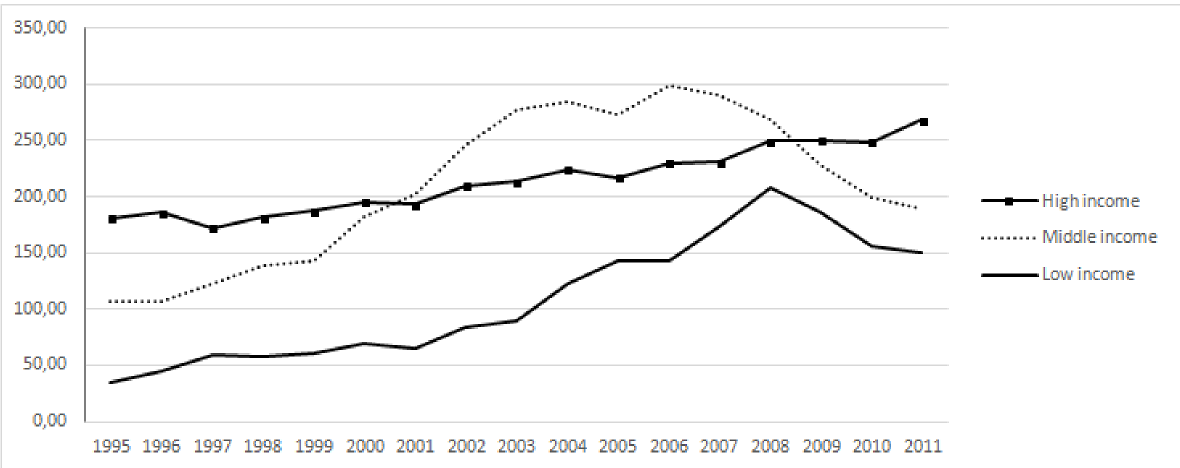

Figure 2: Transport infrastructure investment per capita of EU countries (period 1995-2011). For country classification see Figure 1. Source: Own calculation based on OECD (2015).

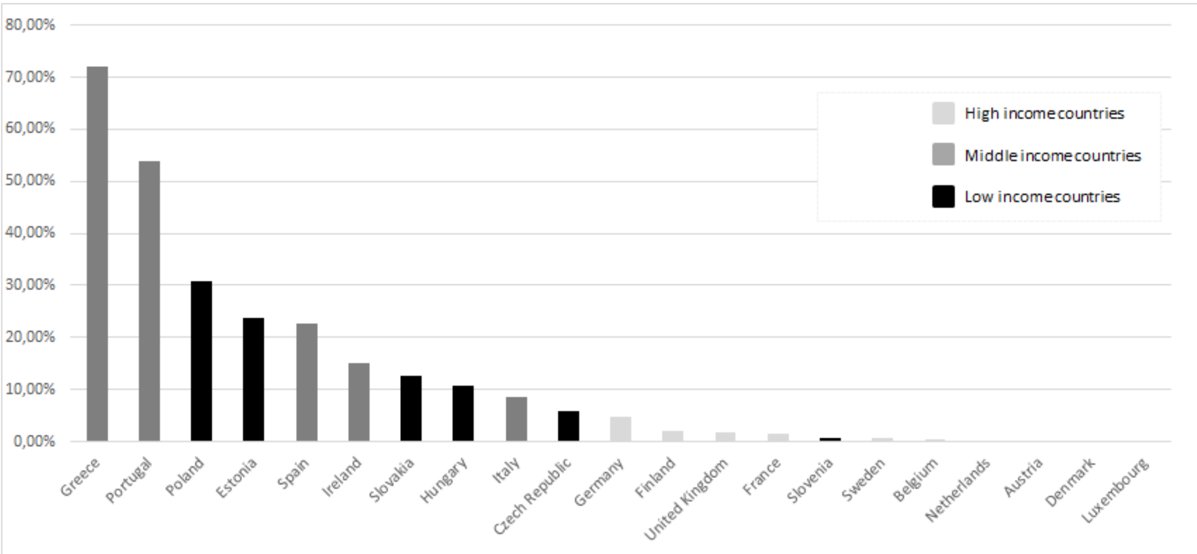

Figure 3: Share of EU financed infrastructure investment in total infrastructure investment (period 2000-2006, period 2003-2006 for low income countries). For country classification see Figure 1. Source: Own calculation based on OECD (2015) and Sweco (2008).

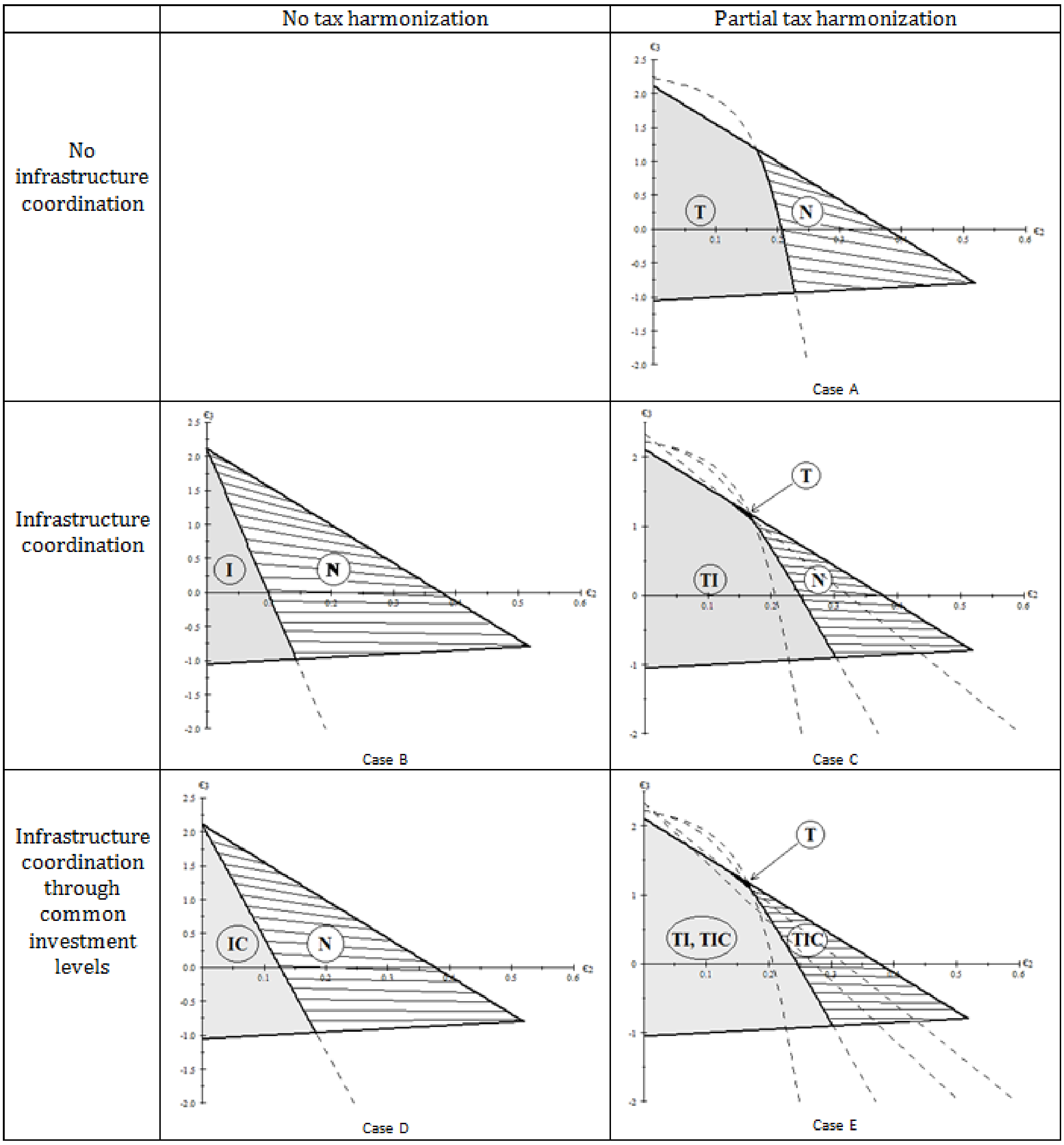

Figure 4: Equilibria are: *No tax harmonization (N), Infrastructure coordination (I), Infrastructure coordination with Common investment levels (IC), partial Tax harmonization (T), partial Tax harmonization with Infrastructure coordination (TI), partial Tax harmonization with Infrastructure coordination through Common investment levels (TIC).*