Partial tax harmonization through infrastructure coordination

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Abstract

In this article we analyze the role that infrastructure coordination plays for the achievement of partial tax harmonization in a coalition of asymmetric regions. We find that infrastructure coordination with different investment levels can facilitate partial tax harmonization between asymmetric regions 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 regions. Our results allow to explain observed features in tax harmonization in the EU15 before the 2004 enlargement.

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 lead 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 transfers of the tax burden from capital towards labor. For example, in 1996, the European Commission already stated that from 1980 to 1994 the implicit average tax on capital has decreased from 44% to 35% at the expense of an increase of the implicit tax on labor from 34% to 40.5% in European Union (EU) member countries (European Commission, 1996). As a response to inefficiently low capital tax

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competition several authors have advocated the coordination of tax rates (Bucovetsky, 1991; Keen and Kanbur, 1993; Fuest and Huber, 2001; Devereux and Fuest, 2010; Keen and Konrad, 2012). While the global harmonization of capital tax rates is hardly achievable, recently, the conditions that allow for partial tax harmonization between a coalition of countries have deserved more attention (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). This is especially the case in the EU where different proposals for the coordination of capital taxation have been made and where, indeed, we have observed a certain harmonization of capital tax rates.[1] Thus, Figure 1 displays the evolution of corporate income tax rates in the EU 15 (except Luxembourg) in the decade before the 2004 EU enlargement. With the exception of Ireland, that dropped tax rates in 1997 from 35% to 13% in 2003, we observe a convergence in the EU15 of corporate tax rates to a 35% level. However, the results in the literature hardly allow to explain this harmonization of capital taxation as European countries are rather different in productivity levels which is an obstacle for (partial) tax harmonization. In this article we analyze the role that infrastructure coordination has played to achieve fiscal harmonization between a coalition of asymmetric countries. A first indicator for the relevance of infrastructure investments in the analysis of fiscal harmonization is the parallel convergence of public per capita investment levels that can be observed in Figure 2. Thus, in 2003, public per capita infrastructure investment has been around 225 Euro in most countries, again with the most notable exception of Ireland where public per capita infrastructure investment has raised from around 80 Euros in 1995 to 350 Euros in 2003. Secondly, notice that this convergence is not accidental but directed by the EU as a major part of public infrastructure investments is financed via EU structural funds. Finally, the main net contributors to this budget are those countries with larger productivity levels (Germany, the Netherlands). Therefore, infrastructure investments de facto serve as a means to reduce asymmetries between EU member countries which could facilitate tax harmonization and therefore be responsible for the tendencies observed in Figure 1.

To analyze the role that infrastructure coordination plays for tax harmonization in a coalition of asymmetric regions 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 (or regions) and by assuming that governments provide local public goods (infrastructure) that enhance the productivity of private firms. In our three jurisdiction model, regions differ in their productivity levels. Regions 1 and 2 decide whether to form a coalition in which commitments are credible. We analyze a three stage game. In stage 1, regions 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] See Dankó (2012) for further information about the proposals for corporate tax harmonization.

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 regions are not too different in their productivity levels. Second, infrastructure coordination with different investment levels can facilitate partial tax harmonization between asymmetric regions. Third, while infrastructure coordination with a common investment level uses less instruments than in the former case, it can be even more effective in facilitating partial tax harmonization between asymmetric regions. We believe that especially this last result can give an explanation for the observed convergence of corporate tax rates in the EU15 at the beginning of this century.

Our analysis is related to several studies. The general model of tax competition has been developed by Zodrow and Mieszkowski (1986) and Wilson (1986) which has shown that the Nash equilibrium capital tax rates chosen by each jurisdiction are not socially optimal.[2] Asymmetries between regions have been first introduced by Bucovetsky (1991) that allows regions to differ in population size. He finds that this kind of asymmetries exacerbates inefficiencies in capital taxation. As a simultaneous tax coordination by all countries is hardly to establish, 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 maintain jointly agreed tax rates. Konrad and Schjelderup (1999) have shown that such a partial tax coordination can increase the welfare of the participating jurisdictions. This depends on the response of jurisdictions from outside of 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 the partial tax coordination in the EU scenario, using a general equilibrium model. Their conclusions suggest that corporate tax coordination would generate moderate welfare growth and all schemes for coordination leave EU member states as winners and others as losers, so it is required to elaborate compensation mechanisms in order to maintain the agreement of coordination. 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 desirable and sustainable in such situation, compared to harmonization or non-cooperative equilibrium. Vrijburg and de Mooij (2010) generalize the analysis of Konrad and Schjelderup (1999), comparing welfare levels and equilibrium tax rates of 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 about 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 all guaran-

[2]See Keen and Konrad (2012) as an overview of the literature for this.

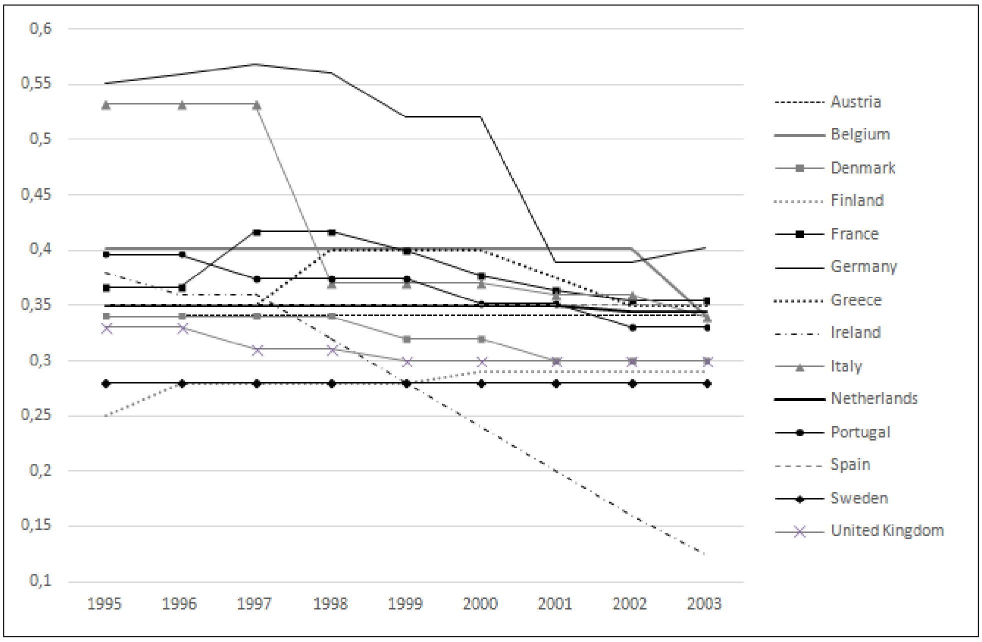

Figure 1: Combined corporate income tax rate of EU-15 countries (except Luxembourg). Source: OECD Tax database.

teed. 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 rather than harmonization, so they would never agree to coordinate their taxes (but 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 to inefficiently low tax rates but also to inefficiently high infrastructure investments. Finally, Han (2013) analyzes how infrastructure investments affect partial tax harmonization between symmetric regions 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 to our paper is that infrastructure investments in his analysis are not subject to coordination between regions 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 concludes. The proofs are in the Appendix.

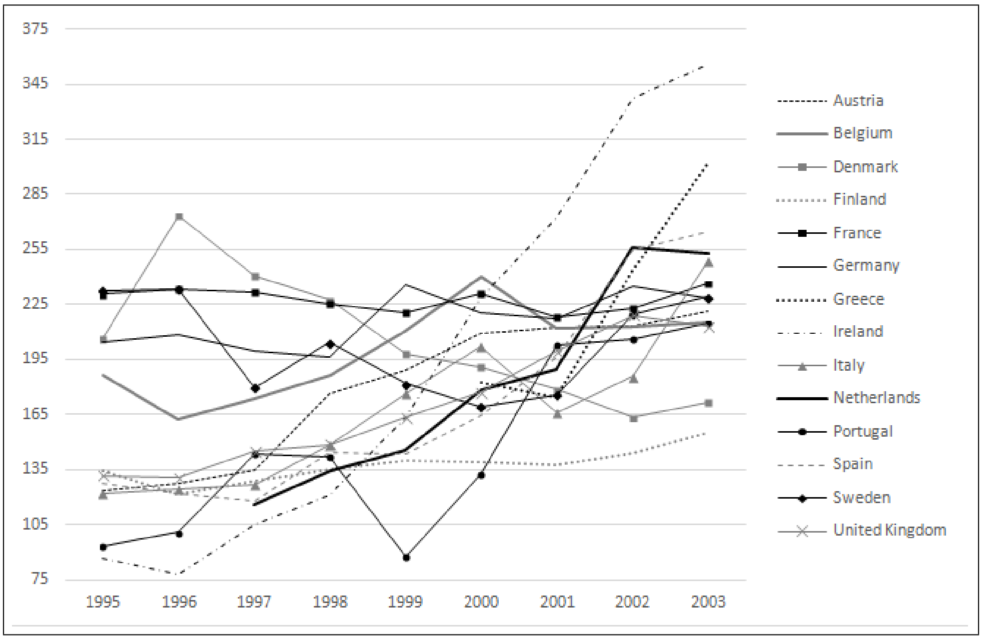

Figure 2: Transport infrastructure investment per capita of EU-15 countries (except Luxembourg). Source: OECD Database.

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 (or regions) and by assuming that governments provide local public goods that enhance the productivity of private firms. To be precise, consider $N = 3$ regions, 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 public goods or infrastructure provided by the government in jurisdiction i at cost $c_i(g_i) = g_i^2/2$ and $\alpha > 0$. Eq. (1) implies that regions even with equal infrastructure investments differ in the level of their productivity levels. Without loss of generality we assume $\epsilon_1 = 0$ and 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:

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

The arbitrage condition together with the market clearing condition ($\sum k_i = 1$) implies that the amount of capital invested in region 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 $i, j, h = 1, 2, 3$; $j \neq i$; $h \neq i, j$.[3]

The tax rates in jurisdiction i are chosen by governments to maximize the welfare W_i of its residents:[4]

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

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 regions 1 and 2 will be able to credibly commit to a common tax rate and therefore consider the formation of a tax coalition. Thus, our assumptions imply that jurisdiction 2 is the more productive region 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 regions ($\epsilon_3 < 0$), or more productive than jurisdiction 1 but less productive than jurisdiction 2 ($0 \leq \epsilon_3 < \epsilon_2$). The timing of the game is as follows. First, in stage 1, regions 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).

3 No infrastructure coordination

3.1 No tax harmonization

First, consider the noncooperative game in which each region chooses its infrastructure investments and capital tax rate separately. In stage 3, the best response function of region i by choosing the tax rate t_i that maximizes welfare given Eq. (3) is:[5]

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

From Eq. (4) we see that tax rates are strategic complements. Furthermore, the optimal tax rate is increasing in the regions and decreasing the infrastructure investments of other

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

[4] 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).

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

regions. On 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, region i chooses the optimal level of infrastructure g_i that maximize welfare which after substitution of the expressions in Eqs. (5) and (2) into (3) it can be written 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 region i is:[6]

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

which means that infrastructure investments are strategic substitutes. On 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) we find the equilibrium tax rates:

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

Using this expression we obtain that capital investments $k_i^N = t_i^N$, infrastructure investments $g_i^N = \frac{8}{9}t_i^N$, and a net return to capital $\rho = \alpha - \frac{19}{27} + \frac{1}{3}\left(\epsilon_i + \epsilon_j + \epsilon_h\right)$. The welfare in region 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 regions we obtain from Eqs. (8) and (9) that infrastructure investments and tax rates are higher in the more productive region (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 regions 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 regions, the Nash equilibrium tax rates and the provision of public goods are inefficiently low and infrastructure investments are inefficiently high.*

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

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 in stage three while the level of infrastructure in stage two is decided separately. We assume that both jurisdictions agree publicly and can credibly commit on a common capital tax rate t_c. Region 3, simultaneously, determines its tax rate t_3. In stage 3, the corresponding best-response functions are:

$$t_c = \frac{4+\epsilon_1+\epsilon_2-2\epsilon_3+g_1+g_2-2g_3+2t_3}{5}, \tag{11}$$

$$t_3 = \frac{2-\epsilon_1-\epsilon_2+2\epsilon_3-g_1-g_2+2g_3+2t_c}{8}, \tag{12}$$

and the stage 3 equilibrium tax rates are:

$$t_c = 1+\frac{\epsilon_1+\epsilon_2-2\epsilon_3+g_1+g_2-2g_3}{6}, \tag{13}$$

$$t_3 = \frac{1}{2}-\frac{\epsilon_1+\epsilon_2-2\epsilon_3+g_1+g_2-2g_3}{12}. \tag{14}$$

In stage 2, as in the previous case, the three regions choose their infrastructure noncooperatively. The reaction functions are:

$$g_i = \frac{138+77\epsilon_i-31\epsilon_j-46\epsilon_3-31g_j-46g_3}{211},\ i,j=1,2; i\neq j, \tag{15}$$

$$g_3 = \frac{6-\epsilon_1-\epsilon_2+2\epsilon_3-g_1-g_2}{16}, \tag{16}$$

and the equilibrium infrastructure investments are given by:

$$g_i^T = \frac{23}{45}+\frac{43}{105}\epsilon_i-\frac{4}{21}\epsilon_j-\frac{23}{105}\epsilon_3,\ i,j=1,2; i\neq j, \tag{17}$$

$$g_3^T = \frac{14}{45}-\frac{8}{105}\epsilon_1-\frac{8}{105}\epsilon_2+\frac{16}{105}\epsilon_3. \tag{18}$$

Substituting Eqs. (17) and (18) into Eqs. (13) and (14) yields the equilibrium tax rates:

$$t_c^T = \frac{16}{15}+\frac{8}{35}\left(\epsilon_1+\epsilon_2-2\epsilon_3\right), \tag{19}$$

$$t_3^T = \frac{7}{15}-\frac{4}{35}\left(\epsilon_1+\epsilon_2-2\epsilon_3\right). \tag{20}$$

Using this expression 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 $g_3^T = \frac{2}{3}t_3^T$. Equilibrium capital per worker is given by $k_1^T = \frac{1}{4}t_c^T - \frac{2}{5}\epsilon_2$, $k_2^T = \frac{1}{4}t_c^T + \frac{2}{5}\epsilon_2$, and $k_3^T = t_3^T$. The net return to capital is $\rho^T = \alpha - \frac{1}{45}\left(49-12\epsilon_2-21\epsilon_3\right)$ and social welfare levels are:

$$W_1^T = \left(\frac{5}{4}t_c^T-\frac{2}{5}\epsilon_2\right)\left(\frac{1}{4}t_c^T-\frac{2}{5}\epsilon_2\right)-\frac{1}{2}\left(\frac{23}{48}t_c^T-\frac{3}{10}\epsilon_2\right)^2, \tag{21}$$

$$W_2^T = \left(\frac{5}{4}t_c^T+\frac{2}{5}\epsilon_2\right)\left(\frac{1}{4}t_c^T+\frac{2}{5}\epsilon_2\right)-\frac{1}{2}\left(\frac{23}{48}t_c^T+\frac{3}{10}\epsilon_2\right)^2, \text{ and} \tag{22}$$

$$W_3^T = \frac{16}{9}\left(t_3^T\right)^2. \tag{23}$$

Regions 1 and 2 will choose a common tax rate when both regions 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 regions in the tax coalition are not too different, i.e., when ϵ_2 is small. The welfare gains from partial tax harmonization for region 2 are larger than for region 1.*

The result obtained in Lemma 2 allows to separate R into two areas which are displayed in Figure 3. Partial tax harmonization is beneficial for regions 1 and 2 if they are not too different in their efficiency levels (i.e., in Area T). If region 2 is much more efficient than region 1, partial tax harmonization is not beneficial for region 1. This is even more the case when the region outside the tax coalition is more productive (see Area N). Regarding the effect of partial tax harmonization, as expected, we find that the regions that form part of the tax coalition increase their tax rates ($t_c^T > t_i^N$ for $i = 1, 2$), while region 3 increases (decreases) its tax rate when its productivity is low (high).[7] Accordingly, in Area T, while regions 1 and 2 gain from tax harmonization, the region outside the tax coalition obtains higher (lower) welfare when its productivity is low (high).[8] Finally, while regions 1 and 2 increase their infrastructure investments after tax harmonization, region 3 increases (decreases) its infrastructure investments when its productivity is low (high).[9] Notice that this implies in light of the result in Lemma 1 that while partial tax harmonization allows to reduce the inefficiencies in tax rates 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 regions 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. Region 3, simultaneously, determines its own level of infrastructure. In stage 3, first, we consider that all regions choose their capital tax rate separately. Thus, stage 3 Nash equilibrium tax rates are given by Eqs. (5). In stage 2, joint welfare maximization of regions 1 and 2 yields following best response functions for infrastructure investments:

$$g_i = \frac{4}{61}\left(3 + 5\epsilon_i - 4\epsilon_j - \epsilon_3 - 4g_j - g_3\right), \; i, j = 1, 2; i \neq j, \quad (24)$$

$$g_3 = \frac{8}{65}\left(3 - \epsilon_1 - \epsilon_2 + 2\epsilon_3 - g_1 - g_2\right) \quad (25)$$

[7] 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 $\epsilon_3 > \frac{1}{2}\epsilon_2 + \frac{133}{87}$.

[8] 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 $\epsilon_3 = 2.1$.

[9] 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 $\epsilon_3 > \frac{1}{2}\epsilon_2 + 0.1155$.

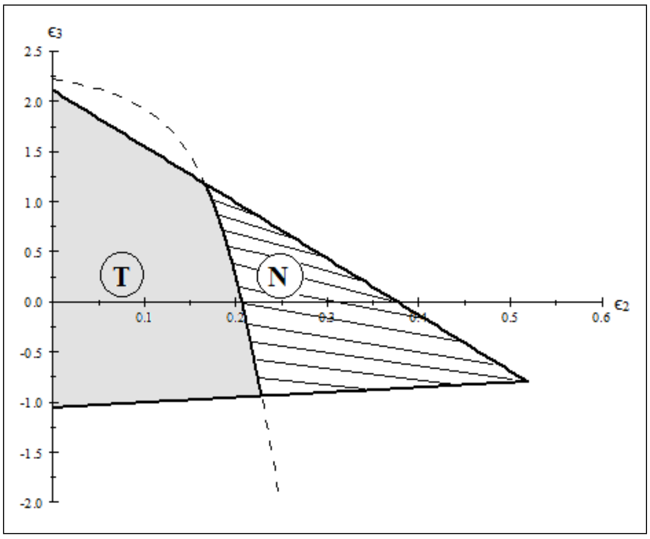

Figure 3: Equilibria under tax harmonization without infrastructure coordination. Equilibria are: *Partial Tax harmonization* (T), *No tax harmonization* (N).

and the Nash equilibrium values:

$$g_i^I = \frac{76}{549} + \frac{4}{305}\left(33\epsilon_i - 28\epsilon_j - 5\epsilon_3\right), \; i, j = 1, 2; i \neq j, \tag{26}$$

$$g_3^I = \frac{184}{549} - \frac{8}{61}\left(\epsilon_1 + \epsilon_2 - 2\epsilon_3\right). \tag{27}$$

Substituting Eqs. (26) and (27) into Eqs. (5) yields the equilibrium tax rates:

$$t_i^I = \frac{19}{61} + \frac{1}{305}\left(114\epsilon_i - 69\epsilon_j - 45\epsilon_3\right), \; i, j = 1, 2; i \neq j, \tag{28}$$

$$t_3^I = \frac{23}{61} - \frac{9}{61}\left(\epsilon_1 + \epsilon_2 - 2\epsilon_3\right). \tag{29}$$

Again, using this expression 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 $g_3^I = \frac{8}{9}t_3^I$. Equilibrium capital per worker is given by $k_1^I = t_1^I$, $k_2^I = t_2^I$, and $k_3^I = t_3^I$. The net return to capital is $\rho^I = \alpha - \frac{437}{549} + \frac{19}{61}\epsilon_2 + \frac{23}{61}\epsilon_3$ and social welfare levels are:

$$W_1^I = 2\left(t_1^I\right)^2 - \frac{1}{2}\left(\frac{4}{9}t_1^I - \frac{4}{15}\epsilon_2\right)^2, \tag{30}$$

$$W_2^I = 2\left(t_2^I\right)^2 - \frac{1}{2}\left(\frac{4}{9}t_2^I + \frac{4}{15}\epsilon_2\right)^2, \text{ and} \tag{31}$$

$$W_3^I = \frac{130}{81}\left(t_3^I\right)^2. \tag{32}$$

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

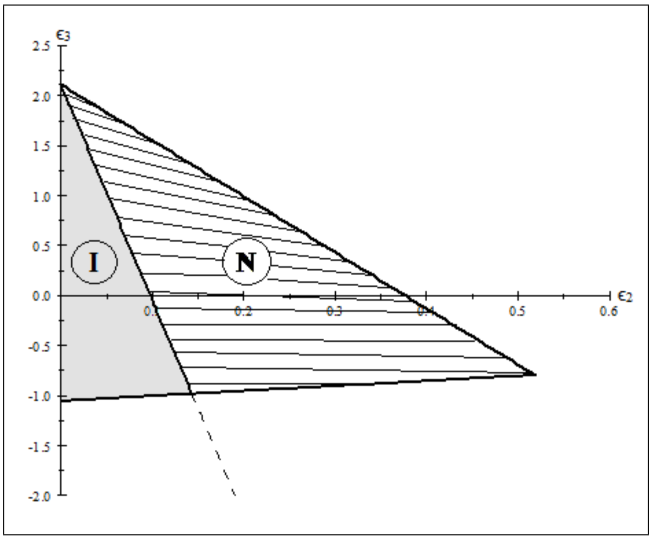

Figure 4: Equilibria in the absence of tax harmonization under infrastructure coordination. Equilibria are: *Infrastructure coordination* (I), *No coordination* (N).

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

From Lemma 3 we see that partial infrastructure coordination will take place when regions 1 and 2 are sufficiently symmetric (Area I in Figure 4), while in case of large asymmetries there will be no infrastructure coordination (Area N in Figure 4). The consequences of a partial coordination of infrastructure investments are a reduction of infrastructure investments in regions 1 and 2 while investments in region 3 increase.[10] Capital tax rates in all regions decrease after infrastructure coordination as regions 1 and 2 try to compensate the loss of attractiveness of their regions due to the reduced infrastructure investments with a tax reduction while region 3 increases its capital tax rate.[11]

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. The stage 3 equilibrium tax rates are the same as in the partial tax coordination case (T) and, thus, are given by Eqs. (13) and (14). In stage 2, joint welfare maximization of regions 1 and 2 yields the following best response

[10] 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 $g_3^I - g_3^N = \frac{32}{31\,293}(9\epsilon_2 - 18\epsilon_3 + 38) > 0$.

[11] 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: $t_3^I - t_3^N = \frac{4}{3477}(9\epsilon_2 - 18\epsilon_3 + 38) > 0$.

functions for infrastructure investments:[12]

$$g_i = \frac{30+41\epsilon_i-31\epsilon_j-10\epsilon_3-31g_j-10g_3}{103}, \; i,j=1,2; i\neq j, \tag{33}$$
$$g_3 = \frac{6-\epsilon_1-\epsilon_2+2\epsilon_3-g_1-g_2}{16}. \tag{34}$$

The equilibrium infrastructure investments are given by:

$$g_i^{TI} = \frac{35}{177}+\frac{32\epsilon_i-27\epsilon_j-5\epsilon_3}{59}, \; i,j=1,2; i\neq j, \tag{35}$$
$$g_3^{TI} = \frac{62}{177}-\frac{4(\epsilon_1+\epsilon_2-2\epsilon_3)}{59}. \tag{36}$$

Substituting Eqs. (35) and (36) into Eqs. (13) and (14) yields the equilibrium tax rates:

$$t_c^{TI} = \frac{56}{59}+\frac{12}{59}(\epsilon_1+\epsilon_2-2\epsilon_3), \tag{37}$$
$$t_3^{TI} = \frac{31}{59}-\frac{6}{59}(\epsilon_1+\epsilon_2-2\epsilon_3). \tag{38}$$

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 $g_3^{TI}=\frac{2}{3}t_3^{TI}$. Equilibrium capital per worker is given by $k_1^{TI}=\frac{1}{4}t_c^{TI}-\frac{1}{2}\epsilon_2$, $k_2^{TI}=\frac{1}{4}t_c^{TI}+\frac{1}{2}\epsilon_2$, and $k_3^{TI}=t_3^{TI}$ and the net return to capital is $\rho^{TI}=\alpha-\frac{217}{177}+\frac{1}{59}(14\epsilon_2+31\epsilon_3)$. Social welfare levels in the different regions are:

$$W_1^{TI} = \left(\frac{5}{4}t_c^{TI}-\frac{1}{2}\epsilon_2\right)\left(\frac{1}{4}t_c^{TI}-\frac{1}{2}\epsilon_2\right)-\frac{1}{2}\left(\frac{5}{24}t_c^{TI}-\frac{1}{2}\epsilon_2\right)^2, \tag{39}$$
$$W_2^{TI} = \left(\frac{5}{4}t_c^{TI}+\frac{1}{2}\epsilon_2\right)\left(\frac{1}{4}t_c^{TI}+\frac{1}{2}\epsilon_2\right)-\frac{1}{2}\left(\frac{5}{24}t_c^{TI}+\frac{1}{2}\epsilon_2\right)^2, \text{ and} \tag{40}$$
$$W_3^{TI} = \frac{16}{9}\left(t_3^{TI}\right)^2. \tag{41}$$

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 lets us expect that partial tax harmonization is easier to achieve when regions in the tax coalition coordinate their infrastructure investments. The following result states this formally.

Proposition 4 *Infrastructure coordination between asymmetric regions that form a tax coalition can facilitate (hinder) partial tax harmonization when the productivity level of the region outside the coalition is low (large).*

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

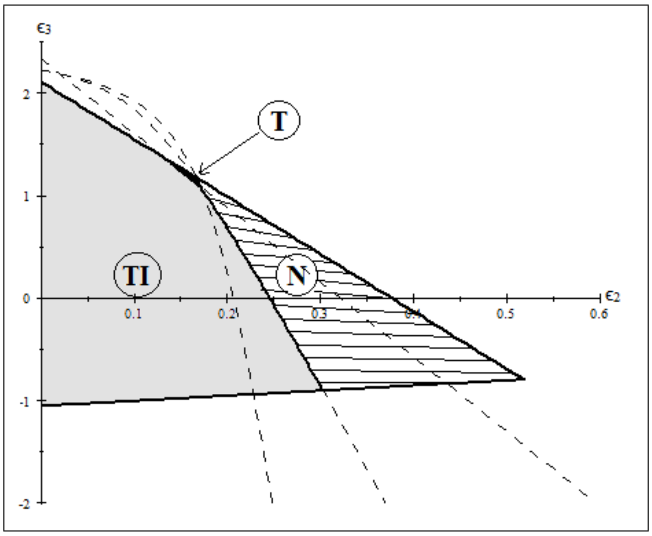

Figure 5: Equilibria under tax harmonization with infrastructure coordination. Equilibria are: *Partial Tax harmonization with Infrastructure coordination* (TI), *Partial Tax harmonization without infrastructure coordination* (T), *No coordination* (N).

From Lemma 3 we know that both regions gain from infrastructure coordination when their productivity levels are not too different. Comparing Figures 3 and 5, we observe that these additional gains enlarge the area in which partial tax harmonization is welfare enhancing for both regions (Area TI in Figure 5). Therefore, we have that infrastructure coordination allows to reach partial tax harmonization agreements between asymmetric regions 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 regions that form the tax coalition increase tax rates and decrease infrastructure investments when region 3's productivity is not too high. This means that both kind of inefficiencies (two low tax rates and too high infrastructure investments) are reduced inside the tax coalition in this case. When region 3's productivity is large, the only difference is that region 2 increases its infrastructure investments instead of decreasing them[13] Regarding the region outside the tax coalition we find that its behavior crucially depends on its productivity level. When region 3's productivity is low, it increases capital tax rates and infrastructure investments. Instead, when region 3's productivity is high, it decreases capital tax rates and infrastructure investments.[14]

[13]From Eqs. (9) and (37): $t_c^{TI} - t_1^N = \frac{1}{3363}(2071 + 1215\epsilon_2 - 837\epsilon_3) > 0$ 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 (35) 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 $g_2^{TI} - g_2^N = \frac{-1}{30\,267}(2983 - 7920\epsilon_2 - 1683\epsilon_3)$.

[14]This can be observed immediately from Eqs (9) and (38) as $t_3^{TI} - t_3^N = \frac{1}{3363}(189\epsilon_2 - 378\epsilon_3 + 646)$ and from Eqs. (8) and (36) as $g_3^{TI} - g_3^N = \frac{2}{30\,267}(1098\epsilon_2 - 2196\epsilon_3 + 817)$.

5 Infrastructure coordination through a common investment level

5.1 No tax harmonization

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

$$g_c = \frac{2}{77}\left(6+\epsilon_1+\epsilon_2-2\epsilon_3-2g_3\right), \tag{42}$$

$$g_3 = \frac{8}{65}\left(3-\epsilon_1-\epsilon_2+2\epsilon_3-2g_c\right) \tag{43}$$

and the Nash equilibrium values:

$$g_c^{IC} = \frac{2}{61}\epsilon_1+\frac{2}{61}\epsilon_2-\frac{4}{61}\epsilon_3+\frac{76}{549}, \tag{44}$$

$$g_3^{IC} = \frac{16}{61}\epsilon_3-\frac{8}{61}\epsilon_2-\frac{8}{61}\epsilon_1+\frac{184}{549}. \tag{45}$$

Substituting Eqs. (44) and (45) into Eqs. (5) yields the equilibrium tax rates:

$$t_i^{IC} = \frac{19}{61}+\frac{1}{183}\left(44\epsilon_i-17\epsilon_j-27\epsilon_3\right), \tag{46}$$

$$t_3^{IC} = \frac{23}{61}-\frac{9}{61}\left(\epsilon_1+\epsilon_2-2\epsilon_3\right). \tag{47}$$

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 $g_3^{IC} = \frac{8}{9}t_3^{IC}$. Equilibrium capital per worker is given by $k_1^{IC} = t_1^{IC}$, $k_2^{IC} = t_2^{IC}$, and $k_3^{IC} = t_3^{IC}$. The net return to capital is $\rho^{IC} = \alpha - \frac{437}{549} + \frac{19}{61}\epsilon_2 + \frac{23}{61}\epsilon_3$ and social welfare levels are:

$$W_1^{IC} = 2\left(t_1^{IC}\right)^2-\frac{1}{2}\left(\frac{4}{9}t_1^{IC}+\frac{2}{27}\epsilon_2\right)^2, \tag{48}$$

$$W_2^{IC} = 2\left(t_2^{IC}\right)^2-\frac{1}{2}\left(\frac{4}{9}t_2^{IC}-\frac{2}{27}\epsilon_2\right)^2, \text{ and} \tag{49}$$

$$W_3^{IC} = \frac{130}{81}\left(t_3^{IC}\right)^2. \tag{50}$$

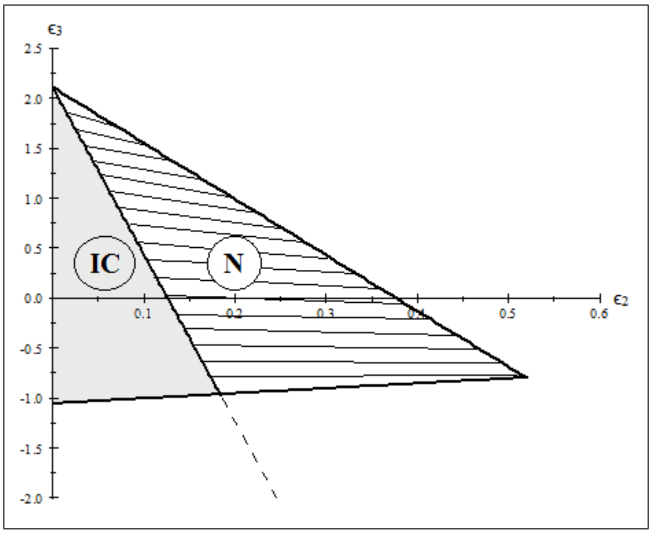

Figure 6: Equilibria in the absence of tax harmonization under infrastructure coordination through common investments. Equilibria are: *Infrastructure coordination with Common investment levels* (IC), *No coordination* (N).

Lemma 5 *For given ϵ_3, $\exists(\epsilon_2, \epsilon_3) \in R$ partial infrastructure coordination with common investment levels takes place when the regions in the tax coalition are not too different, i.e., when ϵ_2 is small. The welfare gains from partial infrastructure coordination with common investment levels for region* 1 *are larger than for region* 2.

Comparing Lemmas 3 and 5, 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 regions inside the coalition have similar productivity levels. However, while under infrastructure coordination with different investment levels the more productive region (region 2) obtains larger welfare gains, under infrastructure coordination with a common investment level it is the less productive region (region 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 regions 1 and 2 and, therefore, makes region 1 more and region 2 less attractive for capital investments. Infrastructure coordination allows regions 1 and 2 to reduce infrastructure investments and, thus, to reduce inefficiencies in these investments while tax rates are also decreased which increases inefficiencies.[15] Instead, the region outside the tax coalition increases infrastructure investments and tax rates.[16]

[15] From Eqs. (9) (8), (46) and (44) 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 6.

[16] From Eqs (9), (8), (45) and (47) 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 6.

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. The stage 3 equilibrium tax rates are the same as in the partial tax coordination case (T) and, thus, are given by Eqs. (13) and (14). In stage 2, joint welfare maximization of regions 1 and 2 yields the following best response functions for infrastructure investments:

$$g_c = \frac{15}{67} + \frac{5}{134}\epsilon_1 + \frac{5}{134}\epsilon_2 - \frac{5}{67}\epsilon_3 - \frac{5}{67}g_3, \text{ and} \tag{51}$$

$$g_3 = \frac{3}{8} - \frac{1}{16}\epsilon_1 - \frac{1}{16}\epsilon_2 + \frac{1}{8}\epsilon_3 - \frac{1}{8}g_c. \tag{52}$$

The equilibrium infrastructure investments are given by:

$$g_c^{TIC} = \frac{35}{177} + \frac{5(\epsilon_1 + \epsilon_2 - 2\epsilon_3)}{118}, \text{ and} \tag{53}$$

$$g_3^{TIC} = \frac{62}{177} - \frac{4(\epsilon_1 + \epsilon_2 - 2\epsilon_3)}{59}. \tag{54}$$

Substituting Eqs. (53) and (54) into Eqs. (13) and (14) yields the equilibrium tax rates:

$$t_c^{TIC} = \frac{56}{59} + \frac{12}{59}(\epsilon_1 + \epsilon_2 - 2\epsilon_3), \tag{55}$$

$$t_3^{TIC} = \frac{31}{59} - \frac{6}{59}(\epsilon_1 + \epsilon_2 - 2\epsilon_3). \tag{56}$$

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 $g_3^{TIC} = \frac{2}{3}t_3^{TIC}$. Equilibrium capital per worker is given by $k_1^{/TIC} = \frac{1}{4}t_c^{TIC} - \frac{1}{4}\epsilon_2$, $k_2^{TIC} = \frac{1}{4}t_c^{TIC} + \frac{1}{4}\epsilon_2$, and $k_3^{TIC} = t_3^{TIC}$ and the net return to capital is $\rho^{TIC} = \alpha - \frac{217}{177} + \frac{1}{59}(14\epsilon_2 + 31\epsilon_3)$. Social welfare levels in the different regions are:

$$W_1^{TIC} = \left(\frac{5}{4}t_c^{TIC} - \frac{1}{4}\epsilon_2\right)\left(\frac{1}{4}t_c^{TIC} - \frac{1}{4}\epsilon_2\right) - \frac{1}{2}\left(\frac{5}{24}t_c^{TIC}\right)^2, \tag{57}$$

$$W_2^{TIC} = \left(\frac{5}{4}t_c^{TIC} + \frac{1}{4}\epsilon_2\right)\left(\frac{1}{4}t_c^{TIC} + \frac{1}{4}\epsilon_2\right) - \frac{1}{2}\left(\frac{5}{24}t_c^{TIC}\right)^2, \text{ and} \tag{58}$$

$$W_3^{TIC} = \frac{16}{9}\left(t_3^{TIC}\right)^2. \tag{59}$$

Proposition 6 *Infrastructure coordination through the choice of a common investment level allows partial tax harmonization between asymmetric regions that cannot be achieved by infrastructure coordination with different investment levels. This is the case when region 2's productivity is large and the productivity of the region outside the tax coalition is low.*

A comparison of Figures 5 and 7 shows that partial infrastructure coordination in which regions agree upon a common investment level allows to reach an agreement on

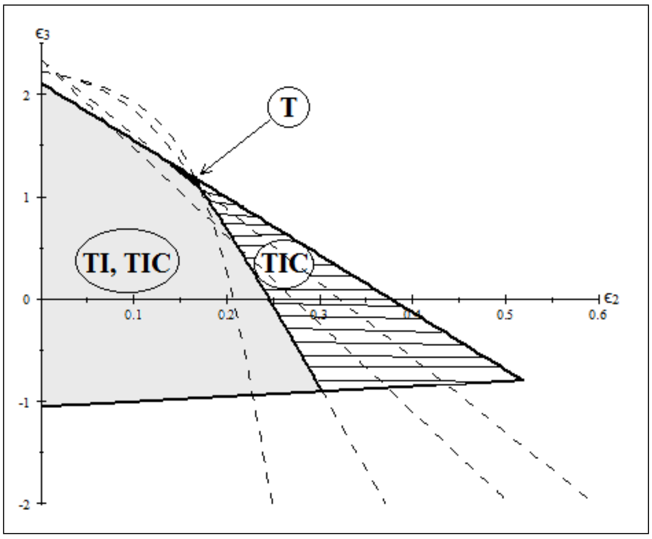

Figure 7: Equilibria under tax harmonization with infrastructure coordination through common investments. Equilibria are: *Partial Tax harmonization with Infrastructure coordination through Common investment levels* (TIC), *Partial Tax harmonization with Infrastructure coordination with different investment levels* (TI), *Partial Tax harmonization without infrastructure coordination* (T).

partial tax harmonization that cannot be achieved under infrastructure coordination with different investment levels. This is the case when regions 1 and 2 are fairly asymmetric and region 3's productivity is high (i.e., in area TIC in Figure 7). This result is obtained because under partial tax harmonization with infrastructure coordination through *a common* investment level even when regions are asymmetric, region 1 gains from infrastructure coordination (see Lemma 5) while region 2 gains from tax coordination (see Lemma 2). Under partial tax harmonization with infrastructure coordination through different investment levels only the more prodcutive region (i.e., region 2) gains from the formation of a tax coalition when asymmetries in the tax coalition are high. Comparing both kinds of infrastrucutre coordination we also observe from Eqs. (37) and (55) that tax rates are the same in both cases ($t_c^{TIC} = t_c^{TI}$) while region 1 (region 2) inverts more (less) in infrastructures under infrastructure coordination through a common investment level.[17] The region outside the tax coalition chooses the same capital tax rate and infrastructure investment in both cases.[18]

6 Conclusions

Tax harmonization has become an important concern in most developed economies because tax competition has constantly decreased capital tax rates over the last decades which has lead to a shift of the tax burden from capital towards labor. As the global

[17]As $t_c^{TIC} = t_c^{TI}$, from Eqs. (35) and (55) 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 $g_2^{TI} = \frac{5}{24}t_c^{TI} + \frac{1}{2}\epsilon_2 > \frac{5}{24}t_c^{TIC} = g_c^{TIC}$.

[18]See Eqs. (38), (36), (56) and (54).

harmonization of capital taxation is hardly to achieve, 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: 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 allows to explain the observed harmonization of corporate tax rates in the EU15 between 1995 and 2003 where a simultaneous convergence of public infrastructure investments facilitated via EU structural funds took place.

Our result has an important policy implication. As asymmetries between jurisdictions are an important handicap to accomplish 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 an harmonization of tax rates in the tax coalition.

Our analysis opens also 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 regions. 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 jurisdiction 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 regions 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 regions 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 regions 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 regions ($0 < \mu < g_i^N$, $\forall i$). 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 (22) we have:

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

Region 2 is always better off under partial tax harmonization. Regarding region 1, from Eqs. (10) and (21) we have:

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

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 regions 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 region 2. ■

Proof of Lemma 3. From Eqs. (10), (30) and (31) 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, region 2 always gains from infrastructure coordination when region 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 regions 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 4. First, consider region 2. We have:

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

Region 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 region 1 we have:

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

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 regions 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:

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

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 regions 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 3):

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 regions.

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 region 1 does not agree to coordinate infrastructure investments which is the preferred outcome for region 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 region 1 loses from both partial tax harmonization and partial tax harmonization with infrastructure coordination.

■

Proof of Lemma 5. From Eqs. (10), (48) and (49) 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. Region 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 6. First, consider region 1. From Eqs (10), (21), (39), and (57) we have that region 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 region 2. From Eqs. (10) and (58) we have that region 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 regions are better off under TIC than under N, No harmonization (N) is not an equilibrium. Furthermore, from Eqs. (22) and (58) 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 regions 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. (40) and (58) we have:

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

This result implies that among both forms of tax harmonization with infrastructure coordination region 2 prefers infrastructure coordination with *different* investment levels while region 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 7):

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 regions 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 region 1 does not agree to coordinate infrastructure investments with different investment levels which is the preferred outcome for region 2 and region 2 does not agree to coordinate infrastructure investments with a common investment level which is the preferred outcome for region 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 regions prefer partial tax harmonization with infrastructure coordination with a common investment level to no coordination and partial tax harmonization without infrastructure coordination is less preferred by region 1 to no coordination.

■