Optimal Taxation under Commitment: International Public Goods and Imperfect Capital Mobility

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Abstract

We consider a two-country RBC world, where each jurisdiction is able to borrow or lend to the other in the form of foreign assets, bearing some kind of mobility cost. Under the assumption of perfect capital mobility between the two countries and if tax authorities are able to commit on their non-cooperative future policy, then they will engage in a tax reduction race, which eventually will result in inefficiently low capital tax rates and an underprovided public good. However, as our study points out, this is far from what is predicted by the theory as a race to the bottom. The existence of extremely high mobility costs renders our economy practically closed and any benefit from cooperation tends to be eliminated. Furthermore, the introduction of asymmetry in our model enhances the effect of coordination versus competition, confirming the standard theoretical and empirical finding that, in terms of welfare, tax jurisdictions are better off if they cooperate. We also find that it is the combination of international capital mobility and international public goods, that maximizes the welfare gains from cooperation, although the interaction of the associated spillovers is non linear.

1 Introduction

Capital tax competition is an ongoing debate among the economists and raises concerns in developed countries quite a few years now. The dominating view in Europe is that tax competition tends to push capital taxes into undesirably low levels. In the core of this analysis is the view that taxes from abroad are hard to collect, therefore, in order to generate enough revenues, government must tax capital income at the source. Additionally, if we assume that capital is perfectly mobile across countries, then source-based capital taxation leads to capital flight. Therefore, if governments' target is to attract foreign capital, they will participate in a capital tax reduction race which would unavoidably push the source-based capital taxes to zero. If, instead, governments share information that would enable them to harmonize their tax policies regarding foreign-source income, things would be different.

However, the empirical foundation for this traditional view, on the impact of perfect capital mobility on capital tax rates, is rather mixed. In the first years of 1980, the integration of European financial markets enabled near-perfect capital mobility across countries. According to *Mendoza and Tesar* [26], the years that followed, tax competition came across different stages with puzzling results. Instead of the *"race to bottom"* in capital taxes, the UK reduced its capital tax to a rate closer to those of France, Germany and Italy, while capital tax rates displayed only minor fluctuations in these countries. Following the ambiguous impact of tax competition, the views on this matter also varied widely across countries and over time. In 1997, the official European position was that tax competition was harmful and needed to be restricted. On the contrary, by 2001, the EU commissioner regarded the tax burden as excessive and competition was seen as a healthy way to reduce it. Several key EU politicians insisted that tax competition was harmful and needed to be addressed. France and Germany were among the countries that supported tax harmonization, while Britain and Ireland were among the countries that promoted tax competition.

In general, international economics qualify the need for international coordination regarding tax policy, since non-cooperative strategies usually lead to suboptimal outcomes. As the economies become more integrated, the respective jurisdictions increase their degree of engagement in tax competition phenomena, resulting in contraction of their revenues and under-provision of the public good, with significant welfare loss. To reverse this situation, the relevant literature suggests that countries should cooperate. However, the welfare gains from cooperation are not that significant qualitatively. Several studies support that the welfare gains from coordinated tax policies do not exceed 1 percent of gross domestic product, regardless of the specification or other policy scenarios. Nevertheless, the impact on total output is more pronounced.

The purpose of this paper is to revisit the fundamental assumptions of international economics on policy coordination. From the point of view of a Ramsey (benevolent) policymaker, tax harmonization makes countries better off, in terms of welfare. We depart from most of the related literature not only by incorporating an international public good (see *Kammas and Philippopoulos, 2009*)[19], but also by utilizing a richer model setup with elastic labor supply. Furthermore, we consider the case where countries differ in their level of productivity and we find out that the argument in favor of cooperation over competition is even stronger in the case of asymmetric countries. We claim that it is the combination of international capital mobility and international public goods, that maximizes the welfare gains from cooperation, although the interaction of the associated spillovers is non linear.

First of all, an international public good is a public good, the consumption of which does not exhaust its availability for others and the exclusion of consumers is impossible. The term "international" refers to its benefits that may extend beyond national boundaries. Various such goods have been identified, such as defence policy, environmental quality, well-defined property rights, an open trading system, etc. In addition, EU member states witness positive spillovers and economies of scale for internal security and immigration policy. Thus, the importance of international public goods in modern economies motivates sufficiently their incorporation in our model. As it will become clear, the abovementioned results vary substantially once we introduce international public goods.

We consider a two-country, two-period general equilibrium model where consumers value government consumption. The specification is quite similar to *Persson and Tabellini (1992)*[30], *Kammas and Philippopoulos (2009)* and *Klein et al (2017)*[14], yet our version allows for a logarithmic utility function and elastic labor supply, sacrificing tractability over flexibility. Strategic interaction is present, in the sense that each jurisdiction applies taxes on capital and labor, in order to finance its second-period expenditures. Capital is mobile between countries, while labor is not, and the representative agent from each country may invest capital(Foreign Direct Investment) in any country, subject to mobility costs. The cross-country spillovers stem out of the international capital mobility and the international public good. The first one leads to the well-know tax competition effect, while the second one causes the free riding problem on the other country's contribution.

In the first part of the paper, we assume that governments in each country behave as Ramsey planners, choosing their tax policy in the beginning of the period, through cooperation or non-cooperation. The model predicts that in the case of non-cooperative policies, tax authorities will engage in a tax reduction race, with clear welfare loss. On the other hand, the increased capital tax rates under cooperation, result in improved welfare, as the openness of the global market increases(perfect capital mobility).

The complexity of the model implies that the only possible solution can be derived numerically. We observe that, in equilibrium, welfare gain from cooperation is quantitatively small, even in the case of perfect capital mobility. In addition, as mobility costs increase, any advantage from cooperation vanishes and the cooperative solution coincides with the Nash solution. The idea is that low tax rates may harm the provision of the public good, but they are good for investment and future consumption. On the other hand, the cooperative solution contributes more to the public good, however higher capital tax rates discourage investors and consumers. This is already shown in Mendoza and Tesar (2005).

Once international public goods are inserted into the utility function, welfare changes drastically and the Nash solution differentiates from the cooperative one. We claim that the spillover stemming out of the international public good reinforces the effect of perfect capital mobility. Thus, when tax policy is chosen by Ramsey policymakers, in a two-country world with international public goods, the well-known theoretical and empirical finding that cooperation makes all countries better off, is confirmed.

2 Literature

Capital tax competition has raised cause for concerns in EU policy circles for a long time. Both *OECD (1998)*[37] and *European Commission (2001)* consider tax competition a harmful practice that needs to be restrained. In fact, it is hard to collect taxes on income from abroad, so governments instead should tax capital income at the source to generate sufficient revenues. Moreover, if capital is mobile across countries, taxing capital income would lead to capital flight. Given that tax authorities do not share information to tax foreign-source income, a capital tax policy will trigger a tax competition for capital inflows. Thus, tax competition tends to inefficiently low capital taxes, along with reduced capital tax revenues and underprovision of the public good.

Zodrow and Mieszkowski (1986)[39] implement a model with identical tax authorities to show that competition for mobile capital leads to reduced tax rates, compared to a closed-economy setting. If we assume that there is an increase in the domestic capital tax rate, the domestic net rate of return on capital will decrease leading to capital outflow. The foreign capital tax-bases would grow, and tax foreign tax revenues would rise, triggering a positive externality. This implies that capital tax rates set under integrated capital markets, would be lower compared to the situation when capital is immobile.

Cooper (1988)[9] is concerned with strategic complementarity in agents' payoff functions and shows how these complementarities and spillovers may lead to coordination failures, such as multiple, Pareto-ranked equilibria and a multiplier process associated with changes in exogenous variables.

Bucovetsky and Wilson (1991)[5] stress out the importance of opening a region's borders to capital flows. Their model also incorporates a wage tax and shows that smaller economies choose to impose a zero-capital tax rate, given that income can only be taxed at the source. Nevertheless, the well-known problem of the under-provision of the public good is also present at their work.

Correia (1996)[10] shows that in a small open economy framework, where only source-based capital taxes are available, and the net world interest rate is exogenous and invariant, capital variations do not alter drastically the optimal tax path of the closed economy. When perfect capital mobility is introduced, the optimal choice of capital taxes does not change substantially. However, the optimal decisions in the open economy (e.g. *Razin and Sadka (1991)[33]*) almost coincide to the closed economy solution (*Feldstein (1978)*[11]), when the system of taxation is the worldwide, and change significantly when the territorial system is used.

Lejour and Verbon (1997)[25] and *Koethenbuerger and Lockwood (2010)*[24] assume the existence of a negative cross-border tax externality because of a preference on the part of households for portfolio diversification. Their model setup does not include intertemporal externality and in fact, if the assumption of a preference for diversification is removed, the standard "race-to-the bottom" result arises. In addition to this, both *Lejour and Verbon (1997)* and *Koethenbuerger and Lockwood (2010)* assume only balanced growth paths, as well as a savings rate which is independent of the rate of return on capital.

Persson and Tabellini (2000)[31] prove that tax competition between two symmetric countries results in inefficiently low capital tax rates, with negative consequences on global welfare. The distortion is greater the more mobile is capital. Perfect capital mobility implies zero tax rates on capital and both countries tax only labor.

According to *Wildasin (2003)*[38], capital tax rate decreases with the mobility of capital, confirming the traditional view. The model describes a small open economy where the adjustment of capital inputs comes at an adjustment cost, the net world interest rate is exogenous, capital taxes are time-invariant and there are also lump-sum taxes.

Mendoza and Tesar (2005) observe that the integration of European financial markets in the 1980s allowed capital to move almost-freely across countries with harmonized indirect taxes, but largely differentiated factor taxes. The years that followed, capital tax competition provided ambiguous results on whether a "race to the bottom" took place. Specifically, the UK lowered its capital tax to a rate closer to those of France, Germany and Italy, while capital taxes changed slightly in these countries. *Mendoza and Tesar* utilize a Neoclassical growth model of tax competition, with the basic international externalities of tax policy, that is in line with the facts of the aforementioned period.

Klein et al. (2005)[23] and *Quadrini (2005)*[32] incorporate limited commitment of tax policy in a fully dynamic open economy model of optimal taxation. Their analysis is limited at the steady state of asymmetric countries and how this is affected using capital and labor taxes. *Quadrini (2005)* introduces capital mobility and shows that there is a sudden decrease in capital tax rates. *Kammas and Philippopoulos (2009)*, provide a quantitative assessment of the welfare benefit of international tax policy coordination. They find that in a world economy with international capital mobility and international public goods, the welfare gains from cooperation can be really big, although in the absence of international public goods the quantitative difference of cooperative and non-cooperative case is negligible.

Gross (2014)[13] studies large open economies and finds that in the long-run capital tax rates are zero, a result which was established in *Chamley (1986)*[6] and *Judd (1985)*[18]. This outcome is robust whether the jurisdictions set their policy cooperatively or not, and is independent of the degree of capital mobility, the number of countries, or a country's size relative to the rest of the world. *Klein et al. (2017)* focus on the same model as *Gross (2014)* and they extend their analysis not only on the long-run equilibrium, but also on the transition to the steady state. They solve an optimal taxation problem under commitment, treating the other government's policies as given. Numerically, source-based capital taxes are initially positive and slowly decline towards zero.

Chari et al. (2018)[7] study alternative setups of the Ramsey allocation including residence-based taxation of equity returns, foreign asset returns and firms profits. They also consider value-added taxes with and without border adjustments and argue that, given standard preferences, free trade is optimal in the second best allocation and capital tax should be zero in the steady state. Also, they find no evidence that capital should be taxed along the transition.

[12]

3 World Economy

The world economy is composed of two identical countries, indexed by h and f, (i.e. home and foreign country respectively). Each country is inhabited by a representative agent and regarding the tax authorities we make the following assumptions. In the first part of our analysis we focus on benevolent Ramsey national governments. The private agents of each country consume at home and invest at home and abroad, bearing a mobility or transaction cost. The government in each country employs two policy instruments, tax on domestic and foreign capital invested in the home country, and tax on labor, to finance the provision of a public good with international benefits. Domestic and foreign investors are taxed at the same rate, following the source principle of taxation.

Sequence of Events

In the beginning of the game, governments choose, once-and-for-all, their tax policies and their contributions to the public good. In turn, private agents decide how much they will consume(present and future), work and invest(home and abroad). To derive the World Competitive Equilibrium for any feasible tax policies, we work with backward induction, solving the private agents' problem by taking prices and policies as given. Next, we solve for Nash national tax policies, in the sense that each government chooses its own tax rates optimally, subject to the WCE and taking as given the policies of the other government. Finally, we also solve for cooperative policies and compare the welfare values.

Our model is similar to the one used by *Persson and Tabellini (1992)* and *Kammas and Philippopoulos (2009)*. The differences are that we use a fully logarithmic utility function compared to the log-linear utility, used by the aforementioned authors, and the production function includes both capital and labor. We also add an international public good in a two-country version of the model, as in *Bjorvatn and Schjelderup (2002)*[3]. The two countries produce the same commodity.

3.1 Households

The representative household in country i maximizes

$$U = \mu_1 \log(c_{i,1}) + \beta^i \{\mu_1 \log(c_{i,2}) + \mu_2 \log(1 - l_{i,2}) + \mu_3[\log(g_{i,2}) + \theta \log(g_{j,2})]\} \tag{1}$$

where $c_{i,1}$ and $c_{i,2}$ are private consumption in first and second period respectively, and $g_{i,2}$ and $g_{j,2}$ are the public goods produced in the two countries, where $i \neq j$. Moreover, $0 \leq \beta^i \leq 1$ is the time preference rate in country i and $0 < \mu_1 < 1$, $0 < \mu_2 < \mu_1$, $\mu_3 = 1 - \mu_1 - \mu_2$, $0 \leq \theta \leq 1$, are the weights given to private consumption, labor, public spending and international public good respectively. The household maximizes (1) subject to the budget constraints of the two periods:

$$c_{i,1} + k_{i,2} + f_{i,2} = e_{i,1} \tag{2}$$

$$\begin{aligned} c_{i,2} + k_{i,3} + f_{i,3} =& (1 + (1 - \tau^i_{k,2}) r_{i,2} - \delta^i) k_{i,2} + (1 - \tau^i_{l,2}) w_{i,2} l_{i,2} \\ &+ (1 + (1 - \tau^j_{k,2}) r_{j,2} - \delta^j) f_{i,2} - m_{i,2} \frac{f^2_{i,2}}{2} \end{aligned} \tag{3}$$

The first-period budget constraint implies that the initial endowment, $e_{i,1}$, may be consumed, $c_{i,1}$, invested at home, $k_{i,2}$, or invested abroad, $f_{i,2}$. In the second period, income from capital and labor is taxed at rates $0 \leq \tau^i_{k,2} \leq 1$, $0 \leq \tau^i_{l,2} \leq 1$, $0 \leq \tau^j_{k,2} \leq 1$ and $0 \leq \tau^j_{l,2} \leq 1$, while capital invested abroad is subject to mobility cost, $m_{i,2} \geq 0$. A zero value of mobility cost implies perfect capital mobility, while as $m_{i,2}$ goes to infinity, capital is completely immobile. The household takes as given government-determined capital and labor tax rates, and the gross factor payment rates, $r_{i,2}$, $w_{i,2}$, $r_{j,2}$ and $w_{j,2}$.

Private agents choose their consumption, leisure and investment, by taking policy variables as given. The first-order conditions with respect to $k_{i,2}$, $f_{i,2}$ and $l_{i,2}$ are

$$c_{i,2} = \beta^i \Big[1 + (1 - \tau^i_{k,2}) r_{i,2} - \delta^i\Big] c_{i,1} \tag{4}$$

$$c_{i,2} = \beta^i \Big[(1 + (1 - \tau^j_{k,2}) r_{j,2} - \delta^j) - m_{i,2} f_{i,2}\Big] c_{i,1} \tag{5}$$

$$l_{i,2} = 1 - \frac{\mu_2 c_{i,2}}{\mu_1 (1 - \tau^i_{l,2}) w_{i,2}} \tag{6}$$

so that $(1 - \tau^i_{k,2}) r_{i,2} - \delta^i = \Big[(1 - \tau^j_{k,2}) r_{j,2} - \delta^j\Big] - m_{i,2} f_{i,2}$, i.e. net returns are equalized.

3.2 Firms

Firms operate in the second period and maximize their profits, taking factor prices as given. Their profits are given by:

$$\Pi_{i,2} = y_{i,2} - r_{i,2}K_{i,2} - w_{i,2}L_{i,2} \tag{7}$$

where $y_{i,2}$ is firm's output and $K_{i,2}$, $L_{i,2}$ are the two inputs(capital and labor) employed by the firm. Notice that the capital demanded by the firm is the sum of the capital invested at home by the domestic and foreign investors.

$$K_{i,2} = k_{i,2} + f_{j,2} \tag{8}$$

The production function is Cobb-Douglas:

$$y_{i,2} = A^i(K_{i,2})^{\alpha^i}(L_{i,2})^{1-\alpha^i},\ 0 < \alpha^i < 1, \tag{9}$$

where α^i is the capital income share in country i. We assume that firms produce one composite final good under perfect competition, hence they earn zero profits in equilibrium.

Firms choose $K_{i,2}$ and $L_{i,2}$ acting competitively:

$$r_{i,2} = \frac{\alpha^i y_{i,2}}{K_{i,2}} \tag{10}$$

$$w_{i,2} = \frac{(1-\alpha^i)y_{i,2}}{L_{i,2}} \tag{11}$$

so that in equilibrium they receive zero profits, $\Pi_{i,2} = 0$.

3.3 Public Sector

The government in each country collects tax revenues to finance its public spending, subject to the budget constraint of the second period:

$$g_{i,2} = \tau^i_{k,2} r_{i,2}(k_{i,2} + f_{j,2}) + \tau^i_{l,2} l_{i,2} w_{i,2} \tag{12}$$

where $\tau^i_{k,2}, \tau^i_{l,2}$ and g^i_2 are the three fiscal policy instruments employed by the government, out of which only two can be independently set. In what follows we treat $g_{i,2}$ as the residually determined policy instrument.

3.4 World Competitive Equilibrium(for any feasible policy)

A *World Competitive Equilibrium* for this two-country world economy is defined by sequence of prices $\{r_{h,2}, r_{f,2}, w_{h,2}, w_{f,2}\}$ and allocations $\{c_{h,1}, c_{h,2}, c_{f,1}, c_{f,2}, k_{h,2}, k_{f,2}, l_{h,2}, l_{f,2}, f_{h,2}, f_{f,2}\}$ such that: (a) households in each country maximize utility subject to their corresponding budget constraints, and the no-Ponzi-game constraints, taking as given pre-tax prices, factor rental rates, the values of all fiscal policy variables and initial capital stock, (b) firms maximize profits subject to the Cobb-Douglas technologies taking as given pre-tax factor prices, (c) the government budget constraint is satisfied for given tax rates. In what follows, we use the standard home and foreign country notation, where h stands for the home country and f stands for the foreign country. The resource constraints of the world economy in the two periods are:

$$(c_{h,1} + c_{f,1}) + (k_{h,2} + k_{f,2}) = e_{h,1} + e_{f,1} \tag{13}$$

$$(c_{h,2}+c_{f,2})-(1-\delta^h)k_{h,2}-(1-\delta^f)k_{f,2}+(g_{h,2}+g_{f,2}) = (y_{h,2}+y_{f,2})-m_{h,2}\frac{f_{h,2}^2}{2}-m_{f,2}\frac{f_{f,2}^2}{2} \tag{14}$$

The no-transversality conditions imply that $k_{h,3} \equiv k_{f,3} \equiv 0$ and $f_{h,3} \equiv f_{f,3} \equiv 0$. In equilibrium, the total capital in each country is equal to the sum of the private capital and the Foreign Direct Investment. This implies

$$K_{h,2} = k_{h,2} + f_{f,2} \tag{15}$$

and

$$K_{f,2} = k_{f,2} + f_{h,2} \tag{16}$$

The equilibrium in labor market implies that demand equals supply

$$L^f_{h,2} = l_{h,2} \tag{17}$$

and

$$L^f_{f,2} = l_{f,2} \tag{18}$$

For our convention we define the net factor returns as:

$$R_{h,2} \equiv (1 - \tau^h_{k,2})r_{h,2} - \delta^h \tag{19}$$

$$W_{h,2} \equiv (1 - \tau^h_{l,2})w_{h,2} \tag{20}$$

Equations in the foreign country are defined in a symmetric way. Then, given the four independent policy instruments, $R_{h,2}$, $R_{f,2}$, $W_{h,2}$ and $W_{f,2}$, the *World Competitive Equilibrium* system is described by:

$$c_{h,1} + k_{h,2} + f_{h,2} = e_{h,1} \tag{21}$$

$$c_{f,1} + k_{f,2} + f_{f,2} = e_{f,1} \tag{22}$$

$$c_{h,2} = (1 + R_{h,2})k_{h,2} + W_{h,2}l_{h,2} + (1 + R_{f,2})f_{h,2} - m_{h,2}\frac{f_{h,2}^2}{2} \tag{23}$$

$$c_{f,2} = (1 + R_{f,2})k_{f,2} + W_{f,2}l_{f,2} + (1 + R_{h,2})f_{f,2} - m_{f,2}\frac{f_{f,2}^2}{2} \tag{24}$$

$$c_{h,2} = \beta^h(1 + R_{h,2})c_{h,1} \tag{25}$$

$$c_{f,2} = \beta^f(1 + R_{f,2})c_{f,1} \tag{26}$$

$$c_{h,2} = \beta^h\Big\{(1 + R_{f,2}) - m_{h,2}f_{h,2}\Big\}c_{h,1} \tag{27}$$

$$c_{f,2} = \beta^f\Big\{(1 + R_{h,2}) - m_{f,2}f_{f,2}\Big\}c_{f,1} \tag{28}$$

$$l_{h,2} = 1 - \frac{\mu_2 c_{h,2}}{\mu_1 W_{h,2}} \tag{29}$$

$$l_{f,2} = 1 - \frac{\mu_2 c_{f,2}}{\mu_1 W_{f,2}} \tag{30}$$

$$g_{h,2} = y_{h,2} - (R_{h,2} + \delta^h)(k_{h,2} + f_{f,2}) - W_{h,2}l_{h,2} \tag{31}$$

$$g_{f,2} = y_{f,2} - (R_{f,2} + \delta^f)(k_{f,2} + f_{h,2}) - W_{f,2}l_{f,2} \tag{32}$$

where

$$y_{h,2} = A^h(k_{h,2} + f_{f,2})^{\alpha^h} l_{h,2}^{1-\alpha^h} \text{ and } y_{f,2} = A^f(k_{f,2} + f_{h,2})^{\alpha^f} l_{f,2}^{1-\alpha^f}$$

is the output produced in each country.

Equations (21-32) give, respectively, the first-period consumption, the second-period consumption, capital invested in each country, capital invested abroad, labor supply and government budget constraint. This is for each country h, f. Hence, we have 12 equations in the paths of:

$$\{c_{h,1}, c_{h,2}, c_{f,1}, c_{f,2}, k_{h,2}, k_{f,2}, f_{h,2}, f_{f,2}, l_{h,2}, l_{f,2}, g_{h,2}, g_{f,2}\}$$

for any given feasible policy $\{R_{h,2}, W_{h,2}, R_{f,2}, W_{f,2}\}$. Notice that the complexity of the model implies that the only possible solution can be derived numerically. Before we proceed to optimal policies, it is useful to distinct the effects of domestic tax policy on foreign welfare and vice versa. The model supports two possible spillovers among the two countries. The first one stems from international capital mobility, while the second is due to international public goods. Since, capital can be invested either in home or abroad, the two countries have an incentive to lower their tax rates to attract more capital, triggering the so-called tax-competition effect. Moreover, the higher tax rate on either of the two countries hurts the income and welfare of the investors who invest abroad, generating the tax-the-foreigner effect. International public goods cause the free riding effect. If, for example, the home country increases its tax rate, it contributes to the provision of the global public good, motivating the foreign country to lower its tax rate and free ride on the global public good. The tax competition and free riding externalities squeeze the non-cooperative tax rates below their efficient level. The tax-the-foreigner effect may be positive or negative depending on whether the home country is exporter or importer of capital.

4 Policy with Commitment

4.1 Cooperative policies

Suppose now that governments coordinate their actions, or equivalently, there is a Ramsey planner who maximizes the weighted sum of welfare across the two countries, subject to the constraints of the World Competitive Equilibrium. The objective function is

$$W^{coop} = \gamma U^h + (1-\gamma)U^f \tag{33}$$

subject to the 12 equations (21-32) of the WCE. Parameters $e_{h,1}$ and $e_{f,1}$ are the initial endowments and

$$y_{h,2} = A^h(k_{h,2} + f_{f,2})^{\alpha^h} l_{h,2}^{1-\alpha^h} \text{ and } y_{f,2} = A^f(k_{f,2} + f_{h,2})^{\alpha^f} l_{f,2}^{1-\alpha^f}$$

is the total output produced at home and foreign country respectively. Also, parameter γ stands for the weight given to each country by the Ramsey planner.

Lagrange Function of the Ramsey Planner

$$
\begin{aligned}
L^{coop} = W^{coop} &+ \lambda_1\Big\{c_{h,1} + k_{h,2} + f_{h,2} - e_{h,1}\Big\} \\
&+ \lambda_2\Big\{c_{f,1} + k_{f,2} + f_{f,2} - e_{f,1}\Big\} \\
&+ \lambda_3\left\{c_{h,2} - (1 + R_{h,2})k_{h,2} - W_{h,2}l_{h,2} - (1 + R_{f,2})f_{h,2} + m_{h,2}\frac{f_{h,2}^2}{2}\right\} \\
&+ \lambda_4\left\{c_{f,2} - (1 + R_{f,2})k_{f,2} - W_{f,2}l_{f,2} - (1 + R_{h,2})f_{f,2} + m_{f,2}\frac{f_{f,2}^2}{2}\right\} \\
&+ \lambda_5\Big\{c_{h,2} - \beta^h(1 + R_{h,2})c_{h,1}\Big\} \\
&+ \lambda_6\Big\}c_{f,2} - \beta^f(1 + R_{f,2})c_{f,1}\Big\} \\
&+ \lambda_7\left\{l_{h,2} - 1 + \frac{\mu_2 c_{h,2}}{\mu_1 W_{h,2}}\right\} \\
&+ \lambda_8\left\{l_{f,2} - 1 + \frac{\mu_2 c_{f,2}}{\mu_1 W_{f,2}}\right\} \\
&+ \lambda_9\Big\{c_{h,2} - \beta^h(1 + R_{f,2} - m_{h,2}f_{h,2})c_{h,1}\Big\} \\
&+ \lambda_{10}\Big\{c_{f,2} - \beta^f(1 + R_{h,2} - m_{f,2}f_{f,2})c_{f,1}\Big\} \\
&+ \lambda_{11}\Big\{g_{h,2} - y_{h,2} + (R_{h,2} + \delta^h)(k_{h,2} + f_{f,2}) + W_{h,2}l_{h,2}\Big\} \\
&+ \lambda_{12}\Big\{g_{f,2} - y_{f,2} + (R_{f,2} + \delta^f)(k_{f,2} + f_{h,2}) + W_{f,2}l_{f,2}\Big\}
\end{aligned} \tag{34}
$$

The optimization process yields a system of 28 equations in 28 unknowns. Substituting out multipliers, refines the system into a set of 16 equations in:

$$\{c_{h,1}, c_{h,2}, c_{f,1}, c_{f,2}, k_{h,2}, k_{f,2}, l_{h,2}, l_{f,2}, f_{h,2}, f_{f,2}, R_{h,2}, W_{h,2}, g_{h,2}, R_{f,2}, W_{f,2}, g_{f,2}\},$$

the solution of which is the cooperative equilibrium of our model.

4.2 Non-cooperative policies

Assume now, that each government sets, independently of the other, capital and labor tax rates to maximize the welfare of its representative household, subject to the constraints that (1) domestic and foreign private agents optimize and satisfy their budget constraints, (2) foreign taxes are given (at their equilibrium level), (3) markets clear, and that (4) its own government budget constraint is satisfied. As in *Gross et al. (2017)* we define equilibrium policies assuming that the government takes the equilibrium policies of the other government as given. Also, we do not impose the world resource constraint on either government, but in equilibrium it must be satisfied.

The home government maximizes

$$U_h = \mu_1 \log(c_{h,1}) + \beta^h\{\mu_1 \log(c_{h,2}) + \mu_2 \log(1 - l_{h,2}) + \mu_3[\log(g_{h,2})]\} \tag{35}$$

subject to the WCE equations (21-32).

A usual technical problem is that one cannot derive an indirect utility function, that is, cannot write the utility function of the government as a function of the policy instruments only. This is a well-known feature in the literature of optimal taxation (see e.g. *Chamley 1986*). Therefore, policymakers, when they act optimally and regardless of the cooperative or non-cooperative regime, choose the endogenous variables of the world competitive equilibrium subject to the equations consisting the world competitive equilibrium.

Lagrange Function of the domestic country

$$
\begin{aligned}
L_h = U_h &+ \lambda_1\Big\{c_{h,1} + k_{h,2} + f_{h,2} - e_{h,1}\Big\} \\
&+ \lambda_2\Big\{c_{f,1} + k_{f,2} + f_{f,2} - e_{f,1}\Big\} \\
&+ \lambda_3\left\{c_{h,2} - (1+R_{h,2})k_{h,2} - W_{h,2}l_{h,2} - (1+R_{f,2})f_{h,2} + m_{h,2}\frac{f_{h,2}^2}{2}\right\} \\
&+ \lambda_4\left\{c_{f,2} - (1+R_{f,2})k_{f,2} - W_{f,2}l_{f,2} - (1+R_{h,2})f_{f,2} + m_{f,2}\frac{f_{f,2}^2}{2}\right\} \\
&+ \lambda_5\Big\{c_{h,2} - \beta^h(1+R_{h,2})c_{h,1}\Big\} \\
&+ \lambda_6\Big\}c_{f,2} - \beta^f(1+R_{f,2})c_{f,1}\Big\} \\
&+ \lambda_7\left\{l_{h,2} - 1 + \frac{\mu_2 c_{h,2}}{\mu_1 W_{h,2}}\right\} \\
&+ \lambda_8\left\{l_{f,2} - 1 + \frac{\mu_2 c_{f,2}}{\mu_1 W_{f,2}}\right\} \\
&+ \lambda_9\Big\{c_{h,2} - \beta^h(1+R_{f,2} - m_{h,2}f_{h,2})c_{h,1}\Big\} \\
&+ \lambda_{10}\Big\{c_{f,2} - \beta^f(1+R_{h,2} - m_{f,2}f_{f,2})c_{f,1}\Big\} \\
&+ \lambda_{11}\Big\{g_{h,2} - y_{h,2} + (R_{h,2}+\delta^h)(k_{h,2}+f_{f,2}) + W_{h,2}l_{h,2}\Big\} \\
&+ \lambda_{12}\Big\{g_{f,2} - y_{f,2} + (R_{f,2}+\delta^f)(k_{f,2}+f_{h,2}) + W_{f,2}l_{f,2}\Big\}
\end{aligned}
\tag{36}
$$

Hence, the home government solves a maximization problem with respect to the set of variables we described above. The set of first-order conditions consists of 26 equations in 26 unknowns. 14 out of 26 equations regard the optimality conditions for the variables and the rest of them are the 12 constraints of the WCE. Working in the same way, the foreign government solves its own maximization problem and derives its own optimality conditions, which will be symmetric to those of the home country. Each of the sets of optimality conditions represents the best response function system of each country. We may either solve the system as it is or substitute out multipliers and eliminate the number of equations. Whatever is the case, the resulting Nash solution must be identical. Finally, we end up with a system of 16 equations in

$$\{c_{h,1}, c_{h,2}, c_{f,1}, c_{f,2}, k_{h,2}, k_{f,2}, l_{h,2}, l_{f,2}, f_{h,2}, f_{f,2}, R_{h,2}, W_{h,2}, g_{h,2}, R_{f,2}, W_{f,2}, g_{f,2}\}$$

The solution of this system yields the Nash equilibrium of the model.

5 Numerical Solutions

5.1 Symmetric Countries

In this section, we present the results of our quantitative analysis and compare the welfare benefits between the cooperative and the non-cooperative regime. The following tables report the equilibrium tax rates on capital and labor, the respective macroeconomic fundamentals and their percentage change, as we move from unilateral policy choice to coordinated actions. We are particularly interested in investigating whether cooperative policies are superior to non-cooperative policies, between symmetric countries, as capital mobility varies from perfect mobility to no mobility at all. In these early steps we aim to establish a well-defined, robust solution, keeping our model as simple as possible. This is why we focus only on international capital mobility variations, subtracting IPGs from our analysis (set $\theta = 0$). In the following section, we consider IPGs and their impact on tax policy issues.

Here, we observe that as capital tax base becomes strictly immobile ($m_2 \rightarrow \infty$), our model practically depicts a closed economy, where the cooperative and the non-cooperative solutions coincide. The main findings are rather standard and support the theory of optimal taxation in open economies with international capital mobility cost. As cost rises, the tax competition effect becomes fiercer and the cooperative solution is more desirable compared to the Nash. Moreover, the Nash capital tax rate does not exceed the cooperative tax rate, for all possible parameter combinations. Also, welfare under Nash is less than or equal to welfare under cooperation and the Nash result coincides with the coordination result, only under the presence of extremely high mobility cost(practically closed economies). Finally, labor tax rate under Nash is positively correlated to the market openness.

A vigorous examination of the results reveals rather intuitive quantitative findings. For all possible mobility cost values the welfare difference between the Nash and the cooperative solution is small. For example, when capital mobility is almost perfect $m_2 = 0.1$, the Nash capital and labor tax rates are $\tau_{k,2}^{nc} = 0.077$ and $\tau_{l,2}^{nc} = 0.249$, while the cooperative ones are $\tau_{k,2}^{c} = 0.402$ and $\tau_{l,2}^{c} = 0.190$, *Table 1.A*. Although the difference between policy instruments is significant, the welfare gain from cooperation is small and amounts to only 2 percentage points *(Table 1.B)*. We are not the first to show this. *Mendoza and Tesar(2003)*[27], quantified the macroeconomic effects of capital tax competition in the EU, employing a two-country dynamic general equilibrium model and they found that gains from coordination were trivial. This result does not come as a surprise, if we consider that higher tax rates may be good for public good provision, but are bad for private consumption in the second period. Thus, we have two effects that work in the opposite direction: the increased public good provision improves welfare, while higher tax rates hurt investment and subsequently future consumption, reducing the welfare gains from cooperation. In that sense, Nash tax rates are not that bad quantitatively. Also, as the world economy presents less frictions($m_2 \rightarrow 0$), tax competition rises, along with the difference between the Nash and the cooperative capital tax rates. Hence, the welfare gain from cooperation takes its maximum value (2%), when capital is perfectly mobile. We also observe that mobility costs do not affect coordinated policies of symmetric countries, although, we expect this to change when we introduce asymmetry in our model.

Regarding macroeconomic fundamentals, we observe the substitution effect, emerging from coordinated policies (*Table 1.B*). In particular, as economies become more integrated and when policymakers act unilaterally, consumption in period 2 rises, while consumption in period 1 falls. In the case of perfect capital mobility, the cooperative regime

Table 1.A Ramsey Policies, public good is local, i.e. $\theta = 0$, mobility cost, m_2, increases

$\theta = 0$, **changing** m_2												
m_2	**Non-cooperative (Nash)**						**Cooperative**					
	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2
0.0	0.000	0.257	4.046	2.943	5.520	0.562	0.402	0.190	4.310	3.100	4.953	1.238
0.1	0.077	0.249	4.095	2.965	5.415	0.695	0.402	0.190	4.310	3.100	4.953	1.238
0.2	0.129	0.242	4.129	2.982	5.342	0.785	0.402	0.190	4.310	3.100	4.953	1.238
0.3	0.167	0.236	4.154	2.995	5.290	0.849	0.402	0.190	4.310	3.100	4.953	1.238
0.4	0.196	0.232	4.173	3.006	5.250	0.897	0.402	0.190	4.310	3.100	4.953	1.238
0.5	0.218	0.228	4.188	3.014	5.219	0.935	0.402	0.190	4.310	3.100	4.953	1.238
0.6	0.236	0.225	4.200	3.021	5.194	0.965	0.402	0.190	4.310	3.100	4.953	1.238
0.7	0.251	0.222	4.210	3.028	5.173	0.990	0.402	0.190	4.310	3.100	4.953	1.238
0.8	0.263	0.220	4.218	3.033	5.155	1.011	0.402	0.190	4.310	3.100	4.953	1.238
0.9	0.273	0.218	4.225	3.037	5.140	1.028	0.402	0.190	4.310	3.100	4.953	1.238
∞	0.402	0.190	4.310	3.100	4.953	1.238	0.402	0.190	4.310	3.100	4.953	1.238

Table 1.B Capital Mobility, no IPG

$\theta = 0$, changing m_2, (%)						
m_2	W	c_1	c_2	y_2	k_2	g_2
0.0	3.3	5.0	-10.0	7.0	-8.0	120.0
0.1	2.0	5.0	-9.0	5.0	-7.0	78.0
0.2	1.3	4.0	-7.0	4.0	-6.0	58.0
0.3	0.9	3.0	-6.0	4.0	-5.0	46.0
0.4	0.7	3.0	-6.0	3.0	-5.0	38.0
0.5	0.6	3.0	-5.0	3.0	-4.0	32.0
0.6	0.5	3.0	-5.0	3.0	-4.0	28.0
0.7	0.4	2.0	-4.0	2.0	-4.0	25.0
0.8	0.3	2.0	-4.0	2.0	-3.0	23.0
0.9	0.3	2.0	-4.0	2.0	-3.0	20.0
∞	0.0	0.0	0.0	0.0	0.0	0.0

loses about 9% of period-2 consumption, over the non-cooperative solution. Another interesting characteristic in this type of models is that the output gain from cooperation versus competition is bigger than the welfare gain. See, for example, the first row of *Table 1.B*, where the welfare and the output gain from cooperation amounts to 2.0% and 5.0% respectively. Furthermore, as expected, savings in the forms of capital are 7% lower when tax jurisdictions choose their policy jointly. This is due to the increased capital tax rate, which may be good for public good provision, but is bad for private investment and second-period consumption. Indeed, the cooperative provision of public good may even be 78% higher than the Nash provision, in the absence of mobility cost.

Summing up, coordinated tax policies are preferable to unilateral actions, as they lead to welfare improvements, which, however, are negligible. As it will become clear later, the introduction of international public goods provides tax jurisdictions a stronger incentive to cooperate.

In our experiments we use the following parameter values: $A^h \equiv A^f = 6.0$, $\alpha^h \equiv \alpha^f = 0.46$, $\beta^h \equiv \beta^f = 0.99$, $\delta^h \equiv \delta^f = 0.01$, $\mu_1 = 0.48$, $\mu_2 = 0.40$, $\mu_3 = 1 - \mu_1 - \mu_2$, $e_{h,1} \equiv e_{f,1} = 5.0$.

5.1.1 Asymmetric Countries

Although the case of symmetric countries is intuitive about international capital mobility spillovers and the welfare benefit of cooperative tax policies, it is rather Utopian when it comes to real life situations. In fact, there can be numerous types of asymmetries such as differences in capital stock, time preference rate, depreciation rate, productivity, share of capital in production process, etc. In this section, we depart from the symmetric world and focus on the case of asymmetric countries and particularly on TFP differences (see e.g. *Micossi (2016)*[28]).

Firstly, we assume that capital is perfectly mobile between countries and, keeping all other parameters constant, we test the responsiveness of the model to different TFP values. Specifically, we gradually increase the home country's productivity (A^h) and we solve for the Nash and the cooperative regimes. We report that the model yields well-defined numerical solutions, even in the case when the domestic country is twice as productive as the foreign. Following *Micossi (2016)*, TFP difference between United States and Eurozone, amounted to about 12%, in 2014. The gap between U.S. and the periphery of the Eurozone was much more intense, reaching about 25% *(Figure 1)*. Our experiment can be perceived as a representation of the economic interdependence between U.S. and Eurozone, or between U.S. and the EU-Periphery, or between U.S. and the EU-Core, etc. The introduction of asymmetry allows us to compare not only the fundamentals' change from cooperation(gains or losses) between the two countries, but also, which of the countries is benefited more. As theory predicts, not all countries are equally benefited from cooperative policies. We show that, as domestic TFP rises, domestic welfare rises with decreasing rate, while the foreign welfare faces an exponential growth. We suspect that for extreme TFP differences, home country would be worse off from cooperation. The motivation behind this analysis is to show that the incentive to cooperate is stronger than the symmetric case and to clarify which of the countries contributes more to this result.

Figure 1: TFP in Eurozone, Periphery, CORE and United States from 1995 to 2014, *Stefano Micossi, "Balance-of-payments adjustment in the Eurozone", 2016*

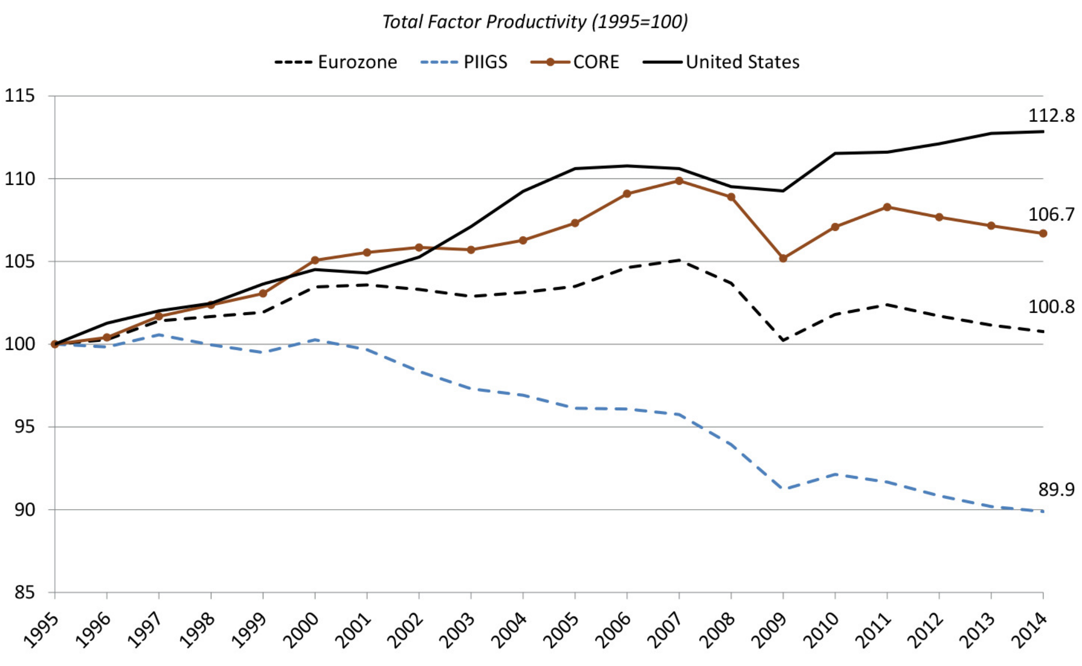
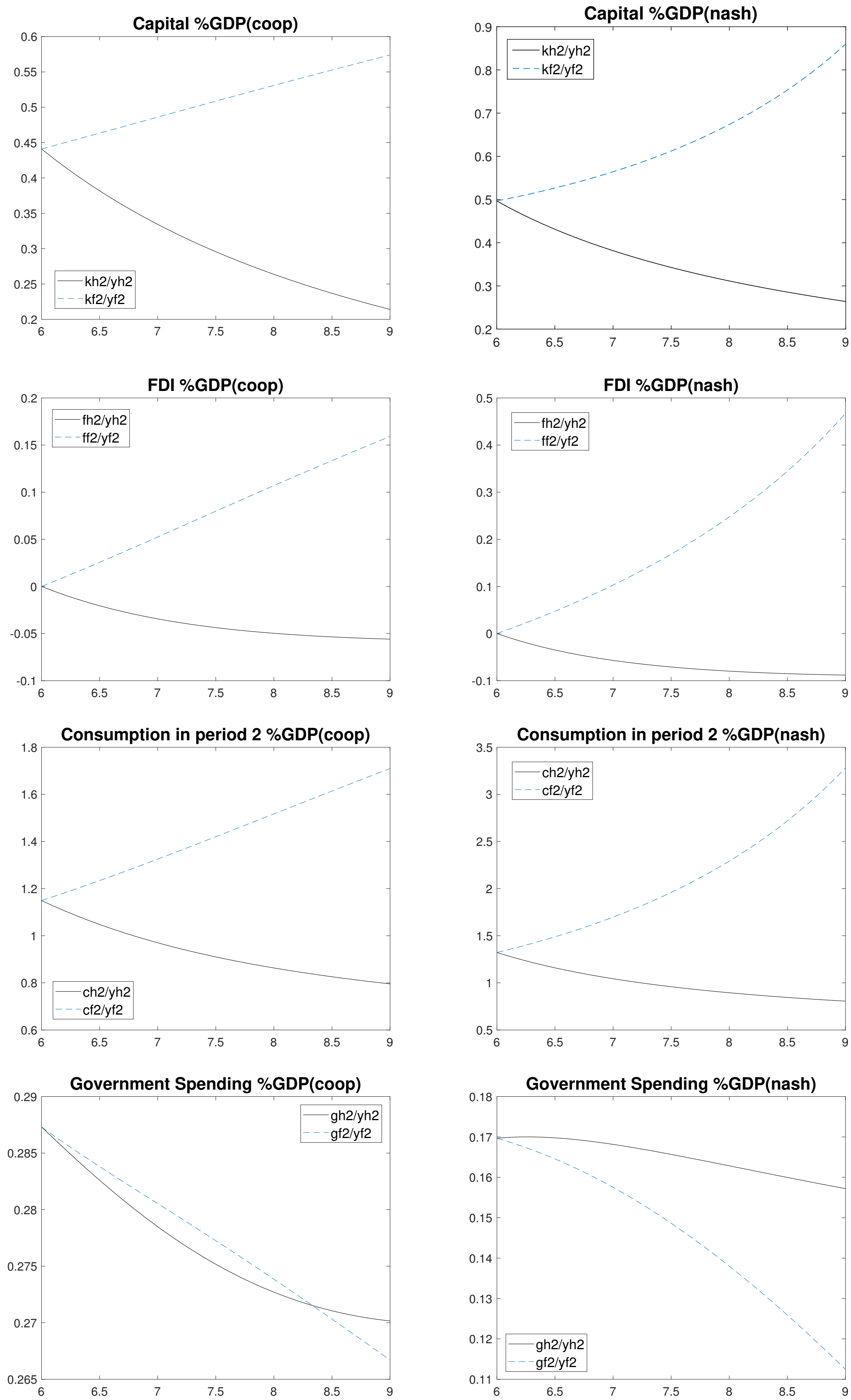
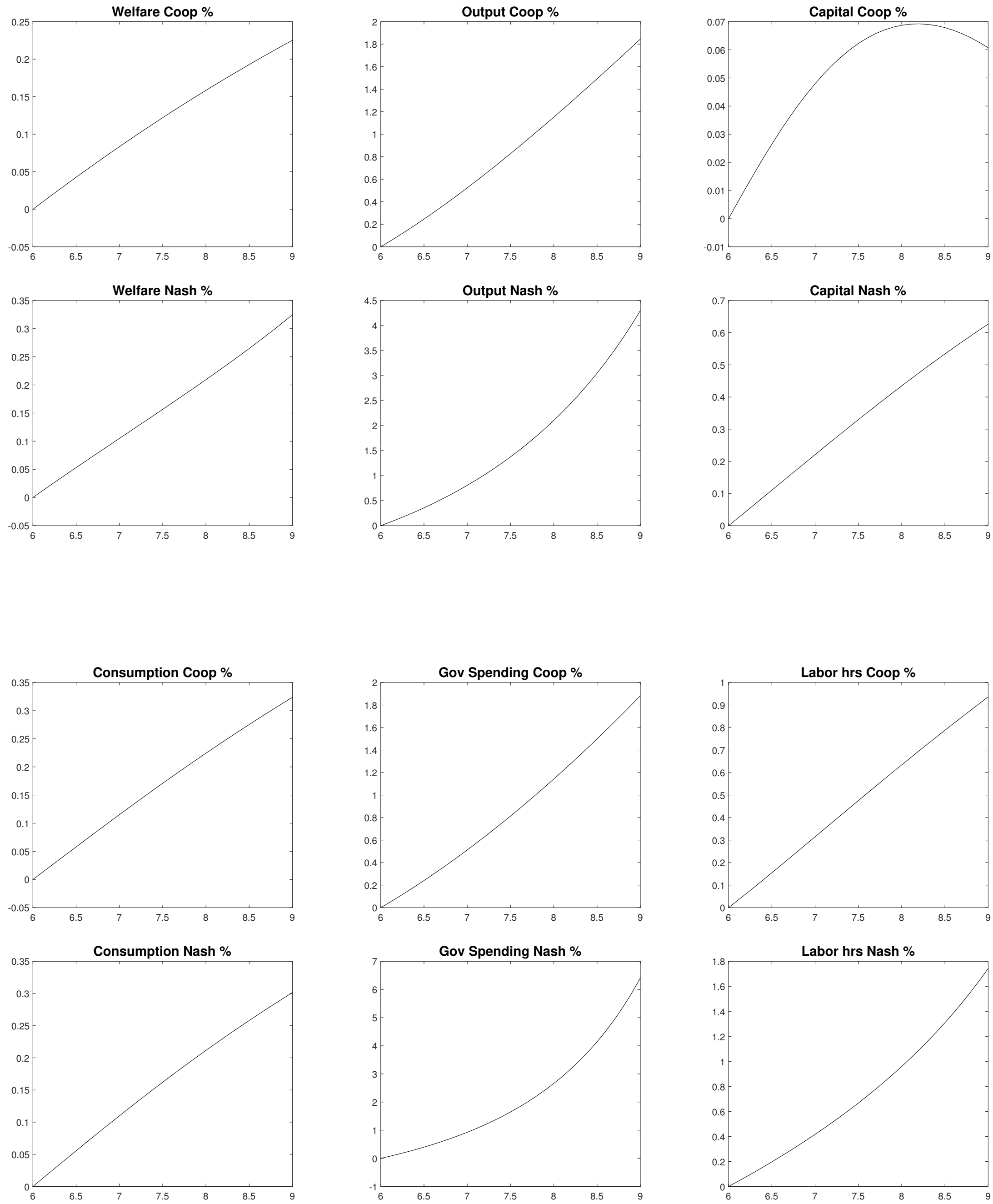


Figure 2: Sensitivity analysis in Domestic TFP (A^h) changes, shares of GDP



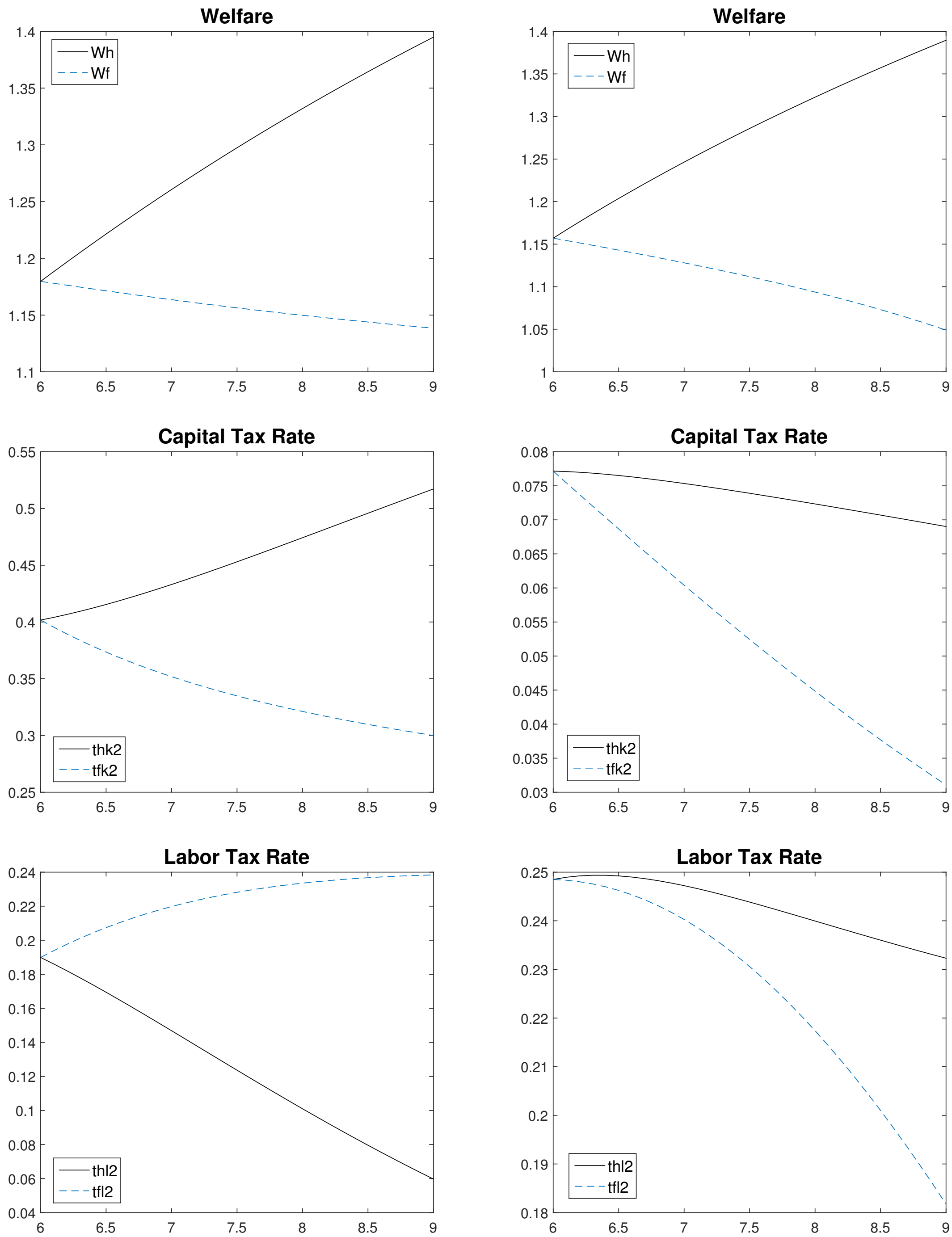
As expected, uncoordinated tax policies and perfect capital mobility strengthen tax competition and result in inefficiently low capital and labor tax rates, compared to the coordinated actions, for every value of A^h. In *Figure 2* we present a rather standard, but intuitive sensitivity analysis of the domestic TFP change. As home country becomes more productive, its capital-to-GDP ratio falls, while the foreign country's ratio grows, regardless of the cooperative or the Nash solution. Also, the home country witnesses severe capital-to-GDP fall in coordinated policies, while the drop is less pronounced in competitive policies. In general, the gap between home and foreign country widens, as productivity of home country grows, and it is more intense in the Nash solution. FDI and consumption in second period, as a share of GDP, display very similar pictures. On the other hand, government spending as a share of GDP, is rather similar for both countries, and much higher in the cooperative solution, obviously, due to higher capital tax rates.

Figure 3: Cooperative to non-cooperative, gains or losses, in relative terms



In *Figure 3*, we point out the gains or loses, from cooperation and non-cooperation, of the home country relative to the foreign, as domestic TFP rises. When domestic productivity is about 20% higher, the home country gains 11% more welfare under cooperation, and 15% more under Nash. The difference in output is more prominent: output is 1.5 times greater in Nash and 0.8 times greater in cooperative strategies. Also, capital gain amounts to 70% more for the home country under non-coordination, and 7% more under coordination. The domestic gains in government spending also appear greater under Nash than cooperation. However, domestic second-period consumption appears marginally larger under cooperation.

Figure 4: Sensitivity analysis in Domestic TFP (A^h) changes, levels of welfare, capital and labor tax rates



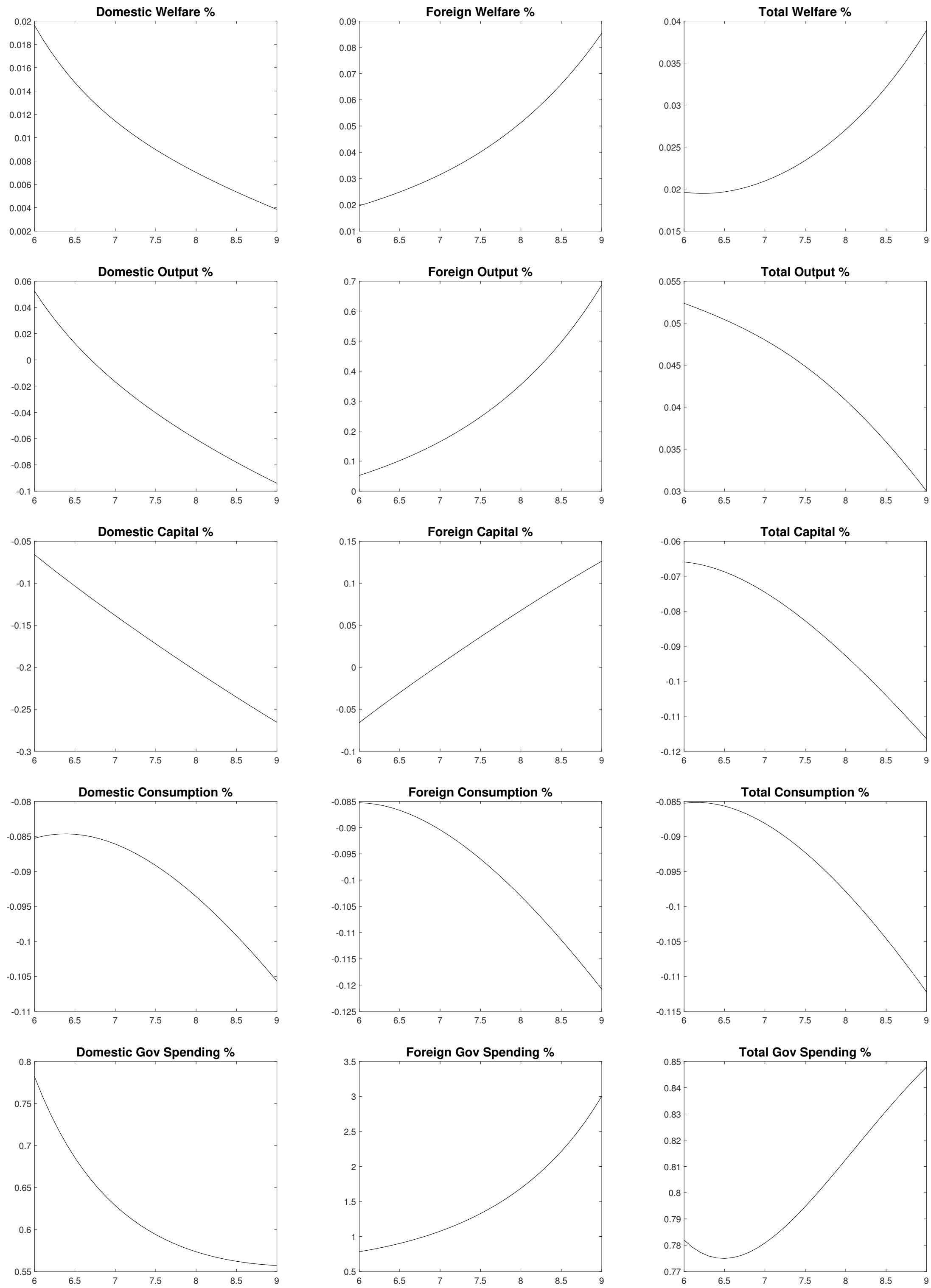
In *Figure 4*, we provide a sensitivity analysis in coordinated and non-coordinated policies, by comparing the welfare level, capital and labor tax rates of both economies, as domestic TFP rises. The first column of the figure stands for the cooperative results, while the second refers to the non-cooperative ones. The domestic welfare level displays a linear growth both under coordination and non-coordination. However, as the domestic economy increases its productivity level, foreign welfare drops with higher rate when governments act unilaterally. Furthermore, the cooperative regime is characterized by significantly higher capital tax rates. Assuming that the home country is 25% more productive, the domestic capital tax rate is set around 45%, while the foreign barely reaches 35%. Under non-cooperative policies, however, capital taxes are inefficiently low in both countries, due to the tax competition effect. In particular, given the same productivity difference of 25% between the countries, domestic and foreign capital taxes are set around 7% and %5 respectively. Regarding coordinated labor taxation, we observe that the more productive country relies less on labor taxes compared to the foreign, which is not a surprise if we consider the trade-off between capital and labor tax rates. Non-coordination, yields around 25% labor tax rates for both countries.

Up to this point, we have outlined the fundamentals' change with respect to different domestic TFP values, for both countries, under cooperative and non-cooperative strategies. In terms of GDP shares, the foreign country gains more than the home country, both under Nash and under cooperation. Instead, in both setups, when we compare domestic-over-foreign fundamentals' change, we conclude that the more productive country enjoys bigger benefits than the less productive and more importantly, the gains are more pronounced if it acts in its own self-interest. Finally, capital taxes are set higher and labor taxes display significant difference between the home country(more productive) and the foreign country in the cooperative regime.

In *Figure 5*, we disentangle the gains or losses, from cooperation over competition, for each country and for the weighted sum of both countries. Domestic welfare gains fall, while foreign welfare gains rise with growing rate, as the home country raises its productivity. This translates into a rise of 2% to 5% in total welfare gains. Since, the foreign country gains more in relative terms, it should be more prone to cooperation than the home country. Also, the relative domestic output, private consumption, capital and government spending, decrease with the rise of domestic productivity, whereas the relative foreign fundamentals go the opposite direction, except foreign private consumption that faces a slight drop. Interestingly, relative total output, capital and consumption also fall with domestic productivity rise. Hence, quite naturally, arises the question, where the rise in relative total welfare comes from. The most important message from this experiment is that the increase in domestic productivity causes a big rise in relative total public good provision. In other words, cooperation yields 78% to 85% higher public good provision, compared to Nash strategies, dragging the relative total welfare up to 2% to 4%.

In *Tables 2 and 3*, we fix domestic TFP at certain values and we test the responsiveness of the model to increasing mobility cost. We present the cooperative and the non-cooperative results for both countries, while in *Table 4*, we fix the TFP difference at 18%, so that it represents the productivity gap between EU-CORE and EU-Periphery in 2014, as in *Micossi 2016*. The degree of market openness plays a decisive role regarding the level of capital and labor tax rates. In the first half of *Tables 2 and 3* we fix domestic TFP 33% higher than the foreign, while in the second half, we consider 100% productivity gap. The first part of the tables presents a more realistic asymmetry in productivity, however, we focus on the second part of *Table 2* ($A^h = 12.0$), which qualitatively presents the same results as the first part, yet the increased magnitude of welfare gains, stemming out of the extreme productivity gap, allows us to derive clearer conclusions.

Figure 5: Cooperation versus Non-cooperation, home, foreign and total gains or losses as domestic country becomes more productive, i.e. A^h increases



Firstly, when governments cooperate *(Table 2)*, the capital tax rate of the more productive country would be set higher, as capital becomes more mobile. In contrast, the less productive country reduces its capital tax rate as mobility costs fall. Hence, the provision of the domestic public good increase with market openness, while foreign public good's provision decrease. Also, the less frictions the capital market presents, the more pronounced is the level of the domestic output, whereas, the foreign output is almost double when markets are closed. In *Table 3*, tax jurisdictions engage in a tax competition race, which leads to inefficiently low capital tax rates and underprovision of the international public good. As mobility cost tends to infinity, the Nash solution coincides with the cooperative solution, as in the symmetric case. Furthermore, consumption in period 2 rises with capital mobility in both countries, whereas consumption in period 1 decreases. Finally, in terms of welfare, tax jurisdictions are better off if they cooperate, nevertheless, any gains from tax harmonization are eliminated, as capital becomes less mobile.

Table 2. Cooperative strategies when home country is 33% and 100% more productive than the foreign, m_2 changing

$A^h = 8.0$					Productive country					
m_2	c_1	c_2	k_2	l_2	f_2	y_2	$\tau_{k,2}$	$\tau_{l,2}$	g_2	W
0.1	3.491	6.088	1.860	0.403	-0.351	7.053	0.474	0.101	1.923	1.332
0.2	3.466	6.125	1.881	0.398	-0.347	7.032	0.452	0.111	1.885	1.332
0.3	3.441	6.154	1.897	0.393	-0.338	6.993	0.433	0.121	1.849	1.332
0.4	3.417	6.174	1.908	0.388	-0.325	6.945	0.416	0.130	1.816	1.331
0.5	3.395	6.189	1.915	0.384	-0.311	6.891	0.402	0.137	1.786	1.330
0.6	3.376	6.199	1.920	0.380	-0.295	6.835	0.391	0.144	1.759	1.329
0.7	3.358	6.206	1.921	0.376	-0.280	6.780	0.381	0.149	1.736	1.328
0.8	3.343	6.210	1.922	0.373	-0.265	6.727	0.374	0.154	1.716	1.327
0.9	3.330	6.213	1.921	0.370	-0.251	6.678	0.367	0.158	1.699	1.326
∞	3.165	6.119	1.835	0.332	0.000	5.833	0.341	0.195	1.530	1.305
					Less productive country					
0.1	2.909	4.973	1.740	0.247	0.351	3.278	0.321	0.234	0.898	1.150
0.2	2.915	4.952	1.738	0.248	0.347	3.292	0.333	0.233	0.919	1.151
0.3	2.924	4.935	1.739	0.251	0.338	3.321	0.344	0.232	0.942	1.152
0.4	2.933	4.922	1.742	0.254	0.325	3.360	0.354	0.231	0.965	1.154
0.5	2.942	4.911	1.747	0.257	0.311	3.405	0.362	0.229	0.988	1.155
0.6	2.952	4.903	1.753	0.261	0.295	3.452	0.369	0.227	1.009	1.157
0.7	2.961	4.898	1.759	0.264	0.280	3.500	0.375	0.225	1.029	1.158
0.8	2.970	4.894	1.765	0.267	0.265	3.545	0.379	0.224	1.047	1.159
0.9	2.978	4.892	1.772	0.270	0.251	3.589	0.383	0.222	1.063	1.161
∞	3.100	4.953	1.901	0.314	0.000	4.310	0.402	0.190	1.238	1.180
$A^h = 12.0$					**Productive country**					
m_2	c_1	c_2	k_2	l_2	f_2	y_2	$\tau_{k,2}$	$\tau_{l,2}$	g_2	W
0.1	4.196	7.969	1.468	0.491	-0.664	11.575	0.628	-0.024	3.192	1.545
0.2	4.143	8.093	1.523	0.485	-0.665	11.641	0.598	-0.011	3.133	1.549
0.3	4.089	8.203	1.574	0.479	-0.663	11.681	0.569	0.003	3.073	1.551
0.4	4.035	8.299	1.622	0.473	-0.657	11.698	0.540	0.017	3.012	1.553
0.5	3.983	8.383	1.665	0.467	-0.648	11.696	0.512	0.032	2.953	1.553
0.6	3.933	8.455	1.704	0.461	-0.637	11.677	0.485	0.046	2.895	1.554
0.7	3.886	8.516	1.739	0.455	-0.625	11.643	0.460	0.060	2.838	1.553
0.8	3.842	8.567	1.768	0.449	-0.610	11.596	0.437	0.072	2.784	1.553
0.9	3.801	8.610	1.794	0.443	-0.595	11.540	0.416	0.084	2.732	1.552
∞	3.240	8.472	1.760	0.351	0.000	8.847	0.286	0.200	2.118	1.497
					Less productive country					
0.1	2.774	5.087	1.563	0.182	0.664	2.275	0.260	0.233	0.558	1.114
0.2	2.780	5.065	1.555	0.181	0.665	2.262	0.273	0.235	0.570	1.116
0.3	2.787	5.044	1.550	0.182	0.663	2.261	0.285	0.236	0.585	1.118
0.4	2.796	5.023	1.548	0.183	0.657	2.272	0.297	0.238	0.602	1.120
0.5	2.805	5.003	1.547	0.184	0.648	2.293	0.308	0.239	0.620	1.123
0.6	2.814	4.985	1.549	0.187	0.637	2.322	0.318	0.240	0.641	1.125
0.7	2.824	4.967	1.551	0.189	0.625	2.357	0.328	0.242	0.663	1.128
0.8	2.835	4.951	1.555	0.192	0.610	2.399	0.337	0.243	0.686	1.131
0.9	2.845	4.936	1.561	0.195	0.595	2.445	0.345	0.243	0.710	1.134
∞	3.100	4.953	1.900	0.314	0.000	4.309	0.402	0.190	1.238	1.180

Moreover, the foreign country gains more, in relative terms, from cooperation than the domestic. The interesting thing here though is that, under perfect capital mobility, the home country, which is 100% more productive than the foreign, is worse off if cooperates. A possible explanation could be that the Ramsey planner weighs equally the welfare of the two countries. Hence, the productivity difference may be good for the total welfare under cooperation, but the domestic economy would be better off, acting in its own self-interest, as coordinated policies assign vital domestic resources for the greater good.

Table 3. Non-cooperative strategies when home country is 33% and 100% more productive than the foreign, m_2 changing

$A^h = 8.0$					**Productive country**					
m_2	c_1	c_2	k_2	l_2	f_2	y_2	$\tau_{k,2}$	$\tau_{l,2}$	g_2	W
0.1	3.261	6.717	2.338	0.355	-0.599	7.506	0.072	0.240	1.222	1.323
0.2	3.262	6.655	2.256	0.355	-0.518	7.309	0.117	0.228	1.291	1.325
0.3	3.261	6.606	2.199	0.354	-0.459	7.158	0.147	0.220	1.335	1.326
0.4	3.257	6.566	2.156	0.353	-0.413	7.035	0.170	0.215	1.365	1.326
0.5	3.253	6.531	2.122	0.352	-0.375	6.931	0.187	0.211	1.387	1.325
0.6	3.248	6.502	2.094	0.351	-0.342	6.841	0.201	0.208	1.403	1.324
0.7	3.244	6.476	2.071	0.350	-0.315	6.764	0.213	0.206	1.415	1.324
0.8	3.239	6.454	2.052	0.348	-0.291	6.697	0.222	0.205	1.425	1.323
0.9	3.235	6.434	2.035	0.347	-0.270	6.637	0.231	0.204	1.433	1.322
∞	3.165	6.119	1.835	0.332	0.000	5.833	0.341	0.195	1.530	1.305
					Less productive country					
0.1	2.771	5.544	1.630	0.181	0.599	2.419	0.045	0.217	0.334	1.094
0.2	2.805	5.435	1.676	0.197	0.518	2.672	0.089	0.228	0.439	1.115
0.3	2.832	5.352	1.708	0.210	0.459	2.858	0.127	0.234	0.528	1.128
0.4	2.855	5.287	1.733	0.220	0.413	3.006	0.159	0.236	0.604	1.137
0.5	2.874	5.237	1.752	0.228	0.375	3.128	0.186	0.237	0.668	1.143
0.6	2.891	5.198	1.767	0.235	0.342	3.231	0.207	0.237	0.722	1.148
0.7	2.905	5.167	1.781	0.241	0.315	3.319	0.225	0.236	0.768	1.152
0.8	2.918	5.142	1.792	0.247	0.291	3.395	0.241	0.235	0.807	1.155
0.9	2.929	5.122	1.801	0.251	0.270	3.461	0.253	0.234	0.841	1.157
∞	3.100	4.953	1.901	0.314	0.000	4.310	0.402	0.190	1.238	1.180
$A^h = 12.0$					**Productive country**					
m_2	c_1	c_2	k_2	l_2	f_2	y_2	$\tau_{k,2}$	$\tau_{l,2}$	g_2	W
0.1	3.668	9.421	2.502	0.428	-1.170	13.805	0.072	0.212	2.037	1.553
0.2	3.675	9.389	2.432	0.428	-1.107	13.566	0.098	0.202	2.090	1.556
0.3	3.675	9.343	2.352	0.426	-1.027	13.254	0.125	0.192	2.141	1.557
0.4	3.668	9.299	2.289	0.424	-0.957	12.977	0.146	0.186	2.174	1.557
0.5	3.657	9.257	2.238	0.422	-0.895	12.730	0.162	0.182	2.197	1.557
0.6	3.645	9.219	2.196	0.419	-0.841	12.508	0.174	0.179	2.212	1.556
0.7	3.631	9.183	2.160	0.417	-0.791	12.306	0.184	0.177	2.222	1.554
0.8	3.617	9.149	2.130	0.414	-0.747	12.122	0.193	0.176	2.228	1.552
0.9	3.602	9.118	2.104	0.412	-0.706	11.952	0.199	0.176	2.231	1.551
∞	3.240	8.471	1.760	0.351	0.000	8.847	0.286	0.200	2.118	1.497
					Less productive country					
0.1	2.564	6.199	1.267	0.030	1.170	0.308	0.006	0.044	0.008	0.735
0.2	2.599	6.071	1.294	0.053	1.107	0.569	0.018	0.079	0.029	0.872
0.3	2.641	5.910	1.332	0.079	1.027	0.881	0.041	0.117	0.072	0.966
0.4	2.676	5.770	1.367	0.099	0.957	1.139	0.069	0.146	0.126	1.019
0.5	2.706	5.649	1.399	0.115	0.895	1.359	0.099	0.169	0.186	1.052
0.6	2.732	5.545	1.428	0.129	0.841	1.551	0.128	0.186	0.247	1.076
0.7	2.754	5.455	1.454	0.141	0.791	1.721	0.154	0.200	0.308	1.093
0.8	2.775	5.379	1.479	0.151	0.747	1.875	0.178	0.211	0.367	1.105
0.9	2.793	5.316	1.501	0.161	0.706	2.015	0.200	0.219	0.423	1.115
∞	3.100	4.953	1.901	0.314	0.000	4.310	0.402	0.190	1.238	1.180

Table 4.A Ramsey Policies, between Productive(e.g. EU-Core) and Less productive(e.g. EU-Periphery) countries and as mobility cost, m_2, changes

changing m_2												
	Productive country (e.g. EU-CORE)											
m_2	**Non-cooperative (Nash)**						**Cooperative**					
	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2
0.1	0.077	0.249	4.685	3.019	5.632	0.796	0.411	0.176	4.793	3.164	5.155	1.361
0.2	0.127	0.241	4.672	3.032	5.563	0.880	0.406	0.177	4.787	3.161	5.161	1.353
0.3	0.163	0.234	4.663	3.042	5.513	0.939	0.403	0.179	4.776	3.157	5.165	1.346
0.4	0.190	0.230	4.655	3.050	5.474	0.983	0.400	0.180	4.764	3.153	5.168	1.339
0.5	0.211	0.226	4.648	3.056	5.443	1.016	0.397	0.181	4.752	3.150	5.170	1.334
0.6	0.228	0.222	4.642	3.061	5.418	1.043	0.395	0.182	4.740	3.146	5.171	1.329
0.7	0.241	0.220	4.637	3.065	5.397	1.065	0.394	0.183	4.729	3.144	5.172	1.324
0.8	0.253	0.218	4.633	3.068	5.379	1.084	0.393	0.184	4.719	3.141	5.172	1.321
0.9	0.263	0.216	4.628	3.071	5.363	1.099	0.392	0.185	4.710	3.139	5.172	1.318
∞	0.388	0.191	4.577	3.113	5.157	1.289	0.388	0.191	4.577	3.113	5.157	1.289
	Less productive country (e.g. EU-Periphery)											
m_2	**Non-cooperative (Nash)**						**Cooperative**					
	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2
0.1	0.071	0.247	3.778	2.925	5.420	0.628	0.381	0.203	4.102	3.054	4.954	1.168
0.2	0.122	0.243	3.859	2.946	5.344	0.723	0.385	0.202	4.108	3.057	4.949	1.175
0.3	0.160	0.239	3.917	2.962	5.288	0.794	0.388	0.201	4.117	3.059	4.945	1.182
0.4	0.189	0.235	3.962	2.975	5.246	0.848	0.391	0.200	4.129	3.063	4.942	1.188
0.5	0.212	0.231	3.998	2.986	5.213	0.890	0.393	0.199	4.141	3.066	4.940	1.194
0.6	0.231	0.229	4.028	2.995	5.187	0.925	0.395	0.198	4.152	3.069	4.939	1.199
0.7	0.246	0.226	4.053	3.003	5.166	0.953	0.396	0.198	4.163	3.071	4.939	1.203
0.8	0.259	0.224	4.074	3.010	5.148	0.977	0.397	0.197	4.173	3.073	4.938	1.206
0.9	0.270	0.222	4.092	3.016	5.133	0.997	0.398	0.196	4.182	3.075	4.938	1.209
∞	0.402	0.190	4.309	3.099	4.953	1.238	0.402	0.190	4.309	3.100	4.953	1.238

Table 4.B % welfare gains or losses from cooperation

m_2	**Nash**			**Cooperative**			*Gains %*		
	W_{CORE}	W_{Per}	W_{TOT}	W_{CORE}	W_{Per}	W_{TOT}	*CORE*	*Per*	*TOT*
0.1	1.190	1.147	1.169	1.209	1.174	1.192	1.6	2.7	2.0
0.2	1.196	1.156	1.176	1.209	1.174	1.192	1.1	1.8	1.3
0.3	1.199	1.162	1.180	1.209	1.174	1.192	0.8	1.2	0.9
0.4	1.201	1.165	1.183	1.209	1.175	1.192	0.6	0.9	0.7
0.5	1.202	1.168	1.185	1.208	1.175	1.192	0.5	0.7	0.6
0.6	1.203	1.170	1.186	1.208	1.175	1.192	0.4	0.6	0.5
0.7	1.203	1.171	1.187	1.208	1.176	1.192	0.4	0.5	0.4
0.8	1.204	1.172	1.188	1.207	1.176	1.192	0.3	0.4	0.3
0.9	1.204	1.173	1.188	1.207	1.176	1.192	0.3	0.3	0.3
∞	1.203	1.180	1.191	1.203	1.180	1.192	0.0	0.0	0.0

In *Table 4.A*, we compare the Nash to the cooperative solution, between and within the productive(EU-Core) and the less productive(e.g. EU-Periphery) countries, as mobility cost varies. The main findings of our study are verified here. The "North" imposes higher capital tax rate compared to the "South", regardless of the policy chosen(cooperative or non-cooperative). As mobility cost falls, both jurisdictions compete for capital inflows by lowering their capital taxation, while under coordinated actions, the Northern countries increase and the Southern countries decrease their capital tax rate. In addition, labor taxation functions as a substitute of the capital taxation, depending on the degree of market openness. Particularly, when the economies act competitively, the capital tax competition effect, cause a rise to labor tax rates in both countries. Instead,

Table 4.C. % output gains or losses from cooperation

m_2	**Nash**			**Cooperative**			*Gains %*		
	y_{CORE}	y_{Per}	y_{TOT}	y_{CORE}	y_{Per}	y_{TOT}	*CORE*	*Per*	*TOT*
0.1	4.685	3.778	8.463	4.793	4.102	8.900	2.3	8.6	5.1
0.2	4.672	3.859	8.531	4.787	4.108	8.894	2.5	6.5	4.3
0.3	4.663	3.917	8.580	4.776	4.117	8.894	2.4	5.1	3.7
0.4	4.655	3.962	8.617	4.764	4.129	8.893	2.3	4.2	3.2
0.5	4.648	3.998	8.647	4.752	4.141	8.893	2.2	3.6	2.8
0.6	4.642	4.028	8.670	4.740	4.152	8.892	2.1	3.1	2.6
0.7	4.637	4.053	8.690	4.729	4.163	8.892	2.0	2.7	2.3
0.8	4.633	4.074	8.706	4.719	4.173	8.891	1.9	2.4	2.1
0.9	4.628	4.092	8.720	4.710	4.182	8.891	1.8	2.2	2.0
∞	4.577	4.309	8.887	4.577	4.309	8.887	0.0	0.0	0.0

under cooperation, the more productive North looses its labor tax policy and the less productive South tightens their, when markets are open. Also, perfect capital mobility seems to benefit total output of the Core countries, whereas Periphery countries produce more when their economies are closed. *Table 4.B* depicts the welfare levels and gains for both countries, under cooperative and non-cooperative policies. As we converge to a world with zero capital mobility frictions, the less productive group gains more in terms of relative welfare. However, if economies face capital mobility restrictions, any advantage from cooperation, for either of the two groups, disappears.

As in the tradition, we do welfare analysis. However, it is interesting to explore the implications of economic integration on total output, under the same policy context. This can be particularly useful, since welfare might sometimes be driven by leisure, leading to ambiguous conclusions. We observe that, in general, results are bigger in terms of output and also, for any given level of mobility cost, the Periphery gains are much more pronounced compared to the Core, as the degree of economic integration increases (*Table 4.C*).

Summing up, we conclude that the standard argument in favor of tax coordination also applies in the case of asymmetric countries. Though, the less productive country enjoys much greater welfare gains than the more productive one, and thus, has stronger to cooperate. This observation is supported by the relative difference in all fundamentals, between the more productive and the less productive country, which is even bigger in the case of Nash solution. Also, when both mobility cost and asymmetry in productivity exist, cooperation is good for the aggregate world economy, but is not necessarily Pareto efficient, meaning that, in a non-symmetric world, cooperation can make some countries worse off. The latter can happen when one country is 100% more productive than the other.

6 Allowing for International Public Goods

Our analysis so far supports that in a world economy where two countries trade with each other and deal with a single spillover, namely capital mobility, tax policy coordination is preferable to competition, as it makes both countries better off. This result is even stronger in the case of asymmetric countries. In this section, we enrich our model with International Public Goods (IPGs). As it will become clear later, IPGs induce countries to coordinate their actions, as the welfare gains from cooperation are even bigger. However, before we proceed, it is important to decode the definition of IPGs and their importance in the international agenda.

IPGs received major attention at the United Nations Development Programme's publication *Global Public Goods*[20]. Nowadays, international, and particular, global public goods are crucial to domestic and individual well-being. Among public bads, we consider the well-known examples of banking crises, Internet-based crime, and increased risk of ill-health as a consequence of the increased trade and travel. Within the class of public goods are the international standards for international transport and communication, coordinated taxation, monetary policy, governance, trade and more. Before the late 1980s, all these issues were concerns of national interest, however, the years that followed, global economic integration raised policy questions that were subject to international coordination. Nowadays, these questions are still to be answered and cooperation among nations seems even more urgent.

The reasons why public goods and bads are going international, is a matter out of our discussion. Instead, we are interested in defining the main characteristics–nonrivalry and nonexcludability–of a public good, from an international perspective. It is particularly important to identify who is going to benefit from the provision of a public good, so that a public good is qualified as international. The significance of this relies on the fact that despite the market integration, the world continues to be marked by tenacious inequalities and clear dividing lines, where some people have the ability to set public policy agendas and where some goods, although considered public, are more easily-accesible to some people than others. Defining the beneficiaries–*the publicum*–will help in correcting supply problems. As *Conybeare (1984)*[8] notes, *" in the public good game the degree of suboptimality is normally considered to be a function of the extent to which the qualities of publicness are present and of the number of beneficiaries"*. IPGs vary substantially from other public goods, in terms of diversity among beneficiary groups and more importantly in terms of the size of these groups, which may reach billions of people. Thus, extreme diversity and magnitude within beneficiary groups that include developing and industrial countries, people of different cultures that live in difference ecosystems and come from different historical backgrounds, imply different interests and concerns and the cooperation will not be easy to achieve. Given the large number of participants, collective action problems, such as free riding or prisoner's dilema, emerge.

The *free-rider problem* was first described by *Hume*, in the mid-18 century. According to his writings, a thousand citizens would fail to jointly work for the common good, as a result of a single individual's incentive to *"free himself of the trouble and expense, and... lay the whole burden on others"* [17]. *Garrett Hardin* [15] reinstated the issue in *"The Tragedy of the Commons"*. In his work, if shepherds were to share a common pasture, they would eventually increase their herd beyond any limit, causing overgrazing and land degradation. *Olson (1971)* [29] argues that people face a powerful incentive to avoid contributing personal resources to common endeavours. People are afraid of expressing their interest, because they think that if they do so, they would also have to pay the bill. In turn, the public good supplier receives the wrong signal, markets do not clear, public goods are undersupplied and resource allocations are suboptimal.

Prisoner's Dilemma is a situation in which lack of information prevents cooperation between two prisoners (*R. Hardin 1971*[16], *Brams 1973*[4], *Riker and Ordeshook 1973*[34], *Kimber 1981*[22], *Conybeare 1984*, *Oye 1986*[21]). In general, if the two prisoners cooperate and confess the crime, their punishment would be less severe than if they do not cooperate. Instead, they act on their own self-interest and they end-up serving more years in prison. This well-known example is very intuitive and applies to many real-life situations, in which two or more players face incentives to diverge from cooperation, unless there are mechanisms that encourage communication and trust. The supply of public goods also suffers from coordination failures in the form of rent seeking on the part of policy-makers and bureaucrats, public expenditure biases in favour of influential population segments, etc(*Olson 1971*, *Strange 1996*[36], *World Bank 1997*[1]).

The global economic and financial integration has given rise to a new set of public policy challenges. What can be thought of an action of national interest, may sometimes be bad from an international perspective. The extended magnitude of challenges such as, the AIDS epidemic, climate change and financial crises, demands collective effort and induces governments to work cooperatively. What if nations do not cooperate and international public goods were not provided? Would this mean the end of world as we know it? Under certain circumstances, *the fate of the Earth depends on them being provided*[2], thus if we fail to supply these goods, our world is exposed to great danger. It is our duty to care about the wellbeing of ours and future generations, by preventing nuclear proliferation, by suppressing killer pandemics, by mitigating climate change and by promoting fundamental scientific knowledge. Only if we realize the power of this concept, we should be able to determine why these international public goods are under-provided and show that they are under-provided for similar reasons.

Nevertheless, one has to be aware when it comes to define a public good as international. In practice, the definition of a public good is not a trivial task. For example, poverty alleviation is often considered an IPG, providing the right arguments to characterize almost all development activities as IPGs too. On the other hand, only few goods are pure public goods. Most of these goods are, in fact, "impure" or mixed, with features of both public and private goods. In our example, the reduction of poverty cannot be considered as an IPG itself, but the goods that play a decisive role in reducing poverty are indeed IPGs. *Table 5*, was presented by World Bank in 2001[35] and indicates goods that can reasonably considered IPGs.

How can IPGs Help Reduce Poverty?

IPGs could yield a high payoff in terms of poverty reduction by improving outcomes in certain policy domains that are particularly relevant to developing countries. This would improve the effectiveness of aid.

Health	Infectious diseases severely disrupt economic life in many developing countries. They kill many adults during their productive years, and the dislocation of families to escape these scourges reduces investment in child development. Even when disease does not kill or threaten to kill, it often reduces economic activity well below its potential. For example, malaria continues to impose a high cost through lost workdays.
Environment	Many tropical developing countries are more vulnerable to projected climate change than countries in the temperate zones. Global warming is likely to affect food production in the tropics adversely and may increase the range of tropical contagious diseases. Some low-lying developing countries, such as Bangladesh, are also likely to be disproportionately affected if sea levels rise, because they lack the resources and infrastructure to cope with the resulting floods.
Knowledge	Modern information and communications technologies have greatly enhanced developing countries' ability to tap into the global knowledge pool. These technologies help improve people's access to services and resources, thereby empowering them and expanding their economic opportunities. For example, biotechnology has improved plant varieties and the genetic potential of livestock, allowing more flexible crop management and boosting productivity. This may accelerate the reduction of rural poverty, which has recently slowed in a number of countries with a large number of poor.
Peace and Security	Conflict triggers instability and social dislocation, hampering growth and undoing progress in poverty reduction. As Africa's experience demonstrates, civil wars and domestic unrest can easily spread, destabilizing entire regions and limiting countries' abilities to share in the benefits of expanding world trade, financial flows, and technological advances.
Financial Stability	Boom and bust economic cycles prevent countries from consolidating progress in poverty reduction, because it is the poorest who are the most vulnerable to these swings. For example, evidence from metropolitan areas in Brazil shows recent large swings in the poverty rate, which edged up in the wake of the emerging market financial crisis and has fallen again since late 1999 thanks to the resumption of growth.

Although a number of global and regional endeavors to create IPGs entail considerable investment costs, others do not. For example, the chief input into the creation and promulgation of rules and standards to safeguard financial stability is negotiations, not capital. Such policy initiatives may therefore have even higher financial payoffs in terms of poverty reduction.

Table 6. *Source: World Bank (2001)*

6.1 Symmetric Countries

In *Tables 7.A-C, 8.A-C* we account for international public goods and their interaction with market openness. Specifically, in *Table 7.A*, we consider the case when there is zero capital mobility ($m_2 \to \infty$), so that it is only public goods that generate cross-country spillovers. We observe that the introduction of international public goods leads to a considerable rise in cooperative taxes, while leaving the Nash solution unaffected. Furthermore, the cooperative labor tax rate increases from 19%, when there is no IPG, to 32%, when the public good is fully international. Regarding total output and first-period private consumption, the changes are negligible, while second-period consumption registers gradual decrease as the magnitude of international public good rises.

Now, if we compare *Table 1.B* and *Table 7.A* we obtain some very interesting results. Firstly, in these tables we focus on a different spillover at a time. *Table 1.B* is about capital mobility, leaving out of the equation the IPGs, while *Table 7.A* considers IPGs without capital mobility. Secondly, we observe that the capital mobility spillover may yield higher gain from cooperation compared to the IPG spillover, only in the case of zero mobility cost. Thirdly, both market openness and IPGs increase the cooperative provision of public good, with the effect being more pronounced in the economy with capital mobility spillover. Fourthly, as the magnitude of IPG increases, second-period cooperative consumption falls by 2% to 20%, whereas, when capital is perfectly mobile the reduction barely reaches 10%. Whatever the case, the drop in second-period consumption is attributed to the substitution effect caused by the cooperative capital tax rate, which, by definition, is higher than the Nash tax rate. Finally, we notice that the immobility of capital implies a monotonic rise of welfare benefit in θ. As the public good becomes more "international", each country faces a stronger incentive to free ride on other country's provision of public goods, causing a rise in the difference between the two tax rates(Nash and cooperative) and a monotonic increase of the gains from policy harmonization.

In *Table 7.B*, we present the combined result of both international public goods and capital mobility. In particular, we fix the impact of IPGs at a modest level of 30% and allow for mobility cost variations. Harmonized policies yield higher capital and labor tax rates, which, in turn, lead to increased public good provision and lower second-period consumption. Notice that the cooperative solution is robust to mobility cost changes. On the other hand, as economies become more integrated, non-cooperative actions trigger capital tax competition and render markets more dependent on labor tax rates. Also, second-period consumption rises and the public good is under-provided due to inadequate capital taxation. *Table 8.B* is indicative of the gains and losses, from cooperation over competition, in this specific example. In the special case of perfect capital mobility, the welfare gain from cooperation amounts to 6.2%, essentially outweighing by 100% the welfare benefits of the previous cases(either capital mobility, or IPGs only). Another striking result is public good's provision under cooperation, which appears 170% higher than the Nash solution, when mobility cost converges to zero. Moreover, relative second-period consumption and capital register 15% and 8% decrease, while first-period consumption and total output rise by 5% and 7% respectively.

Finally, in *Tables 7.C-8.C* we consider economies with limited mobility cost, and IPGs with magnitude ranging from 0% to 100%. Again, as θ increases, the cooperative solution is associated with increasing capital and labor tax rates, resulting in high provision of public good and decreased second-period private consumption, while total output and first-period consumption present negligible change. We observe that the combination of the two spillovers results in significant welfare gains as θ rises. At this point, we underline the non-monotonic effect of θ. We fix $m_2 = 0.1$ and focus on the effects from changes in θ. The welfare gains from cooperation reach a peak of 5 percentage points when market is

70% open, revealing that the higher the magnitude of international spillovers from public goods provision, the higher the benefit from cooperation. But, after this critical value of θ the welfare gain from cooperation gets lower with θ. This is due to the reduced incentive to compete for mobile tax bases as the public good turns from local to international. For example, if the public good is fully international there is no incentive to compete for mobile tax bases[3]. If we set $\theta = 1$, the solution is independent of the value of m_2 (see *Table 7.A* and *Table 7.C*). As *Bjorvatn and Schjelderup* point out, there is undersupply of public goods in the Nash equilibrium due to free riding. To sum up, when both spillovers are present, their interaction is non linear due to the non monotonic behavior of θ.

Table 7.A Ramsey Policies, practically closed economies, i.e. $m_2 \to \infty$, public good is international

$m_2 \to \infty$, **changing** θ												
θ	**Non-cooperative (Nash)**						**Cooperative**					
	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2
0.0	0.402	0.190	4.310	3.100	4.953	1.238	0.402	0.190	4.310	3.100	4.953	1.238
0.1	0.402	0.190	4.310	3.100	4.953	1.238	0.433	0.205	4.311	3.100	4.856	1.335
0.2	0.402	0.190	4.310	3.100	4.953	1.238	0.463	0.220	4.311	3.101	4.763	1.429
0.3	0.402	0.190	4.310	3.100	4.953	1.238	0.491	0.234	4.312	3.102	4.673	1.519
0.4	0.402	0.190	4.310	3.100	4.953	1.238	0.519	0.247	4.313	3.102	4.586	1.605
0.5	0.402	0.190	4.310	3.100	4.953	1.238	0.545	0.261	4.314	3.103	4.503	1.689
0.6	0.402	0.190	4.310	3.100	4.953	1.238	0.571	0.273	4.315	3.104	4.423	1.769
0.7	0.402	0.190	4.310	3.100	4.953	1.238	0.595	0.286	4.315	3.104	4.345	1.847
0.8	0.402	0.190	4.310	3.100	4.953	1.238	0.619	0.297	4.316	3.105	4.270	1.922
0.9	0.402	0.190	4.310	3.100	4.953	1.238	0.642	0.309	4.316	3.106	4.198	1.994
1.0	0.402	0.190	4.310	3.100	4.953	1.238	0.664	0.320	4.317	3.106	4.128	2.064

Table 7.B Ramsey Policies, both international public good and capital mobility (1)

$\theta = 0.3$, **changing** m_2												
m_2	**Non-cooperative (Nash)**						**Cooperative**					
	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2
0.0	0.000	0.257	4.046	2.943	5.520	0.562	0.491	0.234	4.312	3.102	4.673	1.519
0.1	0.102	0.245	4.111	2.973	5.381	0.737	0.491	0.234	4.312	3.102	4.673	1.519
0.2	0.162	0.237	4.151	2.994	5.297	0.841	0.491	0.234	4.312	3.102	4.673	1.519
0.3	0.203	0.231	4.178	3.008	5.241	0.909	0.491	0.234	4.312	3.102	4.673	1.519
0.4	0.231	0.226	4.197	3.020	5.200	0.957	0.491	0.234	4.312	3.102	4.673	1.519
0.5	0.252	0.222	4.211	3.028	5.170	0.993	0.491	0.234	4.312	3.102	4.673	1.519
0.6	0.269	0.219	4.222	3.035	5.147	1.021	0.491	0.234	4.312	3.102	4.673	1.519
0.7	0.282	0.216	4.231	3.041	5.128	1.043	0.491	0.234	4.312	3.102	4.673	1.519
0.8	0.293	0.214	4.239	3.046	5.112	1.061	0.491	0.234	4.312	3.102	4.673	1.519
0.9	0.302	0.212	4.245	3.050	5.099	1.076	0.491	0.234	4.312	3.102	4.673	1.519
∞	0.402	0.190	4.310	3.100	4.953	1.238	0.491	0.234	4.312	3.102	4.673	1.519

Table 7.C Ramsey Policies, both international public good and capital mobility (2)

$m_2 = 0.1$, **changing** θ												
θ	**Non-cooperative (Nash)**						**Cooperative**					
	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2	$\tau_{k,2}$	$\tau_{l,2}$	y_2	c_1	c_2	g_2
0.0	0.077	0.249	4.095	2.965	5.415	0.695	0.402	0.190	4.310	3.100	4.953	1.238
0.1	0.084	0.248	4.100	2.967	5.405	0.707	0.433	0.205	4.311	3.100	4.856	1.335
0.2	0.092	0.247	4.105	2.970	5.394	0.720	0.463	0.220	4.311	3.101	4.763	1.429
0.3	0.102	0.245	4.111	2.973	5.381	0.737	0.491	0.234	4.312	3.102	4.673	1.519
0.4	0.114	0.244	4.119	2.977	5.364	0.758	0.519	0.247	4.313	3.102	4.586	1.605
0.5	0.129	0.242	4.129	2.982	5.342	0.785	0.545	0.261	4.314	3.103	4.503	1.689
0.6	0.150	0.239	4.143	2.989	5.314	0.819	0.571	0.273	4.315	3.104	4.423	1.769
0.7	0.177	0.235	4.161	2.999	5.276	0.867	0.595	0.286	4.315	3.104	4.345	1.847
0.8	0.218	0.228	4.188	3.014	5.219	0.935	0.619	0.297	4.316	3.105	4.270	1.922
0.9	0.282	0.216	4.231	3.041	5.128	1.043	0.642	0.309	4.316	3.106	4.198	1.994
1.0	0.402	0.190	4.310	3.100	4.953	1.238	0.664	0.320	4.317	3.106	4.128	2.064

Table 8.A Closed economies, IPG only

$m_2 \to \infty$, θ changing, (%)

θ	W	c_1	c_2	y_2	k_2	g_2
0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	-2.0	0.0	0.0	7.9
0.2	0.1	0.0	-3.8	0.0	-0.1	15.4
0.3	0.3	0.1	-5.7	0.1	-0.1	22.7
0.4	0.6	0.1	-7.4	0.1	-0.2	29.6
0.5	0.8	0.1	-9.1	0.1	-0.2	36.4
0.6	1.2	0.1	-10.7	0.1	-0.2	42.9
0.7	1.5	0.2	-12.3	0.1	-0.3	49.1
0.8	2.0	0.2	-13.8	0.1	-0.3	55.2
0.9	2.4	0.2	-16.7	0.2	-0.3	61.0
1.0	2.9	-0.2	-20.0	0.2	-0.3	66.7

Table 8.B IPG and capital mobility (1)

$\theta = 0.3$, m_2 changing, (%)

m_2	W	c_1	c_2	y_2	k_2	g_2
0.0	6.2	5.4	-15.3	6.6	-7.7	170.1
0.1	3.6	4.3	-13.2	4.9	-6.3	106.0
0.2	2.5	3.6	-11.8	3.9	-5.4	80.6
0.3	1.9	3.1	-10.8	3.2	-4.7	67.1
0.4	1.6	2.7	-10.1	2.7	-4.1	58.6
0.5	1.4	2.4	-9.6	2.4	-3.7	52.9
0.6	1.2	2.2	-9.2	2.1	-3.4	48.7
0.7	1.1	2.0	-8.9	1.9	-3.1	45.6
0.8	1.0	1.8	-8.6	1.7	-2.8	43.1
0.9	0.9	1.7	-8.4	1.6	-2.6	41.1
∞	0.3	0.1	-5.7	0.1	-0.1	22.7

Table 8.C IPG and capital mobility (2)

$m_2 = 0.1$, θ changing, (%)

θ	W	c_1	c_2	y_2	k_2	g_2
0.0	2.0	4.5	-8.5	5.2	-6.6	78.2
0.1	2.5	4.5	-10.2	5.1	-6.5	89.0
0.2	3.0	4.4	-11.7	5.0	-6.5	98.3
0.3	3.6	4.3	-13.2	4.9	-6.3	106.0
0.4	4.1	4.2	-14.5	4.7	-6.2	111.7
0.5	4.6	4.1	-15.7	4.5	-6.0	115.2
0.6	4.9	3.8	-16.8	4.1	-5.7	116.0
0.7	5.0	3.5	-17.6	3.7	-5.3	113.1
0.8	4.9	3.0	-18.2	3.0	-4.6	105.5
0.9	4.2	2.1	-18.1	2.0	-3.3	91.2
1.0	2.9	0.2	-16.7	0.2	-0.3	66.7

6.2 Asymmetric Countries

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