Essays on Optimal Taxation

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This dissertation is submitted for the degree of
Doctor of Philosophy

School of Economic Sciences November 2020

I dedicate this Thesis to my loving family for their unconditional love and support.

Declaration

I hereby declare that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university and that to the best of my knowledge does not contain any materials previously published or written by another person except where due reference is made in the text. The views expressed in this thesis are those of the author only, and do not necessarily reflect the institutions that the author is currently or previously affiliated with.

George Liontos
November 2020

Acknowledgements

First of all, I would like to express my gratitude and appreciation to my supervisor, Professor Apostolos Philippopoulos (AUEB). Since my first steps as a researcher, his presence was and remained vital throughout this long and difficult journey. From the moment I started working with him, his inspiring words made me realise why a researcher should always be a perfectionist and why scientific knowledge should always be built upon well-established foundations. Being an academician is far from being an easy task, let alone being the person Mr Philippopoulos is. This thesis is completed thanks to its patience, guidance and persistence. It has been an honor that he trusted me as his PhD student and also as his teaching assistant. Following his path, I became a better researcher, but most importantly, I became a better person.

In addition, I would like to especially thank the second member of my thesis committee, Associate Professor Evangelos Vassilatos (AUEB), for his continuous scientific and psychological support over the past four years. I also feel grateful to him for trusting me to teach the tutorials of his courses. Furthermore, I would like to acknowledge the third member of my thesis committee, Professor George Economides (AUEB) who has always been supportive to me ever since the beginning of my PhD.

I would also like to thank Professor George Alogoskoufis (AUEB) for supervising my Master's Degree Dissertation. I am thankful for comments and support received by Assistant Professor Pantelis Kammas (AUEB). I would also like to express my appreciation to the remaining members of my thesis committee, Professor Theodore Palivos (AUEB) and Professor Plutarchos Sakellaris (AUEB) for their time and consideration.

Moreover, I acknowledge the encouragement and support received by Associate Professor Stylianos Arvanitis (AUEB), Professor Konstantinos Gatsios (AUEB) and Post Doctoral Researcher Vassiliki Bageri (AUEB). I will always be grateful to them because as a teaching assistant to their courses, I developed valuable public speaking skills and obtained significant knowledge on Economics.

Part of the thesis was presented at various workshops and conferences. I am thankful for comments and valuable discussions from Professor Torsten Persson (Institute for International Economic Studies), Assistant Professor Evangelos Dioikitopoulos (AUEB) and Professor

Frank Bohn (Radboud University) as well as various seminar or conference participants at the European Public Choice Society Meeting (Jerusalem, April 2019), the 23rd International Conference on Macroeconomic Analysis and International Finance (Rethymno, Crete, May 2019) and the 17th and 18th Conference on Research on Economic Theory and Econometrics (Tinos, July 2018-2019).

The secretariats of the Department have been tremendously helpful over all administration tasks these years. Special thanks to Ms. Maria Metaxa, Ms. Maria Marogianni, Ms. Vaia Valioti and Mrs. Athanasia Tsetseri.

My daily routine in the Econometrics Lab became a pleasure thanks to my close colleagues Danai Sarri and George Tsomidis. Sharing our thoughts and emotions made our journey much easier. I would also like to express my gratitude to Anastasia Chatzilena, Tryphon Christou, Galateia Makri, Vasiliki Dimakopoulou, Eleni Kyrkopoulou, Alexandra Sarafidou, and Maria Vidali for our mutually created precious and enjoyable moments.

I am grateful to my dear friend Ioannis Gogios for always providing his critical insight in various discussions and his support in my darkest hours. Also, I could not be thankful enough for having Kyriakos Georgitsopoulos and Elias Sarantopoulos as my closest friends. We shared tons of magic moments over the past twelve years and these fellas are responsible for these.

Moreover, I feel blessed for having Professor of Clinical Psychology Lambros Stavrou (University of Ioannina, Greece) as my godfather and mentor. Thanks to him, I became more self-contained by putting in place some of the most scattered parts of my personality. It is his own way of doing things and his perspective about life that prompted me to evolve as a person. I am glad that he is still one of the few people in my life that I consider them as fixed points of reference. One of the most motivating moments for me was when I heard him repeating the famous latin phrase *"primus inter pares"* meaning first among equals.

Last but not least, I want to thank my loving family for their unconditional love and support. My father Emilios Liontos and my mother Areti Koukia did their best creating a large and beautiful family and helping their kids evolve. Despite the difficulties, our team stayed together and grew stronger day by day. Father, Mother, I want to thank you for always being there for me and bearing all my absurd thoughts and actions. Now that I realize your struggles and fears I feel thankful to you for being the parents that you are. If only I could be half as the parent as you were for me. As the oldest sibling in my family, I feel proud for my brother Alexis and my sisters Maria and Irene. All three of them are fighters and inspire me through their ability to thrive in almost any circumstance. Guys, I want you to know that I love you from the bottom of my heart and I really hope that I could transfer some of my knowledge and experience to you.

This Thesis is my greatest accomplishment so far. Not only because it introduced me to academic knowledge and research, but also because it exceeded the conventional academic limits. For me this process was a spiritual quest for self-awareness that eventually shaped my beliefs and my life perspective. This everlasting journey is summarized in the following phrase

Evolution through knowledge and knowledge through evolution

which, to the best of my knowledge, has not been mentioned in any previous works.

Athens, Greece
30.09.2020

Abstract

Within a unified general equilibrium framework, we revisit the problem of international optimal taxation when policymakers commit and do not commit themselves to future policy, when they cooperate or not in their setting of policy, and when the underlying economies can differ in some key fundamentals. This rich setup allows us to shed light to some debated policy issues, namely, how cross-country asymmetries should shape the design of national tax policies and how in turn this design affects macroeconomic outcomes as well the distribution of benefits and costs from international policy cooperation. In addition, we study two kinds of international policy cooperation, flexible cooperation and rigid cooperation, which respectively mean that cooperative policies are country-specific or just single (one-size-fits-all). A general result is that, once we leave the symmetric world and allow for cross-country differences, flexible cooperation, although superior to Nash in terms of lifetime aggregate output and welfare, may hurt some countries so it is not Pareto improving. In the same direction, without policy commitment the standard results are reversed, meaning that cooperation proves to be counter-productive at least for a large range of parameter values. This happens mainly because, without commitment, capital tax rates are too high in general, so that tax competition, as implied by non-cooperation, works to mitigate this distortion. Putting all this together, we end up with a general second-best admission that in the presence of several distortions, taking just one out (here, lack of cooperation), is not necessarily productive. These results may partly explain why little progress has been made in moving to fiscal unions with cooperative national fiscal policies and why the burden of taxation has been shifted onto labor, the relatively immobile factor of production. Moreover, in the EU, this could rationalize the introduction of fiscal transfers from the winners to the losers.

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Chapter 1

Introduction to the Thesis

This Thesis revisits the problem of international optimal taxation when policymakers commit and do not commit themselves to future policy, when they cooperate or not in their setting of policy, and when the underlying economies can differ in some key fundamentals. As is well-known economies can differ in many ways but some differences are considered to be more crucial. Here, within a unified general equilibrium framework and following the related literature (*Chapter 2*), we will focus on cross-country asymmetries associated with differences in TFP, initial public debt, market competition and institutions. It is widely recognized that it is differences in these fundamentals[1] that in turn shape/cause differences in macroeconomic outcomes and performance like GDP, growth, fiscal deficits, current accounts, inflation, etc. This rich setup allows us to shed light to some debated policy issues, namely, how cross-country asymmetries should shape the design of national tax policies and how in turn this design affects macroeconomic outcomes as well the distribution of benefits and costs from international policy cooperation. In addition, driven by the work of *Alesina et al. (2005)[2]* as well as by policy practice at the EU and EZ level, we study two kinds of international policy cooperation, flexible cooperation and rigid cooperation which respectively mean that cooperative policies are country-specific or just single (one-size-fits-all).

This work is divided into two distinct parts, *Part A* and *Part B*. *Part A* (*Chapters 3-5*) focuses on optimal policy with commitment (*Ramsey-type equilibria*). Specifically, in *Chapter 3*, we present the model and solve for the world decentralised competitive equilibrium for any feasible policy, in *Chapter 4*, we solve for optimal non-cooperative and cooperative policies in symmetric economies and in *Chapter 5*, we focus on cross-country asymmetries related to differences in TFP, initial public debt, (product and labour) market competition and institutions.

[1] *see Acemoglu 2009, Chapter 4[1]* and many others.

In *Part B* (*Chapters 6-8*) we consider optimal policy with and without commitment. Particularly, in *Chapter 6* we describe the model and highlight the differences from *Part A*. Then, we solve for the world decentralised competitive equilibrium for any feasible policy. In *Chapter 7*, we solve for optimal policies with and without commitment in symmetric economies and in *Chapter 8*, we solve for optimal policies in non-symmetric countries that differ in their total factor productivities, their inherited public debt-to-GDP ratio and their product market competition.

Chapter 2

Literature and how this work differs

My work builds upon two classic and still growing literatures. The first is the literature on the optimal mix of taxes over time that goes back to *Kydland and Prescott (1977)[32]*, *Chamley (1986)[12]*, *Judd (1985)[24]*, *Fischer (1980)[20]*, etc, while, reviews can by found in *Ljungqvist and Sargent (2012)[35]*, *Drazen (2000)[17]* and *Persson and Tabellini (2000)[44]*. This literature has emphasized the importance of commitment technologies and how optimally chosen tax policies change when policymakers are free to reoptimize over time. The former is known as the Ramsey tax policy problem, while the latter solves for time-consistent policies. The second literature is on international tax competition[1] and the so-called race-to-the-bottom problem[2]. In that literature, positive cross-border externalities[3] (if a country cuts its tax rate unilaterally, this decreases capital and welfare in the other country other things equal) imply that non-cooperative (Nash) tax rates are inefficiently low. Most of this literature has focused on equilibria with policy commitment, either in symmetric economies (see e.g. *Persson and Tabellini (2000)[44]* for a review) or non-symmetric economies (see e.g. *Mendoza and Tesar (2005)[38]*). Notable exceptions that have solved

[1] *Capital tax competition has raised cause for concerns in EU policy circles for a long time. Both OECD[50] and European Commission (2001) consider tax competition a harmful practice that needs to be restrained. Zodrow et al. (1986)[52] show that competition for mobile capital leads to reduced tax rates, while Cooper et al. (1988)[14] show how strategic complementarities in agents' payoff functions may lead to coordination failures.*

[2] *Persson et al. (2002)[45] and Wildasin (2003)[51] prove that the higher the capital mobility the worse are consequences of tax competition between symmetric countries on global welfare and tax authorities rely on the labour tax base to finance their expenditures.*

[3] *Correia (1996)[15] shows that in a small open economy framework capital variations do not alter drastically the optimal tax path of the closed economy. Similarly, Razin et al. (1991)[47] find that the optimal decisions in the open economy almost coincide to the closed economy solution. Lejour et al. (1997)[33] and Koethenbuerger et al. (2010)[30] obtain the standard "race-to-the-bottom" result in the absence of portfolio diversification assumption.*

for time-consistent tax policies in asymmetric economies include *Klein et al. (2005)[28]* and *Quadrini (2005)[46]*.[4]

Here, within a unified general equilibrium framework, we revisit the problem of international optimal taxation when policymakers commit and do not commit themselves to future policy, when they cooperate or not in their setting of policy, and when the underlying economies can differ in some key fundamentals. This rich setup allows us to shed light to some debated policy issues, namely, how cross-country asymmetries should shape the design of national tax policies and how in turn this design affects macroeconomic outcomes as well the distribution of benefits and costs from international policy cooperation. In addition, driven by the work of *Alesina et al. (2005)[2]* as well as by policy practice at the EU and EZ level, we study two kinds of international policy cooperation[5], flexible cooperation and rigid cooperation, which respectively mean that cooperative policies are country-specific or just single (one-size-fits-all)[6].

[4] *Their analysis is limited at the steady state of asymmetric countries and how this is affected using capital and labour taxes.*

[5] *Kammas et al. (2009)[25], 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.*

[6] *On the various systems of taxation, Bucovetsky et al. (1991)[11] show that smaller economies choose to impose a zero-capital tax rate, given that income can only be taxed at the source.*

Part I

Part A: Optimal policy with commitment

Chapter 3

Model

Consider a conventional neoclassical world economy model consisting of two countries. For simplicity, we use a two-period economy as in e.g. *Persson and Tabellini (1992)[43]* and many others in this literature. In each country, there is a representative household, a representative firm and the national government. The household maximizes lifetime utility choosing consumption, work/leisure and investment between the two periods. The latter can be in the form of domestic capital, foreign capital and domestic government bonds. The firm maximizes profits choosing capital and labor inputs to produce a single traded good. With capital mobility across countries, the firm's capital can be owned by both domestic and foreign investors. The government is benevolent and, in order to finance utility-enhancing public goods/services, it taxes labor income, capital income invested in its own country (according to a residence-based system of taxation) and issues bonds.

The sequence of events is as follows. In the beginning of the time horizon, each government chooses its tax-spending-debt policies once-and-for-all acting either non-cooperatively (Nash) or cooperatively. In turn, having observed policy, private agents make their own decisions acting competitively. Since policy is chosen once-and-for-all before private decisions (especially, savings or investment) have been made, we solve for a commitment or Ramsey-type equilibrium (which can be either Nash or cooperative). To solve the model, we will typically work by backward induction. That is, we will first solve private agents' problems and derive the associated decentralized world equilibrium which is for any feasible policy mix in each country. Then, by taking all this into account, governments will choose their policies either by playing Nash or by acting cooperatively.

The domestic country will be denoted by the superscript d and the foreign country by the superscript f. The problems of agents (households, firms and the government) in each country are analogous so we will present the domestic economy only, except otherwise stated.

3.1 Households

In the domestic country, each household maximises:

$$\sum_{t=1}^{2} \beta^{t-1} U^d \left(c_t^d, l_t^d, g_t^d \right) \tag{3.1}$$

where $0 < \beta < 0$ is the time discount factor and c_t^d, l_t^d and g_t^d are consumption, work effort and public spending respectively.

For simplicity, the period utility function is assumed to be of log-linear form:

$$U^d \left(c_t^d, l_t^d, g_t^d \right) = \mu_1 \log c_t^d + \mu_2 \log(1 - l_t^d) + \mu_3 \log g_t^d \tag{3.2}$$

where the parameters $0 \leq \mu_1, \mu_2, \mu_3 \leq 1$ are the weights given to consumption, leisure and public spending respectively.

The budget constraints of the household in the two periods, $t = 1, 2$, are respectively:

$$c_1^d + k_2^d + b_2^d + f_2^d = \left(1 + (1 - \tau_{k,1}^d) r_1^d - \delta \right) k_1^d + (1 - \tau_{l,1}^d) w_1^d l_1^d + (1 + \rho_1^d) b_1^d + (1 - \tau_{k,1}^d) \pi_1^d \tag{3.3}$$

$$\begin{aligned} c_2^d = & \left(1 + (1 - \tau_{k,2}^d) r_2^d - \delta \right) k_2^d + (1 - \tau_{l,2}^d) w_2^d l_2^d + (1 - \tau_{k,2}^d) \pi_2^d \\ & + (1 + \rho_2^d) b_2^d + \left(1 + (1 - \tau_{k,2}^f) r_2^f - \delta \right) f_2^d - m \frac{\left(f_2^d \right)^2}{2} \end{aligned} \tag{3.4}$$

where k_2^d is capital invested at home at the end of the first period earning a gross return r_2^d in the next period, b_2^d is domestic government bonds purchased at the end of the first period earning a gross return ρ_2^d in the next period, f_2^d is investment abroad at the end of the first period earning a gross return r_2^f in the next period (if f_2^d is negative, it will denote foreign liabilities), w_t^d is the real wage rate, π_t^d is dividends paid by firms, the parameter $0 < \delta \leq 1$ is the capital depreciation rate, the parameter $m \in [0, +\infty)$ is a measure of costs associated with investment abroad as in *Persson and Tabellini (1992)* and $0 \leq \tau_{l,t}^d$, $\tau_{k,t}^d$, $\tau_{k,t}^f \leq 1$ are tax rates on labor income, capital income earned at home and capital income earned abroad respectively. In a two-period model, the terminal conditions are $k_3^d = b_3^d = f_3^d \equiv 0$.

The first-order conditions include the budget constraints and the optimality conditions for l_1^d, l_2^d, k_2^d, b_2^d and f_2^d which are respectively:

$$\frac{\mu_1}{c_1^d} (1 - \tau_{l,1}^d) w_1^d = \frac{\mu_2}{1 - l_1^d} \tag{3.5}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d = \frac{\mu_2}{1-l_2^d} \tag{3.6}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1+(1-\tau_{k,2}^d)r_2^d - \delta\right) \tag{3.7}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1+\rho_2^d\right) \tag{3.8}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1+(1-\tau_{k,2}^f)r_2^f - \delta - mf_2^d\right) \tag{3.9}$$

where, conditions (3.5) and (3.6) give the leisure-consumption trade-off in periods $t=1,2$ and equate the marginal value of labour to the after-tax return to labour, while conditions (3.7), (3.8) and (3.9) are standard Euler conditions for domestic capital, k_2^d, domestic bonds, b_2^d, and foreign capital, f_2^d.

3.2 Firms

The single traded good is produced by a single firm that acts competitively. In each period, $t=1,2$, the firm chooses capital, $\bar{k}_t^d$, and labour, $\bar{l}_t^d$, to maximize profit:

$$\max_{\bar{k}_t^d,\bar{l}_t^d} \pi_t^d = y_t^d - r_t^d\bar{k}_t^d - w_t^d\bar{l}_t^d \tag{3.10}$$

subject to a Cobb-Douglas production function, $y_t^d = A\left(\bar{k}_t^d\right)^a\left(\bar{l}_t^d\right)^{1-a}$, where $a\in(0,1)$ and A are standard technology parameters.

The optimality conditions for the two inputs are:

$$r_t^d = a\frac{y_t^d}{\bar{k}_t^d} \tag{3.11}$$

$$w_t^d = (1-a)\frac{y_t^d}{\bar{l}_t^d} \tag{3.12}$$

so that profits are zero in equilibrium.

3.3 Government

The government taxes labour income at a rate $0 \leq \tau_{l,t}^{d} \leq 1$, capital income earned by both domestic and foreign investors at a rate $0 \leq \tau_{k,t}^{d} \leq 1$ and issues bonds to finance its expenditures. The government budget constraints in the two periods are:

$$g_1^d + (1+\rho_1^d)b_1^d = \tau_{k,1}^d(r_1^d k_1^d + \pi_1^d) + \tau_{l,1}^d w_1^d l_1^d + b_2^d \tag{3.13}$$

$$g_2^d + (1+\rho_2^d)b_2^d = \tau_{k,2}^d\left(r_2^d(k_2^d + f_2^f) + \pi_2^d\right) + \tau_{l,2}^d w_2^d l_2^d \tag{3.14}$$

where g_1^d and g_2^d are government expenditures and b_1^d and b_2^d are beginning-of-period government bonds in periods 1 and 2.

3.4 World decentralised competitive equilibrium (for any feasible policy)

In a world decentralised competitive equilibrium (WDCE), which is for any feasible policy: (i) households maximise welfare in each country (ii) firms maximise profits in each country (iii) all constraints are satisfied in each country (iv) all markets clear including the world asset/capital market. Notice that, with capital mobility allowed between period 1 and 2, the market-clearing conditions for capital in the second period are $\bar{k}_2^d = k_2^d + f_2^f$ in the domestic economy and $\bar{k}_2^f = k_2^f + f_2^d$ in the foreign economy.

Collecting equations, we have the system:

Domestic economy

$$c_1^d + k_2^d - (1-\delta)k_1^d + f_2^d + g_1^d = y_1^d \tag{3.15}$$

$$c_2^d - (1-\delta)k_2^d + g_2^d = y_2^d - (1-\tau_{k,2}^d)r_2^d f_2^f + \left(1 + (1-\tau_{k,2}^f)r_2^f - \delta\right)f_2^d - m\frac{\left(f_2^d\right)^2}{2} \tag{3.16}$$

$$\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d = \frac{\mu_2}{1-l_1^d} \tag{3.17}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d = \frac{\mu_2}{1-l_2^d} \tag{3.18}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1 + (1-\tau_{k,2}^d)r_2^d - \delta\right) \tag{3.19}$$

$$\frac{c_2^d}{c_1^d} = \beta\Big(1 + (1-\tau_{k,2}^f)r_2^f - \delta - mf_2^d\Big) \tag{3.20}$$

$$g_1^d + \Big(1 + (1-\tau_{k,1}^d)r_1^d - \delta\Big)b_1^d = y_1^d\Big(\tau_{k,1}^d a + \tau_{l,1}^d(1-a)\Big) + b_2^d \tag{3.21}$$

$$g_2^d + \Big(1 + (1-\tau_{k,2}^d)r_2^d - \delta\Big)b_2^d = y_2^d\Big(\tau_{k,2}^d a + \tau_{l,2}^d(1-a)\Big) \tag{3.22}$$

Foreign economy

$$c_1^f + k_2^f - (1-\delta)k_1^f + f_2^f + g_1^f = y_1^f \tag{3.23}$$

$$c_2^f - (1-\delta)k_2^f + g_2^f = y_2^f - (1-\tau_{k,2}^f)r_2^f f_2^d + \Big(1 + (1-\tau_{k,2}^d)r_2^d - \delta\Big)f_2^f - m\frac{\Big(f_2^f\Big)^2}{2} \tag{3.24}$$

$$\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f = \frac{\mu_2}{1-l_1^f} \tag{3.25}$$

$$\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f = \frac{\mu_2}{1-l_2^f} \tag{3.26}$$

$$\frac{c_2^f}{c_1^f} = \beta\Big(1 + (1-\tau_{k,2}^f)r_2^f - \delta\Big) \tag{3.27}$$

$$\frac{c_2^f}{c_1^f} = \beta\Big(1 + (1-\tau_{k,2}^d)r_2^d - \delta - mf_2^f\Big) \tag{3.28}$$

$$g_1^f + \Big(1 + (1-\tau_{k,1}^f)r_1^f - \delta\Big)b_1^f = y_1^f\Big(\tau_{k,1}^f a + \tau_{l,1}^f(1-a)\Big) + b_2^f \tag{3.29}$$

$$g_2^f + \Big(1 + (1-\tau_{k,2}^f)r_2^f - \delta\Big)b_2^f = y_2^f\Big(\tau_{k,2}^f a + \tau_{l,2}^f(1-a)\Big) \tag{3.30}$$

where, in the above, we use the following equations describing gross wages, capital and bond returns in the two countries at $t = 1,2$:

$$w_t^d = (1-a)\frac{y_t^d}{l_t^d} \tag{3.31}$$

$$w_t^f = (1-a)\frac{y_t^f}{l_t^f} \tag{3.32}$$

$$r_t^d = a\frac{y_t^d}{k_t^d + f_t^f} \tag{3.33}$$

$$r_t^f = a\frac{y_t^f}{k_t^f + f_t^d} \tag{3.34}$$

$$\rho_t^d = (1-\tau_{k,t}^d)r_t^d - \delta \tag{3.35}$$

$$\rho_t^f = (1-\tau_{k,t}^f)r_t^f - \delta \tag{3.36}$$

Therefore, we have a system of 16 equations in 16 endogenous variables, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d$, $l_2^d, l_1^f, l_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, \tau_{k,2}^d, \tau_{k,2}^f$. This is given the independently set policy instruments. The latter include the rest of the tax rates, $\tau_{k,1}^d, \tau_{k,1}^f, \tau_{l,1}^d, \tau_{l,2}^d, \tau_{l,1}^f, \tau_{l,2}^f$, and the public spending items, $g_1^d, g_2^d, g_1^f, g_2^f$. In other words, in each period, one policy instrument needs to follow residually to close the government budget constraint. Here, it is assumed that this role is played by the end-of-period public debt in the first period (b_2^d and b_2^f) and by the tax rate on capital in the second period ($\tau_{k,2}^d$ and $\tau_{k,2}^f$); this is why these variables are included in the category of endogenous variables. We report however that the specific classification of policy instruments into endogenous and independently set at this level is not important to our results since policy will be chosen optimally. This comes next.

3.5 Optimal policy with commitment

We now endogenise policy under commitment. Following the related literature on tax competition, we will compare the case in which national policies are chosen non-cooperatively, as in a typical Nash equilibrium, to the case in which national policies are chosen cooperatively by a fictional world social planner. In both cases, national policymakers or the world planner will be constrained by the WDCE as presented above.

Note that the initial period capital tax rates, $\tau_{k,1}^d$ and $\tau_{k,1}^f$, have to be taken as given by policymakers because, as is well known, if the taxation of initial capital (where the latter is fully inelastic) is allowed, the optimization problem is reduced to a first-best one which is trivial (see e.g. *Ljungqvist and Sargent, 2012, chapter 16[35]*). Besides, here, although this is for algebraic simplicity only, we will treat first-period public spending in both countries, g_1^d and g_1^f, as exogenous variables.

3.5.1 Non-cooperative policies (Nash): Definition

In a non-cooperative (Nash) game, each national government chooses its own policies to maximize the welfare of its own citizens by taking as given the policies of the other government and by taking into account the system of equations summarizing the WDCE.

In other words, the domestic government chooses the independently set domestic policy instruments $\tau_{l,1}^d, \tau_{l,2}^d, g_2^d$ to maximise:

$$
\begin{aligned}
U^d\left(c_t^d, l_t^d, g_t^d\right) = {} & \mu_1 \log c_1^d + \mu_2 \log(1 - l_1^d) + \mu_3 \log g_1^d \\
& + \beta\left(\mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d) + \mu_3 \log g_2^d\right)
\end{aligned}
\tag{3.37}
$$

subject to the WDCE in equations (3.15)-(3.30).

Since the problem is too complex to be specified in a primal form (meaning that one cannot express the objective function and the constraints as functions of the independently set policy instruments only), we will follow usual practice by solving the problem in its dual form (*see e.g. Atkinson and Stiglitz, 1980*). This means that policymakers, in addition to the independently set policy instruments, re-choose all the allocations and the residually determined instruments of the WDCE system.

From the viewpoint of the domestic government, the solution to this dual optimization problem, in a Nash non-cooperative game, yields a system of 35 equations in 35 endogenous variables. Specifically, counting equations, we have the 16 constraints/equations of the WDCE, the optimality conditions for the 16 variables being determined by the WDCE system (as said, these variables are rechosen in a dual solution to the government problem), plus the three optimality conditions for the domestic independent policy instruments, $\tau_{l,1}^d$, $\tau_{l,2}^d$ and g_2^d. Counting endogenous variables, always for the individual country that plays Nash, we have the 16 variables of the WDCE system, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, l_1^f, l_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, \tau_{k,2}^d, \tau_{k,2}^f$, plus the 16 dynamic Lagrangean multipliers corresponding to the 16 equations of the WDCE system, plus the three optimally chosen instruments, $\tau_{l,1}^d$, $\tau_{l,2}^d$ and g_2^d. This is given the independent policy choices of the other country, $\tau_{l,1}^f$, $\tau_{l,2}^f$ and g_2^f, and the assumed exogenous policy variables, $\tau_{k,1}^d$, $\tau_{k,1}^f, g_1^d$ and g_1^f. The foreign country solves an analogous problem and obtains a similar set of 35 equations in 35 unknowns. That is, in equilibrium, we will end up with 54 equations in 54 variables (namely, 35+35-16) since the 16 equations of the WDCE are common to both countries and the same applies to the 16 variables that are endogenous at WDCE level.[1]

3.5.2 Cooperative policies: Definition

When national policies are chosen jointly by a fictional world social planner, the latter maximises a weighted average of households' welfare in each country with equal weights, γ, given to each one of them. Thus, the objective is now:

$$
\max W^{coop} = \gamma U^d + (1-\gamma) U^f \tag{3.38}
$$

[1] *For a detailed view of the non-cooperative (Nash) solution, see Appendix A.1.1.*

subject to the equations summarizing the WDCE (3.15-30).

The maximization is with respect to the independent policy instruments in the two countries, $\tau_{l,1}^d$, $\tau_{l,2}^d$, g_2^d, $\tau_{l,1}^f$, $\tau_{l,2}^f$ and g_2^f. We will thus have a system of 38 equations in 38 unknowns. Counting equations, we have the 16 constraints/equations of the WDCE, the optimality conditions for the 16 variables being determined by the WDCE system, plus the six optimality conditions for the independent policy instruments. Counting endogenous variables, we have the 16 variables of the WDCE system, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, l_1^f, l_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, \tau_{k,2}^d, \tau_{k,2}^f$, plus the 16 dynamic Lagrangean multipliers corresponding to the 16 equations of the WDCE system, plus the 6 optimality conditions for the 6 independent policy instruments, $\tau_{l,1}^d$, $\tau_{l,2}^d$, g_2^d, $\tau_{l,1}^f$, $\tau_{l,2}^f$ and g_2^f. This is given the the assumed exogenous policy instruments $\tau_{k,1}^d$, $\tau_{k,1}^f$, g_1^d and g_1^f.[2]

[2] *For a detailed view of the cooperative solution, see Appendix A.1.2.*

Chapter 4

Numerical solutions for symmetric economies

Since the complexity of the model does not allow for analytical solutions, we will resort to numerical solutions derived by MATLAB®. To study the properties of Nash and cooperative equilibria, we will start by solving for symmetric equilibria where both countries use the same policy strategies and end up with the same allocations and prices. Non-symmetric equilibria will be studied in the next section.

4.1 Parameterization

We now describe the benchmark parameterization of our symmetric two-country model. We use conventional values for the parameters and the exogenously set policy instruments. The aggregate productivity, A, which is a scale parameter, is set at 1 (see also e.g. *King and Rebelo (1999)* [26]). The power coefficient measuring the capital share of income, α, is set at 0.4 (see e.g. *Garcia-Verdu (2005)*[21]). Following usual practice, we set the time discount factor, β, equal to 0.9. In addition, symmetry implies that the social planner weighs equally ($\gamma = 0.5$) the utility of the household in each economy. The depreciation rate of private capital, δ, is set at 1, which is a typical assumption in two-period models. The weights of consumption, leisure and public goods in the utility function are set at $\mu_1 = 0.30$, $\mu_2 = 0.60$ and $\mu_3 = 1 - \mu_1 - \mu_2$ respectively (see e.g. *Papageorgiou et al. (2011)*[41]). The adjustment cost parameter associated with moving capital abroad is set at $m = 0.1$ (see e.g. *Persson and Tabellini (1992)[43]*), which translates to almost perfect capital mobility across countries. Furthermore, the exogenously set policy variables are based on OECD and European Commission estimates. Specifically, the value of private capital stock, k_1, is set at 0.5 and the initial public debt-to-output ratio, b_1/y_1, is set at 0.6. Finally, the first-period capital tax rate, τ_1^k, and the first-period public spending-to-output ratio, g_1/y_1, are set equal to 0.15 and 0.10 respectively (see *Table 3.1*). We nevertheless report from the start that the results below are robust to changes in these values at least within sensible ranges.

Table 4.1 Baseline parameterization

Variable	Description	Value
A	aggregate productivity (TFP)	1.00
α	productivity of private capital	0.40
β	time discount factor	0.90
γ	utility weight given to each country by the social planner	0.50
δ	depreciation rate of private capital	1.00
μ_1	consumption weight in the utility function	0.30
μ_2	leisure weight in the utility function	0.60
μ_3	public good weight in the utility function $(1-\mu_1-\mu_2)$	0.10
m	capital mobility cost	0.10
k_1	initial capital stock	0.50
τ_1^k	first-period capital tax rate	0.15
τ_t^l	labour tax rates $(t=1,2)$	0.20
g_t/y_t	public spending as a share of GDP $(t=1,2)$	0.10
b_1/y_1	initial public debt as a share of GDP	0.60

4.2 Symmetric WDCE (for any feasible policy)

Table 4.2 summarises the symmetric WDCE for any feasible policy. This means that, to get this solution, we need to set exogenously all policy variables except from those that adjust residually (b_2, τ_2^k) to close the government budget constraint in each period and in each country, as we explained above in the WDCE system (*Section 3.4*). In other words, in addition to the preset instruments defined above (k_1, b_1/y_1, g_1/y_1, τ_1^k in both countries), here we also set exogenously τ_1^l, τ_2^l, g_2/y_2 in both countries. Keep in mind however that these policy instruments will be chosen optimally, and hence will move to the list of endogenous variables, when we solve for optimal policies below.

Inspection of the results in *Table 4.2* reveals a well-defined solution with values that are not far away from those observed in the data for an average developed country.[1] The residually determined capital tax rate, τ_2^k, is 17%, while, regarding the impact of policy on macroeconomic outcomes, the solution roughly corresponds to the EU's average in 2017. In particular, hours at work (l_1) are equal to 26%, while consumption (c_1/y_1) and investment

[1] *For a detailed view on the evolution of macroeconomic outcomes in the Eurozone see https://stats.oecd.org.*

(i_1/y_1) account for 67% and 22% of first-period GDP respectively. In the second period, labour hours fall at 21%, while full depreciation of capital implies zero investment so that the distribution of total output between consumption and public spending is $c_2/y_2 = 0.9$ and $g_2/y_2 = 0.1$.[2]

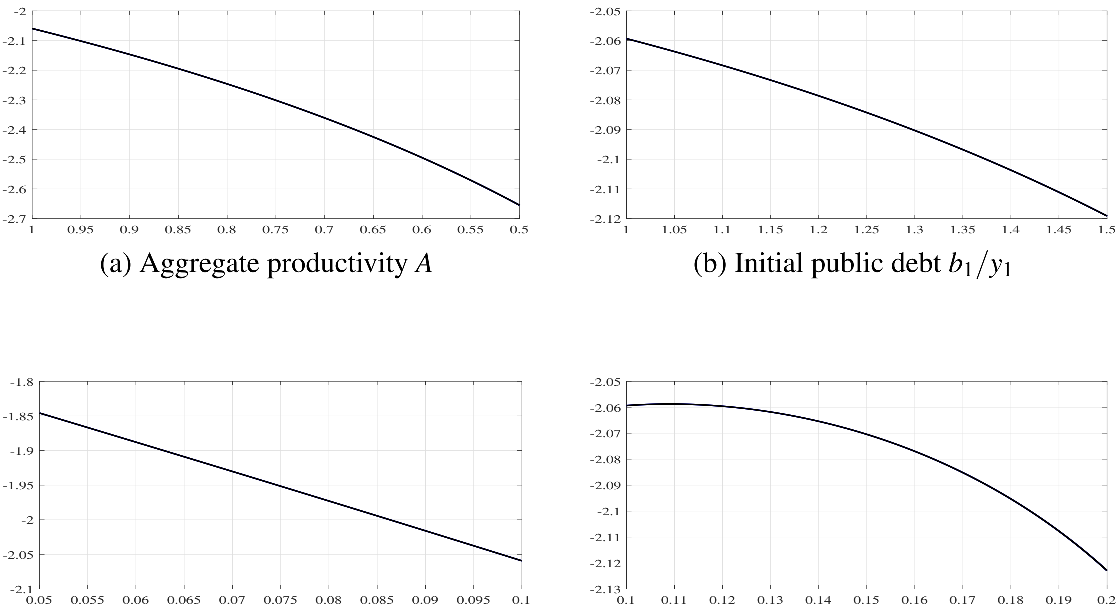
Table 4.2 *Symmetric world decentralized competitive equilibrium (WDCE). Data in the parentheses are obtained from Eurostat and OECD and refer to EU's averages in 2017.*

cap tax rate		**labour hrs**		**Shares**			
τ_2^k	0.1667	l_1	0.2623	c_1/y_1	0.6750	c_2/y_2	0.9000
	(0.2168)		(0.2000)		(0.5200)		
		l_2	0.2105	i_1/y_1	0.2250	i_2/y_2	0.0000
					(0.2010)		
				g_1/y_1	0.1000	g_2/y_2	0.1000
		output			(0.1950)		
		y_1	0.3395	k_1/y_1	1.4700	k_2/y_2	0.5443
welfare		y_2	0.1403	b_1/y_1	0.6000	b_2/y_2	0.1416
W	-2.0330				(1.0000)		

In *Figures 4.1 (a-d)*, to check the working of our model, we study the impact of various parameter values on the economy's welfare. As expected, a decrease in total factor productivity causes an acute welfare loss. Furthermore, whether we consider a rise in the inherited public debt-to-output ratio (b_1/y_1), or a rise in the first-period public spending-to-output ratio (g_1/y_1), the decline in welfare is equivalent, given the distorting nature of the residually adjusted capital tax rate (τ_2^k). Consider, for example, a rise in initial public spending. As households receive direct utility from public goods/services, a rise in the first-period public spending would directly increase their welfare in the first period. However, the higher public spending would be financed by a distorting fiscal policy instrument, τ_2^k, and hence, utility would be lower in the second period. Between these two opposing dynamic effects, the latter dominates and, as a consequence, we end up with lower lifetime discounted utility. Summing up, the model looks capable of yielding well-defined solutions that are in line with the theoretical and empirical features of a typical WDCE. In the next section, we switch to optimal (endogenous) policies.

[2] *For a detailed view of the WDCE (for any feasible policy), see Table A.1 in Appendix A.2.1.*

Figure 4.1 Welfare in a WDCE at different parameter values



(a) Aggregate productivity A (b) Initial public debt b_1/y_1

(c) Public good weight μ_3 (d) Initial p. spending g_1/y_1

4.3 Symmetric Nash equilibrium (SNE)

We now endogenize fiscal policy. We start with the case of non-cooperative (Nash) national fiscal policies as defined in *Subsection 3.5.1* above. Solutions are reported in *Table 4.3* which presents the solution for the optimally chosen fiscal policy instruments and the associated macroeconomic outcomes in a SNE with policy commitment. In this solution, the optimally chosen policy instruments are $\{\tau_2^k, \tau_1^l, \tau_2^l, g_2, b_2\}$ in both countries, while $\{\tau_1^k, k_1, b_1/y_1, g_1/y_1\}$ in both countries are set exogenously at the values defined above in *Section 4.1*.

The solution shows that the burden of taxation falls mainly on the inelastic factor (labor), so that the tax rate on second-period capital is low in a commitment (Ramsey) equilibrium, although it does not converge to zero as would happen in an infinite-time horizon economy (this is further discussed below). Qualitatively, this is as in the celebrated Chamley-Judd result which has served as the benchmark in the literature on optimal factor taxation. Here, in addition, the problem of undertaxation of future capital (and hence the problem of overtaxation of labour) becomes worse because capital is also mobile internationally relatively to labor, so that there is an extra force driving the capital tax rate to an even lower value relative to the case without international competition for mobile tax bases. This is the celebrated "race-to-the-bottom" result (see e.g. *Mendoza et al. (2005)[38]*), which works in the same direction with the Chamley-Judd result. This race-to-the-bottom result is confirmed when we start increasing the transaction cost parameter associated with investment abroad. As this parameter rises, so that capital becomes less and less mobile internationally and the race-to-the-bottom effect gets milder, the problem of future capital undertaxation becomes milder. For example, assuming a big transaction cost, which practically translates into a closed economy, both second-period tax rates on capital, τ_2^k, and labor, τ_2^l, rise from from 2% to 21% and from 25% to 31% respectively.

Table 4.3 Symmetric Nash equilibrium (SNE)

opt policy		**labour hrs**		**shares**			
τ_2^k	0.0157	l_1	0.2355	c_1/y_1	0.6179	c_2/y_2	0.7763
τ_1^l	0.3655	l_2	0.2253	i_1/y_1	0.2821	i_2/y_2	0.0000
τ_2^l	0.2474	**output**		g_1/y_1	0.1000	g_2/y_2	0.2237
g_2	0.0349	y_1	0.3183	k_1/y_1	1.5710	k_2/y_2	0.5757
wel	-2.0037	y_2	0.1559	b_1/y_1	0.6000	b_2/y_2	-0.1009

Regarding the implications of this policy for macro outcomes we observe that consumption (c_1/y_1) and investment (i_1/y_1) as shares of GDP are 62% and 28% respectively in the first period, while the remaining 10% is used for public spending. In the second period, with zero investment (this is by construction in our two-period model), consumption and public spending, again as shares of GDP, rise to 78% and 22% respectively. Note that the low tax rates on capital promote investment between the two periods and so enhance private consumption in the second period (this is confirmed below when we compare results to the cooperative solution).

4.4 Symmetric cooperative equilibrium (SCE)

We continue with the case of cooperative national fiscal policies as defined in *Subsection 3.5.2* above. Solutions are reported in *Table 4.4* which presents the solution for the optimally chosen fiscal policy instruments and the associated macroeconomic outcomes in a SCE with policy commitment. As can be seen, the chosen capital tax rate is now higher than in a SNE. In particular, with our baseline parameterization, it is equal to 21%, while the labour tax rates in the two periods (τ_1^l and τ_1^2) are almost equal to 30%. In other words, the race-to-the-bottom effect is now away by construction so that only the Chamley-Judd type result remains. Notice, however, that, although the tax rate on second-period capital is lower than that on labor, it is not zero as in the infinite-time horizon model typically used in the literature (see *Chamley (1986)*, *Judd (1985)*, *Lucas (1990)*[36], etc). This is because in a two-period model the costs of capital taxation last relatively little (here they last for one period only) so that the optimally chosen capital tax rate is not zero in general (different parameterizations could force it to be lower but it is not easy to make it zero contrary to the infinite-horizon model where the limiting tax rate on capital is zero irrespectively of parameter values to the extent that one excludes imperfections like lack of commitment, externalities, incomplete taxation, imperfect competition, etc).[3]

Table 4.4 Symmetric cooperative equilibrium (SCE)

opt policy		**labour hrs**		**shares**			
τ_2^k	0.2081	l_1	0.2530	c_1/y_1	0.6521	c_2/y_2	0.7500
τ_1^l	0.2638	l_2	0.2151	i_1/y_1	0.2479	i_2/y_2	0.0000
τ_2^l	0.3147	**output**		g_1/y_1	0.1000	g_2/y_2	0.2500
g_2	0.0366	y_1	0.3322	k_1/y_1	1.5049	k_2/y_2	0.5620
wel	-1.9989	y_2	0.1465	b_1/y_1	0.6000	b_2/y_2	0.0392

Concerning the macroeconomic consequences of cooperative optimal policy, given the exogenously given public spending which amounts to 10% of GDP in the first period, consumption and investment represent about 65% and 25% of output respectively, whereas the no-investment assumption in the second period allows higher consumption (75%) and public spending (25%) over GDP. Note that second-period private consumption is lower, while second-period public consumption is higher than in the Nash solution. This is intuitive since Nash optimal policies are good for private investment that favors private consumption in the future (see also *Section 4.5* below). In addition, as in a SNE, first-period output ($y_1 = 0.33$) is more than twice the output in the second period ($y_2 = 0.15$), a typical implication of the higher initial capital stock k_1 relative to the optimally chosen capital k_2. We also report that, due to the milder tax burden in the first period and the full capital depreciation, first-period output is higher than its SNE counterpart. Despite these differences between the SNE and the SCE though, the welfare gains from cooperation over Nash are small in size. In the next section, we provide a comparison of the two equilibria and the gains from cooperation.

4.5 Comparison of equilibria and gains from cooperation

Table 4.5 summarizes the capital and labor taxes, as well as the welfare gains from cooperation. As already discussed in *Sections 4.3* and *4.4* above, cooperation leads to a higher second-period capital tax rate (it rises from 2% in a SNE to 21% in a SCE). As a result, the cooperative regime allows for a milder tax burden on labour: the first-period labor tax rate

[3] *See e.g. Ljungqvist and Sargent (2004)[34]* for a review.

falls by 10 percentage points (it falls from 36% in a SNE to 26% in a SCE), while, the second-period labour tax rate rises by only 6 percentage points (it rises from 25% in a SNE to 31% in a SCE). Overall, as the net burden of taxation is rolled over second-period distorting policy instruments, cooperation has a negative impact on investment between the first and the second period and hence, on second-period levels of consumption, capital and output as well as on labour hours.[4]

Table 4.5 Optimal policies and gains from cooperation in symmetric equilibria

policy	**SNE**	**SCE**
τ_2^k	0.0157	0.2081
τ_1^l	0.3655	0.2638
τ_1^2	0.2474	0.3147
g_2	0.0349	0.0366
welfare	-2.0037	-1.9989

levels %		**shares %**			
l_1	7.43	c_1/y_1	5.53	c_2/y_2	-3.39
l_2	-4.53	i_1/y_1	-12.12	i_2/y_2	—
y_1	4.37	g_1/y_1	0.00	g_2/y_2	11.76
y_2	-6.03	k_1/y_1	-4.21	k_2/y_2	-2.38
W	0.24	b_1/y_1	0.00	b_2/y_2	138.85

Particularly, with cooperative policies, second-period labour supply (l_2), output (y_2) and consumption-to-GDP (c_2/y_2) are noticeably lower than in the SNE (-4%, -6% and -3%), while, at the same time, the loss in investment between the two periods (i_1/y_1) is even more acute (-12%). On the other hand, cooperation leads to 12% more public spending (g_2/y_2) in the second period, and higher levels of consumption and output in the first period.

At this point, we need to underline the effect of each policy regime on output and welfare. As cooperative strategies tend to switch distortions to second-period rather than first-period decisions, the cooperative output is higher than the Nash in the first period and lower in the second, translating into a 4% gain and a 6% loss respectively in quantitative terms. Nevertheless, as expected, cooperation is superior to Nash when the criterion is lifetime utility ("welfare"), although the gains are marginal (at roughly one tenth of one percent). This is as in the most of the related literature (see e.g. *Mendoza and Tesar (2005)*). However, we should point out that this result (namely, the marginal superiority of cooperation vis-a-vis Nash when the criterion is welfare) presupposes that one stays away from other imperfections like politically motivated governments (see e.g. *Persson and Tabellini (1995)*), incomplete factor mobility (see e.g. *Perotti (2001)*), international public goods (see e.g. *Kammas and Philippopoulos (2008)*[25]), or lack of commitment (see next chapters). These results may partly explain why little progress has been made in moving to fiscal unions with cooperative national fiscal policies and why the burden of taxation has been shifted onto labor, the relatively immobile factor of production.

[4] *For a detailed view on macroeconomic outcomes in the SNE and SCE presented here, see Tables A.2-3 in Appendix A.2.2.*

4.6 Robustness analysis

We next consider five experiments that help us to assess the robustness of our results. We focus on the valuation of public goods/services, aggregate factor productivity (TFP), the inherited public debt-to-output ratio, the capital mobility cost and finally the labour share of income in the production function.[5] *Tables 4.6 - 10* depict the optimal capital and labour income taxes and the welfare gains from cooperation in each case.[6]

(i) Decrease in the valuation of public goods/services: In this experiment we explore how the results from the symmetric benchmark case change when the weight given to the public good in the utility function, μ_3, decreases (*Table 4.6*). As already mentioned in *Sections 3.1* and *3.3*, households receive direct utility from public spending, which, by construction, is financed by capital and labour taxation. Therefore, a decrease in the valuation of the public good weakens the social need for tax revenues. Hence, the tax burden on capital and labour decreases in both periods and in both regimes (SNE and SCE), yet this reduction is disproportional in the SNE, as the capital tax rate drops by only 1pp (from 2% to 1%), while the labour tax rates decline sharply from 36% to 26% in the first period and from 25% to 17% in the second period. On the contrary, cooperation allows for a more efficient allocation of the tax burden between capital and labour income, a pattern which is preserved in all the cases we consider. Specifically, the capital tax rate decreases from 21% to 14%, while, at the same time, the labour tax cuts are even more acute (the labour tax rates decrease from 26% to 19%, and from 32% to 22%, in the first and second period respectively). Overall, although cooperation continues to lead to higher levels of lifetime discounted utility and output as compared to the Nash solution, as the public good loses its desirability, the superiority of cooperation vis-a-vis Nash becomes narrower.

(ii) Decrease in aggregate productivity: So far we have assumed that the value of aggregate productivity, A, (scale parameter) is 1. This experiment investigates the implications of a decrease in aggregate productivity. In *Table 4.7*, we present the optimal policies and the gains from cooperation that correspond to productivity-specific equilibria. As expected, a decline in TFP causes a contraction of the tax base in both economies, which in turn translates into lower optimal tax rates on both factors of production and in both regimes (SNE and SCE). The most prominent reductions concern the first-period Nash labour tax rate and the second-period cooperative capital tax rate. Specifically, in the case where productivity decreases by say 30%, we observe that the Nash labour income tax $\tau_1^{l(SNE)}$ displays a 4 pp drop and settles at around 32%, similarly to the cooperative capital tax rate $\tau_2^{k(SCE)}$ which also declines by 4 percentage points to 17%. As in the previous experiment (decrease in

[5] *For an in-depth decomposition of the Cobb-Douglas production function, see Jones (2013)[23], Ch. 4*
[6] *For a detailed robustness analysis see Tables A.4-8 in Appendix A.2.3.*

Table 4.6 Robustness of the valuation of public goods/services, μ_3

μ_3	*0.10	0.07	0.05	0.03
$\tau_2^{k(SNE)}$	0.016	0.014	0.013	0.011
$\tau_1^{l(SNE)}$	0.366	0.324	0.293	0.259
$\tau_2^{l(SNE)}$	0.247	0.216	0.194	0.170
$\tau_2^{k(SCE)}$	0.208	0.178	0.157	0.135
$\tau_1^{l(SCE)}$	0.264	0.234	0.211	0.187
$\tau_2^{l(SCE)}$	0.315	0.274	0.245	0.214
Welfare Gains %	0.240	0.142	0.082	0.025
Output Gains %	1.186	0.939	0.774	0.626

Table 4.7 Robustness of the aggregate productivity, A

A	*1.00	0.90	0.80	0.70
$\tau_2^{k(SNE)}$	0.016	0.016	0.015	0.015
$\tau_1^{l(SNE)}$	0.366	0.352	0.339	0.326
$\tau_2^{l(SNE)}$	0.247	0.242	0.236	0.229
$\tau_2^{k(SCE)}$	0.208	0.196	0.184	0.174
$\tau_1^{l(SCE)}$	0.264	0.257	0.249	0.242
$\tau_2^{l(SCE)}$	0.315	0.305	0.294	0.284
Welfare Gains %	0.240	0.205	0.173	0.147
Output Gains %	1.186	1.181	1.101	1.066

the valuation of the public good), cooperation continues to be superior to Nash both in terms of lifetime discounted utility and output, but this superiority decreases with TFP. This happens because a lower TFP leads to lower optimal tax rates throughout and this narrows any differences between non-cooperative and cooperative tax policies.

Table 4.8 Robustness of the initial public debt-to-GDP ratio, b_1/y_1

b_1/y_1	*0.60	0.70	0.80	0.90
$\tau_2^{k(SNE)}$	0.016	0.016	0.016	0.015
$\tau_1^{l(SNE)}$	0.366	0.387	0.408	0.428
$\tau_2^{l(SNE)}$	0.247	0.256	0.264	0.272
$\tau_2^{k(SCE)}$	0.208	0.228	0.248	0.267
$\tau_1^{l(SCE)}$	0.264	0.275	0.286	0.297
$\tau_2^{l(SCE)}$	0.315	0.331	0.347	0.362
Welfare Gains %	0.240	0.284	0.333	0.381
Output Gains %	1.186	1.427	1.696	1.952

Table 4.9 Robustness of labour productivity, $1-a$

$1-a$	*0.60	0.40	0.20	0.18
$\tau_2^{k(SNE)}$	0.016	0.009	0.004	0.003
$\tau_1^{l(SNE)}$	0.366	0.566	0.913	0.949
$\tau_2^{l(SNE)}$	0.247	0.249	0.161	0.146
$\tau_2^{k(SCE)}$	0.208	0.394	0.569	0.586
$\tau_1^{l(SCE)}$	0.264	0.270	0.245	0.243
$\tau_2^{l(SCE)}$	0.315	0.398	0.479	0.488
Welfare Gains %	0.240	1.571	12.50	16.79
Output Gains %	1.186	7.394	32.72	40.36

(iii) Increase in the initial public debt-to-GDP ratio: In this experiment we consider a rise in the inherited public debt ratio, b_1/y_1 (*Table 4.8*). Despite that the initial debt burden gets higher, the Nash capital tax rate remains roughly equal to 2% (as in the benchmark case), due to the tax competition effect. Therefore, in order to service their higher level of public debt, the countries resort to tax revenues generated mainly from labour income. This

may help explain why labour tax rates, and in particular those in the first-period, display such a prominent rise (they increase from 36% to 42%). On the other hand, when countries cooperate, the capital tax rates constitute an important element of the tax mix, as for every 10% increase in the public debt, they rise by almost 2 pp and eventually settle at around 27%. In the same direction, the burden of taxation follows a balanced distribution between the first and the second period as the labour income is taxed analogously. Moreover, the welfare gains from cooperation are increasing in the level of initial public debt and they can be as high as 0.38% (this is 50% more than in the benchmark case), while, at the same time, the output gains are even bigger at 2%. The mechanism behind these results is the chosen tax policy. In a typical SNE, the capital tax rate is mainly used to attract foreign capital and so it loses its redistributive role. Hence, policymakers rely more on labour taxation and this creates serious disincentives to labour supply, which in turn causes an output loss and a poor macroeconomic performance. Overall, in contrast to the previous experiments (decrease in the valuation of the public good and in TFP), where the superiority of cooperation vis-a-vis Nash faded out with the decrease in the respective parameter (μ_3 and A), the gains from cooperation regarding the lifetime discounted utility and output increase with the level of the initial debt burden.

(iv) Decrease in the labour share of income: Here, we investigate the impact of a decreasing labour share of income, $1-a$ (this is the power coefficient of labour), on optimal fiscal policy, welfare and output. As we can see in *Table 4.9*, the SNE implies that a decrease in the labour share (and hence an increase in the capital share), is accompanied by lower capital and labour tax rates in the second period and an almost confiscatory labour tax rate in the first period. Specifically, in the extreme case where only 18% of GDP is paid to labor (while the remaining 82% is paid to capital), the capital and labour tax rates fall to 0% and 15% respectively in the second period, while the labour tax in the first period absorbs 95% of labour income. Cooperation, on the other hand, smooths out the distortions caused by the decreasing labour share, as both factors of production hold equal amounts of the tax burden. In contrast to the SNE, the second-period capital and labour tax rates rise to 59% and 49% respectively in the second period, with the first-period labour tax rate registering only a marginal 2pp decrease to 24%. Hence, given the above developments, we anticipate that households' decisions (on consumption, savings and leisure) would be seriously distorted in the SNE and thus, lifetime discounted output and welfare would be considerably lower relative to the SCE. Indeed, there is no doubt that cooperation is the superior strategy, as it results in 17% more welfare and 40% more output compared to the Nash solution. Therefore, the superiority of cooperation increases sharply as the share of labor falls.

Table 4.10 Robustness of capital mobility cost m

m	*0.1	10	100	1000
$\tau_2^{k(SNE)}$	0.016	0.105	0.191	0.206
$\tau_1^{l(SNE)}$	0.366	0.321	0.274	0.265
$\tau_2^{l(SNE)}$	0.247	0.276	0.308	0.314
$\tau_2^{k(SCE)}$	0.208	0.208	0.208	0.208
$\tau_1^{l(SCE)}$	0.264	0.264	0.264	0.264
$\tau_2^{l(SCE)}$	0.315	0.315	0.315	0.315
Welfare Gains %	0.240	0.085	0.010	0.000
Output Gains %	1.186	0.594	0.065	0.002

(v) Increase in capital mobility cost: The last robustness experiment studies the effects of an increase in the adjustment cost parameter associated with moving capital abroad, m. Theory suggests that, in a world where income taxation is the only distortion, the optimal choice of tax policy is designed to reach a second-best welfare optimum at most. This experiment exposes the positive relationship between capital mobility and tax competition, by proving that a higher capital adjustment cost results in equilibria that are ranked higher compared to the benchmark case of almost perfect capital mobility. It is also useful because it highlights the role of policy coordination as a mechanism that offsets the growing mobility of capital flows. We report that when policy is conducted by cooperative counterparts, the level of capital mobility has no effect on the results, rendering all the SCE solutions equivalent to those obtained in the closed-economy version of the model. If instead governments act on their own self-interest, they are tempted to decrease capital tax rates to attract foreign capital, an effect which gets stronger in the benchmark case of perfect capital mobility. As it is apparent from *Table 4.10*, when capital mobility costs are too high the non-cooperative tax scheme converges to the cooperative one, meaning that the higher the mobility costs, the closer we get to the cooperative solution. In the limit, if capital is completely immobile, the Nash equilibrium coincides with the cooperative one. In sum, the superiority of cooperation increases as the degree of capital mobility rises and vise versa.

Chapter 5

Numerical solutions for non-symmetric economies

In what follows we study asymmetric economies. Economies can differ in many ways but some differences are considered to be more crucial. Here, following the literature (*Chapter 2*), we will focus on cross-country asymmetries related to differences in TFP, initial public debt, market competition and institutions. It is widely recognized that it is differences in these fundamentals[1] that in turn shape/cause differences in macroeconomic outcomes and performance like GDP, growth, fiscal deficits, current accounts, inflation, etc. We will first present some data on asymmetries in some key fundamental variables between the core and the periphery of the Eurozone (EZ). Then, building on this evidence, we will incorporate these asymmetries into our model and resolve for Nash and cooperative equilibria in national fiscal policies.

5.1 Evidence on cross-country asymmetries in the EZ

We start with a brief presentation of some related EZ data. This will provide empirical support for the types of asymmetries added to the model.

Fig. 5.1 is indicative of the productivity gap between the core and the periphery of the Eurozone. As can be seen, since the inception of the Euro and up to the financial crisis of 2008, the evolution of TFP in the core was fairly similar to the US's. Although the productivity in both economies suffered a severe blow since then, the US made a rapid rebound and returned to TFP growth, while the core, despite the sporadic recovery of 2009-2011, still follows a diverging route. However, regarding the periphery, all data suggest that

[1] *see Acemoglu 2009, Chapter 4[1] and many others.*

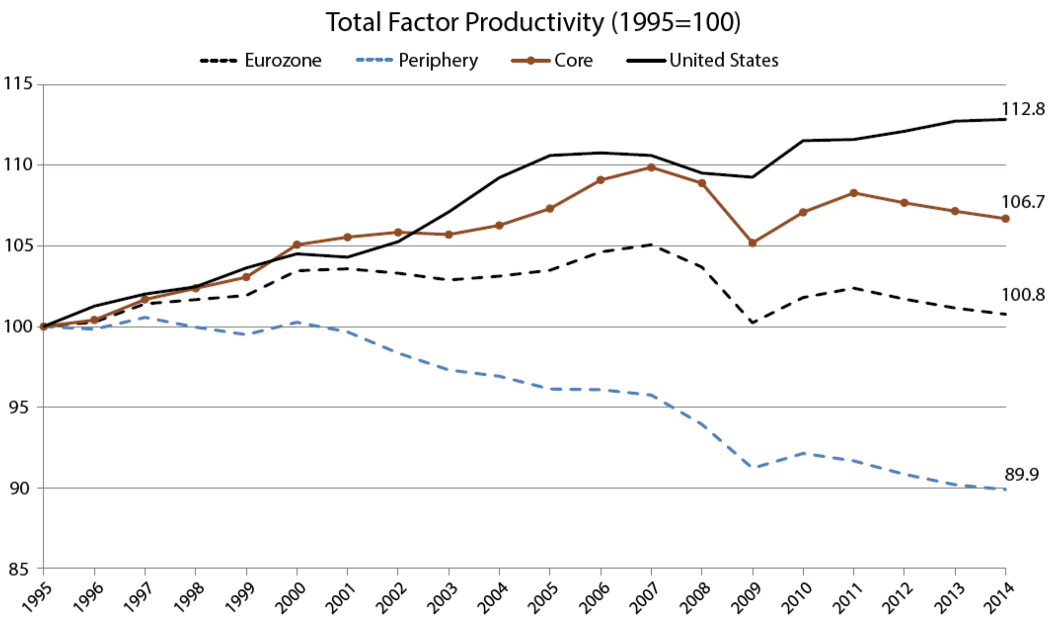


Figure 5.1 Total factor productivity (TFP), in the periphery and the core of Eurozone. *Source: Conference Board*

the euro-project initiation coincided with an adverse structural break in productivity, which has only got worse since the outburst of the crisis. A possible explanation of this gap is proposed by *Micossi (2016)*: *"lax financial conditions and the shifting composition of output towards non-tradables in the periphery, linked to real exchange rate appreciation, may help explain these developments"*.

Fig. 5.2 displays public debt-to-GDP ratios in the core and the periphery of the Eurozone, from 1995 to 2020. The graph depicts the convergence of debt ratios (to about 60%), which commenced in the mid 1990's and was suspended abruptly by the global financial crisis of 2008 in the majority of member states. Both the north and the south were struck hard by financial market distress and economic uncertainty, though the impact was much more pronounced in the periphery. Not only debt-to-GDP became divergent, but also, in some of the peripheral countries, the debt-to GDP ratio reached levels[2] that questioned their sustainability.

[2]*Debt ratios stand above 120% in three countries (Greece, Italy, and Portugal), at 197% in Greece (where each bout of austerity has only raised the level higher, despite private creditors' write-offs of €100 billion), above 100% in Belgium and Ireland, and close to 100% in France and in Spain, where they are still rising. That Greece cannot honour these debts and that some kind of debt relief will again be required is obvious; and yet the current adjustment programme agreed with EU institutions entails a fresh cut of the public sector deficit of some 4.5 percentage points of GDP, in a country that has already lost a quarter of its output since the Global Crisis struck. This was the price to be paid to gain approval of the new rescue package in the German Bundestag, but has hardly improved the credibility and sustainability of Eurozone policies.*

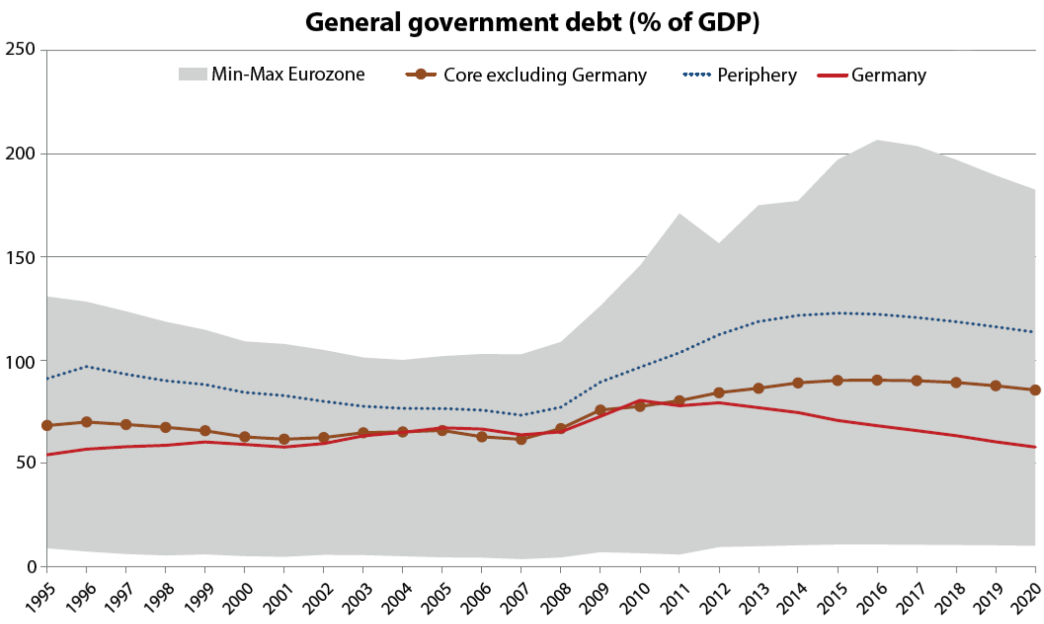


Figure 5.2 General government debt (% of GDP), in the periphery and the core of Eurozone.
Source: IMF

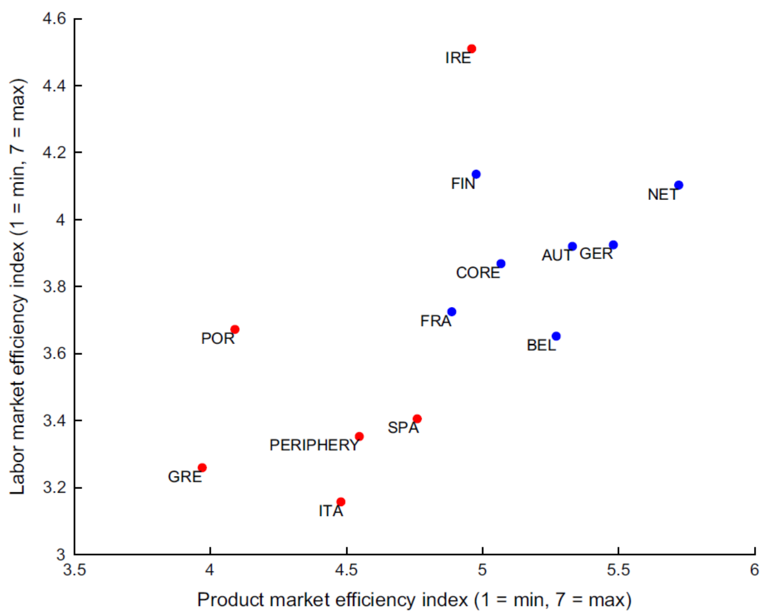


Figure 5.3 Market competition, in the periphery and the core of Eurozone.
Source: Eggertson et al. (2014)

Fig. 5.3 presents indexes of economic flexibility obtained from the World Economic Forum (2012)[48] that capture the degree of competition[3] in product and labor markets. As we see, the economies in the periphery of EZ score poorly[4] along both dimensions. In light of these arguments it is perhaps not surprising that structural reforms are the cornerstone of both academics and international agencies' policy advice.

As *Alogoskoufis et al. (2019)* [5] *suggest*

"Although financial market integration and effective regulation of financial markets have taken a priority since the 2010 crisis, the euro area remains a single currency area with significant real and financial asymmetries, segregated national fiscal systems, weak coordination of fiscal policies and a virtually non-existent federal budget. At the same time, the European Central Bank (ECB) remains the only major central bank in the industrialized world which cannot function properly as a lender of last resort to governments and commercial banks. In addition, labor markets in the euro area remain fragmented, contributing to major differences in unemployment rates, which are exacerbated by the notoriously low degree of labor mobility in Europe."

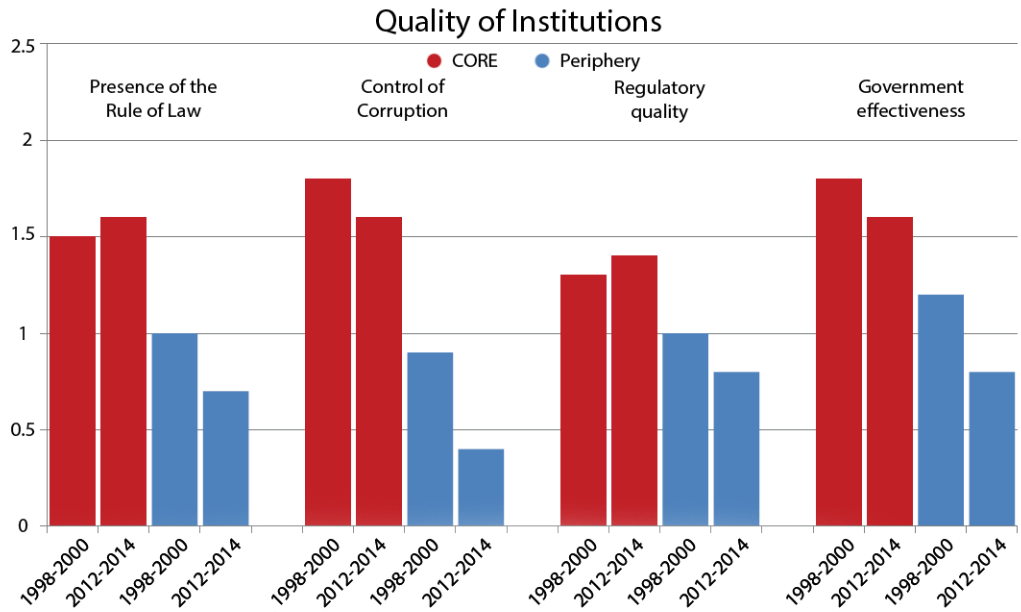


Figure 5.4 Quality of institutions, in the periphery and the core of Eurozone.
Source: World Bank

[3] *The product market efficiency index is an average of the scores in the categories related to market competition. The labor market efficiency index is an average of the scores in the categories related to wage flexibility. See World Economic Forum (2012) for more details.*

[4] *OECD estimates of business markups and regulations burden paint a similar picture.*

[5] *See Alogoskoufis et al. (2019)[3].*

Fig. 5.4 depicts *World Bank* indices that capture the quality of institutions in the core and the periphery of Eurozone, before and after the introduction of the euro. As it can be seen, key institutional quality indices, that are relevant for the presence of law, corruption control, regulatory quality and government effectiveness, deteriorated after the inception of the euro, with the impact being more acute in the periphery. On average, the core economies strengthened their judicial and regulatory framework despite the adverse socioeconomic circumstances of the Global Crisis of 2008, while the periphery economies witnessed significant degeneration of almost all their institutional mechanisms. While a drop in government effectiveness may be due to some extent to the dramatic cuts in public expenditure required by austerity, there is no reason why the preservation of the rule of law, the control of corruption or the quality of regulation should have worsened in response to the Global Crisis. Historical evidence instead, suggest that significant structural imbalances between the core and the periphery of Eurozone could possibly explain not only the inferior quality of institutions in the periphery, but also their poor evolution through time. A large weight in these results for the periphery is attributable to Italy.

5.2 Modelling cross-country asymmetries

In what follows, we will solve for optimal fiscal policy (Nash and cooperative) in non-symmetric equilibria. Regarding the kind of asymmetries, following the evidence provided above, we will focus on four types of cross-country asymmetries: First, we will assume that countries differ in their total factor productivities (TFP). Second, we will assume that countries differ in their initial public debt-to-GDP burdens. Third, we will assume that countries differ in either product or labour market competition. Fourth, we will assume that countries differ in their institutional qualities and in particular on the degree of protection of property rights. We will study one asymmetry at a time so as to be able to understand how each one of them works.

In terms of modeling, the first two types of asymmetry are straightforward to be added to the model. Total factor productivity and initial debt are respectively a parameter and an initial condition only, so they can be added easily; of course, now we have to solve for non-symmetric equilibria, which makes the dimensionality of the system considerably bigger as explained in *Subsection 3.5.1* above, but this does not add any complexity to the model itself. On the other hand, allowing for imperfect competition and institutional problems necessitates non-trivial modelling extensions which are presented in detail in *Appendices A.3.1* and *A.3.2* respectively. Here, in the main text, we just report that, in order to allow for imperfect competition we will use the well-known *Dixit-Stiglitz[16] model of imperfectly* *substitutable inputs that result in market power.*[6] To model institutional quality, on the other hand, we assume that firms in the periphery country can keep a fraction only of their output produced, which means that total output is a contestable prize because of weak property rights, while the rest of the fraction can be taken away by households who compete with each other for a share of the contestable prize in a Tullock-type redistributive contest that hurts everybody in equilibrium.[7]

5.3 Flexible and rigid cooperation of international unions

Concerning the cooperative framework, we will further distinguish between flexible and rigid international unions as in *Alesina et al. 2005[2].* In a flexible union, the planner chooses cooperatively country-specific policies. On the other hand, in a rigid union, the planner chooses cooperatively a single policy meaning a *"one-size-fits-all"* policy, which, although its optimally chosen as in the case of flexible integration, applies to all countries (examples include tax harmonization, a common tariff policy, a single monetary policy, etc). In our model, in the case of a rigid union, the planner solves the same problem as in the case of flexible cooperation, but, instead of choosing a different tax rate for each economy ($\tau^d_{k,2}, \tau^f_{k,2}, \tau^d_{l,1}, \tau^f_{l,1}, \tau^d_{l,2}, \tau^f_{l,2}$), it chooses union-wide tax rates ($\tau^k_2, \tau^l_1, \tau^l_2$) that apply to both countries. Typically, flexible cooperation is expected to more efficient, but rigid cooperation is easier to implement politically (see e.g. *Alesina et al. 2005*). Therefore, in what follows, we will solve for three types of asymmetric equilibria: (i) non-cooperative Nash (ii) cooperative policies in a flexible union (iii) cooperative policies in a rigid union. The details are presented in *Appendix A.3.3*.

5.4 Numerical solutions for non-symmetric equilibria and gains from cooperation

5.4.1 Asymmetries in TFP

We start with cross-country differences in TFP, where, as is the case in the data, the periphery is assumed to be less productive than the core (we set in particular, $A^{core} = 1 > A^{per} = 0.7$). In *Table 5.1* we present the solution for the optimally chosen fiscal policy instruments, the

[6] *There are numerous applications of this popular model (see e.g. Benassy et al. (1996)[8]). For applications to the EU, see Eggertsson et al. (2014)[19] and Koliousi et al. (2018)[31].*

[7] *See e.g. Besley et al. (2010)[10], Angelopoulos et al. (2009)[5], (2011)[4], Park et al. (2005)[42], Economides et al. (2007)[18].*

lifetime discounted level of output and welfare, and also, the gains from cooperation in non-symmetric equilibria with policy commitment.[8] As can be seen, both the capital undertaxation and the race-to-the-bottom results, previously addressed in the SNE, are also present in the non-symmetric Nash equilibrium (NSNE), in contrast to the non-symmetric cooperative equilibrium (NSCE) in which the race-to-the-bottom effect is away by construction. Recall that the problem of undertaxation of future capital is worse in the non-cooperative solution because of the "race-to-the-bottom" result that works in the same direction with the Chamley-Judd result (see *Section 4.3* above). Now, not only the capital tax rates in the NSCE are higher than in the NSNE, but also, due to the assumed differences in TFP, the optimally chosen policy mix differs substantially between the two countries. The Nash capital tax rates (5% in the core and 0% in the periphery) are considerably lower as compared to those chosen under flexible cooperation (18% in the core and 12% in the periphery). Nevertheless, the union-wide capital tax rate under rigid cooperation (8%) is close to the non-cooperative ones, as the policymaker chooses to set the single tax rate closer to the needs of the low-productivity country.

Table 5.1 Optimal policy and gains from cooperation when TFP, A, is lower in the periphery.

Optimal policy

	Nash		**Flexible**		**Rigid**	
τ_2^k	0.05	0.00*	0.18	0.12*	0.08	
τ_1^l	0.33	0.35*	0.26	0.30*	0.32	
τ_2^l	0.26	0.22*	0.30	0.27*	0.25	
g_2	0.04	0.02*	0.04	0.02*	0.04	0.02*
y	0.47	0.31*	0.47	0.31*	0.48	0.30*
W	-2.00	-2.32*	-1.99	-2.32*	-1.99	-2.32*

Gains from cooperation %

	Flex vs Nash		**Rig Vs Nash**	
y	0.49	1.20*	1.35	-1.80*
W	0.31	-0.10*	0.20	-0.16*

*The parameter associated with TFP in the periphery, A^{per}, is set at 0.7. * denotes macroeconomic outcomes in the periphery.*

Furthermore, as a consequence of capital undertaxation, the inelastic factor (labor) bears a disproportionally high amount of the tax burden compared to the elastic factor (capital), a problem which is mostly observed in the NSNE and is getting worse with the degree of international competition (that is when capital mobility increases). Specifically, in the non-cooperative framework, the first-period labour tax rate is roughly equal to 34% in both countries, yet, the second-period tax on labour income is much lower, 26% and 22% in core and periphery countries respectively. On the other hand, flexible cooperation implies a milder tax burden on labour, as the labour tax rates in both countries vary between 26% and 30% (in

[8] *See Table A.9 in Appendix A.3.4 for a detailed presentation of the optimal solution when countries differ in their total factor productivities (TFP).*

both periods), while, the union-wide labour tax rates under rigid cooperation are equal to 32% and 25% respectively in the first and second period.

Not surprisingly, the less productive country enjoys lower lifetime discounted output and welfare levels than the productive country in all cases studied. However, note that cooperation (both flexible and rigid) benefits only the high TFP country. Under flexible cooperation, the core economy enjoys 0.5% more output and 0.3% more welfare than Nash, whereas its gains under rigid cooperation are equal to 1.4% and 0.2% respectively. On the contrary, cooperation, and especially the rigid one, is too restrictive for the low TFP country, as it registers 1.8% less output and 0.2% less welfare compared to the non-cooperative strategy. It turns out that neither the flexible allocation of the tax burden between capital and labour, nor the union-wide policy mix, are able to mitigate the problems of under-investment and low-factor returns in the periphery country and, hence, this country would be better off by choosing its tax policy unilaterally. In sum, cooperation leads to non-trivial distributions implications across countries.

Table 5.2 Asymmetric Nash equilibrium when TFP, A, is lower in the periphery

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.05	0.00*	l_1	0.23	0.25*	c_1/y_1	0.66	0.57*	c_2/y_2	0.70	0.93*
τ_1^l	0.33	0.35*	l_2	0.24	0.20*	i_1/y_1	0.28	0.28*	i_2/y_2	0.00	0.00*
τ_2^l	0.26	0.22*				x_1/y_1	-0.04	0.05*	x_2/y_2	0.09	-0.20*
g_2	0.04	0.02*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.21	0.27*
			y_1	0.32	0.23*	k_1/y_1	1.58	2.14*	k_2/y_2	0.52	0.79*
Wel	-2.00	-2.32*	y_2	0.17	0.08*	b_1/y_1	0.60	0.60*	b_2/y_2	-0.05	-0.22*

*The parameter associated with TFP in the periphery, A^{per}, is set at 0.7. * denotes macroeconomic outcomes in the periphery.*

Table 5.3 Asymmetric cooperative equilibrium when TFP, A, is lower in the periphery

flexible cooperation

Optimal Policy			Labour hours			Shares					
τ_2^k	0.18	0.12*	l_1	0.25	0.26*	c_1/y_1	0.68	0.59*	c_2/y_2	0.69	0.88*
τ_1^l	0.26	0.30*	l_2	0.23	0.20*	i_1/y_1	0.26	0.26*	i_2/y_2	0.00	0.00*
τ_2^l	0.30	0.27*				x_1/y_1	-0.03	0.05*	x_2/y_2	0.08	-0.15*
g_2	0.04	0.02*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.23	0.27*
			y_1	0.33	0.24*	k_1/y_1	1.53	2.10*	k_2/y_2	0.51	0.76*
Wel	-1.99	-2.32*	y_2	0.16	0.08*	b_1/y_1	0.60	0.60*	b_2/y_2	0.04	-0.12*

rigid cooperation

Optimal Policy			Labour hours			Shares					
τ_2^k	0.08		l_1	0.23	0.27*	c_1/y_1	0.69	0.55*	c_2/y_2	0.64	1.09*
τ_1^l	0.32		l_2	0.26	0.17*	i_1/y_1	0.28	0.26*	i_2/y_2	0.00	0.00*
τ_2^l	0.25					x_1/y_1	-0.07	0.09*	x_2/y_2	0.15	-0.40*
g_2	0.04	0.02*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.21	0.31*
			y_1	0.31	0.24*	k_1/y_1	1.60	2.07*	k_2/y_2	0.48	0.92*
Wel	-1.99	-2.32*	y_2	0.18	0.07*	b_1/y_1	0.60	0.60*	b_2/y_2	-0.05	-0.20*

*The parameter associated with TFP in the periphery, A^{per}, is set at 0.7. * denotes macroeconomic outcomes in the periphery.*

5.4.2 Asymmetries in inherited public debt

In this experiment we consider cross-country differences in inherited public debt. In particular, based on the empirical evidence presented in *Section 5.1*, we assume that the periphery starts with a higher initial debt-to-GDP ratio than the core (we set $b_1^{core}/y_1 = 0.6$, $b_1^{per}/y_1 = 0.9$). Results are reported in *Table 5.4* which presents the optimally chosen fiscal policy, the corresponding macroeconomic outcomes and the gains from cooperation (in output and welfare terms) in non-symmetric equilibria with policy commitment.[9] As in the case of asymmetries in TFP, the "race-to-the-bottom" result that stems from international tax competition (present in a typical NSNE) intensifies the Chamley-Judd result (present in all commitment-type equilibria) and hence, the Nash capital tax rates are relatively low in both countries. Notice that this effect is so strong that, despite the level of asymmetry, the capital tax in the periphery (2%) is only 1 pp higher relative to the core. On the other hand, policy coordination (NSCE) alleviates the problem of tax competition and leads to a more balanced allocation of the tax burden in both economies. Specifically, the country-specific capital tax

[9] *See Table A.10 in Appendix A.3.4 for a detailed presentation of the optimal solution when countries differ in their initial public debt-to-GDP burdens.*

rate is equal to 24% in the core and 23% in the periphery, while the union-wide capital tax goes even higher at 25%, implying that the policymaker chooses a single tax rate closer to the fiscal needs of the high-debt country.

In addition, the strong fiscal imbalances in the periphery worsen the problem of labour overtaxation and hence this country depends more on tax revenues generated from labour income, as compared to the core country. This problem becomes more acute in the non-cooperative case, in which the first-period labour tax rates are equal to 37% and 42%, in the core and the periphery respectively, while their second-period counterparts are notably lower at 25% and 27%. On the contrary, the problem is getting milder under policy coordination, as capital and labour bear relatively equal shares of the tax burden in both countries. Despite that the higher level of public debt force the periphery to apply higher tax rates on the inelastic factor (31% and 35%, in the first and second period respectively) relative to the core (25% and 33%), the overall tax burden on labour under flexible cooperation is considerably lower than in the NSNE in both economies. Furthermore, the union-wide (rigid) labour taxes (28% and 34%) are equal to the arithmetic averages of those applied in the two countries under flexible cooperation, an outcome that could possibly indicate that the two countries receive equal treatment by the social planner.

Table 5.4 Optimal policy and gains from cooperation when initial public debt, b_1/y_1, is higher in the periphery.

Optimal policy

	Nash		**Flexible**		**Rigid**	
τ_2^k	0.01	0.02*	0.24	0.23*	0.25	
τ_1^l	0.37	0.42*	0.25	0.31*	0.28	
τ_2^l	0.25	0.27*	0.33	0.35*	0.34	
g_2	0.03	0.03*	0.04	0.03*	0.04	0.03*
y	0.46	0.44*	0.46	0.45*	0.46	0.45*
W	-2.00	-2.02*	-2.00	-2.01*	-2.00	-2.01*

Gains from cooperation %

	Flex vs Nash		**Rig Vs Nash**	
y	0.76	2.47*	0.88	2.15*
W	0.10	0.52*	0.11	0.34*

*The parameter associated with inherited public debt in the periphery, b_1^{per}/y_1, is set at 0.9. * denotes macroeconomic outcomes in the periphery.*

Regarding the implications of optimal policies for the macroeconomy, we report that despite its higher level of initial public debt, the periphery economy ends up with trivially lower levels of lifetime discounted output and welfare, as compared to the core economy, and this holds in all policy regimes. The reason behind this development is that, by construction, an increase in the size of public debt does not necessarily reduce the size of the tax base, in contrast to the other forces of growth considered here.

Moreover, focusing on the percentage gains from cooperation, we observe that no matter what is the type of cooperation (flexible or rigid), both countries reap gains from cooperation, yet the lion's share from those gains goes to the relatively disadvantaged economy. Specifically, under flexible cooperation the core economy enjoys 0.8% more output and 0.1% more welfare than in the Nash solution, while, at the same time, the respective gains in the periphery amount to 2.5% and 0.5%. As similar results hold in the case of rigid cooperation, we presume that cooperation (both flexible and rigid, but especially the former) serves mainly the needs of the high-debt country. The intuition is that the low-debt country, for the sake of cooperation, is forced to set relatively high tax rates that are compatible with the fiscal needs of the high-debt country, and hence are helpful for both economies, but mostly for the indebted periphery neighbour. Summing up, the policy differences between non-cooperative and cooperative strategies, as highlighted above, incur non-trivial implications on the macroeconomic environment of the two countries.

Table 5.5 Asymmetric Nash equilibrium when public debt, b_1/y_1, is higher in the periphery

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.01	0.02*	l_1	0.24	0.22*	c_1/y_1	0.62	0.62*	c_2/y_2	0.78	0.78*
τ_1^l	0.37	0.42*	l_2	0.22	0.22*	i_1/y_1	0.28	0.28*	i_2/y_2	0.00	0.00*
τ_2^l	0.25	0.27*				x_1/y_1	0.00	0.00*	x_2/y_2	0.00	0.01*
g_2	0.03	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.22	0.21*
			y_1	0.32	0.30*	k_1/y_1	1.57	1.65*	k_2/y_2	0.58	0.57*
Wel	-2.00	-2.02*	y_2	0.16	0.15*	b_1/y_1	0.60	0.90*	b_2/y_2	-0.11	-0.06*

*The parameter associated with inherited public debt in the periphery, b_1^{per}/y_1, is set at 0.9. * denotes macroeconomic outcomes in the periphery.*

Table 5.6 Asymmetric cooperative equilibrium when public debt, b_1/y_1, is higher in the periphery

flexible cooperation

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.24	0.23*	l_1	0.26	0.24*	c_1/y_1	0.65	0.67*	c_2/y_2	0.77	0.73*
τ_1^l	0.25	0.31*	l_2	0.21	0.21*	i_1/y_1	0.24	0.24*	i_2/y_2	0.00	0.00*
τ_2^l	0.33	0.35*				x_1/y_1	0.01	-0.01*	x_2/y_2	-0.03	0.03*
g_2	0.04	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.26	0.24*
			y_1	0.34	0.32*	k_1/y_1	1.49	1.57*	k_2/y_2	0.58	0.54*
Wel	-2.00	-2.01*	y_2	0.14	0.14*	b_1/y_1	0.60	0.90*	b_2/y_2	0.06	0.11*

rigid cooperation

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.25		l_1	0.25	0.24*	c_1/y_1	0.65	0.67*	c_2/y_2	0.71	0.78*
τ_1^l	0.28		l_2	0.22	0.20*	i_1/y_1	0.25	0.23*	i_2/y_2	0.00	0.00*
τ_2^l	0.34					x_1/y_1	0.00	0.00*	x_2/y_2	0.00	0.01*
g_2	0.04	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.30	0.22*
			y_1	0.33	0.32*	k_1/y_1	1.52	1.54*	k_2/y_2	0.56	0.55*
Wel	-2.00	-2.01*	y_2	0.15	0.14*	b_1/y_1	0.60	0.90*	b_2/y_2	0.01	0.17*

*The parameter associated with inherited public debt in the periphery, b_1^{per}/y_1, is set at 0.9. * denotes macroeconomic outcomes in the periphery.*

5.4.3 Asymmetries in market competition

In this experiment we focus on asymmetries that take the form of imperfect competition in product and labour markets. Structural reforms that promote market competition, are considered, by both academics and policymakers, a key policy task for the economies in the periphery of Eurozone so as to regain competitiveness and boost output. *Eggertson et al. (2014)*[19] find that a permanent reduction in the price and wage markups by 10 percentage points in the periphery may increase domestic output by 5.5%. In light of these arguments, we solve for optimal fiscal policy (Nash and cooperative) under the assumption of non-competitive product and labour markets in the periphery and study their macroeconomic implications. The theoretical model is presented in *Appendix A.3.1*. *Tables 5.7 - 5.8* depict the optimally chosen fiscal policy instruments, the corresponding macroeconomic results and the gains from cooperation (in output and welfare terms) in non-symmetric equilibria with policy commitment.[10]

Imperfect product market in the periphery

We start with the case of imperfect product markets in the periphery. Theory suggests that firms in a non-competitive market use their monopolistic power $(1-\phi^{per})$ to achieve mark-ups, which, in turn, reduce factor returns and wages. Unlike the case of asymmetries in TFP in which the direct decline in output (caused by a TFP decrease) leads to a reduction in factor returns, here it is the other way around; it is the decrease in factor returns that triggers the decline in output. As we see in *Table 5.7*, the unilateral policy selection exacerbates the problem of capital undertaxation, observed in all commitment-type equilibria. Under the assumption of almost perfect capital mobility, countries engage in tax competition for mobile factors ("race-to-the-bottom" effect), so that capital tax rates are low in the NSNE. Particularly, as the competitive economy (core) taxes about 4% of its capital income, the non-competitive economy (periphery) pays a 2% subsidy to its own capital income, in order to undo the distortions caused by market imperfections. On the other hand, when countries coordinate their actions (NSCE) the "race-to-the-bottom" effect is again taken away and capital taxes are considerably higher, both under the flexible and under the rigid regimes. Notice however that there are important differences between the country-specific and the union-wide policies. Although the flexible capital tax rates are 20 pp higher than their Nash counterparts (24% in the core and 21% in the periphery), the rigid capital tax is only 10 pp higher (14%).

[10] *See Tables A.11 and A.12 in Appendix A.3.4 for a detailed presentation of the optimal solution when countries differ either in the product or in the labour market competition.*

In addition, as the periphery experiences a narrower tax base in the second period (due to product market imperfections), the Nash labour tax rate in the second period (23%) is 18 percentage points lower than in the first period (41%). On the contrary, the competitive core country allocates the labour tax burden more proportionally over time (35% in the first period and 25% in the the second one). Under flexible cooperation, however, it is the competitive country the one with disproportional taxes on labour income (24% and 33%), whereas the periphery follows a smoother approach (30% and 26%) with more weight given to first-period policy. Furthermore, the union-wide labour tax rates (33% and 27%) are closer to the ones imposed in the non-competitive country under flexible cooperation.

Table 5.7 Optimal policy and gains from cooperation when product market, ϕ, is non-competitive in the periphery.

	Optimal policy							Gains from cooperation %				
	Nash		Flexible		Rigid				Flex vs Nash		Rig Vs Nash	
τ_2^k	0.04	-0.02*	0.24	0.21*	0.14							
τ_1^l	0.35	0.41*	0.24	0.30*	0.33							
τ_2^l	0.25	0.23*	0.33	0.26*	0.27			y	0.77	2.46*	2.00	-0.90*
g_2	0.04	0.03*	0.04	0.03*	0.04	0.03*						
y	0.46	0.43*	0.47	0.44*	0.47	0.43*						
W	-2.00	-2.02*	-2.00	-2.01*	-1.99	-2.03*		W	0.26	0.31*	0.35	-0.40*

*The parameter associated with product market competition in the periphery, ϕ^{per}, is set at 0.9. * denotes macroeconomic outcomes in the periphery.*

By comparing the gains from cooperation, we find that the cooperatively chosen country-specific tax rates benefit both countries, but mostly the non-competitive periphery economy. Specifically, the competitive country (core) enjoys 0.8% more output and 0.26% more welfare relative to non-cooperation, whereas the respective gains of its non-competitive neighbour (periphery) amount to 2.5% and 0.31%. Rigid cooperation on the other hand, is too restrictive for the country with heavy product market imperfections. The disadvantaged periphery economy registers output and welfare losses of 0.9% and 0.4% respectively, as compared to the Nash solution. Meanwhile, the core country makes the most out of its higher factor returns (as the foreign capital flies from the periphery to the core) and ends up with 2% more output and 0.4% more welfare (than the NSNE).

The intuition behind these results is that a flexible union allows for a balanced allocation of the tax burden not only between capital and labour, but also over time and this mitigates the asymmetry distortions. Moreover, due to the erosion of its tax base, the periphery country faces lower tax rates in the second period and higher in the first period, as compared to the core country. Hence, the optimal policy in the competitive core country plays the role of an absorption mechanism that partially offsets the asymmetry distortions in the periphery. On the contrary, the policymaker of a rigid union is constrained not only by the asymmetry in the periphery, but also by the fewer policy options at her disposal (5 optimally chosen instruments instead of 8). Hence, in the presence of imperfect product markets in the periphery, the union-wide policy is highly responsive to the level of asymmetry and hence, its effectiveness is questionable. To sum up, again cooperation results in considerable policy and distributional implications across countries.

Imperfect labor market in the periphery

Here, we consider the case of imperfect labor markets in the periphery. *Table 5.8* shows that non-cooperation intensifies the problem of capital undertaxation (and hence the problem of labour overtaxation). In addition, almost perfect capital mobility implies a fierce form of tax competition that leads to even lower capital taxes, as compared to the cooperative solution. Specifically, whilst the competitive core economy taxes about 4% of its capital income, its non-competitive neighbour, in order to minimize the distortions caused by labour market imperfections, applies a considerably lower tax at roughly 1% of its own capital income. On the contrary, when countries cooperate (NSCE), the "race-to-the-bottom" effect is confronted effectively and capital taxes are much higher in both regimes (flexible and rigid). Nevertheless, as in the case of imperfect product markets, we report important differences between the country-specific and the union-wide policies. Despite that the flexible capital tax rates are 20 pp higher than their Nash counterparts (24% in the core and 21% in the periphery), the rigid capital tax is only 10 pp higher (15%).

Table 5.8 Optimal policy and gains from cooperation when labour market, ψ, is non-competitive in the periphery.

	Optimal policy						Gains from cooperation %				
	Nash		**Flexible**		**Rigid**			**Flex vs Nash**		**Rig Vs Nash**	
τ_2^k	0.04	0.01*	0.24	0.21*	0.15						
τ_1^l	0.35	0.43*	0.23	0.34*	0.37						
τ_2^l	0.26	0.11*	0.33	0.20*	0.20		y	1.24	1.76*	2.30	-2.70*
g_2	0.04	0.03*	0.04	0.03*	0.05	0.02*					
y	0.46	0.42*	0.47	0.43*	0.47	0.41*					
W	-2.00	-2.03*	-1.99	-2.03*	-2.00	-2.05*	W	0.32	0.21*	0.15	-0.71*

*The parameter associated with labour market competition in the periphery, ψ^{per}, is set at 0.7. * denotes macroeconomic outcomes in the periphery.*

Furthermore, as households in the periphery use their negotiating power $(1-\psi^{per})$ to ease the tax burden on their labour income, the Nash labour tax rate in the second period

(11%) is 32 percentage points lower than in the first period (43%). In sharp contrast, the competitive core country allocates the labour tax burden more proportionally over time (35% in the first period and 26% in the the second). Flexible cooperation on the other hand, implies a smoother allocation of the labour tax rates between the first (23% in the core and 34% in the periphery) and the second period (33% and 20%), yet the burden of taxation on first-period policy instruments is even higher relative to the case of product market imperfections. Moreover, the union-wide labour tax rates (37% and 20%) correspond mostly to the ones imposed in the non-competitive periphery country under flexible cooperation.

The comparison of gains from cooperation reveals that the cooperatively chosen country-specific tax rates benefit both countries, and particularly the competitive core country when the welfare criterion is used. Specifically, the competitive country (core) enjoys 1.2% more output and 0.32% more welfare relative to non-cooperation, whereas the respective gains of its non-competitive neighbour (periphery) amount to 1.8% and 0.21%. Rigid cooperation on the other hand, is too restrictive for the country with labor market imperfections. The disadvantaged economy registers output and welfare losses of 2.7% and 0.71% respectively, as compared to the Nash solution. Meanwhile, the core country seizes the opportunity to attract foreign capital thanks to its higher factor returns (foreign capital flies from the periphery to the core) and ends up with 2.3% more output and 0.15% more welfare (than the NSNE).

The Nash results are driven by the structure of asymmetry. In the second period (when the peripheral labour markets become non-competitive) households in the periphery use their negotiating power as a leverage to achieve low taxes on their labour income and this happens in both regimes (non-cooperation and cooperation). In conjunction with the Chamley-Judd result (which tends to decrease the tax rate on the mobile factor), this development leads to an even higher labour tax rate in the first period, as compared to the case where asymmetries took the form of product market imperfections. The race-to-the-bottom effect (an inherent property of unilateral policy selection) simply intensifies the first two results, adding an extra burden to the first-period labour income.

Regarding the cooperative results, the intuition is that a flexible union allows for a more balanced allocation of the tax burden not only between capital and labour, but also across time, and this reduces the asymmetry distortions. Moreover, the labour market imperfections in the periphery bring about lower tax rates in the second period and higher in the first period, as compared to the core country. Therefore, as we underlined in the case of imperfect product markets, the optimal policy in the competitive core country counterbalances the labour market distortions in the periphery. Nevertheless, the distortions created by labour market imperfections are too much to be addressed effectively by the policymaker of a rigid union, which, by definition, has fewer policy instruments at her disposal. Summing up, again cooperation results in considerable policy and distributional implications across countries.

Table 5.9 Asymmetric Nash equilibrium when product market, ϕ, is non-competitive in the periphery

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.04	-0.02*	l_1	0.24	0.22*	c_1/y_1	0.64	0.62*	c_2/y_2	0.74	0.82*
τ_1^l	0.35	0.41*	l_2	0.23	0.20*	i_1/y_1	0.28	0.27*	i_2/y_2	0.00	0.00*
τ_2^l	0.25	0.23*				x_1/y_1	-0.02	0.02*	x_2/y_2	0.04	-0.05*
g_2	0.04	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.22	0.23*
			y_1	0.32	0.31*	k_1/y_1	1.57	1.62*	k_2/y_2	0.55	0.60*
Wel	-2.00	-2.02*	y_2	0.16	0.14*	b_1/y_1	0.60	0.60*	b_2/y_2	-0.08	-0.18*

The parameter associated with product market competition in the periphery, ϕ^{per}, is set at 0.9. * denotes macroeconomic outcomes in the periphery.

Table 5.10 Asymmetric cooperative equilibrium when product market, ϕ, is non-competitive in the periphery

flexible cooperation

Optimal Policy			Labour hours			Shares					
τ_2^k	0.24	0.21*	l_1	0.26	0.24*	c_1/y_1	0.67	0.66*	c_2/y_2	0.73	0.78*
τ_1^l	0.24	0.30*	l_2	0.22	0.20*	i_1/y_1	0.24	0.23*	i_2/y_2	0.00	0.00*
τ_2^l	0.33	0.26*				x_1/y_1	-0.01	0.01*	x_2/y_2	0.02	-0.03*
g_2	0.04	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.25	0.25*
			y_1	0.33	0.32*	k_1/y_1	1.50	1.55*	k_2/y_2	0.54	0.55*
Wel	-2.00	-2.01*	y_2	0.15	0.13*	b_1/y_1	0.60	0.60*	b_2/y_2	0.08	-0.02*

rigid cooperation

Optimal Policy			Labour hours			Shares					
τ_2^k	0.14		l_1	0.23	0.25*	c_1/y_1	0.68	0.61*	c_2/y_2	0.63	0.96*
τ_1^l	0.33		l_2	0.26	0.17*	i_1/y_1	0.28	0.23*	i_2/y_2	0.00	0.00*
τ_2^l	0.27					x_1/y_1	-0.06	0.06*	x_2/y_2	0.12	-0.19*
g_2	0.04	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.25	0.24*
			y_1	0.31	0.33*	k_1/y_1	1.60	1.52*	k_2/y_2	0.48	0.69*
Wel	-1.99	-2.03*	y_2	0.18	0.11*	b_1/y_1	0.60	0.60*	b_2/y_2	-0.05	-0.07*

*The parameter associated with product market competition in the periphery, ϕ^{per}, is set at 0.9. * denotes macroeconomic outcomes in the periphery.*

Table 5.11 Asymmetric Nash equilibrium when labour market, ψ, is non-competitive in the periphery

Optimal Policy			Labour hours			Shares					
τ_2^k	0.04	0.01*	l_1	0.24	0.22*	c_1/y_1	0.64	0.61*	c_2/y_2	0.74	0.84*
τ_1^l	0.35	0.43*	l_2	0.23	0.18*	i_1/y_1	0.28	0.28*	i_2/y_2	0.00	0.00*
τ_2^l	0.26	0.11*				x_1/y_1	-0.02	0.02*	x_2/y_2	0.04	-0.05*
g_2	0.04	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.22	0.21*
			y_1	0.32	0.30*	k_1/y_1	1.57	1.64*	k_2/y_2	0.55	0.64*
Wel	-2.00	-2.03*	y_2	0.16	0.13*	b_1/y_1	0.60	0.60*	b_2/y_2	-0.07	-0.22*

*The parameter associated with labour market competition in the periphery, ψ^{per}, is set at 0.7. * denotes macroeconomic outcomes in the periphery.*

Table 5.12 Asymmetric cooperative equilibrium when labour market, ψ, is non-competitive in the periphery

flexible cooperation

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.24	0.21*	l_1	0.25	0.24*	c_1/y_1	0.67	0.64*	c_2/y_2	0.72	0.79*
τ_1^l	0.23	0.34*	l_2	0.22	0.18*	i_1/y_1	0.24	0.25*	i_2/y_2	0.00	0.00*
τ_2^l	0.33	0.20*				x_1/y_1	-0.02	0.02*	x_2/y_2	0.04	-0.04*
g_2	0.04	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.25	0.25*
			y_1	0.33	0.32*	k_1/y_1	1.50	1.57*	k_2/y_2	0.53	0.63*
Wel	-1.99	-2.03*	y_2	0.15	0.12*	b_1/y_1	0.60	0.60*	b_2/y_2	0.08	-0.09*

rigid cooperation

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.15		l_1	0.21	0.25*	c_1/y_1	0.73	0.56*	c_2/y_2	0.58	1.15*
τ_1^l	0.37		l_1	0.29	0.13*	i_1/y_1	0.28	0.24*	i_2/y_2	0.00	0.00*
τ_2^l	0.20					x_1/y_1	-0.11	0.09*	x_2/y_2	0.19	-0.43*
g_2	0.05	0.02*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.23	0.28*
			y_1	0.29	0.33*	k_1/y_1	1.70	1.51*	k_2/y_2	0.41	0.92*
Wel	-2.00	-2.05	y_2	0.20	0.09*	b_1/y_1	0.60	0.60*	b_2/y_2	-0.09	-0.17*

*The parameter associated with labour market competition in the periphery, ψ^{per}, is set at 0.7. * denotes macroeconomic outcomes in the periphery.*

5.4.4 Asymmetries in institutional quality

The last experiment focuses on cross-country differences in institutional quality, and particularly on the poor protection of property rights in the periphery. Following the seminal work of *Tullock (1967)[49], North (1990)[39], Acemoglu (2009)[1]* and many others, and building on the related quantitative macroeconomic literature on ill-defined property rights and rent seeking (see e.g. *Angelopoulos et al. (2009, 2011)[5][4]* and *Christou et al. (2020)[13]*), we assume that firms in the periphery country can keep only 85% of their output produced, because the rest is expropriated by households that engage in rent-seeking activities. The theoretical model is presented in *Appendix A.3.2*. The results presented in *Table 5.13* describe the optimal cooperative and non-cooperative policies, the corresponding output and welfare levels as well as the gains from cooperation in commitment-type equilibria.[11] We report from the start that the assumption of poorly protected property rights in the periphery has strong effects on policy decisions and hence, the outcomes are differentiated to a large extent from the cases we have studied so far. Below, we disentangle the propagation mechanism through which this particular type of asymmetry affects the optimal decisions of policymakers.

Table 5.13 Optimal policy and gains from cooperation when institutional quality, θ, is worse in the periphery.

Optimal policy

	Nash		**Flexible**		**Rigid**	
τ_2^k	0.07	0.03*	0.10	0.11*	0.02	
τ_1^l	0.31	0.40*	0.28	0.38*	0.39	
τ_2^l	0.26	0.20*	0.27	0.24*	0.22	
g_2	0.04	0.03*	0.04	0.03*	0.04	0.02*
y	0.48	0.41*	0.48	0.41*	0.48	0.40*
W	-2.00	-2.08*	-1.99	-2.08*	-2.00	-2.08*

Gains from cooperation %

	Flex vs Nash		**Rig Vs Nash**	
y	1.54	-0.87*	0.74	-1.91*
W	0.34	-0.25*	-0.38	0.06*

*The parameter associated with institutional quality in the periphery, θ^{per}, is set at 0.15. * denotes macroeconomic outcomes in the periphery.*

Theoretical and empirical evidence suggest (see also *Section 5.1* above) that the poor quality of institutions is one of the major reasons why some economies are trapped in bad equilibria. In our example, as households in the periphery expropriate a fraction of the output produced within their borders (due to poorly protected property rights), we anticipate that the core country (with the wider tax base) should be able to sustain higher tax rates on the mobile factor (capital) relative to the periphery. Although this thinking is confirmed in

[11] *See Table A.13 in Appendix A.3.4 for a detailed presentation of the optimal solution when countries differ in their institutional qualities.*

the non-cooperative regime, it does not hold in the case of cooperation. In particular, the Nash capital tax rate in the periphery (3%) is 4 percentage points lower than in the core, whereas, under flexible cooperation, the cooperatively chosen country-specific capital tax is slightly higher in the periphery (11% in the periphery vis-a-vis 10% in the core). This happens because cooperation eliminates tax competition for mobile factors and hence the periphery is now less worried about capital flight and focuses more on the problem of its poor institutions. As institutional quality degenerates in the periphery, the respective tax base becomes narrower and the tax revenues are at stake. In order to secure the collection of the remaining tax revenues, the country needs to impose a slightly higher capital tax than the core.

Moreover, as above in the experiments with asymmetries in TFP and market competition, the race-to-the-bottom and the Chamley-Judd results work in the same direction with the narrower tax bases in the periphery country (caused by its bad institutions) and, as a consequence, policymakers face a strong incentive to impose a lower tax not only on second-period capital, but also on second-period labour income, a practice which essentially shifts the burden of taxation on first-period labour income. This result is more acute in the periphery where the Nash labour tax rate in the first period (40%) is 20 pp higher than the second period, while the respective rate in the core (31%) is only 5 pp higher. On the other hand, in the absence of the tax competition effect, flexible cooperation leads to a more balanced allocation of the labour tax burden between the two periods and this happens in both economies. Interestingly, despite its cooperative structure, the union-wide policy mix under rigid cooperation is close to the tax scheme adopted by the periphery economy under non-cooperation; the single capital tax rate barely exceeds 2%, while the labour tax rate in the first period (39%) is 17 pp higher than in the second period.

This policy diversity (as discussed above) leads to contrasting results with respect to the gains from cooperation enjoyed by each economy. In output terms, cooperation, both flexible and rigid, is productive in the core (1.5% and 0.7% more output than in the Nash solution respectively in flexible and rigid policies) and counterproductive in the periphery (0.8% and 2% less output than in the Nash solution, respectively in flexible and rigid policies). When the welfare criterion is used, flexible cooperation leads to qualitatively similar results but of smaller magnitude (0.3% gain in the core and 0.3% loss in the periphery), whereas rigid cooperation is counterproductive in the core (0.4% loss) and marginally productive in the periphery (0.1% gain). In other words, the optimally chosen tax rates under flexible cooperation serve the fiscal needs of the core country with strong institutions, which however prove to be a luxury for the peripheral country; the latter would prefer even lower tax rates to mitigate its (low-factor return and under-accumulation) problem.

Table 5.14 Asymmetric Nash equilibrium when institutional quality, θ, is worse in the periphery

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.07	0.03*	l_1	0.23	0.23*	c_1/y_1	0.68	0.60*	c_2/y_2	0.67	0.97*
τ_1^l	0.31	0.40*	l_2	0.25	0.22*	i_1/y_1	0.28	0.24*	i_2/y_2	0.00	0.00*
τ_2^l	0.26	0.20*	s_2	1.00	0.73*	x_1/y_1	-0.06	0.06*	x_2/y_2	0.13	-0.21*
g_2	0.04	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.20	0.24*
			y_1	0.32	0.32*	k_1/y_1	1.58	1.59*	k_2/y_2	0.50	0.71*
Wel	-2.00	-2.08*	y_2	0.18	0.11*	b_1/y_1	0.60	0.60*	b_2/y_2	-0.04	-0.20*

*The parameter associated with institutional quality in the periphery, θ^{per}, is set at 0.15. * denotes macroeconomic outcomes in the periphery.*

Table 5.15 Asymmetric cooperative equilibrium when institutional quality, θ, is worse in the periphery

flexible cooperation

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.10	0.11*	l_1	0.23	0.24*	c_1/y_1	0.70	0.59*	c_2/y_2	0.64	1.05*
τ_1^l	0.28	0.38*	l_2	0.26	0.20*	i_1/y_1	0.28	0.23*	i_2/y_2	0.00	0.00*
τ_2^l	0.27	0.24*	s_2	1.00	0.72*	x_1/y_1	-0.08	0.08*	x_2/y_2	0.16	-0.32*
g_2	0.04	0.03*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.20	0.27*
			y_1	0.32	0.32*	k_1/y_1	1.58	1.55*	k_2/y_2	0.47	0.79*
Wel	-1.99	-2.08*	y_2	0.19	0.09*	b_1/y_1	0.60	0.60*	b_2/y_2	0.00	-0.18*

rigid cooperation

Optimal Policy			**Labour hours**			**Shares**					
τ_2^k	0.02		l_1	0.21	0.25*	c_1/y_1	0.70	0.56*	c_2/y_2	0.58	1.25*
τ_1^l	0.39		l_2	0.29	0.18*	i_1/y_1	0.31	0.24*	i_2/y_2	0.00	0.00*
τ_2^l	0.22		s_2	1.00	0.73*	x_1/y_1	-0.11	0.10*	x_2/y_2	0.21	-0.51*
g_2	0.04	0.02*	**Output**			g_1/y_1	0.10	0.10*	g_2/y_2	0.21	0.26*
			y_1	0.29	0.33*	k_1/y_1	1.70	1.52*	k_2/y_2	0.44	1.92*
Wel	-2.00	-2.08*	y_2	0.21	0.08*	b_1/y_1	0.60	0.60*	b_2/y_2	-0.10	-0.22*

*The parameter associated with institutional quality in the periphery, θ^{per}, is set at 0.15. * denotes macroeconomic outcomes in the periphery.*

5.5 Discussion of results

In this section, we studied cross-country asymmetries in some fundamentals that are widely recognized as the main driving forces behind differences in macroeconomic outcomes and performance like in GDP, growth, fiscal deficits, current accounts, inflation, etc. We solved for optimal fiscal policy (Nash and cooperative) in non-symmetric equilibria, that were characterized by four types of cross-country differences: First, we assumed that countries differ in their total factor productivities (TFP). Second, we assumed that countries differ in their inherited public debt-to-GDP ratios. Third, we assumed that countries differ in product or labour market competition. Fourth, we assumed that countries differ in their institutional qualities and in particular on the degree of protection of property rights. We also distinguished between flexible cooperation (cooperatively chosen country-specific policies) and rigid cooperation (cooperatively chosen single, or one-size-fits-all, policy) following *Alesina et al. (2005)*.

A general result is that, once we leave the symmetric world and allow for cross-country differences, flexible cooperation, although superior to Nash in terms of lifetime aggregate output and welfare, may hurt some countries so it is not Pareto improving. This happens when asymmetries are in the form of differences in TFP[12] and institutional quality[13]. Particularly, in the case of asymmetries in TFP, both groups of countries enjoy output gains from flexible cooperation, yet, in terms of welfare, cooperation is productive for the core and counterproductive for the periphery. In the case of asymmetries in institutional quality, flexible cooperation implies (output and welfare) gains for the core countries with healthy institutions but loses for the periphery. Nevertheless, in both cases the former dominate the latter and so aggregate outcomes improve. In the EU, this could rationalize the introduction of fiscal transfers from the winners to the losers. On the other hand, when asymmetries are

[12] *When countries differ in TFP, both the capital under-taxation and the race-to-the-bottom results (previously addressed in the SNE) are present in the NSNE, unlike the NSCE in which the latter effect is removed by construction. Note that this type of asymmetry leads to optimal tax schemes that are substantially differentiated across the two countries and also, the union-wide capital tax rate chosen under rigid cooperation corresponds mostly to the needs of the low-productivity country. As is typical in commitment-type policies, the inelastic factor (labor) bears a disproportionally high amount of the tax burden compared to the elastic factor (capital), a problem which is mostly observed in the NSNE and is getting worse with the degree of international capital mobility. Cooperation on the other hand (both flexible and rigid), reduces this effect.*

[13] *When countries differ in their institutional qualities, the "race-to-the-bottom" result intensifies the Chamley-Judd result and hence, the Nash capital tax rates are low in both countries. On the other hand, policy coordination alleviates the problem of tax competition and raises the level of capital taxation. Similar to the case of asymmetries in TFP, the union-wide capital tax is closer to that needed by the country with poor institutions. Additionally, the periphery depends more on tax revenues generated from labour income as compared to its core neighbor in the NSNE, unlike the NSCE in which capital and labour bear relatively equal shares of the tax burden.*

in the form of differences in market competition[14][15] and inherited public debt[16], flexible cooperation is Pareto improving by benefiting all countries.

Regarding rigid cooperation and one-size-fits-all policies, this can hurt the periphery countries with low TFP and non-competitive product and labor markets. However, despite that rigid cooperation is again non-productive in the periphery economy with poor institutions in terms of output, when the criterion is lifetime utility, rigid cooperation is marginally productive in the periphery and non-productive in the core. Actually, when asymmetries are in the form of institutional quality and market competition, the losses of those countries more than offset the benefits of their counterparts so that rigid cooperation is counter-productive even in terms of aggregate output and welfare; that is, in those cases, rigid cooperation can be particularly harmful not only to the disadvantaged periphery country, but also to the world economy as well.

Putting these results together, international tax cooperation, and especially the rigid one, proves to be too restrictive for countries with low TFP and non-competitive markets. These countries cannot afford the luxury of relatively high tax rates that naturally come with international cooperation. By contrast, in the case of asymmetries in inherited public debt, no matter what is the type of cooperation (flexible or rigid), both countries reap gains from cooperation, with the lion's share from those gains going to the relatively disadvantaged economy. The intuition is that the low-debt core country, for the sake of cooperation, is forced to set relatively high tax rates that serve mostly the needs of the high-debt periphery country,

[14] *In the case of asymmetries in product market competition, tax competition for mobile factors leads to relatively low Nash capital taxes in both countries but mostly in the non-competitive one. On the other hand, policy coordination confronts effectively the problem of tax competition and hence the tax burden on capital increases. In addition, the narrower tax base in the periphery (caused by its non-competitive product market) implies that the Nash labour tax rate is much higher in the first period, whereas the competitive core country follows a balanced allocation of the labour tax burden over time. Nevertheless, under flexible cooperation it is the competitive country that imposes uneven taxes on labour income, while the union-wide labour tax rates are closer to those needed by the non-competitive periphery country.*

[15] *In the case of asymmetries in labour market competition, we observe, once again, that the capital taxes are low in the NSNE and high in the NSCE in both countries. Moreover, thanks to their negotiating power, households in the periphery achieve a lower Nash labour tax in the second period, as compared to households in the core. If instead countries cooperate, the country-specific labour taxes are distributed proportionally over time, while the union-wide labour taxes serve mainly the needs of the non-competitive periphery country.*

[16] *When countries differ in their inherited public debt, the Nash capital tax rate in the periphery is lower than in the core, whereas, under flexible cooperation, the country-specific capital tax is marginally higher in the periphery. In addition, relative to the previous cases (asymmetries in TFP and product markets), the race-to-the-bottom and the Chamley-Judd results work in the same direction with the problem of the smaller tax base in the periphery and hence, policymakers impose a lower tax not only on second-period capital, but also on second-period labour income. This practice essentially shifts the burden of taxation on first-period labour income, with the result being more acute in the periphery. On the other hand, in the absence of tax competition, flexible cooperation leads to a balanced allocation of the labour tax burden between the two periods in both economies. Notwithstanding its cooperative structure, the union-wide policy mix is close to the tax scheme adopted by the periphery economy under non-cooperation.*

and this proves to be helpful for both economies. This is because, with debt problems, a relatively high tax rate is also what the periphery country needs, so there is no conflict of interests as in the case with different TFPs and institutions.

Therefore, here, we get a second-best result: when several imperfections and asymmetries are present, taking just one out (here, lack of cooperation) is not necessarily productive. As we proved, introducing cross-country differences in a two-country model with capital mobility and solving for commitment-type equilibria, leads to non-trivial distributions implications that largely depend on the type and level of asymmetry. In some cases or asymmetries, the output and/or welfare losses realized by the disadvantaged economy are so strong that may turn cooperation into a harmful practice for the world economy as well.

Part II

Part B: Optimal policy with and without commitment

Chapter 6

Model

As in *Part A*, we use a two-period neoclassical world economy model consisting of two countries. This is as in e.g. *Fischer (1980)[20]*, *Persson and Tabellini (1992, 2000)[43][44]* and many others in this literature. In each country, there is a representative household, a representative firm and the government. The household maximizes lifetime utility choosing consumption, work/leisure and savings between the two periods. The latter can be in the form of domestic capital, domestic government bonds and foreign assets/debt. The firm maximizes profits choosing capital and labor inputs to produce a single traded good. With capital mobility across countries, the firm's capital can be owned by both domestic and foreign investors. Unlike *Part A* in which capital was the only mobile factor, here we assume that labour is also mobile internationally and hence, the members of the representative household can work both at home and abroad. The government is benevolent taxing capital and labor income invested in the country (according to a residence-based system of taxation) and issuing bonds to finance utility-enhancing public expenditures.

The main difference from *Part A* is that now we solve for equilibria without policy commitment which means that policy is not chosen once-and-for-all at the start of the time horizon. Now, instead, policy-makers are free to re-optimize in each time period. In our context, this practically means that second-period tax policy is chosen after private agents have made their saving decisions in the first period. This guarantees that optimal policy will be time consistent. But we will also solve for equilibria with commitment, as in the first Part, for reasons of comparability.

Equilibrium with commitment

With commitment, the sequence of events is as in *Part A*. That is, in the beginning of the time horizon, each government chooses its tax-spending-debt policies once-and-for-all acting either non-cooperatively (Nash) or cooperatively. In turn, having observed policy, private agents make their own decisions acting competitively. Since policy is chosen once-and-for-all before private decisions (especially, savings or investment) have been made, we solve for a commitment or Ramsey-type equilibrium (which can be either Nash or cooperative). To solve the model, we will typically work by backward induction. That is, we will first solve private agents' problems and derive the associated decentralized world equilibrium which is for any feasible policy mix in each country. Then, by taking all this into account, governments will choose their policies either by playing Nash or by acting cooperatively.

Equilibrium without commitment

Without commitment, the timing is as follows (see also e.g. *Fischer (1980)[20]*, *Persson and Tabellini, 2000, pp. 310-11[44]*): (a) Each government chooses its first-period policies acting either non-cooperatively (Nash) or cooperatively. (b) In turn, private agents in each country make their first-period decisions and, in particular, their savings decisions acting competitively. (c) Each government chooses its second-period policies acting either non-cooperatively (Nash) or cooperatively. (d) Private agents make their second-period decisions acting competitively. We will work with backward induction starting from the last stage. As is usually assumed (*see e.g. Klein et al. (2008)[27]*), private agents act non-strategically taking economic and political choices as given in all stages.

To simplify the model, in most cases below, we will assume that, in the first period, the government does not act optimally but simply one of its policy instruments adjusts to satisfy the government budget constraint. This is only for keeping the final equilibrium system relatively small and does not affect our main results; the important thing here is the optimal choice of tax policy in the second period after first-period saving decisions have been made.

The domestic country will be denoted by the superscript d and the foreign country by the superscript f. The problems of agents (households, firms and the government) in each country are analogous so we will present the domestic economy only, except otherwise stated.

6.1 Households

As in *Part A*, each household in the domestic country maximises:

$$\sum_{t=1}^{2} \beta^{t-1} U^d \left(c_t^d, l_t^d, s_t^d, g_t^d \right) \tag{6.1}$$

where $0 < \beta < 0$ is the time discount factor and c_t^d, l_t^d, s_t^d and g_t^d are consumption, work effort at home and abroad and public spending respectively.

For simplicity, the period utility function is assumed to be of log-linear form:

$$
\begin{aligned}
U^d\left(c^d, l^d, s^d, g^d\right) &= \mu_1 \log c_1^d + \mu_2 \log(1 - l_1^d) + \mu_3 \log g_1^d \\
&\quad + \beta\left(\mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d - s_2^d) + \mu_3 \log g_2^d\right)
\end{aligned}
\tag{6.2}
$$

where the parameters $0 \leq \mu_1, \mu_2, \mu_3 \leq 1$ are the weights given to consumption, leisure and public spending respectively.

The budget constraints of the household in the two periods, $t = 1, 2$, are respectively:

$$
\begin{aligned}
c_1^d + k_2^d + b_2^d + f_2^d &= \left(1 + (1 - \tau_{k,1}^d) r_1^d - \delta\right) k_1^d + (1 - \tau_{l,1}^d) w_1^d l_1^d \\
&\quad + (1 + \rho_1^d) b_1^d + (1 - \tau_{k,1}^d) \pi_1^d
\end{aligned}
\tag{6.3}
$$

$$
\begin{aligned}
c_2^d = &\left(1 + (1 - \tau_{k,2}^d) r_2^d - \delta\right) k_2^d + (1 - \tau_{l,2}^d) w_2^d l_2^d + (1 - \tau_{k,2}^d) \pi_2^d + (1 + \rho_2^d) b_2^d \\
&+ \left(1 + (1 - \tau_{k,2}^f) r_2^f - \delta\right) f_2^d - m\frac{\left(f_2^d\right)^2}{2} + (1 - \tau_2^f) w_2^f s_2^d - j\frac{\left(s_2^d - \bar{s}\right)^2}{2}
\end{aligned}
\tag{6.4}
$$

where k_2^d is capital invested at home at the end of the first period earning a gross return r_2^d in the next period, b_2^d is domestic government bonds purchased at the end of the first period earning a gross return ρ_2^d in the next period, f_2^d is foreign assets acquired at the end of the first period earning a gross return r_2^f in the next period (if f_2^d is negative, it will denote foreign liabilities), w_t^d is the real wage rate, π_t^d is dividends paid by firms, the parameter $0 < \delta \leq 1$ is the capital depreciation rate, the parameter $m \in [0, +\infty)$ is a measure of costs associated with investment abroad as in *Persson and Tabellini (1992)*, the parameters $j \in [0, +\infty)$ and $0 < \bar{s} \leq 1$ capture the costs associated with household's members moving abroad as in *Artuc et al. (2015)[6]* and $0 \leq \tau_{l,t}^d$, $\tau_{l,t}^f$, $\tau_{k,t}^d$, $\tau_{k,t}^f \leq 1$ are tax rates on labor income earned at home, labor income earned abroad, capital income earned at home and capital income earned abroad respectively. In a two-period model, we set $k_3^d = b_3^d = f_3^d \equiv 0$.

The first-order conditions include the budget constraints and the optimality conditions for l_1^d, l_2^d, s_2^d, k_2^d, b_2^d and f_2^d which are respectively:

$$
\frac{\mu_1}{c_1^d}(1 - \tau_{l,1}^d) w_1^d = \frac{\mu_2}{1 - l_1^d} \tag{6.5}
$$

$$
\frac{\mu_1}{c_2^d}(1 - \tau_{l,2}^d) w_2^d = \frac{\mu_2}{1 - l_2^d - s_2^d} \tag{6.6}
$$

$$\frac{\mu_1}{c_2^d}\left((1-\tau_{l,2}^f)w_2^f - j(s_2^d - \bar{s})\right) = \frac{\mu_2}{1-l_2^d - s_2^d} \tag{6.7}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1+(1-\tau_{k,2}^d)r_2^d - \delta\right) \tag{6.8}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1+\rho_2^d\right) \tag{6.9}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1+(1-\tau_{k,2}^f)r_2^f - \delta - mf_2^d\right) \tag{6.10}$$

where, conditions (6.5), (6.6) and (6.7) give the leisure-consumption trade-off in periods $t = 1,2$ and equate the marginal value of labour (at home and abroad) to the after-tax return to labour, while conditions (6.8), (6.9) and (6.10) are standard Euler conditions for domestic capital, k_2^d, domestic bonds, b_2^d, and foreign capital, f_2^d.

6.2 Firms

The single traded good is produced by a single firm that acts competitively. In each period, $t = 1,2$, the firm chooses capital, $\bar{k}_t^d$, and labour, $\bar{l}_t^d$, to maximize profit:

$$\max_{\bar{k}_t^d,\bar{l}_t^d} \pi_t^d = y_t^d - r_t^d\bar{k}_t^d - w_t^d\bar{l}_t^d \tag{6.11}$$

subject to a Cobb-Douglas production function, $y_t^d = A\left(\bar{k}_t^d\right)^a\left(\bar{l}_t^d\right)^{1-a}$, where $a \in (0,1)$ and A are standard technology parameters.

The optimality conditions for the two inputs are as in *Part A*:

$$r_t^d = a\frac{y_t^d}{\bar{k}_t^d} \tag{6.12}$$

$$w_t^d = (1-a)\frac{y_t^d}{\bar{l}_t^d} \tag{6.13}$$

so that profits are zero in equilibrium.

6.3 Government

As in *Part A*, the government taxes capital income earned by both domestic and foreign investors at a rate $0 \leq \tau_{k,t}^d \leq 1$, labour income earned by domestic workers at a rate $0 \leq \tau_{l,t}^d \leq 1$

and issues bonds to finance utility-enhancing public expenditures. The difference from *Part A* is that here, with internationally mobile labour, the domestic government has an additional source of tax revenues; that is, labour income earned by foreign workers that work in the domestic country is also taxed at a rate $0 \leq \tau^d_{l,t} \leq 1$. Hence, the within-period government budget constraints are:

$$g^d_1 + (1+\rho^d_1)b^d_1 = \tau^d_{k,1}(r^d_1 k^d_1 + \pi^d_1) + \tau^d_{l,1} w^d_1 l^d_1 + b^d_2 \tag{6.14}$$

$$g^d_2 + (1+\rho^d_2)b^d_2 = \tau^d_{k,2}\left(r^d_2(k^d_2 + f^f_2) + \pi^d_2\right) + \tau^d_{l,2} w^d_2 (l^d_2 + s^f_2) \tag{6.15}$$

where g^d_1 and g^d_2 are government expenditures and b^d_1 and b^d_2 are beginning-of-period government bonds in periods 1 and 2.

6.4 World decentralised competitive equilibrium (for any feasible policy)

In a world decentralized competitive equilibrium (WDCE), which is for any feasible policy: (i) households maximise welfare in each country (ii) firms maximise profits in each country (iii) all constraints are satisfied in each country (iv) all markets clear including the world asset/capital and labour markets. Notice that, with capital mobility allowed between period 1 and 2, the market-clearing conditions for capital in the second period are $\bar{k}^d_2 = k^d_2 + f^f_2$ in the domestic economy and $\bar{k}^f_2 = k^f_2 + f^d_2$ in the foreign economy. In addition, with labour mobility allowed in the second period, the market-clearing conditions for labour are $\bar{l}^d_2 = l^d_2 + s^f_2$ in the domestic economy and $\bar{l}^f_2 = l^f_2 + s^d_2$ in the foreign economy.

Collecting equations, we have the system:

Domestic economy

$$c^d_1 + k^d_2 - (1-\delta)k^d_1 + f^d_2 + g^d_1 = y^d_1 \tag{6.16}$$

$$\begin{aligned} c^d_2 - (1-\delta)k^d_2 + g^d_2 = y^d_2 - (1-\tau^d_{k,2})r^d_2 f^f_2 + \left(1 + (1-\tau^f_{k,2})r^f_2 - \delta\right) f^d_2 \\ - m\frac{\left(f^d_2\right)^2}{2} - (1-\tau^d_{l,2})w^d_2 s^f_2 + (1-\tau^f_{l,2})w^f_2 s^d_2 - j\frac{\left(s^d_2 - \bar{s}\right)^2}{2} \end{aligned} \tag{6.17}$$

$$\frac{\mu_1}{c^d_1}(1-\tau^d_{l,1})w^d_1 = \frac{\mu_2}{1-l^d_1} \tag{6.18}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d = \frac{\mu_2}{1-l_2^d-s_2^d} \tag{6.19}$$

$$\frac{\mu_1}{c_2^d}\left((1-\tau_{l,2}^f)w_2^f - j(s_2^d-\bar{s})\right) = \frac{\mu_2}{1-l_2^d-s_2^d} \tag{6.20}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1+(1-\tau_{k,2}^d)r_2^d-\delta\right) \tag{6.21}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1+(1-\tau_{k,2}^f)r_2^f-\delta-mf_2^d\right) \tag{6.22}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1+\rho_2^d\right) \tag{6.23}$$

$$g_1^d + \left(1+(1-\tau_{k,1}^d)r_1^d-\delta\right)b_1^d = \tau_{k,1}^d r_1^d k_1^d + \tau_{l,1}^d w_1^d l_1^d + b_2^d \tag{6.24}$$

$$g_2^d + (1+\rho_2^d)b_2^d = \tau_{k,2}^d r_2^d(k_2^d+f_2^f) + \tau_{l,2}^d w_2^d(l_2^d+s_2^f) \tag{6.25}$$

Foreign economy

$$c_1^f + k_2^f - (1-\delta)k_1^f + f_2^f + g_1^f = y_1^f \tag{6.26}$$

$$\begin{aligned} c_2^f - (1-\delta)k_2^f + g_2^f = y_2^f &- (1-\tau_{k,2}^f)r_2^f f_2^d + \left(1+(1-\tau_{k,2}^d)r_2^d-\delta\right)f_2^f \\ &- m\frac{(f_2^f)^2}{2} - (1-\tau_{l,2}^f)w_2^f s_2^d + (1-\tau_{l,2}^d)w_2^d s_2^f - j\frac{(s_2^f-\bar{s})^2}{2} \end{aligned} \tag{6.27}$$

$$\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f = \frac{\mu_2}{1-l_1^f} \tag{6.28}$$

$$\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f = \frac{\mu_2}{1-l_2^f-s_2^f} \tag{6.29}$$

$$\frac{\mu_1}{c_2^f}\left((1-\tau_{l,2}^d)w_2^d - j(s_2^f-\bar{s})\right) = \frac{\mu_2}{1-l_2^f-s_2^f} \tag{6.30}$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right) \tag{6.31}$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\right) \tag{6.32}$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+\rho_2^f\right) \tag{6.33}$$

$$g_1^f + \left(1+(1-\tau_{k,1}^f)r_1^f-\delta\right)b_1^f = \tau_{k,1}^f r_1^f k_1^f + \tau_{l,1}^f w_1^f l_1^f + b_2^f \tag{6.34}$$

$$g_2^f + (1+\rho_2^f)b_2^f = \tau_{k,2}^f r_2^f (k_2^f + f_2^d) + \tau_{l,2}^f w_2^f (l_2^f + s_2^d) \tag{6.35}$$

where, in the above, we use $\rho_1^d = (1-\tau_{k,1}^d)r_1^d - \delta$, $\rho_1^f = (1-\tau_{k,1}^f)r_1^f - \delta$ for bonds returns in $t=1$ and the following equations describing gross wages and capital returns in the two countries at $t=1,2$:

$$w_t^d = (1-a)\frac{y_t^d}{l_t^d + s_t^f} \tag{6.36}$$

$$w_t^f = (1-a)\frac{y_t^f}{l_t^f + s_t^d} \tag{6.37}$$

$$r_t^d = a\frac{y_t^d}{k_t^d + f_t^f} \tag{6.38}$$

$$r_t^f = a\frac{y_t^f}{k_t^f + f_t^d} \tag{6.39}$$

Therefore, we have a system of 20 equations in 20 endogenous variables, $c_1^d, c_2^d, c_1^f, c_2^f$, $l_1^d, l_2^d, s_2^d, l_1^f, l_2^f, s_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, g_2^d, g_2^f, \rho_2^d, \rho_2^f$. This is given the independently set policy instruments. The latter include all tax rates, $\tau_{k,1}^d$, $\tau_{k,2}^d$, $\tau_{l,1}^d$, $\tau_{l,2}^d$, $\tau_{k,1}^f$, $\tau_{k,2}^f$, $\tau_{l,1}^f$, $\tau_{l,2}^f$, and the first-period public spending items, g_1^d, g_1^f. In other words, in each period, one policy instrument needs to follow residually to close the government budget constraint and here it is assumed that this role is played by the end-of-period public debt in the first period in both countries (b_2^d and b_2^f) and by public spending in the second period in both countries (g_2^d and g_2^f) - this is why these variables are included in the list of endogenous variables. We report however that the specific classification of policy instruments into endogenous and independently set at this level is not important to our results since policy will be chosen optimally anyway.

For algebraic simplicity, in what follows, we will assume that all first-period policy instruments (except of course of the residually determined ones, b_2^d and b_2^f) are exogenously set. That is, in the first period, policy will be just feasible and not optimal. This is not important to our main results since here saving and investment decisions are made between the first and the second period only, so it is the second-period policy choices that shape the qualitative difference between optimal policies with, and without, commitment (see also e.g. *Fischer (1980)*). Recall that in *Part A*, as in the literature, first-period capital tax rates were also taken as given so as not to reduce the policy problem to a first-best one (see also e.g. *Ljungqvist and Sargent, 2012, chapter 16[35]*). Now, to keep the final systems relatively small, we include the first-period labor tax rates to the set of exogenously set policy variables.

6.5 Optimal policy with commitment

We now endogenise policy under commitment. Following the related literature on tax competition, we will compare the case in which national policies are chosen non-cooperatively, as in a typical Nash equilibrium, to the case in which national policies are chosen cooperatively by a fictional world social planner. In both cases, national policymakers or the world planner will be constrained by the WDCE as presented above.

6.5.1 Non-cooperative policies (Nash): Definition

In a non-cooperative (Nash) game, each national government chooses its own policies to maximize the welfare of its own citizens by taking as given the policies of the other government and by taking into account the system of equations summarizing the WDCE.

In other words, the domestic government chooses its independently set policy instruments $\tau^d_{k,2}, \tau^d_{l,2}$ to maximise:

$$U^d\left(c^d_t, l^d_t, s^d_t, g^d_t\right) = \mu_1 \log c^d_1 + \mu_2 \log(1 - l^d_1) + \mu_3 \log g^d_1 + \beta\left(\mu_1 \log c^d_2 + \mu_2 \log(1 - l^d_2 - s^d_2) + \mu_3 \log g^d_2\right) \tag{6.40}$$

subject to the equations summarizing the WDCE (6.16-35).

As in *Part A*, since the problem is too complex to be specified in a primal form (meaning that we cannot express the objective function and the constraints as functions of the independently set policy instruments only), we will follow usual practice by solving the problem in its dual form (*see e.g. Atksinson and Stiglitz, 1980[7]*). This means that policymakers, in addition to the independently set policy instruments, re-choose all the allocations and the residually determined instruments of the WDCE system.

From the viewpoint of the domestic government, the solution to this dual optimization problem, in a Nash non-cooperative game, yields a system of 42 equations in 42 endogenous variables. Specifically, counting equations, we have the 20 constraints/equations of the WDCE, the optimality conditions for the 20 variables being determined by the WDCE system (as said, they are re-chosen in a dual solution), plus the two optimality conditions for the domestic independent policy instruments, $\tau^d_{k,2}$ and $\tau^d_{l,2}$. Counting endogenous variables, always for the individual country that plays Nash, we have the 20 variables of the WDCE system, $c^d_1, c^d_2, c^f_1, c^f_2, l^d_1, l^d_2, s^d_2, l^f_1, l^f_2, s^f_2, k^d_2, k^f_2, f^d_2, f^f_2, b^d_2, b^f_2, g^d_2, g^f_2, \rho^d_2, \rho^f_2$, plus the 20 dynamic Lagrangean multipliers corresponding to the 20 equations of the WDCE system, plus the two optimally chosen instruments, $\tau^d_{k,2}$ and $\tau^d_{l,2}$. This is given the independent policy choices of the other country, $\tau^f_{k,2}$ and $\tau^f_{l,2}$, and the assumed exogenous policy instruments

$\tau^d_{k,1}, \tau^f_{k,1}, \tau^d_{l,1}, \tau^f_{l,1}, g^d_1$ and g^f_1. The foreign country solves an analogous problem and obtains a similar set of 42 equations in 42 unknowns. In equilibrium, we end up with 64 equations in 64 variables (namely, 42+42-20) since the 20 equations of the WDCE are common to both countries and the same applies to the 20 variables that are endogenous at WDCE level.[1]

6.5.2 Cooperative policies: Definition

When national policies are chosen jointly by a fictional world social planner, the latter maximises a weighted average of households' welfare in each country with equal weights, γ, given to each one of them. Thus, the objective is now:

$$\max W^{coop} = \gamma U^d + (1-\gamma)U^f \tag{6.41}$$

subject to the 20 WDCE equations.

The maximization is with respect to the independent policy instruments in the two countries, $\tau^d_{k,2}, \tau^d_{l,2}, \tau^f_{k,2}$ and $\tau^f_{l,2}$. We will thus have a system of 44 equations in 44 unknowns. Counting equations, we have the 20 constraints/equations of the WDCE, the optimality conditions for the 20 variables being determined by the WDCE system, plus the four optimality conditions for the independent policy instruments. Counting endogenous variables, we have the 20 variables of the WDCE system, $c^d_1, c^d_2, c^f_1, c^f_2, l^d_1, l^d_2, s^d_2, l^f_1, l^f_2, s^f_2, k^d_2, k^f_2, f^d_2, f^f_2, b^d_2, b^f_2, g^d_2, g^f_2, \rho^d_2, \rho^f_2$, plus the 20 dynamic Lagrangean multipliers corresponding to the 20 equations of the WDCE system, plus the 4 optimality conditions for the 4 independent policy instruments, $\tau^d_{k,2}, \tau^d_{l,2}, \tau^f_{k,2}$ and $\tau^f_{l,2}$. This is given the the assumed exogenous policy instruments $\tau^d_{k,1}, \tau^f_{k,1}, \tau^d_{l,1}, \tau^f_{l,1}, g^d_1$ and g^f_1.[2]

6.6 Optimal policy without commitment

We now work by backward induction. In other words, we will first consider the second period given first period choices. Within each period, the government moves first acting as a leader and then private agents make their choices acting competitively or atomistically (meaning taking policy variables as given in each stage).

[1] *For a detailed view of the non-cooperative (Nash) solution, see Appendix B.1.1.*
[2] *For a detailed view of the cooperative solution, see Appendix B.1.2.*

6.6.1 Non-cooperative (Nash) time-consistent policies: Definition

Solution of stage (D)

The household in the domestic country maximizes its second-period utility by choosing second-period consumption, c_2^d, and work/leisure at home and abroad, l_2^d, s_2^d, subject to its second-period budget constraint and treating policy as given. The equations summarizing this step are the household's second-period budget constraint and the optimality conditions for work at home and abroad:

$$\begin{aligned} c_2^d = &\left(1+(1-\tau_{k,2}^d)r_2^d-\delta\right)k_2^d+(1-\tau_{l,2}^d)w_2^d l_2^d+(1+\rho_2^d)b_2^d \\ &+\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)f_2^d-m\frac{\left(f_2^d\right)^2}{2}+(1-\tau_2^f)w_2^f s_2^d-j\frac{\left(s_2^d-\bar{s}\right)^2}{2} \end{aligned} \tag{6.42}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d=\frac{\mu_2}{1-l_2^d-s_2^d} \tag{6.43}$$

$$\frac{\mu_1}{c_2^d}\left((1-\tau_{l,2}^f)w_2^f-j(s_2^d-\bar{s})\right)=\frac{\mu_2}{1-l_2^d-s_2^d} \tag{6.44}$$

The household in the foreign country solves a similar problem and obtains similar equations:

$$\begin{aligned} c_2^f = &\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)k_2^f+(1-\tau_{l,2}^f)w_2^f l_2^f+(1+\rho_2^f)b_2^f \\ &+\left(1+(1-\tau_{k,2}^d)r_2^d-\delta\right)f_2^f-m\frac{\left(f_2^f\right)^2}{2}+(1-\tau_2^d)w_2^d s_2^f-j\frac{\left(s_2^f-\bar{s}\right)^2}{2} \end{aligned} \tag{6.45}$$

$$\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f=\frac{\mu_2}{1-l_2^f-s_2^f} \tag{6.46}$$

$$\frac{\mu_1}{c_2^f}\left((1-\tau_{l,2}^d)w_2^d-j(s_2^f-\bar{s})\right)=\frac{\mu_2}{1-l_2^f-s_2^f} \tag{6.47}$$

At this stage we have 6 equations in 6 endogenous variables. Particularly, counting equations we have 4 optimality conditions for the 4 variables being determined by households in the WDCE in the second period, $l_2^d, s_2^d, l_2^f, s_2^f$, plus the two second-period budget constraints that define c_2^d and c_2^f.

Solution of stage (C)

In a non-cooperative (Nash) game, each national government chooses its own policies to maximize the welfare of its own citizens by taking as given the policies of the other government as well as all first-period choices, while it takes into account the system of equations summarizing the WDCE in the second period.

In other words, the domestic government chooses its independently set policy instruments $\tau_{k,2}^d, \tau_{l,2}^d$ to maximise:

$$U_2^d\left(c_2^d, l_2^d, s_2^d, g_2^d\right) = \mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d - s_2^d) + \mu_3 \log g_2^d \tag{6.48}$$

subject to the optimality conditions of *stage (D)* as well as the second-period government and household budget constraints in both countries:

$$\begin{aligned} c_2^d - (1-\delta)k_2^d + g_2^d = y_2^d - (1-\tau_{k,2}^d)r_2^d f_2^f + \Big(1 + (1-\tau_{k,2}^f)r_2^f - \delta\Big) f_2^d \\ - m\frac{\left(f_2^d\right)^2}{2} - (1-\tau_{l,2}^d)w_2^d s_2^f + (1-\tau_{l,2}^f)w_2^f s_2^d - j\frac{\left(s_2^d - \bar{s}\right)^2}{2} \end{aligned} \tag{6.49}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d = \frac{\mu_2}{1 - l_2^d - s_2^d} \tag{6.50}$$

$$\frac{\mu_1}{c_2^d}\Big((1-\tau_{l,2}^f)w_2^f - j(s_2^d - \bar{s})\Big) = \frac{\mu_2}{1 - l_2^d - s_2^d} \tag{6.51}$$

$$g_2^d + (1+\rho_2^d)b_2^d = \tau_{k,2}^d r_2^d (k_2^d + f_2^f) + \tau_{l,2}^d w_2^d (l_2^d + s_2^f) \tag{6.52}$$

$$\begin{aligned} c_2^f - (1-\delta)k_2^f + g_2^f = y_2^f - (1-\tau_{k,2}^f)r_2^f f_2^d + \Big(1 + (1-\tau_{k,2}^d)r_2^d - \delta\Big) f_2^f \\ - m\frac{(f_2^f)^2}{2} - (1-\tau_{l,2}^f)w_2^f s_2^d + (1-\tau_{l,2}^d)w_2^d s_2^f - j\frac{(s_2^f - \bar{s})^2}{2} \end{aligned} \tag{6.53}$$

$$\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f = \frac{\mu_2}{1 - l_2^f - s_2^f} \tag{6.54}$$

$$\frac{\mu_1}{c_2^f}\Big((1-\tau_{l,2}^d)w_2^d - j(s_2^f - \bar{s})\Big) = \frac{\mu_2}{1 - l_2^f - s_2^f} \tag{6.55}$$

$$g_2^f + (1+\rho_2^f)b_2^f = \tau_{k,2}^f r_2^f (k_2^f + f_2^d) + \tau_{l,2}^f w_2^f (l_2^f + s_2^d) \tag{6.56}$$

As in the case of commitment-type policies, since the problem is too complex to be specified in a primal form we will follow usual practice by solving the problem in its dual form (see e.g. *Atksinson and Stiglitz, 1980[7]*). This means that policymakers, in addition to the independently set policy instruments, re-choose all the allocations and the residually determined instruments of the WDCE system in the second period.

From the viewpoint of the domestic government, the solution of *stage (C)*, in a non-cooperative (Nash) game, yields a system of 18 equations in 18 endogenous variables.

Specifically, counting equations, we have the 8 constraints/equations of the WDCE in the second period, the optimality conditions for the 8 variables being determined by the WDCE system (as said, they are re-chosen in a dual solution), plus the two optimality conditions for the domestic independent policy instruments, $\tau^d_{k,2}$ and $\tau^d_{l,2}$. Counting endogenous variables, always for the individual country that plays Nash, we have the 8 variables of the WDCE system in the second period, $c^d_2, c^f_2, l^d_2, l^f_2, s^d_2, s^f_2, g^d_2, g^f_2$, plus the 8 dynamic Lagrangean multipliers corresponding to the 8 equations of the WDCE system, plus the two optimally chosen instruments, $\tau^d_{k,2}$ and $\tau^d_{l,2}$. This is given the independent policy choices of the other country, $\tau^f_{k,2}$ and $\tau^f_{l,2}$. The foreign country solves an analogous problem and obtains a similar set of 18 equations in 18 unknowns in the second period.

At this stage, we end up with a system of 28 equations in 28 variables (namely, 18+18-8), since the 8 equations of the WDCE are common to both countries and the same applies to the 8 variables that are endogenous at WDCE level.

Solution of stage (B)

The household in the domestic country maximizes its lifetime discounted utility by choosing first-period consumption, c^d_1, work/leisure, l^d_1, and savings in the form of domestic capital, k^d_2, foreign capital, f^d_2, and private bonds, b^d_2, by taking into account its own budget constraint and its own labor supply decisions of *stage (D)*

The optimality conditions associated with this step are:

$$\frac{\mu_1}{c^d_1}(1-\tau^d_{l,1})w^d_1 = \frac{\mu_2}{1-l^d_1} \tag{6.57}$$

$$\frac{\mu_1}{c^d_1} = \beta\left\{\frac{\left(1+(1-\tau^d_{k,2})r^d_2-\delta\right)\mu_1^2}{(\mu_1+\mu_2)c^d_2} + \frac{\left(1+(1-\tau^d_{k,2})r^d_2-\delta\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau^d_{l,2})w^d_2(1-l^d_2-s^d_2)}\right\} \tag{6.58}$$

$$\frac{\mu_1}{c^d_1} = \beta\left\{\frac{\left(1+(1-\tau^f_{k,2})r^f_2-\delta-mf^d_2\right)\mu_1^2}{(\mu_1+\mu_2)c^d_2} + \frac{\left(1+(1-\tau^f_{k,2})r^f_2-\delta-mf^d_2\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau^d_{l,2})w^d_2(1-l^d_2-s^d_2)}\right\} \tag{6.59}$$

$$\frac{\mu_1}{c^d_1} = \beta\left\{\frac{\left(1+\rho^d_2\right)\mu_1^2}{(\mu_1+\mu_2)c^d_2} + \frac{\left(1+\rho^d_2\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau^d_{l,2})w^d_2(1-l^d_2-s^d_2)}\right\} \tag{6.60}$$

The household in the foreign country solves a similar problem and obtains similar equations:

$$\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f = \frac{\mu_2}{1-l_1^f} \tag{6.61}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^f)w_2^f(1-l_2^f-s_2^f)}\right\} \tag{6.62}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^f)w_2^f(1-l_2^f-s_2^f)}\right\} \tag{6.63}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+\rho_2^f\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+\rho_2^f\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^f)w_2^f(1-l_2^f-s_2^f)}\right\} \tag{6.64}$$

so that $\rho_2^d = (1-\tau_{k,2}^d)r_2^d - \delta$ and $\rho_2^f = (1-\tau_{k,2}^f)r_2^f - \delta$ in equilibrium. At this stage we have 10 new equations in 10 endogenous variables, namely, 8 optimality conditions in $l_1^d, k_2^d, f_2^d, \rho_2^d, l_1^f, k_2^f, f_2^f, \rho_2^f$ and 2 first-period budget constraints that define c_1^d and c_1^f.

Solution of stage (A)

The end-of period government bonds, b_2^d and b_2^f, residually adjust to close the first-period government budget constraint in each country, given that the rest of first-period policy variables, $\tau_{k,1}^d, \tau_{k,1}^f, \tau_{l,1}^d, \tau_{l,1}^f, g_1^d, g_1^f$, are assumed to be exogenous. In other words, as said above, we assume that policy in the first period is simply feasible and not optimal.

Non-cooperative (Nash) equilibrium without commitment

Collecting equations, the non-cooperative equilibrium (Nash) without commitment is a system of 40 equations in 40 endogenous variables, which includes the optimality conditions of each stage, the corresponding Lagrangean multipliers and the budget constraints of the household and the government in each economy and in each period. In particular, counting endogenous variables, we have the 20 variables of the WDCE system, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, s_2^d, l_1^f, l_2^f, s_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, g_2^d, g_2^f, \rho_2^d, \rho_2^f$, plus the 16 dynamic Lagrangean multipliers corresponding to the 16 optimality conditions of *stage (C)*, plus the four optimally chosen instruments, $\tau_{k,2}^d, \tau_{l,2}^d, \tau_{k,2}^f, \tau_{l,2}^f$. This is given the assumed exogenous policy instruments $\tau_{k,1}^d, \tau_{k,1}^f, \tau_{l,1}^d, \tau_{l,1}^f, g_1^d$ and g_1^f.[3]

[3] *For a detailed view of the non-cooperative (Nash) solution without commitment, see Appendix B.2.1.*

6.6.2 Cooperative time-consistent policies: Definition

Solution of stage (D)

The solution here is identical to the one in *stage (D)* in the non-cooperative regime. Hence, we have 6 equations in 6 endogenous variables. Particularly, counting equations we have 4 optimality conditions for the 4 variables being determined by households in the WDCE in the second period, $l_2^d, s_2^d, l_2^f, s_2^f$, plus the two second-period budget constraints that define c_2^d and c_2^f.

Solution of stage (C)

When national policies are chosen jointly by a fictional world social planner, the latter maximises a weighted average of households' second-period welfare in each country with equal weights, γ, given to each one of them. Thus, the objective is now:

$$\begin{aligned} \max W^{coop} = &\gamma\Big(\mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d - s_2^d) + \mu_3 \log g_2^d\Big) \\ &+ (1-\gamma)\Big(\mu_1 \log c_2^f + \mu_2 \log(1 - l_2^f - s_2^f) + \mu_3 \log g_2^f\Big) \end{aligned} \tag{6.65}$$

subject to the government budget constraints and the optimality conditions/constraints that summarize the solution of *stage (D)* above:

$$\begin{aligned} c_2^d - (1-\delta)k_2^d + g_2^d = &y_2^d - (1-\tau_{k,2}^d)r_2^d f_2^f + \Big(1 + (1-\tau_{k,2}^f)r_2^f - \delta\Big)f_2^d \\ &- m\frac{\left(f_2^d\right)^2}{2} - (1-\tau_{l,2}^d)w_2^d s_2^f + (1-\tau_{l,2}^f)w_2^f s_2^d - j\frac{\left(s_2^d - \bar{s}\right)^2}{2} \end{aligned} \tag{6.66}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d = \frac{\mu_2}{1-l_2^d-s_2^d} \tag{6.67}$$

$$\frac{\mu_1}{c_2^d}\Big((1-\tau_{l,2}^f)w_2^f - j(s_2^d - \bar{s})\Big) = \frac{\mu_2}{1-l_2^d-s_2^d} \tag{6.68}$$

$$g_2^d + (1+\rho_2^d)b_2^d = \tau_{k,2}^d r_2^d(k_2^d + f_2^f) + \tau_{l,2}^d w_2^d(l_2^d + s_2^f) \tag{6.69}$$

$$\begin{aligned} c_2^f - (1-\delta)k_2^f + g_2^f = &y_2^f - (1-\tau_{k,2}^f)r_2^f f_2^d + \Big(1 + (1-\tau_{k,2}^d)r_2^d - \delta\Big)f_2^f \\ &- m\frac{(f_2^f)^2}{2} - (1-\tau_{l,2}^f)w_2^f s_2^d + (1-\tau_{l,2}^d)w_2^d s_2^f - j\frac{(s_2^f - \bar{s})^2}{2} \end{aligned} \tag{6.70}$$

$$\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f = \frac{\mu_2}{1-l_2^f-s_2^f} \tag{6.71}$$

$$\frac{\mu_1}{c_2^f}\left((1-\tau_{l,2}^d)w_2^d - j(s_2^f - \bar{s})\right) = \frac{\mu_2}{1-l_2^f - s_2^f} \tag{6.72}$$

$$g_2^f + (1+\rho_2^f)b_2^f = \tau_{k,2}^f r_2^f (k_2^f + f_2^d) + \tau_{l,2}^f w_2^f (l_2^f + s_2^d) \tag{6.73}$$

Following usual practice we solve the problem in its dual form. The solution of *stage (C)*, in a cooperative game, yields a system of 20 equations in 20 endogenous variables. In particular, counting equations, we have the 8 constraints/equations of the WDCE in the second period, the optimality conditions for the 8 variables being determined by the WDCE system, plus the four optimality conditions for the independent policy instruments, $\tau_{k,2}^d, \tau_{l,2}^d, \tau_{k,2}^f$ and $\tau_{l,2}^f$. Counting endogenous variables, we have the 8 variables of the WDCE system, $c_2^d, c_2^f, l_2^d, l_2^f, s_2^d, s_2^f, g_2^d, g_2^f$, plus the 8 dynamic Lagrangean multipliers corresponding to the 8 equations of the WDCE system, plus the four optimally chosen instruments, $\tau_{k,2}^d, \tau_{l,2}^d, \tau_{k,2}^f$ and $\tau_{l,2}^f$.

Solution of stage (B)

Again, the solution of this stage is identical to the one in *stage (B)* in the non-cooperative regime. Hence, we have 10 new equations in 10 endogenous variables, namely, 8 optimality conditions in $l_1^d, k_2^d, f_2^d, \rho_2^d, l_1^f, k_2^f, f_2^f, \rho_2^f$ and the two first-period budget constraints that define c_1^d and c_1^f.

Solution of stage (A)

The end-of period government bonds, b_2^d and b_2^f, residually adjust to close the first-period government budget constraint in each country, given that the rest of first-period policy variables, $\tau_{k,1}^d, \tau_{k,1}^f, \tau_{l,1}^d, \tau_{l,1}^f, g_1^d, g_1^f$, are assumed to be exogenous. As said this is for keeping the model relatively simple.

Cooperative equilibrium without commitment

Collecting equations, the cooperative equilibrium without commitment is a system of 32 equations in 32 endogenous variables, which includes the optimality conditions of each stage, the corresponding Lagrangean multipliers and the budget constraints of the household and the government in each economy and in each period. In particular, counting endogenous variables, we have the 20 variables of the WDCE system, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, s_2^d, l_1^f, l_2^f, s_2^f, k_2^d, k_2^f, f_2^d, f_2^f$, $b_2^d, b_2^f, g_2^d, g_2^f, \rho_2^d, \rho_2^f$, plus the 8 dynamic Lagrangean multipliers corresponding to the 8 equations of the WDCE system in *stage (C)*, plus the four optimally chosen instruments,

$\tau^d_{k,2}, \tau^d_{l,2}, \tau^f_{k,2}, \tau^f_{l,2}$. This is given the the assumed exogenous policy instruments $\tau^d_{k,1}$, $\tau^f_{k,1}$, $\tau^d_{l,1}$, $\tau^f_{l,1}$, g^d_1 and g^f_1.[4]

[4] *For a detailed view of the cooperative solution, see Appendix B.2.2.*

Chapter 7

Numerical solutions for symmetric economies

Since the complexity of the model does not allow for analytical solutions, we will resort to numerical solutions derived by MATLAB®. To study the properties of Nash and cooperative equilibria, we will start by solving for symmetric equilibria where both countries use the same policy strategies and end up with the same allocations and prices. Non-symmetric equilibria will be studied in the next section.

7.1 Parameterization

Most of parameter values are as in *Part A*. The aggregate productivity, A, which is a scale parameter, is set at 1 (see also e.g. *King and Rebelo (1999)[26]*). The power coefficient measuring the capital share of income, α, is set at 0.4 (see e.g. *Garcia-Verdu (2005)[21]*). Following usual practice, we set the time discount factor, β, equal to 0.9. In addition, symmetry implies that the social planner weighs equally ($\gamma = 0.5$) the utility of the household in each economy. The depreciation rate of private capital, δ, is set at 1, which is a typical assumption in two-period models. The weights of consumption, leisure and public goods in the utility function are set at $\mu_1 = 0.30$, $\mu_2 = 0.60$ and $\mu_3 = 1 - \mu_1 - \mu_2$ respectively (see e.g. *Papageorgiou et al. (2011)[41]*). The adjustment cost parameter associated with moving capital abroad is set at $m = 0.1$ (see e.g. *Persson and Tabellini (1992)[43]*), which translates to almost perfect capital mobility across countries. On the other hand, the respective parameters capturing the adjustment costs associated with working abroad are set at $j = 2.0$ and $\bar{s} = 0.1$ (see e.g. *Artuc et al. (2015)[6]*), implying imperfect labour mobility across countries. Furthermore, the exogenously set policy variables are based on OECD and

European Commission estimates. Specifically, the value of private capital stock, k_1, is set at 0.5 and the initial public debt-to-output ratio, b_1/y_1, is set at 0.6. Finally, the capital tax rates, τ_t^k, the labour tax rates, τ_t^l, and the initial public spending as share of GDP, g_1/y_1, are set equal to 0.15, 0.20 and 0.10 respectively (see *Table 7.1*). We nevertheless report from the start that the results below are robust to changes in these values at least within sensible ranges.

Table 7.1 Baseline parameterization

Variable	Description	Value
A	aggregate productivity (TFP)	1.00
α	productivity of private capital	0.40
β	time discount factor	0.90
γ	weight given to each country by the social planner	0.50
δ	depreciation rate of private capital	1.00
μ_1	consumption weight in the utility function	0.30
μ_2	leisure weight in the utility function	0.60
μ_3	public good weight in the utility function $(1-\mu_1-\mu_2)$	0.10
m	capital mobility cost	0.10
j	labor mobility cost	2.00
$\bar{s}$	fixed labor cost in the quadratic cost function	0.10
k_1	initial capital stock	0.50
τ_t^k	capital tax rates $(t=1,2)$	0.15
τ_t^l	labour tax rates $(t=1,2)$	0.20
g_1/y_1	initial public spending as a share of GDP	0.10
b_1/y_1	initial public debt as a share of GDP	0.60

7.2 Symmetric WDCE (for any feasible policy)

Table 7.2 summarises the symmetric WDCE for any feasible policy. This means that, to get this solution we need to set exogenously all policy variables except from those that adjust residually (b_2, g_2) to close the government budget constraint in each period and in each country, as we explained above in the WDCE system (*Section 6.4*), and the interest rate of private bonds in both countries (ρ_2). In other words, in addition to the preset instruments defined above (k_1, b_1/y_1, g_1/y_1, τ_1^k in both countries), here we also set exogenously τ_2^k, τ_1^l and τ_2^l in both countries. Keep in mind however that these policy instruments will be chosen optimally, and hence will move to the list of endogenous variables, when we solve for optimal policies below.

Inspection of the results in *Table 7.2* reveals a well-defined solution with values that are not far away from those observed in the data for an average developed country.[1] The residually determined level of public spending in the second period, g_2, is 0.013, while, regarding the impact of policy on macroeconomic outcomes, the solution roughly corresponds to the EU's average in 2017. In particular, first-period labour supply (l_1) is equal to 26%, while consumption (c_1/y_1) and investment (i_1/y_1) account for 67% and 22% of first-period GDP respectively. In the second period, labour hours fall at 21%, whereas full depreciation of capital implies zero investment so that the distribution of total output between consumption and public spending is 91% and 9% respectively.[2]

Table 7.2 *Symmetric world decentralized competitive equilibrium (WDCE). Data in the parentheses are obtained from Eurostat and OECD and refer to EU's averages in 2017.*

public spending		**labour hrs**		**Shares**			
g_2	0.0129	l_1	0.2628	c_1/y_1	0.6731	c_2/y_2	0.9080
			(0.2000)		(0.5200)		
		l_2	0.2091	i_1/y_1	0.2269	i_2/y_2	0.0000
					(0.2010)		
				g_1/y_1	0.1000	g_2/y_2	0.0920
		output			(0.1950)		
		y_1	0.3399	k_1/y_1	1.4709	k_2/y_2	0.5497
welfare		y_2	0.1403	b_1/y_1	0.6000	b_2/y_2	0.1422
W	-2.0380				(1.0000)		

In *Figures 7.1 (a-d)*, to check the working of our model, we study the impact of various parameter values on the economy's welfare.

As we see in *Figure 7.1 (a)*, a decline in total factor productivity (A) causes a considerable decrease in lifetime discounted utility (welfare). This is intuitive because a lower aggregate productivity leads to a proportional reduction in total output, which in turn is followed by adverse macroeconomic outcomes.

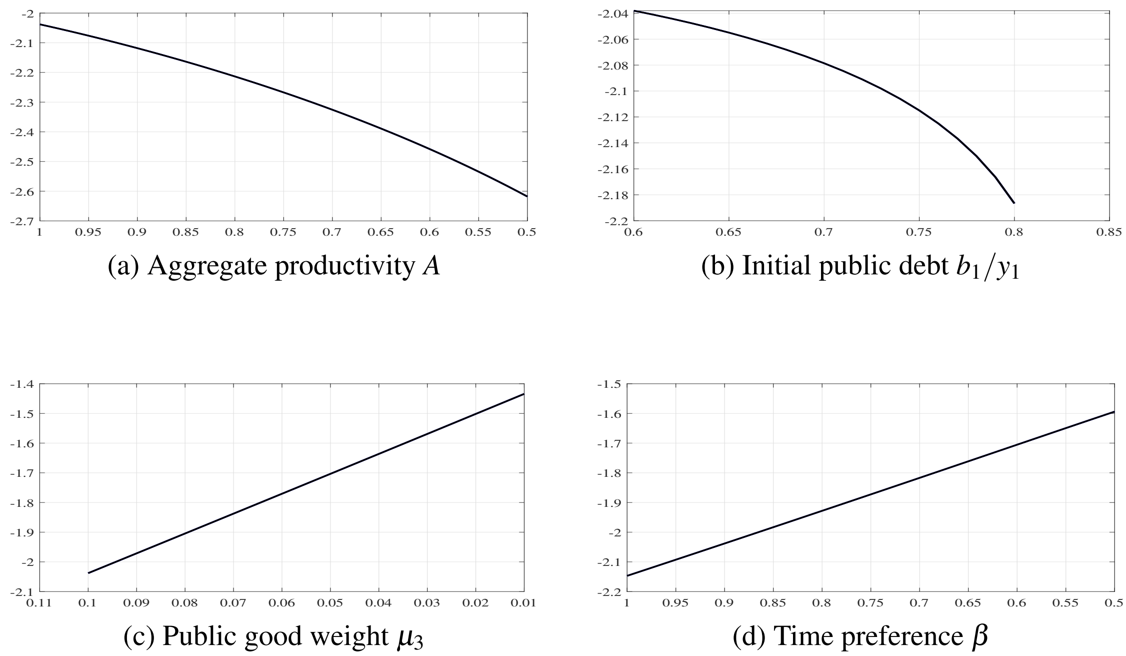
As described in *Figure 7.1 (b)*, an increase in the inherited public debt-to-output ratio (b_1/y_1) is associated with a lower level of welfare, similar to the case of a drop in aggregate productivity. Nevertheless, the propagation mechanism through which the rise in debt is diffused in the macroeconomic environment is much more complicated and hence, requires an in-depth analysis. Taking into account that tax rates (on capital and labour) and public spending (as a share of GDP) are exogenously set in the first period, an increase in the initial debt-to-output ratio leads to a rise in end-of-period public debt (b_2) and a decrease in

[1] *For a detailed view on the evolution of macroeconomic outcomes in the Eurozone see https://stats.oecd.org.*

[2] *For a detailed view of the WDCE (for any feasible policy), see Table B.1 in Appendix B.3.1.*

first-period output (y_1). As theory suggests, a higher public debt in the first period is financed by higher tax revenues in the second period, which, in turn, implies that the policymaker must either increase second-period tax rates (τ_2^k, τ_2^k) or decrease second-period public spending (g_2). With the former option being away by construction in the symmetric WDCE (since we have assumed that second-period tax rates are exogenous), the residually determined second-period public spending must decrease. However, this reduction outruns the increase in end-of-period public debt and hence, fiscal solvency (as dictated by the government budget constraint) is achieved through a decline in second-period output. Summing up, as the initial public debt gets higher, lifetime discounted output and utility will be lower.

Figure 7.1 Welfare in a WDCE at different parameter values



(a) Aggregate productivity A (b) Initial public debt b_1/y_1

(c) Public good weight μ_3 (d) Time preference β

In this experiment we study the impact of a decrease in the valuation of the public good (μ_3) on welfare (*Figure 7.1 (c)*). As already mentioned in *Sections 7.1* and *7.3*, households receive direct utility from public spending, which, by construction, is financed by capital and labour taxation. Therefore, a decrease in the weight given to the public good (in the utility function) weakens the social need for public spending, and hence, smooths out the distortions caused by the fixed (and thus non-optimally chosen) tax rates. In addition, the household's lost interest for the public good is replaced by a higher valuation of its leisure time (μ_2 rises from 0.60 to 0.69). These two effects work in the same direction, and thus, welfare increases.

Results are equivalent when we consider a decrease in the time discount factor (β). As we see in *Figure 7.1 (d)*, as the time preference rate gets lower, the welfare gets higher. Notice that, by definition, a symmetric WDCE with full depreciation of private capital ($\delta = 1$) favors consumption and all first-period decisions over second-period ones. This effect is intensified by rendering the households more impatient and thus, more prone to first-period choices (to consume, work, invest), with positive effects on lifetime discounted utility.

Summing up, the model looks capable of yielding well-defined solutions that are in line with the theoretical and empirical features of a typical WDCE. In the next section, we switch to optimal (endogenous) policies.

7.3 Symmetric Nash equilibrium (SNE) with and without commitment

We now endogenize fiscal policy. We start with the case of non-cooperative (Nash) national fiscal policies as defined in *Subsections 6.5.1* and *6.6.1* above. Results are reported in *Table 7.3* which presents the solution for the optimally chosen fiscal policy instruments and the associated macroeconomic outcomes in a SNE with and without policy commitment. In this solution, the optimally chosen policy instruments are τ_2^k,τ_2^l, g_2, b_2 in both countries, while τ_1^k, τ_1^l, k_1, b_1/y_1, g_1/y_1 in both countries are set exogenously at the values defined above in *Section 7.1*.

We begin our analysis by focusing first on the commitment-type Nash equilibrium, as presented in the upper segment of *Table 7.3*. As we see the burden of taxation falls mainly on labour, the inelastic factor of production, so that the tax rate on second-period capital is low in a commitment (Ramsey) equilibrium, although it does not converge to zero as would happen in an infinite-time horizon economy (this is further discussed below). Qualitatively, this is as in the celebrated Chamley-Judd result which has served as the benchmark in the literature on optimal factor taxation.

In addition, our model supports both capital and labour mobility, albeit at different degrees. This is important because it creates additional policy implications for a non-cooperative solution in which the problem of undertaxation of future capital (and hence the problem of overtaxation of labour) becomes worse due to international capital mobility ("race-to-the-bottom" result). In our context both factors of production are subject to tax competition, so that both tax rates are low relative to the case without international competition for mobile tax bases. Notice however that, by expanding the concept of factor mobility, the celebrated "race-to-the-bottom" result on capital tax rates (see e.g. *Mendoza et al. (2005)[38]*) is milder, as compared to the model without labour mobility used in *Part A*. The reason is that the policymakers are forced to set higher tax rates on capital, in order to offset the distortions caused by the relatively low tax rates on labour.

The race-to-the-bottom result is confirmed when we start increasing the transaction cost parameters associated with investment (m) and working abroad (j). As these parameters rise, so that capital and labour become less and less mobile internationally and the race-to-the-bottom effect gets milder, the problem of factor undertaxation becomes milder. For example, assuming big transaction costs, which practically translates into a closed economy, second-period tax rates on capital, τ_2^k, and labor, τ_2^l, rise from from 6% to 22% and from 21% to 32% respectively.

Table 7.3 Symmetric non-cooperative (Nash) equilibria with and without commitment

Nash equilibrium with commitment

Optimal Policy		**Labour hrs**		**Shares**			
τ_2^k	0.0659	l_1	0.2565	c_1/y_1	0.6522	c_2/y_2	0.8849
τ_2^l	0.2149	l_2	0.1102	i_1/y_1	0.2478	i_2/y_2	0.0000
g_2	0.0167	s_2	0.1000	g_1/y_1	0.1000	g_2/y_2	0.1151
		Output		k_1/y_1	1.4925	k_2/y_2	0.5727
		y_1	0.3350	b_1/y_1	0.6000	b_2/y_2	0.0617
Welfare	-2.0240	y_2	0.1450				

Nash equilibrium without commitment

Optimal Policy		**Labour hrs**		**Shares**			
τ_2^k	0.5226	l_1	0.2360	c_1/y_1	0.7286	c_2/y_2	0.7305
τ_2^l	0.1378	l_2	0.1615	i_1/y_1	0.1714	i_2/y_2	0.0000
g_2	0.0377	s_2	0.1000	g_1/y_1	0.1000	g_2/y_2	0.2695
		Output		k_1/y_1	1.5692	k_2/y_2	0.3908
		y_1	0.3186	b_1/y_1	0.6000	b_2/y_2	0.0456
Welfare	-2.0191	y_2	0.1398				

The lower segment of *Table 7.3* presents the Nash equilibrium without policy commitment. As in *Fischer (1980)[20]* and many others[3] since then, lack of commitment implies that the optimal capital taxes can be very high and near-confiscatory, while the labour taxes can be zero or even negative to undo the distortion in the factor markets, once capital and labour taxes are both optimally chosen. As we see the optimal capital tax rate (52%) is 45pp higher than the respective rate under commitment (7%), since now policy is chosen after private

[3] *see e.g. Klein and Rios-Rull (2003)[29], Ortigueira (2006)[40], Klein et al. (2008)[27] and Martin (2010)[37]*

sector's saving and investment decisions have been made. In other words, time consistency adds realism to a model of international tax policy since time consistent optimal capital tax rates cease to be close to zero even without tax cooperation.

Here, however, we observe a milder version of the *Fischer* result; the optimal capital taxes are high but not confiscatory, while the optimal labour taxes are positive and low but not anywhere close to 0%. An important feature of our time-consistent SNE is that, unlike the commitment-type SNE described above, the degree of capital mobility has, by construction, no effect on tax rates and hence, tax competition stems exclusively from labour mobility. This happens because first-period policy $(\tau_1^k, \tau_1^l, g_1)$ is assumed feasible and not optimal in both countries (see *Subsection 6.6.1*) and as a consequence the parameters associated with agents' first-period decisions do not matter for the solution. Hence, the role of capital mobility cost (m) as a measure of the magnitude of capital tax competition is essentially neutralised. In the second period, however, policy is chosen optimally and the transaction costs associated with working abroad in each country do affect our results. Actually, the unilateral policy selection, as implied by the time-consistent SNE, triggers tax competition for labour factors. In addition, the higher the labour mobility costs, the more willing are the policymakers to apply positive tax rates on labour and reduce drastically the tax burden on capital. In short, the Nash solution under lack of policy commitment leads to a milder version of the Fischer effect (disproportionally high tax burden on capital and low on labour), if labour incurs higher adjustment costs than capital.

The labour-undertaxation result is confirmed when we start decreasing the transaction cost parameter associated with working abroad (s). As this parameter declines, so that labour becomes more and more mobile internationally and tax competition for labour gets fiercer, the problem of labour undertaxation (and hence the problem of capital overtaxation) becomes worse. For example, assuming small labour transaction costs, the second-period capital tax, τ_2^k, rises from 52% to 66%, while, the second-period labour tax rate decreases from 14% to 0%.

Regarding the implications of this policy for macro outcomes we observe that in the commitment-type SNE, consumption (c_1/y_1) and investment (i_1/y_1) as shares of GDP are 65% and 25% respectively in the first period, while the remaining 10% is used for public spending. In the second period, with zero investment (this is by construction in our two-period model), consumption and public spending, again as shares of GDP, rise to 88% and 12% respectively. Note that the low tax rates on capital promote investment between the two periods and so enhance private consumption in the second period (this is confirmed below when we compare results to the cooperative solution). On the other hand, the higher capital tax rates in the time-consistent SNE, benefit consumption (73%) over investment (17%) in the first period, as compared to the commitment case. In addition, consumption in the second period is considerably lower (73%), whereas, public spending is more than two times higher (27%), always compared to the solution with policy commitment.

7.4 Symmetric cooperative equilibrium (SCE) with and without commitment

We continue with the case of cooperative national fiscal policies as defined in *Subsections 6.5.2* and *6.6.2* above. Solutions are reported in *Table 7.5* which presents the solution for the optimally chosen fiscal policy instruments and the associated macroeconomic outcomes in a SCE, with and without policy policy commitment.

We focus first on the cooperative solution with policy commitment presented in the upper segment of *Table 7.4*. As can be seen, the chosen capital tax rate is now higher than in a SNE. In particular, with our baseline parameterization, the capital and labour tax rates are equal to 22% and 32% respectively, a result which is very similar to the one obtained in *Part A*. In other words, the race-to-the-bottom effect is now away by construction so that only the Chamley-Judd type result remains. Notice, however, that, although the tax rate on second-period capital is lower than that on labor, it is not zero as in the infinite-time horizon model typically used in the literature (see *Chamley (1986)*, *Judd (1985)*, *Lucas (1990)[36]*, etc). This is because in a two-period model the costs of capital taxation last relatively little (here they last for one period only) so that the optimally chosen capital tax rate is not zero in general (different parameterizations could force it to be lower but it is not easy to make it zero contrary to the infinite-horizon model where the limiting tax rate on capital is zero irrespectively of parameter values to the extent that one excludes imperfections like lack of commitment, externalities, incomplete taxation, imperfect competition, etc).[4]

The lower segment of *Table 7.4* presents the cooperative solution without policy commitment. As we see, the absence of a commitment technology is associated with a cooperative capital tax (67%) which is 44pp higher than its commitment-type counterpart (23%). This happens because now policy is chosen after private sector's saving and investment decisions have been made. Hence, time consistency adds realism to a model of international tax policy since time consistent optimal capital tax rates cease to be close to zero. Additionally, tax cooperation leads to an even higher capital tax relative to the Nash solution. The mechanism behind this result is that the world social planner internalizes not only the mobility cost of capital, m (this also happens in the SNE), but also the adjustment costs associated with

[4] *See e.g Ljungqvist and Sargent (2004)[34] for a review.*

Table 7.4 Symmetric cooperative equilibria with and without commitment

Cooperative equilibrium with commitment

Optimal Policy		**Labour hours**		**Shares**			
τ_2^k	0.2250	l_1	0.2554	c_1/y_1	0.6560	c_2/y_2	0.7500
τ_2^l	0.3224	l_2	0.1132	i_1/y_1	0.2440	i_2/y_2	0.0000
g_2	0.0363	s_2	0.1000	g_1/y_1	0.1000	g_2/y_2	0.2500
		Output		k_1/y_1	1.4964	k_2/y_2	0.5617
		y_1	0.3341	b_1/y_1	0.6000	b_2/y_2	0.0606
Welfare	-1.9989	y_2	0.1452				

Cooperative equilibrium without commitment

Optimal Policy		**Labour hours**		**Shares**			
τ_2^k	0.6686	l_1	0.2247	c_1/y_1	0.7765	c_2/y_2	0.7500
τ_2^l	0.0000	l_2	0.1857	i_1/y_1	0.1235	i_2/y_2	0.0000
g_2	0.0319	s_2	0.1000	g_1/y_1	0.1000	g_2/y_2	0.2500
		Output		k_1/y_1	1.6161	k_2/y_2	0.2991
		y_1	0.3094	b_1/y_1	0.6000	b_2/y_2	0.0393
Welfare	-2.0529	y_2	0.1278				

working abroad, j, $\bar{s}$ (in both countries). As we discussed in *Section 7.3* above, the latter induce tax competition for labour factors when private agents make their choices acting competitively. However, tax competition is away by construction in a cooperative framework and hence, the capital tax rates are higher, while the labour tax rates are lower relative to the SNE. In sum, cooperation under lack of commitment implies that factor mobility has absolutely no effect on optimal policies and hence, the SCE solution is equivalent to that obtained by the closed-economy version of the model.

Concerning the macroeconomic consequences of cooperative optimal policy under commitment, we report that, given the exogenously given public spending which amounts to 10% of GDP in the first period, consumption and investment represent about 66% and 24% of output respectively, whereas the no-investment assumption in the second period allows higher consumption (75%) and public spending (25%) over GDP. Note that second-period private consumption is lower, while second-period public consumption is higher than in the Nash solution. This is intuitive since Nash optimal policies are good for private investment that favors private consumption in the future (see also *Section 7.5* below). In addition, as in a SNE, first-period output ($y_1 = 0.33$) is more than twice the output in the second period ($y_2 = 0.15$), a typical implication of the higher initial capital stock k_1 relative to the optimally chosen capital k_2. Despite these differences between the SNE and the SCE though, the welfare gains from cooperation over Nash are small in size, a finding which was also addressed in *Part A*.

In the absence of a commitment technology however, consumption and investment amount to 78% and 12% of first-period output respectively, while second-period consumption and public spending over GDP are identical to those in the commitment-type solution (75% and 25% of GDP). Note that second-period private consumption (over GDP) is higher, whereas second-period public consumption (over GDP) is lower relative to the Nash solution. The intuition is that as the burden of taxation falls exclusively on capital, households tend to reduce their consumption (c_2) and savings (k_2), while, on the other hand, they increase their labour effort (l_2), relative to the SNE. Nevertheless, the drop in savings is considerably higher than the rise in work effort and hence, second-period output will be lower, implying that the respective changes in macroeconomic ratios are driven more by a change in the denominator and less by a change in their actual levels. Furthermore, as in a SNE, first-period output ($y_1 = 0.31$) is more than twice the output in the second period ($y_2 = 0.13$) thanks to the higher initial capital stock k_1 relative to the optimally chosen capital k_2. In sharp contrast to the commitment-type solution, the welfare implications from cooperation over Nash are non-trivial. In the next section, we provide a comparison of the two equilibria and the gains from cooperation.

7.5 Comparison of equilibria and gains from cooperation

Table 7.5 summarizes the capital and labor taxes, as well as the welfare and output gains from cooperation, in equilibria with and without policy commitment. We focus first on the commitment solution. As we discussed in *Sections 7.3* and *7.4* above, policy coordination leads to a higher tax burden than non-coordination (higher capital and labour tax rates). As we see in the upper tier of *Table 7.5*, the capital tax rate (τ_2^k) rises from 6% in a SNE to 22% in a SCE, while the labour tax rate (τ_2^l) rises from 21% in a SNE to 32% in a SCE. Note that the latter 11pp increase in the labour tax rate is more acute than the respective 5pp increase in *Part A*, because, here, first-period policy is assumed feasible and not optimal and hence, the cost of a transition from non-cooperative to cooperative optimal policies will be higher in terms of labour taxation. As expected, cooperation has a negative impact on investment between the first and the second period and also, on second-period levels of consumption and capital. With cooperative policies in particular, investment-over-GDP is considerably lower than in the SNE (-1.5%), while, at the same time, the decline in second-period ratios of consumption (c_2/y_2) and capital (k_2/y_2) is even more acute (-15%, -2%). On the other hand, cooperation leads to 117% more public spending (g_2/y_2) in the second period and higher level of consumption in the first period.[5]

If, instead, policymakers do not have access to a commitment technology (see the lower tier of *Table 7.5*), the optimal Nash (52%) and cooperative (67%) capital tax rates are 45pp and 44pp higher than the respective rates in the case with policy commitment, since now policy is chosen after private sector's saving and investment decisions have been made. As we already discussed in *Sections 7.3* and *7.4* above, by assuming away the ability of governments to commit themselves to future policies, we render our model of international tax policy more realistic, since time consistent optimal capital tax rates cease to be close to zero even without tax cooperation. Moreover, cooperation results in a lower tax burden on labour, at the cost however of a higher tax burden on capital, as compared to non-cooperation. With the tax competition effect (on labour factors) being away by construction so that only the Fischer type result remains, the capital tax rate (τ_2^k) rises from 52% in a SNE to 66% in a SCE, while the labour tax rate (τ_2^l) declines from 14% in a SNE to 0% in a SCE. Therefore, similar to the commitment-type cooperative solution, as the burden of taxation is rolled over second-period capital, private investment and second-period capital, always as shares of GDP, will be lower (-28% and -23%). Moreover, consumption-to-output is higher in both periods (6.6%, 2.7%), whereas, public spending-to-output is noticeably lower than in the SNE (-7.2%). Note that public spending in the cooperative regime is financed by tax revenues generated entirely from capital income. Hence, without the contribution of the labour tax base (to the government budget constraint), the overall level of tax revenues will be lower under cooperation, and as a consequence, public spending will also be lower. Another straightforward implication of the labour undertaxation problem is the increase in labour hours (15% more work effort than in the SNE).

At this point, we need to underline the effect of commitment-type policy on output and welfare. As cooperative strategies tend to raise the tax burden on both factors of production, the lifetime discounted output is marginally lower than in the SNE, translating into a 0.15% loss in quantitative terms. Nevertheless, as expected, cooperation is superior to Nash when the criterion is lifetime utility ("welfare"), although the gains are marginal (at roughly one percent). These findings are as in the most of the related literature (see e.g. *Mendoza and Tesar (2005)*) and are identical to those in *Part A*. However, we should point out that the marginal superiority of cooperation vis-a-vis Nash (when the criterion is welfare) presupposes that one stays away from other imperfections like politically motivated governments (see e.g. *Persson and Tabellini (1995)*), incomplete factor mobility (see e.g. *Perotti (2001)*),

[5] *For a detailed view on macroeconomic outcomes in the SNE and SCE presented here, see Table B.2 in Appendix B.3.2.*

Table 7.5 Optimal policies and gains from cooperation in symmetric equilibria

Commitment

policy	**SNE**	**SCE**	**levels %**		**Shares**			
τ_2^k	0.0659	0.2250	l_1	-0.43	c_1/y_1	0.58	c_2/y_2	-15.24
τ_2^l	0.2149	0.3224	l_2	2.72	i_1/y_1	-1.53	i_2/y_2	-
g_2	0.0167	0.0363	s_2	0.00	g_1/y_1	0.00	g_2/y_2	117.20
					k_1/y_1	0.26	k_2/y_2	-1.92
output	0.4655	0.4648	y	-0.15	b_1/y_1	0.00	b_2/y_2	-1.78
welfare	-2.0240	-1.9989	W	1.24				

No-commitment

policy	**SNE**	**SCE**	**levels %**		**Shares**			
τ_2^k	0.5226	0.6686	l_1	-4.79	c_1/y_1	6.57	c_2/y_2	2.67
τ_2^l	0.1378	0.0000	l_2	14.98	i_1/y_1	-27.95	i_2/y_2	-
g_2	0.0377	0.0319	s_2	0.00	g_1/y_1	0.00	g_2/y_2	-7.24
					k_1/y_1	2.99	k_2/y_2	-23.46
output	0.4444	0.4244	y	-4.50	b_1/y_1	0.00	b_2/y_2	-13.82
welfare	-2.0191	-2.0529	W	-1.67				

international public goods (see e.g. *Kammas and Philippopoulos (2008)[25]*), or, in our case, lack of policy commitment.

We find that, in the absence of a commitment-inducing technology, cooperation has detrimental effects not only on output, but also on lifetime discounted utility. Actually, without commitment the standard results are reversed, meaning that cooperation proves to be counter-productive at least for a large range of parameter values. This happens mainly because, without commitment, capital tax rates are too high in general, so that tax competition works to mitigate this distortion. Specifically, with our baseline parameterization, cooperation results in 4.5% less output and 1.7% less welfare than non-cooperation, while an extensive robustness analysis (see *Subsection 7.7* below) indicates that this difference can be even wider if one raises the transaction costs associated with working abroad. The intuition is that the barriers in labour mobility allow the individual policymakers to unilaterally choose a lower capital tax rate in exchange, however, for a higher labour tax tax rate, as compared to cooperation. In fact, the higher the labour adjustment costs are, the smoother is the allocation of the tax burden between the two factors, so that both countries reap considerable output and welfare gains from unilateral rather than from cooperative practices.

Moreover, note that the SNE under lack of commitment outperforms the commitment-type SNE in terms of welfare. This happens because in the non-commitment SNE there are two forces that work in the opposite direction; on one hand, time-consistent policymaking leads to excessively high tax rates on capital and low tax rates on labour, while on the other hand, the barriers to labour mobility weaken the tax competition for labour factors and as a consequence, the tax rates on labour will be higher, while the tax rates on capital will be lower, relative to the SCE. As a combined result, welfare will be higher under non-commitment (two imperfections are present) rather than under commitment (tax competition is the only assumed distortion). Hence, the message here is that in the presence of several distortions in the background (in this chapter the assumed imperfections are tax competition and lack of commitment), taking just one out (lack of cooperation) is not necessarily productive. These results may partly explain why little progress has been made in moving to fiscal unions with cooperative national fiscal policies and why the burden of taxation has been shifted onto labor, the relatively immobile factor of production.

7.6 Robustness analysis

We next consider five experiments that help us to assess the robustness of our results. We focus on the valuation of public goods/services, aggregate factor productivity (TFP), the inherited public debt-to-output ratio and finally the costs associated with capital and labour moving abroad. *Tables 7.6 - 10* depict the optimal policies as well as the lifetime discounted welfare and output gains from cooperation in each case.[6]

(i) Decrease in the valuation of public goods/services: In this experiment we explore how the results from the symmetric benchmark case change when the weight given to the public good in the utility function, μ_3, decreases (*Table 7.6*). As already discussed in *Sections 7.1* and *7.3*, households receive direct utility from public spending, which, by construction, is financed by capital and labour taxation. Therefore, a decrease in the valuation of the public good weakens the social need for tax revenues and hence, translates into lower tax rates on both factors of production. This result is very similar to *Part A* and is addressed in both solutions (commitment and non-commitment) and in both regimes (SNE and SCE), with the reduction being more acute in the cooperative framework. Particularly, in the commitment-type solution, the capital tax rate drops by only 5pp (from 7% to 2%) in the SNE, whereas it declines sharply (from 22% to 5%) in the SCE. In the same direction, a mild 5pp decrease in the Nash labour tax (from from 22% to 17%), corresponds to a 15pp drop in the cooperative tax.

Similar results hold in the time-consistent (non-commitment) solution, although the magnitude is now more profound. Specifically, as the capital tax rate registers a massive 39pp decline in both the SNE (from 52% to 14%) and the SCE (from 67% to 28%), the labour tax rate decreases by only 2pp in the non-cooperative regime (from 14% to 12%), while it remains equal to 0% (benchmark case) under cooperation. This result, namely the zero tax on labour, is a qualitative property of the time-consistent cooperative solution and is robust to changes in parameter values (within a sensible range of parameters) in all cases studied. Recall that, as in the celebrated *Fischer* result, the non-commitment solution implies an excessive tax burden on capital as an exchange for a relatively low tax rate on labour. This effect becomes stronger in the absence of a force that drives the tax rates on the opposite direction (this role is played by tax competition in the SNE), which is exactly the case of policy coordination. In this context, tax competition is away by construction so that the capital taxes are high, while the labour taxes are zero to undo the distortion in the factor markets, once capital and labour taxes are both optimally chosen (see *Section 7.4* above).

[6] For a detailed robustness analysis see *Tables B.6-15* in *Appendix B.3.3*.

As expected, the higher tax rates implied by the SCE hurt lifetime discounted output in both solutions, but mostly in the non-commitment one. When the criterion is lifetime discounted utility, commitment-type cooperation is productive, yet as the public good loses its desirability, this superiority vis-a-vis Nash becomes narrower. On the contrary, cooperation under lack of policy commitment systematically yields lower levels of welfare as compared to the Nash solution, despite that the difference fades out as the valuation of the public good decreases.

Table 7.6 Robustness of the valuation of public goods/services, μ_3

	Commitment						**Non-commitment**					
	Nash			**Coop**			**Nash**			**Coop**		
μ_3	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2
*0.10	0.066	0.215	0.017	0.225	0.322	0.036	0.523	0.138	0.038	0.669	0.000	0.032
0.07	0.054	0.202	0.015	0.157	0.265	0.027	0.377	0.130	0.029	0.522	0.000	0.025
0.05	0.042	0.191	0.014	0.105	0.221	0.020	0.263	0.126	0.021	0.410	0.000	0.019
0.03	0.022	0.173	0.011	0.046	0.172	0.012	0.135	0.121	0.014	0.284	0.000	0.012

	output (y)			**welfare** (W)			**output** (y)			**welfare** (W)		
μ_3	**Nash**	**Coop**	%	**Nash**	**Coop**	%	**Nash**	**Coop**	%	**Nash**	**Coop**	%
*0.10	0.466	0.465	-0.155	-2.024	-1.999	1.240	0.444	0.424	-4.500	-2.019	-2.053	-1.674
0.07	0.455	0.454	-0.136	-1.834	-1.824	0.545	0.443	0.429	-3.152	-1.832	-1.849	-0.939
0.05	0.448	0.447	-0.136	-1.704	-1.701	0.200	0.441	0.430	-2.456	-1.704	-1.714	-0.605
0.03	0.441	0.441	-0.093	-1.569	-1.569	0.013	0.438	0.430	-1.902	-1.570	-1.575	-0.338

(ii) Decrease in aggregate productivity: So far we have assumed that the value of aggregate productivity, A, (scale parameter) is 1. This experiment investigates the implications of a decrease in aggregate productivity. In *Table 7.7*, we present the optimal policies and the gains from cooperation that correspond to productivity-specific equilibria. As expected a decline in TFP causes a contraction of the tax base in both economies, which, in a cooperative framework such as the one we employ here, implies lower tax rates on both factors of production. Non-cooperation instead, goes along with lower tax rates on capital and higher tax rates on labour. Particularly, focusing first on the commitment solution, we find that a marginal 1pp decrease in the Nash capital tax (from 6% to 5%) is accompanied by a 2pp increase in the Nash labour tax (from 22% to 24%), whereas both tax rates decline by 7pp (from 23% to 16%) and 4pp (from 32% to 28%) respectively under cooperation.

The qualitative properties of the solutions described above match those in time-consistent policies, although the impact is now more acute. For instance, in the case where productivity decreases by say 30%, a 13pp decline (from 52% to 39%) in the capital tax is followed by a 3pp rise (from 14% to 17%) in the labour tax in the SNE. Correspondingly, as the cooperative capital tax drops by 10pp (from 67% to 57%), the respective labour tax is unchanged at 0% regardless of the productivity level. As already discussed in the previous experiment

Table 7.7 Robustness of the aggregate productivity, A

	Commitment						Non-commitment					
	Nash			Coop			Nash			Coop		
A	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2
*1.00	0.066	0.215	0.017	0.225	0.322	0.036	0.523	0.138	0.038	0.669	0.000	0.032
0.90	0.062	0.224	0.018	0.204	0.308	0.032	0.480	0.146	0.034	0.637	0.000	0.029
0.80	0.058	0.233	0.018	0.184	0.294	0.028	0.435	0.156	0.029	0.604	0.000	0.025
0.70	0.054	0.241	0.017	0.162	0.279	0.023	0.386	0.167	0.025	0.569	0.000	0.021

	output (y)			welfare (W)			output (y)			welfare (W)		
A	Nash	Coop	%	Nash	Coop	%	Nash	Coop	%	Nash	Coop	%
*1.00	0.466	0.465	-0.155	-2.024	-1.999	1.240	0.444	0.424	-4.500	-2.019	-2.053	-1.674
0.90	0.417	0.417	-0.196	-2.107	-2.092	0.736	0.401	0.383	-4.421	-2.108	-2.139	-1.490
0.80	0.369	0.368	-0.276	-2.205	-2.196	0.408	0.356	0.341	-4.381	-2.208	-2.238	-1.322
0.70	0.321	0.320	-0.287	-2.319	-2.315	0.203	0.311	0.298	-4.389	-2.324	-2.351	-1.162

(decrease in the valuation of the public good), if one combines time-consistent policymaking (that leads to the celebrated Fischer result) with cooperative practices (that take away tax competition for mobile factors) the tax rate on labour will be zero, so that the burden of taxation is shifted entirely towards the end-of-period capital. The case we consider here is not an exception.

A straightforward implication of the cooperative tax mix is the poor macroeconomic performance of both countries. We find that cooperation results in lower levels of lifetime discounted output relative to Nash in both solutions, and particularly in the non-commitment one. Nevertheless, as aggregate productivity falls, the output loss from cooperation vis-a-vis Nash is getting bigger under commitment (from -0.2% to -0.3%) and smaller under lack of commitment (from -4.5% to -4.4%). In terms of lifetime discounted utility, cooperation continues to be superior to Nash in the commitment-type solution, despite that its superiority decreases with TFP (from 1.2% to 0.2%). In sharp contrast, cooperation under lack of commitment is associated with considerable welfare losses (from -1.7% to -1.1%) as compared to non-cooperation, although these losses are decreasing in the level of aggregate productivity.

(iii) Increase in the initial public debt-to-GDP ratio: In this experiment we consider a rise in the inherited public debt ratio, b_1/y_1 (*Table 7.8*). We describe first the commitment-type solution. As the initial debt burden gets higher, the Nash capital tax rate increases from 7% to 11%, while the labour tax rate remains roughly equal to 22% (as in the benchmark case), a result which is very close to the one obtained in *Part A*. This happens because tax competition affects both factors (since they are both mobile internationally), so that both tax rates are low relative to the case without international competition for mobile tax bases. Nevertheless, the tax on labour income is more than two times higher than the respective tax on capital, a typical implication for all commitment-type equilibria. On the other hand, when

countries cooperate, the capital tax rates constitute an important element of the tax mix, as for every 10% increase in the public debt, they rise by almost 3pp and eventually settle at around 32%. Meanwhile, in the case where public debt rises by 30pp, the respective labour tax rate registers a moderate 7pp increase (from 32% to 39%).

Equivalent results hold in the non-commitment solution. The Nash capital tax rate increases sharply by 15pp (from 52% to 67%), while the labour tax rate presents only a marginal increment (from 14% to 15%). Likewise, the cooperative capital tax rate follows a considerable rise (from 67% to 81%), whereas the respective labour tax is exactly zero, which, as we discussed above, is an inherent property of the time-consistent SCE.

As expected, cooperation, by implying higher tax rates than the Nash equilibrium, has a negative impact on lifetime discounted output in both solutions. However, as the inherited public debt increases, the output loss relative to the SNE becomes smaller in the commitment solution (decreases from -0.15% to -0.07%) and larger in the non-commitment solution (increases from -4.5% to -6.3%). Regarding the welfare implications of a rising public debt, we report that cooperation under commitment is associated with remarkable welfare gains, always as compared to non-cooperation. Moreover, in contrast to the previous experiments (decrease in the valuation of the public good and in TFP), these gains are increasing in the level of initial public debt and they can be as high as 6.3%, five times more than in the benchmark case (1.2%). On the contrary, the excessive tax burden on capital, that typically comes with the time-consistent cooperative solution, renders cooperation a harmful strategy for both countries, with welfare losses that range from -1.7% to -3.1%.

Table 7.8 Robustness of the initial public debt-to-GDP ratio, b_1/y_1

	Commitment						**Non-commitment**					
	Nash			**Coop**			**Nash**			**Coop**		
s_1^b	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2
*0.60	0.066	0.215	0.017	0.225	0.322	0.036	0.523	0.138	0.038	0.669	0.000	0.032
0.70	0.079	0.216	0.012	0.259	0.345	0.035	0.574	0.141	0.036	0.719	0.000	0.030
0.80	0.093	0.216	0.008	0.291	0.367	0.034	0.622	0.143	0.035	0.767	0.000	0.028
0.90	0.107	0.215	0.003	0.323	0.388	0.033	0.667	0.146	0.033	0.812	0.000	0.026

	output			**welfare**			**output**			**welfare**		
s_1^b	**Nash**	**Coop**	%	**Nash**	**Coop**	%	**Nash**	**Coop**	%	**Nash**	**Coop**	%
*0.60	0.466	0.465	-0.155	-2.024	-1.999	1.240	0.444	0.424	-4.500	-2.019	-2.053	-1.674
0.70	0.460	0.459	-0.113	-2.045	-2.003	2.068	0.436	0.414	-4.977	-2.029	-2.070	-2.041
0.80	0.454	0.453	-0.115	-2.079	-2.008	3.453	0.428	0.404	-5.577	-2.039	-2.090	-2.496
0.90	0.448	0.448	-0.071	-2.149	-2.012	6.344	0.420	0.394	-6.328	-2.051	-2.115	-3.101

(iv) Increase in capital mobility cost: This robustness experiment studies the effects of an increase in the adjustment cost parameter associated with moving capital abroad, m. We report from the start that the degree of capital mobility has no effect on the non-commitment

solution and hence, the tax rates in the SNE and the SCE coincide with those in the benchmark case. This happens because first-period policy is assumed exogenous in both countries, so that the parameters associated with agents' first-period decisions, including the one that captures the cost of investing abroad, are irrelevant to the solution (see *Section 7.3* above). Hence, in what follows, we are exclusively concerned with the commitment-type solution.

Theory suggests that, in a world where income taxation is the only distortion, the optimal choice of tax policy is designed to reach a second-best welfare optimum at most. As in *Part A*, this experiment exposes the positive relationship between capital mobility and tax competition, by proving that a higher capital adjustment cost results in equilibria that are ranked higher compared to the benchmark case of almost perfect capital mobility. It is also useful because it highlights the role of policy coordination as a mechanism that offsets the growing mobility of capital flows.

When policy is conducted by cooperative counterparts, the level of capital mobility has no effect on the results, rendering all the SCE solutions equivalent to those obtained in the closed-economy version of the model, a finding which was also addressed in the model of *Part A*. If, instead, governments act on their own self-interest, they are tempted to decrease capital tax rates to attract foreign capital, an effect which gets stronger in the benchmark case of (almost) perfect capital mobility. As it is apparent from *Table 7.9*, when capital mobility costs are too high the non-cooperative tax scheme converges to the cooperative one, meaning that the higher the mobility costs, the closer we get to the cooperative solution. In the limit, if capital and labour are completely immobile, the Nash equilibrium coincides with the cooperative one.

Table 7.9 Robustness of capital mobility cost m

	Commitment						**Non-commitment**					
	Nash			**Coop**			**Nash**			**Coop**		
m	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2
*0.10	0.066	0.215	0.017	0.225	0.322	0.036	0.523	0.138	0.038	0.669	0.000	0.032
10.00	0.175	0.262	0.028	0.225	0.322	0.036	0.523	0.138	0.038	0.669	0.000	0.032
100.00	0.213	0.279	0.032	0.225	0.322	0.036	0.523	0.138	0.038	0.669	0.000	0.032
1000.00	0.218	0.281	0.032	0.225	0.322	0.036	0.523	0.138	0.038	0.669	0.000	0.032

	output			**welfare**			**output**			**welfare**		
m	**Nash**	**Coop**	%	**Nash**	**Coop**	%	**Nash**	**Coop**	%	**Nash**	**Coop**	%
*0.10	0.466	0.465	-0.155	-2.024	-1.999	1.240	0.444	0.424	-4.500	-2.019	-2.053	-1.674
10.00	0.464	0.465	0.088	-2.003	-1.999	0.185	0.444	0.424	-4.500	-2.019	-2.053	-1.674
100.00	0.464	0.465	0.196	-2.000	-1.999	0.055	0.444	0.424	-4.500	-2.019	-2.053	-1.674
1000.00	0.464	0.465	0.218	-2.000	-1.999	0.045	0.444	0.424	-4.500	-2.019	-2.053	-1.674

Unlike the previous experiments (decrease in the valuation of the public good and TFP, increase in initial public debt), cooperation under commitment leads to a slightly higher level of lifetime discounted output as compared to the Nash solution. The intuition is that a higher capital mobility cost reduces the tax competition effect (implied by the SNE) and therefore, results in relatively high capital tax rates that reduce the non-cooperative output (particularly in the first period). When the criterion is lifetime discounted utility, cooperation is productive, however the welfare gains diminish as the degree of capital mobility decreases.

(v) Increase in labour mobility cost: The last robustness experiment studies the effects of an increase in the adjustment cost parameter associated with working abroad, j. In the same line as before (increase in capital mobility cost), this experiment confirms the positive correlation between labour mobility and tax competition and identifies policy coordination as a mechanism that neutralizes the distortions caused by the growing mobility of labour flows.

At this point we need to underline that the symmetric cooperative solutions (both under commitment and non-commitment) are insensitive to the degree of labour mobility (see *Table 7.10*). This is by construction in our model since we have assumed that the world social planner internalizes the factor mobility costs and hence, all the effects associated with them (e.g. a decrease in the labour mobility cost leads to tax competition for labour factors). As a consequence, the SCE solutions are equivalent to those obtained in the closed-economy version of the model, an implication which renders our cooperative results rather trivial. Therefore, in what comes next, we focus on the more insightful SNE solutions.

Table 7.10 Robustness of labour mobility cost j

	Commitment						**Non-commitment**					
	Nash			**Coop**			**Nash**			**Coop**		
j	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2	τ_2^k	τ_2^l	g_2
0.30	0.022	0.069	0.001	0.225	0.322	0.036	0.628	0.037	0.034	0.669	0.000	0.032
*2.00	0.066	0.215	0.017	0.225	0.322	0.036	0.523	0.138	0.038	0.669	0.000	0.032
10.00	0.093	0.296	0.025	0.225	0.322	0.036	0.437	0.226	0.041	0.669	0.000	0.032
100.00	0.102	0.321	0.028	0.225	0.322	0.036	0.403	0.262	0.042	0.669	0.000	0.032

	output			**welfare**			**output**			**welfare**		
j	**Nash**	**Coop**	%	**Nash**	**Coop**	%	**Nash**	**Coop**	%	**Nash**	**Coop**	%
0.30	0.463	0.465	0.350	-2.237	-1.999	10.656	0.431	0.424	-1.417	-2.041	-2.053	-0.568
*2.00	0.466	0.465	-0.155	-2.024	-1.999	1.240	0.444	0.424	-4.500	-2.019	-2.053	-1.674
10.00	0.467	0.465	-0.424	-2.006	-1.999	0.329	0.454	0.424	-6.439	-2.008	-2.053	-2.231
100.00	0.467	0.465	-0.492	-2.003	-1.999	0.195	0.457	0.424	-7.056	-2.005	-2.053	-2.374

Regarding the commitment-type solution, we report that a higher degree of labour mobility is compatible with a lower tax burden on both factors of production and particularly on capital. For example, in the extreme case of perfect factor mobility, capital and labour taxes are equal to 2% and 7% respectively, whereas their cooperative counterparts are noticeably higher at 23% and 32%. As expected, with capital being able to move flawlessly across borders (so that the race-to-the-bottom result is in its fiercest form), a rise in the labour cost leads to a correspondingly higher increase in the labour tax (from 7% to 22%) relative to the capital tax (from 2% to 7%), a pattern which is preserved in all our experiments. In addition, if labour mobility costs are too high, so that the labour market is practically closed, the labour tax rate coincides with the cooperative one (32%), whereas the capital tax is roughly equal to 10%. Hence, the message here is that the international mobility of labour not only triggers tax competition for labour, but also intensifies the race-to-the-bottom result (on capital tax rates) caused by capital mobility.

In the non-commitment solution instead, the SNE converges to the SCE only if labour is perfectly mobile. In that case, the Fischer result (an inherent property of time-consistent policies) is amplified by a fierce tax competition for labour factors, so that labour tax rates are zero and capital tax rates are excessively high. However, this effect gets milder if one introduces barriers to labour mobility. In particular, a relatively low labour cost ($j = 0.3$) implies a 4pp rise in the labour tax rate (from 0% to 4%), whereas, in contrast to the commitment solution, the capital tax rate registers an equivalent 4pp drop (from 67% to 63%). In the extreme case of a closed labour market (huge labour transaction costs), the capital tax declines sharply by 23pp (from 63% to 40%) in exchange however of a 22pp rise in the labour tax (from 4% to 26%). Therefore, tax competition for labour factors (as implied by the SNE) operates as a mechanism that offsets the consequences of time-consistent policy, by giving rise to a dynamic policy effect; as labour mobility cost rises, the policymakers are more willing to substitute higher labour tax rates for lower capital tax rates.

Regarding the implications of those policies for the lifetime discounted output, we find that cooperation is systematically counter-productive in both solutions, yet with output losses (vis-a-vis Nash) that are decreasing to the degree of labour mobility. In terms of lifetime discounted utility, the more mobile is the labour factor, the higher are the gains from cooperation under commitment, with the difference being more acute in the case of perfect labour mobility (11% more welfare relative to the Nash solution). Finally, cooperation under lack of commitment is once again inferior to non-cooperation, despite that the welfare losses decrease with labour mobility.

Chapter 8

Numerical solutions for non-symmetric economies

In what follows we study asymmetric economies. Economies can differ in many ways but some differences are considered to be more crucial. Here, following the literature (*Chapter 2*), we will focus on cross-country asymmetries related to differences in TFP, initial public debt and product market competition. It is widely recognized that it is differences in these fundamentals[1] that in turn shape/cause differences in macroeconomic outcomes and performance like GDP, growth, fiscal deficits, current accounts, inflation, etc. Building on the evidence presented in *Part A, Chapter 6*, we will incorporate these asymmetries into our model and resolve for Nash and cooperative equilibria in national fiscal policies.

8.1 Modelling cross-country asymmetries

In what follows, we will solve for optimal fiscal policy (Nash and cooperative) in non-symmetric equilibria. Regarding the kind of asymmetries, following the evidence provided above (*Chapter 5*), we will focus on three types of cross-country asymmetries: First, we will assume that countries differ in their total factor productivities (TFP). Second, we will assume that countries differ in their initial public debt-to-GDP burdens. Third, we will assume that countries differ in product market competition. We will study one asymmetry at a time so as to be able to understand how each one of them works.

In terms of modeling, we follow the same approach as in *Part A*. The first two types of asymmetry are straightforward to be added to the model, since total factor productivity and initial debt are respectively a parameter and an initial condition only, so they can be

[1] *see Acemoglu 2009, Chapter 4[1] and many others.*

added easily; of course, now we have to solve for non-symmetric equilibria, which makes the dimensionality of the system considerably bigger as explained in *Subsections 6.5.1* and *6.6.1* above, but this does not add any complexity to the model itself. On the other hand, allowing for imperfect competition necessitates non-trivial modelling extensions which are presented in detail in *Appendix B.4.1* respectively. Here, in the main text, we just report that, in order to allow for imperfect competition we will the well-known *Dixit-Stiglitz[16] model of imperfectly substitutable inputs that result in market power.*[2]

8.2 Flexible and rigid cooperation

Concerning the cooperative framework, we will further distinguish between flexible and rigid international unions as in *Alesina et al. 2005[2]*. In a flexible union, the planner chooses cooperatively country-specific policies. On the other hand, in a rigid union, the planner chooses cooperatively a single policy meaning a *"one-size-fits-all"* policy, which, although its optimally chosen as in the case of flexible integration, applies to all countries (examples include tax harmonization, a common tariff policy, a single monetary policy, etc). In our model, in the case of a rigid union, the planner solves the same problem as in the case of flexible cooperation, but, instead of choosing a different tax rate for each economy ($\tau^d_{k,2}, \tau^f_{k,2}, \tau^d_{l,2}, \tau^f_{l,2}$), it chooses union-wide tax rates (τ^k_2, τ^l_2) that apply to both countries. Typically, flexible cooperation is expected to more efficient, but rigid cooperation is easier to implement politically (see e.g. *Alesina et al. 2005*). Therefore, in what follows, we will solve for three types of asymmetric equilibria: (i) non-cooperative Nash (ii) cooperative policies in a flexible union (iii) cooperative policies in a rigid union. The details are presented in *Appendix B.4.2*.

8.3 Numerical solutions for non-symmetric equilibria and gains from cooperation

8.3.1 Asymmetries in TFP

We start with cross-country differences in TFP, where, as is the case in the data, the periphery is assumed to be less productive than the core (we set in particular, $A^{core} = 1 > A^{per} = 0.7$). In *Tables 8.1* and *8.2* we present the solution for the optimally chosen fiscal policy instruments,

[2] *There are numerous applications of this popular model (see e.g. Benassy et al. (1996)[8]). For applications to the EU, see Eggertsson et al. (2014)[19] and Koliousi et al. (2018)[31].*

the lifetime discounted level of output and welfare, and also, the gains from cooperation in non-symmetric equilibria with and without policy commitment.[3]

We focus first on the commitment-type solution presented in *Table 8.1.* As can be seen both the capital under-taxation and the race-to-the-bottom results, previously addressed in the SNE, are also present in the non-symmetric Nash equilibrium (NSNE), in contrast to the non-symmetric cooperative equilibrium (NSCE) in which the race-to-the-bottom effect is away by construction. Recall that the problem of undertaxation of future capital is worse in the non-cooperative solution because of the "race-to-the-bottom" result that works in the same direction with the Chamley-Judd result (see *Section 7.3* above). Here in addition, both factors of production are subject to tax competition, since they are both mobile internationally, which in turn implies that both tax rates will be low relative to the case without international competition for mobile tax bases. Therefore, the celebrated race-to-the-bottom result is milder, as compared to a model with capital mobility only (see e.g. *Part A*, *Ch. 3-4*), because policymakers are forced to set higher tax rates on capital, in order to offset the distortions caused by the relatively low tax rates on labour.

Table 8.1 Optimal policy and gains from cooperation when TFP, A, is lower in the periphery, commitment

Optimal policy						
	Nash		**Flex**		**Rigid**	
τ_2^k	0.09	0.03*	0.27	0.15*	0.32	
τ_2^l	0.25	0.17*	0.34	0.27*	0.26	
g_2	0.03	0.01*	0.05	0.02*	0.06	0.01*
y	0.51	0.33*	0.49	0.35*	0.53	0.30*
W	-1.99	-2.24*	-1.99	-2.20*	-1.98	-2.25*

Gains from cooperation %				
	Flex vs Nash		**Rig Vs Nash**	
y	-5.09	6.30*	2.68	-6.97*
W	-0.11	1.97*	0.70	-0.32*

*The parameter associated with TFP in the periphery, A^{per}, is set at 0.8. * denotes macroeconomic outcomes in the periphery.*

As in *Part A* (*Subsection 5.4.1*), not only the tax rates in the NSCE are higher than in the NSNE, but also, due to the assumed differences in TFP, their size differs substantially between the two countries. The Nash capital tax rates (9% in the core and 3% in the periphery) are considerably lower as compared to those chosen under flexible cooperation (27% in the core and 15% in the periphery), while the policymaker of a rigid union chooses to set the single tax rate (32%) closer to that needed by the high-productivity country. Furthermore, as a consequence of capital undertaxation, the inelastic factor (labor) bears a disproportionally high amount of the tax burden compared to the elastic factor (capital), a problem which

[3] *See Tables B.16 and B.17 in Appendix B.4.3 for a detailed presentation of the optimal solution when countries differ in their total factor productivities (TFP).*

is mostly observed in the NSNE and is getting worse with the degree of capital mobility. Despite that this effect is partially offset by the growing mobility of labour flows, the labour tax rates in the non-cooperative regime remain 15pp higher than the capital tax rates (25% in the core and 17% in the periphery), a difference which, as we discussed in *Section 7.6*, can get even wider if one raises the labour mobility cost. Under flexible cooperation however, the labour tax rates are only 7pp (34%) and 12pp (27%) higher than their capital counterparts in the core and the periphery respectively, while the union-wide labour tax is 6pp lower (26%).

Table 8.2 Optimal policy and gains from cooperation when TFP, A, is lower in the periphery, non-commitment

	Optimal policy					
	Nash		**Flex**		**Rigid**	
τ_2^k	0.68	0.63*	0.80	0.69*	0.61	
τ_2^l	-0.07	0.14*	-0.10	-0.04*	0.01	
g_2	0.04	0.01*	0.03	0.02*	0.05	0.01*
y	0.48	0.29*	0.41	0.32*	0.48	0.30*
W	-2.04	-2.29*	-2.11	-2.25*	-2.02	-2.26*

	Gains from cooperation %			
	Flex vs Nash		**Rig Vs Nash**	
y	-12.91	11.43*	1.08	4.21*
W	-3.49	1.54*	0.88	1.00*

*The parameter associated with TFP in the periphery, A^{per}, is set at 0.8. * denotes macroeconomic outcomes in the periphery.*

On the contrary, the excessive tax burden on capital, as implied by the non-commitment solution (see *Table 8.2*), is followed by a relatively low tax burden on labour in all cases studied, as in the celebrated *Fischer* result. However, this effect becomes weaker if both factors of production are mobile internationally and policymakers choose their policies non-cooperatively. Particularly, thanks to its wider tax base, the high-TFP country can afford a higher capital tax than the low-TFP country in the NSNE (68% in the core and 63% in the periphery), whereas, with tax competition being away by construction, the capital tax rates rise to 80% and 69% under flexible cooperation. Interestingly, the union-wide capital tax (61%) is close to the non-cooperative ones, implying that the time-consistent policymaker chooses a single tax rate that serves mainly the needs of the low-productivity country. Note also that, as discussed in *Chapter 7*, the time-consistent optimal capital taxes are higher than in the case with commitment, since now policy is chosen after private sector's saving and investment decisions have been made. This makes a model of international tax policy more realistic since time consistent optimal capital tax rates cease to be close to zero even without international tax cooperation. On the other hand, the problem of overtaxation of future capital is partially offset by considerable cuts in labour taxes. Although in the low-TFP periphery country the labour tax is equal to 14% as a counterweight to the low capital tax, the high-TFP core country is forced to grant a 7% subsidy to labour income to mitigate the negative effects of capital overtaxation. In the absence of tax competition for mobile factors, and particularly for labour, the problem of labour undertaxation becomes worse, as the subsidies can be as high as 10% in the core and 4% in the periphery under flexible cooperation, whereas a less distorting union-wide capital tax is accompanied by a slightly positive union-wide labour tax (1%).

Not surprisingly the less productive country enjoys lower lifetime discounted output and welfare levels than the productive country in both solutions (commitment and non-commitment) and in both regimes (non-cooperation and cooperation). Note however that cooperation is not necessarily the most productive strategy. In the commitment solution, the core country under flexible cooperation registers 5% less output and 0.1% less welfare than Nash, whereas under rigid cooperation enjoys gains of 2.7% and 0.7% respectively. On the contrary, the periphery country reaps gains from flexible cooperation (6.3% more output and 2% more welfare than Nash) and incurs losses from rigid cooperation (7% less output and 0.3% less welfare). It turns out that the flexible allocation of the tax burden between capital and labour mitigates the problems of under-investment and low-factor returns in the periphery, yet the union-wide policy mix fails to do so and hence, the country is more prone to unilateral policies. In the non-commitment solution, flexible cooperation hurts badly the output and welfare of the high-TFP economy (12% less output and 3.5% more welfare than Nash) and benefits those of the low-TFP economy (11% more output and 1.5% more welfare), while rigid cooperation is productive for both neighbours. It appears that the core country, for the sake of flexible cooperation, is forced to set a near-confiscating tax rate on capital and this is particularly harmful for its lifetime discounted output and utility. On the other hand, rigid cooperation is associated with a more balanced distribution of the tax burden between the two factors and this helps both economies. In sum, cooperation leads to non-trivial distributions implications across countries.

8.3.2 Asymmetries in inherited public debt

In this experiment we consider cross-country differences in inherited public debt. In particular, based on the empirical evidence presented in *Section 5.1*, we assume that the periphery bears a higher initial debt-to-GDP ratio than the core (we set $b_1^{core}/y_1 = 0.6$, $b_1^{per}/y_1 = 0.9$). Results are reported in *Tables 8.3* and *8.4* which present the optimally chosen fiscal policy, the corresponding macroeconomic outcomes and the gains from cooperation (in lifetime discounted output and utility) in non-symmetric equilibria with and without policy commitment.[4]

As usual we focus first on the commitment solution. As in the case of asymmetries in TFP, the "race-to-the-bottom" result that stems from international tax competition (present in a typical NSNE) intensifies the Chamley-Judd result (present in all commitment-type equilibria) and hence, the Nash capital tax rates are low in both countries. However, unlike *Part A* in which capital was the only mobile factor, here the assumed mobility of labour flows leads to unilateral cuts in labour taxes in both economies and thus, creates additional policy distortions in a non-cooperative environment. In an attempt to soothe these distortions, the policymakers are forced to increase the capital tax burden by imposing higher capital tax rates. Therefore, the international mobility of both capital and labour gives rise to tax competition for both factors, which in turn translates into a milder version of the celebrated race-to-the-bottom result. Notice however that despite the rise in capital taxes and regardless of the asymmetry level, the race-to-the-bottom result is so strong that not only the tax burden on capital remains low but also, the capital tax in the periphery (10%) is just 3pp higher than in the core. On the other hand, policy coordination (NSCE) alleviates the problem of tax competition and results in a more balanced allocation of the tax burden in both economies. Particularly, the country-specific capital tax rate is equal to 29% in the core and 27% in the periphery, while the union-wide capital tax is equal to 29% implying that the policymaker chooses a single tax rate closer to the fiscal needs of the high-debt country. In the same direction, the strong fiscal imbalances in the periphery barely affect labour taxation in all regimes, as the labour tax rate in the core is higher than in the periphery by only 1pp (22%) in the NSNE and by 2pp (37%) in the NSCE, while the rigid one is equal to 36%. Note that, in contrast to the previous experiment (asymmetries in TFP) in which the union-wide labour tax was lower than the capital one, here the burden of taxation falls heavier on labour even under rigid cooperation.

[4] *See Tables B.18 and B.19 in Appendix B.4.3 for a detailed presentation of the optimal solution when countries differ in their initial public debt-to-GDP burdens.*

Table 8.3 Optimal policy and gains from cooperation when initial public debt, b_1/y_1, is higher in the periphery, commitment

	Optimal policy						Gains from cooperation %				
	Nash		**Flex**		**Rigid**			**Flex vs Nash**		**Rig Vs Nash**	
τ_2^k	0.07	0.10*	0.29	0.27*	0.29						
τ_2^l	0.22	0.21*	0.37	0.35*	0.36		y	-4.42	4.48*	-1.24	1.04*
g_2	0.02	0.00*	0.04	0.03*	0.04	0.03*					
y	0.47	0.44*	0.45	0.46*	0.46	0.45*					
W	-2.02	-2.22*	-2.01	-2.00*	-2.00	-2.01*	W	0.39	9.94*	0.86	9.37*

*The parameter associated with inherited public debt in the periphery, b_1^{per}/y_1, is set at 0.9. * denotes macroeconomic outcomes in the periphery.*

On the contrary, the non-commitment solution typically comes with a near-confiscating tax rate on capital as an exchange for a relatively low tax rate on labour, as in *Fischer (1980)[20]*. Specifically, as we depart from the symmetric benchmark case, a rise in the periphery's public debt by 30pp induces a massive increase in the capital taxes under non-cooperation (by 20pp in both countries) and a less profound increase under flexible (by 7pp and 4pp, in the core and the periphery respectively) and under rigid cooperation (by 8pp). At this point we need to underline that the core country bears a higher capital tax burden than the periphery in both regimes (NSNE and NSCE) and also, the Nash capital taxes are higher (75% and 73%) than the cooperative ones (74% and 71%) in both countries, with the exception of the union-wide tax (75%) which is equal to the one imposed in the core in the NSNE. As compared to the case with commitment, the time-consistent optimal capital taxes are considerably higher, because now policy is chosen after private sector's saving and investment decisions have been made. In sharp contrast, the Nash labour tax rates differ substantially between the two countries. As the high-debt periphery economy increases the tax on labour income at 20%, the core economy grants a 6% subsidy to its own, whereas, the cooperative country-specific and the union-wide labour taxes vary between 0% and 2%. These developments are compatible with the structure of the time-consistent solution and its response to the type of asymmetry. Notice that a higher level of public debt in the periphery is associated with a higher capital tax rate not only in the periphery as one might expect, but also in the core, a result which holds in both the NSNE and the NSCE. This happens because tax competition for capital factors is by construction away in the non-commitment solution, so that both countries, and particularly the core, choose a high tax on capital and a low tax on labour (a typical Fischer result). Although such a rise seems reasonable in the high-debt country, it causes additional distortions to the core country with healthy public finances and hence, the latter proceeds to severe labour tax cuts in order to undo those distortions.

Therefore, tax competition for labour factors, as implied by the Nash solution, leads to a sharp decline in the labour tax in the core and a noticeable rise in the respective rate in the periphery, always relative to the symmetric case. A cooperative framework on the other hand allows for slightly positive and equivalent labour taxes in both countries.

Table 8.4 Optimal policy and gains from cooperation when initial public debt, b_1/y_1, is higher in the periphery, non-commitment

	Optimal policy							Gains from cooperation %				
	Nash		**Flex**		**Rigid**				**Flex vs Nash**		**Rig Vs Nash**	
τ_2^k	0.75	0.73*	0.74	0.71*	0.75							
τ_2^l	-0.06	0.19*	0.02	0.01*	0.00			y	-6.92	9.48*	-4.67	5.10*
g_2	0.04	0.02*	0.03	0.03*	0.03	0.03*						
y	0.43	0.39*	0.40	0.42*	0.41	0.40*						
W	-2.07	-2.10*	-2.08	-2.06*	-2.08	-2.08*		W	-0.70	1.73*	-0.41	0.62*

*The parameter associated with inherited public debt in the periphery, b_1^{per}/y_1, is set at 0.9. * denotes macroeconomic outcomes in the periphery.*

Regarding the implications of optimal policies on the macroeconomy, we report that despite the level of asymmetry, the changes in the levels of lifetime discounted output and welfare are trivial in both countries and in both solutions (commitment and non-commitment). The reason behind this development is that, by construction, an increase in the size of public debt does not necessarily reduce the size of the tax base, in contrast to the other forces of growth considered here.

If, instead, we focus on the percentage gains from cooperation, we draw more intuitive conclusions. Regarding the commitment solution, cooperation, both flexible and rigid, leads to lower levels of output in the core (-4% and -1%) and higher in the periphery (4.5% and 1%), as compared to non-cooperation. When the criterion is lifetime utility, no matter what is the type of cooperation (flexible or rigid), both countries reap gains from cooperation, yet the lion's share from those gains goes to the relatively disadvantaged economy. Specifically, under flexible cooperation the core economy enjoys 0.4% more welfare than Nash, while, the respective gains in the periphery amount to 10%. As similar results hold in the case of rigid cooperation, we presume that cooperation (both flexible and rigid, but especially the former) serves mainly the needs of the high-debt country. The intuition is that the low-debt country, for the sake of cooperation, is forced to set relatively high tax rates that are compatible with the fiscal needs of the high-debt country, and hence are helpful for both economies, but mostly for the indebted periphery neighbour. However, under lack of policy commitment, cooperation is productive only for periphery, as the country experiences notable output and welfare gains vis-a-vis Nash. Apparently the core country is forced to choose a cooperative policy mix that makes the Fischer result more acute and hence, causes serious distortions in its factor markets. It turns out that cooperation is very restrictive for a country with healthy public finances, as the latter would prefer a lower tax rate on capital and a higher tax rate on labour. Summing up, the policy differences between non-cooperative and cooperative strategies, as highlighted above, incur non-trivial implications on the macroeconomic environment of the two countries.

8.3.3 Asymmetries in product market competition

In the last experiment we focus on asymmetries that take the form of imperfect competition in product markets. Structural reforms that promote market competition, are considered, by both academics and policymakers, the key policy option for the economies in the periphery of Eurozone to regain competitiveness and boost output. *Eggertson et al. (2014)[19]* find that a permanent reduction in the price and wage markups by 10 percentage points in the periphery, may increase domestic output by 5.5%. However, in the absence of the appropriate monetary stimulus, ambitious reforms implemented at abnormal times (such as the Global Crisis of 2008) may be detrimental for the short-term growth prospects of vulnerable euro-area countries. In light of these arguments, we solve for optimal fiscal policy (Nash and cooperative) under the assumption of a non-competitive product market in the periphery and study its macroeconomic implications. The theoretical model is presented in *Appendix A.3.1*. *Tables 8.5 - 8.6* depict the optimally chosen fiscal policy instruments, the corresponding macroeconomic results and the gains from cooperation (in output and welfare terms) in non-symmetric equilibria with and without policy commitment.[5]

We start with the commitment-type solution. As we see in *Table 8.5*, tax competition for capital factors, as implied by the Nash solution, exacerbates the problem of capital undertaxation which is addressed in all commitment-type equilibria. Here, unlike *Part A*, the assumed mobility of labour flows leads to tax competition for labour factors as well, so that labour tax rates are also low relative to the case without international tax competition for mobile tax bases. In order to minimize the extra distortion caused by the competitive labour taxes (underprovision of the public good), the individual policymakers are forced to choose higher capital tax rates as compared to the case without labour mobility and therefore, the celebrated race-to-the-bottom result (see e.g. *Mendoza et al. (2005)[38]*) becomes weaker. Notwithstanding, the tax rates on capital are still considerably lower than those on labour in both countries. Particularly, the Nash capital tax rates are equal to 7% and 12% in the core and the periphery respectively, while, under flexible and rigid cooperation, they are equal to 25% in both countries. In addition, as the periphery experiences a narrower tax base in the second period (due to product market imperfections), the Nash labour tax rate (17%) is 6pp lower than the respective rate in the core (23%), a pattern which is also preserved under flexible cooperation (28% in the periphery and 34% in the core). Interestingly, the union-wide labour tax (30%) is in-between the country-specific ones (neither too high, nor too low), thanks to the relatively high union-wide capital tax.

[5] *See Tables B.20 and B.21 in Appendix B.4.3 for a detailed presentation of the optimal solution when countries differ in the product market competition.*

Table 8.5 Optimal policy and gains from cooperation when product market, ϕ, is non-competitive in the periphery, commitment

	Optimal policy							Gains from cooperation %			
	Nash		**Flex**		**Rigid**			**Flex vs Nash**		**Rig Vs Nash**	
τ_2^k	0.07	0.12*	0.25	0.25*	0.26						
τ_2^l	0.23	0.17*	0.34	0.28*	0.30		y	-2.98	2.89*	1.12	-1.90*
g_2	0.02	0.01*	0.04	0.03*	0.05	0.03*					
y	0.48	0.45*	0.47	0.46*	0.49	0.44*					
W	-2.01	-2.06*	-2.00	-2.02*	-1.99	-2.03*	W	0.48	2.04*	0.97	1.34*

*The parameter associated with product market competition in the periphery, ϕ^{per}, is set at 0.95. * denotes macroeconomic outcomes in the periphery.*

In the absence of policy commitment, the capital taxes are typically much higher than those on labour, which qualitatively is as in the celebrated Fischer result. As compared to the symmetric benchmark case, a non-competitive product market in the periphery leads to higher capital tax rates in all regimes and particularly in flexible cooperative policies. Specifically, as the capital tax burden rises by 10pp in both countries under non-cooperation (63% in the core and 61% in the periphery) and about 13pp under rigid cooperation, it goes even higher (18pp) under flexible cooperation (84% in the core and 82% in the periphery). In addition, as discussed above in the previous experiments (asymmetries in TFP and inherited public debt), the tax burden on capital is higher than in the case with commitment, since policy is chosen after private sector's saving and investment decisions have been made. Therefore, by assuming away the ability of governments to commit themselves to future policies, a model international tax policy becomes more realistic, since time consistent optimal capital tax rates cease to be close to zero. Meanwhile, the Nash labour tax rates decline to 2% in the core and 12% in the periphery, whereas the world social planner subsidizes 6% and 21% of the respective labour income under flexible cooperation and about 11% of labour income in both countries under rigid cooperation. Hence, this type of asymmetry behaves as an extra distortion that intensifies the Fischer result, so that the capital tax rates are driven to even higher values relative to the symmetric case. This happens because a non-competitive product market in the periphery widens the tax base in the core and narrows the one in the periphery, since capital relocates from the low factor return country to the one with high factor returns. In turn, the core is able to sustain higher capital taxes than the periphery, which, nevertheless, also raises its own capital tax in an attempt to protect the remaining tax revenues. Note that this effect gets fiercer under cooperation and milder under non-cooperation. The reason behind this development is that cooperation fully undoes the only distortion (tax competition) that is responsible for lower capital and higher labour tax rates. Recall that, in our model, the world social planner internalizes all mobility frictions, and especially the transactions costs associated with working abroad which, in a non-cooperative regime, are held responsible for positive labour and lower capital taxes as compared to cooperation. Instead, the other two remaining imperfections, namely lack of commitment and imperfect product market in the periphery, are both pushing the capital and labour taxes on the opposite direction and therefore, result in a much higher tax burden on capital relative to labour.

The policies presented above induce trivial implications for the levels of lifetime discounted output and welfare, in both countries and in both solutions (commitment and non-commitment). Thus, in what follows, it is more interesting to focus on the percentage gains from cooperation.

Regarding the commitment-type solution, flexible cooperation leads to lower levels of output in the core (-3%) and higher in the periphery (3%), while rigid cooperation is productive in the core (1%) and non-productive in the periphery (-2%), as compared to the Nash solution. In terms of lifetime discounted utility, cooperation, both flexible and rigid, is productive for both countries, yet the lion's share from those gains goes to the relatively disadvantaged economy. Specifically, the competitive country (core) enjoys 0.5% and 1% more welfare under flexible and under rigid cooperation respectively, whereas the gains of its non-competitive neighbour amount to 2% and 1.3%. The intuition is that non-cooperation leads to undertaxation of both factors of production and this is particularly harmful for both countries, but mostly for a non-competitive periphery country which already struggles with the problems of underinvestment and low factor returns. Instead, as the cooperative solutions indicate, both countries would be better off with higher tax rates.

Table 8.6 Optimal policy and gains from cooperation when product market, ϕ, is non-competitive in the periphery, non-commitment

	Optimal policy							Gains from cooperation %			
	Nash		**Flex**		**Rigid**			**Flex vs Nash**		**Rig Vs Nash**	
τ_2^k	0.63	0.61*	0.84	0.82*	0.80						
τ_2^l	0.02	0.12*	-0.06	-0.21*	-0.11		y	-15.96	-1.64*	-10.17	-4.30*
g_2	0.04	0.03*	0.02	0.03*	0.03	0.02*					
y	0.45	0.41*	0.38	0.40*	0.41	0.39*					
W	-2.03	-2.06*	-2.14	-2.13*	-2.10	-2.12*	W	-5.46	-3.23*	-3.61	-2.93*

*The parameter associated with product market competition in the periphery, ϕ^{per}, is set at 0.95. * denotes macroeconomic outcomes in the periphery.*

In sharp contrast, the non-commitment solution reveals that cooperation is non-productive for both countries, and especially for the core, as they both experience severe output and welfare losses relative to the Nash solution. Actually, without commitment the standard results are reversed, meaning that cooperation proves to be counter-productive at least for a large range of parameter values. This happens mainly because, without commitment, capital tax rates are too high in general, so that tax competition works to mitigate this distortion. It turns out that the cooperative policy mix is too restrictive for a country with healthy public finances; the latter would prefer lower capital and higher labour tax rates to mitigate the distortions in its factors markets caused by the unnecessary overtaxation of its end-of-period capital. Summing up, the policy differences between non-cooperative and cooperative strategies, as highlighted above, incur non-trivial implications on the macroeconomic environment of the two countries.

8.4 Discussion of results

In this section we studied asymmetries in economic fundamentals that are widely recognized as the main driving forces behind differences in macroeconomic outcomes and performance like in GDP, growth, fiscal deficits, current accounts, inflation, etc. We solved for optimal fiscal policy (Nash and cooperative) in non-symmetric equilibria, that were characterized by three types of cross-country differences: First, we assumed that countries differ in their total factor productivities (TFP). Second, we assumed that countries differ in their inherited public debt-to-GDP ratios. Third, we assumed that countries differ in product market competition. We also distinguished flexible and rigid (one-size-fits-all) cooperation following *Alesina et al. (2005)*.

The model differs from the model used in *Part A*. Specifically, we solved for equilibria without policy commitment which means that policy is not chosen once-and-for-all at the start of the time horizon. Here, instead, policy-makers are free to re-optimize in each time period which practically means that second-period tax policy is chosen after private agents have made their saving decisions in the first period. This guarantees that optimal policy is time consistent. But we also solved for equilibria with commitment, as in the first Part, for reasons of direct comparability.

A main result is that, once we drop the symmetry assumption and allow for cross-country differences, cooperation is not always the most productive strategy. Moreover, without policy commitment the standard results are reversed, meaning that cooperation proves to be counter-productive at least for a large range of parameter values. This happens mainly because, without commitment, capital tax rates are too high in general, so that tax competition works to mitigate this distortion.

In the case of asymmetries in TFP, the commitment solution implies that cooperation (both flexible and rigid) leads to a higher level of aggregate welfare, in exchange, however, for a lower level of aggregate output relative to the Nash solution. Furthermore, at the individual level, a cooperative union with flexible policies is productive for the periphery and counterproductive for the core (both in terms of output and welfare), while the two countries switch places under rigid cooperation. The mechanism behind these results is the chosen tax policy[6]; firstly, the cooperative tax burden is distributed proportionally between the two

[6] *Both the capital under-taxation and the race-to-the-bottom results are present in the NSNE, in contrast to the NSCE in which the race-to-the-bottom effect is away by construction. Unlike Part A in which capital was the only mobile factor, here, both factors are mobile internationally and hence subject to tax competition, so that both tax rates are low relative to the case without factor mobility. In turn, the policymakers are forced to choose higher capital taxes as compared to Part A, in order to offset the distortions caused by the relatively low labour taxes. Nevertheless, the non-cooperative tax burden on capital is still considerably lower than the respective burden on labour, a problem which is partially resolved in the cooperative solution.*

factors, unlike the NSNE in which the tax burden falls heavier on labour, and secondly, the high-TFP core country bears a much higher tax burden than the periphery under flexible cooperation. Although these developments may be helpful for a low-TFP periphery country which already struggles with the problems of under-investment and low-factor returns (due to its low productivity), they generate additional distortions in the economy of its productive neighbour. The latter would prefer lower labour taxes as it apparent from the case of rigid cooperation.

When it comes to the non-commitment solution, the aggregate levels of output and welfare are higher under rigid and lower under flexible cooperation. Particularly, the losses in the high-TFP core economy outrun the gains in the periphery and hence, flexible cooperation is counterproductive for the world economy as well. On the other hand, both countries enjoy gains from rigid cooperation, yet the lion's share from those gains goes to the low-TFP periphery country. The intuition is that, in contrast to the Nash solution in which labour taxes are positive, the respective rates under flexible cooperation turn into huge subsidies in both countries and this is particularly useful for a low-TFP periphery country with inherent disadvantages (under-investment and low factor returns)[7]. However, since these subsidies are typically financed by higher capital tax rates, they generate additional distortions in the factor markets of the high-TFP core economy, as the country is forced, for the sake of cooperation, to bear a higher than expected capital tax burden. Instead, the core would prefer a relatively balanced distribution of the tax burden, as implied by rigid cooperation.

In the case of asymmetries in inherited public debt, the commitment solution suggests that in terms of aggregate welfare both types of cooperation are productive for the world economy, yet, they are inferior to the Nash solution in terms of aggregate output. A closer look at the individual results reveals that, as in the case of asymmetries in TFP, the biggest share of the welfare gains goes to the high-debt periphery economy. Furthermore, when the criterion is lifetime discounted output, the loss from cooperation in the core is so big that cooperation is counterproductive for the world economy as well. It turns out that policy coordination (both flexible and rigid, but especially the former) serves mainly the needs of the high-debt country. The intuition is that the low-debt core country, for the sake of

[7] *The excessive tax burden on capital is followed by a relatively low tax burden on labour in all cases studied, as in Fischer (1980). Nevertheless, this effect becomes weaker if both factors of production are mobile internationally and policymakers choose their policies atomistically. The high-TFP core country can afford a higher Nash capital tax than its low-TFP neighbour, whereas, without tax competition, the cooperative country-specific capital taxes rise sharply in both countries. Interestingly, the union-wide capital tax is close to the non-cooperative ones, which is exactly what the periphery country needs. Despite that the Nash labour tax remains high in the periphery (as a counterweight to its low capital tax), the high-TFP core country is forced to subsidize its labour income in order to mitigate the negative effects of capital overtaxation. On the other hand, flexible cooperation is associated with considerable labour subsidies in both countries, while a rigid union is able to sustain a slightly positive union-wide labour tax.*

cooperation, is forced to set relatively high tax rates[8] that serve mostly the fiscal needs of the high-debt country. Eventually, this is helpful for both economies, because relatively high tax rates is also what the core country needs (due to its wider tax base), so there is no conflict of interests as in the case with different TFPs.

Although under lack of policy commitment cooperation (both flexible and rigid) is productive in terms of aggregate welfare, thanks to the gains enjoyed by the high-debt periphery country, rigid cooperation leads to a lower level of total output vis-a-vis Nash. Specifically, in the case of flexible cooperation, the low-debt core country incurs important welfare and output losses, which are nevertheless offset by the gains in the periphery. However, in rigid cooperative policies the output loss in the core exceeds the gains in the periphery and hence, rigid cooperation is counterproductive internationally. This happens because the core country is forced to choose a cooperative policy mix[9] that makes the Fischer result more acute and hence, causes serious distortions in its factor markets. It turns out that cooperation serves the needs of the high-debt periphery country, yet it can be very restrictive for a country with healthy public finances, as the latter would prefer a lower tax rate on capital and a higher tax rate on labour.

In the case of asymmetries in product market competition, the commitment solution indicates that cooperation (flexible and rigid) is once again productive in terms of aggregate welfare and counter-productive in terms of aggregate output, as compared to non-cooperation. Particularly, both countries enjoy welfare benefits from cooperation, with the lion's share from those gains going to the relatively disadvantaged economy. Moreover, the output losses in the core and the periphery, under flexible and rigid cooperation respectively, render the cooperative regimes counterproductive (in terms of lifetime discounted output) for the world economy. The intuition behind these developments is that non-cooperation leads to undertaxation[10] of both factors of production and this hurts the welfare of both countries.

[8] *The "race-to-the-bottom" result intensifies the Chamley-Judd result and hence, the Nash capital tax rates are low in both countries. The assumed imperfect mobility of labour flows leads to tax competition for labour factors as well, and hence, tax competition for capital is milder as compared to the model used in Part A. Policy coordination on the other hand, alleviates the problem of tax competition and results in a more balanced allocation of the tax burden in both economies. In contrast to the previous experiment (asymmetries in TFP) in which the union-wide labour tax was lower than the capital one, here the burden of taxation falls heavier on labour even in the case of rigid cooperation.*

[9] *The time-consistent capital tax is near-confiscating as an exchange for a relatively low labour tax. As compared to the symmetric case, a rise in the periphery's public debt induces a massive increase in Nash capital taxes and a less profound increase in the cooperative ones in both countries. Furthermore, the capital tax is higher in the core in all cases studied and also, the Nash capital taxes are higher than the cooperative ones in both countries. Regarding labour taxation, non-cooperation incurs a sizeable tax on labour income in the periphery and a subsidy to the core, while at the same time, the cooperative country-specific and the union-wide labour taxes are marginally positive in both countries.*

[10] *As in the previous experiments, tax competition for capital exacerbates the problem of capital undertaxation which is addressed in all commitment-type equilibria. Additionally, the assumed mobility of labour flows leads*

The problem is more acute in the non-competitive periphery country which already struggles with the problems of underinvestment and low factor returns. Instead, as it is evident from the cooperative solutions, both countries would be better off with higher tax rates.

In the absence of policy commitment, cooperation (both flexible and rigid) is counterproductive for the world economy, as it yields much lower levels of aggregate output and welfare relative to non-cooperation. Specifically, at the individual level, both countries incur important losses from cooperation, yet the economy of the core country suffers a massive drop in its lifetime discounted levels of output and utility. It turns out that the cooperative policy mix[11] is too restrictive for both countries, but mostly for the core country with the competitive product market; the latter would prefer lower capital and higher labour tax rates to mitigate the distortions in its factors markets caused by the unnecessary overtaxation of its end-of-period capital. This happens mainly because, without commitment, capital tax rates are too high in general, so that tax competition works to mitigate this distortion.

to tax competition for labour factors as well, so that labour tax rates are also low. In order to minimize the extra distortion, the policymakers are forced to choose higher capital tax rates and therefore, the celebrated race-to-the-bottom result becomes weaker. Furthermore, the labour tax rates are lower in the periphery both in the NSNE and the flexible NSCE, while, thanks to the relatively high union-wide capital tax, the single union-wide labour tax is moderate relative to the country-specific ones.

[11] *The time-consistent capital tax rates are higher relative to the symmetric case in all regimes and particularly under flexible cooperation. Meanwhile, the Nash labour tax rates decline sharply in the core and slightly in the periphery, whereas labour income in both countries receives huge subsidies under cooperation. Therefore, the asymmetry in product market competition intensifies the Fischer result, so that the capital tax rates are driven to even higher values relative to the symmetric case, a result which is more acute under cooperation. The intuition is that cooperation fully undoes the only distortion (tax competition) that leads to lower capital tax rates.*

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Appendix A

Part A: Optimal policy with commitment

A.1 Optimal policy with commitment

A.1.1 Non-cooperative policies (Nash): Definition

The domestic government maximises

$$U^d\left(c_t^d, l_t^d, g_t^d\right) = \mu_1 \log c_1^d + \mu_2 \log(1 - l_1^d) + \mu_3 \log g_1^d$$
$$+ \beta\left(\mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d) + \mu_3 \log g_2^d\right)$$

with respect to its independently set policy instruments $g_2^d, \tau_{l,1}^d, \tau_{l,2}^d$ and subject to the equations summarizing the WDCE (3.15-30). We form the Lagrangian function of the domestic government as follows

$$L = \mu_1 \log c_1^d + \mu_2 \log(1 - l_1^d) + \mu_3 \log g_1^d + \beta\left(\mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d) + \mu_3 \log g_2^d\right)$$

$$+\lambda_1\left\{c_1^d + k_2^d - (1-\delta)k_1^d + f_2^d + g_1^d - y_1^d\right\}$$

$$+\lambda_2\left\{c_2^d - (1-\delta)k_2^d + g_2^d - y_2^d + (1-\tau_{k,2}^d)r_2^d f_2^f - \left(1 + (1-\tau_{k,2}^f)r_2^f - \delta\right) f_2^d + m\frac{(f_2^d)^2}{2}\right\}$$

$$+\lambda_3\left\{\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d - \frac{\mu_2}{1-l_1^d}\right\}$$

$$+\lambda_4\left\{\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d - \frac{\mu_2}{1-l_2^d}\right\}$$

$$+\lambda_5\left\{\frac{c_2^d}{c_1^d} - \beta\left(1 + (1-\tau_{k,2}^d)r_2^d - \delta\right)\right\}$$

$$+\lambda_6\left\{\frac{c_2^d}{c_1^d}-\beta\left(1+(1-\tau_{k,2}^f)r_2^f-\delta-mf_2^d\right)\right\}$$

$$+\lambda_7\left\{g_1^d+\left(1+(1-\tau_{k,1}^d)r_1^d-\delta\right)b_1^d-\tau_{k,1}^d r_1^d k_1^d-\tau_{l,1}^d w_1^d l_1^d-b_2^d\right\}$$

$$+\lambda_8\left\{g_2^d+\left(1+(1-\tau_{k,2}^d)r_2^d-\delta\right)b_2^d-\tau_{k,2}^d\left(r_2^d(k_2^d+f_2^f)\right)-\tau_{l,2}^d w_2^d l_2^d\right\}$$

$$+\lambda_9\left\{c_1^f+k_2^f-(1-\delta)k_1^f+f_2^f+g_1^f-y_1^f\right\}$$

$$+\lambda_{10}\left\{c_2^f-(1-\delta)k_2^f+g_2^f-y_2^f+(1-\tau_{k,2}^f)r_2^f f_2^d-\left(1+(1-\tau_{k,2}^d)r_2^d-\delta\right)f_2^f+m\frac{(f_2^f)^2}{2}\right\}$$

$$+\lambda_{11}\left\{\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f-\frac{\mu_2}{1-l_1^f}\right\}$$

$$+\lambda_{12}\left\{\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f-\frac{\mu_2}{1-l_2^f}\right\}$$

$$+\lambda_{13}\left\{\frac{c_2^f}{c_1^f}-\beta\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)\right\}$$

$$+\lambda_{14}\left\{\frac{c_2^f}{c_1^f}-\beta\left(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\right)\right\}$$

$$+\lambda_{15}\left\{g_1^f+\left(1+(1-\tau_{k,1}^f)r_1^f-\delta\right)b_1^f-\tau_{k,1}^f r_1^f k_1^f-\tau_{l,1}^f w_1^f l_1^f-b_2^f\right\}$$

$$+\lambda_{16}\left\{g_2^f+\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)b_2^f-\tau_{k,2}^f\left(r_2^f(k_2^f+f_2^d)\right)-\tau_{l,2}^f w_2^f l_2^f\right\}$$

We solve the problem in its dual form, since its complexity does not allow for a primal form specification. This means that policymakers, in addition to the independently set policy instruments, re-choose all the allocations and the residually determined instruments of the WDCE system.

The solution to this dual optimization problem yields a system of 35 equations in 35 endogenous variables. Specifically, counting equations, we have the 16 constraints/equations of the WDCE, the optimality conditions for the 16 variables being determined by the WDCE system, plus the three optimality conditions for the independent policy instruments. Counting endogenous variables, we have the 16 variables of the WDCE system, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, l_1^f, l_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, \tau_{k,2}^d, \tau_{k,2}^f$, plus the 16 dynamic Lagrangean multipliers corresponding to the 16 equations of the WDCE system, plus the three optimally chosen instruments, $\tau_{l,1}^d, \tau_{l,2}^d$ and g_2^d. This is given the independent policy choices of the other country, $\tau_{l,1}^f, \tau_{l,2}^f$ and g_2^f, and the assumed exogenous policy variables, $\tau_{k,1}^d, \tau_{k,1}^f, g_1^d$ and g_1^f. The foreign country solves an analogous problem and gives a similar set of 35 equations in 35 unknowns. That is, in equilibrium, we will end up with 54 equations in 54 variables (namely, 35+35-16) since the 16 equations of the WDCE are common to both countries and the same applies to the 16 variables that are endogenous at WDCE level.

A.1.2 Cooperative policies: Definition

When policies are chosen optimally and jointly by a fictional world social planner, the latter maximises a weighted average of households' welfare in each country with equal weights given to each one of them. Thus, the objective is now:

$$\max W^{coop} = \gamma U^d + (1-\gamma)U^f$$

subject to the equations summarizing the WDCE (3.15-30). We form the Lagrangian function of the world government as follows

$$L = W^{coop} +$$

$$+\lambda_1\left\{c_1^d + k_2^d - (1-\delta)k_1^d + f_2^d + g_1^d - y_1^d\right\}$$

$$+\lambda_2\left\{c_2^d - (1-\delta)k_2^d + g_2^d - y_2^d + (1-\tau_{k,2}^d)r_2^d f_2^f - \left(1+(1-\tau_{k,2}^f)r_2^f - \delta\right) f_2^d + m\frac{(f_2^d)^2}{2}\right\}$$

$$+\lambda_3\left\{\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d - \frac{\mu_2}{1-l_1^d}\right\}$$

$$+\lambda_4\left\{\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d - \frac{\mu_2}{1-l_2^d}\right\}$$

$$+\lambda_5\left\{\frac{c_2^d}{c_1^d} - \beta\left(1+(1-\tau_{k,2}^d)r_2^d - \delta\right)\right\}$$

$$+\lambda_6\left\{\frac{c_2^d}{c_1^d} - \beta\left(1+(1-\tau_{k,2}^f)r_2^f - \delta - m f_2^d\right)\right\}$$

$$+\lambda_7\left\{g_1^d + \left(1+(1-\tau_{k,1}^d)r_1^d - \delta\right) b_1^d - \tau_{k,1}^d r_1^d k_1^d - \tau_{l,1}^d w_1^d l_1^d - b_2^d\right\}$$

$$+\lambda_8\left\{g_2^d + \left(1+(1-\tau_{k,2}^d)r_2^d - \delta\right) b_2^d - \tau_{k,2}^d\left(r_2^d(k_2^d + f_2^f)\right) - \tau_{l,2}^d w_2^d l_2^d\right\}$$

$$+\lambda_9\left\{c_1^f + k_2^f - (1-\delta)k_1^f + f_2^f + g_1^f - y_1^f\right\}$$

$$+\lambda_{10}\left\{c_2^f - (1-\delta)k_2^f + g_2^f - y_2^f + (1-\tau_{k,2}^f)r_2^f f_2^d - \left(1+(1-\tau_{k,2}^d)r_2^d - \delta\right) f_2^f + m\frac{(f_2^f)^2}{2}\right\}$$

$$+\lambda_{11}\left\{\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f-\frac{\mu_2}{1-l_1^f}\right\}$$

$$+\lambda_{12}\left\{\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f-\frac{\mu_2}{1-l_2^f}\right\}$$

$$+\lambda_{13}\left\{\frac{c_2^f}{c_1^f}-\beta\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)\right\}$$

$$+\lambda_{14}\left\{\frac{c_2^f}{c_1^f}-\beta\left(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\right)\right\}$$

$$+\lambda_{15}\left\{g_1^f+\left(1+(1-\tau_{k,1}^f)r_1^f-\delta\right)b_1^f-\tau_{k,1}^f r_1^f k_1^f-\tau_{l,1}^f w_1^f l_1^f-b_2^f\right\}$$

$$+\lambda_{16}\left\{g_2^f+\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)b_2^f-\tau_{k,2}^f\left(r_2^f(k_2^f+f_2^d)\right)-\tau_{l,2}^f w_2^f l_2^f\right\}$$

The maximization is with respect to the independent policy instruments in the two countries, $\tau_{l,1}^d, \tau_{l,2}^d, g_2^d, \tau_{l,1}^f, \tau_{l,2}^f$ and g_2^f. We will thus have a system of 38 equations in 38 unknowns. Counting equations and endogenous variables, we have the 16 constraints/equations corresponding to the 16 variables of the WDCE system, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, l_1^f, l_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d$, $b_2^f, \tau_{k,2}^d, \tau_{k,2}^f$, plus the 16 dynamic Lagrangean multipliers corresponding to the 16 equations of the WDCE system, plus the 6 optimality conditions for the 6 independent policy instruments, $\tau_{l,1}^d, \tau_{l,2}^d, g_2^d, \tau_{l,1}^f, \tau_{l,2}^f$ and g_2^f. This is given the the assumed exogenous policy instruments $\tau_{k,1}^d, \tau_{k,1}^f, g_1^d$ and g_1^f.

A.2 Numerical solutions for symmetric economies

A.2.1 Symmetric WDCE (for any feasible policy)

Table A.1 World decentralized competitive equilibrium (for any feasible policy)

Allocations				**Shares**				**Resid policy**		**Net returns**	
c_1	0.2292	c_2	0.1263	c_1/y_1	0.6750	c_2/y_2	0.9000	τ_2^k	0.1667	R_1	0.2309
k_1	*0.5000	k_2	0.0764	i_1/y_1	0.2250	i_2/y_2	0.0000			R_2	0.6124
b_1	**0.2037	b_2	0.0199	f_1/y_1	0.0000	f_2/y_2	0.0000	**Exog policy**		W_1	0.6213
f_1	0.0000	f_2	0.0000	g_1/y_1	*0.1000	g_2/y_2	0.1000	τ_1^k	*0.1500	W_2	0.3200
l_1	0.2623	l_2	0.2105	k_1/y_1	**1.4727	k_2/y_2	0.5443	τ_1^l	*0.2000	**Welfare**	
y_1	0.3395	y_2	0.1403	b_1/y_1	*0.6000	b_2/y_2	0.1416	τ_2^l	*0.2000	W	-2.0330

* *refers to initial parameter values.* ** *refers to initial parameters that were calculated jointly with the rest of the endogenous variables of the model.*

A.2.2 Comparison of equilibria and gains from cooperation

Table A.2 Symmetric Nash equilibrium (SNE), benchmark case

Allocations				**Shares**				**Optimal policy**		**Net returns**	
c_1	0.1967	c_2	0.1210	c_1/y_1	0.6179	c_2/y_2	0.7763	τ_2^k	0.0157	R_1	0.2164
k_1	*0.5000	k_2	0.0898	i_1/y_1	0.2821	i_2/y_2	0.0000	τ_1^l	0.3655	R_2	0.6839
b_1	**0.1910	b_2	-0.0157	f_1/y_1	0.0000	f_2/y_2	0.0000	τ_2^l	0.2474	W_1	0.5145
f_1	0.0000	f_2	0.0000	g_1/y_1	*0.1000	g_2/y_2	0.2237	g_2	0.0349	W_2	0.3125
l_1	0.2355	l_2	0.2253	k_1/y_1	**1.5710	k_2/y_2	0.5757	**Exog policy**		**Welfare**	
y_1	0.3183	y_2	0.1559	b_1/y_1	*0.6000	b_2/y_2	-0.1009	g_1	**0.0318	W	-2.0037

Table A.3 Symmetric cooperative equilibrium (SCE), benchmark case

Allocations				**Shares**				**Optimal policy**		**Net returns**	
c_1	0.2167	c_2	0.1099	c_1/y_1	0.6521	c_2/y_2	0.7500	τ_2^k	0.2081	R_1	0.2259
k_1	*0.5000	k_1	0.0824	i_1/y_1	0.2479	i_2/y_2	0.0000	τ_1^l	0.2638	R_2	0.5636
b_1	**0.1993	b_1	0.0057	f_1/y_1	0.0000	f_2/y_2	0.0000	τ_2^l	0.3147	W_1	0.5801
f_1	0.0000	f_1	0.0000	g_1/y_1	*0.1000	g_2/y_2	0.2500	g_2	0.0366	W_2	0.2800
l_1	0.2530	l_2	0.2151	k_1/y_1	**1.5049	k_2/y_2	0.5620	**Exog policy**		**Welfare**	
y_1	0.3322	y_2	0.1465	b_1/y_1	*0.6000	b_2/y_2	0.0392	g_1	**0.0332	W	-1.9989

A.2.3 Robustness analysis

Table A.4 Symmetric robustness analysis of public good valuation, μ_3, in the utility function

Non-cooperative policies													
μ_3	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*0.10	0.0157	0.3655	0.2474	0.0898	0.3183	0.1559	0.1967	0.1210	0.2355	0.2253	0.0318	0.0349	-2.0037
0.07	0.0140	0.3238	0.2164	0.0857	0.3176	0.1479	0.2001	0.1225	0.2347	0.2127	0.0318	0.0254	-1.8266
0.05	0.0126	0.2929	0.1939	0.0829	0.3175	0.1425	0.2028	0.1238	0.2346	0.2043	0.0318	0.0186	-1.7018
0.03	0.0111	0.2592	0.1697	0.0801	0.3178	0.1369	0.2060	0.1254	0.2349	0.1958	0.0318	0.0115	-1.5694
Cooperative policies													
μ_3	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*0.10	0.2081	0.2638	0.3147	0.0824	0.3322	0.1465	0.2167	0.1099	0.2530	0.2151	0.0332	0.0366	-1.9989
0.07	0.1781	0.2337	0.2744	0.0792	0.3293	0.1396	0.2171	0.1132	0.2493	0.2036	0.0329	0.0264	-1.8240
0.05	0.1570	0.2114	0.2453	0.0771	0.3277	0.1350	0.2178	0.1157	0.2473	0.1960	0.0328	0.0193	-1.7004
0.03	0.1352	0.1871	0.2144	0.0750	0.3265	0.1303	0.2189	0.1185	0.2457	0.1884	0.0326	0.0118	-1.5690

Table A.5 Symmetric robustness analysis of TFP, A

Non-cooperative policies													
A	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*1.00	0.0157	0.3655	0.2474	0.0898	0.3183	0.1559	0.1967	0.1210	0.2355	0.2253	0.0318	0.0349	-2.0037
0.90	0.0156	0.3524	0.2416	0.0817	0.2892	0.1358	0.1786	0.1052	0.2393	0.2271	0.0289	0.0306	-2.0962
0.80	0.0153	0.3392	0.2355	0.0735	0.2596	0.1163	0.1601	0.0898	0.2432	0.2289	0.0260	0.0265	-2.1999
0.70	0.0151	0.3257	0.2290	0.0650	0.2293	0.0974	0.1413	0.0750	0.2471	0.2308	0.0229	0.0223	-2.3180
Cooperative policies													
A	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*1.00	0.2081	0.2638	0.3147	0.0824	0.3322	0.1465	0.2167	0.1099	0.2530	0.2151	0.0332	0.0366	-1.9989
0.90	0.1963	0.2566	0.3046	0.0754	0.3009	0.1282	0.1954	0.0961	0.2556	0.2176	0.0301	0.0320	-2.0919
0.80	0.1844	0.2493	0.2942	0.0681	0.2691	0.1102	0.1741	0.0826	0.2583	0.2202	0.0269	0.0275	-2.1961
0.70	0.1726	0.2416	0.2837	0.0606	0.2370	0.0926	0.1526	0.0695	0.2610	0.2227	0.0237	0.0232	-2.3146

Table A.6 Symmetric robustness analysis of initial public debt-to-GDP ratio, s_1^b

Non-cooperative policies													
s_1^b	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*0.60	0.0157	0.3655	0.2474	0.0898	0.3183	0.1559	0.1967	0.1210	0.2355	0.2253	0.0318	0.0349	-2.0037
0.70	0.0157	0.3868	0.2562	0.0880	0.3131	0.1536	0.1937	0.1197	0.2292	0.2225	0.0313	0.0338	-2.0087
0.80	0.0155	0.4076	0.2643	0.0863	0.3079	0.1513	0.1908	0.1185	0.2229	0.2199	0.0308	0.0328	-2.0139
0.90	0.0152	0.4278	0.2715	0.0846	0.3028	0.1491	0.1879	0.1173	0.2167	0.2174	0.0303	0.0318	-2.0193
Cooperative policies													
s_1^b	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*0.60	0.2081	0.2638	0.3147	0.0824	0.3322	0.1465	0.2167	0.1099	0.2530	0.2151	0.0332	0.0366	-1.9989
0.70	0.2279	0.2753	0.3311	0.0800	0.3289	0.1432	0.2160	0.1074	0.2487	0.2111	0.0329	0.0358	-2.0030
0.80	0.2477	0.2863	0.3468	0.0777	0.3256	0.1400	0.2153	0.1050	0.2446	0.2071	0.0326	0.0350	-2.0072
0.90	0.2673	0.2968	0.3620	0.0755	0.3224	0.1368	0.2147	0.1026	0.2406	0.2033	0.0322	0.0342	-2.0116

Table A.7 Symmetric robustness analysis of labour share of income, $1-a$

Non-cooperative policies													
$1-a$	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*0.60	0.0157	0.3655	0.2474	0.0898	0.3183	0.1559	0.1967	0.1210	0.2355	0.2253	0.0318	0.0349	-2.0037
0.40	0.0088	0.5663	0.2487	0.1044	0.2974	0.1214	0.1633	0.1016	0.1365	0.1522	0.0297	0.0198	-2.0428
0.20	0.0035	0.9125	0.1607	0.0966	0.2531	0.0929	0.1311	0.0904	0.0166	0.0794	0.0253	0.0025	-2.2209
0.18	0.0034	0.9492	0.1462	0.0928	0.2416	0.0887	0.1247	0.0876	0.0088	0.0721	0.0242	0.0010	-2.3189
Cooperative policies													
$1-a$	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*0.60	0.2081	0.2638	0.3147	0.0824	0.3322	0.1465	0.2167	0.1099	0.2530	0.2151	0.0332	0.0366	-1.9989
0.40	0.3944	0.2695	0.3977	0.0926	0.3389	0.1087	0.2124	0.0816	0.1891	0.1384	0.0339	0.0272	-2.0107
0.20	0.5692	0.2453	0.4789	0.0965	0.3666	0.0892	0.2334	0.0669	0.1060	0.0650	0.0367	0.0223	-1.9432
0.18	0.5860	0.2425	0.4880	0.0968	0.3717	0.0883	0.2377	0.0662	0.0963	0.0579	0.0372	0.0221	-1.9295

Table A.8 Symmetric robustness analysis of capital mobility cost, m

Non-cooperative policies													
m	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*0.10	0.0157	0.3655	0.2474	0.0898	0.3183	0.1559	0.1967	0.1210	0.2355	0.2253	0.0318	0.0349	-2.0037
10.00	0.1049	0.3210	0.2763	0.0866	0.3246	0.1519	0.2056	0.1162	0.2434	0.2210	0.0325	0.0357	-2.0006
100.00	0.1914	0.2735	0.3081	0.0831	0.3310	0.1475	0.2148	0.1110	0.2514	0.2162	0.0331	0.0365	-1.9991
1000.00	0.2064	0.2648	0.3140	0.0824	0.3321	0.1466	0.2165	0.1100	0.2528	0.2153	0.0332	0.0366	-1.9989
Cooperative policies													
m	τ_2^k	τ_1^l	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	g_1	g_2	W
*0.10	0.2081	0.2638	0.3147	0.0824	0.3322	0.1465	0.2167	0.1099	0.2530	0.2151	0.0332	0.0366	-1.9989
10.00	0.2081	0.2638	0.3147	0.0824	0.3322	0.1465	0.2167	0.1099	0.2530	0.2151	0.0332	0.0366	-1.9989
100.00	0.2081	0.2638	0.3147	0.0824	0.3322	0.1465	0.2167	0.1099	0.2530	0.2151	0.0332	0.0366	-1.9989
1000.00	0.2081	0.2638	0.3147	0.0824	0.3322	0.1465	0.2167	0.1099	0.2530	0.2151	0.0332	0.0366	-1.9989

* denotes the benchmark solution obtained with the baseline parameter values.

A.3 Numerical solutions for non-symmetric economies

A.3.1 Modelling market competition

The domestic country will be denoted by the superscript d and the foreign country by the superscript f. The problems of agents (households, firms and the government) in each country are analogous so we will present the domestic economy only, except otherwise stated.

Households

Each household $q = 1, 2, ..., N$ offers differentiated labour services so that there is market power over his/her wages. This means that welfare maximization is also subject to the demand condition for q's labor services (this comes from the intermediate goods firms' problem below):

$$w^d_{q,2} = w^d_2 \left(\frac{l^d_{q,2}}{N l^d_{i,2}} \right)^{\psi^d - 1}$$

where w^d_2 is the average wage rate, $l^d_{q,2}$ is labour services provided by the household of type q to all intermediate goods firms N, and $l^d_{i,2}$ is labour services provided by all types of households to each intermediate goods firm i. The first-order condition for labour supply in the second period is

$$\frac{\mu_1}{c^d_2}(1 - \tau^d_{l,2})\psi^d w^d_2 = \frac{\mu_2}{1 - l^d_2}$$

Firms

There is a single final good and $i = 1, 2, ..., N$ differentiated intermediate goods used for the production of the final good. The final good is produced by a single final good firm that acts competitively, while each differentiated intermediate good i is produced by an intermediate goods firm i that acts as a monopolist in its own product market. We will model firms, and hence market power in the product market, in the standard Dixit-Stiglitz way (see e.g. any macro textbook and *Guo and Lansing 1999*[22], and *Bénassy 2005, chapter 6*[9]).

Final good firm

The final good firm produces y_2^d by using intermediate goods $y_{i,2}^d$ according to a Dixit-Stiglitz production function:

$$y_2^d = \left[\sum_{i=1}^{N} \frac{1}{N} (y_{i,2}^d)^{\phi^d} \right]^{\frac{1}{\phi^d}}$$

where $y_{i,2}^d$ denotes the quantity of the intermediate good of variety $i = 1, 2, ..., N$ used by the final good firm and $0 \leq \phi^d \leq 1$ is a parameter measuring the degree of substitutability (when $\phi^d = 1$, intermediate goods are perfect substitutes in the production of the final good and the intermediate sector is perfectly competitive). Notice that, in a symmetric equilibrium, we will simply have $y_2^d = y_{i,2}^d$. The final-good producer chooses $y_{i,2}^d$ to maximise real profits:

$$\pi_2^d = p_2^d y_2^d - \sum_{i=1}^{N} \frac{1}{N} p_{i,2}^d y_{i,2}^d$$

where p_2^d is the price of the final good and $p_{i,2}^d$ is the price of the intermediate good i. Taking prices as given, the first-order condition for $y_{i,2}^d$ gives the demand function:

$$p_{i,2}^d = p_2^d \left(\frac{y_{i,2}^d}{y_2^d} \right)^{\phi^d - 1}$$

which in turn implies from the zero-profit condition:

$$p_2^d = \left[\sum_{i=1}^{N} \frac{1}{N} (p_{i,2}^d)^{\frac{\phi^d}{\phi^d - 1}} \right]^{\frac{\phi^d - 1}{\phi^d}}$$

notice that, in a symmetric equilibrium, we will simply have $p_{i,2}^d = p_2^d$.

Intermediate goods firms

There are $i = 1, 2, ..., N$ intermediate goods firms. Each intermediate goods firm maximises real profits:

$$\pi^d_{i,2} \equiv \frac{p^d_{i,2}}{p^d_2} y^d_{i,2} - r^d_2 \bar{k}^d_{i,2} - w^d_2 \bar{l}^d_{i,2}$$

where l^d_2 is aggregate labour services provided by all types of workers and used by each firm i. Maximization is subject to the production function:

$$y^d_{i,2} = A(\bar{k}^d_{i,2})^a (\bar{l}^d_{i,2})^{1-a}$$

and the inverse demand function derived above:

$$p^d_{i,2} = p^d_2 \left(\frac{y^d_{i,2}}{y^d_2} \right)^{\varphi^d - 1}$$

The first-order conditions for the two inputs (written directly in a symmetric equilibrium) are

$$w^d_2 = \frac{p^d_{i,2}}{p^d_2} \frac{\varphi^d (1-a) y^d_{i,2}}{l^d_{i,2}} = \frac{\varphi^d (1-a) y^d_{i,2}}{l^d_{i,2}}$$

$$r^d_2 = \frac{p^d_{i,2}}{p^d_2} \frac{\varphi^d a y^d_{i,2}}{k^d_{i,2} + f^f_{i,2}} = \frac{\varphi^d a y^d_{i,2}}{k^d_{i,2} + f^f_{i,2}}$$

$$\pi^d_{i,2} = (1 - \varphi^d) y^d_{i,2}$$

In addition to the above decisions, the firm minimizes its labour cost, $w^d_2 l^d_{i,2}$, for any given level of aggregate labour quantities. Using again a Dixit-Stiglitz aggregator[1], we assume:

$$l^d_{i,2} \equiv \left[\sum_{q=1}^{N} \frac{1}{N} \left(l^d_{q,i,2} \right)^{\psi^d} \right]^{\frac{1}{\psi^d}}$$

where $l^d_{q,i,2}$ denotes the labour services provided by worker of type q and used by the intermediate goods firm of variety i and $0 \leq \psi^d \leq 1$ measures the degree of substitutability of these services. Notice that in a symmetric equilibrium we will simply have $l^d_{q,i,2} \equiv l^d_{i,2}$. The first-order condition yields the firm's demand equations for the labour services provided by worker of type q :

$$w^d_{q,2} = w^d_2 \left(\frac{l^d_{q,i,2}}{l^d_{i,2}} \right)^{\psi^d - 1}$$

[1] See e.g. *Bénassy, 2002, ch. 9.6.*

which in turn implies:

$$w_2^d = \left[\sum_{q=1}^{N} \frac{1}{N}\left(w_{q,2}^d\right)^{\frac{\psi^d}{\psi^d-1}}\right]^{\frac{\psi^d-1}{\psi^d}}$$

In a symmetric equilibrium, we will simply have $p_{i,2}^d = p_2^d$, $l_{q,i,2}^d = l_{i,2}^d$, $w_{q,2}^d = w_2^d$, $y_{i,2}^d = y_2^d$ and $k_{i,2}^d = k_2^d$.

World decentralized competitive equilibrium (for any feasible policy)

A world decentralized competitive equilibrium (WDCE), for any feasible policy, is defined as one in which: (i) households maximise welfare in each country (ii) firms maximise profits in each country (iii) all constraints are satisfied in each country (iv) all markets clear including the world asset/capital market. Notice that, with capital mobility allowed between period 1 and 2, the market-clearing conditions for capital in the second period are $\bar{k}_2^d = k_2^d + f_2^f$ in the domestic economy and $\bar{k}_2^f = k_2^f + f_2^d$ in the foreign economy.

Collecting equations, we have the system:

Domestic economy

$$c_1^d + k_2^d - (1-\delta)k_1^d + f_2^d + g_1^d = y_1^d$$

$$c_2^d - (1-\delta)k_2^d + g_2^d = y_2^d - (1-\tau_{k,2}^d)r_2^d f_2^f + \left(1 + (1-\tau_{k,2}^f)r_2^f - \delta\right) f_2^d - m\frac{(f_2^d)^2}{2}$$

$$\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d = \frac{\mu_2}{1-l_1^d}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)\psi^d w_2^d = \frac{\mu_2}{1-l_2^d}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1 + (1-\tau_{k,2}^d)r_2^d - \delta\right)$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1 + (1-\tau_{k,2}^f)r_2^f - \delta - m f_2^d\right)$$

$$g_1^d + \left(1 + (1-\tau_{k,1}^d)r_1^d - \delta\right) b_1^d = \tau_{k,1}^d r_1^d k_1^d + \tau_{l,1}^d w_1^d l_1^d + b_2^d$$

$$g_2^d + \left(1 + (1-\tau_{k,2}^d)r_2^d - \delta\right) b_2^d = \tau_{k,2}^d\left(r_2^d(k_2^d + f_2^f) + \pi_2^d\right) + \tau_{l,2}^d w_2^d l_2^d$$

Foreign economy

$$c_1^f + k_2^f - (1-\delta)k_1^f + f_2^f + g_1^f = y_1^f$$

$$c_2^f - (1-\delta)k_2^f + g_2^f = y_2^f - (1-\tau_{k,2}^f)r_2^f f_2^d + \left(1+(1-\tau_{k,2}^d)r_2^d - \delta\right) f_2^f - m\frac{(f_2^f)^2}{2}$$

$$\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f = \frac{\mu_2}{1-l_1^f}$$

$$\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)\psi^f w_2^f = \frac{\mu_2}{1-l_2^f}$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+(1-\tau_{k,2}^f)r_2^f - \delta\right)$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+(1-\tau_{k,2}^d)r_2^d - \delta - mf_2^f\right)$$

$$g_1^f + \left(1+(1-\tau_{k,1}^f)r_1^f - \delta\right) b_1^f = \tau_{k,1}^f r_1^f k_1^f + \tau_{l,1}^f w_1^f l_1^f + b_2^f$$

$$g_2^f + \left(1+(1-\tau_{k,2}^f)r_2^f - \delta\right) b_2^f = \tau_{k,2}^f \left(r_2^f(k_2^f + f_2^d) + \pi_2^f\right) + \tau_{l,2}^f w_2^f l_2^f$$

where, in the above, we use the following equations describing profits, gross wages, capital and bond returns in the two countries:

$$\pi_1^d = \pi_1^f = 0,\ \pi_2^d = (1-\phi^d)y_2^d,\ \pi_2^f = (1-\phi^f)y_2^f,$$

$$r_1^d = a\frac{y_1^d}{k_1^d},\ r_1^f = a\frac{y_1^f}{k_1^f},\ r_2^d = \frac{\phi^d a y_2^d}{k_2^d + f_2^f},\ r_2^f = \frac{\phi^f a y_2^f}{k_2^f + f_2^d},$$

$$w_1^d = (1-a)\frac{y_1^d}{l_1^d},\ w_1^f = (1-a)\frac{y_1^f}{l_1^f},\ w_2^d = \frac{\phi^d(1-a)y_2^d}{l_2^d},\ w_2^f = \frac{\phi^f(1-a)y_2^f}{l_2^f}$$

Therefore, we have a system of 16 equations in 16 endogenous variables, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d$, $l_2^d, l_1^f, l_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, \tau_{k,2}^d, \tau_{k,2}^f$. This is given the independently set policy instruments. The latter include the rest of the tax rates, $\tau_{k,1}^d, \tau_{l,1}^d, \tau_{l,2}^d, \tau_{k,1}^f, \tau_{l,1}^f, \tau_{l,2}^f$, and public spending, $g_1^d, g_2^d, g_1^f, g_2^f$. In other words, in each period, one policy instrument needs to follow residually to close the government budget constraint and here it is assumed that this role is played by the end-of-period public debt in the first period (b_2^d and b_2^f) and by the tax rate on capital in the second period ($\tau_{k,2}^d$ and $\tau_{k,2}^f$) - this is why these variables are included in the list of endogenous variables. We report however that the specific classification of policy instruments into endogenous and independently set at this level is not important to our results since policy will be chosen optimally.

A.3.2 Modelling institutional quality

Households

To model institutional quality we assume that firms in the periphery country can keep a fraction only of their output produced, which means that total output is a contestable prize because of weak property rights, while the rest of the fraction can be taken away by households who compete with each other for a share of the contestable prize in a Tullock-type[2] redistributive contest that hurts everybody in equilibrium.

The domestic country will be denoted by the superscript d and the foreign country by the superscript f. The problems of agents (households, firms and the government) in each country are analogous so we will present the domestic economy only, except otherwise stated. We assume that the household further divides its labour time between productive work $s_2^d l_2^d$ and rent-extracting activities, $\left(1-s_2^d\right) l_2^d$, where $0 \leq s_2^d < 1$ and $0 \leq \left(1-s_2^d\right) < 1$ denote the fractions of non-leisure time that the household allocates to productive work and rent extraction. Thus, in addition to the choice of their labour supply, households also choose optimally the amount of their productive labour supply. The budget constraint of the domestic household in period 2 is the following

$$\begin{aligned} c_2^d = & \left(1 + (1 - \tau_{k,2}^d) r_2^d - \delta\right) k_2^d + (1 - \tau_{l,2}^d) w_2^d s_2^d l_2^d + (1 - \tau_{k,2}^d) \pi_2^d + (1 + \rho_2^d) b_2^d \\ & + \left(1 + (1 - \tau_{k,2}^f) r_2^f - \delta\right) f_2^d - m \frac{\left(f_2^d\right)^2}{2} + \frac{(1 - s_2^d) l_2^d}{\sum_{h=1}^N (1 - s_{h,2}^d) l_{h,2}^d} \theta^d y_2^d \end{aligned}$$

The last term of the budget constraint denotes a contestable prize available due to poor institutions. The household aims to grab a fraction of that prize which depends on the extractive effort she puts relative to the extractive efforts put by all other households in the domestic country. $0 \leq \theta^d < 1$ is the economy-wide degree of rent extraction and higher values imply weaker protection of property rights. The household acts competitively by taking prices, policy and economy-wide variables as given.[3] Thus, in addition to its first-period choices, the household chooses c_2^d, l_2^d, s_2^d to maximize its welfare (eq. 3.2), subject to

[2] See e.g. *Besley et al. (2010)*[10], *Angelopoulos et al. (2009)[5], (2011)[4]*, *Park et al. (2005)*[42], *Economides et al. (2007)*[18].

[3] The household is small by taking economy-wide variables (θ^d and $\sum_{h=1}^N (1-s_{h,2}^d) l_{h,2}^d$) as given. We could alternatively assume that the household internalizes the effects of his/her own actions on aggregate outcomes by taking only the actions of other agents as given. This is not important regarding the features of a decentralized equilibrium. What is important is that there are (social) external effects.

its budget constraints (eq. 3.3-4), and initial conditions for first-period capital, bonds and public spending. The optimality conditions for labour supply and productive labour supply are

$$\frac{\mu_1}{c_2^d}\left\{(1-\tau_{l,2}^d)w_2^d s_2^d + \frac{(1-s_2^d)}{\sum_{h=1}^N (1-s_{h,2}^d)l_{h,2}^d}\theta^d y_2^d\right\} = \frac{\mu_2}{1-l_2^d}$$

$$(1-\tau_{l,2}^d)w_2^d l_2^d = \frac{l_2^d}{\sum_{h=1}^N (1-s_2^d)l_2^d}\theta^d y_2^d$$

Firms

Firms may only a keep a fraction of their output produced in the second period. Thus, they choose capital $\bar{k}_2^d$, and labour services, $\bar{l}_2^d$, to maximise their profits

$$\max_{\bar{k}_2^d,\bar{l}_2^d} \pi_2^d = (1-\theta^d)y_2^d - r_2^d\bar{k}_2^d - w_2^d\bar{l}_2^d$$

given their technology $Y_2^d = A(\bar{k}_2^d)^a(\bar{l}_2^d)^{1-a}$, and the economy-wide degree of rent extraction θ^d. Their first-order conditions are

$$r_2^d = (1-\theta^d)a\frac{y_2^d}{\bar{k}_2^d}$$

and

$$w_2^d = (1-\theta^d)(1-a)\frac{y_2^d}{\bar{l}_2^d}$$

so that profits are zero in equilibrium.

Government

The government taxes labour income at a rate $0 \leq \tau_{l,t}^d \leq 1$, capital income earned by both domestic and foreign investors at a rate $0 \leq \tau_{k,t}^d \leq 1$ and issues bonds to finance utility-enhancing public expenditures. The within-period government budget constraints are:

$$g_1^d + (1+\rho_1^d)b_1^d = \tau_{k,1}^d(r_1^d k_1^d + \pi_1^d) + \tau_{l,1}^d w_1^d l_1^d + b_2^d$$

$$g_2^d + (1+\rho_2^d)b_2^d = \tau_{k,2}^d\left(r_2^d(k_2^d + f_2^f) + \pi_2^d\right) + \tau_{l,2}^d w_2^d s_2^d l_2^d$$

where g_1^d and g_2^d are government expenditures and b_1^d and b_2^d are beginning-of-period government bonds in periods 1 and 2.

World decentralized competitive equilibrium (for any feasible policy)

A world decentralized competitive equilibrium (WDCE), for any feasible policy, is defined as one in which: (i) households maximise welfare in each country (ii) firms maximise profits in each country (iii) all constraints are satisfied in each country (iv) all markets clear including the world asset/capital market. Notice that, with capital mobility allowed between period 1 and 2, the market-clearing conditions for capital in the second period are $\bar{k}_2^d = k_2^d + f_2^f$ in the domestic economy and $\bar{k}_2^f = k_2^f + f_2^d$ in the foreign economy.

Collecting equations, we have the system:

Domestic economy

$$c_1^d + k_2^d - (1-\delta)k_1^d + f_2^d + g_1^d = y_1^d$$

$$c_2^d - (1-\delta)k_2^d + g_2^d = y_2^d - (1-\tau_{k,2}^d)r_2^d f_2^f + \left(1 + (1-\tau_{k,2}^f)r_2^f - \delta\right) f_2^d - m\frac{(f_2^d)^2}{2}$$

$$\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d = \frac{\mu_2}{1-l_1^d}$$

$$\frac{\mu_1}{c_2^d}\left\{(1-\tau_{l,2}^d)w_2^d s_2^d + \frac{\theta^d y_2^d}{l_2^d}\right\} = \frac{\mu_2}{1-l_2^d}$$

$$(1-\tau_{l,2}^d)w_2^d l_2^d = \frac{\theta^d y_2^d}{1-s_2^d}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1 + (1-\tau_{k,2}^d)r_2^d - \delta\right)$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1 + (1-\tau_{k,2}^f)r_2^f - \delta - m f_2^d\right)$$

$$g_1^d + \left(1 + (1-\tau_{k,1}^d)r_1^d - \delta\right) b_1^d = \tau_{k,1}^d r_1^d k_1^d + \tau_{l,1}^d w_1^d l_1^d + b_2^d$$

$$g_2^d + \left(1 + (1-\tau_{k,2}^d)r_2^d - \delta\right) b_2^d = \tau_{k,2}^d r_2^d (k_2^d + f_2^f) + \tau_{l,2}^d w_2^d s_2^d l_2^d$$

Foreign economy

$$c_1^f + k_2^f - (1-\delta)k_1^f + f_2^f + g_1^f = y_1^f$$

$$c_2^f - (1-\delta)k_2^f + g_2^f = y_2^f - (1-\tau_{k,2}^f)r_2^f f_2^d + \left(1 + (1-\tau_{k,2}^d)r_2^d - \delta\right) f_2^f - m\frac{(f_2^f)^2}{2}$$

$$\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f = \frac{\mu_2}{1-l_1^f}$$

$$\frac{\mu_1}{c_2^f}\left\{(1-\tau_{l,2}^f)w_2^f s_2^f + \frac{\theta^f y_2^f}{l_2^f}\right\} = \frac{\mu_2}{1-l_2^f}$$

$$(1-\tau_{l,2}^f)w_2^f l_2^f = \frac{\theta^f y_2^f}{1-s_2^f}$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+(1-\tau_{k,2}^f)r_2^f - \delta\right)$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+(1-\tau_{k,2}^d)r_2^d - \delta - m f_2^f\right)$$

$$g_1^f + \left(1+(1-\tau_{k,1}^f)r_1^f - \delta\right)b_1^f = \tau_{k,1}^f r_1^f k_1^f + \tau_{l,1}^f w_1^f l_1^f + b_2^f$$

$$g_2^f + \left(1+(1-\tau_{k,2}^f)r_2^f - \delta\right)b_2^f = \tau_{k,2}^f r_2^f (k_2^f + f_2^d) + \tau_{l,2}^f w_2^f s_2^f l_2^f$$

where, in the above, we use the following equations describing profits, gross wages, capital and bond returns in the two countries:

$$\pi_t^d = \pi_t^f = 0,\ t = 1,2$$

$$r_1^d = a\frac{y_1^d}{k_1^d},\ r_1^f = a\frac{y_1^f}{k_1^f},\ r_2^d = \frac{(1-\theta^d)}{k_2^d + f_2^f}a y_2^d,\ r_2^f = \frac{(1-\theta^f)}{k_2^f + f_2^d}a y_2^f,$$

$$w_1^d = (1-a)\frac{y_1^d}{l_1^d},\ w_1^f = (1-a)\frac{y_1^f}{l_1^f},\ w_2^d = \frac{(1-\theta^d)}{l_2^d}(1-a)y_2^d,\ w_2^f = \frac{(1-\theta^f)}{l_2^f}(1-a)y_2^f$$

Therefore, we have a system of 18 equations in 18 endogenous variables, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d$, $l_2^d, l_1^f, l_2^f, s_2^d, s_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, \tau_{k,2}^d, \tau_{k,2}^f$. This is given the independently set policy instruments. The latter include the rest of the tax rates, $\tau_{k,1}^d, \tau_{l,1}^d, \tau_{l,2}^d, \tau_{k,1}^f, \tau_{l,1}^f, \tau_{l,2}^f$, and public spending, $g_1^d, g_2^d, g_1^f, g_2^f$. In other words, in each period, one policy instrument needs to follow residually to close the government budget constraint and here it is assumed that this role is played by the end-of-period public debt in the first period (b_2^d and b_2^f) and by the tax rate on capital in the second period ($\tau_{k,2}^d$ and $\tau_{k,2}^f$) - this is why these variables are included in the list of endogenous variables. We report however that the specific classification of policy instruments into endogenous and independently set at this level is not important to our results since policy will be chosen optimally.

A.3.3 Flexible and rigid cooperation

Concerning the cooperative framework, we distinguish between flexible and rigid unions. To model flexible cooperation we follow the same procedure as in the symmetric case presented above in *subsection A.1.2*.

In the case of a rigid union however, the planner solves the same problem as in the case of flexible cooperation, but, instead of choosing a different tax rate for each economy, $\tau_{k,2}^d, \tau_{k,2}^f, \tau_{l,1}^d, \tau_{l,1}^f, \tau_{l,2}^d, \tau_{l,2}^f$, she now chooses union-wide or single of one-size-fits-all policy instruments $\tau_2^k, \tau_1^l, \tau_2^l$. A fictional world social planner maximises a weighted average of households' welfare in each country with equal weights, γ, given to each one of them. Thus, the objective is now:

$$\max W^{coop} = \gamma U^d + (1-\gamma) U^f$$

subject to the equations summarizing the WDCE (3.15-30). We form the Lagrangian function of the world government as follows

$$
\begin{gathered}
L = W^{coop} + \\
+\lambda_1 \left\{ c_1^d + k_2^d - (1-\delta) k_1^d + f_2^d + g_1^d - y_1^d \right\} \\
+\lambda_2 \left\{ c_2^d - (1-\delta) k_2^d + g_2^d - y_2^d + (1-\tau_2^k) r_2^d f_2^f - \left(1 + (1-\tau_2^k) r_2^f - \delta\right) f_2^d + m \frac{(f_2^d)^2}{2} \right\} \\
+\lambda_3 \left\{ \frac{\mu_1}{c_1^d} (1-\tau_1^l) w_1^d - \frac{\mu_2}{1-l_1^d} \right\} \\
+\lambda_4 \left\{ \frac{\mu_1}{c_2^d} (1-\tau_2^l) w_2^d - \frac{\mu_2}{1-l_2^d} \right\} \\
+\lambda_5 \left\{ \frac{c_2^d}{c_1^d} - \beta \left(1 + (1-\tau_2^k) r_2^d - \delta\right) \right\} \\
+\lambda_6 \left\{ \frac{c_2^d}{c_1^d} - \beta \left(1 + (1-\tau_2^k) r_2^f - \delta - m f_2^d\right) \right\} \\
+\lambda_7 \left\{ g_1^d + \left(1 + (1-\tau_1^k) r_1^d - \delta\right) b_1^d - \tau_1^k r_1^d k_1^d - \tau_1^l w_1^d l_1^d - b_2^d \right\} \\
+\lambda_8 \left\{ g_2^d + \left(1 + (1-\tau_2^k) r_2^d - \delta\right) b_2^d - \tau_2^k \left(r_2^d (k_2^d + f_2^f) \right) - \tau_2^l w_2^d l_2^d \right\} \\
+\lambda_9 \left\{ c_1^f + k_2^f - (1-\delta) k_1^f + f_2^f + g_1^f - y_1^f \right\} \\
+\lambda_{10} \left\{ c_2^f - (1-\delta) k_2^f + g_2^f - y_2^f + (1-\tau_2^k) r_2^f f_2^d - \left(1 + (1-\tau_2^k) r_2^d - \delta\right) f_2^f + m \frac{(f_2^f)^2}{2} \right\}
\end{gathered}
$$

$$+\lambda_{11}\left\{\frac{\mu_1}{c_1^f}(1-\tau_1^l)w_1^f-\frac{\mu_2}{1-l_1^f}\right\}$$

$$+\lambda_{12}\left\{\frac{\mu_1}{c_2^f}(1-\tau_2^l)w_2^f-\frac{\mu_2}{1-l_2^f}\right\}$$

$$+\lambda_{13}\left\{\frac{c_2^f}{c_1^f}-\beta\left(1+(1-\tau_2^k)r_2^f-\delta\right)\right\}$$

$$+\lambda_{14}\left\{\frac{c_2^f}{c_1^f}-\beta\left(1+(1-\tau_2^k)r_2^d-\delta-mf_2^f\right)\right\}$$

$$+\lambda_{15}\left\{g_1^f+\left(1+(1-\tau_1^k)r_1^f-\delta\right)b_1^f-\tau_1^k r_1^f k_1^f-\tau_1^l w_1^f l_1^f-b_2^f\right\}$$

$$+\lambda_{16}\left\{g_2^f+\left(1+(1-\tau_2^k)r_2^f-\delta\right)b_2^f-\tau_2^k\left(r_2^f(k_2^f+f_2^d)\right)-\tau_2^l w_2^f l_2^f\right\}$$

The maximization is with respect to the independent policy instruments in the two countries, τ_1^l, g_2^d and g_2^f. Notice that rigid cooperation implies fewer optimally chosen instruments at the disposal of the policymaker, which means that the role of the residually adjusted policy instruments is now played by the end-of-period public debt in the first period (b_2^d and b_2^f) and by the tax rates on capital (τ_2^k) and labor (τ_2^l) in the second period. We will thus have a system of 35 equations in 35 unknowns. The equations are the 16 equations of the WDCE, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, l_1^f, l_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, \tau_2^k, \tau_2^l$, the 16 optimality conditions for the same variables rechosen in a dual solution, plus the 3 equations for the 3 independent policy instruments, τ_1^l, g_2^d and g_2^f.

A.3.4 Numerical solutions for non-symmetric equilibria and gains from cooperation

Table A.9 Asymmetries in TFP, $A^{core} = 1.0$, $A^{per} = 0.7$, numerical solution

	Nash		Coop flex		Coop rigid	
	core	per	core	per	core	per
Allocations						
c_1	0.21	0.13	0.22	0.14	0.21	0.13
c_2	0.12	0.08	0.11	0.07	0.12	0.07
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.09	0.06	0.08	0.06	0.09	0.06
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	-0.01	0.01	-0.01	0.01	-0.02	0.02
b_1^{**}	0.19	0.14	0.20	0.14	0.19	0.14
b_2	-0.01	-0.02	0.01	-0.01	-0.01	-0.01
l_1	0.23	0.25	0.25	0.26	0.23	0.27
l_2	0.24	0.20	0.23	0.20	0.26	0.17
y_1	0.32	0.23	0.33	0.24	0.31	0.24
y_2	0.17	0.08	0.16	0.08	0.18	0.07
Optimal Policy						
τ_2^k	0.05	0.00	0.18	0.12	0.08	0.08
τ_1^l	0.33	0.35	0.26	0.30	0.32	0.32
τ_2^l	0.26	0.22	0.30	0.27	0.25	0.25
g_2	0.04	0.02	0.04	0.02	0.04	0.02
g_1^{**}	0.03	0.02	0.03	0.02	0.03	0.02

	Nash		Coop flex		Coop rigid	
	core	per	core	per	core	per
Net returns and wages						
R_1	0.22	0.16	0.22	0.16	0.21	0.16
R_2	0.64	0.63	0.56	0.56	0.61	0.61
W_1	0.54	0.36	0.59	0.38	0.56	0.36
W_2	0.32	0.19	0.29	0.18	0.32	0.18
Shares						
c_1/y_1	0.66	0.57	0.68	0.59	0.69	0.55
i_1/y_1	0.28	0.28	0.26	0.26	0.28	0.26
x_1/y_1	-0.04	0.05	-0.03	0.05	-0.07	0.09
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.58	2.14	1.53	2.10	1.60	2.07
b_1/y_1^*	0.60	0.60	0.60	0.60	0.60	0.60
c_2/y_2	0.70	0.93	0.69	0.88	0.64	1.09
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.09	-0.20	0.08	-0.15	0.15	-0.40
g_2/y_2	0.21	0.27	0.23	0.27	0.21	0.31
k_2/y_2	0.52	0.79	0.51	0.76	0.48	0.92
b_2/y_2	-0.05	-0.22	0.04	-0.12	-0.05	-0.20
Welfare						
W	-2.00	-2.32	-1.99	-2.32	-1.99	-2.32

Table A.10 Asymmetries in inherited public debt, $b_1/y_1^{core} = 0.6$, $b_1/y_1^{per} = 0.9$, numerical solution

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Allocations			
c_1	0.20	0.19	0.22	0.21	0.21	0.22
c_2	0.12	0.12	0.11	0.11	0.10	0.11
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.09	0.08	0.08	0.08	0.08	0.07
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	0.00	0.00	0.00	0.00	0.00	0.00
b_1^{**}	0.19	0.27	0.20	0.29	0.20	0.29
b_2	-0.02	-0.01	0.01	0.02	0.00	0.02
l_1	0.24	0.22	0.26	0.24	0.25	0.24
l_2	0.22	0.22	0.21	0.21	0.22	0.20
y_1	0.32	0.30	0.34	0.32	0.33	0.32
y_2	0.16	0.15	0.14	0.14	0.15	0.14
			Optimal Policy			
τ_2^k	0.01	0.02	0.24	0.23	0.25	0.25
τ_1^l	0.37	0.42	0.25	0.31	0.28	0.28
τ_2^l	0.25	0.27	0.33	0.35	0.34	0.34
g_2	0.03	0.03	0.04	0.03	0.04	0.03
g_1^{**}	0.03	0.03	0.03	0.03	0.03	0.03

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Net returns and wages			
R_1	0.22	0.21	0.23	0.22	0.22	0.22
R_2	0.69	0.69	0.55	0.55	0.54	0.54
W_1	0.51	0.48	0.59	0.56	0.57	0.58
W_2	0.31	0.30	0.27	0.27	0.27	0.27
			Shares			
c_1/y_1	0.62	0.62	0.65	0.67	0.65	0.67
i_1/y_1	0.28	0.28	0.24	0.24	0.25	0.23
x_1/y_1	0.00	0.00	0.01	-0.01	0.00	0.00
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.57	1.65	1.49	1.57	1.52	1.54
b_1/y_1^*	0.60	0.90	0.60	0.90	0.60	0.90
c_2/y_2	0.78	0.78	0.77	0.73	0.71	0.78
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.00	0.00	-0.03	0.03	-0.01	0.01
g_2/y_2	0.22	0.21	0.26	0.24	0.30	0.22
k_2/y_2	0.58	0.57	0.58	0.54	0.56	0.55
b_2/y_2	-0.11	-0.06	0.06	0.11	0.01	0.17
			Welfare			
W	-2.00	-2.02	-2.00	-2.01	-2.00	-2.01

Table A.11 Asymmetries in product market, $\phi^{core} = 1.0$, $\phi^{per} = 0.9$, numerical solution

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Allocations			
c_1	0.20	0.19	0.22	0.21	0.21	0.20
c_2	0.12	0.11	0.11	0.10	0.11	0.11
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.09	0.08	0.08	0.07	0.09	0.08
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	-0.01	0.01	0.00	0.00	-0.02	0.02
b_1^{**}	0.19	0.19	0.20	0.19	0.19	0.20
b_2	-0.01	-0.02	0.01	0.00	-0.01	-0.01
l_1	0.24	0.22	0.26	0.24	0.23	0.25
l_2	0.23	0.20	0.22	0.20	0.26	0.17
y_1	0.32	0.31	0.33	0.32	0.31	0.33
y_2	0.16	0.14	0.15	0.13	0.18	0.11
			Optimal Policy			
τ_2^k	0.04	-0.02	0.24	0.21	0.14	0.14
τ_1^l	0.35	0.41	0.24	0.30	0.33	0.33
τ_2^l	0.25	0.23	0.33	0.26	0.27	0.27
g_2	0.04	0.03	0.04	0.03	0.04	0.03
g_1^{**}	0.03	0.03	0.03	0.03	0.03	0.03

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Net returns and wages			
R_1	0.22	0.21	0.23	0.22	0.21	0.22
R_2	0.66	0.66	0.54	0.54	0.59	0.59
W_1	0.53	0.49	0.60	0.56	0.55	0.53
W_2	0.31	0.28	0.28	0.26	0.31	0.26
			Shares			
c_1/y_1	0.64	0.62	0.67	0.66	0.68	0.61
i_1/y_1	0.28	0.27	0.24	0.23	0.28	0.23
x_1/y_1	-0.02	0.02	-0.01	0.01	-0.06	0.06
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.57	1.62	1.50	1.55	1.60	1.52
b_1/y_1^*	0.60	0.60	0.60	0.60	0.60	0.60
c_2/y_2	0.74	0.74	0.74	0.74	0.74	0.74
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.04	0.04	0.04	0.04	0.04	0.04
g_2/y_2	0.22	0.22	0.22	0.22	0.22	0.22
k_2/y_2	0.55	0.60	0.54	0.55	0.48	0.69
b_2/y_2	-0.08	-0.18	0.08	-0.02	-0.05	-0.07
			Welfare			
W	-2.00	-2.02	-2.00	-2.01	-1.99	-2.03

Table A.12 Asymmetries in labour market, $\psi^{core} = 1.0$, $\psi^{per} = 0.7$, numerical solution

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Allocations			
c_1	0.20	0.19	0.20	0.19	0.21	0.19
c_2	0.12	0.11	0.12	0.11	0.12	0.10
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.09	0.08	0.09	0.08	0.08	0.08
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	0.00	0.00	0.00	0.00	-0.03	0.03
b_1^{**}	0.19	0.18	0.19	0.18	0.18	0.20
b_2	-0.01	-0.03	-0.01	-0.03	-0.02	-0.01
l_1	0.24	0.22	0.24	0.22	0.21	0.25
l_2	0.23	0.18	0.23	0.18	0.29	0.13
y_1	0.32	0.30	0.32	0.30	0.29	0.33
y_2	0.16	0.13	0.16	0.13	0.20	0.09
			Optimal Policy			
τ_2^k	0.04	0.01	0.04	0.01	0.15	0.15
τ_1^l	0.35	0.43	0.35	0.43	0.37	0.37
τ_2^l	0.26	0.11	0.26	0.11	0.20	0.20
g_2	0.04	0.03	0.04	0.03	0.05	0.02
g_1^{**}	0.03	0.03	0.03	0.03	0.03	0.03

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Net returns and wages			
R_1	0.22	0.21	0.22	0.21	0.20	0.23
R_2	0.66	0.66	0.66	0.66	0.60	0.60
W_1	0.53	0.47	0.53	0.47	0.54	0.50
W_2	0.31	0.38	0.31	0.38	0.33	0.33
			Shares			
c_1/y_1	0.64	0.61	0.64	0.61	0.73	0.56
i_1/y_1	0.28	0.28	0.28	0.28	0.28	0.24
x_1/y_1	-0.02	0.02	-0.02	0.02	-0.11	0.09
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.57	1.64	1.57	1.64	1.70	1.51
b_1/y_1^*	0.60	0.60	0.60	0.60	0.60	0.60
c_2/y_2	0.74	0.84	0.74	0.84	0.58	1.15
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.04	-0.05	0.04	-0.05	0.19	-0.43
g_2/y_2	0.22	0.21	0.22	0.21	0.23	0.28
k_2/y_2	0.55	0.64	0.55	0.64	0.41	0.92
b_2/y_2	-0.07	-0.22	-0.07	-0.22	-0.09	-0.17
			Welfare			
W	-2.00	-2.03	-2.00	-2.03	-2.00	-2.05

Table A.13 Asymmetries in institutional quality, $\theta^{core} = 0.0$, $\theta^{per} = 0.15$, numerical solution

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Allocations			
c_1	0.21	0.19	0.22	0.19	0.21	0.18
c_2	0.12	0.10	0.12	0.10	0.12	0.11
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.09	0.08	0.09	0.07	0.09	0.08
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	-0.02	0.02	-0.03	0.03	-0.03	0.03
b_1^{**}	0.19	0.19	0.19	0.19	0.18	0.20
b_2	-0.01	-0.02	0.00	-0.02	-0.02	-0.02
l_1	0.23	0.23	0.23	0.24	0.21	0.25
l_2	0.25	0.22	0.26	0.20	0.29	0.18
s_2	1.00	0.73	1.00	0.72	1.00	0.73
y_1	0.32	0.32	0.32	0.32	0.29	0.33
y_2	0.18	0.11	0.19	0.09	0.21	0.08
			Optimal Policy			
τ_2^k	0.07	0.03	0.10	0.11	0.02	0.02
τ_1^l	0.31	0.40	0.28	0.38	0.39	0.39
τ_2^l	0.26	0.20	0.27	0.24	0.22	0.22
g_2	0.04	0.03	0.04	0.03	0.04	0.02
g_1^{**}	0.03	0.03	0.03	0.03	0.03	0.03

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Net returns and wages			
R_1	0.22	0.21	0.22	0.22	0.20	0.22
R_2	0.62	0.62	0.59	0.58	0.64	0.64
W_1	0.56	0.49	0.58	0.50	0.52	0.49
W_2	0.32	0.27	0.32	0.25	0.34	0.26
			Shares			
c_1/y_1	0.68	0.60	0.70	0.59	0.70	0.56
i_1/y_1	0.28	0.24	0.28	0.23	0.31	0.24
x_1/y_1	-0.06	0.06	-0.08	0.08	-0.11	0.10
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.58	1.59	1.58	1.55	1.70	1.52
b_1/y_1^*	0.60	0.60	0.60	0.60	0.60	0.60
c_2/y_2	0.67	0.97	0.64	1.05	0.58	1.25
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.13	-0.21	0.16	-0.32	0.21	-0.51
g_2/y_2	0.20	0.24	0.20	0.27	0.21	0.26
k_2/y_2	0.50	0.71	0.47	0.79	0.44	0.92
b_2/y_2	-0.04	-0.20	0.00	-0.18	-0.10	-0.22
			Welfare			
W	-2.00	-2.08	-1.99	-2.08	-2.00	-2.08

* *refers to initial parameter values.* ** *refers to initial parameters that were calculated jointly with the rest of the endogenous variables of the model.*

Appendix B

Part B: Optimal policy with and without commitment

B.1 Optimal policy with commitment

B.1.1 Non-cooperative policies (Nash): Definition

The domestic government maximises

$$
\begin{aligned}
U^d\left(c_t^d, l_t^d, s_t^d, g_t^d\right) &= \mu_1 \log c_1^d + \mu_2 \log(1 - l_1^d) + \mu_3 \log g_1^d \\
&\quad + \beta\left(\mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d - s_2^d) + \mu_3 \log g_2^d\right)
\end{aligned}
$$

with respect to its independently set policy instruments $\tau_{k,2}^d, \tau_{l,2}^d$ and subject to the equations summarizing the WDCE (6.16-35). We form the Lagrangian function of the domestic government as follows

$$
\begin{aligned}
L = {} & \mu_1 \log c_1^d + \mu_2 \log(1 - l_1^d) + \mu_3 \log g_1^d + \beta\left(\mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d - s_2^d) + \mu_3 \log g_2^d\right) \\
& + \lambda_1\left\{c_1^d + k_2^d - (1-\delta)k_1^d + f_2^d + g_1^d - y_1^d\right\} \\
& + \lambda_2\Big\{c_2^d - (1-\delta)k_2^d + g_2^d - y_2^d + (1-\tau_{k,2}^d)r_2^d f_2^f - \Big(1 + (1-\tau_{k,2}^f)r_2^f \\
& \quad - \delta\Big) f_2^d + m\frac{(f_2^d)^2}{2} + (1-\tau_{l,2}^d)w_2^d s_2^f - (1-\tau_{l,2}^f)w_2^f s_2^d + j\frac{(s_2^d - \bar{s})^2}{2}\Big\} \\
& + \lambda_3\left\{\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d - \frac{\mu_2}{1-l_1^d}\right\}
\end{aligned}
$$

$$+\lambda_4\Big\{\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d-\frac{\mu_2}{1-l_2^d-s_2^d}\Big\}$$

$$+\lambda_5\Big\{\frac{\mu_1}{c_2^d}\Big((1-\tau_{l,2}^f)w_2^f-j(s_2^d-\bar{s})\Big)-\frac{\mu_2}{1-l_2^d-s_2^d}\Big\}$$

$$+\lambda_6\Big\{\frac{c_2^d}{c_1^d}-\beta\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta\Big)\Big\}$$

$$+\lambda_7\Big\{\frac{c_2^d}{c_1^d}-\beta\Big(1+(1-\tau_{k,2}^f)r_2^f-\delta-mf_2^d\Big)\Big\}$$

$$+\lambda_8\Big\{\frac{c_2^d}{c_1^d}-\beta\Big(1+\rho_2^d\Big)\Big\}$$

$$+\lambda_9\Big\{g_1^d+\Big(1+(1-\tau_{k,1}^d)r_1^d-\delta\Big)b_1^d-\tau_{k,1}^d r_1^d k_1^d-\tau_{l,1}^d w_1^d l_1^d-b_2^d\Big\}$$

$$+\lambda_{10}\Big\{g_2^d+(1+\rho_2^d)b_2^d-\tau_{k,2}^d r_2^d(k_2^d+f_2^f)-\tau_{l,2}^d w_2^d(l_2^d+s_2^f)\Big\}$$

$$+\lambda_{11}\Big\{c_1^f+k_2^f-(1-\delta)k_1^f+f_2^f+g_1^f-y_1^f\Big\}$$

$$+\lambda_{12}\Big\{c_2^f-(1-\delta)k_2^f+g_2^f-y_2^f+(1-\tau_{k,2}^f)r_2^f f_2^d-\Big(1+(1-\tau_{k,2}^d)r_2^d$$
$$-\delta\Big)f_2^f+m\frac{\left(f_2^f\right)^2}{2}+(1-\tau_{l,2}^f)w_2^f s_2^d-(1-\tau_{l,2}^d)w_2^d s_2^f+j\frac{\left(s_2^f-\bar{s}\right)^2}{2}\Big\}$$

$$+\lambda_{13}\Big\{\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f-\frac{\mu_2}{1-l_1^f}\Big\}$$

$$+\lambda_{14}\Big\{\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f-\frac{\mu_2}{1-l_2^f-s_2^f}\Big\}$$

$$+\lambda_{15}\Big\{\frac{\mu_1}{c_2^f}\Big((1-\tau_{l,2}^d)w_2^d-j(s_2^f-\bar{s})\Big)-\frac{\mu_2}{1-l_2^f-s_2^f}\Big\}$$

$$+\lambda_{16}\Big\{\frac{c_2^f}{c_1^f}-\beta\Big(1+(1-\tau_{k,2}^f)r_2^f-\delta\Big)\Big\}$$

$$+\lambda_{17}\Big\{\frac{c_2^f}{c_1^f}-\beta\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\Big)\Big\}$$

$$+\lambda_{18}\Big\{\frac{c_2^f}{c_1^f}-\beta\Big(1+\rho_2^f\Big)\Big\}$$

$$+\lambda_{19}\Big\{g_1^f+\Big(1+(1-\tau_{k,1}^f)r_1^f-\delta\Big)b_1^f-\tau_{k,1}^f r_1^f k_1^f-\tau_{l,1}^f w_1^f l_1^f-b_2^f\Big\}$$

$$+\lambda_{20}\Big\{g_2^f+(1+\rho_2^f)b_2^f-\tau_{k,2}^f r_2^f(k_2^f+f_2^d)-\tau_{l,2}^f w_2^f(l_2^f+s_2^d)\Big\}$$

We solve the problem in its dual form, which means that policymakers, in addition to the independently set policy instruments, re-choose all the allocations and the residually determined instruments of the WDCE system.

The solution to this dual optimization problem yields a system of 42 equations in 42 endogenous variables. Specifically, counting equations, we have the 20 constraints/equations of the WDCE, the optimality conditions for the 20 variables being determined by the WDCE system, plus the four optimality conditions for the independent policy instruments. Counting endogenous variables, we have the 20 variables of the WDCE system, $c_1^d,c_2^d,c_1^f,c_2^f,l_1^d,l_2^d,s_2^d,l_1^f,l_2^f,s_2^f,k_2^d,k_2^f,f_2^d,f_2^f,b_2^d,b_2^f,g_2^d,g_2^f,\rho_2^d,\rho_2^f$, plus the 20 dynamic Lagrangean multipliers corresponding to the 20 equations of the WDCE system, plus the two optimally chosen instruments, $\tau_{k,2}^d$ and $\tau_{l,2}^d$. This is given the independent policy choices of the other country, $\tau_{k,2}^f$ and $\tau_{l,2}^f$, and the assumed exogenous policy instruments $\tau_{k,1}^d,\tau_{k,1}^f,\tau_{l,1}^d,\tau_{l,1}^f,g_1^d$ and g_1^f. The foreign country solves an analogous problem and obtains a similar set of 42 equations in 42 unknowns. In equilibrium, we end up with 64 equations in 64 variables (namely, 42+42-20) since the 20 equations of the WDCE are common to both countries and the same applies to those variables that are endogenous at WDCE level.

B.1.2 Cooperative policies: Definition

The fictional world social planner maximises a weighted average of households' welfare in each country with equal weights given to each one of them. Thus, the objective is now:

$$\max W^{coop}=\gamma U^d+(1-\gamma)U^f$$

subject to the equations summarizing the WDCE (3.15-30). We form the Lagrangian function of the world government as follows

$$L=W^{coop}+$$
$$+\lambda_1\Big\{c_1^d+k_2^d-(1-\delta)k_1^d+f_2^d+g_1^d-y_1^d\Big\}$$

$$+\lambda_2\Big\{c_2^d-(1-\delta)k_2^d+g_2^d-y_2^d+(1-\tau_{k,2}^d)r_2^d f_2^f-\Big(1+(1-\tau_{k,2}^f)r_2^f$$
$$-\delta\Big)f_2^d+m\frac{\left(f_2^d\right)^2}{2}+(1-\tau_{l,2}^d)w_2^d s_2^f-(1-\tau_{l,2}^f)w_2^f s_2^d+j\frac{\left(s_2^d-\bar{s}\right)^2}{2}\Big\}$$
$$+\lambda_3\Big\{\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d-\frac{\mu_2}{1-l_1^d}\Big\}$$

$$+\lambda_4\left\{\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d - \frac{\mu_2}{1-l_2^d-s_2^d}\right\}$$

$$+\lambda_5\left\{\frac{\mu_1}{c_2^d}\left((1-\tau_{l,2}^f)w_2^f - j(s_2^d-\bar{s})\right) - \frac{\mu_2}{1-l_2^d-s_2^d}\right\}$$

$$+\lambda_6\left\{\frac{c_2^d}{c_1^d} - \beta\left(1+(1-\tau_{k,2}^d)r_2^d - \delta\right)\right\}$$

$$+\lambda_7\left\{\frac{c_2^d}{c_1^d} - \beta\left(1+(1-\tau_{k,2}^f)r_2^f - \delta - mf_2^d\right)\right\}$$

$$+\lambda_8\left\{\frac{c_2^d}{c_1^d} - \beta\left(1+\rho_2^d\right)\right\}$$

$$+\lambda_9\left\{g_1^d + \left(1+(1-\tau_{k,1}^d)r_1^d - \delta\right)b_1^d - \tau_{k,1}^d r_1^d k_1^d - \tau_{l,1}^d w_1^d l_1^d - b_2^d\right\}$$

$$+\lambda_{10}\left\{g_2^d + (1+\rho_2^d)b_2^d - \tau_{k,2}^d r_2^d(k_2^d + f_2^f) - \tau_{l,2}^d w_2^d(l_2^d + s_2^f)\right\}$$

$$+\lambda_{11}\left\{c_1^f + k_2^f - (1-\delta)k_1^f + f_2^f + g_1^f - y_1^f\right\}$$

$$+\lambda_{12}\left\{c_2^f - (1-\delta)k_2^f + g_2^f - y_2^f + (1-\tau_{k,2}^f)r_2^f f_2^d - \left(1+(1-\tau_{k,2}^d)r_2^d\right.\right.$$
$$\left.\left.-\delta\right)f_2^f + m\frac{\left(f_2^f\right)^2}{2} + (1-\tau_{l,2}^f)w_2^f s_2^d - (1-\tau_{l,2}^d)w_2^d s_2^f + j\frac{\left(s_2^f-\bar{s}\right)^2}{2}\right\}$$

$$+\lambda_{13}\left\{\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f - \frac{\mu_2}{1-l_1^f}\right\}$$

$$+\lambda_{14}\left\{\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f - \frac{\mu_2}{1-l_2^f-s_2^f}\right\}$$

$$+\lambda_{15}\left\{\frac{\mu_1}{c_2^f}\left((1-\tau_{l,2}^d)w_2^d - j(s_2^f-\bar{s})\right) - \frac{\mu_2}{1-l_2^f-s_2^f}\right\}$$

$$+\lambda_{16}\left\{\frac{c_2^f}{c_1^f} - \beta\left(1+(1-\tau_{k,2}^f)r_2^f - \delta\right)\right\}$$

$$+\lambda_{17}\left\{\frac{c_2^f}{c_1^f} - \beta\left(1+(1-\tau_{k,2}^d)r_2^d - \delta - mf_2^f\right)\right\}$$

$$+\lambda_{18}\left\{\frac{c_2^f}{c_1^f} - \beta\left(1+\rho_2^f\right)\right\}$$

$$+\lambda_{19}\left\{g_1^f + \left(1+(1-\tau_{k,1}^f)r_1^f - \delta\right)b_1^f - \tau_{k,1}^f r_1^f k_1^f - \tau_{l,1}^f w_1^f l_1^f - b_2^f\right\}$$

$$+\lambda_{20}\Big\{g_2^f+(1+\rho_2^f)b_2^f-\tau_{k,2}^f r_2^f(k_2^f+f_2^d)-\tau_{l,2}^f w_2^f(l_2^f+s_2^d)\Big\}$$

The maximization is with respect to the independent policy instruments in the two countries, $\tau_{k,2}^d,\tau_{l,2}^d,\tau_{k,2}^f$ and $\tau_{l,2}^f$. We will thus have a system of 44 equations in 44 unknowns. Counting equations and endogenous variables, we have the 20 constraints/equations corresponding to the 20 variables of the WDCE, $c_1^d,c_2^d,c_1^f,c_2^f,l_1^d,l_2^d,s_2^d,l_1^f,l_2^f,s_2^f,k_2^d,k_2^f,f_2^d,f_2^f$, $b_2^d,b_2^f,g_2^d,g_2^f,\rho_2^d,\rho_2^f$, plus the 20 dynamic Lagrangean multipliers corresponding to the 20 equations of the WDCE system, plus the 4 optimality conditions for the 4 independent policy instruments, $\tau_{k,2}^d$, $\tau_{l,2}^d$, $\tau_{k,2}^f$ and $\tau_{l,2}^f$. This is given the the assumed exogenous policy instruments $\tau_{k,1}^d,\tau_{k,1}^f,\tau_{l,1}^d,\tau_{l,1}^f,g_1^d,g_1^f$.

B.2 Optimal policy without commitment

We now work by backward induction. In other words, we will first consider the second period given first period choices. Within each period, the government moves first. Private agents act competitively in each stage.

B.2.1 Non-cooperative policies (Nash): Definition

Solution of stage (D)

The household in the domestic country maximizes its second-period utility with respect to c_2^d,l_2^d and s_2^d, subject to its second-period budget constraint and treating economic choices as given. We form the Lagrangian function of the domestic household as follows

$$L_2^d=\mu_1\log c_2^d+\mu_2\log(1-l_2^d-s_2^d)+\mu_3\log g_2^d$$

$$+\lambda\Big\{c_2^d-(1-\delta)k_2^d+g_2^d-y_2^d+(1-\tau_{k,2}^d)r_2^d f_2^f-\Big(1+(1-\tau_{k,2}^f)r_2^f$$
$$-\delta\Big)f_2^d+m\frac{(f_2^d)^2}{2}+(1-\tau_{l,2}^d)w_2^d s_2^f-(1-\tau_{l,2}^f)w_2^f s_2^d+j\frac{(s_2^d-\bar{s})^2}{2}\Big\}$$

The equations summarizing this step are the household's second-period budget constraint and the optimality conditions for work at home and abroad:

$$c_2^d=\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta\Big)k_2^d+(1-\tau_{l,2}^d)w_2^d l_2^d+(1+\rho_2^d)b_2^d$$
$$+\Big(1+(1-\tau_{k,2}^f)r_2^f-\delta\Big)f_2^d-m\frac{(f_2^d)^2}{2}+(1-\tau_{l,2}^f)w_2^f s_2^d-j\frac{(s_2^d-\bar{s})^2}{2}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d = \frac{\mu_2}{1-l_2^d-s_2^d}$$

$$\frac{\mu_1}{c_2^d}\Big((1-\tau_{l,2}^f)w_2^f - j(s_2^d-\bar{s})\Big) = \frac{\mu_2}{1-l_2^d-s_2^d}$$

The household in the foreign country solves a similar problem and obtains similar equations:

$$c_2^f = \Big(1+(1-\tau_{k,2}^f)r_2^f-\delta\Big)k_2^f + (1-\tau_{l,2}^f)w_2^f l_2^f + (1+\rho_2^f)b_2^f$$
$$+\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta\Big)f_2^f - m\frac{\left(f_2^f\right)^2}{2} + (1-\tau_{l,2}^d)w_2^d s_2^f - j\frac{\left(s_2^f-\bar{s}\right)^2}{2}$$

$$\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f = \frac{\mu_2}{1-l_2^f-s_2^f}$$

$$\frac{\mu_1}{c_2^f}\Big((1-\tau_{l,2}^d)w_2^d - j(s_2^f-\bar{s})\Big) = \frac{\mu_2}{1-l_2^f-s_2^f}$$

At this stage we have 6 equations in 6 endogenous variables; 4 optimality conditions for the 4 variables being determined by households in the WDCE in the second period, $l_2^d, s_2^d, l_2^f, s_2^f$, plus the two second-period budget constraints that define c_2^d and c_2^f.

Solution of stage (C)

In other words, the domestic government plays Nash by choosing its independently set policy instruments $\tau_{k,2}^d, \tau_{l,2}^d$ to maximise:

$$U_2^d\left(c_2^d, l_2^d, s_2^d, g_2^d\right) = \mu_1 \log c_2^d + \mu_2 \log(1-l_2^d-s_2^d) + \mu_3 \log g_2^d$$

by taking as given the policies of the other government, $\tau_{k,2}^f, \tau_{l,2}^f$, and by taking into account the optimality conditions of *stage (D)*, as well as the second-period budget constraints of the household and the government in each country. We form the Lagrangian function of the domestic government as follows

$$L_2^d = \mu_1 \log c_2^d + \mu_2 \log(1-l_2^d-s_2^d) + \mu_3 \log g_2^d$$

$$+\lambda_1\Big\{c_2^d - (1-\delta)k_2^d + g_2^d - y_2^d + (1-\tau_{k,2}^d)r_2^d f_2^f - \Big(1+(1-\tau_{k,2}^f)r_2^f$$
$$-\delta\Big)f_2^d + m\frac{\left(f_2^d\right)^2}{2} + (1-\tau_{l,2}^d)w_2^d s_2^f - (1-\tau_{l,2}^f)w_2^f s_2^d + j\frac{\left(s_2^d-\bar{s}\right)^2}{2}\Big\}$$
$$+\lambda_2\Big\{\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d - \frac{\mu_2}{1-l_2^d-s_2^d}\Big\}$$

$$+\lambda_3\left\{\frac{\mu_1}{c_2^d}\left((1-\tau_{l,2}^f)w_2^f-j(s_2^d-\bar{s})\right)-\frac{\mu_2}{1-l_2^d-s_2^d}\right\}$$

$$+\lambda_4\left\{g_2^d+(1+\rho_2^d)b_2^d-\tau_{k,2}^d r_2^d(k_2^d+f_2^f)-\tau_{l,2}^d w_2^d(l_2^d+s_2^f)\right\}$$

$$+\lambda_5\Big\{c_2^f-(1-\delta)k_2^f+g_2^f-y_2^f+(1-\tau_{k,2}^f)r_2^f f_2^d-\Big(1+(1-\tau_{k,2}^d)r_2^d$$
$$-\delta\Big)f_2^f+m\frac{\left(f_2^f\right)^2}{2}+(1-\tau_{l,2}^f)w_2^f s_2^d-(1-\tau_{l,2}^d)w_2^d s_2^f+j\frac{\left(s_2^f-\bar{s}\right)^2}{2}\Big\}$$

$$+\lambda_6\left\{\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f-\frac{\mu_2}{1-l_2^f-s_2^f}\right\}$$

$$+\lambda_7\left\{\frac{\mu_1}{c_2^f}\left((1-\tau_{l,2}^d)w_2^d-j(s_2^f-\bar{s})\right)-\frac{\mu_2}{1-l_2^f-s_2^f}\right\}$$

$$+\lambda_8\left\{g_2^f+(1+\rho_2^f)b_2^f-\tau_{k,2}^f r_2^f(k_2^f+f_2^d)-\tau_{l,2}^f w_2^f(l_2^f+s_2^d)\right\}$$

We solve the problem in its dual form. From the viewpoint of the domestic policymaker, the solution to this dual optimization problem in *stage (C)* yields a system of 18 equations in 18 endogenous variables. Specifically, we have the 8 variables of the WDCE system in the second period (4 optimality conditions from *stage (D)*, 2 household and 2 government budget constraints), $c_2^d, c_2^f, l_2^d, s_2^d, l_2^f, s_2^f, g_2^d, g_2^f$, plus the 8 dynamic Lagrangean multipliers corresponding to the 8 equations of the WDCE system, plus the two optimally chosen instruments, $\tau_{k,2}^d$ and $\tau_{l,2}^d$. This is given the independent policy choices of the other country, $\tau_{k,2}^f$ and $\tau_{l,2}^f$. The foreign country solves an analogous problem and obtains a similar set of 18 equations in 18 unknowns.

At this stage, we end up with a system of 28 equations in 28 variables (namely, 18+18-8) since the 8 equations of the WDCE are common to both countries and the same applies to the 8 variables that are endogenous at WDCE level.

Solution of stage (B)

The household in the domestic country maximizes its lifetime discounted utility by choosing $c_1^d, l_1^d, k_2^d, f_2^d$ and b_2^d, taking as given the choices of the foreign household and taking into account its budget constraints and its labor optimality conditions of *stage (D)*. We form the Lagrangian function of the domestic household as follows:

$$L=\mu_1\log c_1^d+\mu_2\log(1-l_1^d)+\mu_3\log g_1^d+\beta\left(\mu_1\log c_2^d+\mu_2\log(1-l_2^d-s_2^d)+\mu_3\log g_2^d\right)$$

$$+\lambda_1\left\{c_1^d+k_2^d-(1-\delta)k_1^d+f_2^d+g_1^d-y_1^d\right\}$$

$$+\lambda_2\Big\{c_2^d-(1-\delta)k_2^d+g_2^d-y_2^d+(1-\tau_{k,2}^d)r_2^d f_2^f-\Big(1+(1-\tau_{k,2}^f)r_2^f$$
$$-\delta\Big)f_2^d+m\frac{\left(f_2^d\right)^2}{2}+(1-\tau_{l,2}^d)w_2^d s_2^f-(1-\tau_{l,2}^f)w_2^f s_2^d+j\frac{\left(s_2^d-\bar{s}\right)^2}{2}\Big\}$$

$$+\lambda_3\left\{\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d-\frac{\mu_2}{1-l_2^d-s_2^d}\right\}$$

$$+\lambda_4\left\{\frac{\mu_1}{c_2^d}\Big((1-\tau_{l,2}^f)w_2^f-j(s_2^d-\bar{s})\Big)-\frac{\mu_2}{1-l_2^d-s_2^d}\right\}$$

The optimality conditions associated with this step are:

$$\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d=\frac{\mu_2}{1-l_1^d}$$

$$\frac{\mu_1}{c_1^d}=\beta\left\{\frac{\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta\Big)\mu_1^2}{(\mu_1+\mu_2)c_2^d}+\frac{\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta\Big)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^d)w_2^d(1-l_2^d-s_2^d)}\right\}$$

$$\frac{\mu_1}{c_1^d}=\beta\left\{\frac{\Big(1+(1-\tau_{k,2}^f)r_2^f-\delta-mf_2^d\Big)\mu_1^2}{(\mu_1+\mu_2)c_2^d}+\frac{\Big(1+(1-\tau_{k,2}^f)r_2^f-\delta-mf_2^d\Big)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^d)w_2^d(1-l_2^d-s_2^d)}\right\}$$

$$\frac{\mu_1}{c_1^d}=\beta\left\{\frac{\left(1+\rho_2^d\right)\mu_1^2}{(\mu_1+\mu_2)c_2^d}+\frac{\left(1+\rho_2^d\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^d)w_2^d(1-l_2^d-s_2^d)}\right\}$$

The household in the foreign country solves a similar problem and obtains similar equations:

$$\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f=\frac{\mu_2}{1-l_1^f}$$

$$\frac{\mu_1}{c_1^f}=\beta\left\{\frac{\Big(1+(1-\tau_{k,2}^f)r_2^f-\delta\Big)\mu_1^2}{(\mu_1+\mu_2)c_2^f}+\frac{\Big(1+(1-\tau_{k,2}^f)r_2^f-\delta\Big)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^f)w_2^f(1-l_2^f-s_2^f)}\right\}$$

$$\frac{\mu_1}{c_1^f}=\beta\left\{\frac{\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\Big)\mu_1^2}{(\mu_1+\mu_2)c_2^f}+\frac{\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\Big)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^f)w_2^f(1-l_2^f-s_2^f)}\right\}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+\rho_2^f\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+\rho_2^f\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^f)w_2^f(1-l_2^f-s_2^f)}\right\}$$

Therefore, at this stage we have 10 new equations in 10 endogenous variables, namely, 8 optimality conditions in $l_1^d, k_2^d, f_2^d, \rho_2^d, l_1^f, k_2^f, f_2^f, \rho_2^f$ and 2 first-period budget constraints that define c_1^d and c_1^f.

Solution of stage (A)

The end-of period government bonds, b_2^d and b_2^f, residually adjust to close the first-period government budget constraint in each country, given that the rest of first-period policy variables, $\tau_{k,1}^d, \tau_{k,1}^f, \tau_{l,1}^d, \tau_{l,1}^f, g_1^d, g_1^f$, are assumed to be exogenous. As said this is for keeping the model relatively simple.

Non-cooperative (Nash) equilibrium without commitment

The non-cooperative equilibrium (Nash) without commitment is a system of 40 equations in 40 endogenous variables. Particularly, we have the 20 constraints/equations corresponding to the 20 variables of the WDCE system, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, s_2^d, l_1^f, l_2^f, s_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, g_2^d, g_2^f, \rho_2^d, \rho_2^f$, plus the 16 dynamic Lagrangean multipliers corresponding to the 16 optimality conditions of *stage (C)*, plus the four optimally chosen instruments, $\tau_{k,2}^d, \tau_{l,2}^d, \tau_{k,2}^f, \tau_{l,2}^f$. This is given the assumed exogenous policy instruments $\tau_{k,1}^d, \tau_{k,1}^f, \tau_{l,1}^d, \tau_{l,1}^f, g_1^d$ and g_1^f.

B.2.2 Cooperative policies: Definition

Solution of stage (D)

The solution here is identical to the one in *stage (D)* in the non-cooperative regime.

$$\begin{aligned} c_2^d = & \left(1+(1-\tau_{k,2}^d)r_2^d-\delta\right)k_2^d + (1-\tau_{l,2}^d)w_2^d l_2^d + (1+\rho_2^d)b_2^d \\ & + \left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)f_2^d - m\frac{\left(f_2^d\right)^2}{2} + (1-\tau_{l,2}^f)w_2^f s_2^d - j\frac{\left(s_2^d-\bar{s}\right)^2}{2} \end{aligned}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d = \frac{\mu_2}{1-l_2^d-s_2^d}$$

$$\frac{\mu_1}{c_2^d}\left((1-\tau_{l,2}^f)w_2^f - j(s_2^d-\bar{s})\right) = \frac{\mu_2}{1-l_2^d-s_2^d}$$

$$c_2^f = \Big(1 + (1 - \tau_{k,2}^f) r_2^f - \delta\Big) k_2^f + (1 - \tau_{l,2}^f) w_2^f l_2^f + (1 + \rho_2^f) b_2^f$$
$$+ \Big(1 + (1 - \tau_{k,2}^d) r_2^d - \delta\Big) f_2^f - m \frac{\left(f_2^f\right)^2}{2} + (1 - \tau_{l,2}^d) w_2^d s_2^f - j \frac{\left(s_2^f - \bar{s}\right)^2}{2}$$
$$\frac{\mu_1}{c_2^f}(1 - \tau_{l,2}^f) w_2^f = \frac{\mu_2}{1 - l_2^f - s_2^f}$$
$$\frac{\mu_1}{c_2^f}\Big((1 - \tau_{l,2}^d) w_2^d - j(s_2^f - \bar{s})\Big) = \frac{\mu_2}{1 - l_2^f - s_2^f}$$

Hence, we have 6 equations in 6 endogenous variables. Particularly, counting equations we have 4 optimality conditions for the 4 variables being determined by households in the WDCE in the second period, $l_2^d, s_2^d, l_2^f, s_2^f$, plus the two second-period budget constraints that define c_2^d and c_2^f.

Solution of stage (C)

The fictional world social planner maximises a weighted average of households' welfare in each country with equal weights given to each one of them. Thus, the objective is now:

$$\max W^{coop} = \gamma\Big(\mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d - s_2^d) + \mu_3 \log g_2^d\Big)$$
$$+ (1 - \gamma)\Big(\mu_1 \log c_2^f + \mu_2 \log(1 - l_2^f - s_2^f) + \mu_3 \log g_2^f\Big)$$

subject to the government budget constraints and the optimality conditions/constraints that summarize the solution of *stage (D)* above. We form the Langrangean function of the world social planner as follows:

$$L = W^{coop} +$$

$$+\lambda_1\Big\{c_2^d - (1 - \delta)k_2^d + g_2^d - y_2^d + (1 - \tau_{k,2}^d) r_2^d f_2^f - \Big(1 + (1 - \tau_{k,2}^f) r_2^f$$
$$- \delta\Big) f_2^d + m\frac{\left(f_2^d\right)^2}{2} + (1 - \tau_{l,2}^d) w_2^d s_2^f - (1 - \tau_{l,2}^f) w_2^f s_2^d + j\frac{\left(s_2^d - \bar{s}\right)^2}{2}\Big\}$$
$$+\lambda_2\Big\{\frac{\mu_1}{c_2^d}(1 - \tau_{l,2}^d) w_2^d - \frac{\mu_2}{1 - l_2^d - s_2^d}\Big\}$$
$$+\lambda_3\Big\{\frac{\mu_1}{c_2^d}\Big((1 - \tau_{l,2}^f) w_2^f - j(s_2^d - \bar{s})\Big) - \frac{\mu_2}{1 - l_2^d - s_2^d}\Big\}$$
$$+\lambda_4\Big\{g_2^d + (1 + \rho_2^d) b_2^d - \tau_{k,2}^d r_2^d (k_2^d + f_2^f) - \tau_{l,2}^d w_2^d (l_2^d + s_2^f)\Big\}$$

$$+\lambda_5\Big\{c_2^f-(1-\delta)k_2^f+g_2^f-y_2^f+(1-\tau_{k,2}^f)r_2^f f_2^d-\Big(1+(1-\tau_{k,2}^d)r_2^d$$
$$-\delta\Big)f_2^f+m\frac{\left(f_2^f\right)^2}{2}+(1-\tau_{l,2}^f)w_2^f s_2^d-(1-\tau_{l,2}^d)w_2^d s_2^f+j\frac{\left(s_2^f-\bar{s}\right)^2}{2}\Big\}$$
$$+\lambda_6\Big\{\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f-\frac{\mu_2}{1-l_2^f-s_2^f}\Big\}$$
$$+\lambda_7\Big\{\frac{\mu_1}{c_2^f}\Big((1-\tau_{l,2}^d)w_2^d-j(s_2^f-\bar{s})\Big)-\frac{\mu_2}{1-l_2^f-s_2^f}\Big\}$$
$$+\lambda_8\Big\{g_2^f+(1+\rho_2^f)b_2^f-\tau_{k,2}^f r_2^f(k_2^f+f_2^d)-\tau_{l,2}^f w_2^f(l_2^f+s_2^d)\Big\}$$

The maximization is with respect to the independent policy instruments in the two countries, $\tau_{k,2}^d,\tau_{l,2}^d,\tau_{k,2}^f$ and $\tau_{l,2}^f$. Following usual practice we solve the problem in its dual form.

At this stage, we will have a system of 20 equations in 20 endogenous variables. Specifically, counting equations, we have the 8 constraints/equations of the WDCE in the second period (4 optimality conditions from *stage (D)*, 2 household and 2 government budget constraints), the optimality conditions for the 8 variables being determined by the WDCE system, plus the four optimality conditions for the independent policy instruments, $\tau_{k,2}^d,\tau_{l,2}^d,\tau_{k,2}^f$ and $\tau_{l,2}^f$. Counting endogenous variables, we have the 8 variables of the WDCE system, $c_2^d,c_2^f,l_2^d,l_2^f,s_2^d,s_2^f,g_2^d,g_2^f$, plus the 8 dynamic Lagrangean multipliers corresponding to the 8 equations of the WDCE system, plus the four optimally chosen instruments, $\tau_{k,2}^d,\tau_{l,2}^d,\tau_{k,2}^f$ and $\tau_{l,2}^f$.

Solution of stage (B)

Again, the solution of this stage is identical to the one in *stage (B)* in the non-cooperative regime.

$$\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d=\frac{\mu_2}{1-l_1^d}$$

$$\frac{\mu_1}{c_1^d}=\beta\left\{\frac{\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta\Big)\mu_1^2}{(\mu_1+\mu_2)c_2^d}+\frac{\Big(1+(1-\tau_{k,2}^d)r_2^d-\delta\Big)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^d)w_2^d(1-l_2^d-s_2^d)}\right\}$$

$$\frac{\mu_1}{c_1^d}=\beta\left\{\frac{\Big(1+(1-\tau_{k,2}^f)r_2^f-\delta-mf_2^d\Big)\mu_1^2}{(\mu_1+\mu_2)c_2^d}+\frac{\Big(1+(1-\tau_{k,2}^f)r_2^f-\delta-mf_2^d\Big)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^d)w_2^d(1-l_2^d-s_2^d)}\right\}$$

$$\frac{\mu_1}{c_1^d} = \beta\left\{\frac{\left(1+\rho_2^d\right)\mu_1^2}{(\mu_1+\mu_2)c_2^d} + \frac{\left(1+\rho_2^d\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^d)w_2^d(1-l_2^d-s_2^d)}\right\}$$

$$\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f = \frac{\mu_2}{1-l_1^f}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^f)w_2^f(1-l_2^f-s_2^f)}\right\}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^f)w_2^f(1-l_2^f-s_2^f)}\right\}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+\rho_2^f\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+\rho_2^f\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_{l,2}^f)w_2^f(1-l_2^f-s_2^f)}\right\}$$

At this stage we have 10 new equations in 10 endogenous variables, namely, 8 optimality conditions in $l_1^d, k_2^d, f_2^d, \rho_2^d, l_1^f, k_2^f, f_2^f, \rho_2^f$ and 2 first-period budget constraints that define c_1^d and c_1^f.

Solution of stage (A)

The end-of period government bonds, b_2^d and b_2^f, residually adjust to close the first-period government budget constraint in each country, given that the rest of first-period policy variables, $\tau_{k,1}^d, \tau_{k,1}^f, \tau_{l,1}^d, \tau_{l,1}^f, g_1^d, g_1^f$, are assumed to be exogenous. As said this is for keeping the model relatively simple.

Cooperative equilibrium without commitment

The cooperative equilibrium without commitment is a system of 32 equations in 32 endogenous variables. Particularly, we have the 20 constraints/equations corresponding to the 20 variables of the WDCE system, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, s_2^d, l_1^f, l_2^f, s_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, g_2^d, g_2^f, \rho_2^d, \rho_2^f$, plus the 8 dynamic Lagrangean multipliers corresponding to the 8 optimality conditions of *stage (C)*, plus the four optimally chosen instruments, $\tau_{k,2}^d, \tau_{l,2}^d, \tau_{k,2}^f, \tau_{l,2}^f$. This is given the assumed exogenous policy instruments $\tau_{k,1}^d, \tau_{k,1}^f, \tau_{l,1}^d, \tau_{l,1}^f, g_1^d$ and g_1^f.

B.3 Numerical solutions for symmetric economies

B.3.1 Symmetric WDCE (for any feasible policy)

Table B.1 World decentralized competitive equilibrium (for any feasible policy)

Allocations				**Shares**				**Resid policy**		**Net returns**	
c_1	0.2288	c_2	0.1274	c_1/y_1	0.6731	c_2/y_2	0.9080	g_2	0.0129	R_1	0.2312
k_1	*0.5000	k_2	0.0771	i_1/y_1	0.2269	i_2/y_2	0.0000			R_2	0.6185
b_1	**0.2040	b_2	0.0200	f_1/y_1	0.0000	f_2/y_2	0.0000			W_1	0.6208
f_1	0.0000	f_2	0.0000	g_1/y_1	*0.1000	g_2/y_2	0.0920	**Exog policy**		W_2	0.3221
l_1	0.2628	l_2	0.2091	k_1/y_1	**1.4709	k_2/y_2	0.5497	τ_2^k	*0.1500	**Welfare**	
y_1	0.3399	y_2	0.1403	b_1/y_1	*0.6000	b_2/y_2	0.1422	τ_2^l	*0.2000	W	-2.0380

* *refers to initial parameter values.* ** *refers to initial parameters that were calculated jointly with the rest of the endogenous variables of the model.*

B.3.2 Comparison of equilibria and gains from cooperation

Table B.2 Commitment-type symmetric Nash equilibrium (SNE), benchmark case

Allocations				**Shares**				**Optimal policy**		**Net returns**	
c_1	0.2185	c_2	0.1283	c_1/y_1	0.6522	c_2/y_2	0.8849	τ_2^k	0.0659	R_1	0.2278
k_1	*0.5000	k_2	0.0830	i_1/y_1	0.2478	i_2/y_2	0.0000	τ_2^l	0.2149	R_2	0.6524
b_1	**0.2010	b_2	0.0089	f_1/y_1	0.0000	f_2/y_2	0.0000	g_2	0.0167	W_1	0.5877
l_1	0.2565	l_2	0.1102	g_1/y_1	*0.1000	g_2/y_2	0.1151			W_2	0.3248
s_1	-	s_2	0.1000	k_1/y_1	**1.4925	k_2/y_2	0.5727	**Exog policy**		**Welfare**	
y_1	0.3350	y_2	0.1450	b_1/y_1	*0.6000	b_2/y_2	0.0617	g_1	**0.0335	W	-2.0240

Table B.3 Commitment-type symmetric cooperative equilibrium (SCE), benchmark case

Allocations				**Shares**				**Optimal policy**		**Net returns**	
c_1	0.2192	c_2	0.1089	c_1/y_1	0.6560	c_2/y_2	0.7500	τ_2^k	0.2250	R_1	0.2272
k_1	*0.5000	k_2	0.0815	i_1/y_1	0.2440	i_2/y_2	0.0000	τ_2^l	0.3224	R_2	0.5519
b_1	**0.2005	b_2	0.0088	f_1/y_1	0.0000	f_2/y_2	0.0000	g_2	0.0363	W_1	0.5887
l_1	0.2554	l_2	0.1132	g_1/y_1	*0.1000	g_2/y_2	0.2500			W_2	0.2768
s_1	-	s_2	0.1000	k_1/y_1	**1.4964	k_2/y_2	0.5617	**Exog policy**		**Welfare**	
y_1	0.3341	y_2	0.1452	b_1/y_1	*0.6000	b_2/y_2	0.0606	g_1	**0.0334	W	-1.9989

Table B.4 Non-commitment symmetric Nash equilibrium (SNE), benchmark case

Allocations				**Shares**				**Optimal policy**		**Net returns**	
c_1	0.2321	c_2	0.1021	c_1/y_1	0.7286	c_2/y_2	0.7305	τ_2^k	0.5226	R_1	0.2167
k_1	*0.5000	k_2	0.0546	i_1/y_1	0.1714	i_2/y_2	0.0000	τ_2^l	0.1378	R_2	0.4887
b_1	**0.1912	b_2	0.0064	f_1/y_1	0.0000	f_2/y_2	0.0000	g_2	0.0377	W_1	0.6077
l_1	0.2360	l_2	0.1615	g_1/y_1	*0.1000	g_2/y_2	0.2695			W_2	0.2765
s_1	-	s_2	0.1000	k_1/y_1	**1.5692	k_2/y_2	0.3908	**Exog policy**		**Welfare**	
y_1	0.3186	y_2	0.1398	b_1/y_1	*0.6000	b_2/y_2	0.0456	g_1	**0.0319	W	-2.0191

Table B.5 Non-commitment symmetric cooperative equilibrium (SCE), benchmark case

Allocations				**Shares**				**Optimal policy**		**Net returns**	
c_1	0.2402	c_2	0.0958	c_1/y_1	0.7765	c_2/y_2	0.7500	τ_2^k	0.6686	R_1	0.2104
k_1	*0.5000	k_2	0.0382	i_1/y_1	0.1235	i_2/y_2	0.0000	τ_2^l	0.0000	R_2	0.4433
b_1	**0.1856	b_2	0.0050	f_1/y_1	0.0000	f_2/y_2	0.0000	g_2	0.0319	W_1	0.6197
l_1	0.2247	l_2	0.1857	g_1/y_1	*0.1000	g_2/y_2	0.2500			W_2	0.2683
s_1	-	s_2	0.1000	k_1/y_1	**1.6161	k_2/y_2	0.2991	**Exog policy**		**Welfare**	
y_1	0.3094	y_2	0.1278	b_1/y_1	*0.6000	b_2/y_2	0.0393	g_1	**0.0309	W	-2.0529

* *refers to initial parameter values.* ** *refers to initial parameters that were calculated jointly with the rest of the endogenous variables of the model.*

B.3.3 Robustness analysis

Table B.6 Robustness analysis of public good valuation, μ_3, commitment

Symmetric Nash equilibria (SNE)													
μ_3	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.10	0.0659	0.2149	0.0830	0.3350	0.1450	0.2185	0.1283	0.2565	0.1102	0.1000	0.0335	0.0167	-2.0240
0.07	0.0537	0.2020	0.0815	0.3279	0.1410	0.2136	0.1260	0.2475	0.1033	0.1000	0.0328	0.0150	-1.8341
0.05	0.0417	0.1905	0.0805	0.3234	0.1385	0.2106	0.1250	0.2418	0.0989	0.1000	0.0323	0.0135	-1.7039
0.03	0.0223	0.1734	0.0795	0.3190	0.1361	0.2076	0.1250	0.2364	0.0947	0.1000	0.0319	0.0111	-1.5693
Symmetric cooperative equilibria (SCE)													
μ_3	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.10	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989
0.07	0.1568	0.2646	0.0802	0.3271	0.1412	0.2142	0.1145	0.2466	0.1058	0.1000	0.0327	0.0267	-1.8241
0.05	0.1047	0.2209	0.0794	0.3227	0.1386	0.2111	0.1188	0.2410	0.1011	0.1000	0.0323	0.0198	-1.7005
0.03	0.0460	0.1722	0.0786	0.3185	0.1362	0.2080	0.1238	0.2357	0.0965	0.1000	0.0318	0.0124	-1.5691

Table B.7 Robustness analysis of public good valuation, μ_3, non-commitment

Symmetric Nash equilibria (SNE)													
μ_3	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.10	0.5226	0.1378	0.0546	0.3186	0.1398	0.2321	0.1021	0.2360	0.1615	0.1000	0.0319	0.0377	-2.0191
0.07	0.3765	0.1303	0.0628	0.3169	0.1397	0.2225	0.1111	0.2339	0.1380	0.1000	0.0317	0.0286	-1.8318
0.05	0.2632	0.1256	0.0679	0.3159	0.1385	0.2164	0.1171	0.2326	0.1227	0.1000	0.0316	0.0214	-1.7035
0.03	0.1345	0.1211	0.0728	0.3150	0.1365	0.2107	0.1231	0.2315	0.1076	0.1000	0.0315	0.0135	-1.5696
Symmetric cooperative equilibria (SCE)													
μ_3	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.10	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529
0.07	0.5216	0.0000	0.0487	0.3088	0.1332	0.2293	0.1080	0.2240	0.1606	0.1000	0.0309	0.0252	-1.8490
0.05	0.4095	0.0000	0.0552	0.3085	0.1347	0.2225	0.1154	0.2236	0.1442	0.1000	0.0309	0.0192	-1.7138
0.03	0.2840	0.0000	0.0613	0.3082	0.1348	0.2161	0.1226	0.2232	0.1281	0.1000	0.0308	0.0123	-1.5749

Table B.8 Symmetric robustness analysis of TFP, A, commitment

Symmetric Nash equilibria (SNE)													
A	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
1.00	0.0659	0.2149	0.0830	0.3350	0.1450	0.2185	0.1283	0.2565	0.1102	0.1000	0.0335	0.0167	-2.0240
0.90	0.0617	0.2242	0.0768	0.3027	0.1274	0.1957	0.1097	0.2582	0.1128	0.1000	0.0303	0.0177	-2.1073
0.80	0.0578	0.2329	0.0701	0.2702	0.1100	0.1730	0.0921	0.2599	0.1156	0.1000	0.0270	0.0179	-2.2051
0.70	0.0544	0.2407	0.0629	0.2373	0.0929	0.1507	0.0758	0.2617	0.1184	0.1000	0.0237	0.0172	-2.3194
Symmetric cooperative equilibria (SCE)													
A	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
1.00	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989
0.90	0.2044	0.3083	0.0750	0.3017	0.1276	0.1965	0.0957	0.2568	0.1167	0.1000	0.0302	0.0319	-2.0918
0.80	0.1835	0.2938	0.0682	0.2690	0.1102	0.1740	0.0827	0.2581	0.1203	0.1000	0.0269	0.0276	-2.1961
0.70	0.1622	0.2790	0.0610	0.2362	0.0931	0.1516	0.0698	0.2596	0.1238	0.1000	0.0236	0.0233	-2.3147

Table B.9 Symmetric robustness analysis of TFP, A, non-commitment

Symmetric Nash equilibria (SNE)													
A	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
1.00	0.5226	0.1378	0.0546	0.3186	0.1398	0.2321	0.1021	0.2360	0.1615	0.1000	0.0319	0.0377	-2.0191
0.90	0.4800	0.1463	0.0531	0.2890	0.1240	0.2070	0.0904	0.2391	0.1599	0.1000	0.0289	0.0336	-2.1078
0.80	0.4347	0.1559	0.0510	0.2590	0.1079	0.1822	0.0785	0.2424	0.1582	0.1000	0.0259	0.0294	-2.2084
0.70	0.3864	0.1669	0.0480	0.2286	0.0918	0.1578	0.0666	0.2459	0.1562	0.1000	0.0229	0.0252	-2.3238
Symmetric cooperative equilibria (SCE)													
A	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
1.00	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529
0.90	0.6367	0.0000	0.0374	0.2802	0.1141	0.2147	0.0855	0.2270	0.1857	0.1000	0.0280	0.0285	-2.1392
0.80	0.6036	0.0000	0.0361	0.2506	0.0999	0.1895	0.0749	0.2293	0.1857	0.1000	0.0251	0.0250	-2.2376
0.70	0.5692	0.0000	0.0340	0.2207	0.0854	0.1646	0.0640	0.2318	0.1857	0.1000	0.0221	0.0213	-2.3508

Table B.10 Robustness analysis of initial public debt-to-GDP ratio, s_1^b, commitment

Symmetric Nash equilibria (SNE)													
s_1^b	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.60	0.0659	0.2149	0.0830	0.3350	0.1450	0.2185	0.1283	0.2565	0.1102	0.1000	0.0335	0.0167	-2.0240
0.70	0.0791	0.2160	0.0798	0.3331	0.1405	0.2200	0.1283	0.2541	0.1048	0.1000	0.0333	0.0122	-2.0453
0.80	0.0928	0.2160	0.0767	0.3313	0.1361	0.2215	0.1284	0.2518	0.0996	0.1000	0.0331	0.0077	-2.0793
0.90	0.1071	0.2148	0.0735	0.3295	0.1318	0.2230	0.1285	0.2495	0.0946	0.1000	0.0329	0.0033	-2.1486
Symmetric cooperative equilibria (SCE)													
s_1^b	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.60	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989
0.70	0.2586	0.3452	0.0785	0.3324	0.1407	0.2206	0.1055	0.2532	0.1076	0.1000	0.0332	0.0352	-2.0030
0.80	0.2912	0.3671	0.0755	0.3306	0.1363	0.2220	0.1022	0.2510	0.1020	0.1000	0.0331	0.0341	-2.0075
0.90	0.3228	0.3882	0.0726	0.3290	0.1320	0.2234	0.0990	0.2488	0.0966	0.1000	0.0329	0.0330	-2.0123

Table B.11 Robustness analysis of initial public debt-to-GDP ratio, s_1^b, non-commitment

Symmetric Nash equilibria (SNE)													
s_1^b	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.60	0.5226	0.1378	0.0546	0.3186	0.1398	0.2321	0.1021	0.2360	0.1615	0.1000	0.0319	0.0377	-2.0191
0.70	0.5738	0.1405	0.0493	0.3156	0.1340	0.2347	0.0979	0.2323	0.1610	0.1000	0.0316	0.0362	-2.0285
0.80	0.6217	0.1433	0.0443	0.3128	0.1282	0.2372	0.0936	0.2288	0.1605	0.1000	0.0313	0.0347	-2.0392
0.90	0.6667	0.1463	0.0394	0.3101	0.1223	0.2396	0.0891	0.2255	0.1599	0.1000	0.0310	0.0331	-2.0512
Symmetric cooperative equilibria (SCE)													
s_1^b	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.60	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529
0.70	0.7191	0.0000	0.0328	0.3064	0.1201	0.2430	0.0901	0.2210	0.1857	0.1000	0.0306	0.0300	-2.0699
0.80	0.7668	0.0000	0.0275	0.3035	0.1120	0.2456	0.0840	0.2175	0.1857	0.1000	0.0303	0.0280	-2.0901
0.90	0.8118	0.0000	0.0224	0.3007	0.1032	0.2482	0.0774	0.2142	0.1857	0.1000	0.0301	0.0258	-2.1148

Table B.12 Robustness analysis of capital mobility cost, m, commitment

Symmetric Nash equilibria (SNE)													
m	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.10	0.0659	0.2149	0.0830	0.3350	0.1450	0.2185	0.1283	0.2565	0.1102	0.1000	0.0335	0.0167	-2.0240
10.00	0.1754	0.2620	0.0807	0.3336	0.1453	0.2196	0.1174	0.2547	0.1150	0.1000	0.0334	0.0279	-2.0026
100.00	0.2128	0.2788	0.0798	0.3331	0.1453	0.2200	0.1136	0.2541	0.1168	0.1000	0.0333	0.0317	-2.0000
1000.00	0.2177	0.2811	0.0797	0.3330	0.1453	0.2201	0.1131	0.2540	0.1170	0.1000	0.0333	0.0322	-1.9998
Symmetric cooperative equilibria (SCE)													
m	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.10	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989
10.00	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989
100.00	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989
1000.00	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989

Table B.13 Robustness analysis of capital mobility cost, m, non-commitment

Symmetric Nash equilibria (SNE)													
m	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.10	0.5226	0.1378	0.0546	0.3186	0.1398	0.2321	0.1021	0.2360	0.1615	0.1000	0.0319	0.0377	-2.0191
10.00	0.5226	0.1378	0.0546	0.3186	0.1398	0.2321	0.1021	0.2360	0.1615	0.1000	0.0319	0.0377	-2.0191
100.00	0.5226	0.1378	0.0546	0.3186	0.1398	0.2321	0.1021	0.2360	0.1615	0.1000	0.0319	0.0377	-2.0191
1000.00	0.5226	0.1378	0.0546	0.3186	0.1398	0.2321	0.1021	0.2360	0.1615	0.1000	0.0319	0.0377	-2.0191
Symmetric cooperative equilibria (SCE)													
m	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.10	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529
10.00	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529
100.00	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529
1000.00	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529

Table B.14 Robustness analysis of labour mobility cost, j, commitment

Symmetric Nash equilibria (SNE)													
j	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.30	0.0215	0.0692	0.0783	0.3323	0.1454	0.2207	0.1443	0.2530	0.1196	0.1000	0.0332	0.0011	-2.2373
2.00	0.0659	0.2149	0.0830	0.3350	0.1450	0.2185	0.1283	0.2565	0.1102	0.1000	0.0335	0.0167	-2.0240
10.00	0.0927	0.2959	0.0860	0.3368	0.1444	0.2171	0.1190	0.2587	0.1040	0.1000	0.0337	0.0254	-2.0055
100.00	0.1015	0.3210	0.0870	0.3373	0.1442	0.2166	0.1161	0.2595	0.1019	0.1000	0.0337	0.0281	-2.0028
Symmetric cooperative equilibria (SCE)													
j	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.30	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989
2.00	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989
10.00	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989
100.00	0.2250	0.3224	0.0815	0.3341	0.1452	0.2192	0.1089	0.2554	0.1132	0.1000	0.0334	0.0363	-1.9989

Table B.15 Robustness analysis of labour mobility cost, j, non-commitment

Symmetric Nash equilibria (SNE)													
j	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.30	0.6283	0.0369	0.0427	0.3119	0.1318	0.2380	0.0982	0.2277	0.1794	0.1000	0.0312	0.0336	-2.0413
2.00	0.5226	0.1378	0.0546	0.3186	0.1398	0.2321	0.1021	0.2360	0.1615	0.1000	0.0319	0.0377	-2.0191
10.00	0.4366	0.2256	0.0645	0.3243	0.1437	0.2274	0.1028	0.2429	0.1452	0.1000	0.0324	0.0409	-2.0081
100.00	0.4029	0.2620	0.0684	0.3265	0.1446	0.2254	0.1024	0.2458	0.1382	0.1000	0.0327	0.0422	-2.0053
Symmetric cooperative equilibria (SCE)													
j	τ_2^k	τ_2^l	k_2	y_1	y_2	c_1	c_2	l_1	l_2	s_2	g_1	g_2	W
0.30	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529
2.00	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529
10.00	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529
100.00	0.6686	0.0000	0.0382	0.3094	0.1278	0.2402	0.0958	0.2247	0.1857	0.1000	0.0309	0.0319	-2.0529

B.4 Numerical solutions for non-symmetric economies

B.4.1 Modelling product market competition

The domestic country will be denoted by the superscript d and the foreign country by the superscript f. The problems of agents (households, firms and the government) in each country are analogous so we will present the domestic economy only, except otherwise stated.

Households

Each household $q = 1, 2, ..., N$ offers differentiated labour services so that there is market power over his/her wages. This means that welfare maximization is also subject to the demand condition for q's labor services (this comes from the intermediate goods firms' problem below):

$$w_{q,2}^d = w_2^d \left(\frac{l_{q,2}^d}{N l_{i,2}^d} \right)^{\psi^d - 1}$$

where w_2^d is the average wage rate, $l_{q,2}^d$ is labour services provided by the household of type q to all intermediate goods firms N, and $l_{i,2}^d$ is labour services provided by all types of households to each intermediate goods firm i. The first-order condition for labour supply at home in the second period is

$$\frac{\mu_1}{c_2^d}(1 - \tau_{l,2}^d) = \frac{\mu_2}{1 - l_2^d - s_2^d}$$

Firms

There is a single final good and $i = 1, 2, ..., N$ differentiated intermediate goods used for the production of the final good. The final good is produced by a single final good firm that acts competitively, while each differentiated intermediate good i is produced by an intermediate goods firm i that acts as a monopolist in its own product market. We will model firms, and hence market power in the product market, in the standard Dixit-Stiglitz way (see e.g. any macro textbook and *Guo and Lansing 1999*[22], and *Bénassy 2005, chapter 6*[9]).

Final good firm

The final good firm produces y_2^d by using intermediate goods $y_{i,2}^d$ according to a Dixit-Stiglitz production function:

$$y_2^d = \left[\sum_{i=1}^{N} \frac{1}{N} (y_{i,2}^d)^{\phi^d} \right]^{\frac{1}{\phi^d}}$$

where $y_{i,2}^d$ denotes the quantity of the intermediate good of variety $i = 1, 2, ..., N$ used by the final good firm and $0 \leq \phi^d \leq 1$ is a parameter measuring the degree of substitutability (when $\phi^d = 1$, intermediate goods are perfect substitutes in the production of the final good and the intermediate sector is perfectly competitive). Notice that, in a symmetric equilibrium, we will simply have $y_2^d = y_{i,2}^d$. The final-good producer chooses $y_{i,2}^d$ to maximise real profits:

$$\pi_2^d = p_2^d y_2^d - \sum_{i=1}^{N} \frac{1}{N} p_{i,2}^d y_{i,2}^d$$

where p_2^d is the price of the final good and $p_{i,2}^d$ is the price of the intermediate good i. Taking prices as given, the first-order condition for $y_{i,2}^d$ gives the demand function:

$$p_{i,2}^d = p_2^d \left(\frac{y_{i,2}^d}{y_2^d} \right)^{\phi^d - 1}$$

which in turn implies from the zero-profit condition:

$$p_2^d = \left[\sum_{i=1}^{N} \frac{1}{N} (p_{i,2}^d)^{\frac{\phi^d}{\phi^d - 1}} \right]^{\frac{\phi^d - 1}{\phi^d}}$$

notice that, in a symmetric equilibrium, we will simply have $p_{i,2}^d = p_2^d$.

Intermediate goods firms

There are $i = 1, 2, ..., N$ intermediate goods firms. Each intermediate goods firm maximises real profits:

$$\pi_{i,2}^d \equiv \frac{p_{i,2}^d}{p_2^d} y_{i,2}^d - r_2^d \bar{k}_{i,2}^d - w_2^d \bar{l}_{i,2}^d$$

where l_2^d is aggregate labour services provided by all types of workers and used by each firm i. Maximization is subject to the production function:

$$y_{i,2}^d = A(\bar{k}_{i,2}^d)^a (\bar{l}_{i,2}^d)^{1-a}$$

and the inverse demand function derived above:

$$p_{i,2}^d = p_2^d \left(\frac{y_{i,2}^d}{y_2^d} \right)^{\varphi^d - 1}$$

The first-order conditions for the two inputs (written directly in a symmetric equilibrium) are

$$w_2^d = \frac{p_{i,2}^d}{p_2^d} \frac{\varphi^d (1-a) y_{i,2}^d}{l_{i,2}^d + s_{i,2}^f} = \frac{\varphi^d (1-a) y_{i,2}^d}{l_{i,2}^d + s_{i,2}^f}$$

$$r_2^d = \frac{p_{i,2}^d}{p_2^d} \frac{\varphi^d a y_{i,2}^d}{k_{i,2}^d + f_{i,2}^f} = \frac{\varphi^d a y_{i,2}^d}{k_{i,2}^d + f_{i,2}^f}$$

$$\pi_{i,2}^d = (1-\varphi^d) y_{i,2}^d$$

In a symmetric equilibrium, we will simply have $p_{i,2}^d = p_2^d$, $l_{q,i,2}^d = l_{i,2}^d$, $w_{q,2}^d = w_2^d$, $y_{i,2}^d = y_2^d$, $k_{i,2}^d = k_2^d$ and $s_{i,2}^d = s_2^d$.

World decentralized competitive equilibrium (for any feasible policy)

In a world decentralized competitive equilibrium (WDCE), which is for any feasible policy: (i) households maximise welfare in each country (ii) firms maximise profits in each country (iii) all constraints are satisfied in each country (iv) all markets clear including the world asset/capital and labour markets. Notice that, with capital mobility allowed between period 1 and 2, the market-clearing conditions for capital in the second period are $\bar{k}_2^d = k_2^d + f_2^f$ in the domestic economy and $\bar{k}_2^f = k_2^f + f_2^d$ in the foreign economy. In addition, with labour mobility allowed in the second period, the market-clearing conditions for labour are $\bar{l}_2^d = l_2^d + s_2^f$ in the domestic economy and $\bar{l}_2^f = l_2^f + s_2^d$ in the foreign economy.

Collecting equations, we have the system:

Domestic economy

$$c_1^d + k_2^d - (1-\delta)k_1^d + f_2^d + g_1^d = y_1^d \tag{B.1}$$

$$\begin{aligned} c_2^d - (1-\delta)k_2^d + g_2^d = y_2^d - (1-\tau_{k,2}^d)r_2^d f_2^f + \left(1 + (1-\tau_{k,2}^f)r_2^f - \delta\right) f_2^d \\ - m\frac{\left(f_2^d\right)^2}{2} - (1-\tau_{l,2}^d)w_2^d s_2^f + (1-\tau_{l,2}^f)w_2^f s_2^d - j\frac{\left(s_2^d - \bar{s}\right)^2}{2} \end{aligned} \tag{B.2}$$

$$\frac{\mu_1}{c_1^d}(1-\tau_{l,1}^d)w_1^d = \frac{\mu_2}{1-l_1^d} \tag{B.3}$$

$$\frac{\mu_1}{c_2^d}(1-\tau_{l,2}^d)w_2^d = \frac{\mu_2}{1-l_2^d-s_2^d} \tag{B.4}$$

$$\frac{\mu_1}{c_2^d}\left((1-\tau_{l,2}^f)w_2^f - j(s_2^d-\bar{s})\right) = \frac{\mu_2}{1-l_2^d-s_2^d} \tag{B.5}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1 + (1-\tau_{k,2}^d)r_2^d - \delta\right) \tag{B.6}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1 + (1-\tau_{k,2}^f)r_2^f - \delta - m f_2^d\right) \tag{B.7}$$

$$\frac{c_2^d}{c_1^d} = \beta\left(1 + \rho_2^d\right) \tag{B.8}$$

$$g_1^d + \left(1 + (1-\tau_{k,1}^d)r_1^d - \delta\right) b_1^d = \tau_{k,1}^d r_1^d k_1^d + \tau_{l,1}^d w_1^d l_1^d + b_2^d \tag{B.9}$$

$$g_2^d + (1+\rho_2^d)b_2^d = \tau_{k,2}^d\left(r_2^d(k_2^d + f_2^f) + \pi_2^d\right) + \tau_{l,2}^d w_2^d(l_2^d + s_2^f) \tag{B.10}$$

Foreign economy

$$c_1^f + k_2^f - (1-\delta)k_1^f + f_2^f + g_1^f = y_1^f \tag{B.11}$$

$$\begin{aligned} c_2^f - (1-\delta)k_2^f + g_2^f = y_2^f - (1-\tau_{k,2}^f)r_2^f f_2^d + \left(1 + (1-\tau_{k,2}^d)r_2^d - \delta\right) f_2^f \\ - m\frac{(f_2^f)^2}{2} - (1-\tau_{l,2}^f)w_2^f s_2^d + (1-\tau_{l,2}^d)w_2^d s_2^f - j\frac{(s_2^f - \bar{s})^2}{2} \end{aligned} \tag{B.12}$$

$$\frac{\mu_1}{c_1^f}(1-\tau_{l,1}^f)w_1^f = \frac{\mu_2}{1-l_1^f} \tag{B.13}$$

$$\frac{\mu_1}{c_2^f}(1-\tau_{l,2}^f)w_2^f = \frac{\mu_2}{1-l_2^f-s_2^f} \tag{B.14}$$

$$\frac{\mu_1}{c_2^f}\left((1-\tau_{l,2}^d)w_2^d - j(s_2^f-\bar{s})\right) = \frac{\mu_2}{1-l_2^f-s_2^f} \tag{B.15}$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+(1-\tau_{k,2}^f)r_2^f-\delta\right) \tag{B.16}$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+(1-\tau_{k,2}^d)r_2^d-\delta-mf_2^f\right) \tag{B.17}$$

$$\frac{c_2^f}{c_1^f} = \beta\left(1+\rho_2^f\right) \tag{B.18}$$

$$g_1^f + \left(1+(1-\tau_{k,1}^f)r_1^f-\delta\right)b_1^f = \tau_{k,1}^f r_1^f k_1^f + \tau_{l,1}^f w_1^f l_1^f + b_2^f \tag{B.19}$$

$$g_2^f + (1+\rho_2^f)b_2^f = \tau_{k,2}^f\left(r_2^f(k_2^f+f_2^d)+\pi_2^f\right) + \tau_{l,2}^f w_2^f(l_2^f+s_2^d) \tag{B.20}$$

where, in the above, we use the following equations describing profits, gross wages, capital and bond returns in the two countries:

$$\pi_1^d = \pi_1^f = 0,\ \pi_2^d = (1-\phi^d)y_2^d,\ \pi_2^f = (1-\phi^f)y_2^f,$$
$$r_1^d = a\frac{y_1^d}{k_1^d},\ r_1^f = a\frac{y_1^f}{k_1^f},\ r_2^d = \frac{\phi^d a y_2^d}{k_2^d+f_2^f},\ r_2^f = \frac{\phi^f a y_2^f}{k_2^f+f_2^d},$$
$$w_1^d = (1-a)\frac{y_1^d}{l_1^d},\ w_1^f = (1-a)\frac{y_1^f}{l_1^f},\ w_2^d = \frac{\phi^d(1-a)y_2^d}{l_2^d+s_2^f},\ w_2^f = \frac{\phi^f(1-a)y_2^f}{l_2^f+s_2^d}$$

Therefore, we have a system of 20 equations in 20 endogenous variables, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, s_2^d, l_1^f, l_2^f, s_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, g_2^d, g_2^f, \rho_2^d, \rho_2^f$. This is given the independently set policy instruments. The latter include the the tax rates, $\tau_{k,1}^d, \tau_{k,2}^d, \tau_{l,1}^d, \tau_{l,2}^d, \tau_{k,1}^f, \tau_{k,2}^f, \tau_{l,1}^f, \tau_{l,2}^f$, and the public spending items, g_1^d, g_1^f. In other words, in each period, one policy instrument needs to follow residually to close the government budget constraint and here it is assumed that this role is played by the end-of-period public debt in the first period (b_2^d and b_2^f) and by the public spending in the second period (g_2^d and g_2^f) - this is why these variables are included in the list of endogenous variables.

B.4.2 Flexible and rigid cooperation

Concerning the cooperative framework, we distinguish between flexible and rigid unions. To model flexible cooperation we follow the same procedure as in the symmetric case presented above in *subsection B.1.2*.

In the case of a rigid union however, the planner solves the same problem as in the case of flexible cooperation, but, instead of choosing a different tax rate for each economy, $\tau^d_{k,2}, \tau^f_{k,2}, \tau^d_{l,2}, \tau^f_{l,2}$, she now chooses union-wide or single of one-size-fits-all policy instruments τ^k_2, τ^l_2.

Commitment solution

A fictional world social planner maximises a weighted average of households' welfare in each country with equal weights, γ, given to each one of them. Thus, the objective is now:

$$\max W^{coop} = \gamma U^d + (1-\gamma) U^f$$

subject to the equations summarizing the WDCE (6.16-35). We form the Lagrangian function of the world government as follows

$$
\begin{gathered}
L = W^{coop} + \\
+\lambda_1 \left\{ c^d_1 + k^d_2 - (1-\delta)k^d_1 + f^d_2 + g^d_1 - y^d_1 \right\} \\
+\lambda_2 \Big\{ c^d_2 - (1-\delta)k^d_2 + g^d_2 - y^d_2 + (1-\tau^k_2) r^d_2 f^f_2 - \Big(1 + (1-\tau^k_2) r^f_2 \\
- \delta \Big) f^d_2 + m \frac{\left(f^d_2\right)^2}{2} + (1-\tau^l_2) w^d_2 s^f_2 - (1-\tau^l_2) w^f_2 s^d_2 + j \frac{\left(s^d_2 - \bar{s}\right)^2}{2} \Big\} \\
+\lambda_3 \left\{ \frac{\mu_1}{c^d_1}(1-\tau^l_1) w^d_1 - \frac{\mu_2}{1-l^d_1} \right\} \\
+\lambda_4 \left\{ \frac{\mu_1}{c^d_2}(1-\tau^l_2) w^d_2 - \frac{\mu_2}{1-l^d_2 - s^d_2} \right\} \\
+\lambda_5 \left\{ \frac{\mu_1}{c^d_2} \Big((1-\tau^l_2) w^f_2 - j(s^d_2 - \bar{s}) \Big) - \frac{\mu_2}{1-l^d_2 - s^d_2} \right\} \\
+\lambda_6 \left\{ \frac{c^d_2}{c^d_1} - \beta \Big(1 + (1-\tau^k_2) r^d_2 - \delta \Big) \right\} \\
+\lambda_7 \left\{ \frac{c^d_2}{c^d_1} - \beta \Big(1 + (1-\tau^k_2) r^f_2 - \delta - m f^d_2 \Big) \right\}
\end{gathered}
$$

$$+\lambda_8\left\{\frac{c_2^d}{c_1^d}-\beta\left(1+\rho_2^d\right)\right\}$$

$$+\lambda_9\left\{g_1^d+\left(1+(1-\tau_1^k)r_1^d-\delta\right)b_1^d-\tau_1^k r_1^d k_1^d-\tau_1^l w_1^d l_1^d-b_2^d\right\}$$

$$+\lambda_{10}\left\{g_2^d+(1+\rho_2^d)b_2^d-\tau_2^k r_2^d(k_2^d+f_2^f)-\tau_2^l w_2^d(l_2^d+s_2^f)\right\}$$

$$+\lambda_{11}\left\{c_1^f+k_2^f-(1-\delta)k_1^f+f_2^f+g_1^f-y_1^f\right\}$$

$$+\lambda_{12}\left\{c_2^f-(1-\delta)k_2^f+g_2^f-y_2^f+(1-\tau_2^k)r_2^f f_2^d-\left(1+(1-\tau_2^k)r_2^d\right.\right.$$
$$\left.\left.-\delta\right)f_2^f+m\frac{\left(f_2^f\right)^2}{2}+(1-\tau_2^l)w_2^f s_2^d-(1-\tau_2^l)w_2^d s_2^f+j\frac{\left(s_2^f-\bar{s}\right)^2}{2}\right\}$$

$$+\lambda_{13}\left\{\frac{\mu_1}{c_1^f}(1-\tau_1^l)w_1^f-\frac{\mu_2}{1-l_1^f}\right\}$$

$$+\lambda_{14}\left\{\frac{\mu_1}{c_2^f}(1-\tau_2^l)w_2^f-\frac{\mu_2}{1-l_2^f-s_2^f}\right\}$$

$$+\lambda_{15}\left\{\frac{\mu_1}{c_2^f}\left((1-\tau_2^l)w_2^d-j(s_2^f-\bar{s})\right)-\frac{\mu_2}{1-l_2^f-s_2^f}\right\}$$

$$+\lambda_{16}\left\{\frac{c_2^f}{c_1^f}-\beta\left(1+(1-\tau_2^k)r_2^f-\delta\right)\right\}$$

$$+\lambda_{17}\left\{\frac{c_2^f}{c_1^f}-\beta\left(1+(1-\tau_2^k)r_2^d-\delta-mf_2^f\right)\right\}$$

$$+\lambda_{18}\left\{\frac{c_2^f}{c_1^f}-\beta\left(1+\rho_2^f\right)\right\}$$

$$+\lambda_{19}\left\{g_1^f+\left(1+(1-\tau_1^k)r_1^f-\delta\right)b_1^f-\tau_1^k r_1^f k_1^f-\tau_1^l w_1^f l_1^f-b_2^f\right\}$$

$$+\lambda_{20}\left\{g_2^f+(1+\rho_2^f)b_2^f-\tau_2^k r_2^f(k_2^f+f_2^d)-\tau_2^l w_2^f(l_2^f+s_2^d)\right\}$$

The maximization is with respect to the union-wide policy instruments, τ_2^k and τ_2^l. We will thus have a system of 42 equations in 42 unknowns. Counting equations and endogenous variables, we have the 20 constraints/equations corresponding to the 20 variables of the WDCE, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, s_2^d, l_1^f, l_2^f, s_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f, g_2^d, g_2^f, \rho_2^d, \rho_2^f$, plus the 20 dynamic Lagrangean multipliers corresponding to the 20 equations of the WDCE system, plus the 2 optimality conditions for the 2 union-wide policy instruments, τ_2^k and τ_2^l. This is given the the assumed exogenous policy instruments $\tau_1^k, \tau_1^l, g_1^d, g_1^f$.

Non-commitment solution

Solution of stage (D)

The solution here is identical to the one in *stage (D)* in the non-cooperative regime, however now households make their second-period decisions by taking as given union-wide instead of country-specific policy instruments.

$$c_2^d = \left(1 + (1 - \tau_2^k) r_2^d - \delta\right) k_2^d + (1 - \tau_2^l) w_2^d l_2^d + (1 + \rho_2^d) b_2^d$$
$$+ \left(1 + (1 - \tau_2^k) r_2^f - \delta\right) f_2^d - m \frac{\left(f_2^d\right)^2}{2} + (1 - \tau_2^l) w_2^f s_2^d - j \frac{\left(s_2^d - \bar{s}\right)^2}{2}$$
$$\frac{\mu_1}{c_2^d}(1 - \tau_2^l) w_2^d = \frac{\mu_2}{1 - l_2^d - s_2^d}$$
$$\frac{\mu_1}{c_2^d}\left((1 - \tau_2^l) w_2^f - j(s_2^d - \bar{s})\right) = \frac{\mu_2}{1 - l_2^d - s_2^d}$$

$$c_2^f = \left(1 + (1 - \tau_2^k) r_2^f - \delta\right) k_2^f + (1 - \tau_2^l) w_2^f l_2^f + (1 + \rho_2^f) b_2^f$$
$$+ \left(1 + (1 - \tau_2^k) r_2^d - \delta\right) f_2^f - m \frac{\left(f_2^f\right)^2}{2} + (1 - \tau_2^l) w_2^d s_2^f - j \frac{\left(s_2^f - \bar{s}\right)^2}{2}$$
$$\frac{\mu_1}{c_2^f}(1 - \tau_2^l) w_2^f = \frac{\mu_2}{1 - l_2^f - s_2^f}$$
$$\frac{\mu_1}{c_2^f}\left((1 - \tau_2^l) w_2^d - j(s_2^f - \bar{s})\right) = \frac{\mu_2}{1 - l_2^f - s_2^f}$$

Hence, we have 6 equations in 6 endogenous variables. Particularly, counting equations we have 4 optimality conditions for the 4 variables being determined by households in the WDCE in the second period, $l_2^d, s_2^d, l_2^f, s_2^f$, plus the two second-period budget constraints that define c_2^d and c_2^f.

Solution of stage (C)

The fictional world social planner maximises a weighted average of households' welfare in each country with equal weights given to each one of them. Thus, the objective is now:

$$\max W^{coop} = \gamma\left(\mu_1 \log c_2^d + \mu_2 \log(1 - l_2^d - s_2^d) + \mu_3 \log g_2^d\right)$$
$$+ (1 - \gamma)\left(\mu_1 \log c_2^f + \mu_2 \log(1 - l_2^f - s_2^f) + \mu_3 \log g_2^f\right)$$

subject to the government budget constraints and the optimality conditions/constraints that summarize the solution of *stage (D)* above. We form the Langrangean function of the world social planner as follows:

$$L = W^{coop} +$$

$$+\lambda_1\Big\{c_2^d - (1-\delta)k_2^d + g_2^d - y_2^d + (1-\tau_2^k)r_2^d f_2^f - \Big(1 + (1-\tau_2^k)r_2^f$$
$$- \delta\Big) f_2^d + m\frac{\left(f_2^d\right)^2}{2} + (1-\tau_2^l)w_2^d s_2^f - (1-\tau_2^l)w_2^f s_2^d + j\frac{\left(s_2^d - \bar{s}\right)^2}{2}\Big\}$$
$$+\lambda_2\left\{\frac{\mu_1}{c_2^d}(1-\tau_2^l)w_2^d - \frac{\mu_2}{1-l_2^d-s_2^d}\right\}$$
$$+\lambda_3\left\{\frac{\mu_1}{c_2^d}\Big((1-\tau_2^l)w_2^f - j(s_2^d-\bar{s})\Big) - \frac{\mu_2}{1-l_2^d-s_2^d}\right\}$$
$$+\lambda_4\Big\{g_2^d + (1+\rho_2^d)b_2^d - \tau_2^k r_2^d(k_2^d+f_2^f) - \tau_2^l w_2^d(l_2^d+s_2^f)\Big\}$$

$$+\lambda_5\Big\{c_2^f - (1-\delta)k_2^f + g_2^f - y_2^f + (1-\tau_2^k)r_2^f f_2^d - \Big(1 + (1-\tau_2^k)r_2^d$$
$$- \delta\Big) f_2^f + m\frac{\left(f_2^f\right)^2}{2} + (1-\tau_2^l)w_2^f s_2^d - (1-\tau_2^l)w_2^d s_2^f + j\frac{\left(s_2^f - \bar{s}\right)^2}{2}\Big\}$$
$$+\lambda_6\left\{\frac{\mu_1}{c_2^f}(1-\tau_2^l)w_2^f - \frac{\mu_2}{1-l_2^f-s_2^f}\right\}$$
$$+\lambda_7\left\{\frac{\mu_1}{c_2^f}\Big((1-\tau_2^l)w_2^d - j(s_2^f-\bar{s})\Big) - \frac{\mu_2}{1-l_2^f-s_2^f}\right\}$$
$$+\lambda_8\Big\{g_2^f + (1+\rho_2^f)b_2^f - \tau_2^k r_2^f(k_2^f+f_2^d) - \tau_2^l w_2^f(l_2^f+s_2^d)\Big\}$$

The maximization is with respect to the union-wide policy instruments, τ_2^k and τ_2^l. Following usual practice we solve the problem in its dual form.

At this stage, we will have a system of 18 equations in 18 endogenous variables. Specifically, counting equations, we have the 8 constraints/equations of the WDCE in the second period (4 optimality conditions from *stage (D)*, 2 household and 2 government budget constraints), the optimality conditions for the 8 variables being determined by the WDCE system, plus the two optimality conditions for the union-wide policy instruments, τ_2^k and τ_2^l. Counting endogenous variables, we have the 8 variables of the WDCE system, $c_2^d, c_2^f, l_2^d, l_2^f, s_2^d, s_2^f, g_2^d, g_2^f$, plus the 8 dynamic Lagrangean multipliers corresponding to the 8 equations of the WDCE system, plus the two optimally chosen instruments, τ_2^k and τ_2^l.

Solution of stage (B)

Again, the solution of this stage is identical to the one in *stage (B)* in the non-cooperative regime.

$$\frac{\mu_1}{c_1^d}(1-\tau_1^l)w_1^d = \frac{\mu_2}{1-l_1^d}$$

$$\frac{\mu_1}{c_1^d} = \beta\left\{\frac{\left(1+(1-\tau_2^k)r_2^d-\delta\right)\mu_1^2}{(\mu_1+\mu_2)c_2^d} + \frac{\left(1+(1-\tau_2^k)r_2^d-\delta\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_2^l)w_2^d(1-l_2^d-s_2^d)}\right\}$$

$$\frac{\mu_1}{c_1^d} = \beta\left\{\frac{\left(1+(1-\tau_2^k)r_2^f-\delta-mf_2^d\right)\mu_1^2}{(\mu_1+\mu_2)c_2^d} + \frac{\left(1+(1-\tau_2^k)r_2^f-\delta-mf_2^d\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_2^l)w_2^d(1-l_2^d-s_2^d)}\right\}$$

$$\frac{\mu_1}{c_1^d} = \beta\left\{\frac{\left(1+\rho_2^d\right)\mu_1^2}{(\mu_1+\mu_2)c_2^d} + \frac{\left(1+\rho_2^d\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_2^l)w_2^d(1-l_2^d-s_2^d)}\right\}$$

$$\frac{\mu_1}{c_1^f}(1-\tau_1^l)w_1^f = \frac{\mu_2}{1-l_1^f}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+(1-\tau_2^k)r_2^f-\delta\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+(1-\tau_2^k)r_2^f-\delta\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_2^l)w_2^f(1-l_2^f-s_2^f)}\right\}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+(1-\tau_2^k)r_2^d-\delta-mf_2^f\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+(1-\tau_2^k)r_2^d-\delta-mf_2^f\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_2^l)w_2^f(1-l_2^f-s_2^f)}\right\}$$

$$\frac{\mu_1}{c_1^f} = \beta\left\{\frac{\left(1+\rho_2^f\right)\mu_1^2}{(\mu_1+\mu_2)c_2^f} + \frac{\left(1+\rho_2^f\right)\mu_2^2}{(\mu_1+\mu_2)(1-\tau_2^l)w_2^f(1-l_2^f-s_2^f)}\right\}$$

At this stage we have 10 new equations in 10 endogenous variables, namely, 8 optimality conditions in $l_1^d, k_2^d, f_2^d, \rho_2^d, l_1^f, k_2^f, f_2^f, \rho_2^f$ and 2 first-period budget constraints that define c_1^d and c_1^f.

Solution of stage (A)

The end-of period government bonds, b_2^d and b_2^f, residually adjust to close the first-period government budget constraint in each country, given that the rest of first-period policy variables, τ_1^k, τ_1^l, g_1^d, g_1^f, are assumed to be exogenous. As said this is for keeping the model relatively simple.

Rigid cooperative equilibrium without commitment

The rigid cooperative equilibrium without commitment is a system of 30 equations in 30 endogenous variables. Particularly, we have the 20 constraints/equations corresponding to the 20 variables of the WDCE system, $c_1^d, c_2^d, c_1^f, c_2^f, l_1^d, l_2^d, s_2^d, l_1^f, l_2^f, s_2^f, k_2^d, k_2^f, f_2^d, f_2^f, b_2^d, b_2^f$, $g_2^d, g_2^f, \rho_2^d, \rho_2^f$, plus the 8 dynamic Lagrangean multipliers corresponding to the 8 optimality conditions of *stage (C)*, plus the two optimally chosen instruments, τ_2^k, τ_2^l. This is given the assumed exogenous policy instruments τ_1^k, τ_1^l, g_1^d and g_1^f.

B.4.3 Numerical solutions for non-symmetric equilibria and gains from cooperation

Table B.16 Asymmetries in TFP, $A^{core} = 1.0$, $A^{per} = 0.8$, commitment numerical solution

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Allocations			
c_1	0.22	0.17	0.22	0.18	0.23	0.17
c_2	0.12	0.10	0.10	0.09	0.11	0.08
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.10	0.05	0.09	0.06	0.09	0.04
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	-0.01	0.01	0.00	0.00	-0.02	0.02
b_1^{**}	0.20	0.16	0.20	0.16	0.20	0.16
b_2	0.01	0.00	0.01	0.00	0.01	0.00
l_1	0.26	0.26	0.26	0.25	0.25	0.26
l_2	0.15	0.07	0.13	0.10	0.20	0.03
s_2	0.07	0.13	0.08	0.12	0.06	0.14
y_1	0.34	0.27	0.34	0.26	0.33	0.27
y_2	0.20	0.07	0.17	0.09	0.22	0.04
			Optimal Policy			
τ_2^k	0.09	0.03	0.27	0.15	0.32	
τ_2^l	0.25	0.17	0.34	0.27	0.26	
g_2	0.03	0.01	0.05	0.02	0.06	0.01
g_1^{**}	0.03	0.03	0.03	0.03	0.03	0.03

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Net returns and wages			
R_1	0.23	0.18	0.23	0.18	0.22	0.18
R_2	0.63	0.63	0.54	0.54	0.52	0.52
W_1	0.58	0.47	0.58	0.47	0.60	0.47
W_2	0.31	0.25	0.26	0.22	0.29	0.20
			Shares			
c_1/y_1	0.64	0.65	0.64	0.67	0.69	0.64
i_1/y_1	0.30	0.20	0.26	0.23	0.28	0.17
x_1/y_1	-0.04	0.05	0.00	0.00	-0.07	0.09
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.48	1.86	1.48	1.89	1.53	1.86
b_1/y_1^*	0.60	0.60	0.60	0.60	0.60	0.60
c_2/y_2	0.63	1.50	0.63	0.92	0.48	2.08
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.08	-0.25	0.00	0.00	0.11	-0.64
e_2/y_2	0.13	-0.37	0.09	-0.15	0.14	-0.72
g_2/y_2	0.15	0.12	0.28	0.23	0.27	0.29
k_2/y_2	0.51	0.82	0.54	0.64	0.41	1.14
b_2/y_2	0.05	0.00	0.06	-0.01	0.03	0.00
			Welfare			
W	-1.99	-2.24	-1.99	-2.20	-1.98	-2.25

Table B.17 Asymmetries in TFP, $A^{core} = 1.0, A^{per} = 0.8$, non-commitment numerical solution

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
Allocations						
c_1	0.25	0.18	0.24	0.20	0.24	0.19
c_2	0.10	0.07	0.08	0.07	0.10	0.08
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.04	0.03	0.03	0.02	0.05	0.03
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	-0.02	0.02	0.01	-0.01	-0.01	0.01
b_1^{**}	0.18	0.15	0.19	0.14	0.19	0.15
b_2	0.00	0.00	0.01	0.00	0.00	0.00
l_1	0.21	0.24	0.23	0.21	0.22	0.24
l_2	0.28	0.05	0.21	0.19	0.25	0.09
s_2	0.04	0.16	0.08	0.12	0.06	0.14
y_1	0.30	0.26	0.31	0.24	0.31	0.26
y_2	0.20	0.03	0.12	0.09	0.19	0.05
Optimal Policy						
τ_2^k	0.68	0.63	0.80	0.69	0.61	
τ_2^l	-0.07	0.14	-0.10	-0.04	0.01	
g_2	0.04	0.01	0.03	0.02	0.05	0.01
g_1^{**}	0.03	0.03	0.03	0.02	0.03	0.03

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
Net returns and wages						
R_1	0.20	0.18	0.21	0.16	0.21	0.17
R_2	0.43	0.43	0.39	0.39	0.46	0.46
W_1	0.63	0.48	0.62	0.51	0.62	0.49
W_2	0.29	0.18	0.24	0.20	0.29	0.20
Shares						
c_1/y_1	0.83	0.71	0.77	0.85	0.78	0.73
i_1/y_1	0.13	0.12	0.10	0.09	0.16	0.12
x_1/y_1	-0.06	0.08	0.03	-0.03	-0.05	0.06
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.67	1.94	1.61	2.10	1.62	1.96
b_1/y_1^*	0.60	0.60	0.60	0.60	0.60	0.60
c_2/y_2	0.49	2.26	0.72	0.78	0.52	1.62
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.08	-0.53	-0.05	0.07	0.07	-0.28
e_2/y_2	0.20	-1.08	0.09	-0.11	0.17	-0.60
g_2/y_2	0.22	0.35	0.24	0.26	0.24	0.26
k_2/y_2	0.20	0.97	0.28	0.23	0.26	0.64
b_2/y_2	0.02	-0.04	0.05	-0.03	0.03	-0.03
Welfare						
W	-2.04	-2.29	-2.11	-2.25	-2.02	-2.26

Table B.18 Asymmetries in inherited public debt, $b_1/y_1^{core} = 0.6$, $b_1/y_1^{per} = 0.9$, commitment numerical solution

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Allocations			
c_1	0.22	0.22	0.22	0.23	0.22	0.22
c_2	0.13	0.13	0.10	0.11	0.10	0.10
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.08	0.07	0.08	0.08	0.08	0.07
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	0.00	0.00	0.01	-0.01	0.00	0.00
b_1^{**}	0.20	0.30	0.20	0.29	0.20	0.30
b_2	0.01	0.03	0.01	0.03	0.01	0.03
l_1	0.26	0.25	0.26	0.25	0.26	0.25
l_2	0.12	0.09	0.09	0.12	0.11	0.10
s_2	0.10	0.10	0.11	0.09	0.10	0.10
y_1	0.33	0.33	0.34	0.33	0.33	0.33
y_2	0.15	0.13	0.12	0.15	0.14	0.13

			Optimal Policy			
τ_2^k	0.07	0.10	0.29	0.27	0.29	
τ_2^l	0.22	0.21	0.37	0.35	0.36	
g_2	0.02	0.00	0.04	0.03	0.04	0.03
g_1^{**}	0.03	0.03	0.03	0.03	0.03	0.03

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
			Net returns and wages			
R_1	0.23	0.22	0.23	0.22	0.23	0.22
R_2	0.65	0.65	0.52	0.52	0.52	0.52
W_1	0.59	0.59	0.59	0.60	0.59	0.60
W_2	0.32	0.32	0.25	0.27	0.26	0.26
			Shares			
c_1/y_1	0.65	0.67	0.64	0.69	0.66	0.68
i_1/y_1	0.25	0.22	0.23	0.24	0.24	0.22
x_1/y_1	-0.01	0.01	0.03	-0.03	0.00	0.00
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.50	1.52	1.49	1.53	1.50	1.52
b_1/y_1^*	0.60	0.90	0.60	0.90	0.60	0.90
c_2/y_2	0.85	1.02	0.82	0.69	0.71	0.78
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.02	-0.02	-0.07	0.06	-0.01	0.01
e_2/y_2	0.01	-0.01	-0.04	0.03	0.00	0.00
g_2/y_2	0.12	0.01	0.30	0.21	0.30	0.21
k_2/y_2	0.56	0.57	0.62	0.51	0.56	0.55
b_2/y_2	0.06	0.24	0.07	0.19	0.06	0.22
			Welfare			
W	-2.02	-2.22	-2.01	-2.00	-2.00	-2.01

Table B.19 Asymmetries in inherited public debt, $b_1/y_1^{core} = 0.6$, $b_1/y_1^{per} = 0.9$, non-commitment numerical solution

	Nash		Coop flex		Coop rigid	
	core	**per**	**core**	**per**	**core**	**per**
Allocations						
c_1	0.25	0.24	0.24	0.25	0.24	0.25
c_2	0.09	0.08	0.09	0.09	0.09	0.09
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.03	0.03	0.03	0.03	0.03	0.03
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	-0.01	0.01	0.01	-0.01	0.00	0.00
b_1^{**}	0.18	0.28	0.19	0.27	0.18	0.27
b_2	0.00	0.03	0.01	0.02	0.00	0.02
l_1	0.21	0.23	0.23	0.21	0.22	0.22
l_2	0.25	0.11	0.16	0.20	0.19	0.18
s_2	0.08	0.12	0.11	0.09	0.10	0.10
y_1	0.30	0.31	0.31	0.30	0.31	0.30
y_2	0.15	0.08	0.10	0.14	0.12	0.11
Optimal Policy						
τ_2^k	0.75	0.73	0.74	0.71	0.75	
τ_2^l	-0.06	0.19	0.02	0.01	0.00	
g_2	0.04	0.02	0.03	0.03	0.03	0.03
g_1^{**}	0.03	0.03	0.03	0.03	0.03	0.03

	Nash		Coop flex		Coop rigid	
	core	**per**	**core**	**per**	**core**	**per**
Net returns and wages						
R_1	0.20	0.21	0.21	0.20	0.21	0.21
R_2	0.38	0.38	0.41	0.41	0.39	0.39
W_1	0.64	0.61	0.62	0.63	0.62	0.63
W_2	0.26	0.21	0.24	0.26	0.24	0.24
Shares						
c_1/y_1	0.85	0.75	0.76	0.83	0.79	0.81
i_1/y_1	0.09	0.11	0.11	0.10	0.10	0.09
x_1/y_1	-0.04	0.04	0.03	-0.03	0.01	-0.01
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.68	1.59	1.60	1.67	1.63	1.65
b_1/y_1^*	0.60	0.90	0.60	0.90	0.60	0.90
c_2/y_2	0.57	1.03	0.86	0.67	0.73	0.77
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.06	-0.12	-0.07	0.05	-0.01	0.01
e_2/y_2	0.11	-0.19	-0.07	0.05	0.00	0.00
g_2/y_2	0.26	0.28	0.28	0.22	0.28	0.22
k_2/y_2	0.18	0.44	0.35	0.22	0.27	0.24
b_2/y_2	0.02	0.33	0.05	0.16	0.04	0.20
Welfare						
W	-2.07	-2.10	-2.08	-2.06	-2.08	-2.08

Table B.20 Asymmetries in product market, $\phi^{core} = 1.0$, $\phi^{per} = 0.95$, commitment numerical solution

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
Allocations						
c_1	0.22	0.22	0.22	0.22	0.22	0.22
c_2	0.13	0.12	0.11	0.11	0.11	0.10
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.09	0.08	0.08	0.08	0.08	0.07
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	-0.01	0.01	0.00	0.00	-0.01	0.01
b_1^{**}	0.20	0.20	0.20	0.20	0.20	0.20
b_2	0.01	0.01	0.01	0.01	0.01	0.01
l_1	0.25	0.26	0.25	0.25	0.25	0.26
l_2	0.13	0.10	0.12	0.12	0.15	0.09
s_2	0.09	0.11	0.10	0.10	0.09	0.11
y_1	0.33	0.34	0.33	0.33	0.33	0.34
y_2	0.17	0.12	0.15	0.14	0.18	0.11
Optimal Policy						
τ_2^k	0.07	0.12	0.25	0.25	0.26	
τ_2^l	0.23	0.17	0.34	0.28	0.30	
g_2	0.02	0.01	0.04	0.03	0.05	0.03
g_1^{**}	0.03	0.03	0.03	0.03	0.03	0.03

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
Net returns and wages						
R_1	0.23	0.23	0.23	0.23	0.22	0.23
R_2	0.63	0.63	0.54	0.54	0.53	0.53
W_1	0.59	0.59	0.59	0.59	0.60	0.59
W_2	0.32	0.31	0.27	0.27	0.28	0.26
Shares						
c_1/y_1	0.67	0.65	0.66	0.66	0.68	0.65
i_1/y_1	0.26	0.22	0.24	0.23	0.26	0.22
x_1/y_1	-0.03	0.03	-0.01	0.01	-0.04	0.04
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.51	1.49	1.50	1.50	1.52	1.49
b_1/y_1^*	0.60	0.60	0.60	0.60	0.60	0.60
c_2/y_2	0.76	1.00	0.71	0.75	0.61	0.91
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.07	-0.05	0.02	0.02	0.08	-0.08
e_2/y_2	0.03	-0.04	0.00	0.00	0.05	-0.07
g_2/y_2	0.13	0.10	0.27	0.23	0.26	0.24
k_2/y_2	0.53	0.60	0.55	0.55	0.48	0.64
b_2/y_2	0.05	0.07	0.06	0.06	0.04	0.08
Welfare						
W	-2.01	-2.06	-2.00	-2.02	-1.99	-2.03

Table B.21 Asymmetries in product market, $\phi^{core} = 1.0$, $\phi^{per} = 0.95$, non-commitment numerical solution

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
Allocations						
c_1	0.24	0.23	0.24	0.26	0.25	0.24
c_2	0.10	0.09	0.07	0.08	0.08	0.08
k_1^*	0.50	0.50	0.50	0.50	0.50	0.50
k_2	0.04	0.05	0.02	0.02	0.02	0.03
f_1	0.00	0.00	0.00	0.00	0.00	0.00
f_2	-0.01	0.01	0.01	-0.01	-0.01	0.01
b_1^{**}	0.18	0.19	0.18	0.18	0.18	0.18
b_2	0.00	0.01	0.00	0.00	0.00	0.00
l_1	0.22	0.24	0.22	0.20	0.21	0.22
l_2	0.23	0.12	0.17	0.24	0.23	0.18
s_2	0.08	0.12	0.11	0.09	0.09	0.11
y_1	0.30	0.32	0.31	0.29	0.30	0.31
y_2	0.17	0.10	0.08	0.12	0.12	0.09
Optimal Policy						
τ_2^k	0.63	0.61	0.84	0.82	0.80	
τ_2^l	0.02	0.12	-0.06	-0.21	-0.11	
g_2	0.04	0.03	0.02	0.03	0.03	0.02
g_1^{**}	0.03	0.03	0.03	0.03	0.03	0.03

	Nash		**Coop flex**		**Coop rigid**	
	core	**per**	**core**	**per**	**core**	**per**
Net returns and wages						
R_1	0.21	0.22	0.21	0.20	0.20	0.21
R_2	0.45	0.45	0.34	0.34	0.37	0.37
W_1	0.63	0.60	0.62	0.64	0.64	0.62
W_2	0.28	0.24	0.21	0.24	0.24	0.22
Shares						
c_1/y_1	0.80	0.72	0.79	0.87	0.85	0.79
i_1/y_1	0.14	0.14	0.08	0.05	0.07	0.09
x_1/y_1	-0.04	0.04	0.03	-0.03	-0.02	0.02
g_1/y_1	0.10	0.10	0.10	0.10	0.10	0.10
k_1/y_1^{**}	1.64	1.56	1.63	1.71	1.69	1.63
b_1/y_1^*	0.60	0.60	0.60	0.60	0.60	0.60
c_2/y_2	0.59	0.94	0.88	0.65	0.67	0.85
i_2/y_2	0.00	0.00	0.00	0.00	0.00	0.00
x_2/y_2	0.07	-0.10	-0.07	0.06	0.04	-0.04
e_2/y_2	0.09	-0.14	-0.10	0.07	0.05	-0.07
g_2/y_2	0.25	0.30	0.28	0.22	0.24	0.26
k_2/y_2	0.26	0.47	0.29	0.13	0.17	0.28
b_2/y_2	0.03	0.07	0.05	0.02	0.03	0.05
Welfare						
W	-2.03	-2.06	-2.14	-2.13	-2.10	-2.12

* *refers to initial parameter values.* ** *refers to initial parameters that were calculated jointly with the rest of the endogenous variables of the model.*