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Keywords
Equity Rules, Environmental Public Goods, Median Voter, Public Support, Relative Income Hypothesis

JEL Codes
H23, Q52, D72, H77

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1 Introduction

Countries' domestic policies are particularly central to today's structure of international climate cooperation. Indeed, the Paris Agreement changed the way international negotiations are constructed: from a top-down approach that had to create mandatory commitments for the parties involved, it built a new bottom-up approach that recognizes the primacy of domestic policy while leaving countries free to define their own efforts. Accordingly, domestic dynamics have entered the international negotiating rooms, as national elections, lobbying, and local protests have clearly influenced international debates on climate change mitigation. An example in this direction is the Yellow Vests movement in France, whose protests stemmed from the introduction of a tax on fuel consumption, perceived as highly regressive by the population (Mehleb et al., 2021). By emphasizing the possible existence of a trade-off between mitigation policies and distributional arguments, the Yellow Vest movement shed light on the importance of legitimizing climate policies (Kinniburgh, 2019). In this sense, it has become clear how strong the relationship between domestic and international dynamics is, as the domestic legitimacy and acceptability of climate policies influence each other and the reputational dynamics of international negotiations.

Building on this perspective, an academic literature studying the importance of public legitimacy and the distributional impacts of policies has recently flourished (see e.g. Ohlendorf et al., 2020, for a meta analysis). Likewise, the concept of "Just Transition", whereby policies are devised to secure workers' rights and livelihoods as economies shift towards more sustainable production processes, has entered not only the academic debate but also directly the policy agenda (Wang and Lo, 2021). However, the link between these aspects and the dynamics of international cooperation is often ignored in the economics literature (Tavoni and Winkler, 2021).

To start filling this gap, this paper studies the relationship between inequality and the international provision of a global public good, with the aim of discussing how the feasibility and efficiency of an international agreement may be affected by the presence of inequalities in the income distributions between and within countries.[1] To do so, we propose a two-country two-stage political economy model in the spirit

[1] Our focus is not to characterize the one-size-fits-all solution to the problem of international cooperation. There is a large body of literature (since at least Carraro and Siniscalco, 1993, Barrett, 1994) considering the realization of international environmental agreements from the perspectives of coalition theory and bargaining theory, and studying under which conditions a large stable coalition for the provision of an environmental public good can be realized, which is not the focus of this paper.

of Putnam (1988). At the international level, two negotiators must agree on the provision of a global public good (such as climate change mitigation), characterized by private costs but public benefits, taking as given the difference between countries' ability-to-pay for the public good. Moreover, each country's negotiator is subject to the preferences of the national median voter, i.e. she will have to ensure that the national electorate accepts the internationally agreed treaty. We assume that agents in each country are heterogeneous in income and preferences for the public good, but that these preferences are positively related to the individual relative income in the country: as a consequence, the more unequal a country is, the lower the preference for environmental quality and thus the willingness-to-pay for the provision of the public good of its median voter. This "relative income hypothesis" assumption, while strong, is based on a robust theoretical and empirical literature dating back to at least Veblen (1899) on the influence of relative income on consumption preferences (see e.g. Magnani, 2000, for a focus on environmental policy). This ensures that inequality plays a role at both the national and international levels in our model.

We first derive the outside option for the negotiators, i.e. the non-cooperative equilibrium tax rates and the resulting autarchic provisions of the public good. We show that these are increasing in the absolute income of the median voter only if her income elasticity of the preference for the environmental public good is greater than one: as already highlighted in previous literature (e.g. Antle and Heidebrink, 1995, Magnani, 2000), a high income elasticity of demand for the public good is necessary to have a higher demand given an increase in income. Moreover, the non-cooperative tax rates and public good provisions depend on the relative income of the median voter. On the one hand, we show that the non-cooperative tax rate is negatively related to the total and average income in the country, since this reduces the median voter's preferences for the public good and thus her willingness-to-pay if median income stays constant. On the other hand, an increase in the total income of the country increases the funds' availability for the autarchic provision of the public good. As a result, this provision increases only if the income elasticity of the median voter is relatively low.

Having defined the outside options of the negotiators, we move to the international agreement. Importantly, we assume that this has to meet a pre-determined international equity rule: indeed, equity considerations are critical in international negotiations for climate-change policy (Lange et al., 2007), as underlined by e.g. the United Nations' International Panel on Climate Change (Chapter 8 IPCC, 2022) and Article 3.1 of the United Nations Framework Convention on Climate Change. Whereas several equity rules have been considered in the literature on climate change negotiations (see e.g. Rose et al., 1998, Lange et al., 2007, Sheriff, 2019, Athanasoglou, 2022), we analyse the international agreement under two commonly used ones. First, we consider a “sovereignty rule”, whereby a common tax rate must be applied in each country, so that the rich country provides more public good than the poor one. The second one entails a “capability approach”: the tax rates are proportional to countries' average income, so that each country's marginal contribution to the public good positively depends on its capacity-to-pay for it.

We focus on the feasibility and efficiency of the agreement under each equity rule. The feasibility condition is determined by the intersection of the so-called “win-sets” of the negotiators (Putnam, 1988), i.e. the international agreement must guarantee non-negative gains for both median voters; efficiency, on the other hand, requires the agreement to be Pareto optimal. We show that the feasibility condition is met when the two countries have relatively similar outside options, i.e. if the non-cooperative tax rates that they would apply without an agreement are relatively similar. Because of the relative income hypothesis, each of these non-cooperative tax rates depends both on the absolute and relative income of the median voters. Thus, an international agreement will be feasible if the two countries have relatively similar income distribution. However, a feasible agreement can also be reached if, for example, one country compensates having a relatively low ability-to-pay for the environmental public good (because the median voter is relatively poor with respect to the median voter from the other country) with a relatively high willingness-to-pay for it (because it comes from a relatively more equal society).

Finally, we compare the two equity rules in terms of three different characteristics of the potential efficient agreement: the resulting aggregate public good provision, the utility of each country's median voter, and the feasibility of the agreement. We highlight the presence of a trade-off between feasibility and total public good provision. Specifically, the equity rule that is more likely to lead to the implementation of an international agreement, often results in a lower aggregate provision of the environmental public good. In this context, the presence of inequality between and within countries hinder the potential for international cooperation to achieve higher levels of the international public good.

The remainder of this paper is organized as follows. Section 2 reviews previous literature. Section 3 formalizes the model and provides the non-cooperative equilibrium. Section 4 analyses the feasibility and efficiency of an international environmental agreement under different equity rules and compares the efficient agreements resulting from each rule. Finally, Section 5 concludes.

2 Previous Literature

Our paper bridges two main strands of literature. First, our model relates to the extensive political economy literature considering the interaction between international strategies and domestic politics. Second, our research question belongs to the literature connecting inequality concerns with environmental policies. We delve deeper into these two connections in the next subsections, respectively.

2.1 Two-level Political Economy

The Paris Agreement has shaped international climate negotiations in the form of a "two-level game" (Keohane and Oppenheimer, 2016), but already the seminal work of Putnam (1988) showed how many international negotiations should be designed in this direction, i.e. considering the possible strategic interactions between international strategies and domestic politics. At the domestic level, government choices are influenced by domestic groups and electoral structures; internationally, the domestic government seeks to maximize domestic goals and minimize negative consequences. Therefore, policymakers play simultaneously on two different levels, involving considerations from both sides in their strategy. Using Putnam's (1988) jargon, the "win-set" for international cooperation is thus influenced by several elements from the two levels, such as preferences and coalitions in the domestic levels, political institutions, and strategies of international actors.

The literature on domestic pressures and international climate cooperation has grown in recent years and is summarized in Tavoni and Winkler (2021), whose review studies strategic incentives at different scales, showing the interplay between domestic and international policy. Related literature, mostly experimental or in political economy, has developed around specific topics, such as lobbying pressures (Marchiori et al., 2017, Habla and Winkler, 2018), media influence (Shapiro, 2016), coalition formation (see Carraro and Siniscalco, 1993, Barrett, 1994, for seminal contributions), and strategic delegation (Siqueira, 2003, Buchholz et al., 2005, Roelfsema, 2007, Kempf and Rossignol, 2013, Battaglini and Harstad, 2016, Loeper, 2017, Spycher and Winkler, 2022). We are closer to the latter, which considers electoral competition between national candidates, who will then have to negotiate an international cooperation agreement on the provision of an (environmental) public good. Whereas we focus on the role played by inequality, these models focus primarily on the conditions under which voters are incentivized to delegate strategically, i.e. to vote for a delegate with a different position than their own.

There are two papers in this large literature that we consider complementary to ours. Loeper (2017) considers the possibility of strategic delegation and its interaction with the international bargaining process. Allowing for heterogeneous consumers' preferences, it discusses whether international cooperation increases public good provision and is socially beneficial, showing that this will depend solely on the shape (and in particular the curvature) of the demand function for the public good. Kempf and Rossignol (2013) develop a two-level model to study the possibility of strategic delegation in the case of an international agreement for public good provision, and point out how distributive and fairness issues between countries are linked with the success of an agreement. The crucial difference between these papers and ours is that we consider that individual preferences for the public good may be correlated with an individual (relative) income, following a long-standing literature summarised in the next subsection.

2.2 Inequality and Environmental Policies

To the best of our knowledge, none of the studies in the previous section explicitly analyzes the role of both domestic and international income inequality in the international provision of an environmental public good.[2] However, there is a large literature on the relationship between domestic inequality and environmental policies. A review is offered by Berthe and Elie (2015), who point out that results can differ greatly depending on the assumptions underlying the model and that a clear consensus (empirical or theoretical) has yet to be reached (see also Drupp et al., 2021). In particular, the underlying assumptions differ with respect to the interests of particular social groups and how policy conflict is resolved (i.e. preference aggregation).[3]

The first aspect concerns the costs and benefits of environmental degradation for different social groups. Roemer (1993) and Boyce (1994), for example, argue that affluent people pursue more polluting consumption activities and are less affected by the risks of environmental degradation. Consequently, they will be less sensitive to environmental protection, giving less importance to the implementation of environmental policies. On the contrary, Scruggs (1998) and Magnani (2000) un-

[2] Kempf and Rossignol (2013) only consider within-country inequality in the special case in which all agents in one country are richer than all agents in the other.

[3] A recent literature has investigated the relationship between income inequality and individual and social willingness-to-pay for environmental public goods. For example, Baumgärtner et al. (2017) show that if the environmental public good and the manufactured good are substitutes, the social willingness-to-pay rises with average income but declines with income inequality.

derline how the demand for environmental policy tends to come from agents less subject to short-term material constraints, and thus from the upper part of the income distribution. In particular, Magnani (2000) maintains, both theoretically and empirically, that the marginal rate of substitution between private consumption and environmental public good depends on relative income, so that poor people care less about the environmental public good than those relatively close to the mean of the income distribution. More broadly, the well-being literature on the so-called relative income effect has a long theoretical tradition, confirmed by empirical studies looking at how individual satisfaction does not depend on its absolute level of consumption, but on the relative social status it generates; see Veblen (1899), Duesenberry (1949), and Hirsch (1976) for seminal contributions, and Ng and Wang (1993) and Verme (2018) for reviews of the literature.

The second aspect is about preference aggregation, that is which political system is taken into account. While some studies, like Boyce (1994) and Scruggs (1998), consider a power weighted social decision rules in which the political demand of the dominant social class tends to be dominant, Magnani (2000) adopts a majority rules framework. Viewing environmental policies as the result of two effects, the absolute income effect and the relative income effect, Magnani (2000) shows that although per capita growth can increase the ability to pay for environmental protection, income inequality can reduce a country's willingness-to-pay through a reduction in the median voter's preferences for consuming the public good. In this paper, we adopt Magnani's (2000) parsimonious framework at the national level, but we add an international level which is insofar missing in this literature.

3 The Model

The starting point of our model is the framework proposed by Putnam (1988), where two negotiators, representing two countries, meet to try to reach an agreement between them; in the case considered here, the agreement will concern national public goods generating cross-border spillovers, like climate change mitigation (as in Kempf and Rossignol, 2013, Loeper, 2017, among many others).

In line with Putnam's (1988) framework, we view the negotiators as individuals with no independent policy preferences, but who seek to reach an agreement that can be accepted by "public opinion" in their country; consistently, we consider that the agreement will have to be subject to the utility function of each country's median voter. Knowing that the agreement could be rejected at the national level could cause negotiations at the international level to fail, and thus the requirement that the agreement must be accepted at the national level imposes a link between the two levels. In this sense, Putnam (1988) underlines that each negotiator's win-set, i.e. the set of all possible international agreements that would be accepted at the national level, is important in determining the definition of the international agreement for two main reasons. First, larger win-sets will make it easier to reach an agreement. Second, the relative size of negotiators' win-sets will influence the distribution of joint gains from the international agreement: in fact, a smaller win-set will cause one of the two negotiators to have greater "bargaining power" in the international arena, lamenting a more binding domestic constraint.

In particular, we consider a two-country economy, where each country $j = \{1, 2\}$ is characterized by a continuum of agents of mass N_j. Throughout, $j \in \{1, 2\}$ refers to an arbitrary country and $-j$ to the other country. Within each country, agents differ in exogenous income: we let y_{ij} denote the income of agent i in country j and $f_j(y)$ represent the population density of agents with income level y in country j. Total income in each country is indicated by Y_j, which is assumed strictly positive. The average income of each country will then be defined by $\overline{y}_j \equiv Y_j/N_j$, while the median individual's income in country j is denoted by y_j. As we are interested in the role of inequality, we will focus on the case in which the majority of the population in each country has income below the average, i.e. $y_j < \overline{y}_j$. No assumptions regarding the difference in population size and income between the two countries are taken. There is no migration nor trade between countries.

As in Kempf and Rossignol (2013), each agent is endowed with a linear separable utility function that positively depends on her private consumption c_{ij} and on the provision of a public good. The public good is by definition non-rival and non-excludable: while the cost of providing the good is individual, its benefits are enjoyable by everyone. We thus assume that the impacts of the public good provisions are the same for any agent, regardless of the country which provides it. In particular, the individual utility W_{ij} of agent i in country j is

$$W_{ij} = \widetilde{W}(c_{ij}, Q_j, Q_{-j}) = c_{ij} + \alpha_{ij} \left[\widetilde{H}(Q_j) + \widetilde{H}(Q_{-j}) \right], \tag{1}$$

where Q_j is the total expenditure on public good provision in country j and $\widetilde{H}(Q_j)$ is the public good provision function which, for simplicity, is assumed logarithmic, i.e. $\widetilde{H}(Q_j) = \ln Q_j$. Importantly, the parameter α_{ij} expresses individual preferences for environmental quality (see Brown, 2022, for an alternative approach with heterogeneity in the distribution of environmental quality rather than in preferences).

Following Magnani (2000), this is assumed to be a positive function, increasing in the relative income of an individual: in particular, it depends on the distance between the individual income and the average income in her own country, expressed by the ratio $R_{ij} \equiv y_{ij}/\overline{y}_j$.[4] This is formalised as follows:

Assumption 1. *Let $\alpha_{ij} \equiv \alpha(R_{ij})$, where $R_{ij} \equiv y_{ij}/\overline{y}_j$. The function α is assumed common between the two countries, strictly positive $\alpha_{ij} \equiv \alpha(R_{ij}) > 0$, continuous, differentiable, and strictly increasing $\alpha'(R_{ij}) > 0$. Therefore, the function α is strictly increasing in y_{ij} and N_j and strictly decreasing in Y_j and $\overline{y}_j$, everything else being equal.*

On the one hand, the utility function in (1) implies that the environmental public good creates utility for each consumer; on the other one, that agents with relatively low income care relatively less for the environmental public good. This "relative income effect" is justified by the idea that the private good can be seen as a "positional good", prioritized by poor agents as compared to the environmental public good (see e.g. Magnani, 2000).

The environmental public good is financed in both countries through a linear income tax, i.e. $Q_j = \tau_j Y_j$, where $\tau_j \in [0,1]$ is the tax rate in country j; this means that individual consumption is $c_{ij} = (1-\tau_j)y_{ij}$. Therefore, the utility of individual i in country j can be expressed as

$$W_{ij} = W(y_{ij}, \alpha_{ij}, \tau_j, \tau_{-j}) = (1-\tau_j)y_{ij} + \alpha_{ij}\left[H(\tau_j) + H(\tau_{-j})\right], \tag{2}$$

where, with a slight abuse of notation, $H(\tau_j) = \ln \tau_j + \ln Y_j$. Note that the marginal benefit obtained from an increase in expenditure on public good is decreasing, given the concavity of the provision function. For what follows, it will prove useful to define the income elasticity of individual preferences for environmental quality as

$$\varepsilon_{ij} \equiv \frac{\partial \alpha_{ij}}{\partial y_{ij}} \frac{y_{ij}}{\alpha_{ij}} = \frac{\partial \alpha_{ij}}{\partial R_{ij}} \frac{R_{ij}}{\alpha_{ij}}, \tag{3}$$

where the second equality follows from applying the chain rule and rearranging.

An important assumption of our model is that we do not allow for transfers between countries (akin to e.g. Barrett, 1994, Kempf and Rossignol, 2013, Loeper,

[4] There is a large literature studying optimal tax policy implications of relative consumption concerns in one-country model, since at least Boskin and Sheshinski (1978). Aronsson and Johansson-Stenman (2015) have extended the framework to a two-country model, where individuals compare themselves with both other domestic residents and people in the other country, arguing that globalization processes have resulted in much better knowledge of the living conditions of others. We leave this extension to future research.

2017, Athanasoglou, 2022). While this may seem like a weakness of our approach, there are several reasons that justify this choice. First, Loeper (2017) argues that it is the empirically more relevant case. Indeed, in the more than 350 international environmental agreements currently in force, side payments to motivate countries to participate are rare (Barrett, 2003, Battaglini and Harstad, 2016); moreover, countries are often reluctant to make them and credibility issues exist (Athanasoglou, 2022). Second, Weikard et al. (2006), Nordhaus (2015), and Athanasoglou (2022) underline that the presence of transfers in international agreements may not help, as it may result in more unstable and complicated agreements that are harder to enforce. Third, Harstad (2007) show that the absence of side-payments is efficient in a bargaining game with private information.

3.1 Non-Cooperative Equilibrium

Before moving to the international agreement, we first derive the non-cooperative equilibrium tax rate. This represents the outside option for the negotiators: if the international agreement is not reached, the non-cooperative tax rates preferred by the two median agents are implemented in the relative country. To define the non-cooperative equilibrium, we consider that each median voter sets the tax rate taking as given the other country's policy decision, which follows from the additivity of the utility function. The optimal tax rate for agent i in country j is

$$\tau_j^*(y_{ij}) = \underset{\tau_j \in [0,1]}{\operatorname{argmax}} \, W_{ij}(y_{ij}, \alpha_{ij}, \tau_j, \tau_{-j}). \tag{4}$$

Consider the median agent in country j with income y_j and individual preferences for environmental quality $\alpha_j = \alpha(R_j)$, where $R_j = y_j/\overline{y}_j$ is the median-to-mean income ratio of country j, and as such we refer to it as a measure of domestic income equality. The income elasticity of the median agent's preferences for environmental quality is ε_j. The non-cooperative equilibrium is described in the following Proposition.

Proposition 1. *There exists a unique non-cooperative equilibrium (τ_1^*, τ_2^*), where τ_j^* refers to the non-cooperative tax rate chosen by the median voter of country j. These tax rates are such that*

$$y_j = \alpha_j H'(\tau_j^*) = \frac{\alpha_j}{\tau_j^*}. \tag{5}$$

Everything else being equal, the non-cooperative tax rate τ_j^* is increasing in the in-

come of the median agent y_j if $\varepsilon_j > 1$ and decreasing in the total income of the country Y_j. The domestic provision of the environmental public good under no-cooperation $H\left(\tau_j^*\right)$ is increasing in the income of the median agent y_j if $\varepsilon_j > 1$ and decreasing in total income of the country Y_j if $\varepsilon_j > 1$.

Proof. See Appendix A.2. □

In case of no cooperation, the optimal taxation for a country corresponds to the optimal taxation for the median voter and it is thus independent of the taxation in the other country, given the additivity of the public good provisions. The non-cooperative equilibrium tax rate depends on both the relative and the absolute income of the country's median agent, since $\tau_j^* = \alpha_j / y_j$. This ratio can be thought of as summarising the relationship between a median voter's willingness-to-pay and its ability-to-pay for the environmental public good. The former is expressed through α_j, the environmental preference parameter depending on relative income R_j; the latter is instead expressed through the median voter's income y_j.

Proposition 1 underlines that the relationship between taxation, public good provision, and the income distribution of a country is not trivial, once one accounts for heterogeneous preferences for the environmental public good. Two interlinked aspects should be underlined: the role of the income elasticity of the preferences for the environmental public good and the relationship between income equality and public good provision.

Under no-cooperation, the equilibrium tax rate and the domestic provision of the environmental public good are monotonic functions of the income of the median agent y_j, but whether these are increasing (decreasing) in the median income depends on whether the income elasticity is greater (lower) than one. This is an effect often stressed in the literature on economic growth, poverty reduction, and environmental quality: to have an increase in the demand for environmental quality given an increase of individual incomes, it is necessary to have a large income elasticity of the demand for environmental quality (e.g. Antle and Heidebrink, 1995, Magnani, 2000).

Moreover, the non-cooperative tax rate and the resulting provision of the environmental public good depend not only on absolute income, but also on its distribution. On the one hand, Proposition 1 shows that, ceteris paribus, the tax rate is negatively related with the total and average income of the country, as an increase in average income depresses the median-to-mean income ratio and thus reduces the median voter' willingness-to-pay. On the other hand, the provision of the public good decreases in total income only when the elasticity is relatively high, as the decrease in the willingness-to-pay may be partially compensated by the fact that a richer country has higher funds' availability for the provision of the public good.

Since these two effects may go in opposite directions, we investigate what a combined change in total income and its distribution across agents entails for the provision of the environmental public good. In particular, consider

$$\frac{\partial Q_j^*}{\partial Y_j \partial R_j} = \frac{\partial \alpha_j}{\partial R_j}\frac{1}{y_j} - Y_j \frac{\partial^2 \alpha_j}{\partial y_j^2}. \tag{6}$$

This shows that an increase in the total income of a country entails a greater provision of the environmental public good under two sufficient conditions. First, the increase in total income is accompanied by a corresponding income redistribution, with a rise in the median-to-mean income ratio R_j. Second, that the individual preferences for environmental quality α_j are concave in individual income y_j (or, equivalently, in income equality R_j).[5] Indeed, this second condition is necessary and sufficient to have an increase in the non-cooperative tax rate following an equality-enhancing increase in total income, since $\partial \tau_j^*/(\partial Y_j \partial R_j) = -\partial^2 \alpha_j / \partial y_j^2$. In other words, when α_{ij} is concave in individual income y_j, an equality-enhancing increase in total income always results in an increase in the provision of the public good since a larger income is subject to a higher tax rate; if α_{ij} is instead convex in individual income y_j, this may not be the case, since a larger income is subject to a lower tax rate.

Having described the outside option to cooperation, in the next section we focus on the existence, feasibility, and efficiency of an international agreement for the provision of the public good.

4 The International Agreement

In our model, agents benefit from the provision of the environmental public good independently from the country providing it, which is a strong argument in favour of the realization of an international agreement. However, agents face a trade-off between private consumption and public good provision, which is characterized by the level of inequality in each country, given the introduction of the weighted preferences with respect to relative income. Moreover, for an international agreement to

[5] If the elasticity is greater than one and the individual preferences for environmental quality are concave, then the elasticity will be decreasing in the (relative or absolute) individual income.

exist, both negotiators need to consider the domestic acceptability of the agreement, that is, the satisfaction of the median agents, however different they may be across countries. Therefore, even if simple, our model features some fundamental dynamics of political economy regarding international agreements for public goods.

As explained above, we consider the presence of two negotiators with no independent policy preferences. The negotiators from the two countries seek to reach an international agreement on the provision of the environmental public good, which consists of a pair of tax rates to be applied in their respective countries. It is assumed that the negotiators are fully rational, able to perfectly predict the final outcome of their decisions, and that there is no uncertainty in the model. Full commitment is also assumed, so that negotiators cannot renege on the agreed tax rates.

Both negotiators are concerned about the acceptability of the agreement by their national electorate: in this sense, each will have as objective an increase in the welfare of their respective median agent (characterized by income y_j and individual preferences for environmental quality α_j) compared to a situation of non-cooperation.[6] In this model, the negotiators only consider the utility of the median agent, allowing us to focus directly on the role of inequality without considering other political economy considerations. However, any international agreement must satisfy two conditions: feasibility and equity.

First, the agreement will need to be feasible, as it must generate non-negative gains for both median agents. On top of representing domestic acceptability, the feasibility condition also captures a necessary characteristic of the agreement: it needs to be convenient for the involved countries, as participation in the international environmental agreement is voluntary. Indeed, more than 350 international environmental agreements are currently in force, and in neither of them sovereign countries can be forced to participate by international organizations (Barrett, 2003, Battaglini and Harstad, 2016).

Second, the agreement will have to meet some pre-determined international equity rules. Whereas we impose the equity rule exogenously, this may represent a situation where voters in either country impose at some constitutional level an equity rule restricting the negotiators. Several equity rules have been considered in the literature on climate change negotiations (see e.g. Rose et al., 1998, Lange et al., 2007, Sheriff, 2019, for some seminal contributions); here, we consider two commonly used ones.[7]

[6] A homothetic way to model this setting would be to consider a simple majority vote system at the domestic level, such that the median voter with income y_j and individual preferences for environmental quality α_j is the delegate for country j in the international negotiations.

[7] Appendix A.10 analyses a third rule such that the median agents must draw equal gains from

In the first one, a common tax rate must be applied in each country, so that the relatively richer one provides more environmental public good than the poorer one, similarly to the "sovereignty rule" encountered in global climate negotiations (Sheriff, 2019, Athanasoglou, 2022). In the general context of international agreements, this rule has been considered by e.g. Harstad (2007) and Kempf and Rossignol (2013), but see Oates (1999) for a review on the fiscal federalism literature, where this rule is known as "uniformity assumption". The second one entails the application of tax rates which are proportional to a country's average income, so that each country's marginal contribution to the environmental public good positively depends on its capacity-to-pay for it.[8] This is similar to the so-called "capability approach" in the literature about fairness in global climate negotiations (Sheriff, 2019, Athanasoglou, 2022).

4.1 Feasibility

For any agent i in country j, the change in utility from an international agreement setting the tuple of tax rates (τ_1, τ_2), compared with the no-cooperation tax rates (τ_1^*, τ_2^*), is

$$\begin{aligned}\Gamma_{ij}(y_{ij}, \alpha_{ij}, \tau_j, \tau_{-j}, \tau_j^*, \tau_{-j}^*) &= W_{ij}(y_{ij}, \alpha_{ij}, \tau_j, \tau_{-j}) - W_{ij}(y_{ij}, \alpha_{ij}, \tau_j^*, \tau_{-j}^*) = \\ &= \alpha_{ij}[H(\tau_j) + H(\tau_{-j}) - H(\tau_j^*) - H(\tau_{-j}^*)] - y_{ij}(\tau_j - \tau_j^*), \quad (7)\end{aligned}$$

i.e. it is defined by the difference between the utility of the agent in a situation of cooperation and the utility in a situation of no-cooperation. This is the sum of two components. First, each agent in any of the two countries receives the same amount of public good independently from its origin (given its symmetric impact across countries), but benefits differently since this is multiplied by the agent-specific preference parameter α_{ij}. In particular, define $\Delta \equiv [H(\tau_j) + H(\tau_{-j}) - H(\tau_j^*) - H(\tau_{-j}^*)]$ as the change in the total provision of the public good between a situation of cooperation and no-cooperation. The utility gain derived from Δ increases in α_{ij}, but since the preference parameter is an increasing function of the relative income position of agent i with respect to the average income of the country j, this utility

the international agreement. Kempf and Rossignol (2013) underlines that this rule corresponds to the "egalitarian solution" in game theory and reminds of the "principle of reciprocity" in international trade agreements (see e.g. Bagwell and Staiger, 1999). A feasible agreement under this equity rule always exists.

[8]One may argue that a country's contribution to the public good should be proportional to total, rather than average, income. Results under this alternative rule are qualitatively similar to the one reported here and available on request.

component increases in relative income within a country. A higher provision of public good, however, might come at the cost of a higher national tax rate, as summarised by the second component: an agent dislikes an increase in taxation linked to an international agreement, and the more so the richer they are.

The condition for which an international agreement will result feasible is that it generates non-negative gains for both median agents (equivalently, it must be individually rational); in the words of Putnam (1988), a feasible international agreement belongs to the win-sets of both negotiators. Given a couple of median agents with income (y_1, y_2) and environmental preferences (α_1, α_2), we refer to the set of feasible agreements as the couples of tax rates such that, if chosen, generate non-negative gains for both median agents, i.e.

$$\begin{aligned} T(y_1, y_2, \alpha_1, \alpha_2) &= \\ &= \{(\tau_1, \tau_2);\ \Gamma_1(y_1, \alpha_1, \tau_1, \tau_2, \tau_1^*, \tau_2^*) \geq 0 \ \text{ and } \ \Gamma_2(y_2, \alpha_2, \tau_1, \tau_2, \tau_1^*, \tau_2^*) \geq 0\}, \quad (8) \end{aligned}$$

where $\Gamma_j \geq 0$ is the gain for the median agent (or the win-set for the negotiator) of country j from an international agreement. If both gains are strictly positive, we refer to it as the set of strongly feasible agreements and we indicate it with $T_+(y_1, y_2, \alpha_1, \alpha_2)$. Note that the feasible set depends on the absolute and relative income of the median agents in the two countries, since the non-cooperative taxation is defined according to them.

Proposition 2. *For any given $(y_1, y_2, \alpha_1, \alpha_2)$, the set of feasible agreements $T(y_1, y_2, \alpha_1, \alpha_2)$ is a convex subset of $[\tau_1^*; 1] \times [\tau_2^*; 1]$ with $(\tau_1^*, \tau_2^*) \in T(y_1, y_2, \alpha_1, \alpha_2)$. Moreover, $T_+(y_1, y_2, \alpha_1, \alpha_2)$ is non-empty.*

Proof. See Appendix A.3. □

Proposition 2 shows that the set of feasible agreements implies more taxation in both countries, compared to a situation of non-cooperation. Obviously, this is a consequence of the presence of positive externalities between the two countries, which means that the non-cooperative solution is sub-optimal as the international agreement implies positive gains for both countries. Indeed, each country gains from cooperation if this implies an increase in taxation from the other country, and thus an increase in the provision of the public good. Since this is true for both countries, the international agreement implies more taxation in both countries.

Note that a feasible international agreement may generate losers and winners. Let us consider a strongly feasible agreement, such that $\Gamma_1 > 0$ and $\Gamma_2 > 0$. For given taxation levels $(\tau_1, \tau_2, \tau_1^*, \tau_2^*)$, whether the individual gain derived from an international agreement is positive depends on her individual income, and in particular on the comparison between the individual increase in utility from the international agreement $\alpha_{ij}\Delta$ and the individual increase in tax paid $y_{ij}(\tau_j - \tau_j^*)$. Moreover, this gain will marginally depend on the income of the individual according to

$$\frac{\partial \Gamma_{ij}}{\partial y_{ij}} = \frac{\partial \alpha_{ij}}{\partial y_{ij}} \left[H(\tau_j) + H(\tau_{-j}) - H(\tau_j^*) - H(\tau_{-j}^*) \right] + \left(\tau_j^* - \tau_j \right). \tag{9}$$

In the right-hand side of equation (9), the first term is positive, as the benefits from a higher provision of the public good are increasing in income by Assumption 1; conversely, the second term is negative, as taxation is higher under an international agreement than under non-cooperation. Thus, the individual gain Γ_{ij} may be decreasing or increasing in individual income, and does not need to be monotonic.

For ease of reading, assume for the time being that there exists a unique income level $\tilde{y}_j$ such that the gain from cooperation is null, $\tilde{\alpha}_j\Delta = \tilde{y}_j(\tau_j - \tau_j^*)$. Further assume that there exists a unique income level $\hat{y}_j$ such that equation (9) is equal to zero, i.e. such that $\partial\alpha_{ij}/\partial y_{ij} = (\tau_j - \tau_j^*)/\Delta$; this corresponds to an elasticity $\hat{\varepsilon}_j = \hat{y}_j \left(\tau_j - \tau_j^*\right) / (\hat{\alpha}_j\Delta)$. As a consequence, to identify winners and losers, we need to look at the second-order derivative of the environmental preference parameter with respect to income, since $\partial^2\Gamma_{ij}/\partial y_{ij}^2 = \Delta\partial^2\alpha_{ij}/\partial y_{ij}^2$, which is greater (lower) than zero if α is convex (concave) in individual income. Thus, if α is assumed to be concave in y_{ij} (equivalently, in relative income R_{ij}), agents in the poorer part of the income distribution, i.e. with income lower than $\tilde{y}_j$, will win from cooperation, which will instead damage the rich part of the population. Conversely, if α is assumed to be convex in individual income, the opposite happens and agents with income higher than $\tilde{y}_j$ will win from cooperation.

In the rest of the paper, we do not need to restrict the shape of the preference function as to have unique $\tilde{y}_j$ and $\hat{y}_j$: one could, for example, assume a more complicated shape of the gain curve, such that, for example, only the middle class wins from cooperation. To focus on the most interesting case, it is enough to assume that the median agents are among the potential winners from cooperation.

4.2 Efficiency

A condition that can be imposed on an international agreement concerns its efficiency, whereby a tuple of taxes agreed upon in an international agreement must belong to the contract curve, which will intersect the set of feasible agreements.

The contract curve is the set of Pareto optima in the economy. It can be obtained maximizing Γ_j for a given Γ_{-j}, i.e. it is the set of solutions to $\max_{\tau_j,\tau_{-j}} \Gamma_j(y_j,\alpha_j,\tau_j,\tau_{-j},\tau_j^*,\tau_{-j}^*)$ subject to $\Gamma_{-j}(y_{-j},\alpha_{-j},\tau_j,\tau_{-j},\tau_j^*,\tau_{-j}^*)$ equal to a given constant. Letting μ be the Lagrange multiplier associated with the constraint, the corresponding Lagrangian is

$$\mathcal{L}(y_j,\alpha_j,\tau_j,\tau_{-j},\tau_j^*,\tau_{-j}^*) = \Gamma_j(y_j,\alpha_j,\tau_j,\tau_{-j},\tau_j^*,\tau_{-j}^*) - \mu\Gamma_{-j}(y_{-j},\alpha_{-j},\tau_j,\tau_{-j},\tau_j^*,\tau_{-j}^*) =$$
$$= -y_j(\tau_j-\tau_j^*) + \mu y_{-j}(\tau_{-j}-\tau_{-j}^*) + (\alpha_j-\mu\alpha_{-j})[H(\tau_j)+H(\tau_{-j})-H(\tau_j^*)-H(\tau_{-j}^*)],$$

whose gradient is equal to

$$\nabla\mathcal{L}(y_j,\alpha_j,\tau_j,\tau_{-j},\tau_j^*,\tau_{-j}^*) = \begin{pmatrix} -y_j+\alpha_j H'(\tau_j)-\mu\alpha_{-j}H'(\tau_j) \\ +\mu y_{-j}+\alpha_j H'(\tau_{-j})-\mu\alpha_{-j}H'(\tau_{-j}) \end{pmatrix}. \tag{10}$$

The contract curve is then defined by

$$\frac{\alpha_1 H'(\tau_1)}{y_1} + \frac{\alpha_2 H'(\tau_2)}{y_2} = \frac{\tau_1^*}{\tau_1} + \frac{\tau_2^*}{\tau_2} = 1. \tag{11}$$

In the next sections, we will discuss the feasibility and efficiency of an international agreement under two different equity rules: equal tax rates across countries and tax rates that are proportional to countries' per capita incomes.

4.3 Agreement Under An Equal Tax Rate Rule

We start our analysis by imposing the requirement that the tax rate under cooperation should be equal across countries. The set of feasible agreements under the equity rule will then be defined by the couples of tax rates for which the gain of cooperation is non-negative for both countries and the two tax rates correspond to the same level, i.e. $T_E(y_1,y_2,\alpha_1,\alpha_2) = T(y_1,y_2,\alpha_1,\alpha_2)\cap E$ where $E=\{(\tau_1,\tau_2)|\tau_1=\tau_2\}$. We denote the cooperative tax rate satisfying this equity rule as τ_E.

We first analyse under which conditions the equity rule can bring to a feasible agreement between the parties. The feasibility condition implies $\alpha_j\Delta_E \geq y_j(\tau_E-\tau_j^*)$, $\forall j$, where the increase in the total provision of the public good given the realization of an agreement is given by $\Delta_E = 2H(\tau_E)-H(\tau_1^*)-H(\tau_2^*)$; equivalently, the win-set for country j's negotiator is given by $\Gamma_j = \alpha_j\Delta_E - y_j(\tau_E-\tau_j^*) \geq 0$. Then, the existence of a feasible agreement under an equal tax rate rule hinges on $\Delta_E \geq \max\{\tau_E/\tau_1^*-1, \tau_E/\tau_2^*-1\}$, implicitly requiring the participation of the country with the lower non-cooperative tax rate. Second, we consider if an agreement reached under the equal tax equity rule can be efficient. We summarise the outcome of the international agreement under an equal tax rate in the following Proposition.

Proposition 3. *A feasible agreement under an equal tax rate rule exists if and only if* $\tau_1^*/\tau_2^* = (\alpha_1/y_1)(y_2/\alpha_2) \in [e/4, 4/e]$. *The efficient agreement under the equal tax rate rule is* $\tau_E = \tau_1^* + \tau_2^* = \alpha_1/y_1 + \alpha_2/y_2$, *which is feasible if and only if* $\ln[(\tau_1^* + \tau_2^*)^2/(\tau_1^*\tau_2^*)] \geq \max\{\tau_1^*/\tau_2^*, \tau_2^*/\tau_1^*\}$.

Proof. See Appendix A.4. □

A feasible international agreement for the provision of an environmental public good under a common tax rate may not exist. The relevant statistics for the existence of this international agreement is the ratio of the optimal tax rates under no-cooperation τ_1^*/τ_2^*, i.e. of the outside options, which in turn depends on the preferences for environmental quality and the income of the two median agents, $(\alpha_1/y_1)/(\alpha_2/y_2)$. An agreement under this equity rule can be reached only when the two negotiators have similar outside options: in particular, the ratio $\tau_1^*/\tau_2^* = (\alpha_1/y_1)/(\alpha_2/y_2)$ must be between $e/4 \approx 68\%$ and $4/e \approx 147\%$ for a feasible agreement to exist, as shown by the solid lines in Figure 1. Not surprisingly, a feasible agreement will be reached when the two countries involved have similar income distributions, i.e. similar median and average incomes. However, a feasible agreement can also be reached if, for example, the country with the relatively poorer median voter (thus a relatively low ability-to-pay y_j) compensates this with a relatively more equal society (thus a relatively high willingness-to-pay α_j) than the opponent.

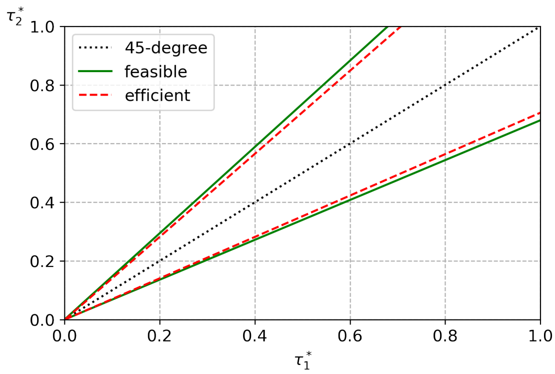


Figure 1: International Agreement Under An Equal Tax Rate

The common efficient tax rate is unique and equal to the sum of the non-cooperative tax rates, which follows from the fact that the environmental public good is given by the sum of the local provisions. As a consequence, the efficient tax rate features the same comparative statics as the non-cooperative ones summarised in Proposition 1: in particular, keeping everything else constant, it is increasing in the income of the median agent in country j if $\varepsilon_j > 1$ and always decreasing in countries' total income. Indeed, a richer agent values more the public good only under a large relative income elasticity of the demand for the public good. Once again, the efficient cooperative tax rate will be feasible only if the two countries have similar outside options, but with a slightly tighter requirement than for the sole feasibility, since τ_1^*/τ_2^* must lie approximately between 71% and 142% for the efficient agreement to be feasible (see the dashed lines in Figure 1).

Focusing on the efficient cooperative tax rate, the following Corollary compares the win-sets of the two negotiators under an equal tax rate rule and provides some comparative statics.

Corollary 3.1. *Under the efficient equal tax rate $\tau_E = \tau_1^* + \tau_2^*$, the negotiator for country j has a bigger win-set than the one for country $-j$, $\Gamma_j > \Gamma_{-j}$, if either i) country j has a higher outside option $\tau_j^* > \tau_{-j}^*$ and a richer median voter $y_j > y_{-j}$; ii) country j has a higher outside option $\tau_j^* > \tau_{-j}^*$, a poorer median voter $y_j < y_{-j}$, but a sufficiently equal income distribution; or iii) country j has a lower outside option $\tau_j^* < \tau_{-j}^*$, a richer median voter $y_j > y_{-j}$, but a more equal income distribution. The win-set of the negotiator for country j under the efficient equal tax rate is increasing in y_j if ε_j is higher than an endogenous threshold ε_E (with $\partial\varepsilon_E/\partial\tau_j^* < 0$ and $\partial\varepsilon_E/\partial\tau_{-j}^* > 0$), decreasing in y_{-j} if $\varepsilon_{-j} > 1$, decreasing in Y_j, and increasing in Y_{-j}.*

Proof. See Appendix A.5. □

The first part of Corollary 3.1 shows that countries with a relatively equal distribution have more to gain from an efficient international agreement since their median voter tends to value more the public good. The second part of the corollary, instead, underlines the important role played by the level of income equality and the income elasticity of demand for the environmental public good for the feasibility of the efficient agreement.

Take, for example, an increase in the total income of country j. Keeping everything else constant, this corresponds to a decrease in its median-to-mean income ratio R_j, i.e. an increase in income inequality within this country. Since its median voter now cares relatively less for the public good, the win-set for the negotiator for country j shrinks. However, the decrease in the willingness-to-pay for the public good of the median voter in country j leads to a decrease in its non-cooperative tax rate τ_j^* (see Proposition 1), which further feeds into a fall in the efficient tax rate

τ_E under this equity rule. This enlarges the win-set of the negotiator for country $-j$. The first effect makes the agreement harder to reach, whereas the second one makes it easier: therefore, whether more inequality in a country makes the efficient agreement more feasible depends on the size of the relative win-sets, on their relative position, and on their joint variation.

The effect of a change in inequality due to a change in median income is more nuanced, but the main message that this may hinder or facilitate reaching an agreement depending on initial conditions is unchanged. For example, consider country j, and assume that its median voter has an elasticity $\varepsilon_j > 1$. As explained in Proposition 1, since this elasticity is higher than one, an increase in the median income of country j (and thus a more equal income distribution within this country) will translate into a higher non-cooperative tax rate τ_j^*. Since this leads to a higher efficient tax rate τ_E under this equity rule, the win-set of the negotiator for country $-j$ will shrink. The negotiator for country j, however, will see an enlargement of its win-set if this elasticity is higher than the endogenous threshold ε_E (whose value is given in Appendix A.5). This threshold could be higher or lower than one, and it is always lower than one if $\tau_j^* \geq \tau_{-j}^*$. Therefore, an increase in income equality in the country with an already higher non-cooperative tax rate will enlarge the win-set of its negotiator, while shrinking the win-set of the opponent. Conversely, if ε_E is greater than one (which happens only for $\tau_j^* < \tau_{-j}^*$), an increase in income equality in country j, through an increase in its median income, may shrink the win-sets of both negotiators. These effects are reversed if $\varepsilon_j < 1$.

In the next subsection, we consider an agreement which internalises part of the income differences between the two countries.

4.4 Agreement Under A Proportional Tax Rates Rule

The second equity rule imposes the requirement that the tax rates under cooperation should be proportional to countries' average incomes so that each country's contribution to the public good reflects their relative ability to incur the costs. Under this equity rule, the set of feasible agreements is defined as $T_K(y_1, y_2, \alpha_1, \alpha_2) = T(y_1, y_2, \alpha_1, \alpha_2) \cap K$ where $K = \{(\tau_1, \tau_2) | \tau_1/\tau_2 = \overline{y}_1/\overline{y}_2 \equiv k\}$, with $k \in \mathbb{R}^+$.

Similarly to the previous section, we analyse the conditions for feasibility and efficiency under this equity rule. The feasibility condition requires the increase in the total provision of the public good to be $\Delta_K \geq \max\{\tau_1/\tau_1^* - 1, \tau_2/\tau_2^* - 1\}$: the willingness to cooperate of the country with the lower outside option (this time in proportional terms, $\tau_j^*/\overline{y}_j$) is then crucial for the realization of the agreement. The outcomes of the feasibility and efficiency conditions under proportional tax rates are expressed in the following Proposition.

Proposition 4. *A feasible agreement under a proportional tax rate rule, such that* $\tau_1/\tau_2 = \overline{y}_1/\overline{y}_2 \equiv k$*, exists if and only if* $\tau_1^*/\tau_2^* = (\alpha_1/y_1)(y_2/\alpha_2) \in [ek/4, 4k/e]$*. The efficient agreement under the proportional tax rate rule is* $\tau_1 = \tau_1^* + k\tau_2^* = \alpha_1/y_1 + k\alpha_2/y_2$ *and* $\tau_2 = \tau_1^*/k + \tau_2^* = \alpha_1/(ky_1) + \alpha_2/y_2$*, which is feasible if and only if* $\ln\left[(\tau_1^* + k\tau_2^*)^2 / (k\tau_1^*\tau_2^*)\right] \geq \max\{k\tau_2^*/\tau_1^*, \tau_1^*/(k\tau_2^*)\}$.

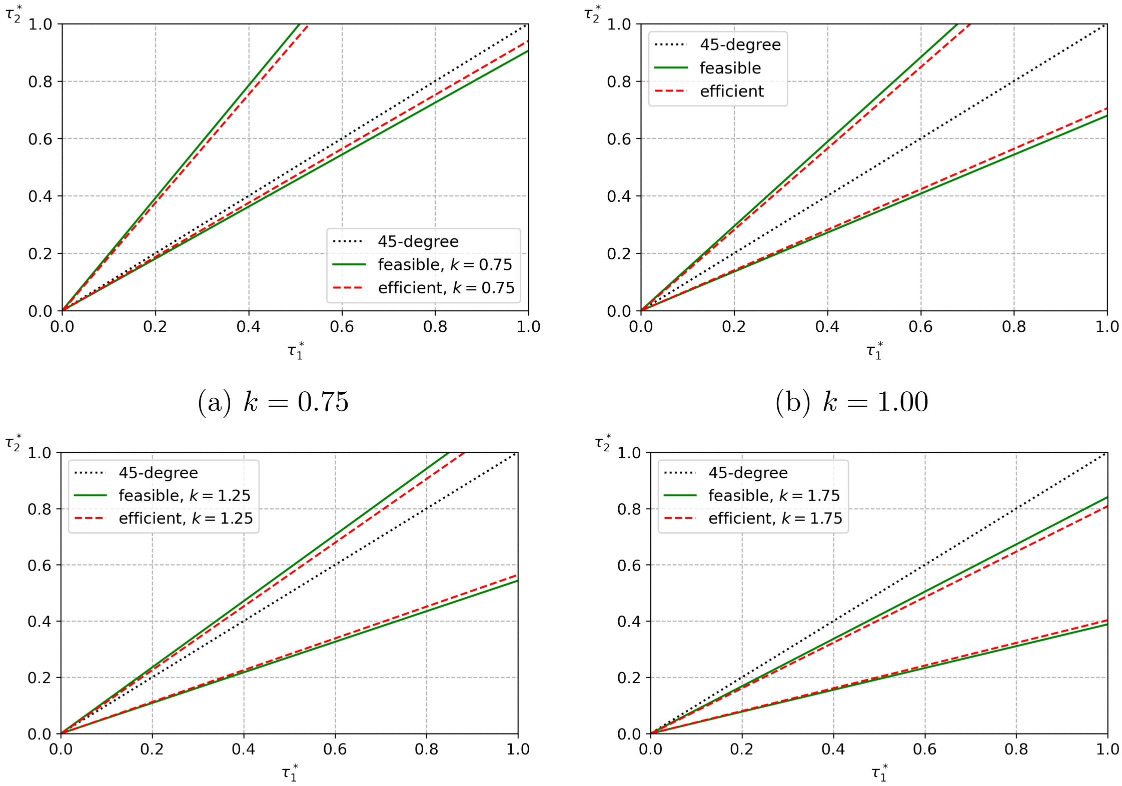
Proof. See Appendix A.6 □

The feasibility of the agreement under this equity rule not only depends on the relative outside options, but also on the distance k between the countries in terms of average income: under this equity rule, this not only indirectly influences the outside options of the countries involved in the agreement through its impact on the environmental preferences, but now also impacts the feasibility conditions directly. Indeed, whereas the previous equity rule enforced a common tax rate across the countries, this agreement partly incorporates the disparity in average income between countries by implementing different tax rates.

On the one hand, this means that the set of non-cooperative tax rates for which an international agreement under this equity rule is feasible is larger than under the equal tax rate equity rule, as shown in Figure 2 for different levels of k (obviously, when $k = 1$, the two rules coincide, as shown in Panel 2b). On the other hand, the cooperative tax rates under the proportional equity rule directly reflect the difference in average income across countries. This is shown by the fact that the feasible sets are skewed in Figure 2 towards the axis corresponding to the country with the higher average income. This is also evident in the efficient tax rates, $\tau_2 = \tau_2^* + \tau_1^*/k$ and $\tau_1 = \tau_1^* + k\tau_2^*$: whereas both countries are expected to marginally contribute more than under no-cooperation, the increase in the cooperative tax rate is relatively higher for the country with higher average income.

Corollary 4.1 presents a comparative analysis of the win-sets of the two negotiators under the proportional tax rate rule. As for the previous equity rule, this analysis is performed considering the efficient cooperative tax rates.

Corollary 4.1. *Under the efficient proportional tax rates* $\tau_1 = \tau_1^* + k\tau_2^*$ *and* $\tau_2 = \tau_2^* + \tau_1^*/k$*, the negotiator for country* 1 *has a bigger win-set than the one for country* 2*,* $\Gamma_1 > \Gamma_2$*, if either i) country* 1 *has a higher proportional outside option* $\tau_1^* > k\tau_2^*$ *and*



(a) $k = 0.75$

(b) $k = 1.00$

(c) $k = 1.25$

(d) $k = 1.75$

Figure 2: International Agreement Under Proportional Tax Rates

a proportionally richer median voter $y_1 k > y_2$*; ii) country 1 has a higher proportional outside option* $\tau_1^* > k\tau_2^*$*, a proportionally poorer median voter* $y_1 k < y_2$*, but a sufficiently equal income distribution; or iii) country 1 has a lower proportional outside option* $\tau_1^* < k\tau_2^*$*, a proportionally richer median voter* $y_1 k > y_2$*, but a more equal income distribution. The win-set of the negotiator for country* j *under the efficient proportional tax rates is increasing in* y_j *if* ε_j *is higher than an endogenous country-specific threshold* $\varepsilon_{j,K}$ *(with* $\partial\varepsilon_{j,K}/\partial\tau_j^* < 0$*,* $\partial\varepsilon_{j,K}/\partial\tau_{-j}^* > 0$*; let* $\overline{y}_j > \overline{y}_{-j}$*, then* $\partial\varepsilon_{j,K}/\partial k > 0$ *and* $\partial\varepsilon_{-j,K}/\partial k < 0$*), decreasing in* y_{-j} *if* $\varepsilon_{-j} > 1$*, decreasing in* Y_j*, and increasing in* Y_{-j}*.*

Proof. See Appendix A.7 □

Corollary 4.1 shows the comparative statics for the win-sets under the proportional tax rates rule. These results are similar in spirit to those for the first equity rule. First, negotiators for more equal countries will tend to have bigger win-sets. Second, an increase in total and average income of a country, without a corresponding increase in equality, will shrink the win-set of the negotiator for this country and enlarge the win-set of the other one, independently of whether the country getting richer was already richer to start with. Third, the size of the elasticity is crucial for whether increases in median income facilitate the realization of the agreement.

However, a crucial difference should be noted. Under the efficient proportional tax rates, the endogenous thresholds for the elasticity required to have a positive relative increase in the win-set, given an increase in the median income of the country, are now country-specific, since they also depend on the ratio of the average incomes of the countries k. Since k is positive but indefinitely high, the threshold for the richer (cf. poorer) country on average could be arbitrarily high (cf. low), and is higher (cf. lower) than the threshold under the equal tax rate equity rule.

4.5 Discussion

Finally, we compare the two equity rules in terms of total provision of public good, median voter's utility level, and feasibility. We use the efficient tax rates for these results.

First, by comparing the efficient tax rates under the proportional equity rule ($\tau_1 = \tau_1^* + k\tau_2^*$ and $\tau_2 = \tau_2^* + \tau_1^*/k$) with the efficient equal tax rate ($\tau_E = \tau_1^* + \tau_2^*$), it is evident that the country with the higher average income must accept a higher tax rate under the proportional equity rule than under the equal tax rate rule, whereas the poorer country benefits from a relatively lower rate. As a consequence, under which equity rule the total provision of environmental public good is higher depends on which of these two marginal effects dominates.

Corollary 5.1. *The total provision of the environmental public good is higher under the efficient proportional tax rates than under the efficient equal tax rate if either i) $k < 1$ and $\tau_1^* > k\tau_2^*$; or ii) $k > 1$ and $\tau_1^* < k\tau_2^*$; they are the same if $k = 1$. The difference in total provision under the proportional tax rates as compared to the efficient equal tax rate increases in the difference in the two countries' average income k if $\tau_1^* < k\tau_2^*$.*

Proof. See Appendix A.8. □

In other words, Corollary 5.1 shows that the total provision of the environmental public good will be higher under the proportional tax rate rule if the country with the higher average income $\overline{y}_j$ is also the one with the lower proportional non-cooperative tax rate $\tau_j^\star/\overline{y}_j$, i.e. if the richer country (on average) is also relatively more unequal. In such a case, the higher is the difference in average income across countries, the higher will be the total provision of the public good under the efficient proportional tax rates relatively to the efficient equal tax rate. As explained above, in this scenario, the country with the "better" outside option (i.e. a lower proportional non-cooperative tax rate) is crucial for the realization of the agreement and can thus obtain a substantial increase in the supply of the public good to compensate for the increased taxation.

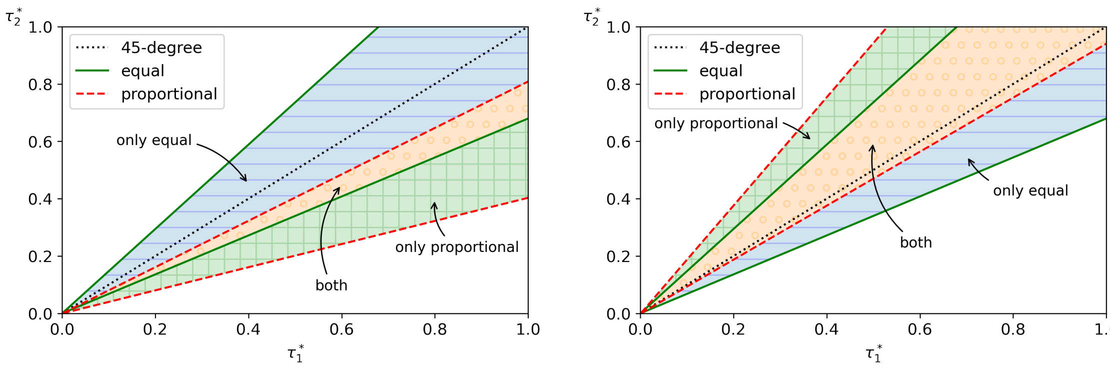
Second, we highlight that how costs and benefits are shared between the two median voters across equity rules depends on both within-country and between-country inequality. That different equity rules lead to different relative benefits and costs is not surprising, and there are evidences that a country's advocacy for a particular rule is often self-serving (Lange et al., 2010).

Corollary 5.2. *The utility derived from the international agreement by the median voter of country j is higher under the efficient equal tax rate than under the efficient proportional tax rates if* $\overline{y}_j > \overline{y}_{-j}$*, the more so the higher is the difference in average incomes across countries. Consider the case in which country 1 has the higher average income,* $k > 1$*: the difference in utility of its median voter from the proportional tax rates as compared to the efficient equal tax rate increases in its median income if either i)* $\varepsilon_1 > 1$ *and* $\tau_1^* < k\tau_2^*$*; or ii)* $\varepsilon_1 < 1$ *and* $\tau_1^* > k\tau_2^*$*; it increases in the median income of country 2 if* $\varepsilon_2 < 1$.

Proof. See Appendix A.9. □

Obviously, the median voter from the country with the higher average income always prefers the equal tax rate rule (the more so, the higher is the difference in average incomes), since she must accept a higher tax rate under the proportional tax rates rule than under the equal tax rate rule; she is indifferent between them only if they are equivalent, i.e. if $k = 1$. However, her relative dislike of the proportional tax rates rule hinges on the income elasticities, on the difference in income across countries, and on the income distributions within countries. An increase in equality in the richer country decreases the relatively dislike of its median voter towards the proportional tax rates rule only if her income elasticity is sufficiently high and if national income inequality was originally relatively high. Conversely, the same effect is reached by an increase in equality in the poorer country only if the elasticity of the median voter in the opponent country is low.

Finally, we compare the feasibility of the efficient agreement under the two equity rules. Whether an agreement is more easily reached under the equal tax rate equity rule or under proportional tax rates depends on the income distribution of the two countries involved, as represented in Figure 3. Consider, without loss of generality, the case in which country 1 is richer on average than country 2, $\bar{y}_1 > \bar{y}_2$, and thus $k > 1$; an example of this situation is represented in Panel 3a. If country 1 is contemporaneously more unequal than country 2, $\alpha_1 < \alpha_2$, the resulting low willingness-to-pay for the environmental good by country 1 could translate in the ratio of the outside options $\tau_1^*/\tau_2^* = (\alpha_1/y_1)/(\alpha_2/y_2)$ lying above the 45-degree line: in such case, the feasible set under an equal tax rate is more likely to contain this ratio than the feasible set under proportional tax rates (which is tilted toward τ_1^*). In this scenario, the equal tax rate equity rule leads to a feasible agreement, while also accruing a higher level of utility for the median voter in the richer country. At the same time, however, it is also associated with a lower aggregate provision of the public good at the international level and a lower level of utility for the median voter of the poorer country.



(a) $k = 1.75$ (b) $k = 0.75$

Figure 3: Feasibility Sets Under Efficient Tax Rates

Conversely, if country 1 is both richer, $\bar{y}_1 > \bar{y}_2$, and more equal, $\alpha_1 > \alpha_2$, i.e. more able-to-pay and contemporaneously more willing-to-pay for the public good, the ratio of the outside options would tend to lie below the 45-degree line, and thus the proportional tax rates may lead to a more easily implemented international agreement. In other words, given that the country with the best outside option is the poorer one, its willingness to cooperate is critical for the international agreement, and its median voter prefers the proportional tax rate rule. However, this agreement results in a lower level of utility for the median voter of the richer country, while also providing a lower aggregate amount of the public good. Panel 3b shows the case in which country 1 is on average poorer than country 2.

5 Conclusion

National characteristics can shape the success of international cooperation against climate change. In this paper, we studied how income inequality within and across countries can affect the success and characteristics of an international agreement for the provision of an environmental public good in a simple two-country two-level political economy model. At the international level, two negotiators aim to agree on the relative provision of the environmental public good. At the national level, the agreement must be acceptable to the median voters, whose preferences for the public good are directly linked to the level of inequality within their own country (in line with the so-called relative income hypothesis). As a consequence, the feasibility of the agreement not only depends on the difference in average income between countries, but also on the domestic income distributions.

We showed that what is particularly crucial for the feasibility of the international agreement is the similarity in the outside options available to both countries, i.e. the non-cooperative tax rates they would implement in the absence of the agreement, which depend on both absolute and relative income of the median voters. As a consequence, even if two countries had identical average incomes, the realization of the agreement would still be hindered if their internal income distributions were to differ significantly. Conversely, when average incomes differ across countries, an international agreement can still be reached if the country with the relatively poorer median voter compensates this with a relatively more equal society. Moreover, we emphasize that the provision of the public good, both domestically and internationally, does not necessarily increase solely based on the wealth of the countries involved; instead, it is contingent upon having more equitable societies, where income inequality is reduced. Finally, we observe that the presence of a wealthier, yet more unequal country, leads to an agreement that benefits more its median voter, while resulting in a lower provision of public good at the international level.

Our results suggest that an international facilitator, aiming to propose an equity rule that would lead to the attainment of an international environmental agreement, needs to take both national and international characteristics into account and may need to trade-off an increase in the total provision of the public good with a decrease in feasibility.

Whereas our model succeeds in capturing some important obstacles in international cooperation recently observed in climate negotiations, it is based on some fairly stringent assumptions, considering e.g. the functional forms adopted (with respect to the production of the public good or the utility function) and the international cooperation setting. Moreover, one could consider different production processes in the two countries, with different levels of emissions or heterogeneous efficiency in abatement technologies. In addition, it would be interesting to expand the domestic setting to consider different ways of aggregating preferences. Finally, existing international environmental agreements often involve multiple stages. Future developments may relax some of the more stringent assumptions and incorporate these realistic features.

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A Appendix

A.1 Some Useful Results

We begin our Appendix with some results which will be useful for the proofs below.

$$\frac{\partial \alpha_{ij}}{\partial y_{ij}} = \frac{\partial \alpha_{ij}}{\partial R_{ij}} \frac{\partial R_{ij}}{\partial y_{ij}} = \frac{\partial \alpha_{ij}}{\partial R_{ij}} \frac{1}{Y_j/N_j} \quad \rightarrow \quad \frac{\partial \alpha_{ij}}{\partial R_{ij}} = \frac{\partial \alpha_{ij}}{\partial y_{ij}} \frac{Y_j}{N_j}, \tag{A.1}$$

$$\frac{\partial \ln \frac{\alpha(y_j/\overline{y}_j)}{y_j}}{\partial y_j} = \left[\frac{\alpha'(y_j/\overline{y}_j)}{\overline{y}_j \alpha(y_j/\overline{y}_j)} - \frac{1}{y_j} \right], \tag{A.2}$$

$$\frac{\partial \tau_j^\star}{\partial y_j} = \frac{\partial \frac{\alpha(y_j/\overline{y}_j)}{y_j}}{\partial y_j} = \frac{y_j \frac{\partial \alpha(y_j/\overline{y}_j)}{\partial y_j} - \alpha(y_j/\overline{y}_j) \frac{\partial y_j}{y_j}}{y_j^2} = \frac{\alpha(y_j/\overline{y}_j)}{y_j^2} \left[\varepsilon_j - 1 \right], \tag{A.3}$$

$$\varepsilon_{ij} \equiv \frac{\partial \alpha_{ij}}{\partial y_{ij}} \frac{y_{ij}}{\alpha_{ij}} = \frac{\partial \alpha_{ij}}{\partial R_{ij}} \frac{y_{ij}}{\alpha_{ij}} \frac{N_j}{Y_j} = \frac{\partial \alpha_{ij}}{\partial R_{ij}} \frac{y_{ij}}{\overline{y}_j} \frac{1}{\alpha_{ij}} = \frac{\partial \alpha_{ij}}{\partial R_{ij}} \frac{R_{ij}}{\alpha_{ij}}, \tag{A.4}$$

$$\begin{aligned} \frac{\partial^2 \alpha_{ij}}{\partial y_{ij}^2} &= \frac{\partial^2 \alpha\left(R_{ij}\right)}{\partial y_{ij}^2} = \frac{\partial^2 \alpha\left(y_{ij}/\overline{y}_j\right)}{\partial y_{ij}^2} = \frac{\partial \left[\frac{\partial \alpha\left(y_{ij}/\overline{y}_j\right)}{\partial y_{ij}} \right]}{\partial y_{ij}} = \frac{\partial}{\partial y_{ij}} \left[\frac{\partial \alpha_{ij}}{\partial R_{ij}} \frac{1}{\overline{y}_j} \right] = \\ &= \frac{1}{\overline{y}_j} \frac{\partial}{\partial y_{ij}} \left[\frac{\partial \alpha_{ij}}{\partial R_{ij}} \right] = \frac{1}{\overline{y}_j} \frac{\partial^2 \alpha_{ij}}{\partial R_{ij}^2} \frac{1}{\overline{y}_j} = \frac{1}{\overline{y}_j^2} \frac{\partial^2 \alpha_{ij}}{\partial R_{ij}^2} \quad \rightarrow \quad \frac{\partial^2 \alpha_{ij}}{\partial R_{ij}^2} = \overline{y}_j^2 \frac{\partial^2 \alpha_{ij}}{\partial y_{ij}^2}, \end{aligned} \tag{A.5}$$

$$\frac{\partial^2 \alpha_{ij}}{\partial y_{ij}^2} > 0 \quad \rightarrow \quad \frac{\partial^2 \alpha_{ij}}{\partial R_{ij}^2} \frac{1}{\overline{y}_j^2} > 0 \quad \rightarrow \quad \frac{\partial^2 \alpha_{ij}}{\partial R_{ij}^2} > 0. \tag{A.6}$$

A.2 Proof of Proposition 1

The preferred non-cooperative tax rate of an agent with income y_{ij} in country j maximises $F(y_{ij}, \tau_{ij}) = y_{ij}(1 - \tau_{ij}) + \alpha_{ij} H(\tau_{ij})$, which is single-peaked in the environmental tax rate τ_{ij}. The first order condition then is $y_{ij} = \alpha_{ij} H'(\tau_{ij})$, or, equivalently, $\tau_{ij}^* = \alpha_{ij}/y_{ij}$. The median agent of country j has income y_j, and so will choose $y_j = \alpha_j H'(\tau_j)$, where α_j is a function of her relative income. The optimal tax rate is increasing in y_j if

$$\frac{\partial \tau_j^*}{\partial y_j} = \frac{\frac{\partial \alpha_j}{\partial y_j} y_j - \alpha_j}{y_j^2} > 0 \qquad \text{i.e.} \quad 1 < \frac{\partial \alpha_j}{\partial y_j} \frac{y_j}{\alpha_j} \equiv \varepsilon_j. \tag{A.7}$$

Conversely, if $\varepsilon_j < 1$, the optimal environmental tax is a decreasing function of income.

The non-cooperative tax rate is negatively correlated with a variation in the total income of the country, as

$$\frac{\partial \tau_j^*}{\partial Y_j} = \frac{\partial \alpha_j / \partial Y_j}{y_j} = \frac{\partial \alpha_j}{\partial R_j}\left(-\frac{y_j N_j}{Y_j^2}\right)\frac{1}{y_j} = \frac{\partial \alpha_j}{\partial R_j}\left(-\frac{N_j}{Y_j^2}\right) < 0, \tag{A.8}$$

where the first ratio on the last right-hand side is positive by Assumption 1 and the second one is negative.

The domestic public good provision under no-cooperation is $\ln Q_j^* = \ln\left(\tau_j^* Y_j\right)$. This is increasing in y_j if

$$\frac{\partial \tau_j^* Y_j}{\partial y_j} = \frac{\frac{\partial \alpha_j}{\partial y_j} y_j Y_j - \alpha_j Y_j}{y_j^2} > 0 \qquad \text{i.e.} \quad 1 < \frac{\partial \alpha_j}{\partial y_j}\frac{y_j}{\alpha_j} \equiv \varepsilon_j. \tag{A.9}$$

Finally, it is increasing in total income of the country if

$$\frac{\partial \tau_j^* Y_j}{\partial Y_j} = -\frac{\partial \alpha_j}{\partial R_j}\frac{N_j}{Y_j} + \frac{\alpha_j}{y_j} > 0 \qquad \text{i.e.} \quad 1 > \frac{\partial \alpha_j}{\partial R_j}\frac{R_j}{\alpha_j} \equiv \varepsilon_j. \tag{A.10}$$

A.3 Proof of Proposition 2

Given the definition of the set of feasible agreements in (8), if $(\tau_1, \tau_2) \in T(y_1, y_2, \alpha_1, \alpha_2)$ then $\Gamma_1 \geq 0$ and $\Gamma_2 \geq 0$, where

$$\begin{aligned} &\Gamma_j \equiv \Gamma_j(y_j, \alpha_j, \tau_1, \tau_2, \tau_1^*, \tau_2^*) = \\ &= \left[W_j(y_j, \alpha_j, \tau_1, \tau_2) - W_j(y_j, \alpha_j, \tau_1^*, \tau_2)\right] + \left[W_j(y_j, \alpha_j, \tau_1^*, \tau_2) - W_j(y_j, \alpha_j, \tau_1^*, \tau_2^*)\right]. \end{aligned} \tag{A.11}$$

The term within the first pair of square brackets is always negative, since τ_1^* maximises $W_1(y_1, \alpha_1, \tau_1, \tau_2)$ for given τ_2 (and vice versa); to have $\Gamma_1 \geq 0$, the term within the second pair of square brackets must be positive. Letting $W_1 = F(y_1, \alpha_1, \tau_1) + \alpha_1 H(\tau_2)$, where $F(y_j, \alpha_j, \tau_j) = y_j(1 - \tau_j) + \alpha_j H(\tau_j)$, this second term can be expressed as

$$F(y_1, \alpha_1, \tau_1^*) + \alpha_1 H(\tau_2) - F(y_1, \alpha_1, \tau_1^*) + \alpha_1 H(\tau_2^*) \geq 0, \tag{A.12}$$

which implies $\tau_2 \geq \tau_2^*$, since H is an increasing function. Similarly, we can find $\tau_1 \geq \tau_1^*$.

The gain derived from the international agreement by the median voter in country 1 can also be expressed as

$$\Gamma_1 = F(y_1, \alpha_1, \tau_1) + \alpha_1 H(\tau_2) - F(y_1, \alpha_1, \tau_1^*) - \alpha_1 H(\tau_2^*). \tag{A.13}$$

This is zero if $\tau_2 = H^{-1}(\widetilde{F}(\tau_1)/\alpha_1)$, where $\widetilde{F}(\tau_1) = F(y_1, \alpha_1, \tau_1^*) + \alpha_1 H(\tau_2^*) -$

$F(y_1, \alpha_1, \tau_1)$ is an increasing convex function on $\tau_1 \in [\tau_1^*; 1]$. Moreover, $1/\alpha_1$ is positive, so $\widetilde{F}(\tau_1)/\alpha_1$ is an increasing convex function. H^{-1} is an increasing convex function, then $\psi_1(\tau_1) = H^{-1}(\widetilde{F}(\tau_1)/\alpha_1)$ defines an increasing convex function on $[\tau_1^*; 1]$. Therefore, $\psi_1(\tau_1^*) = \tau_2^*$. Differentiating,

$$\psi_1'(\tau_1^*) = \frac{\frac{1}{\alpha_1} F'(\tau_1^*)}{H'(H^{-1}(\frac{1}{\alpha_1} F(\tau_1^*))} = \frac{1}{\alpha_1} \frac{F'(\tau_1^*)}{H'(\tau_2^*)} = 0. \tag{A.14}$$

Similarly, one can show that $\Gamma_2 = 0$ if $\tau_1 = \psi_2(\tau_2)$, where ψ_2 is an increasing convex function on $[\tau_2^*; 1]$, and $\psi_2(\tau_2^*) = \tau_1^*$. Then, $T(y_1, y_2, \alpha_1, \alpha_2) = \{(\tau_1, \tau_2) \in [\tau_1^*, 1] \times [\tau_2^*, 1]; \tau_2 \geq \psi_1(\tau_1)\} \cap \{(\tau_1, \tau_2) \in [\tau_1^*, 1] \times [\tau_2^*, 1]; \tau_1 \geq \psi_2(\tau_2)\}$ is a convex set since it is the intersection of two convex sets and it is a closed set, being the intersection of two closed sets, $\{\Gamma_1 \geq 0\}$ and $\{\Gamma_2 \geq 0\}$.

Finally, we want to show that $T_+(y_1, y_2, \alpha_1, \alpha_2)$ is non-empty. Let $(\tau_1, \tau_2) \in]\tau_1^*; 1] \times]\tau_2^*; 1]$ and $h_j = \tau_j - \tau_j^* > 0$, for $j = 1, 2$. Then

$$\begin{aligned}
\Gamma_1 &= \Gamma_1(y_1, \alpha_1, \tau_1, \tau_2, \tau_1^*, \tau_2^*) \\
&= F(y_1, \alpha_1, \tau_1) + \alpha_1 H(\tau_2) - F(y_1, \alpha_1, \tau_1^*) - \alpha_1 H(\tau_2^*) \\
&= F(y_1, \alpha_1, \tau_1) - F(y_1, \alpha_1, \tau_1^*) + \alpha_1 H(\tau_2) - \alpha_1 H(\tau_2^*) \\
&= \frac{\partial F}{\partial \tau}(y_1, \tau_1^*) h_1 + o(h_1) + \alpha_1 H'(\tau_2) h_2 + o(h_2) \; \textit{as } h_1 \to 0^+ \textit{ and } h_2 \to 0^+ \\
&= \alpha_1 H'(\tau_2^*) h_2 + o(h_1) + o(h_2) \qquad \text{since } \tau_1^* = argmax_{\tau_1} F(y_1, \alpha_1, \tau_1) \\
&= \alpha_1 H'(\tau_2^*) h + o(h) \text{ as } h \to 0 \text{ for } h = h_1 = h_2.
\end{aligned}$$

Since $H'(\tau_2^*) > 0$ and $\alpha_1 > 0$, $\Gamma_1 > 0$ for $h > 0$ close to 0. We can write the same proof for $\Gamma_2 > 0$. Thus, $\Gamma_1 > 0$ and $\Gamma_2 > 0$ for $h = h_1 = h_2 > 0$ close to 0, i.e. $T_+(y_1, y_2, \alpha_1, \alpha_2) \neq \varnothing$. $T_+(\widetilde{y_1}, \widetilde{y_2}, \alpha_1, \alpha_2)$ is an open set since $\{\Gamma_1 > 0\}$ and $\{\Gamma_2 > 0\}$ are open sets.

A.4 Proof of Proposition 3

The feasibility condition implies $\alpha_j \Delta_E - y_j(\tau_E - \tau_j^*) \geq 0$, $\forall j$, where the increase in total provision of the public good given the realization of an agreement in this case is given by $\Delta_E = H(\tau_E) + H(\tau_E) - H(\tau_1^*) - H(\tau_2^*)$. Then, the existence of a feasible agreement under an equal tax rate rule hinges on $\Delta_E \geq \max\left\{\tau^E/\tau_1^* - 1, \tau_E/\tau_2^* - 1\right\}$, implicitly requiring the participation of the country with the lower non-cooperative tax rate. Assuming $\tau_2^* > \tau_1^*$, there is an agreement if country 1 agrees, i.e. if

$$\begin{gathered}
\alpha_1 \left[H(\tau_E) + H(\tau_E) - H(\tau_1^*) - H(\tau_2^*)\right] - y_1(\tau_E - \tau_1^*) \geq 0 \\
\alpha_1 \left[\ln \tau_E + \ln Y_1 + \ln \tau_E + \ln Y_2 - \ln \tau_1^* - \ln Y_1 - \ln \tau_2^* - \ln Y_2\right] - y_1(\tau_E - \tau_1^*) \geq 0 \\
\alpha_1 \left[2 \ln \tau_E - \ln \tau_1^* - \ln \tau_2^*\right] - y_1(\tau_E - \tau_1^*) \geq 0.
\end{gathered}$$

In the best case scenario for country 1, the international agreement maximises the gain of its median voter,

$$\frac{\partial \alpha_1 \left[2 \ln \tau_E - \ln \tau_1^* - \ln \tau_2^*\right] - y_1(\tau_E - \tau_1^*)}{\partial \tau_E} = \frac{2\alpha_1}{\tau_E} - y_1 = 0 \quad \text{if} \quad \tau_E = \frac{2\alpha_1}{y_1} = 2\tau_1^*.$$

Then, country 1 accepts if $\alpha_1 \left[2 \ln (2\tau_1^*) - \ln \tau_1^* - \ln \tau_2^*\right] - y_1(2\tau_1^* - \tau_1^*) \geq 0$ or, equivalently, if $\tau_1^*/\tau_2^* \geq e/4$. The other case and the upper bound for the feasible set follow from considering $\tau_1^* > \tau_2^*$ and repeating.

The efficient agreement is derived in the main text; substituting this into the feasible conditions and considering the case $\tau_2^* > \tau_1^*$ gives $\ln[(\tau_1^* + \tau_2^*)^2/(\tau_1^*\tau_2^*)] \geq \tau_2^*/\tau_1^*$. Repeating for the other case ($\tau_1^* > \tau_2^*$), it is derived that the efficient agreement is feasible if $\ln[(\tau_1^* + \tau_2^*)^2/(\tau_1^*\tau_2^*)] \geq \max\{\tau_1^*/\tau_2^*, \tau_2^*/\tau_1^*\}$.

A.5 Proof of Corollary 3.1

The win-set of the median voter from country j under the efficient cooperative tax rate is

$$\Gamma_j = \alpha_j \left[2 \ln \left(\tau_j^* + \tau_{-j}^*\right) - \ln \tau_j^* - \ln \tau_{-j}^*\right] - y_j \tau_{-j}^\star \geq 0.$$

To determine which median voter has the largest win-set, we consider

$$\begin{aligned}
\Gamma_j - \Gamma_{-j} &= \alpha_j \Delta_E - y_j \tau_{-j}^* - \alpha_{-j}\Delta_E + y_{-j}\tau_j^* = \\
&= \Delta_E \left(\alpha_j - \alpha_{-j}\right) - y_j \alpha_{-j}/y_{-j} + y_{-j}\alpha_j/y_j = \\
&= \Delta_E \left(\alpha_j - \alpha_{-j}\right) - \frac{y_j y_j \alpha_{-j} - y_{-j} y_{-j} \alpha_j}{y_{-j} y_j} = \\
&= \frac{\Delta_E \alpha_j y_{-j} y_j - \Delta_E \alpha_{-j} y_{-j} y_j - y_j y_j \alpha_{-j} + y_{-j} y_{-j} \alpha_1}{y_{-j} y_j} \\
&= \frac{\alpha_j y_{-j} \left(\Delta_E y_j + y_{-j}\right) - \alpha_{-j} y_j \left(\Delta_E y_{-j} + y_j\right)}{y_{-j} y_j} > 0 \\
&\leftrightarrow \quad \alpha_j y_{-j} \left(\Delta_E y_j + y_{-j}\right) - \alpha_{-j} y_j \left(\Delta_E y_{-j} + y_j\right) > 0 \\
&\leftrightarrow \quad \alpha_j y_{-j} \left(\Delta_E y_j + y_{-j}\right) > \alpha_{-j} y_j \left(\Delta_E y_{-j} + y_j\right) \\
&\leftrightarrow \quad \frac{\alpha_j}{y_j} \frac{y_{-j}}{\alpha_{-j}} \frac{\Delta_E y_j + y_{-j}}{\Delta_E y_{-j} + y_j} > 1 \\
&\leftrightarrow \quad \frac{\tau_j^*}{\tau_{-j}^*} > \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}},
\end{aligned}$$

where the right-hand side is greater than one if $y_j < y_{-j}$. There are thus three possible cases in which the median voter from country j has a larger win-set.

First, if $\tau_j^* > \tau_{-j}^*$ and $y_j > y_{-j}$, then this condition is automatically satisfied. In particular,

$$\frac{\tau_j^*}{\tau_{-j}^*} > 1 \leftrightarrow \frac{\alpha_j}{y_j} > \frac{\alpha_{-j}}{y_{-j}} \leftrightarrow \frac{\alpha_j}{\alpha_{-j}} > \frac{y_j}{y_{-j}} > 1$$

also implies

$$\frac{\tau_j^*}{\tau_{-j}^*} > \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}} \leftrightarrow \frac{\alpha_j}{y_j} > \frac{\alpha_{-j}}{y_{-j}} \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}} \leftrightarrow \frac{\alpha_j}{\alpha_{-j}} > \underbrace{\frac{y_j}{y_{-j}} \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}}}_{\in\left(1, \frac{y_j}{y_{-j}}\right)},$$

where the term on the right-hand side is higher than one and lower than y_j/y_{-j} since $y_j > y_{-j}$.

Second, if $\tau_j^* > \tau_{-j}^*$ and $y_j < y_{-j}$, then

$$\frac{\tau_j^*}{\tau_{-j}^*} > 1 \leftrightarrow \frac{\alpha_j}{y_j} > \frac{\alpha_{-j}}{y_{-j}} \leftrightarrow \frac{\alpha_j}{\alpha_{-j}} > \underbrace{\frac{y_j}{y_{-j}}}_{\in(0,1)}$$

$$\frac{\tau_j^*}{\tau_{-j}^*} > \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}} \leftrightarrow \frac{\alpha_j}{y_j} > \frac{\alpha_{-j}}{y_{-j}} \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}} \leftrightarrow \frac{\alpha_j}{\alpha_{-j}} > \underbrace{\frac{y_j}{y_{-j}} \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}}}_{\in\left(\frac{y_j}{y_{-j}}, 1\right)},$$

where the term on the right-hand side is lower than one and higher than y_j/y_{-j} since $y_j < y_{-j}$. Thus, for $\Gamma_j > \Gamma_{-j}$, we need

$$\frac{\alpha_j}{\alpha_{-j}} > \underbrace{\frac{y_j}{y_{-j}} \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}}}_{<1},$$

i.e. α_j could be even lower than α_{-j}, but not by too much.

Third, if $\tau_j^* < \tau_{-j}^*$, this can only be satisfied if $y_j > y_{-j}$. In particular, we need both of the following conditions to be true at the same time:

$$\frac{\tau_j^*}{\tau_{-j}^*} < 1 \leftrightarrow \frac{\alpha_j}{y_j} < \frac{\alpha_{-j}}{y_{-j}} \leftrightarrow \frac{\alpha_j}{\alpha_{-j}} < \frac{y_j}{y_{-j}} \in (1, \infty)$$

$$\frac{\tau_j^*}{\tau_{-j}^*} > \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}} \leftrightarrow \frac{\alpha_j}{y_j} > \frac{\alpha_{-j}}{y_{-j}} \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}} \leftrightarrow \frac{\alpha_j}{\alpha_{-j}} > \frac{y_j}{y_{-j}} \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}} \in \left(1, \frac{y_j}{y_{-j}}\right),$$

where the term on the right-hand side is higher than one and lower than y_j/y_{-j}

since $y_j > y_{-j}$. Therefore, for $\Gamma_j > \Gamma_{-j}$, we need

$$\frac{\alpha_j}{\alpha_{-j}} \in \left(\underbrace{\frac{y_j}{y_{-j}} \frac{\Delta_E y_{-j} + y_j}{\Delta_E y_j + y_{-j}}}_{>1}, \frac{y_j}{y_{-j}} \right),$$

i.e. we need country j to be more equal but not by too much.

The median voter's win-set is positively related to its income if and only if

$$\begin{aligned}
\frac{\partial \Gamma_j}{\partial y_j} &= \Delta_E \frac{\partial \alpha_j}{\partial y_j} + \alpha_j \left[\frac{2}{\tau_j^* + \tau_{-j}^*} \frac{\partial \tau_j^*}{\partial y_j} - \frac{1}{\tau_j^*} \frac{\partial \tau_j^*}{\partial y_j} \right] - \tau_{-j}^* = \\
&= \Delta_E \frac{\partial \alpha_j}{\partial y_j} + \alpha_j \left[\left(\frac{\partial \alpha_j}{\partial y_j} \frac{1}{y_j} - \frac{\alpha_1}{y_j^2} \right) \left(\frac{2}{\tau_j^* + \tau_{-j}^*} - \frac{1}{\tau_j^*} \right) \right] - \tau_{-j}^* = \\
&= \Delta_E \frac{\partial \alpha_j}{\partial y_j} + \left[\left(\frac{\partial \alpha_j}{\partial y_j} \frac{\alpha_j}{y_j} - \frac{\alpha_j}{y_j} \frac{\alpha_j}{y_j} \right) \left(\frac{2\tau_j^* - \tau_j^* - \tau_{-j}^*}{\tau_j^* \left(\tau_j^* + \tau_j^* \right)} \right) \right] - \tau_j^* = \\
&= \Delta_E \frac{\partial \alpha_j}{\partial y_j} + \left[\tau_j^* \left(\frac{\partial \alpha_j}{\partial y_j} - \tau_j^* \right) \left(\frac{\tau_j^* - \tau_{-j}^*}{\tau_j^* + \tau_{-j}^*} \frac{1}{\tau_j^*} \right) \right] - \tau_{-j}^* = \\
&= \frac{\partial \alpha_j}{\partial y_j} \left[\Delta_E + \frac{\tau_j^* - \tau_{-j}^*}{\tau_j^* + \tau_{-j}^*} \right] - \tau_j^* \left(\frac{\tau_j^* - \tau_{-j}^*}{\tau_j^* + \tau_{-j}^*} \right) - \tau_{-j}^* = \\
&= \frac{\partial \alpha_j}{\partial y_j} \underbrace{\left[\Delta_E + \frac{\tau_j^* - \tau_{-j}^*}{\tau_j^* + \tau_{-j}^*} \right]}_{\equiv x > 1} - \underbrace{\frac{(\tau_j^*)^2 + (\tau_{-j}^*)^2}{\tau_j^* + \tau_{-j}^*}}_{\equiv z \in (0,1)} \equiv x \frac{\partial \alpha_j}{\partial y_j} - z \geq 0
\end{aligned}$$

i.e. iff $\quad x \frac{\partial \alpha_j}{\partial y_j} \geq z \quad \leftrightarrow \quad \varepsilon_j = \frac{\partial \alpha_j}{\partial y_j} \frac{y_j}{\alpha_j} \geq \frac{z}{x} \frac{y_j}{\alpha_j} = \frac{(\tau_j^*)^2 + (\tau_{-j}^*)^2}{\tau_j^* \left[\Delta_E \left(\tau_j^* + \tau_{-j}^* \right) + \tau_j^* - \tau_{-j}^* \right]} \equiv \varepsilon_E.$

It is positively related to the income of the median agent in country $-j$ if and only if

$$\begin{aligned}
\frac{\partial \Gamma_j}{\partial y_{-j}} &= \alpha_j \left[\frac{2}{\tau_j^* + \tau_{-j}^*} \frac{\partial \tau_{-j}^*}{\partial y_{-j}} - \frac{1}{\tau_{-j}^*} \frac{\partial \tau_{-j}^*}{\partial y_{-j}} \right] - y_j \frac{\partial \tau_{-j}^*}{\partial y_{-j}} = \\
&= \alpha_j \frac{\partial \tau_{-j}^*}{\partial y_{-j}} \left[\frac{2}{\tau_j^* + \tau_{-j}^*} - \frac{1}{\tau_{-j}^*} \right] - y_j \frac{\partial \tau_{-j}^*}{\partial y_{-j}} = \\
&= \alpha_j \frac{\partial \tau_{-j}^*}{\partial y_{-j}} \left[\frac{2\tau_{-j}^* - \tau_j^* - \tau_{-j}^*}{\tau_{-j}^* \left(\tau_j^* + \tau_{-j}^* \right)} \right] - y_j \frac{\partial \tau_{-j}^*}{\partial y_{-j}} = \\
&= \frac{\alpha_j \alpha_{-j} \left(\varepsilon_{-j} - 1 \right)}{y_{-j}^2} \left[\frac{\tau_{-j}^* - \tau_j^*}{\tau_{-j}^* \left(\tau_j^* + \tau_{-j}^* \right)} \right] - \frac{y_j \alpha_{-j} (\varepsilon_{-j} - 1)}{y_{-j}^2} > 0
\end{aligned}$$

i.e. iff $\quad - \left(\varepsilon_{-j} - 1 \right) \frac{\tau_j^* \tau_j^* + \tau_{-j}^* \tau_{-j}^*}{\tau_{-j}^* \left(\tau_1^* + \tau_{-j}^* \right)} \geq 0 \quad \leftrightarrow \quad \varepsilon_{-j} < 1.$

We now focus on a change in total income of the countries. With respect to country j,

$$\begin{aligned}\frac{\partial \Gamma_j}{\partial Y_j} &= \Delta_E \frac{\partial \alpha_j}{\partial Y_j} + \alpha_j \left[\frac{2}{\tau_j^* + \tau_{-j}^*}\frac{\partial \tau_j^*}{\partial Y_j} - \frac{1}{\tau_j^*}\frac{\partial \tau_j^*}{\partial Y_j}\right] = \\ &= \Delta_E \frac{\partial \alpha_j}{\partial Y_j} + \frac{\alpha_j}{\tau_j^*}\frac{\partial \tau_j^*}{\partial Y_j}\frac{\tau_j^* - \tau_{-j}^*}{\tau_j^* + \tau_{-j}^*} = \\ &= \frac{\partial \alpha_j}{\partial Y_j}\left[\Delta_E + \frac{\alpha_j}{y_j}\frac{y_j}{\alpha_j}\frac{\tau_j^* - \tau_{-j}^*}{\tau_j^* + \tau_{-j}^*}\right] = \\ &= \frac{\partial \alpha_j}{\partial Y_j}\left[\Delta_E + \frac{\tau_j^* - \tau_{-j}^*}{\tau_j^* + \tau_{-j}^*}\right],\end{aligned}$$

which is always negative, given that $\partial\alpha_j/\partial Y_j < 0$ and the part within square brackets is positive. With respect to country $-j$,

$$\begin{aligned}\frac{\partial \Gamma_j}{\partial Y_{-j}} &= \alpha_j \left[\frac{2}{\tau_j^* + \tau_{-j}^*}\frac{\partial \tau_{-j}^*}{\partial Y_{-j}} - \frac{1}{\tau_{-j}^*}\frac{\partial \tau_{-j}^*}{\partial Y_{-j}}\right] - y_j \frac{\partial \tau_{-j}^*}{\partial Y_{-j}} = \\ &= \alpha_j \frac{\partial \tau_{-j}^*}{\partial Y_{-j}}\left[\frac{2\tau_{-j}^* - \tau_j^* - \tau_{-j}^*}{\tau_j^* + \tau_{-j}^*}\frac{1}{\tau_{-j}^*}\right] - y_j \frac{\partial \tau_{-j}^*}{\partial Y_{-j}} > 0 \\ \leftrightarrow &\quad \frac{\alpha_j}{y_j}\frac{1}{\tau_{-j}^*}\frac{\tau_{-j}^* - \tau_1^*}{\tau_1^* + \tau_{-j}^*} \leq 1 \quad \leftrightarrow \quad \frac{\tau_j^*}{\tau_{-j}^*}\frac{\tau_{-j}^* - \tau_j^*}{\tau_j^* + \tau_{-j}^*} \leq 1,\end{aligned}$$

which is always satisfied for $\tau_j^* \in [0,1]$ and $\tau_{-j}^* \in [0,1]$.

A.6 Proof of Proposition 4

The existence of a feasible agreement under the proportional tax rate rule hinges on $\Delta_K \geq \max\{\tau_1/\tau_1^* - 1, \tau_2/\tau_2^* - 1\}$. Which of these two terms is the relevant one depends on whether $k\tau_2^* > \tau_1^*$ or, equivalently, $\tau_2^*/\overline{y}_2 > \tau_1^*/\overline{y}_1$. Considering $\tau_2^*/\overline{y}_2 > \tau_1^*/\overline{y}_1$, the agreement will be feasible if country 1 agrees, i.e. if

$$\alpha_1 \left[H(\tau_1) + H\left(\frac{\tau_1}{k}\right) - H(\tau_1^*) - H(\tau_2^*)\right] - y_1(\tau_1 - \tau_1^*) \geq 0$$

$$\alpha_1 \left[\ln \tau_1 + \ln Y_1 + \ln \frac{\tau_1}{k} + \ln Y_2 - \ln \tau_1^* - \ln Y_1 - \ln \tau_2^* - \ln Y_2\right] - y_1(\tau_1 - \tau_1^*) \geq 0$$

$$\alpha_1 \left[\ln \frac{\tau_1^2}{k} - \ln \tau_1^* - \ln \tau_2^*\right] - y_1(\tau_1 - \tau_1^*) \geq 0.$$

In the best scenario for country 1, the international agreement maximises the gain of its delegate,

$$\frac{\partial \alpha_1 \left[\ln \frac{\tau_1^2}{k} - \ln \tau_1^* - \ln \tau_2^*\right] - y_1(\tau_1 - \tau_1^*)}{\partial \tau_1} = \frac{2\alpha_1}{\tau_1} - y_1 = 0 \quad \text{if} \quad \tau_1 = \frac{2\alpha_1}{y_1} = 2\tau_1^*.$$

Then, country 1 accepts if $\alpha_1[\ln[(2\tau_1^*)^2/k] - \ln \tau_1^* - \ln \tau_2^*] - y_1(2\tau_1^* - \tau_1^*) \geq 0$, or, equivalently, if $\tau_1^*/\tau_2^* \geq ek/4$. The upper bound for the feasible set follow from considering $\tau_2^*/\overline{y}_2 < \tau_1^*/\overline{y}_1$ and repeating.

The efficiency condition under this equity rule is $\tau_2 = \tau_1^*/k + \tau_2^*$ and $\tau_1 = k\tau_2 = \tau_1^* + k\tau_2^*$. Substituting these in the feasibility condition for country 1, the efficient agreement is feasible if $\ln\left[(\tau_1^* + k\tau_2^*)^2 / (k\tau_1^*\tau_2^*)\right] \geq k\tau_2^*/\tau_1^*$. The upper bound is obtained by considering the feasibility condition for country 2.

A.7 Proof of Corollary 4.1

The feasibility sets under the efficient agreement ($\tau_1 = \tau_1^* + k\tau_2^*$ and $\tau_2 = \tau_1^*/k + \tau_2^*$) are, respectively,

$$\Gamma_1 = \alpha_1\left[\ln\left(\frac{\tau_1^*}{k} + \tau_2^*\right) + \ln(\tau_1^* + k\tau_2^*) - \ln\tau_1^* - \ln\tau_2^*\right] - y_1(k\tau_2^*)$$
$$\Gamma_2 = \alpha_2\left[\ln\left(\frac{\tau_1^*}{k} + \tau_2^*\right) + \ln(\tau_1^* + k\tau_2^*) - \ln\tau_1^* - \ln\tau_2^*\right] - y_2\left(\frac{\tau_1^*}{k}\right).$$

To determine which median agent has the largest win-set, we consider

$$\begin{aligned}
\Gamma_1 - \Gamma_2 &= \alpha_1\Delta_K - y_1k\tau_2^* - \alpha_2\Delta_K + y_2\frac{\tau_1^*}{k} = \\
&= \Delta_K(\alpha_1 - \alpha_2) - \frac{y_1k\alpha_2}{y_2} + \frac{y_2\alpha_1}{y_1k} \\
&= \Delta_K(\alpha_1 - \alpha_2) - \frac{y_1^2k^2\alpha_2 - y_2^2\alpha_1}{y_2y_1k} \\
&= \frac{\Delta_K\alpha_1y_1y_2k - \Delta_K\alpha_2y_1y_2k - y_1^2k^2\alpha_2 + y_2^2\alpha_1}{y_1y_2k} \\
&= \frac{\alpha_1y_2(\Delta_Ky_1k + y_2) - \alpha_2y_1k(\Delta_Ky_2 + y_1k)}{y_1y_2k} > 0 \\
&\leftrightarrow \quad \alpha_1y_2(\Delta_Ky_1k + y_2) - \alpha_2y_1k(\Delta_Ky_2 + y_1k) > 0 \\
&\leftrightarrow \quad \alpha_1y_2(\Delta_Ky_1k + y_2) > \alpha_2y_1k(\Delta_Ky_2 + y_1k) \\
&\leftrightarrow \quad \frac{\alpha_1}{y_1}\frac{y_2}{\alpha_2}\frac{1}{k}\frac{\Delta_Ky_1k + y_2}{\Delta_Ky_2 + y_1k} > 1 \\
&\leftrightarrow \quad \frac{\tau_1^*}{\tau_2^*}\frac{1}{k} > \frac{\Delta_Ky_2 + y_1k}{\Delta_Ky_1k + y_2},
\end{aligned}$$

where the right-hand side is greater than one if $y_2 > y_1k$.

There are thus three possible cases in which the median agent from country 1 has a larger win-set. First, if $\tau_1^* > \tau_2^*k$ and $y_1k > y_2$, then this condition is automatically satisfied. Second, if $\tau_1^* > \tau_2^* k$ and $y_1 k < y_2$, then

$$\frac{\tau_1^*}{k\tau_2^*} > 1 \leftrightarrow \frac{\alpha_1}{y_1} > \frac{k\alpha_2}{y_2} \leftrightarrow \frac{\alpha_1}{\alpha_2} > \underbrace{k\frac{y_1}{y_2}}_{\in(0,1)}$$

$$\frac{\tau_1^*}{k\tau_2^*} > \frac{\Delta_K y_2 + y_1 k}{\Delta_K y_1 k + y_2} \leftrightarrow \frac{\alpha_1}{y_1} > \frac{k\alpha_2}{y_2}\frac{\Delta_K y_2 + y_1 k}{\Delta_K y_1 k + y_2} \leftrightarrow \frac{\alpha_1}{\alpha_2} > \underbrace{\frac{ky_1}{y_2}\frac{\Delta_K y_2 + y_1 k}{\Delta_K y_1 k + y_2}}_{\in\left(k\frac{y_1}{y_2},1\right)},$$

where the term on the right-hand side is lower than one and higher than ky_1/y_2 since $y_1 k < y_2$. Thus, for $\Gamma_j > \Gamma_{-j}$, we need

$$\frac{\alpha_1}{\alpha_2} > \underbrace{\frac{ky_1}{y_2}\frac{\Delta_K y_2 + y_1 k}{\Delta_K y_1 k + y_2}}_{<1},$$

i.e. α_1 could be even lower than α_2, but not by too much. Third, if $\tau_1^* k < \tau_2^*$, this can only be satisfied if $ky_1 > y_2$. In particular, we need both of the following conditions to be true at the same time:

$$\frac{\tau_1^*}{k\tau_2^*} < 1 \leftrightarrow \frac{\alpha_1}{y_1} < \frac{k\alpha_2}{y_2} \leftrightarrow \frac{\alpha_1}{\alpha_2} < \frac{ky_1}{y_2} \in (1,\infty)$$

$$\frac{\tau_1^*}{k\tau_2^*} > \frac{\Delta_K y_2 + y_1 k}{\Delta_K y_1 k + y_2} \leftrightarrow \frac{\alpha_1}{y_1} > \frac{k\alpha_2}{y_2}\frac{\Delta_K y_2 + y_1 k}{\Delta_K y_1 k + y_2} \leftrightarrow \frac{\alpha_1}{\alpha_2} > \frac{ky_1}{y_2}\frac{\Delta_K y_2 + y_1 k}{\Delta_K y_1 k + y_2} \in \left(1, \frac{ky_1}{y_2}\right),$$

where the term on the right-hand side is higher than one and lower than ky_1/y_2 since $y_1 k > y_2$. Therefore, for $\Gamma_1 > \Gamma_2$, we need

$$\frac{\alpha_1}{\alpha_2} \in \left(\underbrace{\frac{ky_1}{y_2}\frac{\Delta_K y_2 + y_1 k}{\Delta_K y_1 k + y_2}}_{>1}, \frac{ky_1}{y_2}\right),$$

i.e. we need country 1 to be more equal but not by too much.

Considering the comparative static of the gain for cooperation, we first consider whether a marginal change in median income increases the domestic feasibility set.

$$\begin{aligned}
\frac{\partial \Gamma_1}{\partial y_1} &= \frac{\partial \alpha_1}{\partial y_1}(\Delta_K) + \alpha_1 \left[\frac{1}{\frac{\tau_1^*}{k} + \tau_2^*} \frac{1}{k} \frac{\partial \tau_1^*}{\partial y_1} + \frac{1}{\tau_1^* + k\tau_2^*} \frac{\partial \tau_1^*}{\partial y_1} - \frac{1}{\tau_1^*} \frac{\partial \tau_1^*}{\partial y_1} \right] - k\tau_2^* \\
&= \frac{\partial \alpha_1}{\partial y_1}(\Delta_K) + \alpha_1 \frac{\partial \tau_1^*}{\partial y_1} \left[\frac{2}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_1^*} \right] - k\tau_2^* \\
&= \frac{\partial \alpha_1}{\partial y_1}(\Delta_K) + \alpha_1 \left(\frac{\partial \alpha_1}{\partial y_1} \frac{1}{y_1} - \frac{\alpha_1}{y_1} \frac{1}{y_1} \right) \left[\frac{2}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_1^*} \right] - k\tau_2^* \\
&= \frac{\partial \alpha_1}{\partial y_1}(\Delta_K) + \tau_1^* \left(\frac{\partial \alpha_1}{\partial y_1} - \tau_1^* \right) \left[\frac{2\tau_1^* - \tau_1^* - k\tau_2^*}{\tau_1^*(\tau_1^* + k\tau_2^*)} \right] - k\tau_2^* \\
&= \frac{\partial \alpha_1}{\partial y_1}(\Delta_K) + \left(\frac{\partial \alpha_1}{\partial y_1} - \tau_1^* \right) \left[\frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right] - k\tau_2^* \\
&= \frac{\partial \alpha_1}{\partial y_1} \left(\Delta_K + \frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right) - \left[\tau_1^* \left(\frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right) + k\tau_2^* \right] = \\
&= \frac{\partial \alpha_1}{\partial y_1} \underbrace{\left(\Delta_K + \frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right)}_{x_1 > 1} - \underbrace{\frac{(\tau_1^*)^2 + (k\tau_2^*)^2}{\tau_1^* + k\tau_2^*}}_{z_1 > 0} \geq 0 \\
&\text{iff} \quad \varepsilon_1 = \frac{\partial \alpha_1}{\partial y_1} \frac{y_1}{\alpha_1} \geq \frac{z_1}{x_1} \frac{y_1}{\alpha_1} = \frac{z_1}{x_1} \frac{1}{\tau_1^\star} \equiv \varepsilon_{1,K},
\end{aligned}$$

where $\varepsilon_{1,K}$ is greater than zero but could be arbitrarily high.

$$\begin{aligned}
\frac{\partial \Gamma_2}{\partial y_2} &= \frac{\partial \alpha_2}{\partial y_2}(\Delta_K) + \alpha_2 \left[\frac{1}{\frac{\tau_1^*}{k} + \tau_2^*} \frac{\partial \tau_2^*}{\partial y_2} + \frac{k}{\tau_1^* + k\tau_2^*} \frac{\partial \tau_2^*}{\partial y_2} - \frac{1}{\tau_2^*} \frac{\partial \tau_2^*}{\partial y_2} \right] - \frac{\tau_1^*}{k} = \\
&= \frac{\partial \alpha_2}{\partial y_2}(\Delta_K) + \alpha_2 \frac{\partial \tau_2^*}{\partial y_2} \left[\frac{2k}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_2^*} \right] - \frac{\tau_1^*}{k} = \\
&= \frac{\partial \alpha_2}{\partial y_2}(\Delta_K) + \alpha_2 \left(\frac{\partial \alpha_2}{\partial y_2} \frac{1}{y_2} - \frac{\alpha_2}{y_2} \frac{1}{y_2} \right) \left[\frac{2k}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_2^*} \right] - \frac{\tau_1^*}{k} = \\
&= \frac{\partial \alpha_2}{\partial y_2}(\Delta_K) + \tau_2^* \left(\frac{\partial \alpha_2}{\partial y_2} - \tau_2^* \right) \left[\frac{2k\tau_2^* - \tau_1^* - k\tau_2^*}{\tau_2^*(\tau_1^* + k\tau_2^*)} \right] - \frac{\tau_1^*}{k} = \\
&= \frac{\partial \alpha_2}{\partial y_2}(\Delta_K) + \left(\frac{\partial \alpha_2}{\partial y_2} - \tau_2^* \right) \left[\frac{k\tau_2^* - \tau_1^*}{\tau_1^* + k\tau_2^*} \right] - \frac{\tau_1^*}{k} = \\
&= \frac{\partial \alpha_2}{\partial y_2} \left(\Delta_K + \frac{k\tau_2^* - \tau_1^*}{\tau_1^* + k\tau_2^*} \right) - \tau_2^* \frac{k\tau_2^* - \tau_1^*}{\tau_1^* + k\tau_2^*} - \frac{\tau_1^*}{k} = \\
&= \frac{\partial \alpha_2}{\partial y_2} \underbrace{\left(\Delta_K + \frac{k\tau_2^* - \tau_1^*}{\tau_1^* + k\tau_2^*} \right)}_{x_2 > 1} - \underbrace{\frac{k(\tau_2^*)^2 - (\tau_1^*)^2}{\tau_1^* + k\tau_2^*}}_{z_2 > 0} \geq 0 \\
&\text{iff} \quad \varepsilon_2 = \frac{\partial \alpha_2}{\partial y_2} \frac{y_2}{\alpha_2} \geq \frac{z_2}{x_2} \frac{y_2}{\alpha_2} = \frac{z_2}{x_2} \frac{1}{\tau_2^\star} \equiv \varepsilon_{2,K}
\end{aligned}$$

where $\varepsilon_{2,K}$ is greater than zero but could be arbitrarily high, and could be lower or higher than $\varepsilon_{1,K}$.

Considering a change in the income of the delegate of the opponent country:

$$\begin{aligned}
\frac{\partial \Gamma_1}{\partial y_2} &= \alpha_1 \left[\frac{1}{\frac{\tau_1^*}{k} + \tau_2^*} \frac{\partial \tau_2^*}{\partial y_2} + \frac{k}{\tau_1^* + k\tau_2^*} \frac{\partial \tau_2^*}{\partial y_2} - \frac{1}{\tau_2^*} \frac{\partial \tau_2^*}{\partial y_2} \right] - y_1 k \frac{\partial \tau_2^*}{\partial y_2} = \\
&= \alpha_1 \frac{\partial \tau_2^*}{\partial y_2} \left[\frac{2\tau_1^* + 2k\tau_2^*}{\frac{1}{k}(\tau_1^*)^2 + 2\tau_1^*\tau_2^* + k(\tau_2^*)^2} - \frac{1}{\tau_2^*} \right] - y_1 k \frac{\partial \tau_2^*}{\partial y_2} = \\
&= \alpha_1 \frac{\partial \tau_2^*}{\partial y_2} \left[\frac{k\tau_2^* - \frac{1}{k}\tau_1^*}{\tau_2^* \left(\frac{1}{k}(\tau_1^*)^2 + 2\tau_1^*\tau_2^* + k(\tau_2^*)^2 \right)} \right] - y_1 k \frac{\partial \tau_2^*}{\partial y_2} > 0 \\
\text{iff} \quad & \frac{1}{k} \frac{\alpha_1}{y_1} \frac{\alpha_2(\varepsilon_2 - 1)}{y_2^2} \left[\frac{k\tau_2^* - \frac{1}{k}\tau_1^*}{\tau_2^* \left(\frac{1}{k}(\tau_1^*)^2 + 2\tau_1^*\tau_2^* + k(\tau_2^*)^2 \right)} \right] - \frac{\alpha_2(\varepsilon_2 - 1)}{y_2^2} > 0 \\
\leftrightarrow \quad & (\varepsilon_2 - 1) \frac{\tau_1^*(\tau_2^*)^2 - \frac{1}{k^2}(\tau_1^*)^3}{\tau_2^* \left(\frac{1}{k}(\tau_1^*)^2 + 2\tau_1^*\tau_2^* + k(\tau_2^*)^2 \right)} > (\varepsilon_2 - 1) \\
\leftrightarrow \quad & (\varepsilon_2 - 1) \left[\frac{\tau_1^*(\tau_2^*)^2 - \frac{1}{k^2}(\tau_1^*)^3}{\tau_2^* \left(\frac{1}{k}(\tau_1^*)^2 + 2\tau_1^*\tau_2^* + k(\tau_2^*)^2 \right)} - 1 \right] > 0 \\
\leftrightarrow \quad & -(\varepsilon_2 - 1) \frac{\tau_1^*(\tau_2^*)^2 + \frac{1}{k}(\tau_1^*)^3 + \frac{1}{k}(\tau_1^*)^2\tau_2 + k(\tau_2^*)^3}{\tau_2^* \left(\frac{1}{k}(\tau_1^*)^2 + 2\tau_1^*\tau_2^* + k(\tau_2^*)^2 \right)} > 0,
\end{aligned}$$

i.e. Γ_1 is increasing in y_2 only if $\varepsilon_2 < 1$.

$$\begin{aligned}
\frac{\partial \Gamma_2}{\partial y_1} &= \alpha_2 \left[\frac{1}{\frac{\tau_1^*}{k} + \tau_2^*} \frac{1}{k} \frac{\partial \tau_1^*}{\partial y_1} + \frac{1}{\tau_1^* + k\tau_2^*} \frac{\partial \tau_1^*}{\partial y_1} - \frac{1}{\tau_1^*} \frac{\partial \tau_1^*}{\partial y_1} \right] - \frac{y_2}{k} \frac{\partial \tau_1^*}{\partial y_1} = \\
&= \alpha_2 \frac{\partial \tau_1^*}{\partial y_1} \left[\frac{\tau_1^* - k\tau_2^*}{\tau_1^* \left(\tau_1^* + k\tau_2^* \right)} \right] - \frac{y_2}{k} \frac{\partial \tau_1^*}{\partial y_1} = \\
&= \alpha_2 \frac{\alpha_1(\varepsilon_1 - 1)}{y_1^2} \left[\frac{\tau_1^* - k\tau_2^*}{\tau_1^* \left(\tau_1^* + k\tau_2^* \right)} \right] - \frac{y_2}{k} \frac{\alpha_1(\varepsilon_1 - 1)}{y_1^2} > 0 \\
\text{iff} \quad & (\varepsilon_1 - 1) \frac{\alpha_2}{y_2} \left[\frac{k\left(\tau_1^* - k\tau_2^* \right)}{\tau_1^* \left(\tau_1^* + k\tau_2^* \right)} \right] > (\varepsilon_1 - 1) \\
\leftrightarrow \quad & (\varepsilon_1 - 1) \left[\frac{\tau_2^* k \left(\tau_1^* - k\tau_2^* \right)}{\tau_1^* \left(\tau_1^* + k\tau_2^* \right)} - 1 \right] > 0 \\
\leftrightarrow \quad & (\varepsilon_1 - 1) \frac{\tau_1^*\tau_2^* k - \tau_2^*\tau_2^* k^2 - \tau_1^*\tau_1^* - \tau_1^*\tau_2^* k}{\tau_1^* \left(\tau_1^* + k\tau_2^* \right)} > 0 \\
\leftrightarrow \quad & -(\varepsilon_1 - 1) \frac{\tau_2^*\tau_2^* k^2 + \tau_1^*\tau_1^*}{\tau_1^* \left(\tau_1^* + k\tau_2^* \right)} > 0,
\end{aligned}$$

i.e. Γ_2 is increasing in y_1 only if $\varepsilon_1 < 1$.

Since $k = \overline{y_1}/\overline{y_2} = (Y_1/N_1)/(Y_2/N_2)$, a variation in Y_1 or Y_2 would bring

$$\frac{\partial k}{\partial Y_1} = \frac{1}{N_1}\frac{N_2}{Y_2} = \frac{k}{Y_1} \geq 0, \qquad \text{or} \qquad \frac{\partial k}{\partial Y_2} = -\frac{Y_1}{N_1}\frac{N_2}{Y_2^2} = -\frac{k}{Y_2} \leq 0.$$

Considering a change in the total income of the country Y_j:

$$\frac{\partial \Gamma_1}{\partial Y_1} =$$

$$\Delta_K \frac{\partial \alpha_1}{\partial Y_1} + \alpha_1 \left[\frac{1}{\frac{1}{k}\tau_1^* + \tau_2^*} \left(-\frac{\tau_1^*}{k^2}\frac{\partial k}{\partial Y_1} + \frac{1}{k}\frac{\partial \tau_1^*}{\partial Y_1} \right) + \frac{1}{\tau_1^* + k\tau_2^*} \left(\frac{\partial \tau_1^*}{\partial Y_1} + \tau_2^* \frac{\partial k}{\partial Y_1} \right) - \frac{1}{\tau_1^*}\frac{\partial \tau_1^*}{\partial Y_1} \right] - y_1 \tau_2^* \frac{\partial k}{\partial Y_1} =$$

$$\Delta_K \frac{\partial \alpha_1}{\partial Y_1} + \alpha_1 \frac{\partial \tau_1^*}{\partial Y_1} \left[\frac{1}{\frac{1}{k}\tau_1^* + \tau_2^*}\frac{1}{k} + \frac{1}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_1^*} \right] + \frac{\partial k}{\partial Y_1} \left[-\frac{\alpha_1}{k^2}\frac{\tau_1^*}{\frac{1}{k}\tau_1^* + \tau_2^*} + \alpha_1 \frac{\tau_2^*}{\tau_1^* + k\tau_2^*} - y_1 \tau_2^* \right] =$$

$$\Delta_K \frac{\partial \alpha_1}{\partial Y_1} + \frac{\alpha_1}{y_1}\frac{\partial \alpha_1}{\partial Y_1} \left[\frac{2}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_1^*} \right] + \frac{\partial k}{\partial Y_1}\alpha_1 \left[-\frac{1}{k}\frac{\tau_1^*}{\tau_1^* + \tau_2^* k} + \frac{\tau_2^*}{\tau_1^* + k\tau_2^*} - \frac{y_1}{\alpha_1}\tau_2^* \right] =$$

$$\Delta_K \frac{\partial \alpha_1}{\partial Y_1} + \frac{\alpha_1}{y_1}\frac{\partial \alpha_1}{\partial Y_1} \left[\frac{2}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_1^*} \right] + \frac{\partial k}{\partial Y_1}\alpha_1 \left[\frac{-\tau_1^*\tau_1^*/k + \tau_1^*\tau_2^* - \tau_1^*\tau_2^* - \tau_2^*\tau_2^* k}{\tau_1^*\left(\tau_1^* + \tau_2^* k\right)} \right] =$$

$$\frac{\partial \alpha_1}{\partial Y_1} \left[\Delta_K + \frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right] + \frac{\partial k}{\partial Y_1}\alpha_1 \left[\frac{-\tau_1^*\tau_1^*/k - \tau_2^*\tau_2^* k}{\tau_1^*\left(\tau_1^* + \tau_2^* k\right)} \right] =$$

$$-\frac{y_1 N_1}{Y_1^2}\frac{\partial \alpha_1}{\partial R_1} \left[\Delta_K + \frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right] + \frac{N_2}{N_1 Y_2}\alpha_1 \left[\frac{-\tau_1^*\tau_1^*/k - \tau_2^*\tau_2^* k}{\tau_1^*\left(\tau_1^* + \tau_2^* k\right)} \right].$$

This is greater than zero if and only if

$$-\frac{y_1 N_1}{Y_1^2}\frac{\partial \alpha_1}{\partial R_1} \left[\Delta_K + \frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right] \geq -\frac{N_2}{N_1 Y_2}\alpha_1 \left[\frac{-\tau_1^*\tau_1^*/k - \tau_2^*\tau_2^* k}{\tau_1^*\left(\tau_1^* + \tau_2^* k\right)} \right]$$

$$\frac{N_1}{Y_1^2}\frac{\partial \alpha_1}{\partial R_1} \left[\Delta_K + \frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right] \leq \frac{1}{N_1}\frac{N_2}{Y_2}\tau_1^* \left[\frac{-\tau_1^*\tau_1^*/k - \tau_2^*\tau_2^* k}{\tau_1^*\left(\tau_1^* + \tau_2^* k\right)} \right]$$

$$\left(\frac{N_1}{Y_1}\right)^2 \frac{\partial \alpha_1}{\partial R_1} \left[\Delta_K + \frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right] \leq \frac{N_2}{Y_2}\tau_1^* \left[\frac{-\tau_1^*\tau_1^*/k - \tau_2^*\tau_2^* k}{\tau_1^*\left(\tau_1^* + \tau_2^* k\right)} \right]$$

$$\underbrace{\frac{N_1}{Y_1}\frac{\partial \alpha_1}{\partial R}}_{+ve} \underbrace{\left[\Delta_K + \frac{\tau_1^* - k\tau_2^*}{\tau_1^* + k\tau_2^*} \right]}_{x>1} \leq k \underbrace{\left[\frac{-\tau_1^*\tau_1^*/k - \tau_2^*\tau_2^* k}{\tau_1^*\left(\tau_1^* + \tau_2^* k\right)} \right]}_{-ve},$$

which is never satisfied.

$$\frac{\partial \Gamma_2}{\partial Y_2} =$$

$$= \frac{\partial \alpha_2}{\partial Y_2}\Delta_k + \frac{\partial \tau_2^*}{\partial Y_2}\left[\frac{\alpha_2}{\frac{1}{k}\tau_1^* + \tau_2^*} + \frac{\alpha_2 k}{\tau_1^* + k\tau_2^*} - \frac{\alpha_2}{y_2}\right] + \frac{\partial k}{\partial Y_2}\left[-\frac{\alpha_2}{\frac{1}{k}\tau_1^* + \tau_2^*}\frac{\tau_1^*}{k^2} + \frac{\alpha_2 \tau_2^*}{\tau_1^* + k\tau_2^*} + y_2\frac{\tau_1^*}{k^2}\right] =$$

$$= \frac{\partial \alpha_2}{\partial Y_2}\Delta_k + \frac{\partial \alpha_2}{\partial Y_2}\frac{\alpha_2}{y_2}\left[\frac{1}{\frac{1}{k}\tau_1^* + \tau_2^*} + \frac{k}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_2^*}\right] - \frac{k}{Y_2}\alpha_2\left[-\frac{1}{\tau_1^* + k\tau_2^*}\frac{\tau_1^*}{k} + \frac{\tau_2^*}{\tau_1^* + k\tau_2^*} + \frac{y_2}{\alpha_2}\frac{\tau_1^*}{k^2}\right] =$$

$$= \frac{\partial \alpha_2}{\partial Y_2}\Delta_k + \frac{\partial \alpha_2}{\partial Y_2}\tau_2^*\left[\frac{\tau_1^* + k\tau_2^* + \tau_1^* + k\tau_2^*}{(\frac{1}{k}\tau_1^* + \tau_2^*)(\tau_1^* + k\tau_2^*)} - \frac{1}{\tau_2^*}\right] - \frac{\alpha_2}{Y_2}\left[-\frac{\tau_1^*}{\tau_1^* + k\tau_2^*} + \frac{k\tau_2^*}{\tau_1^* + k\tau_2^*} + \frac{\tau_1^*}{k\tau_2^*}\right] =$$

$$= \frac{\partial \alpha_2}{\partial Y_2}\Delta_k + \frac{\partial \alpha_2}{\partial Y_2}\left[\frac{\tau_2^* + 2(\tau_1^* + k\tau_2^*)}{(\frac{1}{k}\tau_1^* + \tau_2^*)(\tau_1^* + k\tau_2^*)} - 1\right] - \frac{\alpha_2}{Y_2}\left[\frac{-k\tau_1^*\tau_2^* + k^2(\tau_2^*)^2 + (\tau_1^*)^2 + k\tau_1^*\tau_2^*}{k\tau_2^*(\tau_1^* + k\tau_2^*)}\right] =$$

$$= \frac{\partial \alpha_2}{\partial Y_2}\left[\Delta_K + \frac{\tau_2^* - \frac{1}{k}\tau_1^*}{\tau_2^* + \frac{1}{k}\tau_1^*}\right] - \frac{\alpha_2}{Y_2}\left[\frac{k^2(\tau_2^*)^2 + (\tau_1^*)^2}{k\tau_2^*(\tau_1^* + k\tau_2^*)}\right] \geq 0$$

$$\text{if} \quad \frac{\partial \alpha_2}{\partial Y_2}\left[\Delta_K + \frac{\tau_2^* - \frac{1}{k}\tau_1^*}{\tau_2^* + \frac{1}{k}\tau_1^*}\right] \geq \frac{\alpha_2}{Y_2}\left[\frac{k^2(\tau_2^*)^2 + (\tau_1^*)^2}{k\tau_2^*(\tau_1^* + k\tau_2^*)}\right],$$

which is never verified, given that the left-hand side is always negative and the right-hand side is always positive.

Finally, considering a change in the total income of the opponent country:

$$\frac{\partial \Gamma_1}{\partial Y_2} =$$

$$= \alpha_1\left[\frac{1}{\frac{\tau_1^*}{k} + \tau_2^*}\left(-\frac{\partial k}{\partial Y_2}\frac{\tau_1^*}{k^2} + \frac{\partial \tau_2^*}{\partial Y_2}\right) + \frac{1}{\tau_1^* + k\tau_2^*}\left(\frac{\partial k}{\partial Y_2}\tau_2^* + k\frac{\partial \tau_2^*}{\partial Y_2}\right) - \frac{1}{\tau_2^*}\frac{\partial \tau_2^*}{\partial Y_2}\right] - y_1\left(\frac{\partial k}{\partial Y_2}\tau_2^* + k\frac{\partial \tau_2^*}{\partial Y_2}\right)$$

$$= \alpha_1\frac{\partial k}{\partial Y_2}\left[-\frac{\tau_1^*}{k^2}\frac{1}{\frac{\tau_1^*}{k} + \tau_2^*} + \frac{\tau_2^*}{\tau_1^* + k\tau_2^*} - \frac{y_1}{\alpha_1}\tau_2^*\right] + \alpha_1\frac{\partial \tau_2^*}{\partial Y_2}\left[\frac{1}{\frac{\tau_1^*}{k} + \tau_2^*} + \frac{k}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_2^*} - \frac{y_1}{\alpha_1}k\right]$$

$$= \alpha_1\frac{\partial k}{\partial Y_2}\left[-\frac{\tau_1^*/k}{\tau_1^* + \tau_2^* k} + \frac{\tau_2^*}{\tau_1^* + k\tau_2^*} - \frac{\tau_2^*}{\tau_1^*}\right] + \alpha_1\frac{\partial \tau_2^*}{\partial Y_2}\left[\frac{k}{\tau_1^* + \tau_2^* k} + \frac{k}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_2^*} - \frac{k}{\tau_1^*}\right]$$

$$= \alpha_1\frac{\partial k}{\partial Y_2}\left[\frac{-\tau_1^*\tau_1^*/k + \tau_1^*\tau_2^* - \tau_1^*\tau_2^* - k\tau_2^*\tau_2^*}{\tau_1^*\left(\tau_1^* + k\tau_2^*\right)}\right] + \alpha_1\frac{\partial \tau_2^*}{\partial Y_2}\left[\frac{2k\tau_1^*\tau_2^* - \tau_1^*\left(\tau_1^* + \tau_2^* k\right) - k\tau_2^*\left(\tau_1^* + \tau_2^* k\right)}{\tau_1^*\tau_2^*\left(\tau_1^* + \tau_2^* k\right)}\right]$$

$$= \alpha_1 \underbrace{\frac{\partial k}{\partial Y_2}}_{-ve} \underbrace{\left[\frac{-\tau_1^*\tau_1^*/k - k\tau_2^*\tau_2^*}{\tau_1^*\left(\tau_1^* + k\tau_2^*\right)}\right]}_{-ve} + \alpha_1 \underbrace{\frac{\partial \tau_2^*}{\partial Y_2}}_{-ve} \underbrace{\left[\frac{-\tau_1^*\tau_1^* - kk\tau_2^*\tau_2^*}{\tau_1^*\tau_2^*\left(\tau_1^* + \tau_2^* k\right)}\right]}_{-ve},$$

which is always greater than zero;

$$\frac{\partial \Gamma_2}{\partial Y_1} =$$

$$= \alpha_2 \left[\frac{1}{\frac{1}{k}\tau_1^* + \tau_2^*} \left(\frac{k}{k^2} - \frac{\tau_1^*}{k^2}\frac{\partial k}{\partial Y_1} \right) + \frac{1}{\tau_1^* + k\tau_2^*} \left(\frac{\partial \tau_1^*}{\partial Y_1} + \tau_2^* \frac{\partial k}{\partial Y_1} \right) - \frac{1}{\tau_1^*}\frac{\partial \tau_1^*}{\partial Y_1} \right] - y_2 \left(\frac{\partial \tau_1^*}{\partial Y_1}\frac{k}{k^2} - \frac{\tau_1^*}{k^2}\frac{\partial k}{\partial Y_1} \right)$$

$$= \frac{\partial \tau_1^*}{\partial Y_1} \left[\frac{1}{k}\frac{\alpha_2}{\frac{1}{k}\tau_1^* + \tau_2^*} + \frac{\alpha_2}{\tau_1^* + k\tau_2^*} - \frac{\alpha_2}{\tau_1^*} - \frac{y_2}{k} \right] + \frac{\partial k}{\partial Y_1} \left[-\frac{\tau_1^*}{k^2}\frac{\alpha_2^*}{\frac{1}{k}\tau_1^* + \tau_2^*} + \frac{\tau_2^*\alpha_2}{\tau_1^* + k\tau_2^*} + y_2\frac{\tau_1^*}{k^2} \right]$$

$$= \frac{\partial \tau_1^*}{\partial Y_1}\alpha_2 \left[\frac{1}{\tau_1^* + k\tau_2^*} + \frac{1}{\tau_1^* + k\tau_2^*} - \frac{1}{\tau_1^*} - \frac{1}{k\tau_2^*} \right] + \frac{k\alpha_2}{Y_1} \left[-\frac{\tau_1^*}{k}\frac{1}{\tau_1^* + k\tau_2^*} + \frac{\tau_2^*}{\tau_1^* + k\tau_2^*} + \frac{\tau_1^*}{\tau_2^* k^2} \right]$$

$$= \frac{\partial \tau_1^*}{\partial Y_1}\alpha_2 \left[-\frac{(\tau_1^*)^2 + k^2(\tau_2^*)^2}{k\tau_1^*\tau_2^*(\tau_1^* + k\tau_2^*)} \right] + \frac{\alpha_2}{Y_1} \left[\frac{(\tau_1^*)^2 + k^2(\tau_2^*)^2}{k\tau_2^*(\tau_1^* + k\tau_2^*)} \right] \geq 0$$

$$\text{i.e. if} \quad \frac{\partial \tau_1^*}{\partial Y_1} \left[-\frac{(\tau_1^*)^2 + k^2(\tau_2^*)^2}{k\tau_1^*\tau_2^*(\tau_1^* + k\tau_2^*)} \right] \geq -\frac{1}{Y_1} \left[\frac{(\tau_1^*)^2 + k^2(\tau_2^*)^2}{k\tau_2^*(\tau_1^* + k\tau_2^*)} \right]$$

which is always verified, given that the left-hand side is always positive and the right-hand side is always negative.

A.8 Proof of Corollary 5.1

Let us compare the provision of the public good under the two equity rules in case of efficiency. With a slight abuse of notation, let $\tau_1^K \equiv \tau_1^* + k\tau_2^*$, $\tau_2^K \equiv \tau_2^* + \tau_1^*/k$, and $\tau_E \equiv \tau_1^* + \tau_2^*$. Moreover, let $H^K \equiv H(\tau_1^K) + H(\tau_2^K)$ and $H^E \equiv 2H(\tau_E)$. Then,

$$H^K - H^E = \ln \tau_1^K + \ln Y_1 + \ln \tau_2^K + \ln Y_2 - \ln \tau_1^E - \ln Y_1 - \ln \tau_2^E - \ln Y_2 =$$
$$= \ln(\tau_1^* + k\tau_2^*) + \ln\left(\frac{1}{k}\tau_1^* + \tau_2^* \right) - \ln(\tau_1^* + \tau_2^*) - \ln(\tau_1^* + \tau_2^*),$$

which is greater than or equal to zero if and only if

$$\frac{(k-1)(k\tau_2^* - \tau_1^*)}{k(\tau_1^* + \tau_2^*)^2} \geq 0$$

i.e. if either i) $k < 1$ and $\tau_1^* > k\tau_2^*$; ii) $k = 1$; or $k > 1$ and $\tau_1^* < k\tau_2^*$. The difference in the provision of the public good under the two equity rule changes according to the difference in the two countries' average income according to

$$\frac{\partial (H^K - H^E)}{\partial k} = \frac{k\tau_2^* - \tau_1^*}{k(k\tau_2^* + \tau_1^*)},$$

from which it follows that $H^K - H^E$ increases in k if $\tau_1^* < k\tau_2^*$.

A.9 Proof of Corollary 5.2

The utility of the median voter of country 1 in case of cooperation is given by

$$W_1 = (1-\tau_1)y_1 + \alpha_1\left[H(\tau_1)+H(\tau_2)\right] = (1-\tau_1)y_1 + \alpha_1(\ln\tau_1 + \ln Y_1 + \ln\tau_2 + \ln Y_2).$$

Let W_j^K and W_j^E be the utility of the median agent in country j under the efficient proportional and equal tax rate, respectively. The utility is equalised under these two equity rules if

$$\begin{aligned}
W_1^K &= W_1^E\\
(1-\tau_1^K)y_1 + \alpha_1 H^K &= (1-\tau_1^E)y_1 + \alpha_1 H^E\\
(1-\tau_1^K)y_1 - (1-\tau_1^E)y_1 &= \alpha_1(\ln\tau_1^E + \ln Y_1 + \ln\tau_2^E + \ln Y_2) - \alpha_1(\ln\tau_1^K + \ln Y_1 + \ln\tau_2^K + \ln Y_2)\\
\left(\tau_1^E - \tau_1^K\right)y_1 &= \alpha_1(\ln\tau_1^E\tau_2^E - \ln\tau_1^K\tau_2^K)\\
(\tau_1^E - \tau_1^K)\frac{y_1}{\alpha_1} &= \ln\frac{\tau_1^E\tau_2^E}{\tau_1^K\tau_2^K}\\
\frac{\tau_1^E}{\tau_1^*} - \frac{\tau_1^K}{\tau_1^*} - \ln\frac{\tau_1^E\tau_2^E}{\tau_1^K\tau_2^K} &= 0\\
\frac{\tau_1^*+\tau_2^*}{\tau_1^*} - \frac{\tau_1^*+k\tau_2^*}{\tau_1^*} - \ln\left(\frac{(\tau_1^*+\tau_2^*)^2}{(\tau_1^*+k\tau_2^*)(\tau_1^*\frac{1}{k}+\tau_2^*)}\right) &= 0\\
(1-k)\frac{\tau_2^*}{\tau_1^*} - \ln\left(\frac{(\tau_1^*+\tau_2^*)^2}{(\tau_1^*+k\tau_2^*)(\tau_1^*\frac{1}{k}+\tau_2^*)}\right) &= 0.
\end{aligned}$$

A solution of this equation for any $\tau_1^* \in [0,1]$ and $\tau_2^* \in [0,1]$ is $k=1$. Consider

$$\frac{\partial(W_1^K - W_1^E)}{\partial k} = -\frac{(\tau_1^*)^2 + k^2(\tau_2^*)^2}{k^2\tau_1^*\tau_2^* + k^2(\tau_2^*)^2},$$

which is always negative. Therefore, $W_1^K - W_1^E$ is decreasing in k, which mean that there is at most one k for each couple (τ_1^*, τ_2^*) which makes $W_1^K - W_1^E = 0$. Given that $k=1$ is a solution, it is the only solution for our interval.

This also means that the utility derived from the efficient proportional tax rate rule by the median voter in country 1 will always be greater than the utility derived from the equal tax rate rule as long as country 1 is on average poorer than country 2 ($k<1$). The difference between the two utility levels will decrease with an increase in k, making the utility under the equal tax rule greater than the utility obtained in the proportional tax rate rule in the case in which country 1 is richer than country 2.

Considering a change in the income of the delegate of country 1:

$$
\begin{aligned}
&\frac{\partial(W_1^K - W_1^E)}{\partial y_1} = \\
&= -\left(\frac{\tau_2^*}{\tau_1^*}\frac{\partial \tau_1^*}{\partial y_1}\right) + \left(\frac{k\tau_2^*}{(\tau_1^*)^2}\frac{\partial \tau_1^*}{\partial y_1}\right) - \left[\frac{2}{\tau_1^* + \tau_2^*}\frac{\partial \tau_1^*}{\partial y_1}\right] + \left[\frac{1}{\tau_1^* + k\tau_2^*}\frac{\partial \tau_1^*}{\partial y_1}\right] + \left[\frac{1}{\frac{1}{k}\tau_1^* + \tau_2^*}\frac{1}{k}\frac{\partial \tau_1^*}{\partial y_1}\right] = \\
&= \frac{\partial \tau_1^*}{\partial y_1}\left(\frac{k\tau_2^*}{(\tau_1^*)^2} - \frac{\tau_2^*}{(\tau_1^*)^2}\right) - \frac{\partial \tau_1^*}{\partial y_1}\left(\frac{2}{\tau_1^* + \tau_2^*} - \frac{2}{\tau_1^* + k\tau_2^*}\right) = \\
&= \frac{\partial \tau_1^*}{\partial y_1}\left((k-1)\frac{\tau_2^*}{(\tau_1^*)^2} - \frac{2}{\tau_1^* + \tau_2^*} + \frac{2}{\tau_1^* + k\tau_2^*}\right) = \\
&= \frac{\partial \tau_1^*}{\partial y_1}\left((k-1)\frac{\tau_2^*}{(\tau_1^*)^2} + (1-k)\frac{2\tau_2^*}{(\tau_1^* + \tau_2^*)(\tau_1^* + k\tau_2^*)}\right)
\end{aligned}
$$

In the case in which $\varepsilon_1 > 1$, this is weakly greater than zero if the term in parentheses is greater or equal to zero,

$$
\frac{k-1}{(\tau_1^*)^2} + (1-k)\frac{2}{(\tau_1^* + \tau_2^*)(\tau_1^* + k\tau_2^*)} \geq 0 \quad \leftrightarrow \quad \frac{k-1}{(\tau_1^*)^2} \geq (k-1)\frac{2}{(\tau_1^* + \tau_2^*)(\tau_1^* + k\tau_2^*)};
$$

if $k > 1$ then

$$
\frac{1}{(\tau_1^*)^2} \geq \frac{2}{(\tau_1^* + \tau_2^*)(\tau_1^* + k\tau_2^*)},
$$

which is satisfied if $\tau_1^* < k\tau_2^*$.

Considering the opponent country median income:

$$
\begin{aligned}
&\frac{\partial(W_1^K - W_1^E)}{\partial y_2} = \\
&\qquad = \frac{\partial \tau_2^*}{\partial y_2}(1-k)\tau_1^* - \left(\frac{2}{\tau_1^* + \tau_2^*}\frac{\partial \tau_2^*}{\partial y_2}\right) + \frac{k}{\tau_1^* + \tau_2^*}\frac{\partial \tau_2^*}{\partial y_2} + \frac{1}{\frac{1}{k}\tau_1^* + \tau_2^*}\frac{\partial \tau_2^*}{\partial y_2} = \\
&\qquad = \frac{\partial \tau_2^*}{\partial y_2}\left[\tau_1^* - k\tau_1^* - \frac{2}{\tau_1^* + \tau_2^*} + \frac{2}{\frac{1}{k}\tau_1^* + \tau_2^*}\right] = \\
&\qquad = \frac{\partial \tau_2^*}{\partial y_2}\left[\frac{(\frac{1}{k}-1)(\tau_1^*)^3 + (\frac{1}{k}-k)(\tau_1^*)^2\tau_2^* + (1-k)\tau_1^*(\tau_2^*)^2 + (2-\frac{2}{k})\tau_1^*}{(\tau_1^* + \tau_2^*)(\frac{1}{k}\tau_1^* + \tau_2^*)}\right].
\end{aligned}
$$

We know that $\frac{\partial \tau_2^*}{\partial y_2} > 0$ if $\varepsilon_2 > 1$; in this case, the term in parentheses will be positive for $k < 1$.

A.10 Agreement Under An Equal Gains Rule

In this appendix, we also consider a third equity rule, which imposes the realization of the same gain from cooperation for the two median agents. In this case, the set of feasible agreements can be expressed as $T^D(y_1, y_2, \alpha_1, \alpha_2) = T(y_1, y_2, \alpha_1, \alpha_2) \cap D$, where $D = \{(\tau_1, \tau_2) | \Gamma_1(y_1, \alpha_1, \tau_1, \tau_2, \tau_1^*, \tau_2^*) = \Gamma_2(y_2, \alpha_2, \tau_1, \tau_2, \tau_1^*, \tau_2^*)\}$. In other words, the existence of a feasible international agreement in this case requires the two win-sets to be equal, $\alpha_1\Delta_D - y_1(\tau_1 - \tau_1^*) = \alpha_2\Delta_D - y_2(\tau_2 - \tau_2^*) \geq 0$, where Δ_D is the increase in total provision of the public good given the realization of the agreement.

Proposition A.1. *Assume $\alpha_j \geq \alpha_{-j}$. A feasible agreement under an equal gain rule always exists and is such that $\tau_j/\tau_j^* \geq \tau_j/\tau_{-j}^*$. The efficient agreement under the equal gain rule is feasible if $\tau_{-j}/\tau_{-j}^* \leq 2$.*

Proof. The increase in total provision of the public good given the realization of the agreement must be $\Delta = [y_1(\tau_1 - \tau_1^*) - y_2(\tau_2 - \tau_2^*)]/(\alpha_1 - \alpha_2)$ for the gains to be equal. Substituting this into $\alpha_1\Delta - y_1(\tau_1 - \tau_1^*) = \alpha_2\Delta - y_2(\tau_2 - \tau_2^*) \geq 0$ gives $\tau_1/\tau_1^* \geq \tau_2/\tau_2^*$ if $\alpha_1 > \alpha_2$ and $\tau_1/\tau_1^* \leq \tau_2/\tau_2^*$ if $\alpha_1 < \alpha_2$.

From the contract curve in (11), the efficiency condition reads as $\tau_1^*/\tau_1 + \tau_2^*/\tau_2 = 1$. Consequently, a feasible agreement entails $\tau_1/\tau_1^* = 1 - \tau_2/\tau_2^*$. If $\alpha_1 > \alpha_2$ (cf. $\alpha_2 > \alpha_1$), this is feasible if $\tau_2/\tau_2^* \leq 2$ (cf. $\tau_2/\tau_2^* \geq 2$). □

Differently from the previous equity rules, an international agreement under equal gains is always feasible: as already highlighted by Kempf and Rossignol (2013), the equal gains requirement amounts to impose a "win–win" solution which limits the bargaining power of the negotiator with the better outside option, and thus reduces their conflict of interests. Proposition A.1 also maintains that the increase in taxation from an international agreement under the equal gains rule will have to be more than proportional for the country with higher domestic income equality than for the more unequal country. Moreover, the ratio of the cooperative taxes diverges as the difference between the inequality levels in the two countries increases. Finally, the ratio between the cooperative tax rates increases in the median voter's income if the elasticity of the environmental preference with respect to the income distribution is greater than one, $\varepsilon_j > 1$.