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Building Climate Coalitions on Preferential Free Trade Agreements

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Abstract

In this paper, we discuss the endogenous formation of climate coalitions in the tradition of the issue-linkage literature. In particular, we propose a preferential free trade agreement on which a climate coalition should be built. The basic idea is that the benefits of free trade provide strong incentives for free riders to join the coalition. As a framework, a multi-stage strategic trade model is used in which a country may discourage greenhouse gas emissions by setting an emissions cap effective on a permit market. In addition, a discriminatory import tariff is imposed on dirty goods. However, at the heart of our approach are the trade privileges granted to coalition members shifting the terms of trade favourably without prodiving incentives towards eco-dumping. As a main result, we find that trade liberalisation is much more effective in building climate coalitions than a single-issue environmental agreement. The parametrical simulation of the model in particular shows that participation in joint emission reduction is higher, consumption patterns are more environmentally friendly, and coalitional welfare is improved. As a policy implication, negotiations on climate treaties and free trade arrangements should be integrated.

JEL classification: Q54, Q56, F18, F15, Q58

Keywords: Climate Change, International Environmental Agreements, Free Trade, Issue Linkage, Tradable Permits, Strategic Trade Policy

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1 Introduction

When the issue of climate change becomes more and more severe, as it is, world-wide collective action is seen indispensible. In the literature, a number of mechanisms have been proposed for how climate coalitions may be formed voluntarily to achieve an effective mitigation of global greenhouse gas emissions. Typically, multilateral cooperation among countries is institutionalised in the form of international environmental agreements (IEAs) such as the Paris Agreement and its predecessors. The international community has acknowledged that incentives to offset free-riding are crucial and should be provided to countries. In the Paris Agreement, for instance, side payments (climate finance) as well as technology transfers and capacity building in the field of mitigation and adaptation are among the incentive measures for emission reduction that have been addressed.

However, the idea of coupling mitigation efforts to other treaty mechanisms in order to raise participation in IEAs and their effectiveness is not new at all and has been proposed in the game-theoretic literature since the early 1990s. The motivation throughout has been to improve on the rather pessimistic propositions in the non-cooperative literature (e.g. Hoel, 1992, Carraro/Siniscalco, 1993, and Barrett, 1994), stating that self-enforcing IEAs can only be implemented under fairly strong restrictions. Either the number of signatories must not be too large or the signatories need to commit to just fairly lax emission reduction targets, compared to the business-as-usual emission scenario. Put differently, there appears to be a trade-off between the effectiveness of an IEA and its stability (Finus, 2003) which must be overcome by an appropriate incentive instrument.

In this respect, various *transfer mechanisms* have been examined extensively and their scope to improve the prospects of cooperation[4] are found rather limited, although the results may highly depend on the specific design of the allocation rules and of the process of coalition formation. For this reason, attention has also been paid to the mechanism of *issue linkage* (e.g. by Carraro/Siniscalco, 1995, 1998, 2001, Carraro, 1999, and Carraro/Marchiori, 2003a) which entails the linkage of the public-good agreement on climate change to other policy issues, particularly to the joint provision of a club good. The idea is that the benefits of enjoying the club good can off-set

[4] Barrett (1997a, 2001), Botteon/Carraro (1997, 2001), Eyckmans/Finus (2006, 2007), Bosello/Buchner/Carraro (2003), Rose et al. (1998), Carraro/Eyckmans/Finus (2006), McGinty (2007), McGinty/Milan/Gelves (2012), Nagashima et al. (2009), Weikard/Finus/Altamirano-Cabrera (2006), and Weikard (2009), among others, address the effect of side-payments and different burden sharing rules on the formation of IEAs.

the incentive to free-ride on the environment (Botteon/Carraro, 1998).[5]

In general, following the dichotomy introduced by Ederington (2010), the literature on issue linkage can be classified into the two types of *negotiation linkage* and *enforcement linkage*, according to the focus of the analysis. Contributions to the first category are typically aimed at studying the impact of cross-issue negotiation on the process of coalition building, either choosing R&D cooperation[6] or trade liberalisation[7]. By contrast, in the second category, issue linkage is understood as the possibility of cross-issue retaliation in order to enforce international cooperation among countries within an existing agreement. Most prominently, trade sanctions are given consideration using a strategic trade framework (e.g. in Abrego et al., 2001, Ederington, 2002, Bajona/Ederington, 2012, and Limão, 2005, 2007). It is evident that this notion of linkage to trade policy issues is quite similar to the related approach of border tax adjustments that have become a popular means to combat carbon leakage (see e.g. Bucher/Schenker, 2010 and Fischer/Fox, 2012). Although the threat of such punitive measures has the potential to create enforcement power to the linked agreement, there is a dispute about the imposition concerning their credibility on the one hand, and their compliance with the non-discrimination rules of the WTO on the other. (Ederington, 2010)

This paper is naturally rooted in the tradition of the literature on negotiation linkage. As such, the potential for the success of a climate coalition in terms of effectiveness and stability crucially depends on the choice of the linked issue as can be learned from the literature. Contributions on R&D-related issue linkages observe that R&D cooperation usually provides a competitive advantage to signatories based, for instance, on a more efficient technology. But this advantage tends to disappear when the coalition size increases. As a consequence, signatories might find it optimal to exclude some countries from the joint environmental and R&D agreement. (Carraro/Siniscalco, 1997, Botteon/Carraro, 1998 and Carraro, 1999) Further gains from R&D cooperation might be even more diminished if technological spillovers to non-signatories are taken into account (Buchner

[5]This mechanism will obviously only come into effect if countries do not have the option of 'cherry-picking' between the issues. The vast majority of contributions adheres to the requirement of a simultaneous membership in both (partial) agreements. Nevertheless, several authors such as Conconi/Perroni (2002) and Carraro/Marchiori (2003a) investigate mixed membership by allowing partially overlapping agreement structures. As a matter of course, this step would bring about participation rates in the single club-good agreement which are probably higher than or equal to the rates in the linked agreement.

[6]See, for instance, Carraro/Siniscalco (1997), Katsoulacos (1997), Botteon/Carraro (1998), Buchner et al. (2002) and Kemfert (2004).

[7]Different forms of regional trade cooperation are considered by Barrett (1997b), Finus/Rundshagen (2000) and Conconi/Perroni (2002).

et al., 2002 and Kemfert, 2004). Previous trade-related approaches focus on different policies liberalizing trade that are harmonised vis-à-vis non-signatories. More precisely, Barrett (1997b) and Finus/Rundshagen (2000) propose the establishment of a free trade agreement among signatories of the IEA combined with a trade ban or a common tariff against non-signatories, respectively. They find that, under favourable circumstances, welfare as well as participation can be enhanced. However, in other cases, issue linkage fails to pose a credible threat because it reduces the welfare of signatories too. Focusing on a traditional free trade agreement, Conconi/Perroni (2002) show for a three-country model with segmented markets that enforced multiple negotiations on environmental and trade issues can stabilise or destabilise full cooperation by eliminating partially overlapping agreement structures which would result from separate negotiations. The outcomes are determined by the importance of trade and the elasticity of policy responses to changes in the valuation of marginal damages since these factors constitute the gains from blocking trade and the possibility of counteracting free-riding on the environment.

Compared to the existing literature, we would like to propose a more general kind of incentive mechanism. Given a world of bilateral trade regulation put in place more or less regularly, signatories of a climate coalition should benefit if, at the same time, they could join a free trade arrangement and enjoy the trade privileges provided. The idea of linking exclusive market and trade benefits to the formation of a climate coalition is currently experiencing a revival within the so-called 'climate club' literature.[8] But, to our knowledge, the coalition-building process with such an incentive mechanism has not been analyzed in a formal way so far for the n-country case. To be able to capture the relevant aspects in both, trade and climate change, an appropriate trade model may be used. The difficulty one might experience here obviously lies in determining the trade pattern prevailing inside the free trade area as well as outside to properly assign the free trade privileges.

Therefore, in the paper we consider a model in the tradition of the strategic trade theory whose basic framework goes back to Eichner/Pethig (2012, 2013a, 2013b, 2015a, 2015b). It includes the environment in form of an unwanted by-product, greenhouse gas emissions, modeled as a global public bad. Accordingly, we build up a multi-stage, multi-sectoral Stackelberg leader-follower framework comprising an international market stage as well as a policy stage on which countries

[8]Originating from the political science literature (e.g. Leal-Arcas, 2011, 2013, Weischer/Morgan/Patel, 2012, Stewart/Oppenheimer/Rudyk, 2013, Leycegui Gardoqui/Ramírez, 2015, and others), the climate club approach has also become popular among environmental economists such as Nordhaus (2015) and Hovi et al. (2015).

can strategically employ trade measures like tariffs as well as environmental measures like emissions caps. However, what is at the core of our model is a preferential free trade arrangement (PFTA), introduced as an incentive mechanism for the endogenous formation of climate coalitions. This set-up requires that the trade flows inside and outside the area of the free trade arrangement must be traced. For this purpose, we need to appropriately model firms' supplies to the various domestic and foreign destination markets regarding a dirty as well as a clean good. Differentiated producer prices and transaction costs naturally have to be taken into account. As a main result of our analysis, we find evidence for the thesis that a free trade agreement can strongly promote the formation of a climate coalition if it is linked to the trade privileges granted.

More precisely, we employ a model in which the strategic trade and environmental policies of the climate coalition vis-à-vis non-signatories are carried out individually (but not independently). Thereby, excludable benefits are entirely generated by preferential trade liberalisation while any punishment or retaliation mechanisms are ruled out. Furthermore, coalition members do not necessarily need to harmonise their tariff rates for maximizing joint welfare which is why incentives to deviate from the policies agreed on do not arise. However, for the sake of simplicity, we may assume symmetry in the initial endowments, technologies, and preferences. As far as policy implications are concerned, such interlinked trade-climate agreements can be implemented by incorporating climate-related provisions within preferential trade agreements like TTIP or CETA. (Leal-Arcas, 2013)

The paper is organised as follows. The next section provides the model with a focus on the microfoundations of the market equilibria and the trade patterns. In section 3 the strategic policies of fringe and coalition countries are modelled in a Stackelberg leader-follower framework at a given coalition size. The endogenous formation of the stable coalition is then explained in section 4, including a discussion on the internal and external stability. In section 5 the results of the numerical simulation of the analytical model are presented followed by some propositions on the role of the preferential free trade area in section 6. Section 7 provides some concluding remarks.

2 The Model

In the following model, we introduce a preferential free trade area which is open only to the signatories of an IEA such that the issue of climate protection is being interlinked with the privileges of trade liberalisation.[9] In this respect, to determine the trade pattern inside and outside the free trade area including the trade flows among the non-signatory countries is crucial. This is made possible by differentiating firms' supplies according to the markets of destination, both domestic and foreign markets. Vice versa, imports have to be differentiated according to the countries of origin. For this purpose, we tried to modify the usual framework for trade models appropriately as stated above.

2.1 The World Economy and the Global Environment

We consider a world economy with $i = 1, \ldots, n$ countries, each of which has an endowment $\overline{r}$ of a composite production factor at its disposal which can be used for the production of either a 'clean' consumer good, x_i, or a 'dirty' consumer good, e_i. The reason why e represents a dirty good is simply given by the fact that it is coupled with greenhouse gas emissions like CO_2 which naturally are modelled as a global public externality. The basic assumption is that the *consumption* of the dirty good, e_i^D, is generating an emission one for one and thus the global emission level is given by the sum $\sum_{j=1}^{n} e_j^D$. The damage function takes the following convex form:[10]

$$D(e_1^D, \ldots, e_n^D) = \frac{\delta}{2} \left(\sum_{j=1}^{n} e_j^D \right)^2 , \tag{1}$$

with the parameter $\delta > 0$ and with marginal damages increasing, i.e. $\frac{\partial D}{\partial e_i^D}, \frac{\partial^2 D}{\partial \left(e_i^D\right)^2} > 0$.

In our model, climate damages are assumed to be external to consumers since society's preferences for the environment will be reflected in the welfare function and are taken care of by the government. Global damages thus affect the welfare of any single country and cannot be ignored apart from any free-riding incentives. However, countries which opt for free-riding may view their impact on global warming negligible compared to the cost of emission abatement. This is exactly the challenge in the combat of a global public bad like it is the case with global warming. The more important is the formation of climate coalitions.

[9] As mentioned above, we draw from the Stackelberg leader-follower framework by Eichner/Pethig (2013a, 2013b, 2015b) for n countries as a starting point. The implementation of a free trade area may be considered as the main contribution of the enhanced model we are going to introduce.

[10] Please note that the superscript D indicates quantities demanded.

2.2 Caps, Tariffs, and Preferential Trade Areas

National governments in principle have two kinds of policy instruments available to address environmental disruptions: a national system of emission permits trading and a trade tariff. Each government is able to set a national cap $e_i > 0$ for ceiling carbon emissions and to auction the number of available emission permits e_i at a permit price π_i. Those households which want to consume the dirty good are required to hold a permit one for one to internalise, more or less perfectly, the externality. Additionally, governments can impose a trade tariff $t_i \in \mathbb{R}$ which may take the form of an import tariff ($t_i > 0$) or of an export tax ($t_i < 0$). The tariff design is equivalent to a unit tax that decouples the domestic producer price of the dirty good from the foreign producer price. (Eichner/Pethig, 2013b)

There is trade taking place in both goods among the various countries. Firms in each country are producing for the domestic as well as for foreign markets. Consequently, firms differentiate supplies with respect to the destination markets as already indicated. This applies to the clean as well as to the dirty good. Not only the prices differ firms receive on domestic and foreign markets, respectively, but the opportunity costs of shipping products abroad do as well. Vice versa, supplies on local markets must be considered as being composed of the imports from various foreign countries in addition to the domestic supply. Naturally, this is a standard feature in trade models.

However, this picture becomes even more complex as soon as an (endogenous) free trade area has to be incorporated into this framework. Then, countries that are part of the free trade area must discriminate between trade with coalition member states and with non-member states. Formally, it may be useful to first sort countries according to their group membership. If country i is a member of the climate and free trade agreement $C := \{1, 2, \ldots, m\}$, it will be called a coalition country, $i \in C$. Accordingly, we call country i a fringe country if it is not a coalition member, i.e. $i \notin C$, or, equivalently, $i \in F := \{m+1, m+2, \ldots, n\}$, $m \leq n$, where F gives the set of fringe countries. Furthermore, the tariff design must take into account that producers in coalition countries, $i \in C$ are generally exempted from any import tariff imposed by any other coalition country, $j \in C$, $j \neq i$. Consequently, firms of a coalition country i receive the domestic producer price $p_j + t_j$, $t_j \in \mathbb{R}$ for their exports to a coalition country j, while producers from fringe countries, $i \notin C$, just receive the producer price p_j. **Table 1** provides an summary of the producer prices prevailing within a preferential free trade arrangement as such.

		Country of Destination		
		$j = i$	$j \in C$	$j \notin C$
Country of Origin	$i \in C$	$p_i + t_i$	$p_j + t_j$	p_j
	$i \notin C$	$p_i + t_i$	p_j	p_j

Table 1: Overview of Producer Prices (for a Firm Located in Country i)

Naturally, as shown in the table, free trade privileges all firms inside the member countries over firms outside due to the tax exemption.

2.3 Producers

In each country, there is a perfectly competitive firm serving the domestic market as well as any potential foreign market. Thereby, it is reasonable to assume that the opportunity costs of providing the dirty good may crucially depend on the respective markets of destination. In general, firms not only must cover the varying transportation costs (at least to some extent) but must meet country-specific import regulations and standards as well. Therefore, any firm will want to differentiate its supply efficiently by taking the transaction costs into account.

A representative firm is located in each country i producing both, the dirty good as well as the clean good. The dirty good's production employs a decreasing returns-to-scale technology (in accordance with Eichner/Pethig (2013a, 2013b, 2015b)) and total production is composed of all supplies specifically made on the different markets of destination, e_{ij}^S.[11] The clean good in turn is produced under a constant returns-to-scale technology and taken as numeraire. Likewise, the country's factor constraint must hold such that the input factor in overall production must not exceed the available endowment, $\overline{r}$. From this, the quadratic production possibility frontier (PPF) for country i can be derived where the superscript S indicates quantities supplied throughout:

$$T\left(e_{i1}^S, \ldots, e_{in}^S\right) = \overline{x} - x_i^S - \alpha_x \sum_{j=1}^{n} \alpha_{e_{ij}} \left(e_{ij}^S\right)^2 = 0, \tag{2}$$

Furthermore, α_x, $\alpha_{e_{ij}}$ give the technology coefficients for the clean and the components of the dirty good, respectively and $\overline{x} > 0$ denotes the maximum producible amount of the clean good. The PPF T is found a decreasing and strictly concave function in any e_{ij}^S, that is $\frac{\partial T}{\partial e_{ij}^S}, \frac{\partial^2 T}{\partial \left(e_{ij}^S\right)^2} < 0$.

[11] Here, the first index represents the country of origin and the second one represents the country of destination.

For the sake of simplicity, we make use of the following specific technology coefficients:

$$\alpha_x = 1, \qquad \alpha_{e_{ij}} = \begin{cases} \alpha_H & \text{if } i = j \\ \alpha^* & \text{if } i \neq j \end{cases} \qquad i, j = 1, \ldots, n. \tag{3}$$

In case of the dirty good, the assumption $0 < \alpha_H < \alpha^*$ is made, hence, opportunity costs shall be the same for all foreign destinations but are considered being generally higher for cross-border trade than for domestic trade for the reasons given above.[12] Therefore, we are able to rule out interfering comparative advantages in explaining trade patterns and environmental impacts, as we entirely try to focus on trade and environmental measures as implemented by coalition and fringe countries.[13]

Taking the prices on the local markets $p_1, \ldots, p_n$ and the tariff rates $t_1, \ldots, t_n$ as given, the representative firm in country i maximises its profits, Π_i, subject to the PPF in (2) by optimally choosing its supplies of the the dirty commodity to the different target markets, $e^S_{i1}, \ldots, e^S_{in}$ as well as the supply of the clean commodity, x^S_i:

$$\begin{aligned} &\max_{x^S_i, e^S_{i1}, \ldots, e^S_{in}} && \Pi_i(x^S_i, e^S_{i1}, \ldots, e^S_{in}) \\ &\text{s.t.} && T\left(x^S_i, e^S_{i1}, \ldots, e^S_{in}\right) = \overline{x} - x^S_i - \left(\alpha_H \left(e^S_{ii}\right)^2 + \alpha^* \sum_{\substack{j=1, \\ j \neq i}}^{n} \left(e^S_{ij}\right)^2 \right) = 0 \end{aligned} \tag{4}$$

Naturally, firms in coalition and fringe countries face different optimisation problems due to the privileges of the free trade arrangement. Those lead to the following specific profit functions, referring to the prices given in **Table 1**:

$$\Pi_i\left(x^S_i, e^S_{i1}, \ldots, e^S_{in}\right) = x^S_i + (p_i + t_i) e^S_{ii} + \sum_{\substack{j=1, \\ j \in C, \\ j \neq i}}^{m} \left(p_j + t_j\right) e^S_{ij} + \sum_{\substack{j=m+1, \\ j \notin C}}^{n} p_j e^S_{ij}, \qquad \text{for } i \in C \tag{5a}$$

$$\Pi_i\left(x^S_i, e^S_{i1}, \ldots, e^S_{in}\right) = x^S_i + (p_i + t_i) e^S_{ii} + \sum_{\substack{j=1, \\ j \neq i}}^{n} p_j e^S_{ij}, \qquad \text{for } i \notin C \tag{5b}$$

[12] It is worth mentioning that the assumptions made in connection with the identical endowments imply symmetry among firms.

[13] However, for analysing the impact of the heterogeneity of countries, one may introduce differences in endowments or production technologies.

The optimal outputs derived from the first-order conditions of the profit maximisation problem yield:

$$e_{ii}^S = \frac{p_i + t_i}{2\alpha_H}, \qquad \left(e_{ij}^S\right)_{\substack{j\in C,\\ j\neq i}} = \frac{p_j + t_j}{2\alpha^*}, \qquad \left(e_{ij}^S\right)_{j\notin C} = \frac{p_j}{2\alpha^*}, \qquad \text{for } i \in C \tag{6a}$$

$$e_{ii}^S = \frac{p_i + t_i}{2\alpha_H}, \qquad \left(e_{ij}^S\right)_{j\neq i} = \frac{p_j}{2\alpha^*}, \qquad \text{for } i \notin C \tag{6b}$$

These quantities naturally aggregate to the total supply function of the firm in country i:

$$e_i^S(p_1, \ldots, p_n) = \sum_{j=1}^{n} e_{ij}^S \tag{7}$$

2.4 Consumers

In each country i, a representative consumer is naturally facing the domestic consumer price $p_i + t_i + \pi_i$ which is composed of the tax-inclusive price of the dirty good and the permit price π_i. Utility is given as a quasi-linear function of the clean good x_i^D and the dirty good e_i^D, respectively. Hence, marginal consumption utility of the dirty good is assumed positive but decreasing, $\frac{\partial U_i}{\partial e_i^D} > 0$, $\frac{\partial^2 U_i}{\partial \left(e_i^D\right)^2} < 0$, whereas marginal utility of the numeraire good x_i^D is constant as usual. Global emissions do not enter the utility function since they are external in the consumers' view. However, the damage generated by climate change is taken into account in the national welfare functions as will be specified later on.

A representative consumer is maximizing utility U_i (with $a, b > 0$) by choosing her demands for the clean and the dirty good, subject to the budget constraint:

$$\begin{aligned} \max_{x_i^D, e_i^D} \quad & U_i\left(x_i^D, e_i^D\right) = x_i^D + a e_i^D - \frac{b}{2}\left(e_i^D\right)^2 \\ \text{s.t.} \quad & y_i - x_i^D - (p_i + t_i + \pi_i) e_i^D = 0 \end{aligned} \tag{8}$$

where y_i is the consumer's income. The consumer takes income as given, since it origins from the instantaneous transfer of all kinds of added value generated in the economy. Hence, income is composed of producer rents, permit income, as well as tariff income:

$$y_i := x_i^S + (p_i + t_i)\, e_{ii}^S + \sum_{\substack{j=1,\\ j\in C,\\ j\neq i}}^{m} (p_j + t_j)\, e_{ij}^S + \sum_{\substack{j=m+1,\\ j\notin C}}^{n} p_j e_{ij}^S + \pi_i e_i^D + t_i \sum_{\substack{j=m+1,\\ j\notin C}}^{n} e_{ji}^S, \qquad \text{for } i \in C \quad (9a)$$

$$y_i := x_i^S + (p_i + t_i)\, e_{ii}^S + \sum_{\substack{j=1,\\ j\neq i}}^{n} p_j e_{ij}^S + \pi_i e_i^D + t_i \sum_{\substack{j=1,\\ j\neq i}}^{n} e_{ji}^S, \qquad \text{for } i \notin C \quad (9b)$$

It will be determined along with the market equilibria. From the first-order conditions of the utility maximisation problem we can derive the demand for the dirty good as follows:

$$e_i^D(p_i, t_i, \pi_i) = \frac{a - (p_i + t_i + \pi_i)}{b} \tag{10}$$

2.5 Markets and General Equilibrium

The model incorporates three kinds of markets which must be simultaneously cleared in the general equilibrium. First, as the demand for the dirty good invokes an equal demand for permits in the national emissions trading scheme, the national permit markets are in equilibrium if the following condition holds:

$$e_i^D\,(p_i, t_i, \pi_i) = e_i, \qquad \forall i = 1, \ldots, n, \tag{11}$$

with e_i being the emission cap set by the national government. This yields the equilibrium permit price π_i^*.

Second, there is a world market for good X, the numeraire, sold at a world price set equal to $p_x \equiv 1$. In equilibrium, the following market-clearing condition must hold:

$$\sum_{j=1}^{n} x_j^D = \sum_{j=1}^{n} x_j^S \tag{12}$$

Finally, in each country i, there is a local market for the dirty good sold at the local price p_i. These markets are in equilibrium if the following conditions hold simultaneously:

$$e_i^D = \sum_{j=1}^{n} e_{ji}^S = e_{ii}^S + \sum_{\substack{j=1,\\ j\in C,\\ j\neq i}}^{m} e_{ji}^S + \sum_{\substack{j=m+1,\\ j\notin C,\\ j\neq i}}^{n} e_{ji}^S, \qquad \forall i = 1, \ldots, n \tag{13}$$

As can be seen in equation (13), the total supply on the local market in country i is the aggregated sum of all imports originating from all foreign firms $j \neq i$ in addition to the supply of the domestic firm i.

By substituting the firms' supplies from (6a) and (6b) for the RHS in (13), and by replacing demand with the emission cap from (11) for the LHS in (13) the equilibrium price of the dirty good can be determined:

$$p_i^*(e_i, t_i) = \frac{2\alpha_H \alpha^* e_i - \alpha^* t_i - (m-1)\alpha_H t_i}{(n-1)\,\alpha_H + \alpha^*}, \qquad \text{for } i \in C \quad (14a)$$

$$p_i^*(e_i, t_i) = \frac{2\alpha_H \alpha^* e_i - \alpha^* t_i}{(n-1)\,\alpha_H + \alpha^*}, \qquad \text{for } i \notin C \quad (14b)$$

The price is increasing in the cap but decreasing in the tariff rate, $\frac{\partial p_i^*}{\partial e_i} > 0$ and $\frac{\partial p_i^*}{\partial t_i} < 0$. The impact of a change in the tariff rate turns out to be larger if country i is a coalition member due to the feedback effect of the tariff $\left| -\frac{(m-1)\alpha_H t_i}{(n-1)\alpha_H + \alpha^*} \right|$ within the coalition. By replacing the equilibrium prices $(p_1^*, \ldots, p_n^*)$ in the total supply function (7) and replacing the quantities in the PPF from (2), the equilibrium quantities of the dirty good $\left(e_i^S\right)^*$ and the clean good $\left(x_i^S\right)^*$ are given.

The equilibrium demand for the clean good can be obtained by combining the budget constraint in (8) and the equilibrium quantities and prices from above in addition to the income functions (9a) and (9b), respectively:

$$\left(x_i^D\right)^* = \left(x_i^S\right)^* + \sum_{j=1}^{n} p_j^* \left(e_{ij}^S\right)^* - p_i^* \left(e_i^D\right)^* + \left(\sum_{\substack{j=1,\\ j \in C,\\ j \neq i}}^{m} t_j \left(e_{ij}^S\right)^* - t_i \sum_{\substack{j=1,\\ j \in C,\\ j \neq i}}^{m} \left(e_{ji}^S\right)^* \right), \qquad \text{for } i \in C \quad (15a)$$

$$\left(x_i^D\right)^* = \left(x_i^S\right)^* + \sum_{j=1}^{n} p_j^* \left(e_{ij}^S\right)^* - p_i^* \left(e_i^D\right)^*, \qquad \text{for } i \notin C \quad (15b)$$

By doing so, it can be shown that Walras' Law holds since, in (15a), the difference in brackets which indicates the net tariff income of a coalition country i coming from the other coalition members $j \in C$, $j \neq i$ will be equal to zero. Hence, if all local markets of the dirty good are in equilibrium, the world market for X must be in equilibrium as well.

2.6 Welfare

The role of a country's government is to maximise national welfare. The welfare function of country i is given by consumer rents (including redistributed income) net of environmental damages $U_i(x_i^D, e_i^D) - D(e_1^D, \ldots, e_n^D)$. By replacing demands using condition (11), as well as utility and damages, welfare W_i of country i is a function of the policies given the policy schemes of all the other countries:

$$W_i\left(e_1, \ldots, e_n, t_1, \ldots, t_n\right) = x_i^D + ae_i - \frac{b}{2}(e_i)^2 - \frac{\delta}{2}\left(\sum_{j=1}^{n} e_j\right)^2 \tag{16}$$

It becomes apparent that the welfare of a coalition member is different from that of a fringe country due to the unequal consumption possibilities of the clean good, x_i^D, which are determined by the interdependency of the markets involved. Hence, the welfare function of a coalition country, $W_{i\in C}$, as well as the one of a non-coalition country, $W_{i\notin C}$, differ in the following term:[14]

$$W_{i\in C} - W_{i\notin C} = \frac{1}{4\alpha^*} \cdot \left(\sum_{\substack{j=1, \\ j\in C \\ j\neq i}}^{m} \left(2p_j^*\left(e_j, t_j\right) t_j + t_j^2\right) - 2(m-1) \cdot \left(p_i^*\left(e_i, t_i\right) t_i + t_i^2\right) \right) \tag{17}$$

The difference on the RHS indicates the net income of country i arising from the total gains of preferential free trade among the members of the climate coalition.

3 Benchmark Cases

In the subsequent analysis, two benchmark scenarios will form the basis for the effectiveness measures which we will use for the evaluation of the Stackelberg solution. The first benchmark is the *'Business As Usual' (BAU) scenario* which gives the non-cooperative Nash equilibrium, equivalent to the outcome of the Stackelberg game at coalition size $m = 0$. In this situation, every country i chooses non-cooperatively a policy scheme (e_i, t_i) that maximises its individual welfare, taking as given the other countries' policy choices. The optimal BAU emission caps e_{BAU} and tariff rates t_{BAU} can be derived from the first-order conditions of the welfare maximisation

[14]Please find the proof for equation (17) attached in the appendix.

problem for country i, yielding:

$$e_{BAU} = \frac{a(2\alpha^* + (n-1)\alpha_H)}{(n-1)\,(b+\delta n)\,\alpha_H + 2\alpha^*(b+\delta n + 2\alpha_H)} \tag{18}$$

$$t_{BAU} = \frac{2a\alpha^*\alpha_H}{(n-1)\,(b+\delta n)\,\alpha_H + 2\alpha^*(b+\delta n + 2\alpha_H)} \tag{19}$$

As can be seen in equation (19), even with policies being chosen independently, there are incentives to pursue protectionist trade policies by imposing a positive tariff rate $t_{BAU} > 0$.

As a second benchmark, the fully cooperative outcome will be calculated assuming that there is a supranational body having the power to enforce cooperation. We refer to this situation as the *'Social Planner' (SP) scenario* which is equivalent to the computation of the Stackelberg game with the exogenous coalition size $m = 10$. With the purpose of maximizing global welfare, defined as the sum over the welfare of all countries, the social planner chooses the entire environmental and trade policies $(e_1, \ldots, e_n, t_1, \ldots, t_n)$. The resulting policy schemes e_{SP} and t_{SP} are:

$$e_{SP} = \frac{a(\alpha^* + (n-1)\alpha_H)}{(n-1)(b+\delta n^2)\alpha_H + \alpha^*(b+\delta n^2 + 2\alpha_H)} \tag{20}$$

$$t_{SP} = 0 \tag{21}$$

As a matter of course, the social planner prefers the environmental policy instrument to internalise the climate externality combined with worldwide free trade.[15]

4 The Stackelberg Game

4.1 Structure

The set-up of the Stackelberg game consists of three stages. In the first and second stage, countries are involved in a strategic policy game. While, in the first stage, coalition countries as Stackelberg leaders can enjoy the first-mover advantage, fringe countries are followers in the second stage. Coalition countries are maximizing joint welfare by coordinating environmental and trade policies but do not necessarily have to harmonise policies. In the second stage, fringe countries are maximizing their own welfare by taking the policies of the coalition as well as those of fringe countries

[15]Please note that we obtain symmetric policy results in both, the BAU and the SP scenario due to the homogeneous production structure prevailing in all countries.

into account. In this respect, fringe countries are viewed as non-cooperative Nash players. In the third stage, agents behave perfectly competitive, taking the governmental policies as given when they maximise their rents from the production and consumption of commodities.

The solution of the Stackelberg game proceeds by backward induction. Fringe countries are facing the optimisation problem:

$$\max_{e_i,t_i} W_{i\notin C}(e_i, t_i; \varepsilon_C, \tau_C, \varepsilon_{F-i}, \tau_{F-i}) \ , \qquad i \notin C, \tag{22}$$

where $\varepsilon_C = (e_1, \ldots, e_m) \geq 0$ and $\tau_C = (t_1, \ldots, t_m) \in \mathbb{R}^n$ indicate the coalition's policy vectors whereas $\varepsilon_{F-i} = (e_{m+1}, \ldots, e_{i-1}, e_{i+1}, \ldots, e_n) \geq 0$ and $\tau_{F-i} = (t_{m+1}, \ldots, t_{i-1}, t_{i+1}, \ldots, t_n) \in \mathbb{R}^n$ denote the environmental and trade policies of the other fringe countries. Solving the first-order conditions of the optimisation problems, the optimal fringe policies $\varepsilon_F(\varepsilon_C, \tau_C)$ and $\tau_F(\varepsilon_C, \tau_C)$ can be derived where $\varepsilon_F = (e_{m+1}, \ldots, e_n) \geq 0$ and $\tau_F = (t_{m+1}, \ldots, t_n) \in \mathbb{R}^n$.

Concerning the optimisation problem of the coalition, member countries maximise the joint welfare of a coalition C:

$$\max_{\varepsilon_C,\tau_C} W_C(\varepsilon_C, \tau_C; \varepsilon_F(\varepsilon_C, \tau_C), \tau_F(\varepsilon_C, \tau_C)) \tag{23}$$

where $W_C = \sum_{i=1}^{m} W_{i\in C}$. Obviously, member countries can take advantage of anticipating how fringe countries will react to their strategies.

The solution of these optimisation problems brings about symmetric policy choices for the group of coalition countries (e_C, t_C) on the one hand, and for that of the fringe countries (e_F, t_F) on the other hand. However, this is just a consequence of the symmetric endowments and production technologies rather than a result of the negotiation game. Although a consideration of heterogeneous countries would, of course, lead to different policy regimes, the qualitative results regarding the benefits of free trade would not be affected.

4.2 Stability and Effectiveness of IEAs

So far, we have dealt with an arbitrary, exogenously given number of coalition countries within the Stackelberg leader-follower framework. In doing so, considerations on the endogenous formation of a coalition and its stability have been omitted from the analysis. Hence, we need to examine which one of the potential coalition sizes $m \in [0, n]$ assures for a stable cooperation among member countries, or, put differently, which one constitutes a self-enforcing IEA.

In the non-cooperative IEA literature, the notion of stability has established as a canonical requirement for environmental treaties to ensure the long lasting existence of climate coalitions of a particular size.[16] In our framework, a coalition of a certain size is found to be self-enforcing if it satisfies the conditions of internal and external stability. A coalition C of size m is defined to be internally stable if no coalition country i, $i \in C$, has an incentive to leave the coalition, and it is considered to be externally stable if no fringe country i, $i \notin C$, has an incentive to join the coalition. Accordingly, the following weak inequalities must hold:[17]

$$W_{i \in C}(m) \geq W_{i \notin C}(m-1) \tag{24}$$

$$W_{i \notin C}(m) \geq W_{i \in C}(m+1) \tag{25}$$

In the subsequent analysis, we will also refer to some effectiveness indicators[18] proposed in the literature (e.g. by Eyckmans/Finus, 2007 and Eichner/Pethig, 2013b) which measure the success of an IEA in terms of the emission and, respectively, welfare gap[19] a climate coalition has been able to close. Therefore, the ratio RE (RW) measures the relative effectiveness of emissions reduction (welfare gains) achieved as it is defined as the difference in global emissions (global welfare) between the BAU scenario and the Stackelberg equilibrium relative to the emission gap (welfare gap) indicated in the denominator:[20]

$$RE = \frac{ne_{BAU} - (me_C + (n-m)\, e_F)}{ne_{BAU} - ne_{SP}} \cdot 100 \tag{26}$$

[16]The stability concept was originally elaborated by D'Aspremont et al. (1983) for the analysis of cartel formation in an oligopoly and later adapted to the IEA context (see Carraro/Siniscalco, 1993, Barrett, 1994, and many others). It should be noted that other stability and equilibrium concepts have been developed further by both, the cooperative and non-cooperative literature on coalition formation, implying different rules of the game. A comprehensive overview is provided by Bloch (1997), Carraro/Marchiori (2003b), Finus (2003), Bréchet/Gerard/Tulkens (2011), among others.

[17]It should be noted that the stability conditions are formulated for the case of symmetric countries. If heterogeneous countries were considered, the condition would require a reformulation to allow for asymmetries across countries (see, for instance, Carraro, 1999).

[18]These measures are also known as the 'closing the gap' indices. (Eyckmans/Finus, 2007) A similar indicator is the *degree of externality* introduced by Finus (2003) relating the actual and the BAU (emissions and welfare) outcomes to the social optimum.

[19]The emission gap (welfare gap) is defined as the difference in global emissions (global welfare) between the BAU scenario and the SP scenario. Thereby, it represents the coalition's scope of potential emission reductions (potential maximum welfare gains).

[20]Again, please note that the effectiveness measures RE and RW are only defined for the symmetric case. An analysis involving heterogeneous countries would require a reformulation.

$$RW = \frac{(mw_C + (n-m)\, w_F) - nw_{BAU}}{nw_{SP} - nw_{BAU}} \cdot 100 \tag{27}$$

The details of the parametrisation and a deeper discussion are presented in the following section.

5 Simulation Results and the Gains of the Free Trade Area

In this section we present the solution of the model. That requires to endogenise the coalition size m which has been kept exogenous so far in the analytical market solution. With respect to the solution of the policy stages of the Stackelberg game, we have to refer to numerical simulations. These are exemplified by a run with the parameter values: $a = 100$, $b = 20$, $\overline{x} = 20$, $\alpha_H = 2000$, $\alpha^* = 2200$, $\delta = 10$ and $n = 10$.[21] We consider a variation in coalition sizes in the range of $m \in [1, 10]$. The results obtained are then valued against the benchmarks introduced in section 3.

Based on the stability considerations in section 4, all coalitions of integer size $m \in [0, n]$ that satisfy the equations $W_{i\in C}(m) - W_{i\notin C}(m-1) \geq 0$ and $W_{i\notin C}(m) - W_{i\in C}(m+1) \geq 0$ simultaneously, are found to be both internally and externally stable. **Figure 1** depicts the stability outcomes of the simulation.

Figure 1: Coalition stability of the Stackelberg equilibrium with PFTA

As **Figure 1** suggests, only a coalition of endogenous size $m^* = 7$ turns out to be internally as well as externally stable. Given the fact that it is the only coalition size that can be sustained in the long run, the results for this particular coalition shall receive our special attention.

[21] The parameter choice is made in accordance with Eichner/Pethig (2013b).

In order to emphasise the effect of the preferential free trade arrangement on the coalition-building process, we will compare the results achieved with a situation where the PFTA is ruled out. In the absence of any tariff privileges, a traditional IEA is constituted which we may call the $\neg PFTA$ scenario. In that case, the stable coalition size is found at $m^* = 3$ confirming the standard results of the IEA literature.[22] A comparison of the results of the respective scenarios allows an assessment of the extent to which the PFTA as an incentive device affects the outcomes of the simulation.

Emission Outcomes. First of all, let's have a look at the emission outcomes viewed against the benchmark scenarios BAU (green line) and SP (red line) as well as against the $\neg PFTA$ scenario (right subfigure). As **Figure 2** suggests, the total reduction of emissions achieved by the climate coalition increases in the coalition size, whether there is free trade or not. However, it should be emphasised that, for the stable coalition size, the climate coalition is much more effective when it is linked to a free trade arrangement than otherwise. The respective values of the relative emissions effectiveness RE are 56.72 and 10.17 per cent.

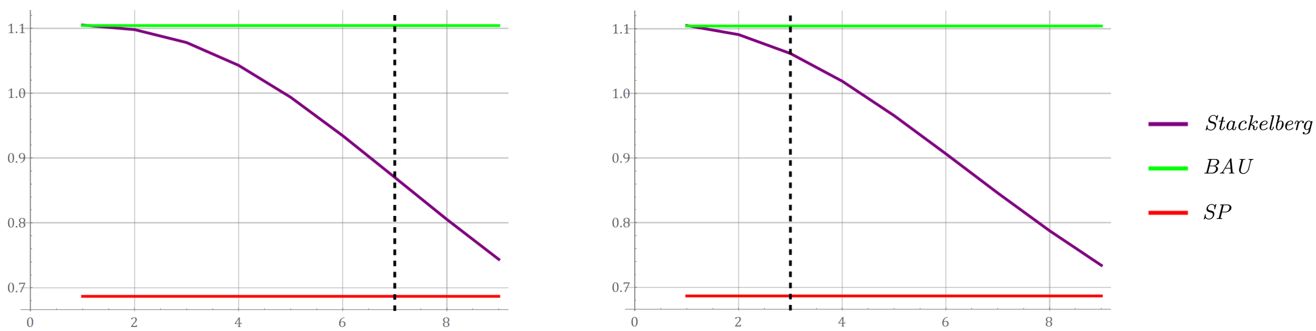

Figure 2.a: Stackelberg Game with PFTA ($m^* = 7$)

Figure 2.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 2: Global Emissions in the Stackelberg Equilibrium

Moving on to the country level, we shall obtain a more detailed picture for the fringe and coalition countries. **Figure 3** shows the national emission caps set by each country given the coalition size. Again, what can be generally observed is that the climate coalition linked to a free trade agreement is much more effective in terms of emission reduction than the one without free trade. We find member countries to set fairly tight caps close to the SP benchmark for reducing their emissions substantially. At the same time, this policy brings about a shift in the consumption pattern on the market level, away from the dirty good towards the clean good. In contrast, fringe countries increase their emissions even above the BAU level such that consumption turns out to

[22]Please find the stability function for the baseline scenario depicted by **Figure 9** in the appendix.

be much dirtier.

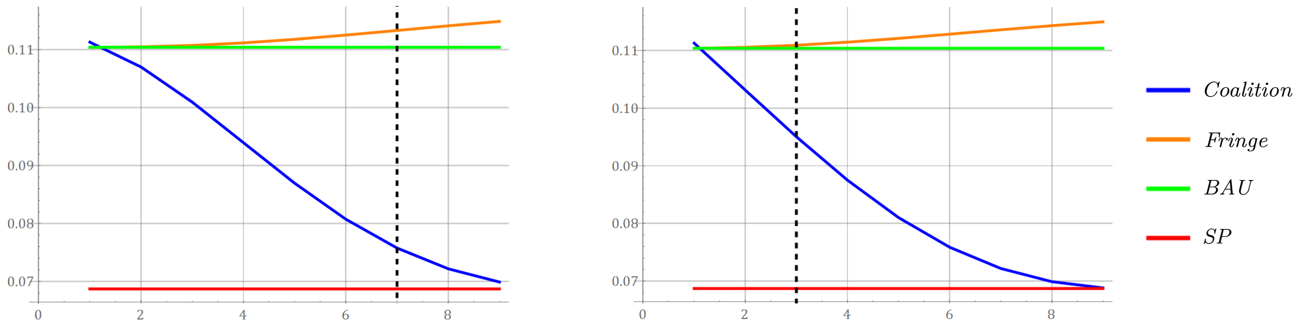

Figure 3.a: Stackelberg Game with PFTA ($m^* = 7$) Figure 3.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 3: National Emission Caps in the Stackelberg Equilibrium

Welfare Outcomes. The previous findings raise the issue of the induced change in welfare from a national as well as a global perspective. As **Figure 4** suggests, the linked agreement can lead to a considerable increase in global welfare at the stable coalition size compared to the $\neg PFTA$ scenario. Here, the relative welfare effectiveness RW of 70.11 per cent is much higher than what a single IEA can achieve, that is just 17.91 per cent.

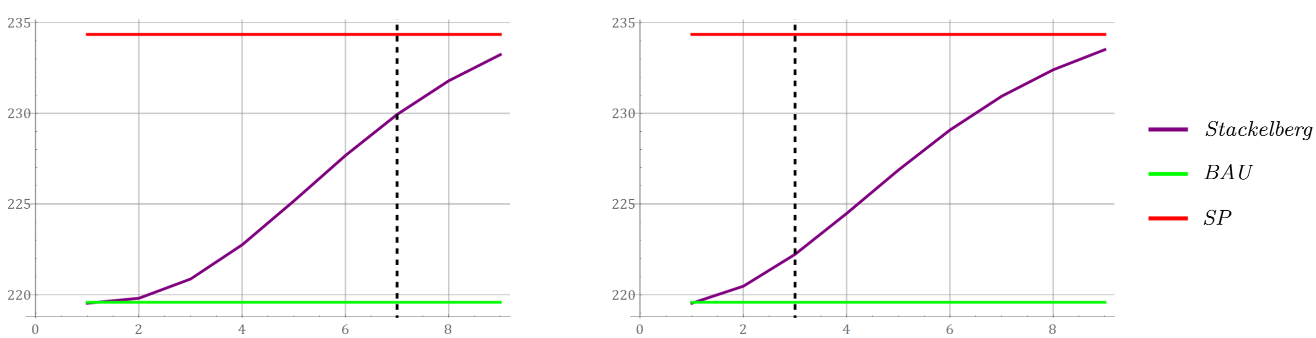

Figure 4.a: Stackelberg Game with PFTA ($m^* = 7$) Figure 4.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 4: Global Welfare in the Stackelberg Equilibrium

These outcomes are mainly driven by the reduction of climate damages which, compared to the BAU level, fall by about 38 per cent at the stable coalition size and naturally is to the advantage of all countries. But still, the results for the welfare of the coalition countries differ from those of fringe countries as depicted in **Figure 5**. They must be explained by other components of the welfare function.[23]

[23] It is worth mentioning that the mitigation of climate damages nevertheless is an important welfare component. This conclusion is supported by the fact that individual welfare levels in **Figure 5** are nearly always above the

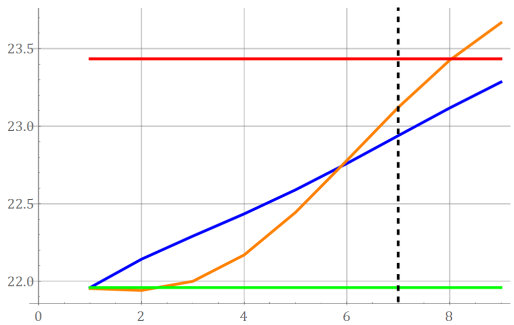

Figure 5.a: Stackelberg Game with PFTA ($m^* = 7$)

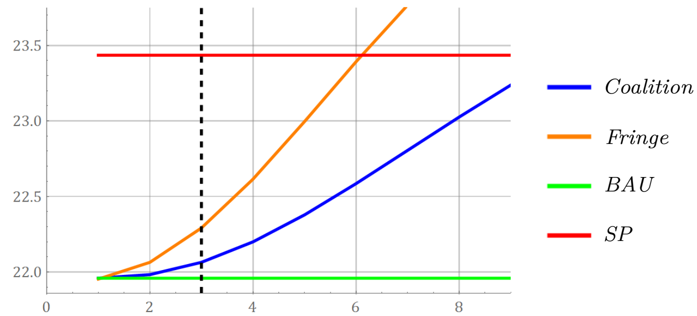

Figure 5.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 5: National Welfare in the Stackelberg Equilibrium

Figure 5 reveals that, for $m \leq 5$, fringe countries would gain when they join in and coalition countries lose when leaving. This finding for the linked agreement stands in sharp contrast to the outcomes of the $\neg PFTA$ scenario in which the individual welfare functions of coalition and fringe countries diverge from the smallest coalition size $m = 1$ onwards, with the latter exceeding the former. This result can be attributed to the distribution of consumption utility between both groups of countries and illustrates how the free trade area can work as an incentive device for the formation of climate coalitions.[24]

Trade Policies. After having addressed the environmental policies, we would like to extend the discussion to the trade policies as part of the policy mix chosen by the two groups of countries. These are of particular interest given the fact that they constitute the magnitude of the trade privileges provided within the coalition. As can be seen in **Figure 6**, both fringe and coalition countries implement an import tariff rate, that is $t_C, t_F > 0$, based on the given parametrisation. The most interesting result is that the tariff rates imposed by the coalition are low and decreasing in coalition size which implies that the coalition pursues a less protectionist trade policy. Fringe countries, in return, do not seem to be able to take advantage of their free-riding position and to raise their tariffs rates much above the BAU level. A comparison to the $\neg PFTA$ scenario shows

BAU level although both coalition and fringe countries suffer a loss in consumption utility compared to the strategy of unilateral free-riding, as can be seen by **Figure 13** in the appendix.

[24]The market outcomes shown in **Figures 10 to 13** in the appendix illustrate that, in the linked Stackelberg game, the trade privileges of the PFTA provide a higher consumption utility for coalition countries than in fringe countries for coalition sizes of $m \leq 5$ although consumption of the dirty good is more restricted. This is due to the expanded consumption possibilities with respect to the clean good which do not prevail in the fringe countries. However, the increase in consumption of the clean good is diminishing in the coalition size. Consequently, fringe countries outpace the coalitional consumption utility at some point due to the higher consumption levels of the dirty good which are also reflected in the utility function. For the case of a traditional IEA, consumption utility is always higher in fringe countries since coalition countries consume less of the clean good as they cannot take advantage of environmental dumping.

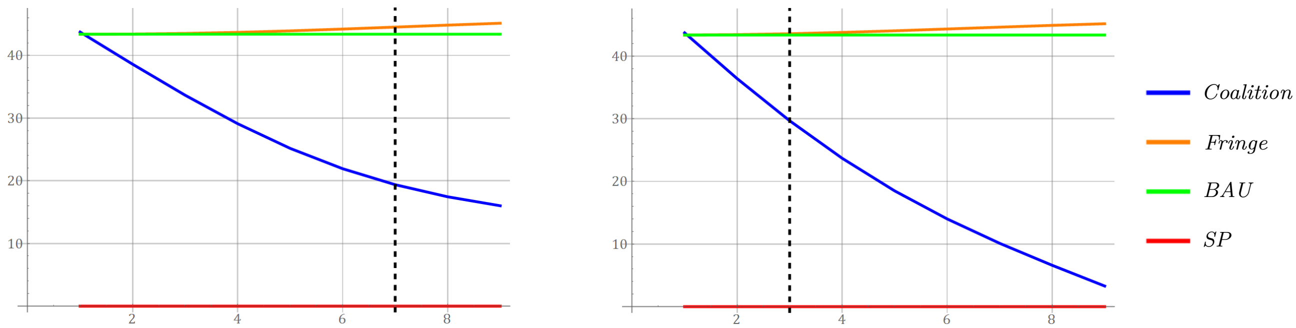

Figure 6.a: Stackelberg Game with PFTA ($m^* = 7$)   Figure 6.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 6: Tariff Rates in the Stackelberg Equilibrium

that, for the stable coalition size, the absence of preferential free trade would bring about much higher tariff rates and thus a much more distorted allocation. Again, the linked agreement is much closer to the Social Planner solution than the one with the link missing. Moreover, since trade policies determine the gap between the price coalition and fringe producers receive, we may discuss their impact on firms' production decisions and, thereby, on the sectoral structure of countries.

Trade Patterns. In consideration of the fact that environmental policies take effect on the demand side, the supply structure shows a rather reversed picture. As production of the dirty good is not restricted by the cap, coalition countries can specialise in the production of the dirty good and fringe countries in the production of the clean good, albeit full specialisation is precluded by convex economies.

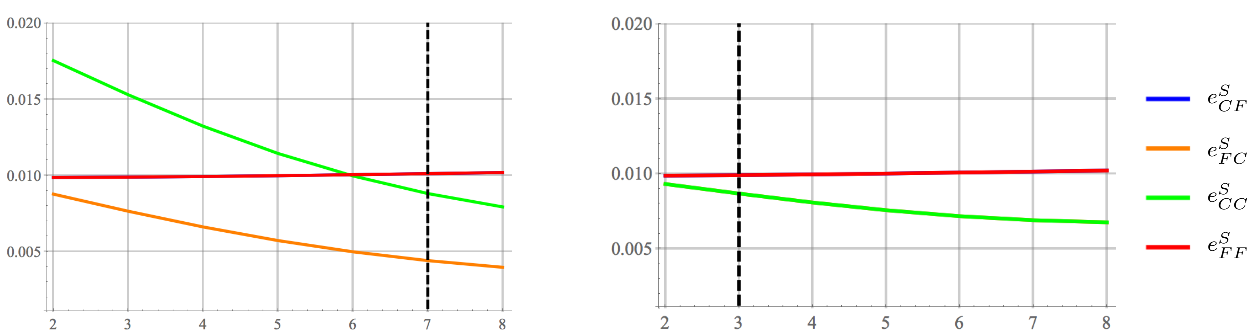

Figure 7.a: Stackelberg Game with PFTA ($m^* = 7$)   Figure 7.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 7: Individual Supplies of the Dirty Good in the Stackelberg Equilibrium

As far as the dirty good is concerned, **Figure 7** suggests that the volume of trades among coalition countries, e^S_{CC}, increases while part of the imports from fringe countries, e^S_{FC}, is banned, compared to the $\neg PFTA$ scenario.[25] The overall trade pattern, however, is such that the coalition has to net import the clean good from the fringe countries to meet its excess demand while the pattern for the fringe countries turns out to be reversed.[26]

Terms of trade. As a matter of course, the trade equilibrium described above is largely driven by the terms of trade prevailing for the coalition and fringe countries in the scenarios considered. In view of the fact that there is no single world market for the dirty good but rather n local markets, the terms on which a coalition country $i \in C$ can export the dirty good is given by the price it receives on a fringe market relative to the coalitional price, i.e. $TOT_C = \frac{p_F}{p_C}$. Likewise, the terms of trade of a fringe country $i \notin C$ must then be the reciprocal value of this price ratio, $TOT_F = \frac{p_C}{p_F}$.[27] The findings for the numerical simulation are shown in **Figure 8**.

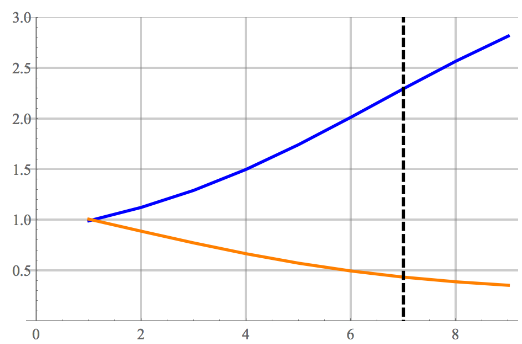

Figure 8.a: Stackelberg Game with PFTA ($m^* = 7$)

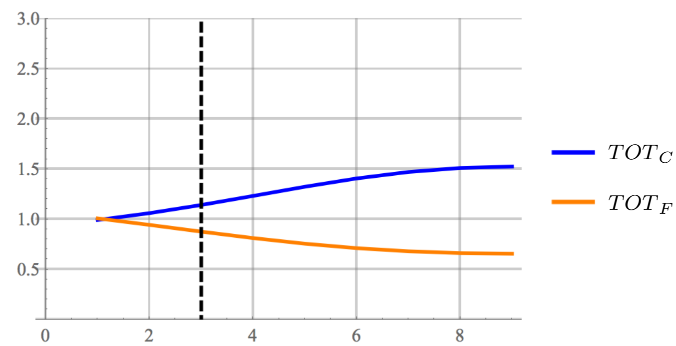

Figure 8.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 8: Terms of Trade in the Stackelberg Equilibrium

According to **Figure 8**, starting from an equal level, the terms of trade are improving for the coalition and deteriorating for the fringe countries, the more the larger is the coalition size m. Of course, this is a consequence of the increased strategic advantage of the climate coalition. In the $\neg PFTA$ scenario, the difference in the terms of trade between the groups turns out to be much smaller due to the absence of preferential trade privileges within the coalition. From this, we can conclude that PFTA succeeds in altering the terms of trade favourably which is enabled

[25] Please note that the graphs indicating the trade volumes exported to a fringe country, e^S_{CF} and e^S_{FF}, are exactly overlapping in **Figure 7**. Moreover, in the $\neg PFTA$ scenario, the curves of the supplies designated to a coalition market, e^S_{FC} and e^S_{CC}, superpose as well.

[26] Please find this outcome depicted by **Figure 14** and **Figure 15** in the appendix.

[27] Again, this definition of the terms of trade refers to symmetric countries and is expressed in terms of the clean good because all local prices of the dirty good are in fact relative prices divided by $p_x = 1$.

by a diversion of trade flows of the dirty good within the coalition. Therefore, free trade provides a competitive advantage to coalition firms over fringe firms as far as trade volumes of the dirty good are concerned.

Economic Intuition. In order to explain how the policy outcomes materialise and how policies will govern prices and the trade pattern, we would like to give an economic intuition for the simulation results. Although both, coalition and fringe countries have two policy tools available, they use these instruments very differently to maximise welfare: On the one hand, coalition countries opt for pretty strict emission caps to internalise the climate externality and keep distortionary tariffs moderate. This finding is clearly a result of the fact that, as the coalition grows in size, the environment gets more and more valued. At the same time, terms of trade improve, remarkably not at the expense of environmental quality. On the other hand, fringe countries opt for pretty lax caps but high tariff rates because, in their view, emission damages are almost external and free-riding thus is welfare-enhancing. Overall, we find policies being chosen as one would expect from an environmental point of view.

What we would like to emphasise, above all, is that the outcomes are perfectly in line with what we had in mind with the implementation of a free trade area. It can be shown that the PFTA has a major impact on the market for the clean good which, in turn, alters consumption utilities and the welfare of countries. The tariff privileges provided to member states shifts consumption away from the dirty to the clean good to the advantage of producers and consumers within the coalition.[28] In contrast, fringe countries must increase production of the clean good since exports of the dirty good to the coalition are not as profitable as under unilateral tariff policies. Moreover, they have to curb consumption even below the BAU level. The change in the consumption possibilities of the clean good changes consumption utility for coalition countries favourably and it deteriorates that of the fringe which makes it more beneficial to join the climate coalition when it is linked to a free trade agreement. Finally, this leads to a fairly large coalition which is successful in preserving the environment while the number of countries still opting for a free ride is pretty low.

[28] Of course, this is due to the fact that environmental policies are imposed on consumers, resulting in the specialisation in the production of the dirty good. If, instead, the emissions trading scheme was implemented among producers, we would expect market results to be reversed. More precisely, production of the dirty good will be restricted in the coalition which makes it necessary to net import the dirty good from the fringe countries to meet the excess demand. Then the coalition has the position as an exporter on the world market for the clean good.

6 Sensitivity Analysis

In the following, we are conducting a sensitivity analysis to quantify the advantage of a free trade area in terms of effectiveness and stability for different parameter constellations.[29] The results of a variation in the production coefficients are shown below in **Table 2**, for both the agreements considered.

α_H	500	1000	1250	1500	1750	2000	2250	2500
α^*	550	1100	1375	1650	1925	2200	2475	2750
emission gap	2.274	1.142	0.863	0.667	0.525	0.417	0.334	0.268
welfare gap	296.3	83.98	50.96	32.55	21.60	14.76	10.34	7.395
m^*	3	3	4	5	6	7	10	10
RE	13.71%	10.94%	20.75%	31.76%	43.56%	56.72%	100.00%	100.00%
RW	24.24%	19.13%	33.56%	47.22%	59.40%	70.11%	100.00%	100.00%

Table 2: Variations of α_H and α^* in the Linked Agreement

Table 2 provides an insight into the interrelation between the stability and effectiveness outcomes and the parametrisation: First, for the scenario with the preferential free trade agreement, the stable coalition size m^* grows as the opportunity cost of the dirty good, α_H and α^*, increase. This is an expected outcome because, as the dirty good becomes more expensive in terms of the clean good, the incentives of the countries to take a free ride decrease. Furthermore, the advantage of the SP scenario over the BAU is diminishing since the dirty good is already consumed less in the BAU scenario due to its cost-intensive production. This finding is supported by the fact that the emission and welfare gaps are decreasing in α_H and α^*. At the same time, the relative effectiveness of the climate coalition is increasing as measured by RW and RE (except for the case of $\alpha_H = 1000$ and $\alpha^* = 1100$). It can also be shown that, by linking the climate treaty with a free trade agreement, the grand coalition can be stabilised with the technology parameters of $\alpha_H = 2250$ and $\alpha^* = 2475$ which brings about the SP solution in a self-enforcing way.

For the purpose of comparison, the production coefficients α_H and α^* have also been altered for the $\neg PFTA$ scenario, as **Table 3** illustrates.[30]

[29] The sensitivity analysis for the other parameters suggests that stability as well as the relative effectiveness measures RE and RW are consistently decreasing in b, δ, and n which confirms the findings by Eichner/Pethig (2015b). Therefore, we have decided to concentrate on the most striking findings, resulting from a variation in the production coefficients α_H and α^*.

[30] Since the two scenarios refer to the same benchmarks, emission and welfare gaps are found to be identical and,

α_H	500	1000	1250	1500	1750	2000	2250	2500
α^*	550	1100	1375	1650	1925	2200	2475	2750
$m^*_{\neg PFTA}$	3	3	3	3	3	3	3	3
$RE_{\neg PFTA}$	14.56%	12.70%	11.87%	11.18%	10.62%	10.17%	9.802%	9.513%
$RW_{\neg PFTA}$	25.67%	22.49%	21.04%	19.81%	18.79%	17.91%	17.16%	16.49%

Table 3: Variations of α_H and α^* in the Traditional IEA ($\neg PFTA$ Scenario)

Most interestingly, the findings of the parametric variation turn out to be much less favourable if the Stackelberg game is conducted without a preferential free trade area. For the values considered, the stable coalition always includes three members and does not grow with an increase in opportunity costs which contrasts with the outcome above. In addition, the relative effectiveness in emissions as well as in welfare is somewhat decreasing in α_H and α^* which clearly implies that the incentives to abate emissions diminish if the dirty good becomes more expensive in terms of the clean good.[31]

In summary, the results suggest that, except for parameter values less than or equal to $\alpha_H = 1000$ and $\alpha^* = 1100$, the preferential free trade area always performs better than unilateral trade policies among coalition countries, for the parameters considered.

7 Concluding Remarks

The objective of this paper has been to address the role of trade liberalisation for the endogenous formation of climate coalitions. We find strong support for linking climate negotiations to negotiations on a PFTA while strategic trade and environmental policies vis-à-vis non-signatories are carried out individually. More precisely, in doing so, we tried to examine how the size, effectiveness, and stability of the climate coalition could be driven by the benefits of trade liberalisation.

The main focus of the analysis is on the exploitation of trade privileges given to members of the climate coalition such that the PFTA serves as an incentive mechanism to join the coalition. The parametrical simulation shows evidence that the welfare gains provided by free trade improve

therefore, left out in **Table 3**. This implies that the denominators of the RE and RW measures are the same in case of the $\neg PFTA$ agreement.

[31] More precisely, this outcome can be reduced to the fact that emission reductions (welfare gains) achieved by the traditional IEA fall by a larger amount than the emission gap (welfare gap) in the denominator.

not only the effectiveness of the climate coalition in terms of emission reduction but also its stability by discouraging free-riding. Our approach entails a stable coalition size of $m^* = 7$ in the numerical simulation. This result is explained by a favourable shift of the terms of trade that enables the coalition to consume more of the clean good while consumption of the dirty good is diminished. At the same time, the shift in the consumption pattern facilitates emission reduction within the coalition which, compared to the BAU scenario, leads to a significant mitigation of global emissions and climate change damages. As a consequence, global welfare is found growing.

Moreover, the findings of the sensitivity analysis suggest that the gains from the free trade agreement are in line with the size of the opportunity costs of the dirty good. For most of the parameter values considered, the linked agreement outperforms the single-issue IEA in terms of emissions and welfare effectiveness. Only in the special case of the dirty good being very cheap relative to the clean good, outcomes turn out to be in disfavour of the free trade agreement. But interestingly, if the climate agreement is not linked to a free trade area, the effectiveness of the coalition will be decreasing in the size of the opportunity costs of the dirty good. All in all, in our framework, issue linkage with trade liberalisation is found to have the potential to promote and sustain broader international cooperation on climate change.

Regarding the policy implications of our analysis, it might be argued that issues related to trade and climate change should, at any rate, be dealt with together in international negotiations, irrespective of how such a linkage is implemented. Issue linkage following a top-down approach could involve joint multilateral negotiations of both the UNFCCC and WTO regimes. However, given the slow progress of multilateral trade negotiations within the WTO context, a bottom-up approach could be even more effective for the short-term implementation of mitigation measures (Kernohan/De Cian, 2007). The legal compatibility of climate clubs with the WTO regime has been examined by Leycegui Gardoqui/Ramírez (2015) who find several ways for how a legal space could be built for this approach within the WTO. In this respect, our findings make a good case for the formulation of an explicit amendment to the WTO regulatory framework to cover the problems arising from climate change such that the tariff regime proposed would be legalised in accordance with the WTO principles, the MFN (Most-Favoured Nation) principle in particular.

References

Abrego, L., Perroni, C., Whalley, J. and Wigle, R.M. (2001): *Trade and Environment: Bargaining Outcomes from Linked Negotiations*, in: Review of International Economics, Vol. 9(3), pp. 414-428.

Bajona, C. and Ederington, J. (2012): *Domestic Policies, Hidden Protection and the GATT/WTO*, Working Paper, Last revised: September 3, 2012, Available at: ssrn.com/abstract=2140943.

Barrett, S. (1994): *Self-Enforcing International Environmental Agreements*, in: Oxford Economic Papers, Vol. 46 (Supplement 1), pp. 878-894.

Barrett, S. (1997a): *Heterogeneous international environmental agreements*, in: Carraro, C. (ed.), International Environmental Negotiations: Strategic Policy Issues, Edward Elgar, Cheltenham/Brookfield, pp. 9-25.

Barrett, S. (1997b): *The strategy of trade sanctions in international environmental agreements*, in: Resource and Energy Economics, Vol. 19(4), pp. 345-361.

Barrett, S. (2001): *International cooperation for sale*, in: European Economic Review, Vol. 45(10), pp. 1835-1850.

Bloch, F. (1997): *Non-cooperative models o coalition formation in games with spillovers*, in: C. Carraro; D. Siniscalco (eds.), New directions in the economic theory of the environment, Cambridge University Press, Cambridge, pp. 311-352.

Bosello, F., Buchner, B. and Carraro, C. (2003): *Equity, development, and climate change control*, in: Journal of the European Economics Association, Vol. 1(2-3), pp. 601-611.

Botteon, M. and Carraro, C. (1997): *Burden sharing and coalition stability in environmental negotiations with asymmetric countries*, in: Carraro, C. (ed.), International Environmental Negotiations: Strategic Policy Issues, Edward Elgar, Cheltenham/Brookfield, pp. 26-55.

Botteon, M. and Carraro, C. (1998): *Strategies for environmental negotiations: issue linkage with heterogeneous countries*, in: Hanley, N. and Folmer, H. (eds.), Game Theory and the Global Environment, Edward Elgar, Cheltenham/Northhampton, pp. 181-203.

Botteon, M. and Carraro, C. (2001): *Environmental Coalitions with Heterogeneous Countries: Burden-Sharing and Carbon Leakage*, in: Ulph, A. (ed.), Environmental Policy, International Agreements, and International Trade, Oxford University Press, Oxford/New York, pp. 38-65.

Bréchet, T., Gerard, F. and Tulkens, H. (2011): *Efficiency vs. Stability in Climate Coalitions: A Conceptual and Computational Appraisal*, in: The Energy Journal, Vol. 32(1), pp. 49-75.

Bucher, R. and Schenker, O. (2010): *On Interactions of Optimal Climate Policy and International Trade: An Assessment of Border Carbon Measures*, NCCR Research Paper No. 2010/04.

Buchner, B., Carraro, C., Cerosimo, I. and Marchiori, C. (2002): *Back to Kyoto? US Participation and the Linkage between R&D and Climate Cooperation*, Fondazione Eni Enrico Mattei, Nota di Lavoro No. 22.2002.

Carraro, C. (1999): *The structure of international environmental agreements*, in: C. Carraro (ed.), International Environmental Agreements on Climate Change, Kluwer, Dordrecht/Boston/London, pp. 9-25.

Carraro, C. and Siniscalco, D. (1993): *Strategies for the international protection of the environment*, in: Journal of Public Economics, Vol. 52(3), pp. 309-328.

Carraro, C. and Siniscalco, D. (1995): *Policy coordination for sustainability: commitments, transfers, and linked negotiations*, in: Goldin, I. and Winters, L.A. (eds.), The economics of sustainable development, Cambridge University Press, Cambridge, pp. 264-288.

Carraro, C. and Siniscalco, D. (1997): *R&D cooperation and the stability of international environmental agreements*, in: C. Carraro (ed.), International Environmental Negotiations: Strategic Policy Issues, Edward Elgar, Cheltenham/Brookfield, pp. 71-96.

Carraro, C. and Siniscalco, D. (1998): *International environmental agreements: Incentives and political economy*, in: European Economics Review, Vol. 42(3-5), pp. 561-572.

Carraro, C. and Siniscalco, D. (2001): *Transfers, Commitments, and Issue Linkage in International Environmental Negotiations*, in: Ulph, A. (ed.), Environmental Policy, International Agreements, and International Trade, Oxford University Press, Oxford/New York, pp. 19-37.

Carraro, C., Eyckmans, J. and Finus, M. (2006): *Optimal transfers and participation decisions in international environmental agreements*, in: The Review of International Organization, Vol. 1(4), pp. 379-396.

Carraro, C. and Marchiori, C. (2003a): *Endogenous Strategic Issue Linkage in International Negotiations*, Fondazione Eni Enrico Mattei, Nota di Lavoro No. 40.2003.

Carraro, C. and Marchiori, C. (2003b): *Stable coalitions*, in: C. Carraro (ed.), The Endogenous Formation of Economic Coalitions, Edward Elgar, Cheltenham/Northampton, pp. 156-198.

Conconi, P. and Perroni, C. (2002): *Issue linkage and issue tie-in in multilateral negotiations*, in: Journal of International Economics, Vol. 57(2), pp. 423-447.

D'Aspremont, C., Jacquemin, A., Gabszewicz, J.J. and Weymark, J.A. (1983): *On the Stability of Collusive Price Leadership*, in: The Canadian Journal of Economics, Vol. 16(1), pp. 17-25.

Ederington, J. (2002): *Trade and Domestic Policy Linkage in International Agreements*, in: International Economic Review, Vol. 43(4), pp. 1347-1367.

Ederington, J. (2010): *Should Trade Agreements Include Environmental Policy?*, in: Review of Environmental Economics and Policy, Vol. 4(1), pp. 84-102.

Eichner, T. and Pethig, R. (2012): *Stable Climate Coalitions (Nash) and International Trade*, Center for Economic Studies & Ifo Institute, CESifo Working Paper No. 3915.

Eichner, T. and Pethig, R. (2013a): *Self-enforcing environmental agreements and international trade*, in: Journal of Public Economics, Vol. 102, pp. 37-50.

Eichner, T. and Pethig, R. (2013b): *Trade Tariffs and Self-enforcing Environmental Agreements*, Center for Economic Studies & Ifo Institute, CESifo Working Paper No. 4464.

Eichner, T. and Pethig, R. (2015a): *Is trade liberalization conducive to the formation of climate coalitions?*, in: International Tax and Public Finance, Vol. 22(6), pp. 932-955.

Eichner, T. and Pethig, R. (2015b): *Self-enforcing international environmental agreements and trade: taxes versus caps*, in: Oxford Economic Papers, Vol. 67(4), pp. 897-917.

Eyckmans, J. and Finus, M. (2006): *Coalition Formation in a Global Warming Game: How the Design of Protocols Affects the Success of Environmental Treaty-Making*, in: Natural Resource Modeling, Vol. 19(3), pp. 323-358.

Eyckmans, J. and Finus, M. (2007): *Measures to enhance the success of global climate treaties*, in: International Environmental Agreements, Vol. 7(1), pp. 73-97.

Finus, M. (2003): *Stability and design of international environmental agreements: the case of transboundary pollution*, in: H. Folmer; T. Tietenberg (eds.), The International Yearbook of Environmental and Resource Economics 2003/2004, Edward Elgar, Cheltenham, pp. 82-158.

Finus, M. and Rundshagen, B. (2000): *Strategic Links between Environmental and Trade Policies if Plant Location is Endogenous*, University of Hagen, Working Paper No. 283.

Fischer, C. and Fox, A.K. (2012): *Comparing policies to combat emissions leakage: Border carbon adjustments versus rebates*, Journal of Environmental Economics and Management Vol. 64(2), 199-216.

Hoel, M. (1992): *International Environment Conventions: The Case of Uniform Reductions of Emissions*, in: Environmental and Resource Economics, Vol. 2(2), pp. 141-159.

Hovi, J., Sprinz, D.F., Sælen, H. and Underdal, A. (2015): *The Club Approach: A Gateway to Effective Climate Cooperation?*, Mimeo, Paper presented at The Second Environmental Protection and Sustainability Forum in Bath (UK), April, Last revised: March 23, 2015, Available at: www.bath.ac.uk/ipr/pdf/events/climate-change/Hovi.pdf.

Katsoulacos, Y. (1997): *R&D spillovers, cooperation, subsidies and international agreements*, in: C. Carraro (ed.), International Environmental Negotiations: Strategic Policy Issues, Edward Elgar, Cheltenham/Brookfield, pp. 97-109.

Kemfert, C. (2004): *Climate coalitions and international trade: assessment of cooperation incentives by issue linkage*, in: Energy Policy, Vol. 32(4), pp. 455-465.

Kernohan, D. and De Cian, E. (2007): *Trade, the environment and climate change: multilateral versus regional agreements*, in: Carraro, C. and Egenhofer, C. (eds.): Climate and Trade Policy, Edward Elgar, Cheltenham/Brookfield, 71-93.

Leal-Arcas, R. (2011): *Top-Down versus Bottom-Up Approaches for Climate Change Neogtiations: An Analysis*, in: The IUP Journal of Governance and Public Policy, Vol. 6(4), pp. 7-52.

Leal-Arcas, R. (2013): *Climate Change Mitigation from the Bottom Up: Using Preferential Trade Agreements to Promote Climate Change Mitigation*, in: Carbon and Climate Law Review, Vol. 7(1), pp. 34-42.

Leycegui Gardoqui, B. and Ramírez, I. (2015): *Addressing Climate Change: A WTO Exception to Incorporate Climate Clubs*, Think Piece, Last revised: May 2015, Available at: e15initiative.org/publications/wto-exception-to-incorporate-climate-clubs.

Limão, N. (2005): *Trade policy, cross-border externalities and lobbies: do linked agreements enforce more cooperative outcomes?*, in: Journal of International Economics, Vol. 67(1), pp. 175-199.

Limão, N. (2007): *Are Preferential Trade Agreements with Non-trade Objectives a Stumbling Block for Multilateral Liberalization?*, in: Review of Economic Studies, Vol. 74(3), pp. 821-855.

McGinty, M. (2007): *International environmental agreements among asymmetric nations*, in: Oxford Economic Papers, Vol. 59(1), pp. 45-62.

McGinty, M., Milan, G. and Gelves, A. (2012): *Coalition Stability in Public Goods Provision: Testing an Optimal Allocation Rule*, in: Environmental and Resource Economics, Vol. 52(3), pp. 327-345.

Nagashima, M., Dellink, R., van Ierland, E. and Weikard, H.-P. (2009): *Stability of international climate coalitions - A comparison of transfer schemes*, in: Ecological Economics, Vol. 68(5), pp. 1476-1487.

Nordhaus, N. (2015): *Climate Clubs: Overcoming Free-riding in International Climate Policy*, in: American Economic Review, Vol. 105(4), pp. 1339-1370.

Rose, A., Stevens, B., Edmonds, J. and Wise, M. (1998): *International Equity and Differentiation in Global Warming Policy: An Application to Tradable Emission Permits*, in: Environmental and Resource Economics, Vol. 12(1), pp. 25-51.

Stewart, R.B., Oppenheimer, M. and Rudyk, B. (2013): *Building Blocks for Global Climate Protection*, in: Stanford Environmental Law Journal, Vol. 32(2), pp. 341-392.

Weikard, H.-P. (2009): *Cartel Stability under an Optimal Sharing Rule*, in: The Manchester School, Vol. 77(5), pp. 575-593.

Weikard, H.-P., Finus, M. and Altamirano-Cabrera, J.-C. (2006): *The impact of surplus sharing on the stability of international climate agreements*, in: Oxford Economic Papers, Vol. 58(2), pp. 209-232.

Weischer, L., Morgan, J. and Patel, M. (2012): *Climate Clubs: Can Small Groups of Countries make a Big Difference in Addressing Climate Change?*, in: Review of European Community and International Environmental Law, Vol. 21(3), pp. 177-192.

Appendix

Proof of Equation (17)

Replacing equations (15a) and (15b), respectively, for x_i^D in the welfare function (16) yields the welfare function of a coalition country, $W_{i\in C}$, as well as the one of a non-coalition country, $W_{i\notin C}$:

$$W_{i\in C}\left(e_1,\dots,e_n,t_1,\dots,t_n\right) = ae_i - \frac{b}{2}(e_i)^2 - \frac{\delta}{2}\left(\sum_{j=1}^{n} e_j\right)^2 - p_i^*(e_i,t_i)e_i + \overline{x} + \frac{\left(p_i^*(e_i,t_i)\right)^2 - t_i^2}{4\alpha_H}$$

$$+ \frac{1}{4\alpha^*}\cdot\left(\sum_{\substack{j=1,\\ j\in C\\ j\neq i}}^{m}\left(p_j^*\left(e_j,t_j\right)+t_j\right)^2 + \sum_{\substack{j=m+1,\\ j\notin C}}^{n}\left(p_j^*\left(e_j,t_j\right)\right)^2 - 2(m-1)\cdot\left(p_i^*\left(e_i,t_i\right)t_i + t_i^2\right)\right), \tag{A.1a}$$

$$W_{i\notin C}\left(e_1,\dots,e_n,t_1,\dots,t_n\right) = ae_i - \frac{b}{2}(e_i)^2 - \frac{\delta}{2}\left(\sum_{j=1}^{n} e_j\right)^2 - p_i^*(e_i,t_i)e_i + \overline{x} + \frac{\left(p_i^*(e_i,t_i)\right)^2 - t_i^2}{4\alpha_H}$$

$$+ \frac{1}{4\alpha^*}\cdot\left(\sum_{\substack{j=1,\\ j\neq i}}^{n}\left(p_j^*\left(e_j,t_j\right)\right)^2\right), \tag{A.1b}$$

where $(p_1^*,\dots,p_n^*)$ denote the local equilibrium prices from (14a) and (14b), respectively. Their difference makes up the trade privileges of the PFTA stated in equation (17).

Stability in the $\neg PFTA$ Scenario

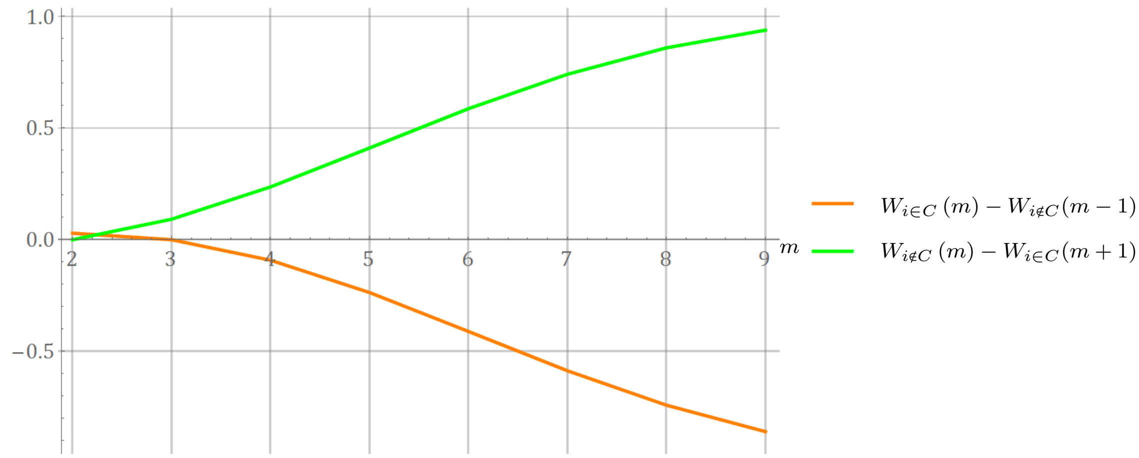

Figure 9: Internal and external coalition stability of the Stackelberg equilibrium without PFTA

Further Market Outcomes for the Simulation

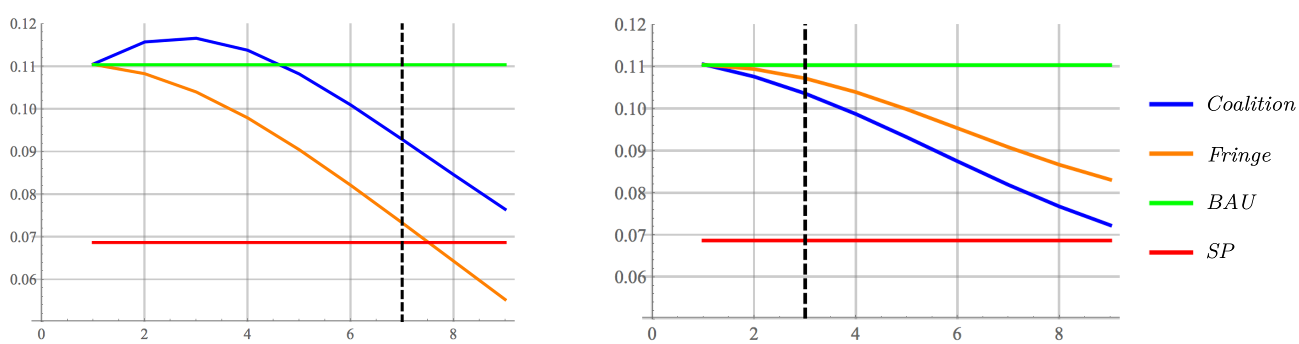

Figure 10.a: Stackelberg Game with PFTA ($m^* = 7$)   Figure 10.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 10: Production of the Dirty Good in the Stackelberg Equilibrium

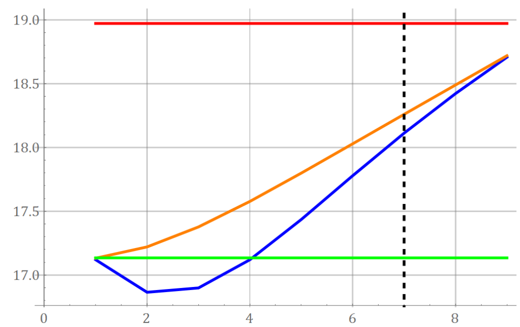

Figure 11.a: Stackelberg Game with PFTA ($m^* = 7$)

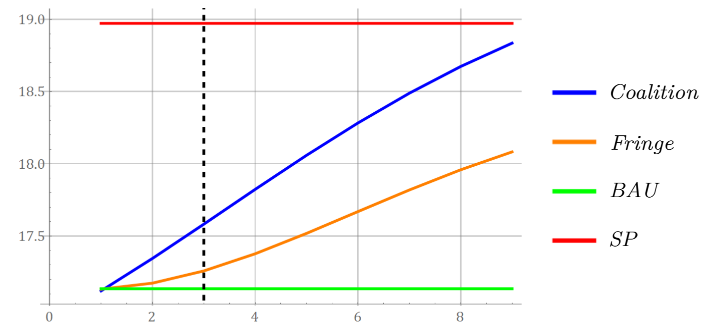

Figure 11.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 11: Production of the Clean Good in the Stackelberg Equilibrium

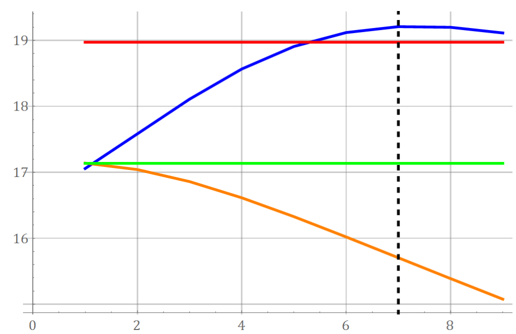

Figure 12.a: Stackelberg Game with PFTA ($m^* = 7$)

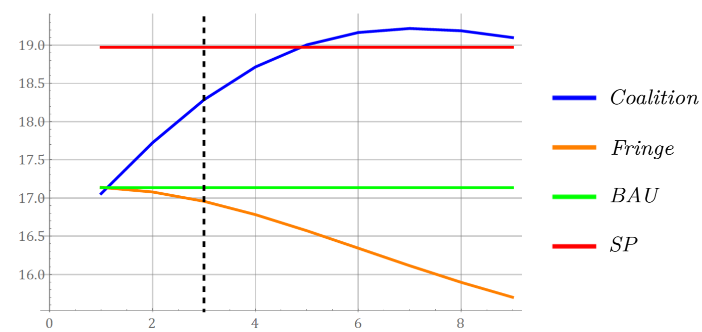

Figure 12.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 12: Consumption of the Clean Good in the Stackelberg Equilibrium

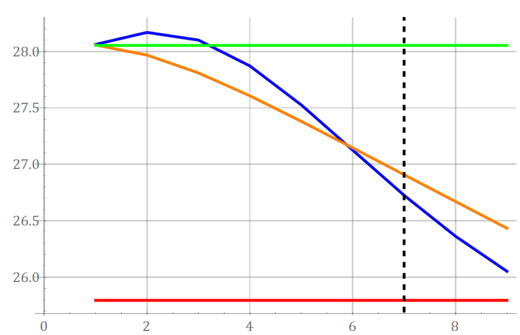

Figure 13.a: Stackelberg Game with PFTA ($m^* = 7$)

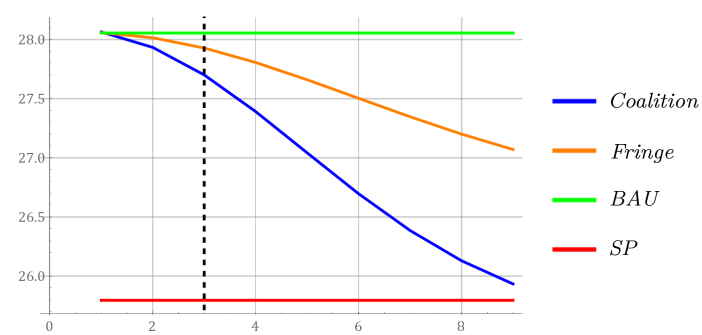

Figure 13.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 13: Consumption Utility in the Stackelberg Equilibrium

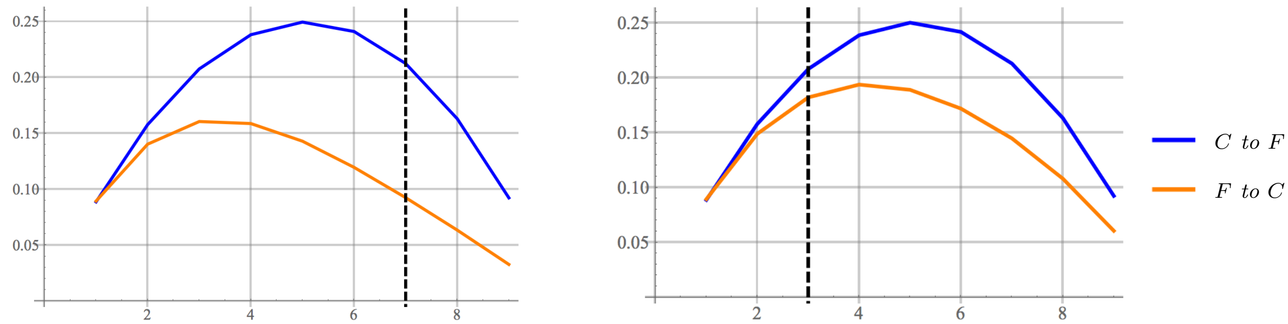

Figure 14.a: Stackelberg Game with PFTA ($m^* = 7$)

Figure 14.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 14: Inter-Group Trade Patterns for the Dirty Good in the Stackelberg Equilibrium

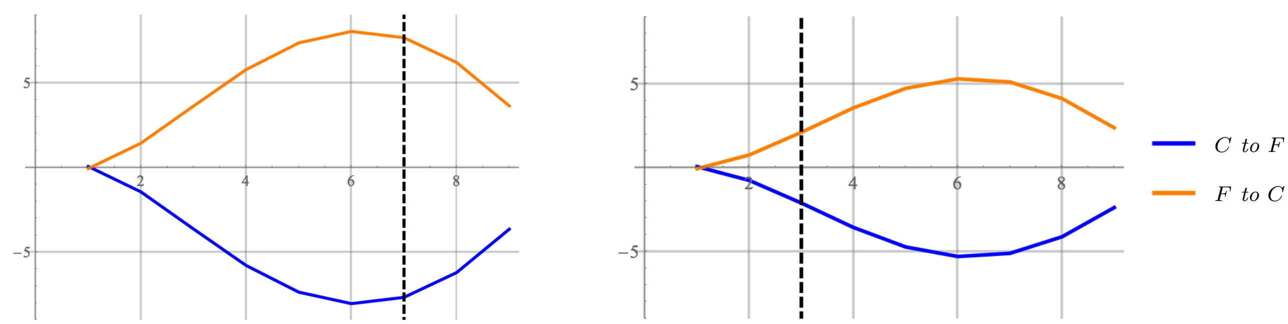

Figure 15.a: Stackelberg Game with PFTA ($m^* = 7$)

Figure 15.b: Stackelberg Game without PFTA ($m^* = 3$)

Figure 15: Inter-Group Trade Patterns for the Clean Good in the Stackelberg Equilibrium