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Formation of Climate Coalitions and Preferential Free Trade - The Case for Participation Linkage

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Abstract

We study the endogenous formation of climate coalitions linked to a preferential free trade arrangement. In a multi-stage strategic trade and participation game, coalition and fringe countries dispose of a discriminatory tariff on dirty imports as well as emission permits imposed on domestic producers and traded on a common permit market inside the coalition, or respectively local markets outside. The participation game is solved by Monte-Carlo simulation, while the general equilibrium and the policy game are solved analytically. We find that preferential free trade can create effective climate coalitions in terms of depth and breadth.

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

Keywords: Climate Change, International Environmental Agreements, Preferential Free Trade, Issue Linkage, Emission Permits

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1 Introduction

As the issue of global warming is felt to become increasingly severe, new collective strategies are discussed in international climate policy. Although the Paris Agreement provides a global deal and a more realistic policy framework for post-2020 climate change action, it is also being criticized for the 'pledge and review' mechanism which has been adopted to implement the bottom-up approach agreed upon in the 2011 Durban Platform. The problem is that the nationally determined contributions (NDCs) registered at the UNFCCC so far are not considered enough to the ambition required to meet the ('well below') two-degree target. A recent synthesis report by the UNFCC estimates that the current path could lead to an increase in global mean temperatures of 2.7 degrees celsius by the end of the century (UNFCC, 2021). Moreover, insights from experimental game theory indicate that the review process is unlikely to be able to straighten things out (Barrett/Dannenberg, 2016). The Paris Agreement does not seem to have led to a 'broad-and-deep' cooperation outcome yet.

Given the broad concern on the state of climate change, more and more economists demand that any collective action going beyond the NDCs needs to be accompanied by trade-related measures to induce reluctant countries to raise efforts. In the literature, such trade incentive tools have been designed either to privilege countries cooperating on the climate issue or to penalize countries not doing so. In this paper, we propose to build a link between climate coalitions and a preferential free trade arrangement. The basic idea is to enable coalition members to favorably shift the terms of trade on international markets by trade diversion and trade creation, and hence to discourage fringe countries from free riding on the environment. The objective is to increase both, participation in international environmental agreements (IEAs) as well as their effectiveness in reducing greenhouse gas emissions on a global scale.

The study of the endogenous coalition formation in the non-cooperative game literature on IEAs [4] is based on the pioneering work of D'Aspremont et al., 1983[5], which was developed in the context of price cartels and adapted to IEAs on emission reductions by Carraro/Siniscalco, 1993, and Barrett, 1994, among others. The model essentially consists of two stages: an (open membership) participation stage and a policy stage. In the participation stage players decide whether to join the IEA. In the policy stage the signatories (coalition countries) and the non-signatories (fringe countries) set their policies (e.g. abatement, taxes and tariffs) maximizing their aggre-

[4] See Hovi et al., 2014, Marrouch/Amrita, 2016 for excellent overviews of the field.
[5] A formal analysis of this type of model is conducted in Karp/Simon, 2013

gate and individual welfare, respectively, in a simultaneous (Cournot/Nash) or sequential mode (Stackelberg).

As free-riding incentives are inherent in the provision of a public good like emission reductions, various mechanisms (transfer payments, issue linkages, etc.) have been investigated with regards to increasing participation and effectiveness of climate coalitions (Hovi et al., 2014, Marrouch/Amrita, 2016). Issue linkage[6] is a mechanism whereby the free riding incentives inherent in an IEA are offset by incentives originating from other issues such as R&D or trade, among others (Marrouch/Amrita, 2016). Consequently, the basic model above has been extended by a third stage involving trade, typically with segmented markets at the country level, in a partial equilibrium setting with imperfect competition (Barrett, 1997, Dong/Zhao, 2009, Lui, 2010, Al Khourdajie/Finus, 2020, Diamantoudi et al., 2020), or in a general equilibrium setting with perfect competition (Eichner/Pethig, 2013 (without issue linkage), Eichner/Pethig, 2015 (without market segmentation), Kuhn et al., 2015, Kuhn et al., 2019, Kuhn et al., 2018). In the strategic trade literature, the same three stage timing was also used by Yi, 1996, Conconi, 2000 and Melatos/Woodland, 2007 to evaluate the effects of free trade and customs unions on coalition formation.

In the tradition of the literature on participation linkage, we describe a multistage strategic trade model incorporating a preferential free trade area which is open to the signatories of an IEA only. In the model there are two tradable goods, a clean good traded on an international market and a dirty good i traded internationally on segmented markets. The dirty good generates a negative externality in form of welfare-lowering emissions on a global scale. In order to internalize this externality, countries can dispose of two instruments, an emission cap and an import tariff levied on the dirty good. Domestic producers have to purchase emission permits for every unit of the dirty good produced. Foreign producers in addition have to face a tariff for their exports while trade among coalition members is privileged by tariff exemption.

Modeling a preferential free trade area crucially requires to track the trade flows among countries, both with respect to the countries of origin as well as with respect to the countries of destination. More precisely, there is the challenge to differentiate a country's excess supply with respect to the various destinations of its exports and a country's excess demand with respect to the various origins of its imports. In typical trade models[7] with just two countries this information is naturally given by the trade pattern, but, no longer if more than two countries are involved in trade. In the

[6] A comprehensive discussion of the wider topic of issue linkage can be found in Maggi, 2016.

[7] See e.g. the reviews of Bagwell/Staiger, 2016, Maggi, 2014 on the formation of trade agreements.

latter case a scheme of discriminatory tariffs could neither be imposed, nor the trade pattern be determined. The solution to this problem naturally leads to a segmented market structure which is well in line with Debreu, 1959 who differentiates markets with respect to location and time in his Theory of Value, but also in line with recent literature like e.g. Shapiro et al., 2018, Lapan et al., 2019.

An IEA linked to a preferential free trade agreement (PFTA) in the context of the basic model described above was first introduced in Kuhn et al., 2015, ,Kuhn et al., 2018, Kuhn et al., 2019, and more recently analyzed by Diamantoudi et al., 2020. In the present paper, we use a different model. We employ a Nash simultaneous moves game ruling out the negotiation power of coalition members to isolate the impacts of the free trade arrangement on coalition formation. Further, we consider the case of a common market for tradable emission permits implemented among coalition members. Permits are imposed on producers enabling countries to channel emission and trade policies more effectively (compared to consumption permits), at least in this framework. We assume perfect competition to shift the focus on the strategic behavior of countries away from the strategic behavior of firms which in turn would create additional disruptions to be dealt with. Moreover, we consider the counteracting impact of a free trade area amongst fringe countries. With respect to the simulation methodology, we employ Monte-Carlo Simulation techniques which perform better than a particular parameter choice with sensitivity analysis in terms of generality of the results achieved. Additionally, we provide analytical comparative statics results for the general equilibrium.

We should in particular emphasize, that environmental damages are dealt with an emission trading system instead of a carbon tax. Compared to tradable permits, border carbon adjustments (BCA), for instance, are a form of tariff scheme that is imposed on dirty imports in order to counteract unfair competitive advantages resulting from eco-dumping strategies by non-signatories. In Al Khourdajie/Finus, 2020 countries set their carbon prices which in turn determine their tariffs. Al Khourdajie/Finus, 2020 find that this design is conducive to increase participation and effectiveness in climate coalitions. In our model countries have two policy instruments available. Emission permits impact the carbon price, but tariffs are not coupled with carbon prices and can be set independently. The latter point may lead to a more efficient allocation.

We find strong evidence for the thesis that a PFTA can promote the formation of a 'broad-and-deep' climate coalition (confirming Kuhn et al., 2019, Diamantoudi et al., 2020), even more, if producers face a coalition-wide emission trading system. This finding can be attributed to the fact that coalition countries have more and better options available to channel their policies for governing the market outcomes. In this respect, naturally, terms of trade effects will play a predominant role in deteriorating free riding incentives. Interestingly, even if countries free-riding on the environment are given the option to form a trading block amongst themselves to enhance their negotiation power on international markets we find that the formation of climate coalitions hardly gets hampered.

The paper is organized as follows. In Section 2 we describe the model providing the micro-foundation of the market equilibria in accordance with the trade structure. In addition, the policy game and the participation game is formulated. In Section 3 comparative statics results for the general equilibrium are discussed. Section 4 presents the results for the endogenous coalition formation under free trade and no free trade, as well as the counteracting impact of a free trade area amongst fringe countries. Section 5 gives some intuition on the results achieved followed by some concluding remarks in section 6.

2 The Model

The following model involves three stages: a coalition participation stage, a policy stage, and a market stage. First, in the participation game, countries decide on whether to join the climate coalition or not (open membership). In making this decision, a country is able to fully anticipate its optimal Nash strategies in the follow-up policy game given the policies of the other countries and the coalition size. In the Nash equilibrium the optimal policies of all countries (discriminatory tariff on dirty imports as well as an emission cap) get determined simultaneously with the coalition exploiting the power of policy coordination. Finally, given the policies and trade structure, market participants take their decisions, leading to a general equilibrium composed of world markets for a clean good, a dirty good, a common permit market inside the coalition, and local permit markets in fringe countries. Accordingly, the solution proceeds by backwards induction.

2.1 Preferential Free Trade Area

We are assuming $i = 1, ..., n$ countries maximizing social welfare. There is international trade in a clean good as well as in a dirty good, with p_x being the price for the clean good. The production e_i^S of the dirty good is coupled with emissions e_i one to one, $e_i(e_i^S) = e_i^S$. All countries face the same global emissions $e = \sum_i e_i$ due to the public good characteristics of the global externality while damages $D_i(e)$ may be specific. Further, there is a common cap and trade system inside the coalition while permit markets in fringe countries are local. Hence, each country has two instruments at its disposal: an emission cap e_i and a tariff t_i on the dirty good. The emission trading system will be described in detail, together with the tariffs, in section 2.2. Moreover, each country has to strategically decide on whether to become a coalition member ($i \in C$) or to stay out as a fringe country ($i \in F$ with $C \cap F = \varnothing$). Incomes and prices are determined by the conditions of the general equilibrium taking Walras' Law into account.

In modeling the free trade area we first have to recall from trade theory that there is a fundamental difference between a model with more than two countries and traditional trade models, in particular with respect to the determination of trade patterns. While in a two country model the trade pattern is determined along with the equilibria on international markets, in the case of three countries and more excess demand and excess supply does not provide any information on the destination and origin of trade flows. A preferential free trade area however requires to be able to track trade flows with respect to the countries of origin as well as with respect to the countries of destination. Otherwise, tariffs could not be levied selectively on dirty good imports. Equally, in solving a firm's optimization problem it could not be taken into account that firms are facing different prices on foreign markets because of tariff exemption.

A possible solution to this problem is the assumption of a segmented market structure, in which the total supply of a firm is decomposed into the supplies to the various destinations, i.e. $e_i^S = \sum_{j \in C \cup F} e_{ij}^S$. Here, e_{ij}^S denotes the supply of the representative firm located in origin country i to destination country j. In case $j = i$ the firm serves the domestic market. Further, we have to differentiate between producers located in coalition countries and those located in fringe countries. Producers i inside the free trade area receive the foreign consumer price $(p_j + t_j)$ for the exports to another coalition country $j \in C$ due to tax exemption while producers outside the free trade area receive the foreign producer price p_j only. This is what constitutes the advantage and the gains of free trade. In the absence of a free trade area a coalition producer would only receive the foreign producer price p_j throughout. The corresponding decision problem of the producers will be described in more detail below.

The advantage of this approach is given by the fact that trade flows can be identified with respect to their origin as well as their destination as a pre-condition for incorporating a free trade area with discriminatory tariffs.

2.2 Markets

2.2.1 Producers

Producers maximize profits Π_i by deciding on the supply of the dirty good, e_i^S, the supply of the clean good x_i^S, and the demand for emission permits. For each unit of the dirty good produced firms have to acquire one permit. The coalition producers $i \in C$ acquire an emission permit at price π_c on the coalition market while fringe producers $i \in F$ have to pay the local permit price π_i. Furthermore, firms have to decide on the destinations of the differentiated supply of the dirty good, $(e_{i1}^S, \ldots, e_{in}^S)$. Policy decisions and prices for goods and permits are taken as given.

Both, coalition and fringe firms face a certain production possibility frontier $T_i = T_i\left(x_i^S, e_{i1}^S, \ldots, e_{in}^S\right)$. With regard to the transformation function, it is quite reasonable to assume that the opportunity costs of shipping the dirty good to the various destinations abroad differ not only because transportation costs must be beared but as well because country-specific import regulations and standards must be met while transaction costs on the home market may be lower.

Formally, producers face the following optimisation problems:

$$\max_{x_i^S, e_i^S} \Pi_\mathrm{i} = p_x x_i^S + (p_i + t_i - \pi_c) e_{ii}^S + \sum_{\substack{j \in C, \\ j \neq i}} (p_j + t_j - \pi_c)\, e_{ij}^S + \sum_{j \in F} (p_j - \pi_c) e_{ij}^S \qquad \text{for } i \in C$$

$$\text{s.t.} \quad T_i\left(x_i^S, e_{i1}^S, \ldots, e_{in}^S\right) = 0$$

$$\max_{x_i^S, e_i^S} \Pi_\mathrm{i} = p_x x_i^S + (p_i + t_i - \pi_i) e_{ii}^S + \sum_{\substack{j \\ j \neq i}} (p_j - \pi_i) e_{ij}^S \qquad \text{for } i \in F$$

$$\text{s.t.} \quad T_i\left(x_i^S, e_{i1}^S, \ldots, e_{in}^S\right) = 0$$

In case of fringe countries forming a free-trade area amongst themselves (see section 4), the objective function in the second optimisation problem takes the form:

$$\Pi_i = p_x x_i^S + (p_i + t_i - \pi_i) e_{ii}^S + \sum_{\substack{j \in F, \\ j \neq i}} (p_j + t_j - \pi_i)\, e_{ij}^S + \sum_{j \in C} (p_j - \pi_i) e_{ij}^S \qquad \text{for } i \in F$$

The differentiated supply of the dirty good as introduced here is comparable to the iceberg approach widely used in trade theory. In case of iceberg costs, only a fraction of the good originally produced and shipped abroad is reaching the consumers in the destination countries, (i.e. a fraction "melts off" during transport). Or, in other words, firms have to produce more than one unit of the good if they want to sell one unit on the world market. Hence, the opportunity costs of shipping the goods to different destinations, inclusive of transaction costs, are different, and so are firm's supplies at the given world market price. Or, if more than two countries are involved in international trade supply prices on segmented markets have to be differentiated according to the shares lost in transport.

In contrast, in our model transaction costs of shipping goods abroad are reflected in a firm's transformation function rather than in terms of exogenous losses in quantity.

2.2.2 Consumers

Consumers try to maximize utility U_i by deciding on the optimal demand for the dirty good e_i^D as well as for the clean good x_i^D, taking the level of income y_i, the price for the dirty good $p_i + t_i$, and the world market price for the clean good p_x as given. The consumer's optimization problem can therefore be written as follows:

$$\begin{aligned} \max_{x_i^D, e_i^D} \quad & U_i\left(x_i^D, e_i^D\right) \\ \text{s.t.} \quad & p_x x_i^D + (p_i + t_i) e_i^D = y_i \end{aligned}$$

where p_i denotes the local producer price.

We will turn to the markets in the next section.

2.2.3 Markets

The general market equilibrium can now be characterised by the following set of equations:

Coalition Permit Market: $$\sum_{i \in C, j \in C \cup F} e_{ij}^S = e_c$$

Fringe Permit Markets: $$\sum_j e_{ij}^S = e_i \qquad \forall i = m+1, \ldots, n$$

Local Dirty Good Markets: $$e_i^D = \sum_j e_{ji}^S \qquad \forall i = 1, \ldots, n$$

Global Clean Good Market: $$\sum_j x_j^D = \sum_j x_j^S$$

Coalition Consumer Incomes: $$y_i = \Pi_i + t_i \sum_{j \in F} e_{ji} + \frac{\pi_c e_c}{m} \qquad \forall i = 1, \ldots, m$$

Fringe Consumer Incomes: $$y_i = \Pi_i + t_i \sum_{j \neq i} e_{ji} + \pi_i e_i \qquad \forall i = m+1, \ldots, n$$

The first four (sets of) equations simply state the market equilibrium conditions for permits, the dirty good and the clean good. In case of the coalition permit market, please recall that the supply of coalition permits originates from the emission caps set by the member countries: $e_c = \sum_{i \in C}^m e_i$. The last two sets of equations describe consumer incomes which consist of profits Π_i, tariff incomes $t_i \sum e_{ji}$, and the share of revenues from the permit markets ($\frac{\pi_c e_c}{m}$ and $\pi_i e_i$, $i \in F$). Obviously, coalition countries lack tariff revenues from the other members because of tax exemption due to free trade.

It can be shown that Walras' Law applies, hence we may take the clean good as numeraire with $p_x = 1$. This follows from the fact that consumers will expend their entire income. We will therefore have $p_x x_i^D + (p_i + t_i) e_i^D = \Pi_i + t_i \sum_{j \in F} e_{ji} + \frac{\pi_c e_c}{m}$ and $p_x x_i^D + (p_i + t_i) e_i^D = \Pi_i + t_i \sum_{j \neq i} e_{ji} + \pi_i e_i$ for coalition and fringe consumers, respectively. Now, assuming that all markets except that for the clean good are in equilibrium, substituting Π_i by the respective firms profits, and aggregating these equations for all countries, we get $p_x \sum_i x_i^D = p_x \sum_i x_i^S$ after some elementary algebraic operations, i.e. the market for the clean good is also balanced.

2.3 Policy Game and Coalition Participation

The social welfare function $W_i := U_i(x_i^D, e_i^D) - D_i(e)$ of each country $i = 1, ..., n$ takes consumption utility $U_i(x_i^D, e_i^D)$ into account in addition to global environmental damages $D_i(e)$. In making the decision on whether to participate in the coalition or not, there is a trade-off between the gains of free trade in addition to the benefits of policy coordination on the one hand, and the rents from free-riding on the environment on the other hand. This framework is modeled as a simultaneous moves game with joint decision making by the coalition members and individual decision making by the fringe players, for any given coalition size m. The optimization problem for a coalition C of member size m is thus:

$$\max_{e_c,(t_i)_{i\in C}} \sum_{i\in C} W_i\left(e_c,(t_i)_{i\in C};(e_i)_{i\in F},(t_i)_{i\in F},m\right) \quad \text{with } C=\{1,\ldots,m\}$$

where welfare W_i depends on the policy instruments only since market reactions are already endogenized in the general equilibrium at this stage $x_i^D = x_i^D((e_j)_{j=1\ldots n},(t_j)_{j=1\ldots n};m)$, $e_i^D = e_i^D((e_j)_{j=1\ldots n},(t_j)_{j=1\ldots n},m)$, $e=e((e_j)_{j=1\ldots n},(t_j)_{j=1\ldots n},m)$, and where $e_c=\sum_{i\in C} e_i$ stands for the coalition-wide cap. The coalition welfare does not depend on the individual caps, $(e_i)_{i\in C}$, because a common permit market will assure for an efficient allocation of permits among the local producers. The decisions of the fringe countries $(e_i)_{i\in F},(t_i)_{i\in F}$ and the coalition size m are taken as given. Please note that due to international trade local consumption of clean and dirty goods neither have to be necessarily equal to local production nor to the local cap.

Fringe countries maximize their individual welfare in the policy game

$$\max_{e_i,t_i} W_i\left(e_i,t_i;(e_j)_{j\neq i},(t_j)_{j\neq i},m\right)$$

Here, the decisions of all other countries $(e_j)_{j\neq i},(t_j)_{j\neq i}$ and the coalition size m are taken as given. Further, as above, market reactions are again considered endogenized. Consequently, countries get involved in a strategic trade and environmental policy game because the countries'optimal policies cannot be set independently .

After the policy decisions have been endogenized the individual welfare W_i will depend only on m and on whether a country is part of the coalition or not. Therefore, in the participation game, each country has to decide whether to participate in a coalition of size m or to stay out, fully anticipating the potential gains and losses of its move. For the symmetric case, a coalition of size m is said to be internally and externally stable if there is no incentive for countries to leave or join (D'Aspremont et al., 1983), that is:

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

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

Taken together, finally, these inequalities determine the stable coalition size m^*. [8]

3 General Equilibrium and Comparative Statics

An analytical solution for the market equilibrium (see appendix) in the three country case, $n = 3$, is obtained for the following specifications. The utility function is taken as a quasi-linear function with a saturating non-linear term in the dirty good, $U_i(x_i^D, e_i^D) = ax_i^D + be_i^D - c\left(e_i^D\right)^2$. The production possibility frontier is given by $T_i\left(x_i^S, e_{i1}^S, \ldots, e_{in}^S\right) = \overline{x} - \alpha x_i^S - \beta \sum_{j=1}^{n} \left(e_{ij}^S\right)^2 = 0$. And finally, the damage function with increasing marginal damages is given by $D(e_1^D, \ldots, e_n^D) = \delta\left(\sum_{j=1}^{n} e_j^D\right)^2$.

From the price equations (see appendix) the comparative statics results can easily be calculated. The findings for the case of free trade and $m = 2$ are summarized in the following table:

Derivatives	d/de_c	d/de_j	d/dt_i	d/dt_j
p_i	< 0	< 0	> 0	< 0
$p_k,\ k \in C, k \neq i$	< 0	< 0	< 0	< 0
p_j	< 0	< 0	< 0	> 0
π_c	< 0	< 0	$= 0$	< 0
π_j	< 0	< 0	< 0	$= 0$

Table 1: Price reactions to policy changes in a coalition country $i \in C$ and fringe country $j \in F$

In general, we find that the price of the dirty good is falling in response to a higher foreign tariff rate, $\frac{dp_i}{dt_j} < 0$, and rising in response to a higher domestic tariff rate, $\frac{dp_i}{dt_i} > 0$. [9] The implications of this result, however, are quite different depending on where the producers are located. We find, on the one hand, for fringe producers $\frac{d(p_i - t_i)}{dt_i} < 0$. This means that they receive a lower price net of tariff for the exports than before, irrespectively of the destination. On the other hand, coalition producers earn the higher foreign consumer price. [10] (Please recall the results given in the appendix again.) Consequently, a shift in trade away from fringe countries towards coalition members takes place.

[8] Since a coalition of $m = 1$ is not meaningful, the internal stability criterion for this border case actually reads $W_{i\in C}(2) \geq W_{i\notin C}(0)$.

[9] The impact of a tariff change on the permit price $\frac{d\pi_c}{dt_i}$ for $i \in C$, $\frac{d\pi_j}{dt_j}$ for $j \in F$ is zero because the domestic supply of dirty goods (and by implication the demand for permits) is unaffected by trade policy.

[10] This does not hold if the the coalition has no free trade. Then $\frac{d(p_i - t_i)}{dt_i} < 0$ holds also for coalition producers.

With respect to the emission caps, we find for every coalition size $\frac{dp_i}{de_c} < 0$, $\frac{dp_i}{de_j} < 0$ for $i \in C$ and $j \in F$. Foreign producer prices are falling along with an increase in the available amount of permits because firms increase their supply of the dirty good to the foreign markets (as well as the domestic supplies). At the same time, this means that an eco-dumping policy aimed at improving the terms of trade does not work out, in particular not for the fringe countries which may otherwise want to employ environmental measures in lieu of tariffs. We will come back to this point below.

4 Coalition Formation, Welfare Gains and Environmental Outcomes

4.1 Coalition Formation

Having obtained a solution for the market equilibrium, we proceed to analyze the coalition formation. For this purpose, we first solve for the optimal policies in the Nash Equilibrium, given a coalition size m (see appendix). In the next and final step, we observe the effects of free trade on coalition formation, welfare and environmental outcomes by means of a Monte-Carlo Simulation on a subset of the parameter space, $\mathcal{P} = \{(a, b, c, \alpha, \beta, \delta) \in [0, 10]^6\}$. To be more precise, we draw a random sample of parameter values $S \subset \mathcal{P}$ from the uniform distribution over $\mathcal{P}$. For reasons of computational tractability we focus on the interior solutions for the producers' and consumers' problems, $I \subset S$, only. Finally, every parameter sample which gives an interior solution gets evaluated for its internal and external stability, welfare gain, and environmental outcome under the various trade regimes. For $|S| = 100.000$ samples drawn $|I| = 20651$ interior solutions were found.

Let $m_{PFTA} : \mathcal{P} \mapsto \{0, 2, 3\}$, and $m_{\neg PFTA} : \mathcal{P} \mapsto \{0, 2, 3\}$ be functions that map the parameter space P onto the stable coalition size $m \in \{0, 2, 3\}$ under free trade and no free trade, respectively. Then, Figure 1 depicts the histogram of $M(p) := (m_{PFTA}(p), m_{\neg PFTA}(p))$ over the interior solutions I. Each cell (k, l) gives the absolute proabability, $P(M = (k, l))$, of observing a transition of coalition size l to coalition size k as a consequence of free trade (see appendix for the numerical values). Hence, on the diagonal ((0,0), (2,2), (3,3)) we see the stability outcomes where free trade does not have any impact (apprx. 34.96%). Above-left the diagonal ((0,2), (0,3), (2,3)) we find the probabilities for a decreasing size of the climate coalition due to free trade (0%), while below-right

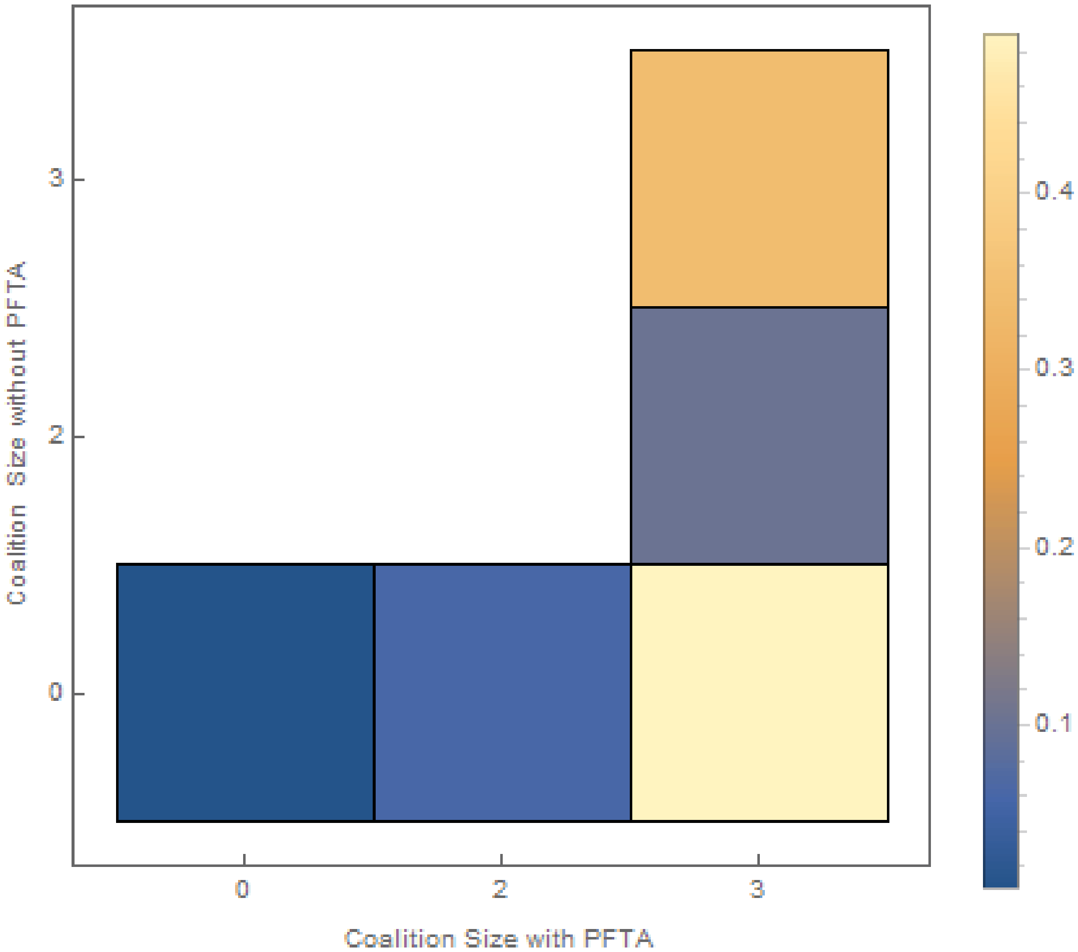

Figure 1: Incentive to join the climate coalition with and without free trade.

the diagonal ((2,0), (3,0), (3,2)) we find the probabilities for an increasing size of the coalition (apprx. 65.04%). From these results we can the derive the conditional transition probabilities from coalition size l to the grand coalition, $P(m_{PFTA} = 3|m_{\neg PFTA} = l)$. We see that grand coalitions never get smaller, $P(m_{PFTA} = 3|m_{\neg PFTA} = 3) = 1$. The probability for transitions from coalitions of size 2 to the grand coalition is $P(m_{PFTA} = 3|m_{\neg PFTA} = 2) = 1$, and from coalition size 0 is around $P(m_{PFTA} = 3|m_{\neg PFTA} = 0) = 88,02\%$. For the transition from size 0 to coalitions of size 2 $P(m_{PFTA} = 2|m_{\neg PFTA} = 0) = 10.52\%$. As an important result, we can state that the formation of climate coalitions is either unaffected or even more is fostered by free trade. But, never is it hampered.

This picture, however, might change if we allow for free trade among fringe countries as a counteracting strategy to favourably shift the terms of trade on international markets. In this case, let m_{PFTA} again be defined as above, and let $m^*_{PFTA} : \mathcal{P} \mapsto \{0, 2, 3\}$ be a function that maps

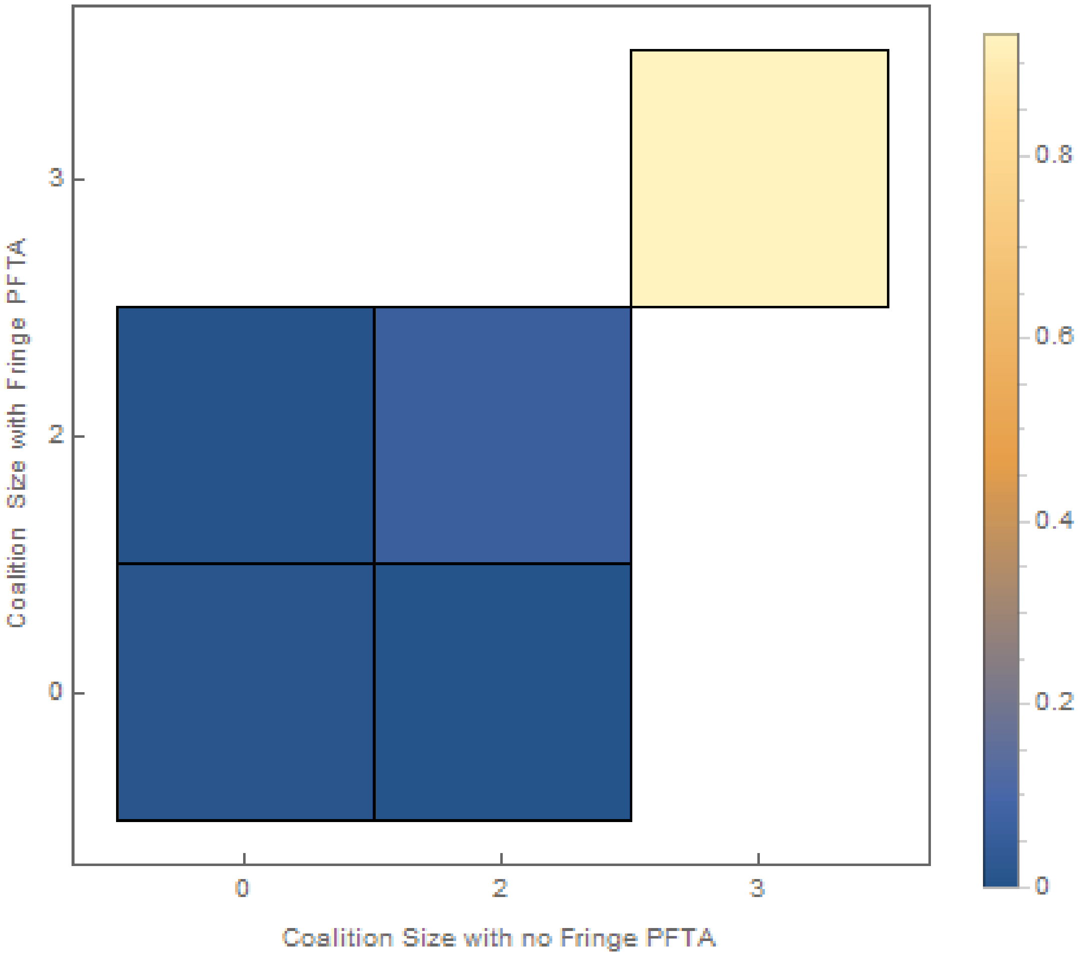

Figure 2: Stable Coalition Sizes with and without Free Trade among Fringe; Coalition with Free Trade

the parameter space P onto the stable coalition size $m \in \{0, 2, 3\}$ when coalition countries as well as fringe countries each can take a free trade arrangement. Then, Figure 2 is depicting the histogram of $M^*(p) = (m_{PFTA}(p), m^*_{PFTA}(p))$ over the interior solutions I. It is illustrating the impact of free trade among fringe countries on the size of the climate coalition. By account of (0,0), (2,2), (3,3), we see that the absolute probability for the coalition size to be unaffected when fringe countries engange in free trade is pretty high (apprx. 99.81%). In the lower left quadrant we find mixed results. On the one hand, the coalition size increases, with probability $P(M^* = (0, 2)) = 0.15\%$, and transition probabilty $P(m^*_{PFTA} = 2 | m_{PFTA} = 0) = 2.59\%$. On the other hand, the coalition size decreases, with probability given by $P(M^* = (2, 0)) = 0.03\%$, and transition probability $P(m^*_{PFTA} = 0 | m_{PFTA} = 2) = 4,90\%$. The intuition behind this result is as follows: Environmental damages generated by more trade in the dirty good among the fringe incentivizes the formation of climate coalitions, but only if consumption utility does not fully compensate for the disutility of higher environmental damages. All in all, the probability for fringe countries to be able to counteract climate coalitions by establishing their own free trade area is found remarkably small.

4.2 Welfare Outcomes

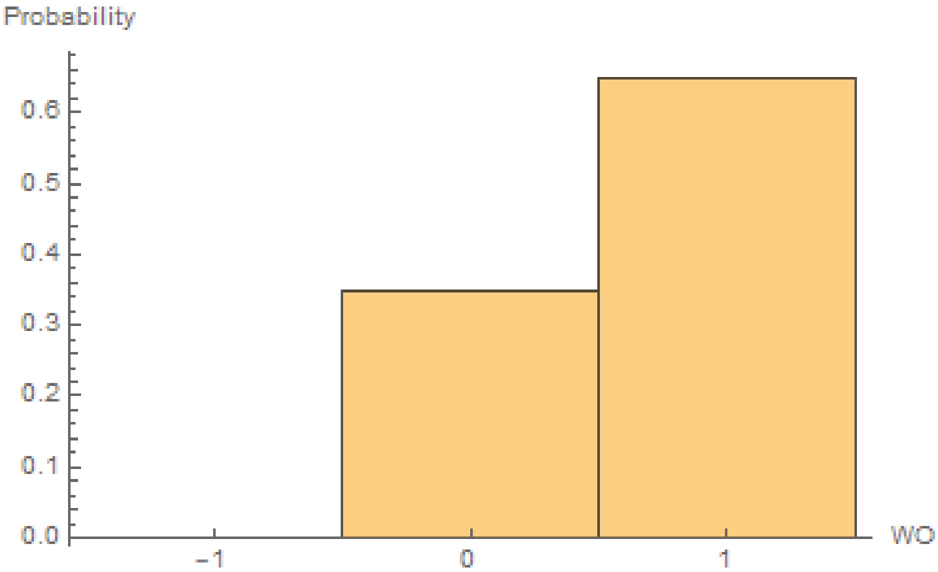

Figure 3: Global Welfare Outcomes, WO

Next, we analyze the effect of climate coalitions on global welfare linked to free trade in comparison to the unlinked case. For fringe countries free trade is ruled out here by assumption. Let global welfare be defined as the sum over the welfares of the individual countries, and let $W_G^{PFTA} : \mathcal{P} \mapsto \mathbb{R}$, $W_G^{PFTA} := \sum_i W_i^{PFTA}$, and $W_G^{\neg PFTA} : \mathcal{P} \mapsto \mathbb{R}$, $W_G^{\neg PFTA} := \sum_i W_i^{\neg PFTA}$ be functions that map the parameter space onto the welfare outcomes for the stable coalition size, with and without free trade, respectively. Figure 3 then shows the histogram of global welfare outcomes, WO over I, defined as:

$$WO = \begin{cases} 1 & W_G^{PFTA} > W_G^{\neg PFTA} \\ 0 & W_G^{PFTA} = W_G^{\neg PFTA} \\ -1 & W_G^{PFTA} < W_G^{\neg PFTA} \end{cases}$$

Here, the values 1, 0, -1 indicate whether global welfare is increased, unchanged or decreased by free trade. We can conclude that global welfare never gets reduced by free trade, but is either unaffected or is increased with probability around 34.96% and 65.04%, respectively.

4.3 Environmental Outcomes

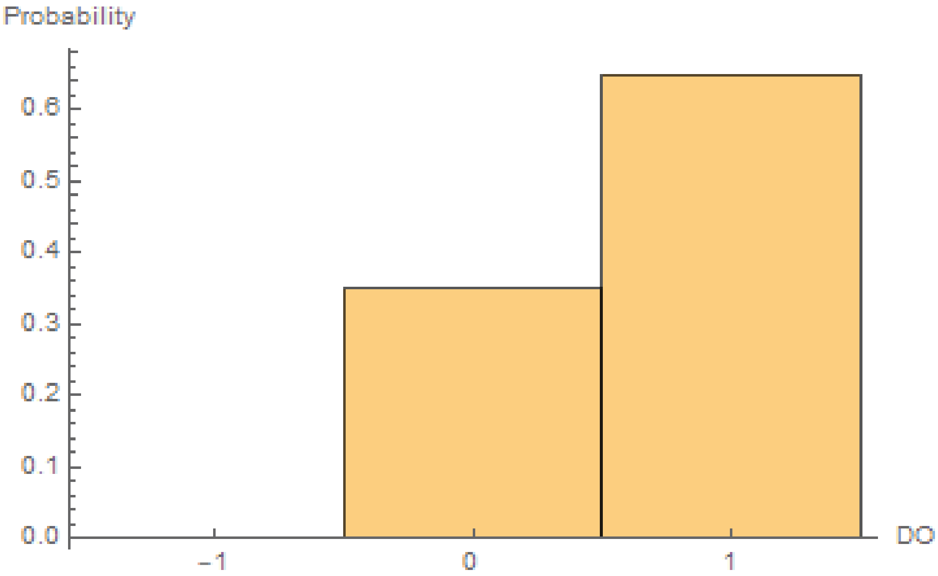

Figure 4: Global Damages Outcomes, *DO*

Finally, let's take a look on how the environmental outcomes are affected by free trade. Consider the damages functions $D_G^{PFTA} : \mathcal{P} \mapsto \mathbb{R}$, $D_G^{PFTA} := \sum_i D_i^{PFTA}$, and $D_G^{\neg PFTA} : \mathcal{P} \mapsto \mathbb{R}$, $D_G^{\neg PFTA} := \sum_i D_i^{\neg PFTA}$ for the free trade and no free trade scenario, respectively. Figure 4 then shows the histogram of the damages outcomes DO over I, defined as:

$$DO = \begin{cases} 1 & D_G^{PFTA} < D_G^{\neg PFTA} \\ 0 & D_G^{PFTA} = D_G^{\neg PFTA} \\ -1 & D_G^{PFTA} > D_G^{\neg PFTA} \end{cases}$$

Here, the values indicate whether global environmental damages are decreased, unchanged, or increased by free trade. Again, most probably, i.e. in the vast majority of cases, environmental pressures are reduced by linking free trade with climate negotiations. [11]

As a main result of the paper, we can conclude that linking free trade to climate negotiations leads to more comprehensive and more effective climate coalitions.

[11] However, we should notice that with a low probability of apprx. 0.10% free trade leads to bigger environmental damages. However, these reductions are sub-optimal from a global perspective, as these cases only occur when a small coalition without free trade is transitioning to the grand coalition with free trade, the latter being the globally optimal outcome.

5 Discussion

What is the economic intuition behind the propositions stated? Although both, coalition and fringe countries, have two policy tools available, they use these instruments very differently to maximize welfare, as comparative statics results indicate.

On the one hand, coalition countries opt for pretty strict emission caps to internalize the climate externality while implementing highly distortionary tariffs. This finding is clearly a result of the fact that, as the coalition grows in size, the environment gets more and more valued. However, such a sound environmental policy puts coalition firms in a worse position compared to their fringe competitors due to higher permit costs. Coalition countries are thus forced to pursue highly protectionist trade policies to improve their terms of trade, remarkably not at the expense of environmental quality. This gives rise to a trade barrier between the coalition and the fringe countries which reduces inter-group trade flows substantially. At the same time, a high degree of interdependency between markets for the dirty good and the permit markets enables the coalition to exert environmental discipline on the fringe caps (the more the larger is the coalition size) due to downward pressure on the fringe permit prices.[12] As a consequence of the trade-diverting effects of the free trade area, coalition members succeed, to some degree, in insulating their local markets and the coalitional permit market from the impact of the fringe policies.

On the other hand, the situation of being exposed to price pressures[13] without being able to retaliate against coalitional tariffs leads to a considerable welfare loss in the fringe countries due to the deterioration of consumption possibilities in both goods. After all, that might explain why fringe countries find it optimal to join the coalition. Yet, even when fringe are taking the option to form a free trade area themselves, they hardly are able to behave as free-riders by opting for pretty lax caps and high tariff rates. So, they do not really succeed in undermining any environmental efforts made by the coalition members.

These outcomes finally illustrate how a free trade area can provide strong incentives to the formation of climate coalitions. Although a situation is considered in which supply-side environmental and trade policies are implemented to correct a negative *consumption* externality, their impact on domestic and foreign market prices induce countries to join the climate-trade agreement and internalize climate damages to a large extent.

[12] For more information on the impacts of policies on the markets, please again inspect the comparative statics analysis in section 3

[13] As a matter of fact, even for those countries a certain degree of emission reduction is welfare-enhancing which is why fringe countries do not find it optimal to let permit prices fall to zero.

6 Concluding Remarks

The objective of this paper has been to address the role of a preferential free trade arrangement for the endogenous formation of climate coalitions. In contrast to Kuhn et al. (2019), a cap-and-trade emission trading scheme is implemented on the supply side as well as on a coalitional scale to internalize climate damages. Moreover, fringe countries are given the power to retaliate by forming a free trade area themselves while coalition countries no longer can take advantage of the Stackelberg leadership. From a methodological point of view, the model could be solved analytically up to the policy game while the solution of the participation game has been obtained by Monte Carlo simulation.

We find strong support for joint negotiations on climate change mitigation and preferential free trade if producers participate in a coalition-wide permit market. This result can by explained by the behavior of perfectly competitive firms which is determined not only by the local prices for the dirty good but also by the domestic permit price to be paid. Thereby, strong possibilities for effective price discrimination against non-coalition countries are created. Compared to the case of national emission trading schemes obligating consumers, trade privileges can be better exploited by the climate coalition. Moreover, the additional arbitrage opportunities on the coalition wide permit market lead to an equalization of the opportunity costs of producing the dirty good among coalition producers as the most efficient allocation of resources.

Therefore, the PFTA serves quite well as an incentive mechanism to discourage free-riding behavior and incentivizes coalition formation in the Monte Carlo simulation, with a positive impact on global welfare and climate mitigation. Moreover, it has been shown that the advantage provided by a PFTA can be sustained for a large variation in the opportunity costs of the dirty good as well as in the other parameter values.

These results are, of course, driven by a favorable shift in the terms of trade. The coalition is able to shift a considerable part of the burden of climate mitigation onto the group of fringe countries by manipulating the prices on the fringe markets. Coalition countries thus succeed in insulating their own markets comparably well against leakage effects. The tightening of the cap is accompanied by a trade barrier established vis-à-vis free-riders which makes fringe consumers much worse off since they must curb demand for both, the dirty and the clean good. That is why countries find it beneficial to join the coalition.

Although, in our framework, issue linkage with trade liberalization is found to have the potential to promote and sustain a broad and deep international cooperation on climate change, it represents a double-edged sword with regard to the policy implications. More precisely, the coalition's strategy of imposing protectionist tariff policies is likely to give rise to conflict with the current WTO framework.[14] At the same time, it is obvious that discriminative trade tools must be given legal space in the WTO (as suggested by Leycegui Gardoqui/Ramírez, 2015) if dirty products should be dealt with effectively. Then, sooner or later, an explicit amendment to the WTO regulatory framework is inevitable in order to be able to cope with externalities arising from climate change with appropriate trade-related incentives.

Declarations

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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[14]Even though there are numerous exemptions from the Most-Favoured-Nation principle, all of them are subject to strict requirements with regard to the establishment of trade barriers vis-à-vis other WTO members. That is why the linked free-trade area can neither be considered consistent with GATT Art. XXIV nor with GATT Art. XX.

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Market Solutions

The formulas for the prices were obtained by first solving the first order conditions of producers and consumers for their demand and supply functions, respectively. Then, we substituted these equations into the general equilibria conditions and solved for the prices. The calculations were done with a computer algebra system [15].

1. Climate Coalition with Free Trade

$m = 0$:

$p_i = \frac{3ab\beta+9\alpha bc}{3a(a\beta+3\alpha c)} - \sum_j \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_j + \frac{4\alpha c}{3(a\beta+3\alpha c)} t_i - \sum_{j\neq i} \left(\frac{2\alpha c}{3(a\beta+3\alpha c)} t_j \right) \qquad i = 1, 2, 3$

$\pi_i = \frac{b}{a} - \frac{2a\beta+2\alpha c}{3a\alpha} e_i - \sum_{j\neq i} \left(\frac{2c}{3a} e_j + \frac{1}{3} t_j \right) \qquad i = 1, 2, 3$

$m = 2$:

$p_i = \frac{3ab\beta+9\alpha bc}{3a(a\beta+3\alpha c)} - \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_c - \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_3 + \frac{2\alpha c}{3(a\beta+3\alpha c)} t_i - \frac{\alpha c}{3(a\beta+3\alpha c)} t_j - \frac{2\alpha c}{3(a\beta+3\alpha c)} t_3 \qquad i, j \in C, j \neq i$

$\pi_c = \frac{b}{a} - \frac{a\beta+2\alpha c}{3a\alpha} e_c - \frac{2c}{3a} e_3 - \frac{1}{3} t_3$

$p_3 = \frac{3ab\beta+9\alpha bc}{3a(a\beta+3\alpha c)} - \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_c - \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_3 - \sum_{j\in C} \left(\frac{\alpha c}{3(a\beta+3\alpha c)} t_j \right) + \frac{4\alpha c}{3(a\beta+3\alpha c)} t_3$

$\pi_3 = \frac{b}{a} - \frac{2c}{3a} e_c - \frac{2a\beta+2\alpha c}{3a\alpha} e_3 - \sum_{j\in C} \frac{t_j}{3}$

$m = 3$:

$p_i = \frac{b}{a} - \frac{2c}{3a} e_c \qquad i = 1, 2, 3$

$\pi_c = \frac{2a\beta+6\alpha c}{9a\alpha} e_c$

2. Climate Coalition without Free Trade

$m = 0$: Same as in the previous case.

$m = 2$:

$p_i = \frac{3ab\beta+9\alpha bc}{3a(a\beta+3\alpha c)} - \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_c - \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_3 + \frac{4\alpha c}{3(a\beta+3\alpha c)} t_i - \sum_{j\neq i} \left(\frac{2\alpha c}{3(a\beta+3\alpha c)} t_j \right) \qquad i \in C$

$\pi_c = \frac{b}{a} - \frac{2a\beta+4\alpha c}{6a\alpha} e_c - \frac{2c}{3a} e_3 - \sum_{i\in C} \frac{1}{6} t_i - \frac{t_3}{3}$

$p_3 = \frac{3ab\beta+9\alpha bc}{3a(a\beta+3\alpha c)} - \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_c - \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_3 + \frac{4\alpha c}{3(a\beta+3\alpha c)} t_3 - \sum_{j\in C} \left(\frac{2\alpha c}{3(a\beta+3\alpha c)} t_j \right)$

$\pi_3 = \frac{b}{a} - \frac{2c}{3a} e_c - \frac{2a\beta+2\alpha c}{3a\alpha} e_3 - \sum_{j\in C} \frac{t_j}{3}$

$m = 3$:

$p_i = -\frac{3ab\beta+9\alpha bc}{3a(a\beta+3\alpha c)} - \frac{2a\beta c+6\alpha c^2}{3a(a\beta+3\alpha c)} e_c + \frac{4\alpha c}{3(a\beta+3\alpha c)} t_i - \sum_{j\neq i} \frac{2\alpha c}{3(a\beta+3\alpha c} t_j \qquad i = 1, 2, 3$

$\pi_c = \frac{b}{a} - \frac{2a\beta+6\alpha c}{9a\alpha} e_c - \sum_{i\in C} \frac{2}{9} t_i$

[15] Mathematica v.12

3. Fringe Countries with Free Trade

$m = 0$:

$p_i = \frac{b}{a} - \sum_{i \in C} \frac{2c}{3a} e_i \qquad i = 1, 2, 3$

$\pi_i = \frac{b}{a} - \frac{2a\beta + 2\alpha c}{3a\alpha} e_i - \sum_{j \neq i} \frac{2c}{3a} e_j \qquad i = 1, 2, 3$

$m = 2, 3$: Same as in the first case.

Nash Equilibria

The analytical solutions of the Nash-Equilibria were obtained with the help of a computer algebra system [16] by substituting the market solutions into the welfare functions and solving the Nash-Equilibrium conditions for the policy decision variables. Solutions for $n > 3$ can also be found but have even higher complexity.

1. Climate Coalition with Free Trade For the case where coalition countries have free trade among themselves we obtain the following results.

$m = 0$: $\qquad t_i = \frac{3b\beta}{5a\beta + 9\alpha(c+3\epsilon)} \quad e_i = \frac{9\alpha b}{2(5a\beta + 9\alpha(c+3\epsilon))} \qquad i = 1, 2, 3$

$m = 2$:

$$t_i = \frac{3b\beta(15a^3\beta^3 + 6a\alpha^2\beta c(8c+41\epsilon) + 4\alpha^3 c^2(4c+45\epsilon) + a^2\alpha\beta^2(47c+72\epsilon))}{60a^4\beta^4 + 48\alpha^4 c^3(2c+9\epsilon) + a^3\alpha\beta^3(323c+666\epsilon) + 3a^2\alpha^2\beta^2 c(199c+697\epsilon) + 2a\alpha^3\beta c^2(215c+927\epsilon)} \qquad i = 1, 2$$

$$e_c = \frac{12\alpha b(12a^3\beta^3 + a^2\alpha\beta^2(37c-18\epsilon) + 3a\alpha^2\beta c(11c-13\epsilon) + 2\alpha^3 c^2(4c-9\epsilon))}{60a^4\beta^4 + 48\alpha^4 c^3(2c+9\epsilon) + a^3\alpha\beta^3(323c+666\epsilon) + 3a^2\alpha^2\beta^2 c(199c+697\epsilon) + 2a\alpha^3\beta c^2(215c+927\epsilon)}$$

$$t_3 = \frac{3b\beta(12a^3\beta^3 + 2\alpha^3 c^2(4c-63\epsilon) + 3a\alpha^2\beta c(14c-37\epsilon) + a^2\alpha\beta^2(43c-18\epsilon))}{60a^4\beta^4 + 48\alpha^4 c^3(2c+9\epsilon) + a^3\alpha\beta^3(323c+666\epsilon) + 3a^2\alpha^2\beta^2 c(199c+697\epsilon) + 2a\alpha^3\beta c^2(215c+927\epsilon)}$$

$$e_3 = \frac{3\alpha b(30a^3\beta^3 + 16\alpha^3 c^2(2c+9\epsilon) + 6a\alpha^2\beta c(19c+52\epsilon) + a^2\alpha\beta^2(109c+144\epsilon))}{2(60a^4\beta^4 + 48\alpha^4 c^3(2c+9\epsilon) + a^3\alpha\beta^3(323c+666\epsilon) + 3a^2\alpha^2\beta^2 c(199c+697\epsilon) + 2a\alpha^3\beta c^2(215c+927\epsilon))}$$

$m = 3$: $\qquad e_c = \frac{9\alpha b}{2a\beta + 6\alpha(c+9\epsilon)}$

2. Climate Coalition without Free Trade In the case were the climate coalition has no free trade area the equilibria are given as follows.

$m = 0$: Same as in the previous case.

$m = 2$:

$$t_i = \frac{3b\beta(a\beta + \alpha c)(15a^2\beta^2 + a\alpha\beta(23c+72\epsilon) + 2\alpha^2 c(4c+81\epsilon))}{2(45a^4\beta^4 + 42\alpha^4 c^3(2c+9\epsilon) + 3a\alpha^3\beta c^2(107c+450\epsilon) + a^3\alpha\beta^3(233c+513\epsilon) + a^2\alpha^2\beta^2 c(425c+1497\epsilon))} \qquad i = 1, 2$$

$$e_c = \frac{3\alpha b(69a^3{\sim}beta^3 + a\alpha^2\beta c(191c-282\epsilon) + 12a^2\alpha\beta^2(17c-12\epsilon) + 14\alpha^3 c^2(4c-9\epsilon))}{2(45a^4\beta^4 + 42\alpha^4 c^3(2c+9\epsilon) + 3a\alpha^3\beta c^2(107c+450\epsilon) + a^3\alpha\beta^3(233c+513\epsilon) + a^2\alpha^2\beta^2 c(425c+1497\epsilon))}$$

$$t_3 = \frac{3b\beta(21a^3\beta^3 + a\alpha^2\beta c(65c-144\epsilon) + 2\alpha^3 c^2(10c-81\epsilon) + 6a^2\alpha\beta^2(11c-3\epsilon))}{2(45a^4\beta^4 + 42\alpha^4 c^3(2c+9\epsilon) + 3a\alpha^3\beta c^2(107c+450\epsilon) + a^3\alpha\beta^3(233c+513\epsilon) + a^2\alpha^2\beta^2 c(425c+1497\epsilon))}$$

$$e_3 = \frac{3\alpha b(30a^3\beta^3 + 14\alpha^3 c^2(2c+9\epsilon) + 3a\alpha^2\beta c(31c+94\epsilon) + a^2\alpha\beta^2(95c+144\epsilon))}{2(45a^4\beta^4 + 42\alpha^4 c^3(2c+9\epsilon) + 3a\alpha^3\beta c^2(107c+450\epsilon) + a^3\alpha\beta^3(233c+513\epsilon) + a^2\alpha^2\beta^2 c(425c+1497\epsilon))}$$

$m = 3$: $t_1 = t_2 = t_3 = 0 \quad e_c = \frac{9\alpha b}{2a\beta + 6\alpha(c+9\epsilon)}$

[16] Mathematica v12

The identical results for $m = 0$ are due to the fact that there are only fringe countries, with the same trade arrangements.

For $m = 3$ the difference to the previous case lies in the fact that the coalition countries still have tariffs available, but (endogeneously) choose to set them to 0.

3. Fringe Countries with Free Trade Finally, for the case where the fringe countries have free trade among themselves the results read:

$m = 0$: $\quad e_i = \frac{3\alpha b}{2a\beta + 6\alpha(c+3\epsilon)} \quad i = 1, 2, 3$

$m = 2, 3$: Same as in the first case

The identity of the last two cases results from the fact that there is either one ($m = 2$) or no fringe country ($m = 3$). In both cases, the coalition countries have the same trade arrangements, while there is no (other) fringe country to have free trade with.

Numerical Probabilities

$m_{\neg PFTA}/m_{PFTA}$	0	2	3
3	0 %	0 %	34.1485 %
2	0 %	0 %	10.1496 %
0	0.81352 %	5.85928 %	49.0291 %

Table 2: Coalition Size Outcomes with and without Free Trade

$m_{\neg PFTA}/m_{PFTA}$	0	2	3
3	0 %	0 %	93.3272 %
2	0.154956 %	5.82538 %	0
0	0.658564 %	0.0338967 %	0 %

Table 3: Coalition Size Outcomes with Fringe PFTA and without Fringe PFTA

	Decrease	Unchanged	Increase
WO	0 %	34.962 %	65.038 %

	Increase	Unchanged	Decrease
DO	0.10169 %	34.962 %	64.9363 %

Table 4: Changes Global Welfare and Damages