Modelling trade and climate change policy: A strategic framework for global environmental negotiators

Article *in* Journal of Water and Climate Change · June 2016

DOI: 10.2166/wcc.2016.123

Khalid Ahmed
University of Cambridge

Naveed Shaikh
Shaheed Zulfikar Ali Bhutto Institute of Science and Technology, Dubai

Ilhan Ozturk
Çağ Üniversitesi

Modelling trade and climate change policy: a strategic framework for global environmental negotiators

Khalid Ahmed, Naveed Ahmed, Muhammad Shahbaz, Ilhan Ozturk and Wei Long

ABSTRACT

In the past, failure of trade–climate talks might have created negative signs, but international trade actually induces more participation and helps to attain joint agreement. Carbon permit trading has a key role to play in the abatement process. Participation in global multilateral negotiations and a country's self-interest with respect to entering an abatement process depends upon either the scale of climate change damage or the punishment level that affects its economy. Thus, this study assumes N good cases for countries that have substantial emission levels. We analyse the change in utility function through a business-as-usual scenario for both group and individual country levels. The model designed in this study examines the data on emissions and GDP for selected developing and developed countries and the rest of the world. The data calibrations are similar to those of Cai *et al.* (2009) and use the temperature and emission projections of Mendelsohn (2007) and Stern (2006), respectively. However, this study extends the model to a strategic level at which countries can choose coalition partners to undertake abatement for mutual benefits, considering the terms of trade. The results possess strong trade–environment policy options and help them to reach certain multilateral agreement.

Key words | climate change, tariffs, trade

Khalid Ahmed
Sukkur Institute of Business Administration,
Sukkur 65200,
Pakistan

Naveed Ahmed
Shaheed Zulfiqar Ali Bhutto Institute of Science and Technology (SZABIST), Dubai International Academic City,
Dubai,
UAE

Muhammad Shahbaz
Energy Research Center,
COMSATS Institute of Information Technology,
Lahore,
Pakistan

Ilhan Ozturk (corresponding author)
Faculty of Economics and Administrative Sciences,
Cag University,
33800 Mersin,
Turkey
E-mail: *ilhanozturk@cag.edu.tr*

Wei Long
Wuhan University of Technology,
Wuhan,
Hubei,
P.R. China

INTRODUCTION

The increasing participation in global climate change talks even after consecutive failures demonstrates the strong motivation of nations to reach a certain outcome. Such continual motivation not only serves to protect the global environment but also incurs the least possible harm to countries' individual economic development. Ahmed & Long (2013) opine that the 'time factor' plays a vital role towards the success of climate change negotiations, and their findings anticipate several more rounds of multilateral talks to reach unanimous joint agreement. However, how is such slow-paced progress tolerable in view of the increasing cost of environmental damage? Progress is strategically necessary for all stakeholders. However, the period can be minimized if a comprehensive policy tool is recognized by both developing and advanced countries that are also the major players in negotiations. To solve this situation strategically, countries must be provided incentives and bear penalties for their positive and negative actions, respectively.

This study initially determines the incentive for an individual country, which potentially increases the participation rate. Subsequently, non-participating countries are strictly dealt with via punishment. Here, punishment is referred to as 'tariffs', and incentives are referred to as 'side payments' or 'carbon permits'. The key rationale behind such a strategic setting is to address the global externality of climate change, which requires collective efforts to address. Explicit

doi: 10.2166/wcc.2016.123

scholarly work is available on both international trade and the environmental community to demonstrate this issue, and various policy options are under consideration, which are actively discussed in negotiations. However, a paucity of scientific work exists that could lead to viable policy options for cooperation based on the self-interest of participating countries (Jacoby *et al.* 1999; Najam *et al.* 2003; Aldy & Stavins 2007; Peters & Hertwich 2008; Mattoo *et al.* 2009; Hufbauer *et al.* 2009; Madani 2013).

The increasingly adverse effects of changing climate have already resulted in substantial natural disasters globally, and developing countries are highly vulnerable to such effects (Messerlin 2010; Ahmed & Long 2013). Although the international community is sufficiently convinced to declare climate change the greatest threat in history, consensus must develop for multilateral agreement. To analyse the decision process of nations under certain complex situations, a game theoretic framework provides exhaustive solutions at various strategic levels. Game theory is an essential tool to investigate the cooperative and non-cooperative behaviour of players in various strategic situations. It has long been a tradition to test unilateral and multilateral efforts of global key climate change players and their political interactions, which underscore international negotiations. In addition to presenting an extended survey, we would rather focus in this section on the role of international trade in such strategic negotiations to support cooperative outcomes.

Recent studies argue that countries' willingness to participate extensively in climate change negotiations depends upon two key factors: the incentive provided to enter negotiations and the level of damage caused by global warming (Helm 1994; Carbone *et al.* 2009; Ostrom 2010; Nordhaus 2010; Pittel & Rubbelke 2012; Harstad 2012). The research exclusively covers the topic of what makes players negotiate. The first case more affects the participation of small countries, whereas the latter case is more convincing for advanced economies. For example, the United States did not sign the Kyoto Protocol, but the increasing natural calamities in the country have finally convinced it to formalize climate change policy. This study is based on an incentive-oriented policy because, to enhance the participation of small countries in global climate change negotiations, time is needed. Thus, international trade can play a vital role in shaping various abatement and adaptation tools (e.g., Border Tax Adjustments, emission permits, carbon capture, green technology transfer and technical assistance).

This work is based on the work of Shapley & Shubik (1969), who state that the participation of small countries is more likely if they are provided with incentives. The argument is that the cost of abatement for small players (small countries) is greater than the benefit arising from improved environmental quality. Therefore, the core of the game is empty without incentive or, more precisely, a transfer utility (similar work is followed and supported by the arguments of Barrett (1994, 1997), Uzawa (1999), Walsh & Whalley (2008) and Cai *et al.* (2009)). Initially, we have followed the structure of Uzawa (1999), which was followed by Cai *et al.* (2009) and Tian & Whalley (2010) with transferable utility. Unlike these last two, our study includes penalties to force participants, which are feasible if climate change damage exceeds the projections of Mendelsohn (2007) and Stern (2006). Hence, we use carbon tariffs as penalty, financial transfers as reward and carbon emission permits (emission trading) as strategic incentives – which could be the least costly method to reduce emissions if financial transfers are less than expected. The model used in this study extends to tradable carbon permits as non-cooperative arrangements and discusses the outcomes. When countries are given a strategic choice to participate in abatements voluntarily, carbon permits provide a cost-effective means of accomplishing the desired goal. Similarly, the simulation results are based on the non-cooperative outcomes.

The recent climate change talks (Copenhagen, Durban and Doha) demonstrated that without the substantial participation of large developing economies, climate change negotiations will remain fruitless. Therefore, it is necessary to include large developing economies, i.e., Brazil, Russia, India, China, South Africa, Mexico and Turkey (hereafter referred as BRICS + 2). We have thus chosen the data on trade and consumption for OECD countries, large non-OECD countries (BRIC + 2 in this study) and the rest of the world (ROW). The data also include the countries' GDP average ratio from 2007 to 2009 with base year 2006. The model is calibrated with a business-as-usual (BAU) scenario assumption. Therefore, we estimate the same data to alternate with global climate change estimated data presented in Stern (2007) review, which states that the global temperature increase will reach 3 °C and 5 °C by 2036 and 2056, respectively. Similarly, we analyse single periods of either 30 or 50 years.

Furthermore, we assess the effect of penalties (tariffs) assessed using the Armington (1969) trade elasticities model, which evaluates countries' decisions and willingness to participate in negotiations. The countries' reduction in the consumption of own single homogeneous good tends to increase environmental gains, and higher tariffs on imported products increase the share of participation. However, aside from transferring large financials as in the case of Tian & Whalley (2010), carbon permits are more likely feasible as incorporated in our study. Carbon permits not only induce higher willingness to participate but also incur less cost for carbon reduction. Hence, they provide the trade equilibrium of single good and carbon permits. The recent literature, which depicts non-cooperative outcomes in various environmental negotiation games, encourages the inclusion of trade permits at group and sub-group levels as a strategic incentive. We have simulation results that support this argument and extend this model. Moreover, if financial transfers from the developed countries are not provided or, if provided, are not sufficient, carbon permits provide an alternative policy option to governments to endow emission rights at regional and sub-regional levels to enhance welfare. In our study, these countries largely either do not participate in negotiations or are countries in ROW (in the model). These countries are less attractive to large economies but are affected by the climate change externality.

As mentioned by Weber & Peters (2009), trade presents challenges to climate policy through carbon leakage and competitiveness concerns but also presents potential solutions via cooperative trade agreements, technology transfer, or carbon tariffs against recalcitrant nations. In addition, according to Peters & Hertwich (2008) and Weber & Matthews (2007), international trade can undermine climate policy through carbon leakage and competitiveness concerns. Weber & Peters (2009) investigated how trade might affect climate policy in the US and specifically examined the use of carbon tariffs as suggested by recent bills before the US Congress. Consequently, Weber & Peters argue that although political agreement might necessitate at least the threat of carbon tariffs, cooperative agreements such as global sectoral agreements and technology sharing could be more productive in the short term.

In light of the above discussion, it is revealed that past work has mostly emphasized large penalties or financial transfers to induce the participation of countries in the negotiations. However, this study tries to analyse both the cases when countries are convinced in their self-interest through penalties or financial transfers and when countries decide not to participate at all. In the latter case, there is a possibility of co-operation between non-cooperating countries. In such a case, carbon permits provide an alternative policy option that allows these countries to co-operate in self-interest primarily based on the rising threats of climate change or the cost of damage due to climate change in their countries. These countries can co-operate at regional and sub-regional levels when seeking welfare effects from carbon emission permits. It has been long contested whether the large developing economies should enter negotiations. However, our findings would provide a sufficient scientific basis for their decision whether to enter multilateral agreement or not. In addition, our simulation results help BRICS + 2 countries determine whether entering a multilateral agreement is feasible for them in their current state. The policy implications of this study are extremely significant for climate change negotiations under the United Nations Framework Convention on Climate Change (UNFCCC).

MODEL DESCRIPTION

This study attempts to analyse empirically how international trade induces greater participation and helps to attain joint or multilateral agreement. Carbon permit trading has a key role to play in the abatement process. Participation in global multilateral negotiations and a country's self-interest in adding to the abatement process depend upon either the scale of climate change damage or the punishment level that affects its economy. To perform the analysis, we assume one good case and N good cases for countries with substantial emission levels. We analyse the change-in-utility function under the BAU scenario at individual and group levels. The model seeks data on emissions and GDP for BRIC + 2 countries, selected OECD countries and the ROW. Later, these groups are also referred to as regions and coalitions. We calibrate the data under the BAU scenario, in which we assume no change in countries' growth rates for the model period (i.e., 30 and 50 years) based on Mendelsohn & Williams (2007) and Stern (2006), respectively. The projections assume that keeping the current level of growth and emissions levels constant, the earth's temperature will rise by 3 °C and 5 °C and changes in product form less than 1% and up to 20%, respectively. These assumptions follow the alternative projections based on the BAU scenario, in which the growth rate was measured as of 2006. However, the data calibration in this study takes the GDP of each country from 2006 (which is an average of 2005 to 2007 to reduce the error in future projections). Using this data calibration will subsequently help us to assess the welfare effect by changing consumption in the regions. (We analyse the effect of composite consumption of goods (exported and imported) by a country. The goods are both single homogeneous and 'N' good case.) For later assumptions of financial transfers and tariffs or trade sanctions, the assumed cost of abatement and, in some cases, discount rate are also used as indicators.

Furthermore, we assess the role of international trade on participation using the Armington model, which defines a country's consumption of own goods and imported goods in the case of a non-homogeneous or N good case. Higher tariffs on imported goods lead to inducing participation, but countries opt to rely on their own goods in a one-good case. Our results show that for a coalition, the effects of higher tariffs are more feasible than in the individual case. The OECD countries can enhance participation of major non-OECD countries (BRIC + 2 in this study) through tariff lines, financial transfers and emission permits. Due to a trade effect over the consumption pattern, the change in own consumption would be a mixture of a country's consumption of own goods and imported goods. The trade equilibrium with respect to temperature change arising from such a situation has three levels: temperature change and utility function, composite final good consumption and composite imported goods.

Subsequently, we have analysed the financial transfers to offset the cost effects of participation to major developing countries. It is essential to provide countries with an incentive after imposing high tariff lines to minimize the withdrawal ratio. The financial transfer will induce more participation in such scenarios. Although it is expected that the combination of trade penalties along with appropriate transfer will induce an improved participation ratio, it is likely that few developed countries will agree to transfer large amounts. Hence, transfers can be equal to or comparatively less than the benefits arising from emission reductions by OECD countries. Another potential problem in financial transfers could be determining the mode of such transfers. Would they require a specific regulatory agency? There exist well-working international trade and environmental bodies, i.e., the World Trade Organization (WTO) and the UNFCCC, respectively. WTO can address trade sanctions and their implications, and UNFCCC can scientifically regulate climate protection measures and their levels to disseminate funds and set up tariffs transparently. In the long term, the possibility of a separate and independent regulatory body can also be established to undertake the task. However, a later part of this paper discusses this issue in detail.

The use of financial transfers for participation is a highly feasible strategy when countries have mutually vested trade interests. In such cases, when countries are reluctant to execute transfers or if they do transfer but not the amount projected, carbon trading is used as an alternative strategy. Carbon trading is also driven by self-interest, with an outcome of the same repercussions assumed under the rest of the model. Moreover, under a non-cooperative strategy, carbon trading works by each country deciding its emission rights by viewing its marginal reduction in emission cost. This approach also gives a country the right to behave strategically within its region and formalize terms of trade.

Utility change function and Cobb–Douglas form for each country

The model used in this section is based on the Cobb–Douglas function, which is a standard production function of a single good with two factors as mentioned in Equation (1). In its original form, the function has two output utility functions, denoted by α and β for labour and capital:

$$Y = AL^{\beta}.\, K^{\alpha} \tag{1}$$

Turning to this study case, the model here involves a BAU scenario consisting of a single-period analysis in which each country grows at the same growth rate throughout the model period, for example, 30 or 50 years. Each country is assumed to have a single heterogeneous good that is consumed and either is produced domestically or is imported. The same consumption is linked with emission produced out of that potential consumption, which subsequently aids global temperature rise. The utilities are associated with consumption and temperature change; utility coming from consumption is considered positive, and utility of temperature change is treated as negative. Countries have upper-bound limits in consumption (for domestically produced goods); consumption of amounts less than those limits would also reduce the temperature rise effect for the rest of the model countries. The utility function is assessed for the consumption of goods and for temperature change for 30- and 50-year periods, in which change in potential consumption shows the potential output from a single country over the same period.

As mentioned by Equation (2) in Cobb–Douglas form, where ΔC_k shows the consumption changed over the period for each country k, consuming a good appears in utility form as mentioned earlier. G represents the global temperature, which is considered the point, i.e., 15 °C no economic activities can continue. When ΔG (change in temperature) reaches that point, the utility becomes zero, which means that there will be no welfare effect associated with temperature change. β denotes the utility term of increasing adverse effects of temperature change, which later is calibrated to identify various other damage using the BAU global temperature change predicted by Stern (2006) and Mendelsohn & Williams (2007).

$$\Delta U_k = \Delta U_k\ (\Delta C_k,\ \Delta T) = \Delta C_k^{\alpha}.(\frac{G - \Delta G}{G})^{\beta} \tag{2}$$

As global temperatures change, emissions also change. Therefore, to identify an individual country's emission intensity, we simply use the temperature change function. This function is determined by the country's consumption change and emission level. The country's emission level is used as power b in the model period in Equation (3):

$$\Delta G = g\left(\sum\nolimits_k^e \Delta C_k\right) = a\left(\sum\nolimits_k^e \Delta C_k\right)^b + c \tag{3}$$

Considering the country's decision to participate in negotiations, which depends entirely upon the utility associated with the reduced consumption and changed temperature, if utility lost with lowering consumption is greater than the utility gained with lowered temperature because of reduction in consumption, the country will be willing to participate. In other cases, the country will be better off. This decision to participate is algebraically shown by Equation (4). The participation will occur if $d\Delta U_k/d\Delta C_k$ is negative.

$$\frac{d\Delta U_k}{d\Delta C_k} = \frac{\partial \Delta U_k(\Delta C_k, \Delta T)}{\partial \Delta C_k} + \frac{\partial \Delta U_k(\Delta C_k, \Delta T)}{\partial \Delta T}\frac{\partial(\Delta T)}{\partial \Delta C_k} \leq 0 \tag{4}$$

$$\frac{d\Delta U_n}{d\Delta C_n} = \frac{\partial \Delta U_n(\Delta C_n, \Delta T)}{\partial \Delta C_n} + \frac{\partial \Delta U_n(\Delta C_n, \Delta T)}{\partial \Delta T}\frac{\partial(\Delta T)}{\partial \Delta C_n} \leq 0 \tag{5}$$

The same in Cobb–Douglas is presented by Equation (6):

$$\frac{d\Delta U_k}{d\Delta C_k} = \alpha\left(\frac{G - \Delta G}{G}\right)^{\beta} \Delta C_k^{\alpha - 1} - \frac{\beta}{G}\,\Delta C_k^{\alpha}\left(\frac{G - \Delta G}{G}\right)^{\beta - 1} abe_k\left(\sum\nolimits_k^e \Delta C_k\right)^{b-1} \leq 0 \tag{6}$$

$$\frac{d\Delta U_n}{d\Delta C_n} = \alpha\left(\frac{G - \Delta G}{G}\right)^{\beta} \Delta C_n^{\alpha - 1} - \frac{\beta}{G}\,\Delta C_n^{\alpha}\left(\frac{G - \Delta G}{G}\right)^{\beta - 1} abe_n\left(\sum\nolimits_n^e \Delta C_n\right)^{b-1} \leq 0 \tag{7}$$

Role of international trade in climate change negotiation participation

In this section, we analyse the role of international trade in global climate change negotiation participation. Using the Armington structure and unlike in the previous section, we here employ nested constant elasticity of substitution (CES) for each good in each country case, seeking N good N country in the model. In the presence of trade, the country's own good consumption does not equal its potential change in consumption. That change depends upon the composite of all good consumptions, which is used by different countries because the same goods are also exported to other countries.

Therefore, the temperature change and top-level utility functions are expressed by Equations (8) and (9).

$$\Delta U_k = \Delta U_k\,(\Delta CR_k,\ \Delta T) = \Delta C_k^{\alpha}\cdot\left(\frac{G-\Delta G}{G}\right)^{\beta} \tag{8}$$

$$\Delta G = g\left(\sum\nolimits_k^e \Delta CS_k\right) = a\left(\sum\nolimits_k^e \Delta CS_k\right)^b + c \tag{9}$$

where ΔCR_k denotes the overall change in consumption and is presented in Cobb–Douglas form similar to Equation (2). However, here, composite consumption for country is associated with temperature change function, and the explanation for ΔT and β will remain the same. ΔCS_k denotes the own good consumption by country k, whereas e_k is exogenous and constant to the base year of 2006. Moreover, ΔCR_k must be equal to or less than ΔCS_k in a top-level composite consumption and temperature change function. Alternatively, in one good case previously mentioned, ΔCR_k must equal ΔCS_k. ΔCS_k is the upper-bound limit and determines the country's decision to participate in negotiations. As in this study's model, we have three groups of countries: OECD, BRIC + 2 and ROW, pertaining to the condition in which countries must initiate a carbon reduction based on a percentage given by composite consumption of goods. A similar trend is followed by other countries over time. The decision to join the negotiations, particularly by BRIC + 2 countries, is essential and tends to respond to certain incentives.

In a nested CES function shown as CR_k in Equation (10), we have used a similar but a production function later in carbon permit trading. Composite consumption of both a domestic and an imported good by a country is determined by solving an optimization problem at the third level of nesting, as shown in Equations (10)–(12). Here, D_k and M_k represent domestic and imported consumption; their prices are p_k^i and p_k^j, respectively. σ is a substitution elasticity, and consumption share is represented by α_1^k and α_2^k. This model is similar to the Armington model, with N goods and N countries.

$$Max\ CR_k = CR_k(D_k, M_k) = \left(\left(\alpha_1^k\right)^{\frac{1}{\sigma}} D_k^{\frac{\sigma-1}{\sigma}} + \left(\alpha_2^k\right)^{\frac{1}{\sigma}} M_k^{\frac{\sigma-1}{\sigma}}\right)^{\sigma/(\sigma-1)} \tag{10}$$

$$s.t.\, p_k^i D_k + p_k^j M_k \le I_k = p_k^i CS_k \tag{11}$$

$$M_k = \frac{\alpha_2^k I}{\left(p_k^j\right)^{\sigma}\left(\alpha_1^k\left(p_k^i\right)^{(1-\sigma)} + \alpha_2^k\left(p_k^j\right)^{(j-\sigma)}\right)} \quad (k = 1\ldots, n) \tag{12}$$

$$D_k = \frac{\alpha_1^k I}{\left(p_k^j\right)^{\sigma}\left(\alpha_1^k\left(p_k^i\right)^{(1-\sigma)} + \alpha_2^k\left(p_k^j\right)^{(j-\sigma)}\right)} \quad (k = 1\ldots, n) \tag{13}$$

Similarly, to determine the composite imported good case, the CES function in the Armington trade model is the N-1 goods case because a country can export one good and imports N-1 goods as shown by Equations (14) and (15). This result derives from sub-utility maximization and is given by Equations (16) and (17). R is a country that imports good s from country k. p_k^i are prices. The consumption share and substitution elasticity of the 2nd level is denoted by (R_s^k) and (σ_j), respectively.

$$Max\ M_k = H\left(C_1^k,\ C_2^k,\ C_3^k,\ \ldots C_{k-1}^k,\ C_{k+1}^k,\ \ldots C_n^k\right) = \left(\sum_{s\neq k} (R_s^k)^{\frac{1}{\sigma_j}} (Q_s^k)^{(\sigma_{j-1})/\sigma_j}\right)^{\sigma_j/(\sigma_{j-1})} \tag{14}$$

$$s.t. \sum_{s\neq k} p_s^{f_k} Q_s^k \le I_k^i = p_k^i M_k \tag{15}$$

$$p_k^i\left[\sum_{s\neq k} R_s^k (p_s^{f_k})^{1-\sigma_j}\right]^{1/(1-\sigma_j)} \tag{16}$$

$$Q_s^k = \frac{R_s^k\ p_k^i\ M_k}{p_s^{f_k}\sum_{s\neq k} R_s^k (p_s^{f_k})^{1-\sigma_j}} = \frac{R_s^k (p_k^i)^{\sigma_j} M_k}{(p_s^{f_k})^{\sigma_j}} \tag{17}$$

Trade equilibrium and decision to participate in negotiations

The trade equilibrium in this structure is given by ΔCS_k for prices $p_k^i \cdots p_k^n$; therefore, the global market clears Equation (18):

$$\sum_{s\neq k} Q_k^s + D_k = \Delta CS_k \qquad (k = 1,\ \ldots, N) \tag{18}$$

The reduction in ΔCS_k will result in decreased emissions but, unlike in the one-good case, the reduction will affect all of the countries due to the trade effect for all quantities and prices. Thus, the decision to participate in negotiations will be more likely due to burden sharing. This trade-consumption nested model assesses utility change over composite consumption change and temperature change. The model has both a trade and a non-trade effect. The change in ΔCS_k will have a direct effect on consumption change. The reduction on own good consumption will result in lowering the price for good k, which is a loss and is referred to as the budget constraint of the country. In our model, this example can be mentioned because OECD countries' reducing ΔCS_k will increase the BRIC + 2 countries willingness to participate. For BRIC + 2 countries to do the same, they need incentives to cover their GDP loss in the form of transfers based on percentage of GDP. The change in consumption is exogenous and varies from country to country.

Model enhancement

Strategic interaction in the absence of cooperation and data calibration: We have enhanced this model to a strategic level in which countries do not participate in negotiations but instead form small coalitions to trade emission permits within their regions. This is most likely the case if developed countries (OECD in this study) refuse to transfer to developing countries (BRIC + 2). For this purpose, we have used the same BAU scenario with fixed investment, taxes and revenues, with growth projections assumed in our case up to 2015. The regions are divided into Japan, China, USA, EU, Russia, Brazil, Australia, India and ROW. The abatement cost is projected as the region's willingness to participate.

The equilibrium outcome in this case would be given by Equation (19):

$$1/E_k^d[\mu_b k + \nabla k] - \sum_s Sv(1 + \frac{derow}{de\vartheta_k^b}) = 0 \qquad (19)$$

where E_k^d represents the unit expenditure function with E market price and d consumption and k is a region. μ_{bk} denotes the price of an emission right in which μ is the vector price of emission right b in region k. μ_{bk} also determines the cost associated with the reduction in marginal emission rights for region k. ∇k represents the conventional markets in which emission rights are bought and sold between agreement parties. $\sum_s Sv$ is a global emission level, and $1 + (derow/de\vartheta_k^b)$ determines the carbon leakage. This notation considers that the terms of trade in carbon trading come with caps. Thus, the only source of leakage can come from non-strategic partners, which in this case are the ROW countries. ϑ_k^b denotes emission permits in region k.

The international trading system provides the base for emission trading. Coalitions can be formed at regional and sub-regional levels, and they have the right to fix the terms of trade. The coalitions can be formed, reformed and transferred. When giving the Armington treatment, the elasticities in the Armington model are the best source to determine the value of carbon leakage and provide a term of trade effect.

DATA ANALYSIS

Consumption and environment trend under utility change function

After having constructed a mathematical representation of our model, the data are now calibrated to evaluate the results. For this purpose, we have derived the relevant data from two key sources: the World Development Indicators (WDI) of the World Bank and Stern Review (2007). We have used the larger groups (coalitions) and individual countries in our analysis to develop more practical results for further policy recommendations. The key developing and developed economies are covered in our study to establish a dynamic policy base. First, we analyse the trend of consumption and environment in terms of the utility function, in which we assume single good and N-good cases for the model countries and groups mentioned in Table 1, under the BAU scenario as the base case of the model. The projections are spread over 30 and 50 years based on Stern (2006) and Mendelsohn & Williams (2007), respectively, assuming no change in GDP growth rate of model countries and groups over the same period. The GDP is given for the base year 2006, but the figures are an average of 2005 to 2007 for each economy and region. These average

Table 1 | Average current GDP (2005–2007 in $US trillions) of model countries and 2036 and 2056 projections

Country name	Country code	2005	2006	2007	Average (base 2006) (CS_k^{2006})	By 2036 (CS_k^{2036})	By 2056 (CS_k^{2056})
BRIC + 2	BRIC + 2	6.07	7.22	9.08	7.46	444.93	2,210.83
Brazil	BRA	0.88	1.09	1.37	1.11	33.73	130.98
India	IND	0.83	0.95	1.24	1.01	58.88	281.55
China	CHN	2.26	2.71	3.49	2.82	244.39	1,323.07
Russia	RUS	0.76	0.99	1.30	1.02	62.22	298.04
Mexico	MEX	0.85	0.95	1.04	0.95	28.35	99.12
Turkey	TUR	0.48	0.53	0.65	0.55	17.36	78.07
OECD members	OED	35.80	37.76	41.34	38.30	432.99	1,507.14
EU	EMU	10.14	10.76	12.37	11.09	112.05	313.69
USA	USA	12.56	13.31	13.96	13.28	176.31	573.43
Japan	JPN	4.57	4.36	4.36	4.43	48.67	161.33
S. Korea	KOR	0.84	0.95	1.05	0.95	40.76	137.24
Canada	CAN	1.13	1.28	1.42	1.28	42.18	111.38
Australia	AUS	0.69	0.74	0.85	0.76	35.92	148.43
UK	GBR	2.30	2.45	2.83	2.52	44.87	153.66
ROW (less BRIC + 2 and OECD)	ROW	–	–	–	4.59	43.73	89.14
World	WLD	–	–	–	50.35	921.65	3,807.11

Source: Author's own compilation from World Bank.

figures tend to render more appropriate results in later calculations of tariffs and financial transfers, which ought to show as a ratio of GDP. The discount rate is set to 1.5% and remains unchanged, similar to GDP growth under BAU. The illustration of base year (2006) GDP in terms of volume is shown in Table 1. The BAU output projections of the model's assumed periods of 30 and 50 years (2036 and 2056) are also mentioned in Table 2. The change in production output (ΔCS_k) is determined by the change in consumption (ΔCR_k) through the welfare effect of each country, which subsequently helps countries to decide whether to participate in negotiations.

The welfare effect of an individual country is evaluated through assuming a 1% reduction in consumption and its counter effect of environment quality; countries decide to participate when the loss of consumption utility is less than the utility gained from environmental quality. This notion is applicable in model parameters after calibration. In the next step, we move to the emission intensity with respect to output, in which we assume that a change in consumption is associated with the temperature change function.

Consumption and temperature change under utility change function

Here, we assume the BAU scenario in terms of utility function in which the change in consumption changes temperature. The goods are consumed by the country itself or traded beyond its borders during the model time, for example, over 30 or 50 years. The trade expands over the base case; thus, a global temperature results, which creates global warming. This situation is similar to the above case because utility gained from the consumption of composite goods (either imported or own) is associated with the utility loss from a rising global temperature, as represented previously in Equations (8) and (9). For this purpose, we use the following data as shown in Tables 3 and 4. The emission level and emission intensity of model countries in the base year of 2006 and projections over 30 and 50 years are treated as a single period in the model. This approach helps us to analyse the effect of goods used and utility over the nil growth in the period. The same trade data are used to analyse imports/exports, considering BAU under the uniform

Table 2 | Projected* output ($US trillions) with discounting and PPP respectively by 2056

Country name	Country code	By 2036	By 2056
BRIC + 2	BRIC + 2	804.55	4,422.20
Brazil	BRA	52.31	183.26
India	IND	88.47	703.66
China	CHN	436.01	2,778.33
Russia	RUS	93.98	478.71
Mexico	MEX	70.34	150.11
Turkey	TUR	63.44	128.13
OECD members	OED	540.76	1,322.00
EU	EMU	141.05	313.52
USA	USA	280.91	573.29
Japan	JPN	63.68	161.22
S. Korea	KOR	58.31	130.69
Canada	CAN	47.56	129.46
Australia	AUS	41.92	11,146
UK	GBR	57.33	102.92
ROW (less BRIC + 2 and OECD)	ROW	171.83	329.69
World	WLD	1,517.14	6,073.89

* Projections based on Stern (2006) and Mendelsohn (2007).

growth rate of the base year (2006 in this study) and zero balance in total. The calibration of the temperature change and damage function is taken from the projections proposed by Stern (2006) and Mendelsohn & Williams (2007).

Table 4 in particular enumerates the projected emission profile of BAU in cumulative form, which further helps us to ascertain the damage cost and financial support required for key developing countries to undertake emission reduction.

Table 5 illustrates the present emission level (base year 2006 level), average growth rate and projected emission concentration over the model period w.r.t. the cumulative profile up to 2036 and 2056. All projections are in billion metric tons (BMT).

Table 5 shows the emission projections in terms of discounting GDP over the model period only by 2056 (50 years in this case). However, in the case of non-cooperation, if the damage cost at some level exceeds the benefits of growth, countries are supposed to initiate climate change efforts in their self-interest. This notion is analysed in the further extended model, in which countries do not participate in negotiations but instead take unilateral efforts or form coalitions on their own in which they are more comfortable. Similarly, trade helps in such a case, with a strategy including carbon trading in international and domestic markets.

Table 3 | Average emission level (2005–2007 in BMT) and projected emission concentration by 2036 and 2056

Country name	Average emission level (2005–2007) as base of (2006) (Δe_i^{2006})	Emission international level 2006	Projected average growth rate	Projected PPP index
BRIC + 2	10.08	11.32	0.31	10.24
Brazil	0.52	0.49	0.04	1.43
India	2.03	2.34	0.06	2.51
China	4.23	2.13	0.07	2.13
Russia	2.59	2.37	0.06	1.62
Mexico	0.44	1.98	0.04	1.34
Turkey	0.27	2.01	0.04	1.21
OECD members	13.11	3.14	0.14	5.06
EU	4.04	0.31	0.015	0.85
USA	5.81	0.49	0.02	1.01
Japan	0.49	0.26	0.015	0.95
S. Korea	0.48	0.25	0.01	0.67
Canada	0.56	0.21	0.01	0.61
Australia	0.38	0.29	0.02	0.53
UK	0.53	0.37	0.01	0.44
ROW (less BRIC + 2 and OECD)	7.46	6.62	0.17	0.92
World	30.65	21.08	0.62	16.22

Source: Author's own compilation from WDI World Bank.

Emission-trading arrangements

To analyse a potential negative of strategic interaction in climate change, we analyse the possibility of emissions trading if countries refuse to enter negotiations and form independent coalitions and groups to abate emissions. In this respect, carbon trading provides the best alternative, particularly to developing countries. Tariffs and financial transfers might not be a feasible strategy for developed countries, in two cases in particular: if the ratio of transfers is very high

Table 4 | Projected emission (BMT) by 2036 and 2056

Country name	Country code	By 2036	By 2056
BRIC + 2	BRIC + 2	871.49	4,432.60
Brazil	BRA	16.91	65.88
India	IND	118.07	566.9
China	CHN	542.74	2,940.97
Russia	RUS	160.44	771.00
Mexico	MEX	19.37	48.34
Turkey	TUR	13.96	39.51
OECD members	OED	255.65	658.38
EU	EMU	33.12	106.88
USA	USA	91.33	295.21
Japan	JPN	13.46	44.13
S. Korea	KOR	11.71	29.46
Canada	CAN	24.19	30.15
Australia	AUS	21.85	35.43
UK	GBR	9.99	17.12
ROW (less BRIC + 2 and OECD)	ROW	51.99	348.58
World	WLD	1,179.13	5,439.56

Table 5 | Projected emission (in BMT) in terms of discounting GDP by 2056

Country name	Country code	By 2056
BRIC + 2	BRIC + 2	804.55
Brazil	BRA	52.31
India	IND	88.47
China	CHN	436.01
Russia	RUS	93.98
Mexico	MEX	70.34
Turkey	TUR	63.44
OECD members	OED	540.76
EU	EMU	141.05
USA	USA	280.91
Japan	JPN	63.68
S. Korea	KOR	58.31
Canada	CAN	47.56
Australia	AUS	41.92
UK	GBR	57.33
ROW (less BRIC + 2 and OECD)	ROW	171.83
World	WLD	1,517.14

or the economic interests of developed countries are less than the financial needs of a developing country. This strategy provides freedom to countries forming coalitions to split and reform them, keeping in mind the terms of trade effects.

Model parameters/preferences

As mentioned in detail in the beginning, our model is based on a BAU scenario and projections made in Stern's review (2006) concerning emission intensities and the cost of damage associated with them. Following the same parameters, our model assumes a single period analysis, for example, 30 and 50 years, in which the global temperature rises by 3 °C, and the damage incurred due to the associated global warming is mentioned as the ratio of GDP, which is up to 1–20%. The utilities are associated with the consumption, and temperature change is associated with different damage effects. Table 6 shows an exact view of our model parameters and preferences in terms of temperature change and BAU.

In the extended part of the model, we have further included the GTAP trade data to evaluate the strategic interaction of countries and coalitions in non-cooperative arrangements (https://www.gtap.agecon.purdue.edu). For this purpose, the data parameters are set at 20 years as a single time preference, with energy, emission and GDP on a per capita basis. Finally, we also analysed the sensitivity of the model by altering data and assessing global temperature (G) under three different parameters, as mentioned in Table 6.

MODEL RESULTS AND INTERPRETATION

Trade-off between consumption and lowering temperature

The global individual and collective efforts in reducing the temperature are analysed through the assumption of a 1% reduction in consumption over the BAU path for 50 years. Tables 7 and 8 show the simulation results of various countries, large coalitions (BRIC + 2, EU, OECD) and ROW countries. The consumption is of one good that is homogeneous in nature and is an important source of emission. We assume that every country reduces its consumption (positive utility) to participate in the global effort to lower

Table 6 | Calibration preference over the model period

	Temperature change function			
	A	b		
	0.3	0.33		
	BAU assumption under temperature change function			
G (COD)	B	LOU	α	β
10 (15%)	0.25432	5%	0.95634	0.07848
		15%	0.85343	0.16325
10 (35%)	0.64872	25%	0.58788	0.29543
		30%	0.47868	0.49872
10 (50%)	1.00000	35%	0.36541	0.59740
		38%	0.31254	0.69473
20 (15%)	0.42354	40%	0.29890	0.62467
		42%	0.25431	0.76461
20 (25%)	0.76353	44%	0.21141	0.83980
		45%	0.18456	0.91547
20 (35%)	1.00000	46%	0.13654	0.93980
		47%	0.09349	0.94247
10 (10%)	0.49875	48%	0.06154	0.96093
		49%	0.03188	0.97543
30 (15%)	1.00000	50%	0.01717	0.98709

Table 7 | Change in utility w.r.t 1% change in consumption

	Assumed damage ratio				
Country name	**10%**	**20%**	**30%**	**40%**	**50%**
BRIC + 2	– 5.80	– 0.13	– 0.07	– 0.03	0.00
Brazil	– 0.39	– 0.18	– 0.07	– 0.02	0.00
India	– 0.85	– 0.37	– 0.08	– 0.01	0.00
China	– 3.75	– 0.78	– 0.09	0.00	0.00
Russia	– 0.98	– 0.49	– 0.06	0.01	0.00
Mexico	– 0.12	– 0.09	– 0.01	0.00	0.00
Turkey	– 0.07	– 0.02	0.00	0.00	0.00
OECD members	– 9.65	– 2.09	– 0.30	– 0.01	0.01
EU	– 4.01	– 0.90	– 0.28	– 0.03	0.00
USA	– 3.10	– 0.88	– 0.09	– 0.01	0.00
Japan	– 1.40	– 0.71	– 0.39	– 0.13	0.00
S. Korea	– 1.10	– 0.79	– 0.37	– 0.05	0.00
Canada	– 1.04	– 0.70	– 0.33	– 0.08	0.00
Australia	– 1.18	– 0.52	– 0.11	– 0.04	0.00
UK	– 1.68	– 1.13	– 0.70	– 0.02	0.00
ROW (less BRIC + 2 and OECD)	– 4.35	– 1.45	– 0.37	– 0.02	0.00

Note: The temperature assumed is 5 °C, time horizon 2006–2056 (single-good case).

the global temperature (negative utility). A non-negative value represents a country with a higher benefit from lowering temperature in comparison to loss of consumption utility. Tables 7 and 8 differ only in temperature assumption; Table 7 results are calculated with an assumed global temperature change of 5 °C and Table 8 shows the results of a 3 °C change over 50 years. The utility loss ratio is set as 10%, 20%, 30%, 40% and 50%.

Table 7, with an assumed global temperature of 5 °C, shows that the benefit of lowering temperature is higher than the cost of lowering consumption in developing countries at 40% and 50% assumed utility loss ratio, but overall change is slower. However, in the case of developed countries, the break-even is faster between the assumed ratio of consumption utility change; it is up to 20% and 30%. These countries have a lesser trade-off compared with developing countries (up to 50%); the larger countries reap more benefits in the form of a lowering temperature. In the form of large coalitions/groups –, i.e., BRIC + 2, EU, OECD and ROW – as mentioned, seven advanced nations are more inclined towards global climate change efforts compared with small and emerging economies. A similar trend is observed in Table 8, with an assumed temperature change of 3 °C with the exception of China, which has a trade-off at the 50% tier. The rest of the developing countries, i.e., Brazil, India, Russia, Mexico and Turkey, have lower trade-offs compared with developed countries. The overall results of this section imply that the developed countries receive greater benefits from global efforts to reduce temperature. The developing countries still are at a lower level in global efforts to reduce temperature. These results are assumed with no incentive, so it would be encouraging for developed countries to render incentives to enhance the participation of developing countries.

Trade-oriented negotiations and emission reduction commitments

Tariff effect w.r.t. welfare of BRIC + 2

As mentioned, in previous results, small countries' payoff is very high compared with the large economies.

Table 8 | Change in utility w.r.t 1% change in consumption

	Assumed damage ratio				
Country name	**10%**	**20%**	**30%**	**40%**	**50%**
Brazil	– 0.48	– 0.19	– 0.08	– 0.01	0.00
India	– 0.86	– 0.32	0.07	– 0.01	0.00
China	– 3.90	– 0.90	– 0.08	0.00	0.01
Russia	– 0.78	– 0.22	– 0.06	– 0.01	0.00
Mexico	– 0.35	– 0.12	– 0.05	– 0.01	0.00
Turkey	– 0.17	– 0.11	– 0.05	0.00	0.00
EU	– 2.67	– 0.99	– 0.30	– 0.07	0.00
USA	– 3.16	– 1.20	– 0.38	– 0.04	0.00
Japan	– 1.40	– 0.89	– 0.54	– 0.09	0.00
S. Korea	– 1.23	– 0.54	– 0.09	– 0.02	0.00
Canada	– 1.10	– 0.87	– 0.38	– 0.04	0.00
Australia	– 1.09	– 0.76	– 0.06	– 0.01	0.00
UK	– 1.40	– 0.19	– 0.09	– 0.03	0.00

Note: The temperature assumed is 3 °C, time horizon 2006–2056 (single-good case).

Consequently, the developed countries are also more inclined towards climate change negotiations. However, climate change is a global externality; therefore, global efforts are required to reduce global warming. In this scenario, developed countries push developing countries to take part in global efforts to share the responsibility. When the developing countries are resistant to participation in global efforts, the use of trade sanctions in the form of tariffs is considered to force the small countries to participate. The following are the simulation results of an analysis we made for BRIC + 2 countries (the major developing countries) both as a group and as individual countries in the case of trade sanctions (tariffs) used by OECD countries. The results are evaluated in terms of welfare effect of tariffs on developing countries. A country (countries) decides to enter global emission reduction commitments based on the welfare effect of tariffs. If the welfare effect of tariffs is less than that of participating in global commitments, a country (countries) decides to participate, or vice versa. Moreover, the damage cost is assumed at 10%, the temperature change assumption equals 5 °C and 50% proposed emission reduction targets within 50 years are employed as mentioned in the model and in the data calibration in subsequent paragraphs.

Table 9 illustrates the results of BRIC + 2 countries choosing as a group whether to participate in global negotiations on climate change or face tariffs. The table shows that if tariffs are imposed by all of the non-BRIC + 2 countries, the welfare effect will trade off at approximately 369%. Similarly, if the tariffs were only from the OECD region, the trade-off would be at 830%. The BRIC + 2 countries will only decide to participate in global commitment negotiations if the trade sanctions exceed the ratio of the bold text in Table 9. In individual cases, the trade-off differs from country to country, and our simulation results on single-country analysis are shown in the following, in which Tables 10–15 demonstrate the results for Brazil, India, China, Russia, Mexico and Turkey, respectively.

As shown in Table 10, Brazil will participate only if the tariffs are imposed up to 253% by all non-Brazil economies, and 6,788% in the case of OECD countries. The high ratio of tariffs in the OECD case means that the effect of trade sanctions on Brazil's welfare is very low. Thus, the participation of Brazil in global commitments is less desirable unless all non-Brazil countries and regions jointly impose trade sanctions.

Table 9 | Decision to participate or face joint tariffs, impact of tariffs on the welfare of BRIC + 2

Tariffs (%)	**By OECD**	**By all non-BRIC + 2**
0	– 39.44	– 39.44
20	– 37.92	– 37.87
50	– 33.45	– 31.76
100	– 27.65	– 22.25
200	– 20.21	– 9.65
369	– 12.56	**0.05**
500	– 6.38	8.43
830	– **0.03**	18.75
930	7.34	27.54

Table 10 | Decision to participate or face joint tariffs, impact of tariffs on the welfare of Brazil

Tariffs (%)	**By OECD**	**By all non-Brazil**
0	– 5.45	– 5.45
253	– 3.64	**0.01**
6,788	**0.03**	6.43

Table 11 | Decision to participate or face joint tariffs, impact of tariffs on the welfare of India

Tariffs (%)	By OECD	By all non-India
0	− 7.32	− 7.32
189	− 5.64	**0.07**
490	**0.02**	3.43

Table 12 | Decision to participate or face joint tariffs, impact of tariffs on the welfare of China

Tariffs (%)	By OECD	By all non-China
0	− 27.52	− 27.52
283	− 13.45	**0.04**
1,122	**0.01**	43.67

Table 13 | Decision to participate or face joint tariffs, impact of tariffs on the welfare of Russia

Tariffs (%)	By OECD	By all non-Russia
0	− 9.21	− 9.21
81	− 5.39	**0.05**
297	**0.01**	20.54

Table 14 | Decision to participate or face joint tariffs, impact of tariffs on the welfare of Mexico

Tariffs (%)	By OECD	By all non-Mexico
0	− 3.81	− 3.81
30	− 1.92	**0.09**
139	**0.01**	5.34

Table 15 | Decision to participate or face joint tariffs, impact of tariffs on the welfare of Turkey

Tariffs (%)	By OECD	By all non-Turkey
0	− 4.35	− 4.35
386	− 2.73	**0.06**
549	**0.02**	3.57

Table 11 shows the results for India. India's decision to join the international joint commitment is possible at an 89% tariff ratio by all non-India countries and 490% of OECD countries. Thus, the dependence of India's economy upon international trade is very high, and a small imposition of trade sanctions by large countries of the OECD can convince India to join climate change negotiations.

Table 12 illustrates the simulation results of key developing country China, which is not only the highest emitter but also the largest exporter in the world. The effects of trade sanctions are supposed to affect the fragile welfare of the country at a medium ratio. As shown in Table 12, China's participation in global environment negotiations occurs if the tariffs exceed 283% in the case of all non-China regions and 1,122% in the case of OECD economies. China's dependence upon world trade is very high, and its participation in global emission commitments is essential to mitigate substantial emissions in the future. Considering the results of the previous simulation reducing the 1% consumption in one homogeneous good case, China should be willing to participate if the damage cost is increased by 45%. These results are quite encouraging; if the tariff size is expanded up to 283% by all non-China regions, the participation of China is likely, keeping in mind the effect of tariffs on welfare.

Russia is also one of the largest emitters; its participation in global environment negotiations is important. Table 13 shows the results of tariffs' effect on the welfare of Russia if the country elects to face joint tariffs rather than take part in global commitments. Russia's trade-off between facing tariffs and participating in negotiations is at a very low ratio. The following results suggest that if tariffs of 81% are imposed by all non-Russian regions and 297% are imposed by only OECD countries, Russia will join with the joint commitment; otherwise, with tariffs lower than those shown, Russia would be better off not participating.

Table 14 display the results for Mexico. The results suggest that the participation of Mexico in global negotiations would be likely if tariffs up to 30% by all non-Mexico regions and 139% from OECD countries are applied. The reason for the high welfare effect of small tariff ratios is the high dependence of Mexican trade upon NAFTA and the country's very small proportion of trade with the ROW.

Similarly, Table 15 illustrates that Turkey's tariff proportion-to-welfare effect is higher than are those of Mexico, Russia and even India. The tariff ratio to be considered to streamline the role of Turkey in joint commitments is 386% and 549% of tariffs from all non-Turkey regions and OECD, respectively.

Financial support to developing economies inducing joint commitment

The third part of the analysis considers possible financial support from developed to developing countries. The developed countries, which are responsible for a major part of past emissions, are liable to compensate for the environmental damages observed today, and one of the best possible ways is transfers. To protect the world environment from further deterioration, global warming must be controlled or at least reduced in magnitude, based on a substantial portion of projections. Therefore, we analyse the volume of financial help (both in US dollars and as the ratio of percentage of GDP) to key developing countries, i.e., Brazil, India, China, Russia, Mexico and Turkey, from the developed countries, i.e., EU, US, Japan, S. Korea, Canada, Australia, and UK. The results also show the aggregate transfers figure between BRIC + 2 and OECD to provide the exact view of transfers volume. Adopting the same condition under BAU as for the last simulation results, Table 16 depicts the assumed financial transfers as percentage of GDP for a single country and group until 2036 and 2056. BRIC + 2 countries required 2.67 and 3.45% of their GDP on average in single periods of 30 and 50 years, respectively. Similarly, the OECD countries ought to fulfil the same requirement by rendering financial help of 1.83% and 3.95% of their GDP, on average, in the same period. Individually, by 2056, the percentages of recipients' GDP required from OECD countries for Brazil, India, China, Russia, Mexico, and Turkey equal 4.65, 5.34, 4.07, 6.03, 7.87 and 5.69, respectively. Likewise, EU, USA, Japan, S. Korea, Canada, Australia, and UK must share transfers of 4.49, 5.36, 5.41, 6.13, 3.98, 5.74 and 4.56, respectively, as the percentage of their GDP to developing countries. These transfers are assumed figures that can induce the active participation of developing countries in climate change mitigation and adaptation strategies.

Table 17 shows the transfers in terms of $US trillion assuming the 50% damage cost, which was similar to the last case. It is estimated that BRIC + 2 countries require

Table 16 | Assumed financial help (% of GDP) required to BRIC + 2 over model period

Country name	By OECD until 2036	By OECD until 2056
BRIC + 2	2.67	3.45
Brazil	1.39	4.65
India	1.61	5.34
China	3.14	4.07
Russia	2.81	6.03
Mexico	6.36	7.87
Turkey	4.73	5.69
Country name	**To BRIC + 2 until 2036**	**To BRIC + 2 until 2056**
OECD	1.83	3.95
EU	2.59	4.49
US	3.21	5.36
Japan	4.16	5.41
S. Korea	3.28	6.13
Canada	2.54	3.98
Australia	3.19	5.74
UK	2.15	4.56

$US 65.28 trillion from the OECD (group of advanced countries). The country-specific breakout of both developing and developed countries is illustrated by Table 17 in terms of dollars. China is the highest receiver of global transfers because the country is a crucial player in environmental negotiations and as partner in joint commitments.

More specifically, Brazil, India, China, Russia, Mexico and Turkey need 7.64, 14.42, 47.34, 15.04, 3.78, 1.65 ($US trillion), respectively, from OECD countries. China received the highest proportion of transfers, or approximately $US 47.34, which is approximately 70% of total transfers over the model period. The following table comprehensively shows how much an individual BRIC + 2 country needs in transfers from every individual developed country.

Emission trading coalitions in the case of non-cooperation

In some cases, countries do not cooperate in climate change control efforts and stand on their national agenda, financial transfers and tariffs lose their importance, and little effect is accomplished on emission abatement. Therefore, finally, we analyse the emission trading strategy between the countries and groups of countries that step forward in their national

Table 17 | Individual transfers (in $US trillions) from developed to developing countries

Country name	BRIC + 2	Brazil	India	China	Russia	Mexico	Turkey
OECD	65.28	7.64	14.42	47.34	15.04	3.78	1.65
EU	20.31	4.69	4.93	18.73	5.07	0.76	0.98
US	32.84	6.12	7.14	25.43	3.89	1.45	0.15
Japan	9.76	1.60	2.16	9.86	3.01	0.87	0.43
S. Korea	2.91	0.98	0.45	1.77	0.19	0.11	0.09
Canada	3.87	0.12	0.79	2.78	0.36	0.14	0.02
Australia	2.78	0.83	1.11	1.91	0.29	0.06	0.07
UK	4.27	1.17	1.34	4.28	1.45	0.18	0.12

self-interest to reduce emission. Table 18 demonstrates the coalitions for emission trading when bilateral goods trade occurs. The regions and countries choose their coalition partners considering the terms of trade, the cost incurred by emission abatement and level of damage. These effects play a similar role in endowment between countries and regions. The market of goods is taken as homogeneous, regions closer to the trade form effective coalitions, and their emission abatement capacities are higher but with less carbon leakage. As shown in Table 18, the coalition partners US, EU, China, Russia and Japan form an effective and results-oriented abatement strategy in which EU-Rus-Chn is the best coalition (bold line), achieving 19.1% carbon abatement. Similarly, the EU-Chn and Jpn-Rus-Chn coalitions succeed in reducing emissions by 18.3 and 16.5%, respectively.

CONCLUSIONS AND POLICY IMPLICATIONS

Similar to climate change policy establishment, international trading also has a positive effect on climate change negotiations and strategies; trading can compel countries to take part in negotiations. These negotiations are anticipated to reach certain multilateral agreement. The empirical model of this study does not analyse the

Table 18 | Carbon trading coalitions and welfare effect on model countries (σ, σj)

	Change in emission (%)														
Coalitions	EU	US	Jpn	S.K	Can	Aus	UK	Bra	Ind	Chn	Rus	Mex	Tur	G.Emi (%)	G.E.Red (%)
EU-Chn-Ind	1.1	0.5	1.7	0.6	0.5	0.3	0.2	0.1	1.2	2.0	3.4	0	0	1.0	15.2
Jpn-Chn-Rus**	2.1	0.9	1.6	1.0	0.5	0.7	0.3	0.1	0	0.9	2.1	0	0	1.2	16.5
EU-Chn-Ind-Brz	1.6	0.7	2.5	0.6	0.3	0.1	0	0.3	0.4	1.8	1.6	0	0	1.0	14.6
EU-Rus-Chn	**1.7**	**1.1**	**2.8**	**0.9**	**0.6**	**0.7**	**0.5**	**0.9**	**0.8**	**2.4**	**13**	**0**	**0**	**1.5**	**19.1**
US-Chn**	1.0	0.1	1.0	0.4	0.1	0.1	0	0	0	1.3	2.0	0	0	0.6	12.1
EU-Chn*	2.0	0.9	3.5	1.7	0.3	0.5	0.2	0.1	0.2	1.3	2.3	0.1	0	1.3	**18.3**
US-Jpn-Rus	1.1	0.7	1.0	0.1	0.1	0.1	0	0	0.1	1.1	1.9	0	0	0.9	12.1
US-EU-Rus	2.1	1.0	0.8	0.3	0.1	0	0	0	0	2.7	1.5	0	0	0.8	11.3
EU-Rus	0.1	0.2	0.2	0.1	0	0	0	0	0	0.1	2.3	0	0	0.2	11.3
Rus-Chn*	1.3	0.6	1.5	0.9	0.4	0.3	0.4	0.1	0.2	0.3	1.1	0	0	0.6	16.2

Note: Figures less than 0.1 are referred as 0 and we do not consider the no-trade Nash equilibrium.
* Indicates the sub-game perfect Nash equilibrium.
** Indicates the coalition is stable.

results of negotiations. Rather, the study focuses on the role of international trade to encourage participation in multilateral talks on climate change. Trade has remedial implications over the incentive and fair carbon tariff strategies. If the developing countries are expected to act timely with respect to the global externality of climate change, meaningful cooperation from industrialized countries is a prerequisite. Consequently, we analyse here the volume of financial needs that small countries face due to emission reduction costs when participating in global efforts to mitigate climate change. We also outline the break-even point at which developing countries can decide to participate in negotiations and/or face tariffs imposed by the developed countries if it strategically suits developing countries to stay away from the negotiations, bearing in mind the cost–benefit analysis of whether to participate or to face tariffs.

We use the BAU path and utilize the projections of global temperature change and damage assumption for a single period, for example, 30 and 50 years. The target countries are as follows: the key developing countries BRIC + 2 (Brazil, India, China, Russia, Mexico and Turkey) are chosen, keeping in mind their growth and emission profiles; key OECD countries (US, Japan, S. Korea, Australia, Canada, UK and EU with exception of non-OECD high income countries); and ROW. For better policy implications and effectiveness of research, we have summarized the results both as an individual country case and in groups. The findings of the simulation results can be summarized as follows:

1. The consumption and temperature change utility function of model countries in both the one good and N-good cases suggests that small countries have no incentive to initiate joint emission abatement agreements, with the exception of China with marginal effect. Conversely, the developed countries have increasing payoffs between consumption and lowering temperature through global efforts. Thus, it is quite clear that the developed countries will be inclined to stimulate global negotiations towards a multilateral agreement, whereas developing countries must bargain for their potential trade-off before any commitment.
2. The second part of the model analyses the percentage of tariffs likely required as a strategy to force developing countries (BRIC + 2 in this study) to participate in negotiations, both as an individual and in groups. This study found that if tariffs of 830% or 369% by the OECD or all non-BRIC + 2 countries are levied, the BRIC + 2 countries will participate in joint emission abatement because otherwise, they will not be better off. Similar break-even tariff points are evaluated through simulations of individual cases in Tables 10–15.
3. The third part of the empirical analysis found that a total of $US 65.3 trillion would be needed from OECD countries to finance the key developing countries' (BRIC + 2 in our case) streamlining of their joint emission abatement process. For this purpose, China individually required $US 47.34 trillion over the model period. Other BRIC + 2 countries Brazil, India, Russia, Mexico and Turkey require 7.64, 14.42, 15.04, 3.78, 1.65, trillion dollars, respectively. The detailed breakout of each individual major OECD country's share of transfers to each BRIC + 2 is illustrated in Table 17.
4. The final part of the empirical analysis addresses the carbon trading coalition of our model countries in the case of a non-cooperative environment. This strategy is the best and the most cost-effective for emission reduction for developing countries in particular. We found that the best coalition among the model countries is formed by EU-RUS-CHN, which ought to reduce emission intensity by 19.1%. However, we also mentioned other coalitions that should reduce emission levels but by less than the above coalition. The other coalitions, EU-Chn and Rus-Chn, reduce emissions by 18.3% and 16.2%, respectively.

In Table 18, we only consider trade equilibrium results. Countries such as China, Russia and EU have a higher incentive both in trade and emission abatement, whereas coalitions without Japan and US are more strategic and emissions reduction oriented. These simulation results also show that EU countries have an incentive to increase the endowment and to enhance less energy-intensive goods. Similarly, China and Russia can strategically obtain access to energy-intensive markets and increase the export of energy resources outside the coalition partners, respectively.

An emission reduction of from 16% to 19% is considered the best strategic coalition choice, and a percentage of abatement less than 12 is not feasible in terms of either trade effects or abatement reduction targets.

Table 18 does not demonstrate no-trade Nash equilibrium results. However, results are supportive in terms of environment policy in the absence of cooperation between the major emitters of developing and developed countries. The results provide an alternative strategy to achieve substantial abatement reduction through a coalition of countries, with trade protection of developing countries. These results are highly effective for China, Russia and the EU and would help these countries to consider a carbon-trading strategy in the event that a global joint commitment to reduce emissions fails to achieve consensus.

The empirical results of this research aim to provide a clear-cut future perspective of climate change strategies to be applied and practised by developed countries in negotiations and proceedings to a multilateral agreement. The developing countries, which are the growing strategic partners in climate change negotiations and future emission abatement, are provided with valuable empirical research findings to assist them to form their own framework for future interactions.

This study strategically suggests that developing countries form small coalitions in the absence of cooperative arrangements. Such coalitions are primarily formed for carbon trading using terms-of-trade effects and provide the most cost-effective means of reducing emissions in an individual nation's self-interest.

REFERENCES

Ahmed, K. & Long, W. 2013 Climate change and trade policy: from legal complications to time factor. *Journal of International Trade Law and Policy* **12** (3), 258–271.

Aldy, J. E. & Stavins, R. N. (Eds.). 2007 *Architectures for Agreement: Addressing Global Climate Change in the Post-Kyoto World*. Cambridge University Press, Cambridge, UK.

Armington, P. S. 1969 A Theory of Demand for Products Distinguished by Place of Production. [Une théorie de la demande de produits différenciés d'après leur origine] [Una teoría de la demanda de productos distinguiéndolos según el lugar de producción] Staff Papers-International Monetary Fund, 159–178.

Barrett, S. 1994 Self-enforcing international environmental agreements. *Oxford Economic Papers* **46**, 878–894.

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

Cai, Y., Riezman, R. & Whalley, J. 2009 International trade and the negotiability of global climate change agreements (No. w14711). National Bureau of Economic Research, Cambridge, MA, USA.

Carbone, J. C., Helm, C. & Rutherford, T. F. 2009 The case for international emission trade in the absence of cooperative climate policy. *Journal of Environmental Economics and Management* **58** (3), 266–280.

Harstad, B. 2012 Climate contracts: a game of emissions, investments, negotiations, and renegotiations. *The Review of Economic Studies* **79** (4), 1527–1557.

Helm, D. 1994 British utility regulation: theory, practice, and reform. *Oxford Review of Economic Policy* **10** (3), 17–39.

Hufbauer, G. C., Charnovitz, S. & Kim, J. 2009 *Global Warming and the World Trading System*. Peterson Institute for International Economics, Washington, DC, USA.

Jacoby, H. D., Schmalensee, R. & Sue Wing, I. 1999 *Toward a Useful Architecture for Climate Change Negotiations*. OECD, Paris, France. Available at: http://www.oecd.org/dev/1923143.pdf.

Madani, K. 2013 Modeling international climate change negotiations more responsibly: can highly simplified game theory models provide reliable policy insights? *Ecological Economics* **90**, 68–76.

Mattoo, A., Subramanian, A., Van Der Mensbrugghe, D. & He, J. 2009 *Reconciling Climate Change and Trade Policy*. Working Paper 09-15, The World Bank, Washington DC, USA.

Mendelsohn, R. & Williams, L. 2007 Dynamic Forecasts of the Sectoral Impacts of Climate Change. *Human-Induced Climate Change: An Interdisciplinary Assessment*. Cambridge University Press, pp. 107–118.

Messerlin, P. A. 2010 *Climate Change and Trade Policy: From Mutual Destruction to Mutual Support*. Policy Research Working Paper No. 5378, The World Bank, Washington DC, USA.

OECD 2005 *Trade that Benefits the Environment and Development: Opening Markets for Environmental Goods and Services*. OECD, Paris, France.

Ostrom, E. 2010 Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change* **20** (4), 550–557.

Peters, G. P. & Hertwich, E. G. 2008 CO_2 embodied in international trade with implications for global climate policy. *Environmental Science & Technology* **42** (5), 1401–1407.

Pittel, K. & Rübbelke, D. T. 2012 Transitions in the negotiations on climate change: from prisoner's dilemma to chicken and beyond. *International Environmental Agreements: Politics, Law and Economics* **12** (1), 23–39.

Shapley, L. S. & Shubik, M. 1969 On market games. *Journal of Economic Theory* **1** (1), 9–25.

Stern, N. 2006 *Review on the Economics of Climate Change*. HM Treasury, London, UK.

Stern, N. N. H. (Ed.) 2007 *The Economics of Climate Change: the Stern Review*. Cambridge University Press, Cambridge, UK.

Tian, H. & Whalley, J. 2010 Trade sanctions, financial transfers and BRIC participation in global climate change negotiations. *Journal of Policy Modeling* **32** (1), 47–63.

Uzawa, H. 1999 Global warming as a cooperative game. *Environmental Economics and Policy Studies* **2**, 1–38.

Walsh, S. & Whalley, J. 2008 The Global Negotiating Framework for Climate Change Mitigation. Available at: http://www.cigionline.org/community.igloo.

Weber, C. L. & Matthews, H. S. 2007 Embodied environmental emissions in US international trade: 1997–2004. *Environmental Science and Technology* **41**, 4875–4881.

Weber, C. L. & Peters, G. P. 2009 Climate change policy and international trade: policy considerations in the US. *Energy Policy* **37**, 432–440.

First received 17 November 2014; accepted in revised form 6 May 2016. Available online 14 June 2016