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Article

Strategies to Induce Non-cooperating Countries to Join a Climate-policy Coalition

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International climate-control or environmental agreements have substantial impacts on international terms of trade. This would seem to suggest that international environmental coalitions cooperating on climate control could penalize non-cooperating countries through trade sanctions. However, alternative approaches exist in which cooperating nations provide incentives for non-cooperating nations to join their coalition. This paper investigates potential impacts of trade sanctions against non-cooperating nations. It compares different climate coalitions and their impacts on trade and international spillover effects if free-riding countries are sanctioned with trade restrictions. Specifically, the paper looks at the Kyoto Protocol as the prime example of a climate-policy coalition, and the United States as the most important non-cooperating country. Modeling indicates that trade restrictions are not the right tool to induce non-cooperating nations to join a coalition. The United States could most likely be persuaded to cooperate if developing nations participated in a climate-policy coalition in which they both benefited from technology transfer and from emissions trading. Further, it appears that developing countries would benefit most if they participated in international emissions trading without binding emission-reduction targets.

Keywords: Climate coalition, Kyoto Protocol, United States, Research and development, Developing countries

1. Introduction

A continued accumulation of anthropogenic greenhouse gases will ultimately have severe consequences on the climatic, ecological, and social systems. Irreversible climate change has significant costs, and no future efforts can repair the resulting damage. Reduction of greenhouse gas emissions is an international public goal necessitating long-term and global economic efforts, with cooperation between countries. The formulation of the Kyoto Protocol and the subsequent negotiations are one initial outcome of cooperative international climate-control policy action.

The progress of the Kyoto Protocol negotiations confirms that individual countries are mainly concerned with potential economic disadvantages from emission reduction. Whether a stable climate-control policy coalition can be achieved depends on opportunities to reduce conflicts of interest in a minimum agreement. A bargaining process provides opportunities to collaborate for mutual benefit; however, full agreement of all players is unlikely. More realistically, some players may act independently or unilaterally to maximize their own interests, while others create small and stable coalitions (Carraro and Siniscalo 1992, 1993; Hoel 1994). The decision to join a coalition or initiate a

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partial coalition is usually taken based on a comparison of the net benefits of cooperative and non-cooperative strategies (Barrett 1994b). As long as the environment and climate are treated as a public good and there are no penalties or sanction mechanisms for polluters, there will be less economic incentives to unilaterally or cooperatively protect the environment. Moreover, as long as cooperative behavior is only voluntary, a common or global agreement will be shaped by the varying interests of the negotiating countries and incentives will be small to join a climate coalition. These interests must be harmonized between nations or groups of nations. Extensive economic literature on game-theory approaches to international cooperation on climate change has been produced since the early 1990s (Barrett 1992, 1995; Carraro 1999, 2000; Carraro and Siniscalco 1992, 1993; Cesar 1994; Chander and Tulkens 2001; Courtois, Pireau, and Tazda 2001; Endres and Finus 1998; Finus 2000; Finus and Rundshagen 2001; Hoel 1994; Kemfert 2002a, 2004; Kemfert, Lise, and Tol 2003).

A variety of incentives exist for countries to free ride (that is, to benefit from others' efforts to reduce emissions, but take no action themselves). A free-riding position can be seen in the decision of the United States to leave the previously established Kyoto climate-control coalition. Its primary reasons were that compliance would be too costly and that the coalition would not establish emission-limitation commitments for developing countries. In February 2002, President George W. Bush announced a unilateral target of reducing the US economy's greenhouse gas intensity by 18 percent between 2002 and 2012.[1] This would represent a small reduction from projected "business as usual" emissions, and is expected to lead to a rise in total emissions rather than the reduction in total emissions in the United States' proposed commitment under the Kyoto Protocol.

The United States' action has several implications. First, the environmental benefits of the commitments undertaken by Annex B parties will be lower than the benefits they anticipated when the commitments were negotiated.[2] Second, the cost to Annex B parties of meeting their commitments will be higher than anticipated if they participate and accept emission-reduction targets.[3] Third, since the Annex B parties will be committed to larger reductions from their projected emissions than the United States, businesses in Annex B parties might be adversely affected by competition from US businesses. The climate-control coalition might therefore want to persuade the United States to adopt a more stringent emission-reduction target. Strategies to do this might have costs for Annex B parties. However, as long as these costs are less than the costs of a comparable emissions reduction by these parties, the strategy remains viable.

This paper investigates potential strategies that could be used by diverse climate-control coalitions to induce non-cooperating nations, like the United States, to adopt more-stringent greenhouse gas targets. The analysis focuses on trade restrictions, but also includes more-positive incentives for them to return to the climate-control coalition. The impacts of various emission-reduction implementation by non-

1. The aim is to reduce the greenhouse gas intensity of the US economy from its present 183 tons of carbon equivalent emissions per million dollars of GDP in 2002 to 151 tons by 2012.
2. Annex B countries are those countries that ratified the Kyoto protocol with concrete emission-reduction targets.
3. The Kyoto Protocol establishes several forms of emissions trading. The United States was expected to be the largest net buyer of permits. Its withdrawal from the protocol reduces the demand for permits, thus reducing the market price and the compliance cost for Annex B parties.

cooperating nations and the costs and benefits of forming small coalitions like that under the North American Free Trade Agreement (NAFTA) are analyzed. Furthermore, the paper studies the potential impacts of trade sanctions against non-cooperating nations. Finally, it examines the potential impacts of global coalition games, and incentives for non-cooperating countries to return to the climate-control coalition.

2. The international climate-control coalition—a game theory perspective

The greatest success of international climate-control policy to date has been the establishment of the Kyoto Protocol. It is one of the most prominent and most important international environmental agreements in the history of global negotiation and bargaining policies. However, subsequent climate-change negotiation processes confirm that the initial coalition was not stable; the United States, the world's largest economy and emitter of greenhouse gases, has left the coalition and now acts as a singleton and free rider. The reason for this behavior can be explained by game-theory validation: the economic payoffs of free riding are higher than those of joining the coalition.[4]

Cooperation to reduce greenhouse gas emissions must be voluntary, as there is no international authority compelling action by sovereign nations. Unfortunately, as the game-theory literature on climate negotiations indicates (see the list of sources above), cooperation can also increase the incentives for each country to free ride and not fulfill its commitment. If the marginal benefits of additional emission reductions decline, each country gains the benefits of the emission reductions implemented by others and stands to reap fewer benefits from its own action. Although the rules adopted for the Kyoto Protocol include penalties for non-compliance, they may be difficult to enforce, making it effectively a self-enforcing agreement.[5] From a review of the literature, the following conclusions appear to be most important:

- A global, self-enforcing agreement that is stable and profitable to all signatories is highly unlikely to be reached.[6]
- Self-enforcing international environmental agreements are likely to include only a limited number of countries.
- An equilibrium is likely to consist of multiple agreements of different sizes and with different commitments.
- Equity and efficiency cannot be separated because the number of signatories affects the compliance cost each member bears. The compliance cost, in turn, affects the number of signatories (Carraro 2000).

4. The February 14, 2002 announcement by the US administration proposed a voluntary environmental program avoiding huge economic losses resulting from reduction in economic growth.
5. An Annex B party not meeting its commitment can be penalized 1.3 permits from its allocation for the next commitment period for each ton of excess emissions. However, a penalized country can threaten to withdraw from the Protocol. In practice, the penalties, if any, are likely to be negotiated.
6. An agreement is stable if none of the parties has an incentive to leave and no non-parties have an incentive to join. An agreement is profitable if welfare is higher under the agreement than without the agreement. An agreement must be profitable to be stable (Bosello et al. 2001).

- The existence of stable agreements is threatened by leakage; i.e., increased economic activity and emissions by non-members due to emission-reduction action by members. Leakage reduces the environmental benefits due to cooperation, creating an increased incentive to free ride.

According to the game-theoretic literature, the withdrawal of the United States from the Kyoto Protocol is not surprising, especially since it perceived the cost of participation to be high. The adoption of low-cost unilateral action or formation of a separate agreement similar to NAFTA would be consistent with game theory.

3. Preliminary review of some possible incentive strategies

A variety of possible incentive strategies exist to attract free riders or keep partners in an unstable coalition in the game. These include financial transfers (Carraro and Siniscalco 1993; Hoel 1994); issue linkage (Barrett 1995; Carraro and Siniscalco 1995; Folmer and van Mouche 1993; Folmer, van Mouche, and Ragland 1993; Kemfert 2004; Kroeze-Gil and Folmer 1998; Mohr 1995);[7] legal enforcement through third-party arbitration (Barrett 1992); matching (Barrett 1995; Guttman 1978, 1987);[8] self-enforcing strategies (Barrett 1994b; Endres and Finus 1998);[9] social norms (Hoel and Schneider 1997);[10] tit-for-tat (Cesar 1994);[11] trigger strategies (Barrett 1994a; Cesar 1994);[12] and unilateral action (Barrett 1995; Hoel 1991).[13]

Comparison of these strategies indicates that the best for increasing the number of participants and/or emission reductions and for ensuring compliance with commitments appear to be transfers and issue linkage. Unilateral action does not prevent free riding and may lead to increased levels of emissions. Trigger strategies require penalties to be effective and hence are not suitable for a self-enforcing agreement, as they are not renegotiation-proof. Legal enforcement is not feasible where the participants are sovereign nations. Matching, over time, leads all countries to behave in the same manner as the country making the least effort to reduce emissions. Tit-for-tat has been shown to be highly effective, especially if participants in a game are likely to meet again (Axelrod 1984), but governments may not maintain tit-for-tat strategies for climate policy if other policy priorities arise. While social norms may reduce free riding, they differ across countries and may not be effective in ensuring compliance.

If an agreement is profitable, there is a net gain to the parties. In principle, this net gain can be distributed so that each cooperating party is a net beneficiary and attracts new parties. Transfers can take the form of differential emission-reduction commitments with emission-trading mechanisms, such as those established by the Kyoto Protocol. A stable global agreement requires a policy mix that couples global emission trading with a transfer mechanism designed to offset ex-post incentives to free ride

7. Issue linkage means that the issue of climate control or emissions reduction is linked with other economic incentives, such as trade coalitions or technological cooperation.
8. A matching process describes the game where those players cooperate that fit most.
9. Self-enforcing strategies are those in which incentives can lead to reactions by some player to act further in the direction that is intended.
10. That is, cooperation is triggered by some players sharing social norms.
11. Tit-for-tat strategies can merge diverse actions as players react on other players' reactions.
12. Trigger strategies encompass all trigger mechanisms that activate players to join a coalition.
13. That is, individual strategies by some player(s) who do not cooperate.

(Bosello et al. 2001). Transfers to the United States to induce it to adopt a more stringent emissions target are not considered as a strategy for the Kyoto Protocol parties, since this would require renegotiation of the Protocol.

3.1. Issue linkage

If countries that do not benefit from an environmental agreement could benefit from agreement on another issue, and vice versa, linking agreements on two or more issues may enable countries to cooperate on both issues. In principle, issue linkage can improve both profitability and stability of an agreement. Issues that it has been suggested could be linked to climate change include: trade (Barrett 1992, 1995, 1997; Cesar 1994; Conconi and Perroni 2000; Kemfert 2002b; Whalley 1991), research and development (Buchner et al. 2002; Carraro and Siniscalco 1995, 1997; Katsoulacos 1997; Kemfert 2004; Tol, Lise, and Van der Zwaan 2000), international debt (Mohr 1995), other environmental issues such as biodiversity conservation (Barrett 1994a), and international trade (Batyabal 1995; Heister 1993).[14] Issue linkage is more likely to be successful when the benefits of the linked issue can be limited to the parties, unlike climate-control agreements, which benefit all countries regardless of their participation.

As links with other issues merely increase the possible set of solutions (Kroeze-Gil and Folmer 1998), linkage per se does not necessarily lead to better outcomes. Accordingly, studies examining potential links between climate change and international trade conclude that such links will not certainly lead to participation by a larger number of countries. Imposing trade sanctions on non-cooperating countries does not guarantee greater cooperation (Courtois, Pireau, and Tazda 2001). Kemfert (2004) finds that, trade sanctions against non-parties would not provide a significant incentive for countries to join an emission-reduction agreement. Conconi and Perroni (2000) find that the effect of linking trade and environmental agreements is ambiguous;[15] it helps if the environmental policy stakes are small relative to the welfare effects of trade policies.

3.2. Research and development cooperation

Cooperation on research and development (R & D), especially on energy technologies, appears to be a more promising way of expanding cooperation on climate change. Tol, Lise, and Van der Zwaan (2000) find that technology and capital transfers increase the incentive to cooperate. Kemfert (2004) finds that full cooperation on climate change and technological innovation benefits all countries relative to unilateral action, although technological spillover effects reduce the effectiveness of this strategy. Buchner et al. (2002) find that linking R & D cooperation with cooperation on climate-change control is profitable and guarantees the stability of the linked agreement.[16]

14. A strategy that links climate change to international debt is not considered. It is assumed that debt concessions offered by negotiating parties to the United States would be politically unacceptable even in return for more aggressive climate-change targets given the high per capita income of the United States relative to the Kyoto Protocol parties.

15. They distinguish between *issue linkage*, where a country is free to participate in none, either, or both agreements, and *issue tie-in*, where a country must be a party to both or none of the agreements.

16. These results are sensitive to the level of technological spillover assumed.

3.3. Trade restrictions

Barrett (1994) states that trade restrictions are the most obvious enforcement mechanism for an international climate-change agreement, but are difficult to apply for climate change due to the very large number of goods affected, the difficulty of calculating the appropriate border tax for each product, and likely inconsistency with international trade agreements (Barrett 2004b). Aldy, Orszag, and Stiglitz (2001) suggest tariffs or trade restrictions based on the emissions associated with production, including standards that place the production of non-parties at a disadvantage.

World Trade Organization (WTO) rules allow border-tax adjustments for environmental taxation or charging for products (ozone-depleting substances) or physically incorporated inputs (chemicals in plastic products), but not on production processes (CO_2 emissions) or non-physically incorporated inputs (energy used in production). This means that border-tax adjustments are not allowed for production processes or methods (PPMs) used in the exporting country. However, the Shrimp/Turtle case seems to signal an evolution of the WTO rules towards dealing with issues of PPMs (Vikhlyaev 2001).

Some multilateral environmental agreements (MEAs), including CITES (the Convention on International Trade in Endangered Species of Wild Flora and Fauna), the Montreal Protocol on Substances that Deplete the Ozone Layer, and the Basel Convention Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, define "specific" trade measures, usually against non-coalition countries. The Montreal Protocol imposes trade restrictions on goods made with, but not containing, ozone-depleting substances.[17] So far, no trade measure taken pursuant to an MEA has been challenged in the WTO by a non-party. However, the legal ambiguity surrounding the possibility of such a challenge raises uncertainty over the effectiveness of such measures (Vikhlyaev 2001, 18). Buck and Verheyen (2001) conclude that trade sanctions that simply discriminate against goods or services from non-coalition nations are very likely to be incompatible with WTO rules. However, the economic effects of measures allowed under WTO law taken by countries willing to act on climate change should exert pressure on climate change laggards. Buck and Verheyen (2001) conclude that:

- Product (e.g., energy efficiency) standards applied in a non-discriminatory way to imported and domestic products would be compatible with WTO law.
- Eco-labeling schemes that consider indirect environmental impacts of products would most likely violate WTO provisions.
- Procurement programs developed and implemented in the context of an MEA would not violate WTO law even if they included PPM-based technical specifications.
- Trade-restrictive environmental measures—including PPM-based measures—can be justified under the provisions of the General Agreement on Trade and Tariffs (GATT) if such measures have been agreed to and negotiated on a multilateral basis. Trade disputes are more likely to arise from such

17. In other words, the Montreal Protocol imposes trade restrictions based on PPMs despite the fact that WTO rules do not allow border-tax adjustments based on PPMs.

national measures undertaken to fulfill obligations under an MEA than from the provisions of the MEA itself (Zhang and Assunção 2004).

In summary, there are several precedents for multilateral environmental agreements that specify trade measures to be taken against non-party countries. At least one agreement imposes trade restrictions based on production processes or methods. The WTO may be moving towards greater acceptance of trade restrictions based on PPMs. However, considerable legal uncertainty remains in all of these areas. Nevertheless, it appears that the parties to the Kyoto Protocol could amend it to include specific trade measures to be taken against non-cooperating countries such as the United States, provided that they were related to climate change. Those measures could include trade restrictions on specified products based on their method of production.

De Moor et al. (2002) note that President Bush has proposed $4.5 billion in research funding (R&D), suggesting that technology development could be a promising area for cooperation. Barrett (2004b) proposes:

- Collectively funded R & D (including developing countries based on the UNDP's assessment)
- Coordinated adoption of national standards to drive adoption of lower-emitting technologies.

4. The scenarios modeled

This paper investigates different policy strategies of climate negotiations related to trade to induce the United States to adopt a more stringent emission-limitation target. First, it is assumed that the climate-control coalition under the Kyoto Protocol, consisting of Annex B regions Europe (EU), Japan (JPN), Russia (REC), and Canada (CAN), buys no coal from the United States. Second, the climate-control coalition imposes border-tax adjustments on imports from the United States. Third, different climate-control coalitions act strategically against each other; for example, the United States creates a climate-control coalition with Mexico and Canada (NAFTA). Furthermore, the paper studies the potential effectiveness of the incentive strategy of R & D cooperation to bring non-cooperating countries into the coalition. In this scenario, the climate-control coalition and the United States cooperate on R & D, with payments to the United States equal to the reduction in the compliance costs of the Kyoto Protocol parties. Additionally, it is assumed that developing countries adopt national emission-control commitments equal to their "business as usual" emissions, beginning in 2020.

These scenarios can be summarized as follows:

Scenario name	**Description**
Base case	Emission reduction according to the Kyoto Protocol commitments, excepting the United States; strategic action by Russia restricting 50 percent of emission allowances.
No coal	The climate-control coalition buys no coal from the non-cooperating United States.
Trade restriction	The climate-control coalition imposes border taxes to reduce imports from the United States.
NAFTA	A new climate-control coalition between the United States, Mexico, and Canada.
DEV	Developing nations participate in a climate-control coalition.
R & D	Cooperation between members and non-members of the climate-control coalition on R & D for technological progress of energy technologies.

The study and scenario investigation is based on the interregional, multisectoral trade model WIAGEM, which is described in section 7.

5. The role of technological change in emission reduction

Environmental and climate interventions create constraints and incentives that affect the process of technological change. The imposition of climate-control instruments can stimulate invention and innovation. This invention and innovation is carried out primarily in private firms, through increased R & D. A technological innovation can become widely available by technological diffusion processes. The induced-innovation hypothesis, which assumes that policies trigger innovation, recognizes R & D investments as profit-motivated and stimulated by relative price changes. Climate-control policies that increase the price of fossil fuels increase the market for low-carbon technologies. This creates incentives for increased R & D expenditure in the sectors affected by climate change. Increased R & D expenditure should lead to technological developments that reduce the costs of low-carbon technologies. These effects reduce compliance costs and can lead to increased profits (Porter and Van der Linde 1995). However, investment in R & D could also crowd out other types of investments (Gray and Shadbegian 1998), reducing firms' profits. Econometric tests confirm these ambiguous results. Jaffe and Palmer (1997) find that a carbon tax reduces aggregate R & D, causing a decline of knowledge accumulation and the rate of technological progress, which results in a deterioration of income and output. Recent findings, however, illustrate that environmental policies can have a strong positive feedback effect on innovation and may induce beneficial economic outcomes (Popp 2001, 2002).

In economic-energy-environmental modeling concepts, the representation of technological changes is one of the most important sources of uncertainty in determining the economic costs of climate-policy strategies (see Jaffe 2000; Jaffe et al. 1995). In previous modeling concepts, technological changes were treated as exogenous. Economy-climate models that incorporate technological changes endogenously determine technological innovations either by investment in R & D as induced technological progress, by integration of spillover from R & D, or by including technological learning processes, particularly learning-by-doing practices. Numerous modeling approaches investigate the economic effects of technological innovation. On a micro or bottom-up scale, different kinds of technologies are assessed in detail. On a macro-level or top-down scale, aggregated economic feedback effects of technological progress are evaluated. In top-down models, technological progress is mostly represented as an innovation to produce the same amount of output (expressed in terms of gross domestic product (GDP)) with smaller amounts of input. This means an increase in input-factor productivity. In contrast to an exogenous representation of technological progress, induced technological progress triggers endogenously increased productivities by different sources, such as investment-induced technological progress or R & D-induced technological progress.

As reported by Löschel (2002), various modeling results confirm that exclusion of the representation of endogenously determined technological changes tends to overestimate compliance costs. Because initial installation of technological innovations are very often expensive, costs decline over time with increasing experience. A learning curve describes technological progress as a function of accumulated experience in production. Many applied modeling concepts, including bottom-up modeling concepts with a detailed representation of energy technologies, apply learning curves as a meaningful description of technological change (Azar and Dowlatabadi 1999; Gerlagh and Van der Zwaan 2003; Grübler, Nakicenovic, and Victor 1999). Dowlatabadi (1998) finds that emission-abatement costs decline substantially if technological change is induced by technological progress, and when learning-by-doing is considered. Gerlagh and Van der Zwaan (2003) find that the learning-by-doing effects that make cheaper non-carbon technologies available induce positive economic impacts and reduce the costs of climate policies.

Some models that incorporate induced technological changes by increased investment in R & D but also increased opportunity costs do not find large impacts on abatement costs (Buonnano, Carrario, and Galeotti 2003; Goulder and Schneider 1999; Nordhaus 2002). Popp (2004) finds that induced technological change leads to substantial welfare gains but only small climate impacts in the long run. Goulder and Matthai (2000) find that abatement costs are lower with the existence of induced technological change than without. The main difference between modelling experiments that do and do not include induced technological change is that some approaches find productivity increases for some sectors that are positively influenced by induced technological changes, but decreased productivity for other sectors that are influenced negatively. These exercises find that induced technological changes significantly raise the benefits of a specific climate-policy strategy, but do not largely reduce the costs.

In this paper, induced technological changes are modelled by an increase of R & D expenditure that increases energy efficiency. It is found that although R & D spending competes with other investments, abatement costs are reduced (Kemfert 2005).

6. Previous modeling of the impacts of climate-change coalitions

Impacts of different climate-control coalitions have been analyzed by many scientists using a variety of applied modeling concepts. Investigations of the international permit market subsequent to the United States' withdrawal have assumed both a competitive market and strategic behavior by Russia, the Ukraine, and other countries with "hot air".[18] The models used to analyze the international permit market differ in several ways that affect the price, including the emissions covered (from only energy-related CO_2 to all greenhouse gas emissions), the coverage of sinks (from none to the maximum allowable sinks), the projected 2010 emissions in the absence of emission-limitation policies, the scale of clean development mechanism activity (from none to all reductions from "business as usual" emissions in developing countries), and transaction costs for project-based mechanisms (from none to 30 percent). Such differences lead to a range of price estimates from different models.

The United States' withdrawal from the Kyoto Protocol lowers the estimated emission permit price for 2008–2012. If the international permit market is competitive, the price is estimated to be US$(1995)9.20 per ton of carbon (tC), with a range from $0 to $45.90/tC. One-quarter of the studies estimate the amount of "hot air" to be larger than the demand for permits resulting in a zero price. If

18. The emission-limitation commitments of Russia, the Ukraine, and a few other countries are greater than their projected emissions during the 2008–2012 period. This leaves them with a supply of surplus permits that have no cost, so-called hot air.

Russia and the Ukraine are able to act strategically, the permit price is estimated to be $42.60/tC with a range from $4.00 to $110.80/tC. Russia and the Ukraine would need to limit permit sales to 50 percent or less of their "hot air". Any domestic policy in the United States that allows the use of foreign permits for compliance will affect the international permit market. Depending upon the size of the US demand, the supply of Kyoto-mechanism permits from other countries could increase enough to reduce the market power of Russia and the Ukraine, leading to a price of between $9.20 and $42.60/tC.

7. The applied modelling tool, WIAGEM

The analysis of different strategies to induce non-cooperating countries to join or return to a climate coalition is performed using the WIAGEM model. WIAGEM is an integrated assessment model merging models of the global economy, based on a dynamic intertemporal general equilibrium approach, global and regional energy markets, and climate changes (Kemfert 2002). The model covers the period 2000 through 2050 in five-year time steps. This structure allows the economic and climate impacts of proposed climate change mitigation policies to be evaluated.

In the model, the global economy is aggregated into 11 trading regions. The economy of each region is disaggregated into 14 sectors, including five energy sectors: coal, natural gas, crude oil, petroleum and coal products, and electricity. Fossil fuels are produced from fuel-specific resources. Goods are produced for the domestic and export markets. The output of the non-energy sectors is aggregated into a non-energy macro good. The production function for this macro good incorporates technology through transformation possibilities on the output side and constant elasticity substitution (CES) possibilities on the input side. The CES production structure combines a nested energy composite with a capital-labor-land composite. The energy-capital-labor-land composite is combined with material inputs to get the total output of the non-energy macro good.

A representative household in each region allocates lifetime income across consumption in different time periods to maximize lifetime utility. In each period, households choose between current consumption and future consumption, which can be purchased via savings. The trade-off between current consumption and savings is given by a constant intertemporal elasticity of substitution. Domestic and imported varieties of the non-energy macro good are imperfect substitutes in each region, as specified by a CES Armington aggregation function constrained to constant elasticities of substitution. Producers invest as long as the marginal return on investment equals the marginal cost of capital formation. The rates of return are determined by a uniform and endogenous world interest rate such that the marginal productivity of a unit of investment and a unit of consumption is equalized within and across regions.

Table 1. Estimates of international emissions permit prices in 2010: The effects of the US withdrawal from the Kyoto regime

			After US withdrawal from the Protocol		
		With the US in the Protocol	Competitive market	Strategic behavior by Annex B sellers	
Source/model	Currency units	$\$/tCO_2$[a]	$\$/tCO_2$[a]	$\$/tCO_2$[a]	"hot air" sold
Babiker et al. (2002)	US$(1995)	<13.60	<1.40	6.80	50%
Blanchard, Criqui, and Kitous (2002)	US$(1995)	7.60	0	4.60	10%
Böhringer (2001)	US$(1995)[b]	16.90	0	15.50	40%
Böhringer and Löschel (2001)	US$(1995)[c]	10.10	0	8.70	50%
Buchner, Carraro, and Cersosimo (2001)	US$(1990)	7.20[d] 13.50[e]	4.70[d] 12.50[e]		
Ciorba, Lanza, and Pauli (2001)	US$(1997)	10.20[f]	3.40[f]		
De Moor et al. (2002)	US$(1995)			4.10–5.50[g]	
Den Elzen and de Moor (2001)	US$(1990)	9.30	2.60 0–2.90[g]	5.50[k] 4.60–6.20[g]	60%
Eyckmans, Van Regemorter, and van Steenberghe (2001)	US$(1995)	22.00	5.40 0.90–12.00[g]	14.80	100%
Grötter (2001)	US$(1995)[b]	4.10–5.50[g]	0–3.80[g]	0–30.00[g]	
Hagem and Holtsmark (2001)	US$(1995)[h]	15.00	5.00		
Jotzo and Michaelowa (2001)	US$(1995)	1.60	0.90 0.60–1.20[g]	1.10	50%
Jotzo and Tanujaya (2001)	US$(1995)[b]		0.30[i]	12.10	50%
Kemfert (2002)	US$(1995)	14.20	2.20		
Löschel and Zhang (2002)	US$(1995)[c]	11.20	0	18.00[j] 12.50[j] 9.80[j]	36% 43% 45%
Manne and Richels (2001)[k]	US$(1997)	35.10	0.70[l]	30.20[m]	15%
MIT EPPA[n]	US$(1995)		0.50		
Nordhaus (2002)	US$(1995)[b]		3.20[o]		
Average (US$/1995)[p]		13.40	2.50	11.60	
Range		4.10–35.10	0–12.50	1.10–30.20	
Average ($/tC)		49.20	9.20	42.60	
Range ($/tC)		15.00–128.80	0–45.90	4.00– 110.80	

Table 1—*continued*

Notes:

a. Where necessary, reported values are converted from tC to t/CO_2, converted to US$(1995) using the GDP implicit price index (1990 = 86.51, 1995 = 98.10, 1997 = 101.95 and 2000 = 107.04), and rounded to the nearest $0.10.

b. Currency units not specified.

c. Currency units not specified, but results are derived using the POLES (Prospective Outlook on Long-term Energy Systems) model, which uses US$(1995).

d. Including induced technological innovation and diffusion, but no spillover effects.

e. Including induced technological innovation and diffusion with spillover effects.

f. Annex I trading only.

g. Price range for the sensitivity cases analyzed.

h. A separate report on the model indicates that the currency unit is US$(1995).

i. A minimum price of $1/tC is assumed.

j. The estimates assume respectively (1) a cartel involving all countries with “hot air” that maximizes the revenue from the sale of permits, (2) countries with “hot air” maximizing their revenue from the sale of “hot air” subject to the behavior of the other sellers (Nash equilibrium), and (3) Russia maximizing its revenue from the sale of permits with other sellers accepting the market price.

k. Values are scaled from the figures in the paper.

l. Assumes banking is prohibited, so all hot air permits are sold during the first commitment period.

m. Assumes anticipatory behavior and banking.

n. Massachusetts Institute of Technology Emissions Prediction and Policy Analysis model, according to John Reilly (personal communication, October 2001), US$(1995)2/tC.

o. Nordhaus calculates the shadow price of carbon as $9.68/tC in 2005 and $13.99/tC in 2015, averaging these values yields $11.84/tC or $3.22/t$CO_2$ for 2010.

p. Ranges are excluded from the calculation of the average.

Technological change is determined endogenously. R & D spending improves energy efficiency in the CES production function and so enables a region to meet its emission-reduction target with less loss of output. Since the production function is non-linear, the marginal return to R & D decreases as spending rises. Spending on R & D, about 2–3 percent of GDP, competes with other expenditures (crowding out). Technological change has spillover effects reflected through trade effects and capital flows, so countries that do not cooperate in R & D can benefit from the spillover effects.

In addition to the macro good, oil, coal, and gas are traded internationally. The global oil market is characterized by imperfect competition to reflect the ability of the OPEC (Organization of the Petroleum Exporting Countries) regions to use their market power to influence prices. Coal trades in a competitive global market, and gas trades in competitive regional markets, with prices determined by supply and demand in the relevant global or regional market.

Emissions of CO_2, methane (CH_4), and nitrous dioxide (N_2O) occur as a result of energy consumption and economic production activities.[27] These gases are considered to have the most influence on climate change over the 50-year period covered by the model, so exclusion of the remaining gases does not invalidate insights from the analyses.

The climate model estimates the climatic changes due to greenhouse gas emissions and calculates the associated market and non-market damage. The atmospheric concentrations of CO_2, CH_4, and N_2O are based on the first atmospheric lifetime of each gas because of the 50-year time horizon of the model. The atmospheric concentrations affect radiative forcing, which influences the potential and actual surface temperature and the sea level. Market and non-market damage associated with these impacts is calculated as a function of the potential temperature change, the change in regional GDP, and regional coastal protection costs.

The "business-as-usual" case for WIAGEM is similar to the A1B scenario group of the Intergovernmental Panel on Climate Change (IPCC), with global CO_2, CH_4, and N_2O emissions rising from 10 gigatons of carbon (GtC) in 2000 to 16 GtC in 2050, and global GDP rising from US$(1995)26 trillion in 2000 to $161 trillion in 2050. Global CO_2 emissions due to energy and land use under the A1B scenario are 16.4 GtC (range 12.7 to 26.7 GtC) in 2050, and global GDP in the same year is $186 to $205 trillion (IPCC 2001).

8. Results of the modeling

8.1. Base case

The base case assumes that all countries other than the United States ratify the Kyoto Protocol so that it comes into force. The emission-limitation commitments of Annex B parties for the first commitment period are assumed to remain unchanged through 2050 at 3,112 MtC.[19] The base case also assumes that the US target of an 18 percent emission-intensity reduction over 10 years remains in effect through 2050; the emission intensity further declines each decade. The Kyoto Protocol parties and the United States are assumed to comply with their respective commitments. The United States is assumed to implement domestic policies to meet its target.[20]

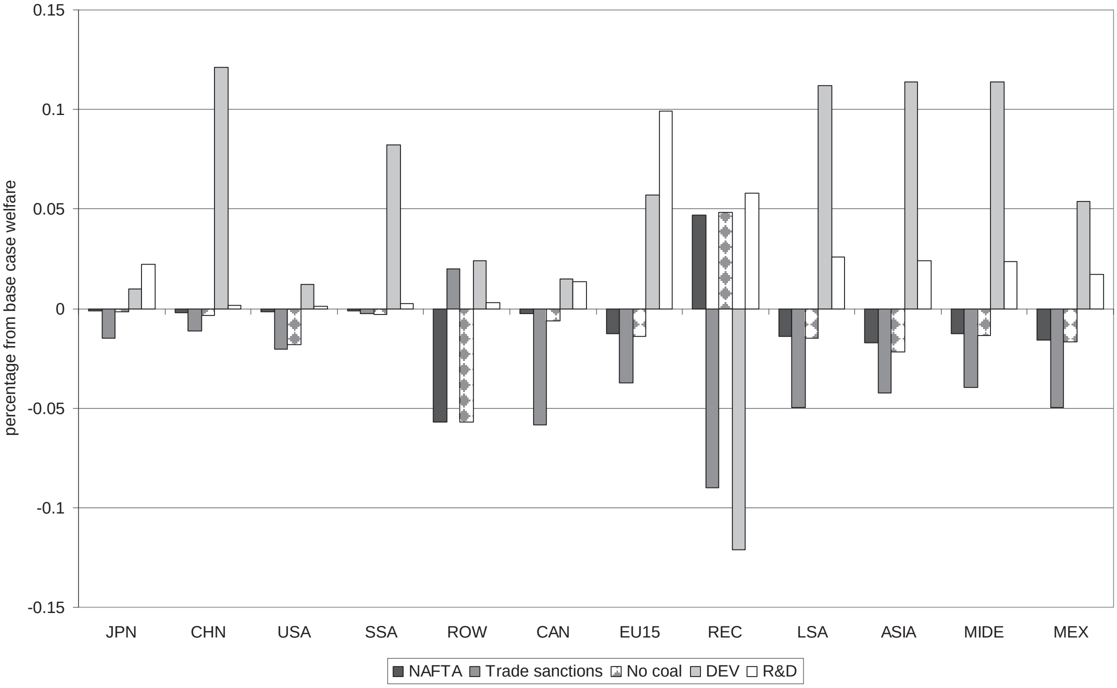
The base case allows the use of sinks for compliance by Annex B parties in accordance with the provisions of the Marrakech Accords, i.e. full use of sinks in Annex B parties plus 1 percent of the Annex B base-year emissions for afforestation and reforestation in developing countries. Full emission trading among Annex B parties and full use of the CDM are allowed; no Annex B party imposes a supplementarity limit on purchases of permits, and with full compliance the commitment period reserve is not binding.

An important assumption is strategic behavior by Russia and the Ukraine, limiting the quantity of permits sold in an effort to maximize revenue. The United States was expected to be a large net buyer of permits. Its withdrawal from the coalition reduces the demand for permits substantially. After the US withdrawal, the amount of “hot air” is large relative to the remaining demand for permits. Since Russia and the Ukraine control almost all of the “hot air”, they could maximize the revenue they receive from

19. This is the annual equivalent of the Annex B commitments (excluding the United States) adjusted slightly to reflect the fact that WIAGEM covers only CO_2, CH_4 and N_2O emissions.

20. Current US domestic policies include the following. The state of Oregon requires new energy facilities to offset part of their greenhouse gas emissions. Massachusetts and New Hampshire have passed legislation that will cap CO_2 emissions by fossil-fuel-fired generating units in those states beginning in 2004. California has passed legislation mandating the establishment of CO_2 emission standards for vehicles. Proposals for a national cap on CO_2 emissions by fossil-fuel-fired generating units are under consideration by the US Congress. Capping the CO_2 emissions of electricity generators at the 2000 level while placing no limits on other sources is not sufficient to meet the national target.

the sale of permits by restricting the quantity sold. It is assumed that 50 percent of their surplus permits for the first commitment period are banked rather than traded.



Note: JPN: Japan; CHN: China; USA: United States; SSA: Sub-Saharan Africa; ROW: Other countries; CAN: Canada, Australia, and New Zealand; EU15: European Union; REC: Russia and Eastern and Central European countries; LSA: Latin America (Argentina, Brazil, Chile, etc.); ASIA: India and other Asian countries (Republic of Korea, Indonesia, Malaysia, Philippines, Singapore, Thailand, Hong Kong, Taiwan); MIDE: Middle East and North Africa; MEX: Mexico.

Figure 1. Percentage welfare changes to the base case

Russia and the Ukraine restrict permit sales to 50 percent of their surplus permits in 2010. The banked permits are used for compliance purposes during later periods. The resulting market price for Kyoto Protocol permits is \$31/tC (US\$(1995)) in 2010, about 25 percent lower than the average price shown in Table 1. The market price rises to \$164/tC in 2050 because Annex B parties must achieve ever-larger reductions from "business as usual" emissions to meet their commitments.

The base case imposes a net cost on the Kyoto Protocol parties but yields a net benefit to the United States.[21] There is a net cost to the Annex B parties other than Russia and the Ukraine, a smaller net benefit to Russia and the Ukraine, and a net cost to developing countries, making an overall net cost to the Kyoto Protocol parties. Developing countries bear a net cost despite having no emission-limitation commitments and selling CDM permits due to lower oil exports and the trade impacts of lower

21. Consistent with these results, de Moor et al. (2002) conclude that the unilateral US target is much less ambitious than those for Annex II parties (that is, Annex B parties excluding Russia, the Ukraine, and other Eastern European countries). They estimate the cost of meeting the US target at US\$(1995)0.3 billion per year in 2010, compared with a cost of \$13 billion to meet the United States' Kyoto Protocol commitment. They also estimate the domestic permit price in the United States in 2010 to be US\$(1995)12.85/tC, compared with an international price under the Kyoto Protocol of US(1995)\$20.90.

economic activity in Annex B parties.[22] The United States reaps a net benefit due to the shift in economic activity from Annex B parties.

Figure 2 illustrates emission-permit prices returned by the model for each of the scenarios.

8.2. NAFTA climate-control coalition scenario

The NAFTA climate-control coalition increases competition on the international emission-permits market. Here, the demand for emission permits increases and therefore so does the price. This leads to economic welfare reductions in the Kyoto coalition, but increases the revenues to the selling region Russia. On the other hand, the NAFTA coalition brings positive economic impacts to Canada, as it could benefit from trade effects within the climate-control coalition. The United States and Mexico could not increase benefits because both countries face real emissions targets, in contrast to the base case.

8.3. No coal scenario

The no coal scenario assumes a restriction on US coal exports. The United States is a large coal exporter. Kyoto Protocol parties—all countries except the United States—are assumed to stop buying coal from the United States, causing its coal exports to drop to zero. This might be achieved through an informal agreement among Kyoto Protocol parties or through an amendment to the Protocol to forbid coal purchases from non-parties, which might allow the restriction to be challenged under WTO rules.

As expected, coal prices in the United States decline slightly (13 percent in 2010), leading to greater coal consumption and higher greenhouse gas emissions (18 percent in 2010), but the United States continues to meet its emission-intensity target. As shown in figure 1, this strategy penalizes the United States by reducing the benefits it reaps from Annex B emission-mitigation actions relative to the base case. In the rest of the world, coal prices rise slightly (5 percent in 2010) and American coal exports are largely replaced by higher production in Russia. As a result, Central and Eastern European countries benefit more from Annex B parties' emission-mitigation actions.

In short, while this strategy would impose a cost on the United States, it is unlikely to be a viable strategy because it would also increase the costs to non-Annex B parties and to Annex B parties other than the Central and Eastern European countries.

8.4. Trade restrictions scenario

The trade restrictions scenario imposes constraints on the United States' trade. The Kyoto Protocol parties are assumed to adopt various product standards and eco-labels to promote the use of less greenhouse-gas-intensive products. These may include both voluntary initiatives promoted by environmental groups and mandatory standards established by governments, and are likely to include standards and labels based both on the product characteristics and on production processes and methods.

22. Babiker, Reilly, and Jacoby (1999) analyze the adverse economic impacts on developing countries resulting from implementation of policies by Annex B parties to meet their Kyoto Protocol commitments and find that selection of efficient policies by Annex B parties largely eliminates the adverse economic impacts on developing countries while reducing the economic costs for Annex B countries.

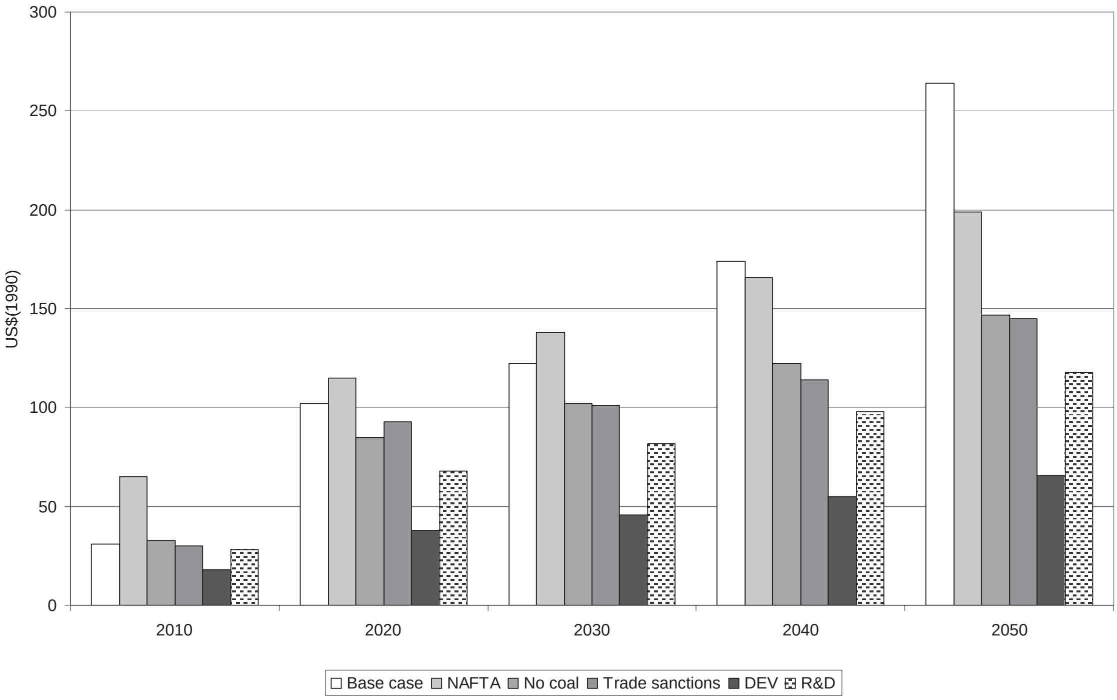


Figure 3. Emission permit prices in different scenarios

To be more acceptable under GATT, some may be adopted as amendments to the Kyoto Protocol. These actions are modeled as a combination of two changes: the emission intensity of goods produced in Kyoto Protocol parties is reduced from the base case by 10 percent in 2010 to reflect the effect of the standards on domestically produced goods; and the Armington elasticities of Kyoto Protocol party regions are adjusted so that consumers in these countries give greater preference to goods and services produced domestically or imported from other Kyoto Protocol parties, at the expense of products from the United States. The combined effect of these adjustments is to reduce imports from the United States by Kyoto Protocol parties by 10 percent from the base case in 2010. The emission intensities and Armington elasticities remain constant thereafter.

The lower emission intensity lowers greenhouse gas emissions by Kyoto Protocol parties, but at a cost. As figure 1 demonstrates, nearly all world regions suffer from trade restrictions. The reduced trade lowers incomes in both the United States and the Kyoto Protocol countries due to the reduced gains from trade. It turns out that trade restrictions actually represent self-induced penalties.

8.5. Developing countries scenario

The developing countries scenario imposes emission restrictions on developing countries based on their "business as usual" emissions. Despite the adoption of the CDM under the Kyoto Protocol, one of the reasons given by President Bush for withdrawing from the Protocol was that it does not require participation by developing countries. The literature contains various proposals for possible developing-country commitments, including: targets that allow emissions growth for the least-developed countries, with graduation to different levels of commitment as per capita income rises (Baumert, Bhandari, and Kete 1999; Aldy, Orszag, and Stiglitz 2001), per capita convergence (Meyer 1999), and the Argentine Proposal which means reduction of CO_2 emissions relative to the "business as usual" emissions (Menem 1998) or the implementation of energy-efficiency or other standards specified as amendments to the Kyoto Protocol.[23]

One of the principles of the UN Framework Convention on Climate Change is that developed countries should take the lead in combating climate change.[24] Since the analysis focuses on the initial commitments of developed countries and assumes they remain unchanged after 2010, a modest target for developing countries seems appropriate.

The specific commitment analysis states that developing countries must limit their emissions to their "business as usual" level beginning in 2020.[25] A more stringent commitment would result in a relatively larger emission reduction by developing countries than by the United States. Delaying the adoption of a developing-country target beyond 2020 would mean a negligible impact by 2010, the focus of the analysis. Limiting developing-country emissions prevents leakage and therefore leads to larger climate-change benefits from the emission reductions implemented by Annex B parties and the United States.

Our analysis disregards a Kuznets curve relationship whereby pollutant emissions rise with per capita income at relatively low incomes and then decline as per capita income further increases. Average turning-point estimates range at the level of per capita income from US$5000 to $8000 (Dasgupta et al. 2002).[26] The notion of the environmental Kuznets curve has been contested on theoretical grounds (Galeotti, Lanza, and Pauli 2001). Arguments include the view that the curve only presents a snapshot of development, and globalization will promote a "race to the bottom" of environmental standards.

Others have argued that such a race will not occur, because other location incentives dominate those of environmental regulation (Eskeland and Harrison 1997; Van Beers and Van den Bergh 1997). Evidence from empirical studies suggests that environmental regulation is the dominant factor in bringing about an environmental Kuznets curve. Put differently, in countries without active environmental policies, an environmental Kuznets curve will not automatically result even if per capita incomes rise sufficiently.[27]

Even if the assumption of the Kuznets curve was to hold in all cases, the turning points estimated for the major greenhouse gas, CO_2, are higher than the levels of per capita emissions that can be expected

23. See Berk et al. (2001, 29–30, box 2) for a useful summary.
24. United Nations Framework Convention on Climate Change, article 3.1.
25. The Montreal Protocol incorporates a 10-year lag between developed and developing countries' commitments.
26. Reasons why pollution levels may decline with increasing per capita emissions are that as per capita levels are higher, society has completed basic investments in health and education and can then turn to the environment. Additionally, more human and material resources are available for monitoring and enforcement of environmental regulations in wealthier societies. Finally, local communities are more apt to, and capable of, defending their rights when income and education increase.
27. Theoretical work on the environmental Kuznets curve indicates that it can result under a certain set of circumstances, including that the type of pollution concerned is local and not cross-border (Dasgupta et al. 2002). In addition, environmental regulation can produce positive economic returns, as shown in the cases of China (Dasgupta, Wang, and Wheeler 1997) or Indonesia (Calkins 1994).

up to 2050 in the developing-country regions considered in WIAGEM. Consequently, the analysis is limited to scenarios where developing-country emissions are limited in relation to their projected "business as usual" emissions.

Developing countries in this scenario are able to trade all of the reduction from their commitment beginning in 2020, rather than just the certified emission reductions, which are limited to 15 percent of the reduction from "business as usual" emissions. As a result, they are able to sell more permits, which increases the supply and reduces the international market price. As shown in figure 1, this results in a net benefit for developing countries and a lower compliance cost for Annex B parties. The benefit to Russia and the Ukraine is reduced, but they still benefit, and the United States benefits more than in the base case.

In short, this strategy is attractive to all Kyoto Protocol parties, and also yields a benefit to the United States. Thus, the Kyoto Protocol parties could, in principle, agree to implement this strategy in return for adoption of a more stringent unilateral target by the United States.

8.6. R & D cooperation scenario

The R & D cooperation case includes R & D-induced technology effects between cooperating nations. The Kyoto Protocol currently does not include specific provisions for cooperation on research and development. Such cooperation could reduce the cost of achieving the emission-reduction commitments. R & D cooperation among Annex B parties is modeled first; then, R & D cooperation among Annex B parties and the United States is modeled to assess the effectiveness of this strategy as a means of inducing the United States to adopt a more stringent unilateral emission target.

As shown in figure 1, R & D cooperation among Annex B parties reduces the compliance costs of Annex B parties and raises the benefits to Central and Eastern European countries relative to the base case. R & D cooperation lowers the cost of reducing emissions, so emissions and compliance costs are lower in Annex B countries. Central and Eastern European countries benefit from the R & D cooperation through lower emissions and larger revenues from the sale of permits. R & D cooperation among Annex B parties increases the burden on developing countries. The adverse trade effects are smaller due to the lower compliance cost for Annex B parties, but the lower revenues from certified emission reduction sales result in a higher net burden. The savings realized by Annex B parties are larger than the increased burden on developing countries, so they could be compensated through technology or financial transfers. Emissions in developing countries also drop due to larger technology spillover effects.

9. Conclusion

This paper studies whether or not there exist strategies that could successfully induce non-cooperating nations, like the USA, to join coalitions of climate policy. It turns out that trade sanctions are not appropriate measures as they trigger economic disadvantages to both punished and punishing regions. However, cooperation on R & D spending to improve energy-efficient technologies might give concrete incentives to non-cooperating nations to join a coalition. The inclusion of developing countries only brings economic advantages to both industrialized and developing nations if developing countries are granted emission permits. An international permit-trading market could reduce compliance costs of industrialized countries. This would make it highly advantageous for the USA to join a climate-policy coalition. Therefore, both strategies to increase incentives to join a climate-policy coalition by R & D cooperation and international emission trading (including developing countries) could be effective strategies.

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