A NO CAP BUT TRADE PROPOSAL FOR GREENHOUS GAS EMISSION REDUCTION TARGETS FOR BRAZIL, CHINA AND INDIA

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Abstract

One problem in international climate policy is the refusal of large developing countries to accept emission reduction targets. Brazil, China and India together account for about 20% of today's CO_2 emissions. We analyse the case in which there is no international agreement on emission reduction targets, but countries do have domestic targets, and trade permits across borders. We contrast two scenarios. In one scenario, Brazil, China and India adopt their business as usual emissions as their target. In this scenario, there are substantial exports of emission permits from developing to developed countries, and substantial economic gains for all. In the second scenario, Brazil, China and India reduce their emissions target so that they have no net economic gain from permit trade. Here, developing countries do not accept responsibility for climate change (as they bear no net costs), but they do contribute to emission reduction policy by refusing to make money out of it. Adopting such break-even targets can be done at minor cost to developed and developing countries (roughly $2 bln/year each in extra costs and foregone benefits), while developing countries are still slightly better off than in the case without international emissions trade. This result is robust to variations in scenarios and parameters. It contrasts with Stewart and Wiener (2003) who propose granting "hot air" to developing countries to seduce them to accept targets. In 2020, China and India could reduce their emissions by some 10% from the baseline without net economic costs.

Keywords : climate policy, developing countries, emission permits, emission reduction targets

JEL Classification

Q540, Q580

1. Introduction

The inclusion of “flexibility mechanisms” in the Kyoto Protocol is frequently hailed as one of its major achievements. This is peculiar, as these flexibility mechanisms are internationally tradable permits, joint implementation, and the clean development mechanism. The latter two instruments are variants of tradable permits. Tradable permits were there before Kyoto, and so was international trade. Nonetheless, “where flexibility” is a crucial component of any attempt to reduce greenhouse gas emissions, and the Kyoto Protocol deserves praise in this regard.

As shown in Rehdanz and Tol (forthcoming), national markets for emission permits would readily merge to form an international market. A multilateral treaty is not needed, although regulators would need to accept imported permits. Domestic regulators would continue to be able to exercise control over national emission reduction policy. Other policy instruments for emission abatement are not as easily internationalized.

Emission reduction targets are the core of the Kyoto Protocol. Internationally treaties result from cooperation between sovereign countries. As is amply shown in the game-theoretic literature, cooperation is hard to achieve for global environmental goods such as greenhouse gas emission reduction. Therefore, it is no surprise that only a small number of countries have substantial obligations under the Kyoto Protocol. These are mainly industrialized countries or countries in transition with very different opinions about how strict their agreed targets actually are. Australia and the USA decided not to ratify the Kyoto Protocol.

Yet, climate change is a global problem, and requires a global solution. In this paper, we investigate how international trade in emission permits can induce countries to accept emission reduction targets. This is especially important as negotiations for the second commitment period of the Kyoto Protocol already started. These deliberations include a radical overhaul of the structure to date. A higher number of countries participating might increase the effectiveness of international climate policy.

This idea is not new. Most of the existing literature on this subject is on enhancing countries incentives to participate in a climate agreement. Stewart and Wiener (2003) e.g. propose to grant “hot air” to developing countries in order to seduce them to accept emission reduction targets and participate in international permit trade. For an overview of different approaches see Aldy *et al*., 2003, Barrett and Stavins, 2003, Bodansky, 2004, Kameyama, 2004 or Torvanger *et al*., 2004. The proposals can be assessed by different criteria including e.g. environmental effectiveness, cost-effectiveness, dynamic efficiency and participation and compliance. Proposals based on countries’ national emission reduction obligations, not bound by international agreements, are rather rare. Some studies exist using game-theoretic approaches. A recent analysis by Buchner and Carraro (2005) provides a game-theoretic assessment on bottom-up climate regimes (in which countries are free to sign agreements and permit trade is included) with a particular focus on China, India and the US. Peck and Teisberg (2003) propose a once-and-for-all agreement on a concentration target, implemented through long-term emission permits. The latter feature provides full where and when flexibility. Countries would initially agree to such a programme as the near-term costs of emission reduction would be low. Countries would stick to the agreement, as the stock of tradable permits would be very valuable asset. Viguier (2004) proposes a “rent-sharing approach” where developing countries would have the opportunity to enter the market for tradable emission permits. A prerequisite is that they agree to a voluntary domestic emission reduction target. His proposal differs from ours in that he also introduces “permanently banked” emission permits, an unnecessary complication. Numerically, Viguier (2004) only studies China. Philibert and Pershing (2001) propose a non-binding target where developing countries would be allocated an emission budget. As long as their actual emissions are below the budget they can sell permits on the market. However, there are no consequences for overselling as they would not be forced to buy permits if their emissions exceed their budget. This undermines the market. Philibert and Pershing (2001) do not quantify their arguments.

The proposal by Bradford (2002) is closely related to ours. In his no-cap-but-trade framework, countries would reduce domestic emissions as they see fit, and contribute voluntarily to a global fund, which would use the money to invest in emission reduction wherever that is cheapest. The main difference between Bradford's and our proposal is that we replace the global fund (and its potential for lobbying, inefficiency and corruption) with the invisible hand.

A special focus of our analysis is on the participation of Brazil, China and India in international permit trade. Although these countries account together for about 20% per cent of CO_2 emissions in 1990, they have no binding emission reduction targets (IEA, 2004). As members of the Non-Annex I countries they are currently excluded from international trade in greenhouse gas emission permits under the Protocol. We use data and projections for CO_2 emissions, population and GDP for the period 1990 to 2020 to investigate if these countries would have an incentive to participate in international trade and to perhaps even agree to emission reduction targets. In contrast to the papers cited above, we estimate the size of the emission reductions and the economic gains and losses.

This paper contrasts four scenarios, the first of which has no emission control. This scenario is only used for anchoring. In the second scenario, emissions are controlled but there is no international trade in emission permits. This scenario is only used as a benchmark for cost comparison. In the third scenario, there is global permit trade. Countries without emission reduction targets (that is, Brazil, China and India) adopt their business as usual emissions as their target. In this scenario, there are substantial exports of emission permits from developing to developed countries, and substantial economic gains for both parties. In the fourth scenario, developing countries reduce their emissions target such that they make no net economic gain from permit trade. Here, developing countries do not accept responsibility for climate change (by accepting part of the burden of emission reduction), but they contribute to emission reduction policy by refusing to make money out of it; they reduce emissions to their break-even point. A comparison of the third and fourth scenario gives the space for negotiation between developed and developing countries. The third scenario gives the minimum bound on emission reductions. The fourth scenario gives the maximum effort (at no cost) of developing countries. In contrast to Stewart and Wiener (2003) we find that granting "hot air" to developing countries in order to seduce them to accept emission reduction targets and participate in international permit trade is not needed. Without hot air, developing countries would also benefit from permit trade.

Section 2 presents the model and the scenarios. Section 3 discusses the results. Besides the scenarios sketched above, sensitivity analyses are shown as well. Section 4 concludes the paper and discusses policy implications.

2. The model

Let us consider a market for tradable emission reduction permits with *I* countries. Emission reduction costs *C* are quadratic. Each country solves the problem:

(1a) $$\min_{R_i,P_i} C_i = \alpha_i R_i^2 Y_i + \pi P_i \text{ s.t. } R_i E_i + P_i \geq E_i - A_i$$

R is proportional emission reduction; *Y* is gross domestic product; *P* denotes the amount of emission permits bought or sold; *π* is the emission permit price; assuming a perfect market, all companies face the same price; *E* are the emissions; *A* are the allocated emission permits; that is, if a country emits more than has been allocated, *E>A*, it will have to reduce emissions or buy permits on the market; *α* is a parameter; countries are indexed by *i*. If a country's allocation exceeds its emissions, *E<A,* the optimization problem is:

(1b) $$\min_{R_j,P_j} C_j = \alpha_j R_j^2 Y_j - \pi R_j E_j + \pi P_j \text{ s.t. } P_j \geq E_j - A_j$$

We assume that the country sells its hot air *P=E-A*, and in addition reduces emissions by *RE* which it sells at the market for *πRE*. Fixing *A*, we in fact assume that countries with hot air do not have market power. Countries with hot air are indexed by *j*. Countries without emission reduction targets are excluded from the market.

The first order conditions of (1) are:

(2a) $$\begin{aligned} &2\alpha_i R_i Y_i - \lambda_i E_i = 0, i = 1,2,...,I \\ &2\alpha_j R_j Y_j - \pi E_i = 0, j = 1,2,...,J \end{aligned}$$

(2b) $$\pi - \lambda_i = 0, i = 1,2,...,I$$

(2c) $$\begin{aligned} &R_i E_i + P_i - E_i + A_i = 0, i = 1,2,...,I \\ &P_j - E_j + A_j = 0, j = 1,2,...,J \end{aligned}$$

where *λ* denotes the Lagrange multiplier. This is a system with 3(*I*+*J*) equations and 3(*I*+*J*)+1 unknowns, but we also have that aggregate supply must equal aggregate supply, that is

(2d) $$\sum_{i=1}^{I} P_i + \sum_{j=1}^{J} P_j - \sum_{j=1}^{J} R_j E_j = 0$$

which allows us to solve for the permit price *π* as well. (2) solves as:

(3a) $$\pi = \lambda_i = \frac{\sum_{i=1}^{I}(E_i - A_i) + \sum_{j=1}^{J}(E_j - A_j)}{\sum_{i=1}^{I} E_i^2 / 2\alpha_i Y_i + \sum_{j=1}^{J} E_j^2 / 2\alpha_j Y_j}$$

(3b) $$R_i = \frac{\pi E_i}{2\alpha_i Y_i}; R_j = \frac{\pi E_j}{2\alpha_j Y_j}$$

(3c) $$P_i = E_i - A_i - \frac{\pi E_i}{2\alpha_i Y_i} E_i; P_j = E_j - A_j$$

So, the permit price goes up if the emission reduction obligation increases or if the costs of emission reduction increase. All companies face the same marginal costs of emission reduction, and the trade-off between reducing emissions in-house and buying or selling permits is driven by the ratio of marginal emission reduction costs and the permit price. The modeled market behaves as expected. Note that the solution without the market in emission permits (P_i=0) is trivial.

Rehdanz and Tol (forthcoming) consider the special case I=2, but include additional market regulation. Rehdanz and Tol (2004) expand the model to two periods, including dynamic permit allocation and banking and borrowing.

Following Tol (2003), we specify

$$(4) \qquad \alpha_i = 1.57 - 0.17\sqrt{\frac{E_i}{Y_i} - \min_i \frac{E_i}{Y_i}}$$

which states that countries that emit a lot of (little) carbon relative to their production, have low (high) emission reduction costs. This specification was calibrated to the literature review of Hourcade *et al.* (1996, 2001). It gives emission reduction costs for each country in the world for which we have emissions and GDP data. In Rehdanz *et al.* (2005), we use this model for all Annex I countries. Here, we restrict ourselves to the seven largest emitters: Brazil, China, European Union, India, Japan, Russia, and the USA.[1] Together, these countries[2] emit about 70% of all carbon dioxide emissions from fossil fuel combustion.[3]

We collected data for the period 1990 to 2020. Data on emissions (measured in tonnes of CO_2) and GDP (measured in constant 1995 US $) for 1990, 1995 and 2000 were taken from the World Resources Institute. The data for emissions and GDP were projected to 2010 and 2020 using information on the average annual percent change for the period 2000 to 2025 (IEA, 2004). Data on population was taken from the World Resources Institute for the whole period from 1990 to 2020. Emission reduction targets for 2010 to 2020 are those of the Kyoto Protocol,[4] except for the USA, which aims to reduce its emission intensity by 18% between 2000 and 2010;[5] this corresponds to a 28% increase in emissions.

[1] For convenience, we excluded other Annex-I countries such as Canada, Australia and New Zealand from our analysis.
[2] Environmental policy in the EU is sufficiently coordinated to regard the EU as a country in this respect.
[3] The number is referring to 1990 data (IEA, 2004).
[4] See http://unfccc.int/resource/docs/convkp/kpeng.pdf.
[5] In the baseline, emission intensity falls by 15%.

3. Results

Table 1 shows the emission reduction targets of the seven countries for 2010 and 2020. In 2010, the EU, Japan and Russia do as agreed in the Kyoto Protocol, and the USA follows its Climate Change Initiative. In 2020, the EU, Japan and Russia reduce emissions by another 8%, 6%, and 0% respectively, relative to 2000; the USA again allows its emissions to increase by 28%. In one scenario, Brazil, China and India accept targets equal to their projected emissions; without international permit trade, these countries would not reduce emissions. This is scenario three as described above. In the other scenario (scenario four, see above), these countries accept break-even targets so that their net gains of emission trade are zero.[6] Substituting (3) in (1), and solving for *A*, the allocated emission permits, while ignoring the response of the other countries, this yields

$$(4) \qquad A_i^* = \frac{\pi}{\alpha_i Y_i}\left[\frac{E_i^2}{4} - \frac{E_i}{2}\right] + E_i$$

In scenario four, Brazil accepts emission targets in 2020 that are some 2% below the baseline, India 8% below baseline, and China 14%.[7]

Table 1 shows the gains of trade for the cases with and without targets for Brazil, China and India (scenarios three and four respectively). All countries gain from trade. Table 1 also shows the difference between Brazil, China and India accepting emission reduction targets and not. Each developing country foregoes gains of emission permit export if it accepts targets, but each country is still better off than in the case without targets and without permit trade (not displayed). Compared to GDP, the foregone gains are minimal. The costs of emission reduction increase in the EU, Japan and the USA, but numbers are again small compared to GDP. Russia gains, as emission permits get more expensive.

Table 1 about here

So, Brazil, China and India can accept real emission reduction targets. They would pay for this with foregone benefits, so the economic and political implications are minimal. OECD countries do pay a higher price for greenhouse gas emission reduction, as the global emissions are lower.

Table 2 shows what would happen if the OECD countries would decide to achieve the global emissions reduction by raising their targets to include the emission reductions of Brazil, China and India in scenario 4. We assume that they would do so proportionally to their targets in Table 1, that is, each country additionally reduces its emissions target by about 10%. Brazil, China and India participate in international emissions trading by adopting their business as usual emissions (scenario 5). Table 2 shows that global emissions are as in Table 1. This is by construction. Global emission reduction reductions costs are also as in Table 2. This results from the Coase (1961) Theorem. From Equation (3a), it is immediate that the marginal cost of emission reduction depends only on the global amount of emission reduction. In each country,

[6] Note that we assume that each country does not anticipate the emissions targets of the other two countries. As a results, each country gains from permit trading.
[7] If the countries were to anticipate each others' targets, emission reduction would be 5%, 27% and 35% below baseline.

the price of carbon permits determines the trade-off between domestic emission reduction and international permit trade. As trade is linear, a redistribution of emission reduction targets implies only a redistribution of the money changing hands through permit trade. See Rehdanz and Tol (2004) for further discussion. If the OECD countries were to increase their emission reduction targets rather than Brazil, China and India, the result would be a sharp increase in the costs for the EU, Japan and the USA, and a sharp increase in the gains for Brazil, China and India. This is especially pronounced in 2020.

Above, Brazil, China and India accept real emission reduction targets so as to nullify their gains from international permit trade (scenario 4). However, they do so without anticipating that the other two developing countries do the same. As a result, Brazil, China and India still gain from trade (cf. Table 1). Table 2 shows the result if the emission reduction targets of the other countries are anticipated (scenario 6). As expected, total emission reduction goes up. The gains of Brazil, China and India go down; to zero for Brazil and India, to almost zero for China (due to rounding). The costs for the EU, Japan and the USA increase. Numerically, the differences are small.

Table 2 about here

Table 3 presents sensitivity analyses, focusing on scenario 4 and the break-even emission reduction targets of Brazil, China and India. Two different scenarios are displayed. First, we investigate how emission reduction targets are affected if unit emission reduction costs are altered. This is displayed in the left half of table 3. Unit emission reduction costs are increased and decreased by 50% for all countries. China and India would accept slightly higher (lower) emission reduction targets if costs are lower (higher). A stricter target increases emission reduction costs (a loss to all), but also the price of permits (a gain to permit sellers). Russia for example would benefit from higher emission reduction costs. If the cost curve is less steep, the point where increased emission reduction costs meet increased revenue from permit sales moves away from the origin (no emission reduction targets for China and India); A^* (Equation (4)) is declining in α, if we ignore the price effect $\left(\frac{\partial \pi}{\partial \alpha_i} > 0\right)$. The effect is opposite for Brazil, because its unit emission reduction costs are higher than in China and India. Hence, its market position is weak, but strengthens (weaken) as China and India weaken (strengthens) their position by decreasing (increasing) their emission reduction targets. The difference in total costs between the low and high costs scenario is very close to a factor of three for all countries.

Table 3 also presents the cases in which the rate of decarbonisation is 0.25% and 0.75% per year; it is 0.50% in the base case (see left half of table 3). This is assumed to take hold only after 2010. If baseline emissions are lower (higher), Brazil, China and India accept more (less) stringent emission reduction targets. This is because less (more) rapid growth of emissions implies reduced (increased) demand for permits by the EU, Japan and the USA; Brazil, China and India respond to restrain (release) the market. Lower (higher) baseline emissions imply lower (higher) emission reduction costs for the EU, Japan and the USA, and lower (higher) gains from permit trade for Brazil, China, India and Russia.

Table 3 about here

Figure 1 shows the results for a further sensitivity analysis. In the scenarios above, the USA limits its 2020 emissions to 128% of its 2000 emissions (just like its 2010 emissions are limited to 128% of its 1990 emissions, at least according to our projections). Without emission reduction, 2020 emissions would be 140% of 2000 emissions. The unwillingness of China and India to adopt emission reduction targets is a major reason why the US targets are so lenient. As China and India do adopt emission reduction targets, we reduce the US target in steps of 7% from 128% to 93% (its Kyoto target). Figure 1 shows the break-even emission reduction for Brazil, China and India. As overall emission reduction is larger, the permit price of carbon dioxide is larger, and the gains of permit export are larger too. Therefore, Brazil, China and India can afford more stringent targets. The relationship between the break-even targets of these three countries and the US target is approximately linear.

Figure 1 about here

4. Discussion and conclusion

This paper considers international trade of emission permits with participation of developing countries when countries are not bound by international agreements. We focus on the three largest developing countries Brazil, China and India and analyse their incentives for participation in emission reduction. We contrast two scenarios. In one scenario, Brazil, China and India adopt their business as usual emissions as their target. In this scenario, there are substantial exports of emission permits from developing to developed countries, and substantial economic gains for both parties (scenario 3). In the second scenario, Brazil, China and India reduce their emissions target such that they make no net economic gain from permit trade (scenario 4). Here, developing countries do not accept responsibility for climate change (by accepting part of the burden of emission reduction), but they contribute to emission reduction policy by refusing to make money out of it. The foregone gains to Brazil, China and India are small, and so are the additional costs to the developed countries.

If developed countries would increase their emission reduction targets by an equivalent amount, this would be more costly (to them) than persuading developing countries to agree to targets (scenario 5). This is because the marginal costs for emission reduction are much lower in developing countries. The global costs are unaffected (Coase Theorem). However, we also find that it might be in the interest of Brazil, China and India to accept real emission reduction targets. They would gain less compared to no targets and free trade, but the would still benefit compared to the case in which they do not partake in emissions trade.

The numbers are interesting. For China (India), the break-even reduction target is some 14% (8%) or 1 bln tCO_2 (0.2 bln tCO_2) below its baseline emissions. The baseline is China's and India's threat point, the situation to which it can return if it dislikes whatever is on offer. China and India have made it clear that they do not want to bear part of the burden of emission reduction; and with their break-even emission reduction they have no net costs. Between threat point and break-even point, there is room for manoeuvre, and this amounts to 1.2 bln tCO_2 in 2020.

Note that China and India will not be alone in reducing emissions. Indeed, in the break-even case, China and India spend the producer surplus from exporting emission permits on emission reduction. If there is no demand for emission permits, that is, the OECD countries do not set emission targets, there is no producer surplus and no emission targets for China and India. Nonetheless, emission abatement targets for China and India may reduce the resistance to climate policy in the USA. Note also that China and India spend their producer surplus, not transfer payments.

The analysis presented here needs extension in at least four directions. Firstly, projects based on the Clean Development Mechanism (CDM) were excluded from our analysis. Instead, we assume a market in emission permits without the distortions and transaction costs that characterize the CDM. Secondly, we present results for a simple model and a limited set of scenarios. However, we believe that our future scenarios and parameter assumptions are not unrealistic. Thirdly, we ignore uncertainty. We assume that Brazil, China and India decide in 2010 on their emission reduction target for 2020, with foresight about their 2020 baseline emissions, as well as about emissions and emission reduction costs of all parties. Uncertainty plus risk aversion would lead to less stringent targets. (On the other hand, in the central case, each country ignores the actions of the other countries.) Fourthly, we omit the effect on the longer term. We show that Brazil, China and India can accept modest emission reduction targets in the medium term. This would reveal their emission reduction costs and create a regulatory framework for abatement, probably easing later emission reduction commitments. However, it is unclear whether technological change is faster in this case than in the case in which Brazil, China and India do not partake in emissions trading at all. These tasks are deferred to future research.

The political realism of the scenarios in this paper is unclear. Brazil, China and India have made it clear that they will not accept emission abatement targets before there is evidence of substantial action by the OECD countries. Previous attempts at bribing them have failed. Yet, as noted above, the proposed scheme does not rely on transfers and automatically comes apart if the OECD does not act. It is clear, however, that the climate problem will not be solved without the active involvement of Brazil, China and India. As future large emitters, they will contribute substantially to the problem. These countries are also believed to be vulnerable to climate change. If Brazil, China and India are not interested in emission reduction, then who would be?

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Table 1. Targets and costs: Base scenarios.

2010	Emission Reduction[a]		Scenario 3[b]		Scenario 4[c]		Difference[d]	
	Scen. 3	Scen. 4	mln $	%GDP	mln $	%GDP	mln $	%GDP
EU	488	488	2639	0.0211	2618	0.0209	-21	-0.0002
Russia	-771	-771	100	0.0193	136	0.0261	35	0.0068
China	0	30	3	0.0002	1	0.0000	-3	-0.0001
India	0	6	1	0.0001	0	0.0000	0	-0.0001
Japan	316	316	5970	0.0887	5957	0.0885	-14	-0.0002
Brazil	0	1	0	0.0000	0	0.0000	0	0.0000
USA	75	75	17	0.0001	15	0.0001	-3	0.0000
2020	**Emission Reduction[a]**		**Scenario 3[b]**		**Scenario 4[c]**		**Difference[d]**	
	Scen. 3	**Scen. 4**	**mln $**	**%GDP**	**mln $**	**%GDP**	**mln $**	**%GDP**
EU	1387	1385	16355	0.1063	14975	0.0973	-1380	-0.0090
Russia	285	275	105	0.0176	444	0.0746	339	0.0569
China	0	1006	1890	0.0579	198	0.0061	-1692	-0.0518
India	0	195	464	0.0324	239	0.0167	-225	-0.0157
Japan	429	429	8967	0.1085	8519	0.1031	-448	-0.0054
Brazil	0	11	27	0.0013	17	0.0008	-10	-0.0005
USA	746	740	663	0.0041	278	0.0017	-385	-0.0024

[a] Emission reduction targets (million tonnes of carbon dioxide), for the case with (scenario 3) and without (scenario 4) targets for Brazil, India and China.
[b] The annual gains of global emission permit trade, in million dollar and percent of GDP, without targets for Brazil, India and China.
[c] The annual gains of global emission permit trade, in million dollar and percent of GDP, with targets for Brazil, India and China.
[d] The difference in gains, in million dollar and percent of GDP, due to Brazil, India and China accepting emission reduction targets.

Table 2. Targets and costs: Alternative scenarios.

2010	**Emission Reduction**[a]				**Costs**[b]			
	Scen. 3	**Scen. 4**	**Scen. 5**	**Scen. 6**	**Scen. 3**	**Scen. 4**	**Scen. 5**	**Scen. 6**
EU	488	488	500	488	62	83	85	87
Russia	-771	-771	-771	-771	-100	-136	-136	-142
China	0	30	0	35	-3	-1	-6	0
India	0	6	0	8	-1	0	-1	0
Japan	316	316	319	316	40	54	55	57
Brazil	0	1	0	1	0	0	0	0
USA	75	75	96	75	9	11	15	12
World	*108*	*145*	*144*	*152*	*7*	*11*	*12*	*14*
2020	**Emission Reduction**[a]				**Costs**[b]			
	Scen. 3	**Scen. 4**	**Scen. 5**	**Scen. 6**	**Scen. 3**	**Scen. 4**	**Scen. 5**	**Scen. 6**
EU	1387	1385	1735	1384	3349	4684	5950	4882
Russia	285	275	275	274	106	-245	-245	-319
China	0	1006	0	1105	-1890	-198	-3831	-8
India	0	195	0	273	-464	-239	-943	0
Japan	429	429	544	429	1055	1489	1906	1554
Brazil	0	11	0	16	-27	-17	-55	0
USA	746	740	1485	739	1468	1822	4512	1861
World	*2847*	*4041*	*4039*	*4220*	*3597*	*7296*	*7294*	*7970*

[a] Million tonnes of carbon dioxide.
[b] Million US dollar.

Table 3. Targets and Costs: Sensitivity analysis.

	Increase and decrease in unit emission reduction costs				Different rates of decarbonisation			
2010	**Emission Target**[a]		**Costs**[b]		**Emission Target**[a]		**Costs**[b]	
	Low Costs	**High Costs**	**Low Costs**	**High Costs**	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**
EU			0.0003	0.0010			0.0007	0.0007
Russia			-0.0134	-0.0391			-0.0261	-0.0261
China	181.6	181.7	0.0000	0.0000	181.7	181.7	0.0000	0.0000
India	201.7	201.8	0.0000	-0.0001	201.8	201.8	0.0000	0.0000
Japan			0.0004	0.0012			0.0008	0.0008
Brazil	206	206.3	0.0000	0.0000	206.3	206.3	0.0000	0.0000
USA			0.0000	0.0001			0.0001	0.0001
World	*124.8*	*124.9*	*-0.0127*	*-0.0369*	*124.9*	*124.9*	*-0.0245*	*-0.0245*

2020	**Emission Target**[c]		**Costs**[b]		**Emission Target**[c]		**Costs**[b]	
	Low Costs	**High Costs**	**Low Costs**	**High Costs**	**Low Emissions**	**High Emissions**	**Low Emissions**	**High Emissions**
EU			0.0152	0.0457			0.0253	0.0358
Russia			-0.0207	-0.0616			-0.0340	-0.0484
China	193.2	193.3	-0.0030	-0.0091	192.2	194.5	-0.0048	-0.0076
India	212.1	212.2	-0.0083	-0.0251	209.1	215.3	-0.0130	-0.0205
Japan			0.0090	0.0270			0.0149	0.0213
Brazil	229.3	229.2	-0.0004	-0.0011	224	234.7	-0.0006	-0.0010
USA			0.0056	0.0168			0.0069	0.0162
World	*134.8*	*134.9*	*-0.0026*	*-0.0074*	*134.4*	*135.4*	*-0.0053*	*-0.0042*

[a] Percent of 1990 emissions.
[b] Million US dollar.
[c] Percent of 2000 emissions.

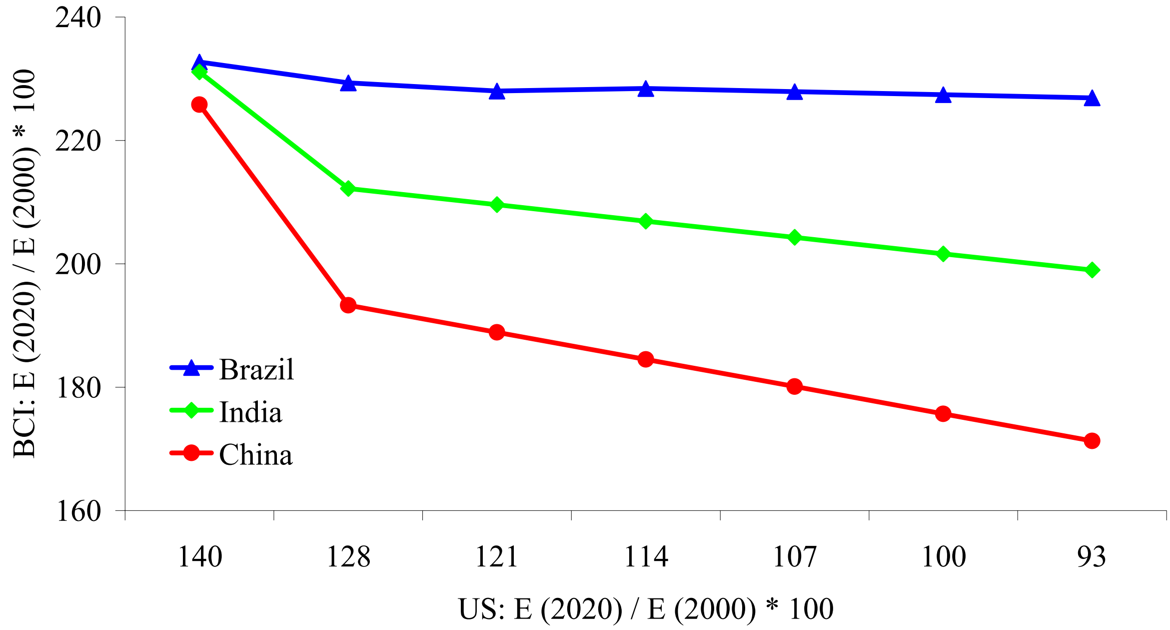

Figure 1. The break-even emission abatement targets of Brazil, China, and India (BCI; expressed as the ratio of 2020 and 2000 emissions) as a function of the emission reduction target of the USA. For illustrative purposes, the business as usual emissions are also shown.

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Research Unit Sustainability and Global Change

Hamburg University and Centre for Marine and Atmospheric Science

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