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Can no-lose targets contribute to a 2 °C target?*

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Abstract

This paper explores the contribution that no-lose target schemes for non-Annex I (NAI) countries can make to achieving the 2 °C target. The analyses rely on marginal abatement cost curves obtained from a global partial equilibrium model for the year 2020 and specifically account for 18 NAI countries' incentives to participate in no-lose target schemes. Findings suggest that implementing uniform no-lose targets as part of the burden-sharing discussed in the IPCC report (Metz et al., 2007) will not lead to global emission levels compatible with the 2 °C target, because uniform no-lose targets are only beneficial to a few NAI countries. Employing more lenient uniform no-lose targets or individualizing no-lose targets for large emitters could increase participation by NAI countries and decrease global emissions, global compliance costs, rents by NAI countries, and compliance costs for Annex I (AI) countries, but the resulting global emission levels would also not be consistent with the 2 °C target. Achieving the 2 °C target requires more stringent emission targets for AI countries and more lenient no-lose targets for NAI countries. In this case, no-lose targets account for 20% to 47% of global emission reductions, while due to emissions trading around 2/3 of global emission reductions are realized in NAI countries. An effective solution may entail no-lose targets for five to seven large NAI countries, only.

Keywords: No-lose targets, Post-Kyoto, burden-sharing, emission trading

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1 Introduction

The recent international climate summits in Copenhagen and Cancun have recognized the goal to keep the mean global temperature increase below 2 °C above pre-industrial levels (United Nations, 2009, 2010). Both Annex I (AI) and non-Annex I (NAI) countries have to contribute in order to achieve substantial reductions in global emissions by the middle of this century (Rogelj et al., 2011; United Nations, 2009). At the United Nations Framework Convention on Climate Change (UNFCCC) summit in Durban in December 2011, it was agreed that from 2020 onwards AI and NAI countries will make reduction efforts under a single agreement. In this regard, the Durban platform (United Nations, 2011) overcomes the dichotomy of the Kyoto framework, which foresees emission reduction targets for AI countries only, and also addresses the demands made by AI countries for a more integrated approach to combating climate change (WRI, 2009; Rajamani, 2009). Yet the challenge remains of how to integrate AI and NAI countries taking into account the "common but differentiated responsibility" of developing and developed countries (United Nations, 1992). AI countries like the USA, Canada or Japan tend to be reluctant to commit to emission targets unless NAI countries like China subscribe to make similar efforts. At the same time, emerging NAI countries fear that binding emission targets will inhibit future economic growth.

So called "no-lose targets" have been proposed as a possible measure to overcome the dichotomy under the Kyoto framework while at the same time safeguarding NAI countries from emission targets which may slow down economic development (United Nations, 2012b; Philibert, 2000; Philibert and Pershing, 2001). A no-lose target presumes that a NAI country agrees to accept a specific non-binding emission target. If the NAI country over-achieves this target, it may sell emission certificates corresponding to the difference between the target and its actual emissions to other countries with binding targets. However, the NAI country will not be penalized if it fails to meet its no-lose target. By over-achieving its no-lose target, a NAI country can generate revenues which might (over-)compensate the associated abatement costs. Conversely, if market prices for these emission certificates are low (e.g. because demand is low relative to supply), or if abatement costs in the NAI country are high (e.g. because economic growth is strong), the NAI country might be better off choosing to exceed the emission target. In sum, no-lose targets provide financial incentives to reduce emissions, but act as a safety valve in the case of high costs. For these reasons, no-lose targets have been termed a "useful transitional device" (Bodansky, 2003) towards NAI countries accepting binding emission targets in the longer run. However, unlike a binding reduction target, a no-lose targets does not guarantee that a given global emission target will be met. A NAI country will only contribute to the envisaged global emission target being achieved if it fulfills its no-lose target. Therefore, we assume that a no-lose target should be such that the NAI country does not incur financial costs from the target. Here, the level of a no-lose target has two effects: On the one hand, a lenient (stringent) no-lose target means low (high) abatement costs and, hence increases (decreases) the chance that the target is profitable for a given certificate price. On the other hand, lenient (stringent) no-lose targets increase (decrease) the supply of certificates and lower (increase) their price. Hence, from the perspective of an individual NAI country, a low individual no-lose target increases the chances that the country will participate in a no-lose targets scheme, but low no-lose targets for other NAI countries will lower this likelihood. Thus, a country's decision to participate also depends on the participation of other countries with no-lose targets.

In this paper we assess to which extent a no-lose targets scheme could contribute to reaching the 2 °C target. Unlike previous studies, we specifically take into account the economic incentives for NAI countries to participate in no-lose targets and consider that these incentives also depend on other no-lose targets countries' participation. Also, by modelling 18 potential no-lose target countries our simulations explicitly reflect heterogeneity across NAI countries, which should provide for a more realistic assessment of the global potential of no-lose target schemes. Our analyses are positive rather than normative in the sense that we explore the extent to which no-lose targets derived from current climate policy discussions are viable and could contribute to global emissions' reductions.

First, we analyze the burden-sharing approach for the year 2020 derived from the Intergovernmental Panel on Climate Change (IPCC) 4th assessment report (Metz et al., 2007). According to den Elzen and Hoehne (2010a), which provides the background analyses for the IPCC assessment by Metz et al. (2007), the increase in global greenhouse gas (GHG) emissions must not exceed 1990 levels by more than 10% to 30% by 2020.[1] The IPCC further suggests emission reduction targets for AI and NAI countries for 2020 which are consistent with the global reduction targets: AI countries must decrease their greenhouse gas emissions by 25% to 40% below 1990 levels (Metz et al. (2007)) and emissions from NAI countries need to stay 15% to 30% below the baseline (den Elzen and Hoehne (2010a)). For the scenarios based on the IPCC burden-sharing agreement, we transform the targets for NAI countries into uniform reduction targets, i.e. all the NAI countries eligible for a no-lose target face the same reduction target (measured as a percentage below baseline emissions).

Our findings for these “IPCC” scenarios suggest that only a few NAI countries find it profitable to comply with their no-lose targets, at best. As a consequence, global emissions will be higher than envisaged. Therefore, we explore alternative options to increase the participation by NAI countries. We show that employing less ambitious uniform no-lose targets for all the eligible NAI countries, or individualizing no-lose targets for the largest emitters, i.e. Brazil, India and China, could achieve higher participation and lower global emissions than under the “IPCC” scenarios. However, the associated global emissions are still much higher than envisaged. Finally, we illustrate how uniform no-lose targets can effectively contribute to achieving the 2 °C target once the burden-sharing between AI and NAI countries is altered.

This last step allows us to also compare our results with the outcome of various types of burden-sharing proposals for ambitious climate agreements. Most burden-sharing proposals are based on equity or fairness principles, such as the individual right to equal emissions (“egalitarian”), NAI countries’ need for economic development and their lower economic capacity to bear mitigation costs (“ability to pay”), and their lower responsibility for climate change (“polluter pays”) (Torvanger and Ringius, 2002, Ekholm et al. 2010). Often, indicators reflecting these principles, or combinations thereof, are used to derive formulas for burden-sharing agreements. Examples for these formula-based burden-sharing approaches include – in addition to the various studies surveyed in the IPCC’s assessment report – the more recent Carbon Space approach (Kanitkar et al. 2010), the Brazilian proposal (UNFCCC 1997), the Greenhouse Develop-

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1 Global emission ranges represent estimates for limiting the global temperature increase to below 2 °C based on emission trajectories up to 2010 and other factors. Different trajectories relate to the different probabilities of meeting the 2 °C target. For details see, for example, Huntingford et al. (2012) or Meinshausen et al. (2009).

ment Rights approach (Baer et al. 2008) or a proposal by Winkler et al. (2009)[2]. In this sense, the no lose-targets employed in this paper may be interpreted as a an instrument which recognizes NAI countries' lower ability to pay and lower historic responsibility for climate change to such an extent, that they do not have to bear any mitigation costs, at least not before 2020. Similar outcomes can be found in the literature. The burden-sharing formula employed in Bosetti and Frankel (2011) also requires that developing countries do not carry any costs in the early years. The studies by Kallbekken and Westskog (2005) and Hagem and Holtsmark (2011) both employ a similar no-cost principle in analysing the economic effects of climate policy scenarios involving either a CDM mechanism or a global cap-and-trade system. Thereby Kallbekken and Westskog distinguish between five developing countries and regions, while Hagem and Holtsmark aggregate developed countries to a single developed region and developing countries to a single developing region. Finally, Schmidt and Marschinski (2010) apply the no-cost principle to a single developing country and explore whether China benefits from participating in the emissions trading market under a country-level binding target.

Methodologically, we use marginal abatement cost curves derived from policy simulations made with the global partial equilibrium model POLES to analytically solve the participation decision of several NAI countries considering no-lose targets. The applied algorithm allows us to determine an equilibrium solution where NAI countries only participate in no-lose targets schemes if these are profitable.

The paper is organized as follows. Section 2 describes the modeling approach and the data. Section 3 presents the results of the "IPCC" scenarios. Section 4 includes the findings for the alternative options considered which involve (i) more lenient uniform no-lose targets, (ii) individualized no-lose targets for some large NAI countries, and (iii) an alternative burden-sharing agreement between AI and NAI countries. Section 5 discusses the alternative burden-sharing found in Section 4 in the light of other burden-sharing proposals in the literature. Finally, Section 6 concludes and provides pointers for designing no-lose targets.

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2 For a detailed overview of different burden-sharing approaches, see den Elzen et al. (1999), Kartha et al. (2009) and den Elzen and Hoehne (2010b).

2 Modeling framework

This section presents the modeling framework applied to analyze the effects of no-lose targets. Section 2.1 introduces the optimization problem for countries facing a no-lose target. In section 2.2 the markets modeled and the flow of traded certificates are introduced. Sections 2.3 and 2.4 describe the data and the assignment of countries to the different markets.

2.1 Optimization problem for a country with no-lose target

The main assumption for modelling a no-lose target is that the target will only be fulfilled if the country facing the no-lose target finds it to be profitable. Hence, we extend the usual optimization problem of a country with a binding reduction target which participates in an emissions trading market by a profitability constraint. A NAI_NLT country i with a no-lose target T_i faces the following optimization problem:

$$\begin{aligned} & CC_i = C_i(r_i) - p^C(r_i - T_i) \rightarrow \min_{r_i} \\ s.t.\ & CC_i = C_i(r_i) - p^C(r_i - T_i) \leq 0, \end{aligned} \tag{0.1}$$

where p^C is the market price for emission certificates, r_i stands for the realized emission reductions in country i compared to the baseline and $C_i(r_i)$ are the associated abatement costs. A country's no-lose target T_i is given as an emission reduction below the baseline and is exogenously given as the outcome of climate negotiations.[3] Hence, country i is assumed to minimize compliance costs CC_i, i.e. abatement costs (for the entire emission reductions) minus revenues from selling emission certificates (the difference between actual and target reductions).

Condition (1.1) reflects that a rational country will fulfill its no-lose target and will hence participate in the international emissions trading market if revenues from selling certificates are not lower than its abatement costs (participation con-

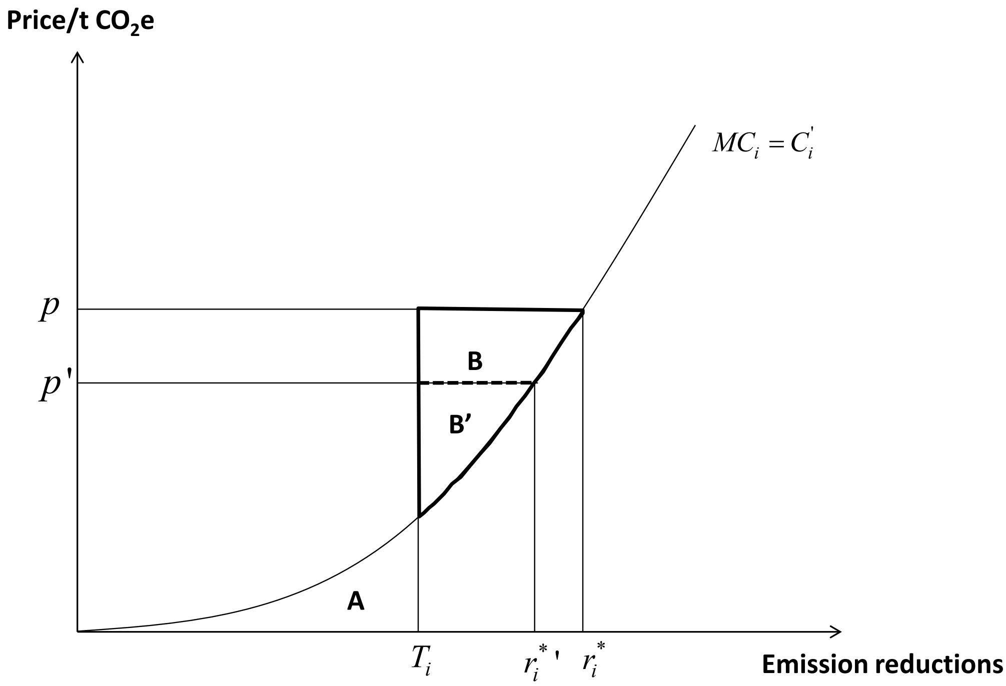
3 A number of game-theoretical studies focus more closely on the negotiation process itself, for example, Carraro and Siniscalco 1993, Barrett, 1994, Peck and Tijsberg, 1999 or Forgo et al., 2005. We do not model the negotiation process or the target setting, but rather explore whether a given no-lose target will be realized.

straint). Hence, the no-lose target must be profitable. Otherwise, a country's emissions are assumed to be at baseline levels (i.e. $r_i = 0$).

Figure 1 illustrates the condition in (1.1) for a NAI_NLT country facing a no-lose target of T_i. For a certificate price of p, the revenues from selling certificates ($r_i^* - T_i$) minus the abatement costs for the associated emission reductions (beyond T_i) is given by the area $B + B'$. The country will participate in the no-lose target scheme if the profits from certificate trading $B + B'$ exceed the abatement costs associated with the no-lose target T_i (area A). The area $B + B' - A$ may also be termed the country's payoff. For a lower certificate price p', the costs of the no-lose target are still A, but they are now higher than the profits from certificate trading (B'). Hence, if the certificate price is at p', the country will not participate in the no-lose targets scheme. In this case, the country's payoff is zero as the country will not reduce any emissions (i.e. $r_i^* = 0$) and, hence, $B + B' - A = 0$.[4]

4 A complete description of all countries' optimization problems and the market clearing conditions implemented is available from the authors upon request.

Figure 1: Abatement costs and revenues from trading for a no-lose target country



Based on a recursive solution algorithm, we calculate an equilibrium solution for NAI_NLT countries with a profitable no-lose target, who participate in the international emissions trading market (IETM*). IETM* fulfills two criteria, internal and external stability. The internal stability of the equilibrium solution ensures that participation is profitable for all participating NAI_NLT countries. The solution is externally stable in that sense that if any NAI_NLT country not participating in the equilibrium solution would join the international emissions trading market, participation would no longer be profitable for at least one participating NAI_NLT country under the new market conditions.[5]

5 A formal description of the algorithm implemented to model the participation and non-participation of NAI_NLT countries in the no-lose target scheme is provided in Appendix A.

2.2 Markets

For the subsequent analyses, we distinguish three groups of countries:

(i.) Annex I countries, which have all committed to binding targets for 2020 (AI),

(ii.) non-Annex I countries, which are eligible to participate in a no-lose target scheme (NAI_NLT) and

(iii.) the remaining non-Annex I countries, which do not have any emission targets (NAI_REST).

Two different markets are modelled: an international emissions trading market and an offsetting market[6]. Countries in the international emissions trading market can freely trade emission certificates among themselves, but may be required to meet a minimum share of their individual emission targets domestically ("domestic quota"). Countries in the offsetting market can sell offsetting credits to countries in the international emissions trading market, but – as they do not face reduction targets – do neither trade with each other nor buy emission certificates from countries in the international emissions trading market. Similarly, countries in the international emissions trading market face an "offsetting limit", which is the maximum share of the individual emission targets that can be met via offsetting credits.

The countries in the three different country groups are assigned to the two markets as follows (see also Figure 2). AI countries are allowed to participate in the international emissions trading market and are subject to domestic quotas and offsetting limits. NAI_NLT countries can participate in the international emissions trading market if they decide to fulfill their no-lose targets. Unlike AI countries, NAI_NLT countries can only sell certificates and are not allowed to buy offsetting credits. Hence, a NAI_NLT country has to fulfill 100% of its no-lose reduction commitment domestically if it wants to sell certificates.[7] NAI_REST countries are assigned to the offsetting market and can sell offsetting credits to the AI countries, but not to NAI_NLT countries.

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6 In essence, the offsetting market represents the Clean Development Mechanism (CDM).

7 It is assumed that non-Annex I countries cannot choose whether they want to be in the NAI_REST group or the NAI_NLT group. Hence, a NAI_NLT country is not allowed to become a member of the offsetting market and sell its emission reductions as offsetting credits instead.

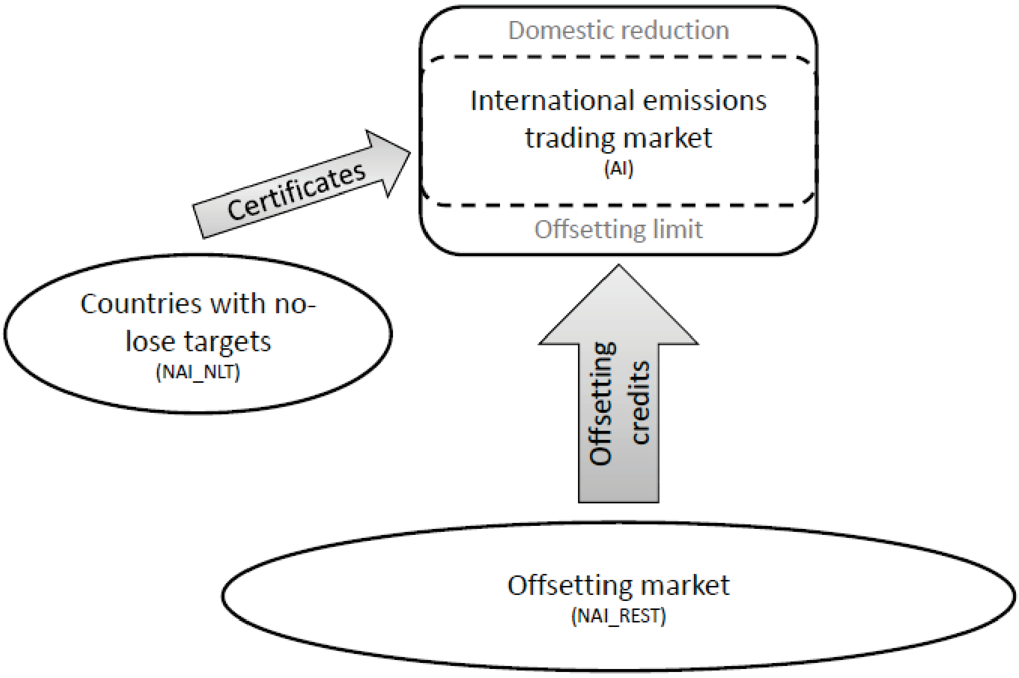
These rules can lead to differences in the prices for emission certificates and offsetting credits. However, the price of the emission certificates traded among AI countries and of the emission certificates sold by NAI_NLT countries must be identical because of arbitrage and because there are no limits on the use of emission certificates from NAI_NLT countries by AI countries.

We assume that the domestic quota levels and the offsetting limit are the same for all AI countries. We set the default value at 10% for the domestic quota and at 20% for the offsetting limit (for the remaining 90% of emission reductions). Hence, AI countries must meet at least 72% of the emission reductions by domestic actions or via certificate trading in the international emissions trading market. We further assume that only a fraction of the total emission reduction potential of a NAI_REST country can be used for offsetting purposes at the prevailing certificates price. Following Castro (2010), we set this share at 20%.[8]

The post-Kyoto negotiations involve discussions about additional mechanisms to help finance abatement activities in NAI countries. To avoid double funding, we assume that countries with no-lose targets will not be eligible for such finance mechanisms.

8 For six developing countries, Castro (2010) estimates that between 1% and 31% of their emission reduction potential is captured via CDM projects. The figure for China for the year 2020 is, for example, 21%.

Figure 2: Types of markets and the flow of traded certificates



2.3 Marginal abatement cost curves and underlying model

Our analyses refer to reduction targets for the year 2020. Calculations are based on marginal abatement cost curves for the year 2020 calculated with the global energy system model POLES[9]. To generate the marginal abatement cost curves, the POLES model was calibrated to the World Energy Outlook 2010, New Policies Scenario (IEA, 2010). To derive marginal abatement cost curves for the year 2020, the model was solved in one-year-steps from 2008 to 2020 with a linearly increasing price for GHG emissions. This implies that emission reduction targets become stricter over time, while the Kyoto Period (2008-2012) is not explicitly modeled.

The POLES model generates marginal abatement cost curves for 58 countries and regions. To further disaggregate the regional level for the analyses, the most recent historical emissions data were used from UNFCCC inventories (United Nations, 2012a) and the International Energy Agency (IEA, 2011). Combining historical data and the growth and abatement rates from the POLES

9 For a description and applications of the POLES model see, for example, Criqui (2001) or Russ and Criqui (2007). POLES is a partial equilibrium model, hence the marginal abatement cost curves do not include macroeconomic effects.

scenario, marginal abatement cost curves were derived for 137 countries for the year 2020.

The marginal abatement cost curves are calculated at the country level and include abatement potentials for all six Kyoto GHGs, but exclude emissions and abatement potentials from land-use, land-use change and forestry (LULUCF) and deforestation (REDD)[10]. World total emissions also include emissions from international bunker fuels. Following the World Energy Outlook 2010, we assume a growth rate of 90% between 1990 and 2020 for bunker fuels (IEA, 2010). Emission reduction targets and measures for bunker fuels are not included. Historical and baseline GHG emissions as well as the emission reduction potential by country groups are displayed in Table 1.

Table 1: Historical and baseline GHG emissions from 1990-2020 by country groups and relative reduction potential in 2020

Country group	Emissions			Reduction potential in 2020		
	1990 [Gt CO_2e]	2005 [Gt CO_2e]	2020 [Gt CO_2e]	10€/t	50€/t	100€/t
AI	18.4	18.5	18.3	9%	20%	29%
NAI_NLT	8.8	15.8	28.4	13%	26%	37%
Of which:						
China	3.7	7.5	14.8	13%	28%	40%
India	1.3	2.0	3.6	13%	27%	40%
Brazil	0.6	0.9	1.5	11%	19%	27%
Iran	0.3	0.6	1.0	11%	17%	22%
Indonesia	0.4	0.6	1.0	14%	25%	36%
Mexico	0.4	0.6	0.7	7%	12%	17%
NAI_REST	3.5	5.0	6.7	13%	24%	33%

10 Including emissions and the emission reduction potential from LULUCF and REDD could change the quantitative as well as qualitative results, in particular for non-Annex I countries like Brazil or Indonesia.

2.4 Country groups

For the subsequent analyses, we define the three country groups introduced above as follows:

AI: All 39 countries listed in Annex B of the Kyoto Protocol (including the USA) and Turkey. An aggregate Annex I target for 2020 is defined and all AI countries are assumed to commit to the same percentage reduction in 2020 compared to 1990 levels, i.e. uniform reduction targets are applied to all AI countries. For a few countries, this assumption results in emission targets which are above baseline emissions in some scenarios (“hot air”).[11]

NAI_NLT: To reduce computation time not all NAI countries are considered eligible for no-lose targets. Instead, the group of NAI_NLT countries only includes countries whose total baseline GHG emissions in 2020 exceed 300 $MtCO_2e$. These 18 countries cover more than 80% of NAI countries’ projected GHG emissions in 2020. [12]

NAI_REST: The remaining 79 NAI countries.

3 “IPCC” scenarios

3.1 “IPCC” scenario definition

The first set of policy scenarios is based on the burden-sharing proposed in the 4th IPCC assessment report (Metz et al., 2007). The studies surveyed therein involve targets in the range of 15% to 80% below 1990 levels for AI countries and of 0% to 40% below baseline for NAI countries. The IPCC burden-sharing concludes that in order to achieve the 2 °C target, emission reductions in the range of 25% to 40% below 1990 levels are necessary for AI countries and a “substantial deviation from baseline in Latin America, Middle East, East Asia and Centrally-Planned Asia” for NAI countries for the year 2020. Den Elzen and

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11 These countries are typically countries from the former Soviet Union like Russia, Belarus and the Ukraine as well as Eastern European States.

12 The countries included in NAI NLT are Argentina (ARG), Brazil (BRA), China (CHN), Egypt (EGY), Indonesia (IDN), India (IND), Iran (IRN), Kazakhstan (KAZ), Republic of Korea (KOR), Malaysia (MYS), Mexico (MEX), Nigeria (NGA), Pakistan (PAK), Saudi Arabia (SAU), Thailand (THA), Taiwan (TWN), Vietnam (VNM) and South Africa (ZAF).

Hoehne (2010a) quantify the required emission reductions from NAI countries as 15% to 30% below baseline in 2020. Further, global emissions in 2020 should not exceed 1990 levels by more than 10% to 30%.

Based on these emission ranges, which are compatible with the 2 °C target, we define three “IPCC” scenarios:

GL_AMB: a global target of 10% above and an Annex I target of 40% below 1990 levels,

AI_LOW: a global emission target of 30% above and an Annex I target of 25% below 1990 levels and

AI_AMB: a global emission target of 30% above and an Annex I target of 40% below 1990 levels.

The GL_AMB scenario combines the more ambitious end of the global reduction range (10% global emission growth) with the more ambitious target for AI countries. The other two “IPCC” scenarios target at the less ambitious end of the global reduction range (30% global emission growth). AI_LOW combines the less ambitious end of the global reduction range (30% global emission growth) with the lower reduction target for AI countries. Hence, GL_AMB and AI_low represent the more ambitious and the less ambitious end of the reduction range for global emission reduction efforts as well as for the AI countries’ reduction efforts. The AI_AMB scenario combines the less ambitious global reduction target with the higher reduction target for AI countries. Hence, for this scenario, no-lose targets are expected to be particularly profitable. To determine individual countries’ targets we assume the same emission reduction rates compared to 1990 levels for all AI countries and the same reduction rates compared to baseline emissions for all NAI_NLT countries. Of course, in absence of generally accepted rules, applying uniform rates as a starting point / benchmark is arbitrary.

Following the approach by den Elzen and Hoehne (2010a), the NAI countries’ aggregated emission target is derived from the global emission target by subtracting the AI countries’ emission target. To calculate the NAI_NLT countries’ emission targets, we further subtracted baseline emissions for the NAI_REST countries applying our modeling baseline. The resulting emission targets were then translated into emission reduction targets below the baseline in 2020.

Compared to our modeling baseline, the reduction targets for NAI_NLT countries correspond to emission reductions of 43%, 30% and 20% below baseline emissions in GL_AMB, AI_LOW and AI_AMB, respectively (see Table 2).

Table 2: Global and regional emission reduction targets for 2020 in the scenarios analyzed

Scenario	global		AI	NAI_NLT	Note
	% to 1990	to baseline [Gt CO2e]	% to 1990	to baseline [Gt CO2e]	
"IPCC" scenarios					
GL_AMB	10	-19.1	-40	-43	
AI_LOW	30	-12.6	-25	-30	
AI_AMB	30	-12.6	-40	-20	
Lower target scenarios					
LT scenarios	>30		-40	-2 to -22	
Individual target scenarios					
BIC_10	>30		-40	Brazil: -12, India: -16, China: -15, Others: -10	
Alternative Burden-Sharing scenarios					
GL_AMB_ALL	10		-84	-13	requires full participation by all NAI_NLT countries
GL_LOW_ALL	30		-56	-9	requires full participation by all NAI_NLT countries
GL_AMB_ALT	10		-72	-31	
GL_LOW_ALT	30		-46	-21	

3.2 Results for "IPCC" scenarios

Results for the "IPCC" scenarios in the equilibrium solution IETM* appear in the upper part of Table 3. Besides the envisaged and the realized emission reductions, the table also presents the findings for certificate prices and offsetting credits (in 2005e/tCO_2e shown in columns 8 and 9) and for changes in global compliance costs and in AI countries' compliance costs compared to a scenario without a no-lose targets scheme (two last columns). Changes in global compliance costs are an indicator of the associated efficiency gains. Changes in AI countries' aggregated compliance costs are given in the last column.

Results in Table 3 indicate that the offsetting limit is not binding for any of the “IPCC” scenarios considered since arbitrage leads to identical prices for emission certificates and offsetting credits. Prices are highest in the more ambitious global target scenario GL_AMB, but since the no-lose targets are also ambitious, participation is not profitable for any NAI_NLT country in GL_AMB. As a consequence, the 10% global emission growth target is not met.

For different reasons, prices are substantially lower in the two other “IPCC” scenarios, both of which aim at the lower global emission growth target of 30%. In AI_LOW, the targets for AI countries are more lenient than in GL_AMB and the high amounts of “hot air” which are traded within IETM* also dampen the price for certificates. As a result, none of the NAI_NLT countries finds it profitable to participate in the international emissions trading market despite their no-lose targets being less ambitious than in the GL_AMB scenario. Thus, AI_LOW also fails to meet the 30% global emission growth target.

In contrast, in scenario AI_AMB, where AI countries’ targets are rather ambitious and no-lose targets are rather weak, eleven NAI_NLT countries find it profitable to participate in the international emissions trading market. Realized emission reductions from NAI_NLT countries add up to 1.8 Gt CO_2e, resulting in global emission reductions of 8.8 Gt CO_2e. Also, AI_AMB allows for substantial efficiency gains compared to a scenario without the participation of the NAI_NLT countries. Notably, global compliance costs decrease by 19% and compliance costs for AI countries decrease by 14% compared to a scenario without a no-lose targets scheme. In particular, those AI countries facing relatively stringent targets benefit from purchasing large numbers of certificates from NAI_NLT countries (about 1.5 Gt CO_2e, accounting for about 20% of the AI countries’ aggregated emission reduction target). NAI_NLT countries are also better off: NAI_NLT countries’ aggregated revenues from selling certificates are 41% higher than required to make participation by these countries profitable. As a result of applying uniform no-lose targets to a very heterogeneous group of NAI countries in substantial differences in the participating NAI_NLT countries’ payoffs can be seen. For example, for Nigeria, payoffs are more than 10 times higher than actually needed to meet its participation constraint. They are “only” 30% higher for Malaysia, Taiwan, Thailand and Vietnam.

Although scenario AI_AMB induces participation by NAI countries and, hence, increases global emission reductions, only 31% of the envisaged emission reductions for NAI_NLT countries are realized and the 30% global emission growth target is still missed. It should be noted though that due to the scenario definitions emissions in AI_AMB are lower than in GL_AMB.

Besides the levels of the no-lose targets, their profitability also depends on the domestic quota, the offsetting limit and the amount of hot air. A high domestic quota and a high offsetting limit on total emission reductions for AI countries reduce the demand for certificates from the international emissions trading market. Meanwhile, “hot air” certificates are a low-cost alternative to certificates from NAI_NLT countries. A sensitivity analysis for the AI_AMB scenario shows that varying the domestic quota and the offsetting limit within reasonable limits does not affect the profitability of the no-lose targets, neither does limiting “hot air” by applying a more sophisticated burden-sharing among AI countries or prohibiting AI countries from selling “hot air”. An overview of the results of the sensitivity analysis is provided in Appendix B.

In sum, only scenario AI_AMB induces several NAI_NLT countries (including India but not China) to participate in no-lose targets, but still fails to achieve the envisaged global emission targets.[13] According to our quantitative analysis, reduction ranges of 25% to 40% below 1990 levels for AI countries in combination with no-lose targets of 15% to 30% below baseline will hence not lead to global emission levels considered compatible with the 2°C target. The results further imply that either AI countries’ targets are too lenient or that NAI_NLT countries’ no-lose targets are too stringent.

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13 For completeness we also analyzed a scenario with a global emission target of 10% above 1990 levels and a reduction target for Annex I countries of 25% below 1990 levels. Similar to the GL_AMB scenario, no NAI_NLT countries were found to participate in NLT.

Table 3: Scenario results applying no-lose targets in 2020

Scenario	Reductions							Prices		Compliance Costs	
	Part. NAI_NLT	Envisaged reductions by NAI_NLT	Realized reductions by NAI_NLT		Certificates sold by NAI_NLT	Realized global reductions	"Hot Air"	Emission certificates	Offsetting credits	Global	AI
	[#]	[Gt CO_2e]	[Gt CO_2e]	[%]	[Gt CO_2e]	[Gt CO_2e]	[Gt CO_2e]	[€/t CO_2e]	[€/t CO2e]	[%]	[%]
"IPCC" scenarios											
GL_AMB	0	11.5	-	0	-	7.1	0.1	153	153	0	0
AI_LOW	0	8.4	-	0	-	4.3	0.2	64	64	0	0
AI_AMB	11*	5.7	1.7	31	1.5	8.8	0.1	102	102	-19	-14
Alternative burden-sharing scenarios[1]											
GL_AMB_ALL	18	3.7	3.7	100	8.6	19.0	-	144	144	141	258
GL_LOW_ALL	18	2.5	2.5	100	5.6	12.6	-	68	68	-2	31
GL_AMB_ALT	5**	8.6	6.2	72	3.6	19.3	-	153	151	220	201
GL_LOW_ALT	7***	5.9	4.5	76	3.2	12.7	-	86	86	24	15

* IND, IDN, KAZ, MYS, NGA, PAK, KOR, ZAF, TWN, THA, VNM

** CHN, IND, KOR, NIG, PAK

*** CHN, IDN, IND, KAZ, KOR,NIG, PAK

[1] Differences in global emission reductions between GL_AMB_ALL and GL_AMB_ALT and GL_LOW_ALL and GL_LOW_ALT are due to rounding errors

4 Alternative scenarios

In this section we present three alternatives to the "IPCC" scenarios to increase participation by NAI_NLT countries. First, we continue to apply uniform targets for NAI_NLT countries, but lower their degree of ambition compared to the "IPCC" scenarios. Then we allow the reduction targets to differ across three large NAI_NLT countries: Brazil, India and China (BIC). By design, the global emission target of 30% will be missed in these alternative scenarios. Last we consider an alternative scenario which is compatible with the 2 °C target by altering the burden-sharing of emission reductions compared to the IPCC scenarios such that no-lose targets for NAI_NLT countries become more lenient, while targets for AI countries become more ambitious. Details on the alternative scenarios are also listed in Table 2.

4.1 Results for scenarios with lenient no-lose targets

If no-lose targets become more lenient, there are two countervailing effects on global emissions. On the one hand, lower no-lose targets imply lower emission reduction contributions by an individual NAI_NLT country. On the other hand, more countries will participate in no-lose targets. Thus, neither very ambitious no-lose target levels, nor a large number of participating NAI_NLT countries, necessarily imply the largest global emission reductions.

The LT (lenient targets) scenarios are based on the AI_AMB scenario. The uniform no-lose targets are gradually increased from 0% to 20%, while the 40% reduction target for AI countries is kept constant. Results of this sensitivity analysis are displayed in Figure 3 and Figure 4.

As the no-lose target level becomes more ambitious, the gap between the envisaged and the realized emission reductions by NAI_NLT countries widens in Figure 3. In case of a 40% reduction target for AI countries up to a uniform reduction rate of 6% below baseline, all NAI_NLT countries are found to participate. The maximum emission reductions from NAI_NLT are achieved for a reduction rate of 18%. In this case, only seven of 18 eligible NAI_NLT countries reduce emissions adding up to a reduction of 3.8 Gt CO_2e compared to the baseline; but this still falls short of the targeted global emission reductions. For higher uniform reduction rates, the payoff for China becomes negative (as indicated by the large drop in realized emission reductions in Figure 3). For stricter no-lose target levels, the certificate price in Figure 4 continues to rise, and the revenue effect induces participation by several smaller NAI_NLT countries, but they cannot make up for China's dropping out of the equilibrium solution IETM* .

It is worth noting that the realized emission reductions from NAI_NLT countries in the scenarios with no-lose targets between 7% and 18% are larger than in the AI_AMB scenario, because many more NAI_NLT countries participate. This illustrates that more lenient no-lose targets may actually result in lower global emissions, lower global compliance costs and lower compliance costs for AI countries than under AI_AMB.

Figure 3: Participation and emission reductions from NAI_NLT countries under a 40% reduction scenario for AI countries in 2020 – sensitivity analysis for no-lose targets

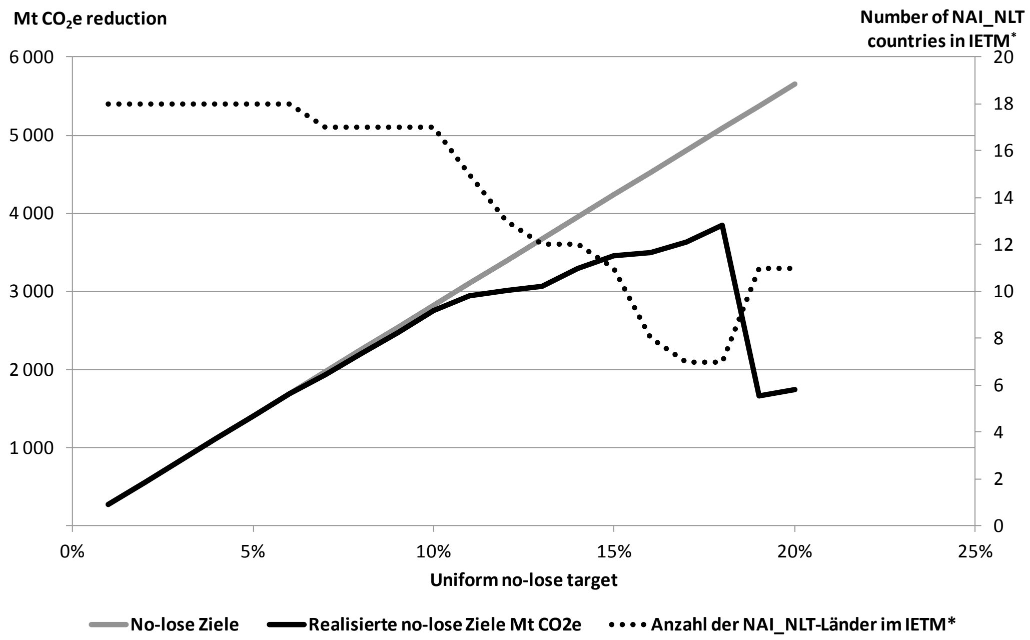
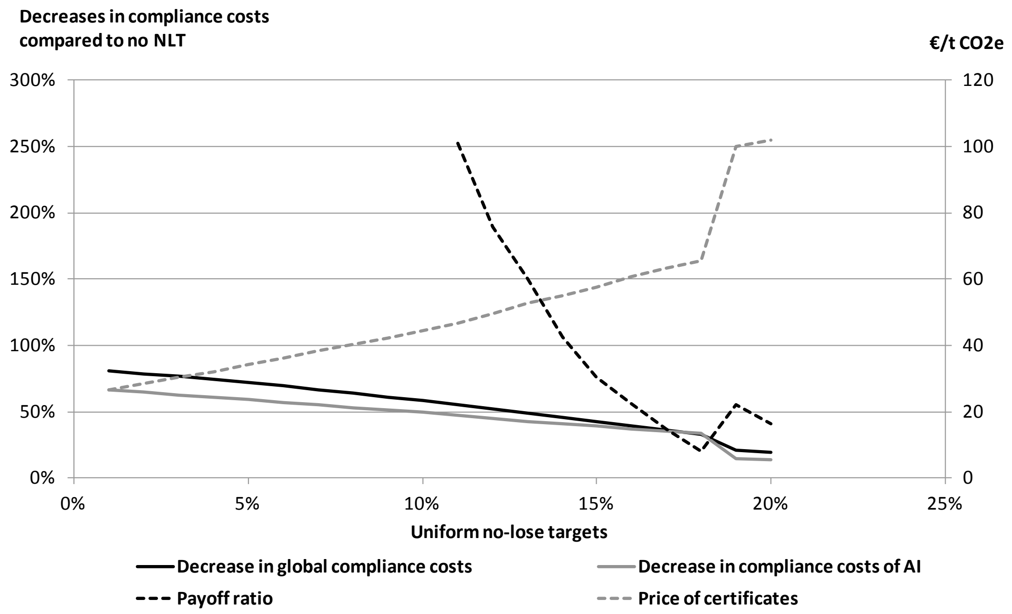


Figure 4: Prices and changes in costs compared to AI_AMB in 2020 - sensitivity analysis for no-lose target levels



4.2 Results for scenarios with individual no-lose targets for large emitters

Section 4.1 illustrated the importance of considering the participation incentives of large emitters when deciding on the level of the reduction rates for NAI_NLT countries. Further, the results of AI_AMB in section 3.2 showed that, in the case of uniform reduction targets, low cost countries can realize high payoffs from profitable no-lose targets. In this section, we deviate from the assumption that all NAI_NLT countries should face a uniform reduction target. Instead, we allow individual no-lose targets for the largest emitters among the NAI_NLT countries, i.e. Brazil, India and China (BIC). Individual targets are better able to account for heterogeneity across NAI_NLT countries, e.g. with respect to abatement costs. Hence, individual no-lose targets can lead to lower payoffs for some NAI_NLT countries, allowing higher global emission reductions, and lower compliance costs at the global level and for AI countries than uniform targets. For NAI_NLT countries other than BIC, we assume a uniform reduction target of 10% below the baseline, while AI countries continue to face a uniform 40% reduction target as before (BIC scenario).

The analysis starts with a uniform no-lose reduction target of 10% for BIC and for all other NAI_NLT countries. In this starting scenario, no-lose targets turn out to be profitable for all NAI NLT countries but Mexico. The reduction rates are then individualized and increased for BIC beginning with China followed by India and Brazil until participation in the international emissions trading market is no longer profitable for at least one of the BIC countries. We refer to the scenario at which participation constraints become binding for all three BIC countries as the “threshold scenario” and to the three reduction targets as the “threshold reduction targets”. Since tighter reduction targets for BIC result in a lower supply of certificates from these countries, certificate prices increase as the no-lose targets become tighter for BIC. Because other NAI_NLT countries benefit from the higher prices, they continue to participate in the IETM.

For IETM*, we find threshold reduction targets for Brazil, India and China of 12%, 16% and 15%, respectively.[14] More detailed results on the scenario as well as the starting scenario are provided in Table 6 in Appendix C. Compared to the starting scenario with uniform no-lose targets of 10% for all NAI_NLT countries, the BIC scenario leads to higher emission reductions of about 1 $GtCO_2e$ and to lower compliance costs for AI countries. In general, the additional effects of individualizing reduction targets for some countries compared to the starting scenario are smaller the closer the uniform targets in the starting scenario are to the “threshold reduction targets”. Compared to the AI_AMB scenario, global compliance costs are 20% lower, the compliance costs of AI countries are 25% lower, while global emission reductions are 22.5% higher in the BIC scenario.

In sum up, individualizing the no-lose targets for the largest emitters leads to lower global emissions than under the “IPCC” scenarios and to similar emissions as the “best” LT scenarios are able to achieve. However, the global emission growth targets of 30% and 10% are still found to be missed by about 1.8 $GtCO_2e$ and 8.3 $GtCO_2e$, respectively.

14 If lower uniform targets than 10% are chosen for NAI_NLT countries other than BIC, the country-specific targets for BIC will be lower and global emissions will be higher because of the revenue effect. Lower targets for other NAI_NLT countries imply a higher supply and lower prices of certificates, and hence lower country-specific threshold reduction targets for BIC. For example, a uniform target of 5% for other NAI_NLT countries results in threshold reduction targets for Brazil, India and China of 11%, 14% and 13%, respectively.

4.3 Results for alternative burden-sharing scenarios

Since none of the scenarios considered so far resulted in the participation of all the eligible NAI_NLT countries, the envisaged global emission growth targets of 10% and 30% were missed. Emission levels for NAI_NLT countries were too high, either because no-lose targets were too ambitious as in the “IPCC” scenarios, or because reduction targets were too lenient as in the LT and BIC scenarios, so that even high ratios of realized versus envisaged reductions were not sufficient to meet the global emission targets. In this section, we explore the effects of shifting the burden of emission reductions between AI and NAI countries while requiring that the global emission growth targets of 10% or 30% are met. All alternative burden-sharing scenarios assume that AI and NAI_NLT countries are subject to uniform reduction targets.

We distinguish two kinds of alternative burden-sharing scenarios. In the “full participation” scenarios, GL_AMB_ALL and GL_LOW_ALL, we calculate the no-lose target level at which all NAI_NLT countries participate in the no-lose targets scheme.[15] In comparison, for the GL_AMB_ALT and GL_LOW_ALT scenarios, we no longer require all the eligible NAI countries to participate in the no-lose targets scheme, but continue to enforce the global emission growth rates of 10% and 30%, respectively.

Our findings for the ”full participation” scenarios suggest that an ambitious global emission growth target of 10% can be reached if AI countries reduce emissions by 84% compared to 1990 levels and if uniform no-lose targets are set at 13%. For the lower 30% global emission growth target, Annex I countries face a reduction rate of 56% and the no-lose target is found to be 9%. In both scenarios, no-lose target emission reductions in NAI_NLT countries (reductions up to in Figure 1) account for about 20% of global emission reductions. An additional 45% of global emission reductions are realized in the NAI_NLT countries, but paid for via certificate trading by AI countries (reductions between and in Figure 1). In this case, about 2/3 of the global emission reductions are realized in NAI_NLT countries. The prices for emission certificates and offsetting credits are found to be 68€/tCO_2e and 144€/tCO_2e for the lower 30% and

15 This scenario corresponds to an international emissions trading scenario, where – just like the AI countries – all the NAI_NLT countries have to meet binding emission targets. Implementing the equivalent outcome (in terms of global emissions) via binding targets for all countries, however, would not recognize the participation constraints of NAI_NLT countries.

the ambitious 10% global emission growth targets, respectively (see lower part of Table 3).

In comparison, the GL_AMB_ALT and GL_LOW_ALT scenarios imply more lenient reduction targets for AI countries, but stricter no-lose targets for NAI_NLT countries and therefore considerably fewer NAI_NLT countries participating in the no-lose target scheme. For the ambitious global emission growth target in 2020, our calculations suggest that Annex I countries need to reduce emissions by 72% below 1990 levels and the no-lose targets for the five NAI_NLT countries is 31% below baseline. For the lower global emission growth target of 30%, the reduction rate for AI countries is found to be 46% and the no-lose targets for the seven NAI_NLT countries is 21%. NAI_NLT countries' own contribution to global emission reductions (reductions up to in Figure 1) increases to about 45% for the ambitious global emission growth target and even 47% for the lower 30% global emission growth target. In addition, 25% (for the ambitious global emission growth target) and 19% (for the lower global emission growth target) of global emission reductions are realized in NAI_NLT countries, but paid for by AI countries (reductions between and in Figure 1). Similar to the full participation scenarios, in the GL_LOW_ALT scenario (GL_AMB_ALT scenario), emission reductions in NAI_NLT countries account for about 2/3 (70%) of global reductions. The prices for emission certificates and offsetting credits are somewhat higher than in the full participation scenarios (see Table 3).

The compliance costs compare the main findings of the alternative burden-sharing scenarios to the "IPCC" scenario with the lowest global emissions, i.e. the AI_AMB scenario. Interestingly, GL_LOW_ALL not only leads – by design – to lower global emissions (by 43%), but also to lower global costs (by 2%), suggesting that this setting is not only more environmentally effective but also globally more cost-efficient. In this case, NAI_NLT countries enjoy large payoffs because of the uniform no-lose targets scheme, while AI countries face higher compliance costs because of more ambitious reduction targets in GL_LOW_ALL compared to AI_AMB. From the perspective of AI countries, both these aspects may render GL_LOW_ALL politically unacceptable. For all other alternative burden-sharing scenarios, the higher global emission reductions also result in higher global compliance costs, in particular for the ambitious global emission growth target.

The findings further suggest that, for the ambitious and the lower global emissions growth targets, "full participation" results in the lowest global compliance costs, but compliance costs for AI countries are significantly higher than in the alternative burden-sharing scenarios not requiring full participation. This finding once again illustrates that, in the case of uniform reduction targets, the additional costs borne by AI countries increase with an increasing number of (high cost) NAI countries participating in the no-lose targets scheme. From this perspective, AI countries should favour no-lose targets that induce participation of large, low-cost NAI countries, rather than all the eligible NAI_NLT countries.

The alternative burden-sharing found in the context of the no-lose target scheme allows comparison with other burden-sharing proposals. The analyses in section 3 suggest that the IPCC burden-sharing will not result in significant emission reductions from NAI countries when uniform no-lose target schemes are used. Our findings in this sub-section imply that no-lose targets may help implement more ambitious global targets if AI countries face substantially more stringent emission targets and NAI countries more lenient no-lose targets than under the IPCC burden-sharing proposal. Our findings for such burden-sharing outcomes are quite similar to those suggested by Winkler et al., who foresee a reduction of 50-70% below 1990 levels for AI countries and 10-20% below baseline for NAI countries by 2020. Similarly, the Greenhouse Development Rights approach which implies emission reductions of 9.4 Gt CO_2e from AI and 4.2 Gt CO_2e from NAI countries is close to the reductions realized in the GL_LOW_ALT scenario where AI countries reduce their emissions by 8.2 Gt CO_2e and NAI countries by 4.5 Gt CO_2e. In contrast, the reduction targets suggested under the Carbon Space approach for the EU of 40% and for the US of 50% below 1990 levels for the EU and the US respectively, are too lenient to be compatible with a 2 °C target implemented via no-lose targets for NAI countries. Furthermore, the reduction target envisaged under the Carbon Space approach for China of 60% below BAU is likely to violate China’s participation constraint in a no-lose target scheme. In comparison, the proposed target for India of about 125% above BAU would be much higher than necessary to render India’s participation in a no-lose target scheme profitable.

5 Conclusions

The model-based quantitative analyses presented in this paper for the year 2020 illustrate that a properly designed no-lose targets scheme can benefit eligible NAI countries, contribute to global emission reductions, and reduce the compliance costs for AI countries. In this respect, climate policy faces the challenge of identifying burden-sharing arrangements which are acceptable to both

AI and NAI countries, and determining no-lose targets which induce the participation of a sufficient number of NAI countries to ensure the global climate target is met without causing undesired distributional effects such as excessive payoffs (rents) for some NAI countries at the expense of AI countries.

More specifically, our findings provide guidance for policymaking. In particular, our findings suggest that implementing no-lose targets for NAI countries under the burden-sharing arrangement as discussed in the latest IPCC assessment report (Metz et al., 2007) will not lead to global emission levels which are compatible with the 2 °C target, because participation in the no-lose targets scheme is only profitable for a few NAI countries, at best. More lenient no-lose targets than those implemented in our “IPCC” scenarios could actually result in lower global emissions, lower global compliance costs and lower compliance costs for AI countries than more ambitious no-lose targets. Likewise, individualizing no-lose targets for large emitters could also increase the participation by NAI countries, lower global emissions and reduce payoffs for NAI countries. While both these options represent a politically less challenging, yet environmentally and economically effective way for NAI countries to contribute to global emission reductions, they do not lead to global emission levels which are consistent with the 2 °C target.

Our findings also show that no-lose targets can help to achieve the 2 °C target in a more environmentally effective and cost-efficient way, if the burden-sharing is adjusted appropriately; that is, if binding emission targets for AI countries become more stringent, while no-lose targets for NAI countries become more lenient compared to the ”IPCC” scenarios. In this case, requiring full participation by all the NAI countries in no-lose targets schemes results in the lowest total compliance costs, but meeting the participation constraint of the high-cost NAI countries involves high compliance costs for AI countries and large payoffs for low-cost NAI countries. Alternatively, requiring only the largest five to seven emitters to participate in a no-lose targets scheme to reach the 2 °C target implies no-lose targets of 21% and 31% below the baseline in 2020 for the ambitious 10% and the lower 30% global emissions growth scenarios, respectively, and, hence, in the range considered in the “IPCC” scenarios. However, the required emission reductions for AI countries in the range of 72% (for the ambitious global emissions growth scenario) and 64% (for the lower global emissions growth scenario) by 2020 compared to 1990 levels are much more ambitious than envisaged in the “IPCC” scenarios. Also in this alternative burden-sharing scenario, NAI countries realize about 2/3 of the required global emission reductions in 2020. While the reduction targets found in our alternative burden-sharing scenarios are less balanced than the burden-sharing suggested by the IPCC, they are in line with other burden-sharing scenarios with a strong focus on developing countries such as the proposal by Winkler et al. (2009), the Carbon Space approach, the Brazilian Proposal, or the Greenhouse Development Rights approach.

The numerical analyses presented in the paper are meant to provide an illustration for the use of no-lose targets. When interpreting our findings, several caveats have to be kept in mind. For example, abatement cost curves are particularly difficult to estimate and emission projections and projections on future abatement technologies and costs are subject to great uncertainties. Furthermore, our findings from the scenarios with individual no-lose targets for large emitters suggest that the contribution of no-lose target schemes to a 2 °C target crucially depend on whether no-lose targets are uniform or country-specific. Hence, further deepening and extending the analysis of individualized no-lose targets may be a promising avenue for future research.

Finally, our analysis does not take into account additional instruments for financing mitigation activities which might render stronger reduction efforts by NAI countries more likely. At the UNFCCC level negotiations, financing mechanisms and technology cooperation tend to be discussed separately from mitigation targets. In principle though, combining economic instruments such as no-lose targets or emissions trading with other financing mechanisms or technology cooperation should help to integrate NAI countries into a future climate policy agreement.

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Appendix A. Solution algorithm

We briefly outline the logic of the solution algorithm for the multi-country optimization problem where several eligible NAI countries face a no-lose target and have to decide whether to participate in the international emissions trading market. The aim of the algorithm is to identify an equilibrium solution IETM* of AI and NAI_NLT countries participating in the international emissions trading market. This equilibrium solution IETM* is characterized by two conditions. First, the participation condition (1.1) is fulfilled for all NAI_NLT countries in IETM*, i.e. participation is profitable ("internal stability"). Second, if any NAI country outside IETM* joined IETM*, participation in IETM* would no longer be profitable for at least one NAI country in IETM* ("external stability"[16]).

Our algorithm employs a recursive function to identify the countries with profitable no-lose targets and consists of four steps. In step 1, all AI and all NAI_NLT countries are assumed to participate in the international emissions trading market. In step 2, the prices for certificates and offsetting credits as well as the emission certificates and offsetting credits traded are determined by solving the optimization problem for all countries in the international emissions trading market and for the NAI_REST countries. The results are then used to calculate compliance costs for the NAI_NLT countries in the international emissions trading market.

Step 3 checks whether the no-lose targets are profitable for the NAI_NLT countries participating in the international emissions trading market. If the no-lose target of at least one NAI_NLT country in the international emissions trading market is found to be unprofitable, the NAI_NLT country with the highest loss, i.e. the largest negative payoff, is eliminated from the international emissions trading market.[17] We then return to step 2 for the resulting new international emissions trading market and calculate prices and costs for all country groups. In this way, the countries for which no-lose targets are not profitable are excluded from the market step-by-step until all no-lose targets of NAI_NLT countries in the international emissions trading market are profitable (internal stability). Finally, in step 4, our algorithm checks whether the international emissions

16 Note that our definition of external stability differs from the game-theoretical criterion of external stability applied to describe the stability of coalitions. For an application to climate policy, see, for example, (Brechet et al., 2010).

17 Of course, using a different selection criterion like loss per capita or loss per unit of GDP would lead to different outcomes.

trading market found in step 3 satisfies external stability. To do so, excluded NAI_NLT countries are individually added to the international emissions trading market beginning with the largest (in terms of emissions) remaining eligible NAI. For the resulting new international emissions trading market we return to step 2 to calculate prices and costs and check if the international emissions trading market is internally stable. If one of the new international emissions trading markets is found to be internally stable, it is the new IETM and we restart step 4. If external stability holds for all these constellations, the international emissions trading market from step 4 is the equilibrium solution IETM*.

Appendix B. Sensitivity analyses

This Appendix contains the results of the sensitivity analyses for the domestic quota, offsetting limit and the amount of “hot air”. To save space, and since the results are qualitatively similar for the other scenarios, we restrict these sensitivity analyses to the IPCC low scenario.

The results of the sensitivity analysis for the domestic quota in the IPCC low scenario are shown in Figure 5. Accordingly, varying the domestic quota between 5% and 40% has no impact on the outcome. A higher domestic quota of 60% and 80% lowers the price for emission certificates and offsetting credits, because a higher domestic quota lowers the demand for certificates and offsetting credits. For a domestic quota of 80%, participation decreases from 11 to 6 NAI NLT countries, because the lower prices render participation unprofitable (revenue effect).

Figure 6 displays the results of the sensitivity analysis for the offsetting limit in the IPCC low scenario. Varying the offsetting limit between 5% and 20% does not change the number of participating countries. Due to the lack of demand for offsetting credits, however, prices decrease for very low offsetting quota.

Finally, Table 5 presents the results of varying the amounts of “hot air”. Since “hot air” pushes certificate prices down and reduces the demand for certificates from NAI NLT countries, reducing “hot air” is expected to increase the participation by NAI NLT countries. Results in Table 5 (second column) suggest that eliminating “hot air” leads to slightly higher prices, but they are not sufficient to entice additional participation by NAI_NLT countries. While excluding “hot air” automatically results in an increase in the global target, column 3 in Table B.8 gives results for a scenario where global emissions are kept constant and AI countries’ targets are adjusted accordingly. In this scenario, however, prices and the number of NAI_NLT countries participating in the no-lose target scheme remain unchanged.

Figure 5: Sensitivity analysis for the domestic quota in the AI_AMB scenario

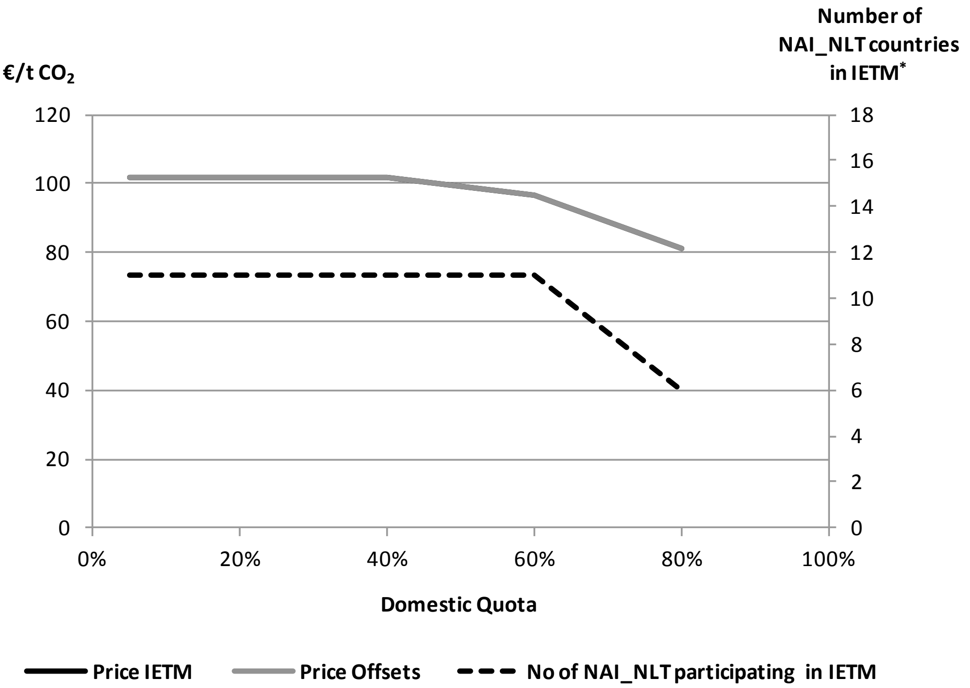

Figure 6: Sensitivity analysis for the offsetting limit in the AI_AMB scenario

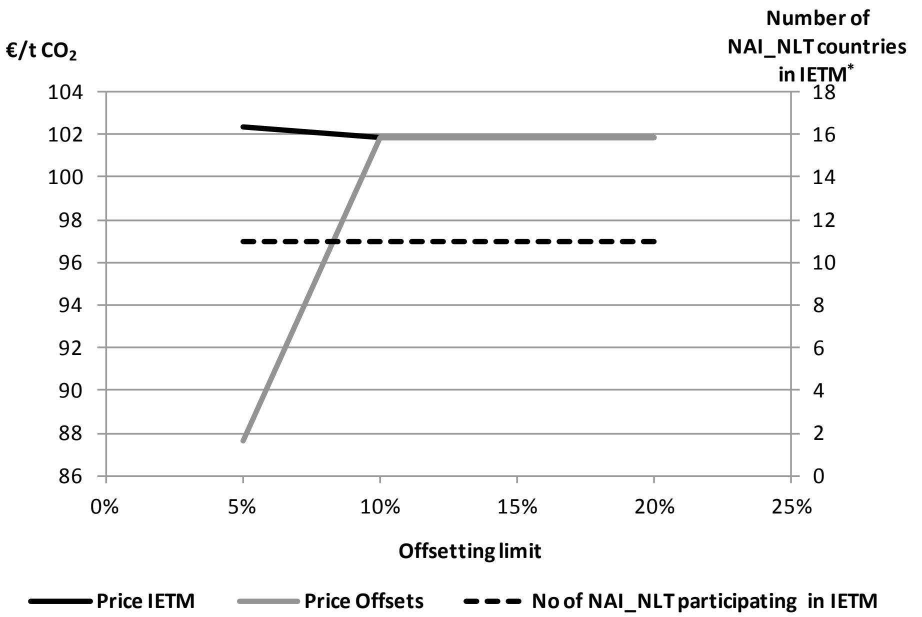

Table 4: Sensitivity analysis for “hot air” in the AI_AMB scenario

	Incl. “hot air”	Excl. “hot air”	Excl. “hot air”, adjusted AI targets
Price Emission certificates [€/t CO_2e]	102	104	102
Price Offsetting Credits [€/t CO_2e]	102	104	102
No. of participating NAI_NLT	11	11	11
Global emission reductions [Gt CO_2e]	8.8	8.9	8.8

Appendix C. Results for BIC scenarios

Table 5: Results for the BIC_10 and the starting scenario

Scenario	Price Emission certificates	Price Offsetting credits	Participating NAI_NLT	Envisaged reductions by NAI_NLT	Realized reductions by NAI_NLT		Realized global reductions
	[€/t CO2e]	[€/t CO2e]	[#]	[Gt CO2e]	[€/t CO2e]	[%]	[Gt CO2e]
BIC_10	53	53	17*	3.8	3.7	98	10.8
Starting scenario	44	44	17*	2.8	2.8	97	9.8

* All NAI_NLT countries but MEX

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