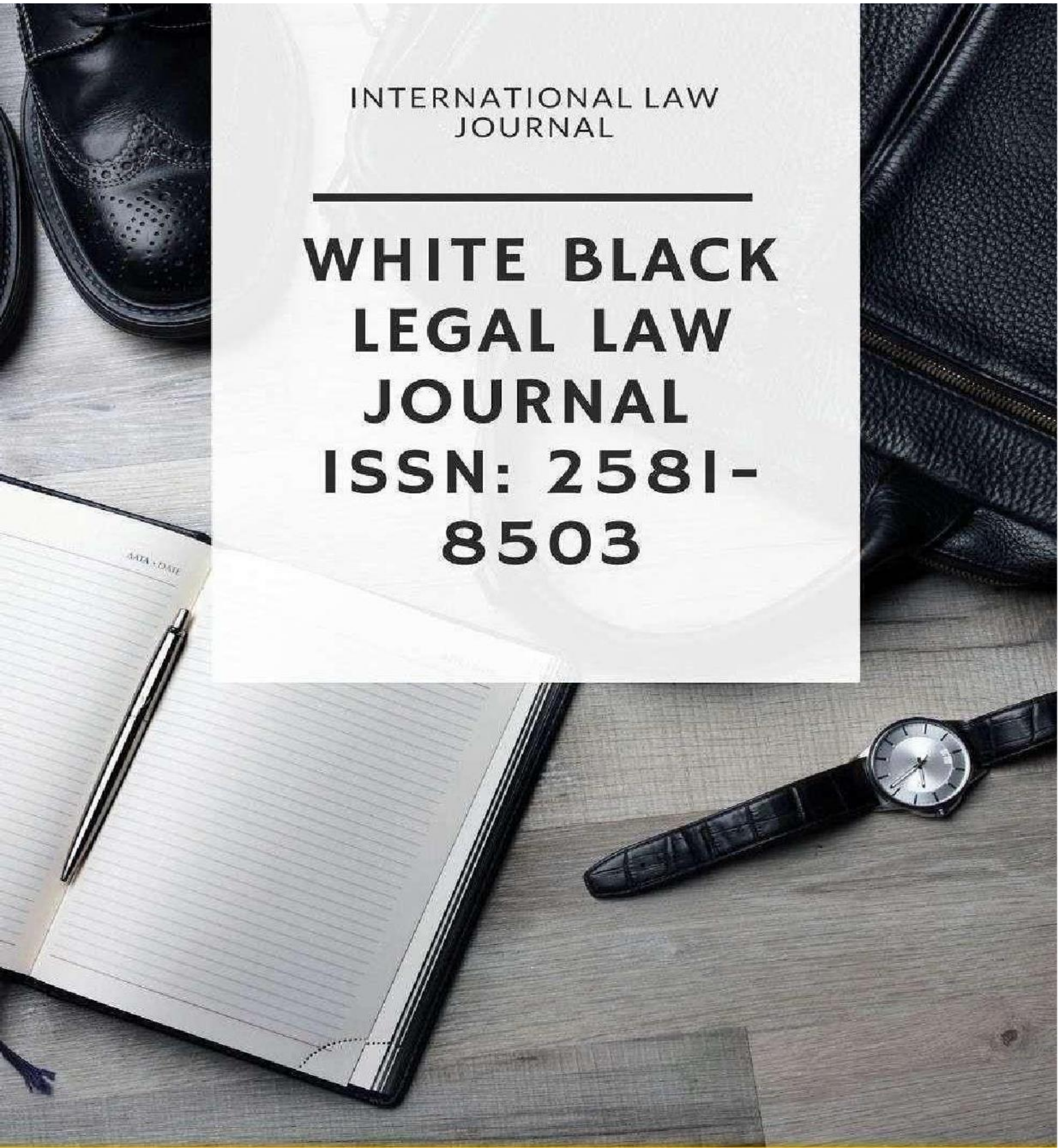

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BRIDGING THE AMBITION GAP IN CLIMATE POLICY: THE EMISSIONS REDUCTION POTENTIAL OF BILATERAL EMISSIONS TRADING UNDER ARTICLE 6.2 OF THE PARIS AGREEMENT

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Course: BBA. LL. B (HONS.), 8th semester

Abstract

Countries' current Nationally Determined Contributions (NDCs) under the Paris Agreement leave a substantial gap to the emissions reductions needed to limit global warming to 2°C. Böhringer et al. (2025) showed the large emis-sions reduction potential of *global* emissions trading even if countries choose their tradable emissions reduction contributions strategically as mutual best-response strategies. However, the prospects for a *global* trading system appear rather bleak. By contrast, countries have already started to trade emissions re-ductions in bilateral agreements under Article 6.2 of the Paris Agreement. Even though bilateral agreements may appear to be a significant restriction at first glance, they prove to be quite effective in terms of global emissions re-ductions when strategic choices of tradable emissions reduction contributions are taken into account. Numerical simulations based on empirical data show that the most effective bilateral trading club – consisting of South Korea or Europe and China – increases global emissions abatement from 17% (relative to BaU) without trading to 30%, and exploits 80% of the emissions reduction potential of a global trading system.

JEL classification: H23, Q54, Q56, Q58, C72

Keywords: Paris Agreement, Article 6, emissions trading, NDCs

1 Introduction

The Nationally Determined Contributions (NDCs) submitted by countries to date under the Paris Agreement are far from sufficient to achieve the emissions reduc-tions needed to limit global warming to at least 2° C. Böhringer et al. (2025) showed that global emissions trading has the potential to close this ambition gap even if each country chooses its tradable emissions reduction contributions non-cooperatively, provided that countries can commit to not accepting countries that violate their NDCs as members of the emissions trading system. However, their analysis is re-stricted to the case where *all* countries participate in a comprehensive global emis-sions trading system. Unfortunately, such a global trading system seems unlikely at present.

At the same time, there is a clear trend towards *bilateral* agreements for trading emissions reductions under Article 6.2 of the Paris Agreement. Article 6.2 en-ables the "use of internationally transferred mitigation outcomes [ITMOs] towards nationally determined contributions" and the rules for bilateral emissions trading were finalized at the 29th Conference of Parties (COP 29) in Baku in 2024. This has created the conditions for exploiting the potential of emissions trading to achieve a more cost-efficient climate policy. As of 14 July 2025, 35 bilateral agreements for the cooperation under Article 6.2 have been signed and 75 more have been ini-tiated, with 61 different countries involved (UNEP Copenhagen Climate Centre, 2025). Also the European Commission's proposal for a 2040 climate target is more open than in the past with regard to the at least limited use of high-quality inter-national credits under Article 6.2. Moreover, some countries have explicitly tied the use of ITMOs to more ambitious climate targets. For example, Brazil considers enhancing its NDC 3.0 target (from -59 % to -67 % by 2030 relative to 2005) using ITMOs generated in Brazil to attract international investment (Erbach & Hourdin, 2025). However, it should be noted that most of these activities, whether planned or already in progress, have so far concerned smaller projects such as those under Japan's Joint Crediting Mechanism, rather than comprehensive emissions trading agreements that we analyze in this paper.

Looking at non-cooperative choices of tradable emissions allowances, Helm (2003) showed that the efficiency gains from emissions trading do not automatically trans-late into higher overall abatement if countries with low concern for climate damages allocate themselves a large number of allowances. To move closer to the coopera-tive first-best within such a non-cooperative second-best environment, several ap-proaches have been discussed. Carbone et al. (2009) expanded the model by Helm (2003) by allowing trading coalitions to block the entry of countries that would choose to allocate excessive allowances. Another line of research emphasizes the role of reputational mechanisms (e.g., naming, blaming, and shaming), whereby international assessments, monitoring by non-governmental organization, and do-mestic electoral incentives can push governments towards more ambitious pledges (Dannenberg et al., 2023; Koliev et al., 2023). A further strand highlights issue linkage, e.g., coupling climate commitments with technology cooperation or trade agreements to improve incentives for cooperation (Carraro & Siniscalco, 1995, 1998; Kemfert, 2004). Our paper builds on Böhringer et al. (2025), who analyzed an NDC-constrained Nash model but focused on a comprehensive global emissions trading system. Our analysis shows that even small bilateral trading clubs can un-lock a large share of the emissions reductions of a global trading system. In this context, research on linking emissions trading schemes (Borghesi & Zhu, 2020; Flachsland et al., 2009a, 2009b; Rose et al., 2018) points to a practical pathway to implement such bilateral cooperation under Article 6 of the Paris Agreement.

Against this background, our research focuses on the potential of bilateral trading under Article 6.2 to foster more restrictive NDCs with higher global emissions re-ductions than would be the case without emissions trading. To quantify the effects of bilateral emissions trading clubs, we conduct numerical simulations based on empirical data for a setting as in Helm (2003) in which countries choose their trad-able emissions reduction contributions non-cooperatively as mutual best response strategies. The quantitative results show that bilateral emissions trading can already be very effective in raising countries' climate ambitions. The most effective bilat-eral trading clubs—in which China is trading with Europe or, alternatively, South Korea—increases global emissions abatement from 17% in the *no-trade* case (i.e., a situation where countries achieve their NDCs through domestic action only) to almost 30% as compared to BaU emissions levels. Remarkably, each of the two bilateral agreements already achieves 80% of the total abatement potential of a comprehensive global trading scheme. China, with its large emissions base and low-cost abatement options is best suited for achieving substantial global emis-sions reductions through bilateral emissions trading—the six most effective (top 6) clubs, which achieve global emissions reductions of between 30% and 25%, all have China as a trading partner. The other trading partner should then be a region with a high willingness to pay for abatement and high costs of implementing abate-ment domestically, such as Europe or South Korea. Overall, our analysis indicates that even a single bilateral emissions trading agreement could put greenhouse gas emissions reductions back on track to achieve the 2°C target.[1]

The remainder of this paper is structured as follows. Section 2 lays out the theo-retical model for describing climate policy decisions by individual countries in a non-cooperative environment. Section 3 presents the data for parameterizing the theoretical model for quantitative simulation analyses. Section 4 discusses simu-lation results with a focus on single bilateral trading clubs. Section 5 extends our analysis to the case of multiple co-existing bilateral clubs. Section 6 concludes.

LITERATURE REVIEW

Transboundary air-pollution agreements have become central to delivering health co-benefits while nations pursue renewable-energy transitions. Recent modelling shows that stricter climate mitigation amplifies external co-benefits, especially for developing regions that rely on foreign emission reductions[1]. The European Union's Carbon Border Adjustment Mechanism (CBAM) exemplifies a policy that links trade rules to cross-border pollution control, aiming to prevent carbon leakage while encouraging cleaner electricity generation[2]. Parallel efforts in the Asia-Pacific illustrate how bilateral emissions-trading under Article 6 of the Paris Agreement can raise global abatement from ≈17 % to ≈30 %, with China-Europe or China-South Korea clubs delivering most of the gains[3]. In South Asia, the absence of a binding framework hampers coordinated action; a proposed UN-anchored transboundary protocol combined with an SAARC political council could institutionalise enforceable standards and financing[4]. Systematic reviews of air-policy synergy stress the need for integrated, region-specific strategies to avoid offsetting effects and to harness complementary benefits of renewable deployment[5]. Empirical work on the European electricity sector demonstrates that low-carbon pathways can cut $PM_{2.5}$ emissions by up to 99 % and reduce excess deaths, yet regional inequality persists, highlighting the importance of coordinated policy design[6]. Finally, integrated assessment models indicate that achieving the 1.5 °C target would accelerate WHO air-quality guidelines globally, averting millions of deaths and delivering health co-benefits that outweigh mitigation costs[7]. Together, these studies underscore that robust, multilateral agreements—grounded in renewable-energy ambition and reinforced by trade, financing, and governance mechanisms—are essential for equitable transboundary air-quality improvement.

[1] https://www.nature.com/articles/s41467-026-68827-0
[2] https://link.springer.com/article/10.1007/s10784-025-09667-z?
[3] https://www.econstor.eu/bitstream/10419/331635/1/cesifo1_wp12170.pdf
[4] https://www.mdpi.com/1660-4601/22/11/1628
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[6] https://link.springer.com/article/10.1007/s10584-024-03851-x?error=cookies_not_supported&code=814d8d05-afbc-4ec4-abc6-3a43d0a97a6d
[7] https://www.nature.com/articles/s41467-025-67276-5

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2 Theoretical model

We consider a set of I countries (or regions), indexed $i = 1, ..., I$. They are charac-terized by increasing, strictly convex abatement costs functions, $c_i(a_i)$, and linear benefit functions, $b_i a$, where a_i is abatement (i.e., emissions reductions) of coun-try i, $a = \sum_{i=1}^{I} a_i$ is the overall (global) abatement level that determines climate damages, and $b_i > 0$ are country-specific marginal benefits of abatement. The as-sumption that benefits of abatement are linear in emissions is widely used in the literature not just because it facilitates the analysis, but also because it is fairly well aligned with the science of climate change. As Golosov et al. (2014, p. 78) puts it: "Linearity is arguably not too extreme a simplification, since the composition of a

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[1] For the top 6 bilateral trading clubs, average global 2030 CO_2 emissions are lower than the global CO_2 emissions from energy consumption averaged across the the various 2°C pathway sce-narios of the integrated assessment models provided by IIASA's AR6 Scenarios Database (Byers et al., 2022).

concave S-to-temperature mapping with a convex temperature-to-damage function may be close to linear" (see also Traeger, 2023; Van den Bijgaart et al., 2016).

In the non-cooperative solution without international emissions trading, to which we refer to as scenario *no-trade*, each country maximizes the difference between its benefits and costs of domestic abatement. The resulting Nash equilibrium abate-ment levels, $a_1^N,...,a_I^N$, satisfy the familiar condition that each country equalizes its marginal costs and benefits of abatement,

$$c_i'(a_i^N) = b_i, \qquad i = 1,...,I. \qquad (1)$$

Furthermore, we follow the argument by Böhringer et al. (2025) that, because coun-tries are free to set their NDCs, these NDCs primarily reflect individually rational Nash behavior (see also Barrett, 2016; Dimitrov et al., 2019). We therefore asso-ciate the abatement levels, $a_1^N,...,a_I^N$ resulting from Eq. (2) with countries' NDCs.

The solution of scenario *no-trade* is inefficient because damages in other countries are ignored and marginal abatement costs are not equalized. Emissions trading addresses the second issue. At the same time, choosing *tradable* emissions reduc-tion contributions ("permits") rather than abatement also changes countries' strate-gic incentives (see Helm, 2003): Countries with high benefits of abatement raise their emissions reduction contributions, as they can now achieve them by exploit-ing lower costs abatement options in other countries. By contrast, countries with low benefits of abatement choose lower emissions reduction contributions in or-der to sell their reduction potential on the international permit market. However, Böhringer et al. (2025) have argued that even though the NDCs are not legally binding, it is difficult to imagine that countries which increase their NDCs as a member of the trading system would accept that others reduce their NDCs upon joining. In particular, such behavior would go beyond simple free-riding on emis-sions reductions because the "hot air" from reduced NDCs comes down to printing money at the cost of others. It would also be in conflict with Article 6.1 of the Paris Agreement according to which the use of ITMOs in the implementation of NDCs is intended to "allow for higher ambition in their mitigation [...] actions". We therefore assume that countries will adhere to their NDCs as a lower bound for their *tradable* emissions reduction contributions, as otherwise they would not be accepted as members of the trading club.

While Böhringer et al. (2025) only considered a comprehensive global trading sys-tem, in this paper we focus on the more realistic situation in which some countries form bilateral coalitions, referred to as "trading clubs". The countries outside a trading club continue to choose domestic abatement as under scenario *no-trade*, thus equalizing their marginal costs and benefits of domestic abatement. More-over, from (1) these choices do not depend on the behavior of trading clubs because benefit functions are assumed to be linear.

We denote by K the set of countries outside a trading club, and by L the set of countries that become members of a bilateral trading club; hence $K \cup L = I$. Using index l for a bilateral trading club, a country i that is a member of trading coali-tion l chooses its tradable emissions reduction contributions (ERCs), ω_i, so as to maximize its own net benefits after trading:

$$\max_{\omega_i} \; b_i a_l - c_i(a_i^*(\omega_l)) - p^*(\omega_l)(\omega_i - a_i^*(\omega_l)) \quad s.t. \quad \omega_i - a_i^N \geq 0, \quad (2)$$

where ω_l are total ERCs of the two members in trading club l, $a_i^*(\omega_l)$ is after-trade equilibrium abatement of country i as a member of trading club l, and $p_l^*(\omega)$ is the equilibrium price of tradable ERCs in trading club l. Accordingly, mem-bers of bilateral trading clubs not only account for the benefits and costs of abate-ment, $b_i a - c_i(a^*(\omega_l))$, but also for revenues or expenditures from trading ERCs, $p_l^*(\omega_l)(\omega_i - a_i^*(\omega_l))$, thereby respecting the NDC constraint $\omega_i - a_i^N \geq 0$. Moreover, when choosing their tradable ERCs, countries anticipate that after-trade abatement $a_i^*(\omega_l)$ and the permit price $p_l^*(\omega_l)$ follow from the conditions that (i) for each trad-ing club member marginal abatement costs equal the permit price, $c_i'(a_i^*(\omega_l)) = p_l^*(\omega_l)$, and ($ii$) the permit market clears, $\sum_{i \in L_l} a_i^*(\omega_l)) - \omega_l = 0$, where L_l is the set of members of trading club l. The constrained maximization problem in (2) then yields the Karush-Kuhn-Tucker conditions for all $i \in L$ (μ_i is the Lagrangian multiplier)[2]:

$$b_i - p_l^*(\omega_l) - p_l^{*\prime}(\omega_l)(\omega_i - a_i^*(\omega_l)) + \mu_i = 0, \qquad (3)$$

[2] All second-order conditions are trivially satisfied given our curvature assumptions.

$$\omega_i - a_i^N \geq 0, \quad \mu_i \geq 0, \; \mu_i \left(\omega_i - a_i^N\right) = 0. \qquad (4)$$

We call this the solution of scenario *strategic*. In comparison to the Nash equi-librium without trading in (1), marginal abatement costs now depend on the permit price $p^{*l}(\omega_l)$. Moreover, there is an additional effect as reducing ERCs makes abate-ment less demanding and, thus, lowers the permit price at which ERCs are traded; and vice versa if ERCs are raised.[3] Finally, μ_i is the shadow price if the NDC constraint binds.

Adding up the first-order conditions (3) for trading club members and using $c_i'(a_i^*(\omega_l)) =$

$_l p^*(\omega_l)$ yields $\sum_{i\in L} b_i = \sum_{i\in L} c'(_i a^*(_i \omega^N)) - \mu_i$, where superscript N indicates the

$l \quad l \quad l$

Nash equilibrium in tradable ERCs. Doing the same with the first-order condi-tion (1) for the case without trading yields $\sum_{i\in L} b_i = \sum_{i\in L} c'(a^N)$ so that in both

$l \quad l \; i \; i$

Nash equilibria, with and without trading, aggregate marginal benefits and costs of abatement are equalized, plus the corrective terms μ_i if the NDC constraint binds. This shows that the difference between the two solutions is mainly due to the fact that trading achieves greater emissions reductions by implementing them cost-effectively through the equalization of the marginal costs of emissions reduction between trading partners. In the remainder of the paper, we use a numerical sim-ulation model based on empirical data to compare the outcomes without and with trading that result from the first-order conditions (1) and (3) to (4), respectively.

3 Data

The region-specific data required for model parametrization consist of (*i*) business-as-usual (BaU) emissions, (*ii*) marginal abatement cost (MAC) curves, and (*iii*) NDCs for emissions reductions.[4] The data on BaU emissions and MAC curves are

[3]Formally, $p^{*\prime} (\omega) = \sum \frac{1}{\quad} ^{-1} > 0$ follows from the equilibrium conditions on the permit $l\, l\;\; i \in l_i\, c''(a_i)$ market (see Helm (2003)).

[4]When discussing data inputs and simulation results, we use the term "regions" instead of "coun-tries" to reflect that our empirical dataset covers 14 geopolitical regions consisting of both individual countries and aggregates of several countries. The regions are treated as unitary actors so that emis-sions trading within these regions, e.g., under the EU ETS, is consistent with the assumption of purely domestic abatement in scenario *no-trade*.

taken from the 36th study of the Energy Modeling Forum (EMF36) on "Carbon Pricing After Paris", which uses the year 2030 as a milestone year for measuring the impacts of the Paris Agreement compared to a business-as-usual (BaU) sce-nario without the Paris Agreement in place (EMF36, Böhringer et al., 2021). In the EMF36 study, several international expert modeling teams provided data for 14 geopolitical regions on how incremental CO_2 emissions pricing leads to regional emissions abatement in their respective models, accounting for different abatement options such as fuel switching, energy efficiency improvements, and energy sav-ings.

Böhringer et al. (2025) used these data to derive regional MAC curves for each of the nine EMF36 models based on a least-square fit to polynomial functions of third degree, $c'(a_i) = k_{1i}a_i + k_{2i}a^2 + k_{3i}a^3$, where k_{1i}, k_{2i}, k_{3i} are the coefficients for region

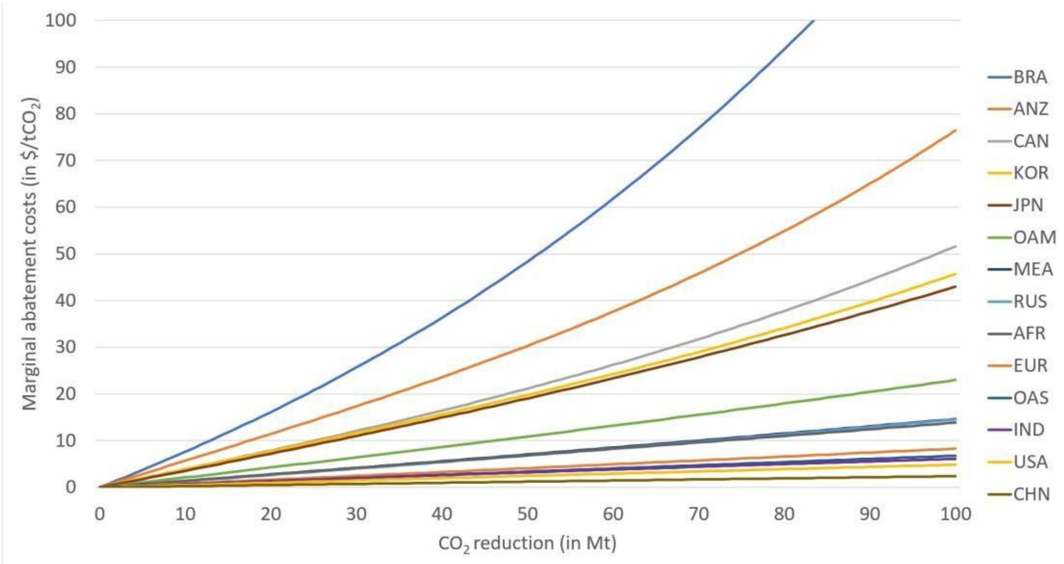
i i i

i.[5] Figure 1 visualizes the average of these curves, indicating substantial differences in the ease of substituting CO_2 emissions across regions due to differences in CO_2 intensity, fuel mixes of CO_2-based energy carriers (oil, coal, gas), initial energy price levels, or pre-existing emissions regulations.

Table 1 shows the region-specific BaU CO_2 emissions from fossil fuel combustion in 2030 and the NDCs as an average value across the EMF36 models. To calculate the region-specific emissions reduction commitments under the Paris Agreement, we start from the unconditional Nationally Determined Contributions (NDCs) submitted by Parties to the UNFCCC up to 2023 (UNFCCC secretariat, n.d.). From these official documents we derive information on each country's NDC pledge, base year, target year, greenhouse gas coverage, and target type. Most countries have set their targets as percentage reductions of total GHG or CO_2 emissions relative to a historical base year or relative to a future BaU scenario base year. Others, including

[5] In Appendix A, Table 3 describes the modeling teams and model acronyms, and Table 4 de-scribes the 14 geopolitical regions in the dataset with their explicit denotations, 3-letter codes, and the constituting countries (for composite regions). Table 6 shows the fitted coefficients for the nine datasets provided by the modeling teams. Of the 14 regions, we consider 10 as sufficiently homo-geneous jurisdictions to join a bilateral trading club (see below), resulting in 45 potential clubs. Our meta-analysis thus covers nine datasets for each of the 45 potential bilateral trading clubs, yield-ing 405 combinations. In four of these—club KOR-CHN using model CEPE, BRA-CHN using model ICES, CAN-CHN using model ICES, and JPN-CHN using model ICES—numerical corner solutions occurred that were not taken into account in the analysis.

Figure 1: Marginal abatement cost curves (averaged across EMF36 models)



For region keys see Table 1.

the bigger emitters China and India, have defined their targets in terms of emissions intensity of GDP.

Following the approach of Böhringer et al. (2021), we translate all NDCs into equiv-alent percentage reductions in CO_2 emissions from fossil fuel combustion relative to 2030 BaU emissions levels. When the NDC target year differs from 2030, the implied percentage reduction gets linearly extrapolated or interpolated. For coun-tries with NDCs covering all GHGs rather than CO_2 only, we apply region-specific scaling factors based on Kitous et al. (2016).[6] For the composite regions in our analysis we aggregate the individual targets by the constituting countries. Overall, the updated NDCs as of 2023 imply global emissions reduction for the *no-trade* case of 17.3% from 2030 BaU emissions levels.

The EMF36 study does not provide monetary estimates for climate damages from

[6]China has committed to reducing the emissions intensity of GDP "by *over* 65%" from the 2005 level. This leaves some room for interpretation and we used the specific value of 66.2% that corresponds to a reduction target of 5% from BaU. Since Brazil is a special case with a relatively high share of non-CO_2 emissions, Brazil's target was based on an expert estimate in the EMF36 study. Given that Brazil's 2023 NDC update implies a 10% higher GHG emission reduction, we scale this estimate accordingly.

Table 1: Average BaU CO_2 emissions and NDCs

Region	Region code	2030 BaU CO_2 emissions (mean)	NDC 2023 emissions reductions
		Mt	% from BaU
global		31834.6	17.3
Africa	AFR	1233.5	8.6
Australia & New Zealand	ANZ	447.2	4.5
Brazil	BRA	456.8	20.8
Canada	CAN	553.1	30
China	CHN	8172.9	5
Europe	EUR	3821.4	37.2
India	IND	3070.4	8.5
Japan	JPN	922.5	23.0
South Korea	KOR	590.5	45.2
Middle East	MEA	2153.5	9.3
Other Americas	OAM	1318.9	10.3
Other Asia	OAS	3037.1	24.0
Russia	RUS	1418.7	1.3
United States	USA	4638.1	31.5

Sources: EMF36 (Böhringer et al., 2021) and own calculations. See Table 4 in Appendix A for the country composition of aggregate regions.

CO_2 emissions, the so-called social costs of carbon (SCC). The literature based on integrated assessment modeling offers a large range for SCC estimates (Metcalf & Stock, 2017; Wang et al., 2019). However, specific SCC estimates are highly dis-puted because many effects of climate change are still subject to larger uncertain-ties, and the translation of these effects into aggregate monetary values depends on controversial value judgments (Pezzey, 2019; Rennert et al., 2022) For our analysis, we follow the argument in Böhringer et al. (2025) that the voluntary NDCs submit-ted by countries under the Paris Agreement essentially codify individually rational Nash behavior and, thus, reveal countries' willingness to pay for the protection of the climate system. Remember that the Nash equilibrium without international emissions trading is given by $c_i'(a_i^N) = b_i$ (see Eq. (1)).[7] We can then calculate

[7]As pointed out in Böhringer et al. (2025), marginal benefits b_i need not be restricted to purely domestic benefits from lower climate damages, but can also capture moral concerns about such the (constant) marginal benefit of abatement, b_i, from the MAC functions and the interpretation of a^N as regions' NDCs.

Figure 2 shows the marginal abatement costs and, thus, the CO_2 prices in the 14 regions if they implement their NDCs exclusively through domestic emissions pric-ing. From the above discussion, these marginal abatement costs also correspond to the marginal benefits of abatement.[8] Since our (meta-)analysis is based on input data from nine EMF36 modeling teams, we have nine different parameterizations of the theoretical model to compute quantitative simulation results. The presentation of results focuses on mean values, but we also use Box-Whisker plots to visualize the distribution of the results based on the median, the mean, the first and third quartile, as well as whiskers within the 1.5-fold interquartile range (i.e., the 1.5-fold distance between the upper and lower quartile).[9] CO_2 prices vary significantly between regions, reflecting differences in the stringency of NDCs and the ease of emissions reduction captured by the curvature of marginal abatement costs curves (see Figure 1). More specifically, mean CO_2 prices range from about 2\$/tCO_2 for Russia (very modest NDC and cheap domestic abatement options) to 272\$/tCO_2 for South Korea and 316\$/tCO_2 for Europe (ambitious NDCs and quite expensive domestic abatement options). The global average amounts to 90\$/tCO_2. The wide range of CO_2 prices indicates potential for substantial cost savings through emis-sions trading, to which we turn now.

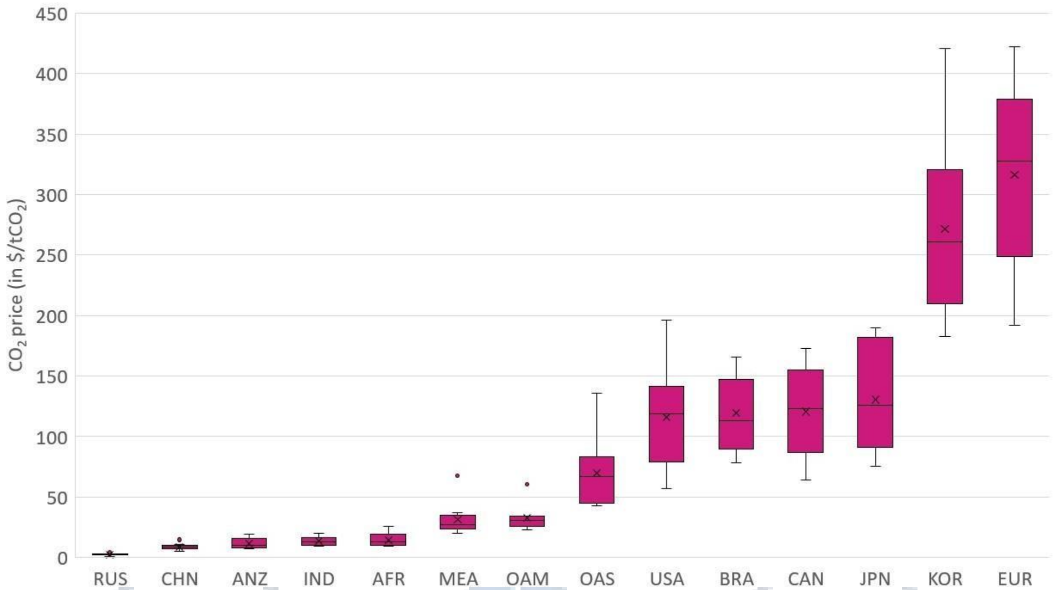
damages occurring elsewhere.

[8]Parties were requested to submit their updated NDCs by 2020, i.e., before a first set of rules under Article 6 was agreed at the COP 26 in 2021 and before the rules for trading under Article 6.2 were finalized at COP29 in 2024. We therefore assume that the updated NDCs we use do not yet account for potential cost savings from emissions trading. While some countries delayed submitting their NDC updates after 2020 or revised their NDCs again, for consistency we rely on the most recent NDCs as of 2023.

[9]All simulation results can be reproduced using the data from Table 1 as well as Table 5 and Table 6 in Appendix A. The numerical model, which consist of the generic first-order conditions parameterized successively with the input data from the nine EMF36 teams, is

implemented in the high-level programming language GAMS (Generalized Algebraic Modeling System). The code is available from the authors upon request.

Figure 2: Regional CO_2 prices to implement 2023 NDCs through domestic emissions pricing only



Note: Box–Whisker plot shows the median (line), mean (cross), first and third quartile (box), and whiskers showing the last datapoints within 1.5 times the interquartile range. Dots indicate outliers. For region keys see Table 1.

4 Global emissions reductions and cost savings from bilateral emissions trading

The EMF36 study as our empirical database covers 14 geopolitical regions. Of these, we consider 10 regions—the eight explicit countries in the dataset (USA, China, Canada, Japan, South Korea, Russia, India, Brazil) and the two politically and economically homogeneous regions of Europe and Australia & New Zealand—as strategically acting entities that are candidates for emissions trading. For consis-tency, the global trading club that we use subsequently for comparison with the outcome of a bilateral trading club is composed of the the same ten strategically acting entities. The four remaining composite regions, Africa, Middle East, Other Americas and Other Asia, are politically and economically rather heterogeneous, and have no supranational organizations like the EU. Moreover, in many coun-tries of these regions the institutions that would be essential to guide and monitor a region-wide emissions trading system are relatively weak. It therefore seems unre-alistic at present that these regions will develop a coherent strategy regarding their choice of tradable emissions reduction contributions, and other regions may be re-luctant to form a trading club with them. Obviously, other countries like the USA under President Donald Trump and Russia at war are also unrealistic partners of a trading club at present. But political circumstances can change, and given our focus on *bilateral* trading clubs, the following results would be only marginally affected if the USA and Russia were excluded as potential trading partners.

We focus on bilateral trading clubs, mainly for three reasons: First, policy-relevant activities under Article 6.2 of the Paris Agreement are limited so far predominantly to bilateral initiatives (UNEP Copenhagen Climate Centre, 2025). Second, the ef-fects of different coalition sizes become most apparent when comparing the ex-tremes of a single bilateral club and a global trading club. Third, with ten strategically acting jurisdictions, the focus on bilateral trading clubs limits the otherwise large number of potential trading clubs to 45.[10]

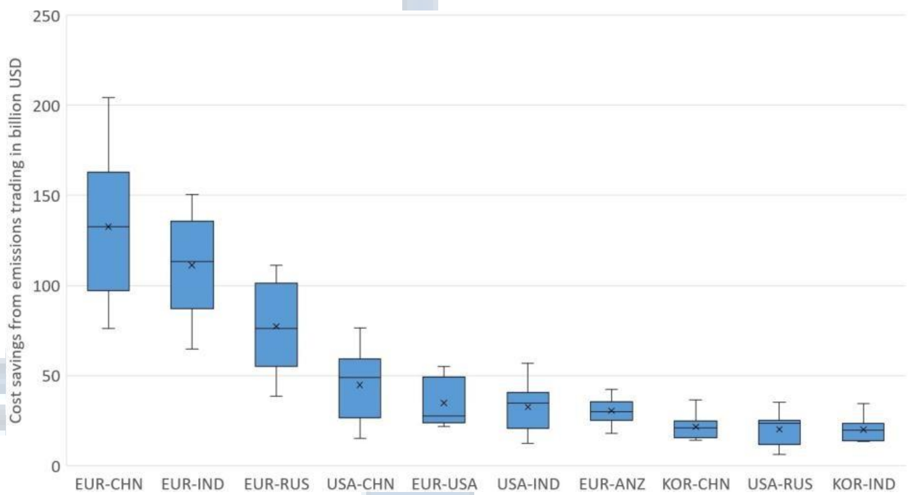
Tables 8 and 9 in Appendix B summarize all results, while the following discussion focuses on the top 10 clubs that achieve the highest cost savings and largest global emissions reductions. Figure 3 shows the top 10 trading clubs with the highest cost savings if all regions kept their initial NDCs, i.e., regions outside the club maintain their domestic abatement costs as of scenario *no-trade* whereas the two members of the respective bilateral trading club trade the emission reduction contributions (ERCs) implied by their NDCs[11]. Intuitively, the greater the difference between the marginal abatement costs for trading partners, the higher the cost savings, provided that the selling low-cost-of-abatement region has sufficient emissions reduction ca-pacity to meet the demand of the buying high-cost-of-abatement region. Therefore, the magnitude of initial BaU emissions for trading partners also plays a decisive role. In our sample, the difference of marginal abatement costs (MAC) to imple-ment NDCs is largest for the trading club of Europe and Russia. Yet, Russia's MAC

10The number of clubs with members between 2 and 10 equals $\sum^{10}_{n=2} \binom{10}{n}$ =1013 while the number of bilateral clubs equals $\binom{10}{2}$ =45.

11We write bilateral clubs as A–B, with the first region (A) being the seller of ERCs

(equivalently,
the buyer of allowances) and the second region (B) being the buyer of ERCs (equivalently, seller of allowances).
curves are substantially steeper than those of China and India (see Figure 1) so that Russia's capacity for cheap emissions reductions is lower. As a consequence, cost savings are higher if Europe forms a club with China or India.

Figure 3: Total cost savings from trading emissions reductions implied by the NDCs for the Top 10 trading clubs

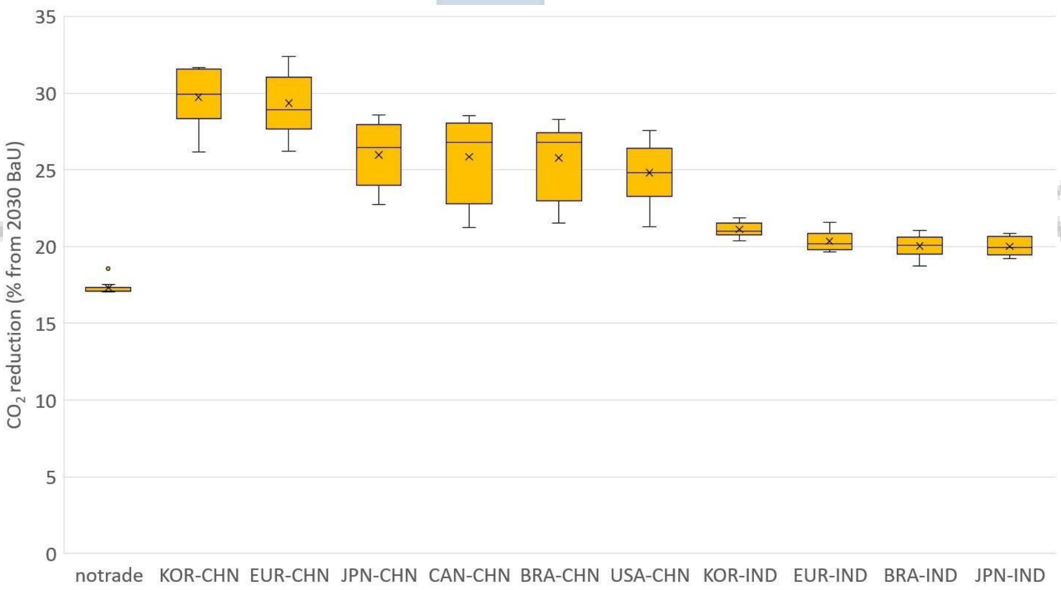


Note: Box–Whisker plot shows the median (line), mean (cross), first and third quartile (box), and whiskers showing the last datapoints within 1.5 times the interquartile range. Dots indicate outliers. For region keys see Table 1.

The potential cost savings from trading shown in Figure 3 are not the only fac-tor that determines the success of a bilateral coalition. In scenario *strategic*, club regions choose their ERCs as mutual best responses, subject to the constraint that they must not fall below their reductions in scenario *no-trade*, i.e., below their NDC abatement levels. In anticipation of the possibility of trading ERCs, high-benefit-of-abatement regions have an incentive to strengthen their ERCs as they can buy cheaper emissions reductions from regions with lower abatement costs. What con-straints this incentive is that higher ERCs drive up the permit price they have to pay, which becomes more costly the more emissions reductions a region purchases from others. By contrast, low-benefit-of-abatement regions can sell more permits if they reduce their ERCs, but must take into account that this reduces the price per permit they receive. The NDC constraint furthermore ensures that low-benefit-of-abatement regions cannot choose abatement targets below their initial NDCs.

The combined effect of these incentives, which are apparent from the first-order condition (3) of the theoretical model, shows up in Figure 4, which reports the top 10 bilateral trading clubs with the highest global emissions reductions in scenario *strategic* (see also Table 8 in Appendix B). Interestingly, the NDC constraint does not bind for any of the top 10 bilateral trading clubs, i.e. none of the regions in a trading club would have an incentive to lower its emissions reduction contributions (ERCs) if these are tradable. By contrast, in a comprehensive trading club of all strategic regions, without the NDC constraint overall emissions reductions would fall from 37.2% to 29.8%. This reflects that countries are primarily deterred from reducing their tradable ERCs in order to sell more emission reductions to other trading partners by the associated reduction in the price per permit sold.[12] This effect is smaller the larger the trading club, which makes it more attractive to free-ride on other countries' emissions reduction contributions.

Figure 4: Global emissions reduction levels of the top 10 trading clubs in scenario *strategic* compared to BaU emissions



Note: Box–Whisker plot shows the median (line), mean (cross), first and third quartile (box), and whiskers showing the last datapoints within 1.5 times the interquartile range. Dots indicate outliers. For region keys see Table 1.

[12]Formally, this trade-off is captured by the term $p^{*'}(\omega_l)(\omega_i - a^*(\omega_l))$ in the first-order condition

l *i*

(3). Reducing ω_i would increase the number of perm$_i$ its sold, $a^*(\omega_l) - \omega_i$, but also lower the permit price, $_l p^{*'}(\omega_l) > 0$.

Five of the top 10 clubs are among those with the highest cost savings from simply trading their ERCs in scenario *no-trade* (Figure 3), including the two most effective ones, i.e., South Korea trading with China (KOR-CHN) and Europe trading with China (EUR-CHN). While KOR-CHN ranks only eighth in terms of cost savings from trading, it is the club that performs best in terms of global emissions reduc-tions.

Accordingly, the gains from trading as captured by Figure 3 matter, but so do the in-centives to adjust one's NDCs in anticipation of trading. South Korea's MAC curve lies substantially above that of Europe (see Figure 1), which results in lower NDCs when measured in absolute emissions reductions due to Europe being substantially larger (the NDCs are 45.2% (KOR) and 37.2% (EUR) reduction from BaU (see Ta-ble 1), which corresponds to absolute emissions reductions of 266.7 (KOR) versus 1422.6 (EUR) Mt CO_2). Scenario *strategic* unlocks this potential as South Korea accepts significantly higher (tradable) ERCs by exploiting low-cost emissions re-ductions in China. This incentive effect in scenario *strategic* induces South Korea and China to increase their joint abatement efforts nearly sevenfold compared to their abatement levels in scenario *no-trade* (see Table 8 in Appendix B). Together with NDC compliance of all other regions, this reduces global BaU emissions in 2030 by 29.7%, compared to 17.3% in scenario *no-trade* and 37.2% in the scenario of a global trading club of all strategic regions (see Figure 4). Remarkably, the single bilateral club of South Korea and China thus already achieves 80% of the total abatement potential of a comprehensive global trading scheme (see Table 8).[13]

EUR-CHN occupies a similar position in both Figures (second and first place) and performs best in terms of joint abatement of the two trading club members, i.e., when the emissions from other regions are disregarded (see Table 8). In this trading club, Europe and China triple their joint abatement efforts compared to scenario *no-trade* and they achieve 79% of the abatement potential of a global trading scheme. The reason why KOR-CHN still performs slightly better in terms of global abate-ment (29.7% vs. 29.4%) lies in the non-trading regions: In the case of a KOR-CHN

[13]Using the notation from section 2, this ratio of global abatement from BaU emissions with a

(∑i∈l a*(ωl)+∑i∈N\l a^N) bilateral club and with global trade is ii .

(∑i∈L a*(ω)+∑i∈K a^N)

i i

trading club, Europe's NDC compliance leads to a significantly higher abatement than South Korea's NDC compliance in the case of the EUR-CHN trading club.

China is a member of the top 6 trading clubs, and the four remaining top 10 clubs all contain India. This underscores the importance of having a trading partner with a large potential for low cost abatement, which results from a combination of low MAC curves, large BaU emissions, and low NDCs.[14] The other coalition partner should then be a region with high benefits of abatement and high costs of imple-menting this domestically. In line with this, the six partners of China in the top-performing coalitions follow exactly the ranking of regional CO_2 prices to imple-ment NDCs (see Figure 2), and, thus, of the regions' marginal benefits of abatement (see Eq. 1), except that Europe and South Korea switch positions.

5 The effectiveness of several bilateral trading clubs

We motivated our analysis by arguing that a comprehensive system of emissions trading involving all countries currently seems politically infeasible, whereas bilat-eral coalitions appear much more realistic and are in fact already emerging. The previous section has shown that even a single bilateral trading club can achieve ma-jor global emissions reductions, provided that it comprises suitable partners. Now we go one step further and investigate the outcome if the ten strategic regions in our sample formed several such bilateral coalitions.

The first column in Table 2 shows the optimal combination of bilateral coalitions that together achieve the highest possible global emissions abatement when each region participates in at most one coalition. The next three columns show the ad-ditional emissions reductions compared to scenario *no-trade* that is achieved by the respective bilateral coalitions and their individual members. It is striking that 73.5% of the additional joint abatement takes place in China, followed by 17% in India. This difference results from the larger potential for cheap abatement options in China, but also from the fact that China is paired with its most favored partner

[14]The first two criteria also apply to the USA, but much of its potential for cost-effective reductions has already been exhausted by its relatively ambitious NDC of 31.5%, compared to 5% for China and 8.5% for India.

in terms of high abatement, whereas India is not (see Figure 4). Furthermore, the numbers in Table 2 show that in each coalition, abatement after trading exceeds the NDC levels for the regions with low costs of abatement, whereas the high-cost regions even reduce abatement.

Table 2: Abatement and welfare changes in clubs in scenario *strategic* compared to scenario *no-trade* Club Abatement change (in Mt CO_2) % Share Joint Welfare change (in billion USD)

	Region 1	Region 2	Joint	/ global club	Region 1	Region 2	Joint
KOR-CHN	−70.8	4014.1	3943.4	62%	853.1	68.3	921.4
JPN-IND	−65.8	929.4	863.5	14%	84.6	16.0	100.6
EUR-USA	−204.8	577.2	372.4	6%	41.9	77.6	119.5
BRA-RUS	−34.7	275.7	241.0	4%	18.7	6.2	24.9
CAN-ANZ	−37.8	81.6	43.8	1%	2.8	3.5	6.3

Row labels refer to bilateral trading clubs consisting of the two named regions. In the columns, the regions result from the club name, e.g. in the club KOR-CHN, region 1 is CHN and region 2 is KOR. For regional codes see Table 1. "% Share Joint / global club" refers to the share of joint abatement change in the respective club relative to the additional abatement of a global coalition of all ten strategic regions - both compared to scenario *no-trade* where countries implement their NDCs without trade.

Nevertheless, both regions always benefit. This is shown in the sixth and sev-enth columns that report welfare gains (i.e., changes in monetarized benefits and costs of abatement) caused by the respective coalition compared to the *no-trade* scenario. The low-cost regions mainly benefit from selling their emissions reduc-tions, whereas the benefits of their respective partners mainly arise from the high valuation for the additional abatement provided by the trading club. For example, in the bilateral trading club KOR-CHN, South Korea's welfare gains from the ben-efits of additional emissions reductions and from lower own emissions reductions amount to $853 billion. China also benefits from lower emissions, but also from significant revenues from the sale of emissions reductions that result in a welfare gain of $68 billion. Thus, in scenario *strategic,* South Korea is financing the higher abatement level in China by choosing a high emissions reduction target and subse-quently purchasing emissions reductions from China.

In total, the additional emissions reductions achieved by the five coalitions com-pared to scenario *no-trade* amount to 86% of the additional abatement that could be achieved by a comprehensive trading club covering all ten strategic regions. The fifth column in Table 2 provides a breakdown of the contributions made by each club. Accordingly, even a single bilateral club that comprises suitable partners—EUR-CHN would attain a similar value like KOR-CHN—attains roughly three-quarter of the additional abatement of a comprehensive club of all ten strategic regions (62% instead of 86%). Thus, our quantitative results suggest that a prag-matic approach of starting with a suitable bilateral coalition does not loose much of the potential of a global trading system.

6 Conclusion

The climate is warming and sea levels rising faster than governments are acting. Moreover, the current erosion of the rule-based world order is dampening hopes for global cooperation on stricter climate policies. In this paper, we have argued that even in this unfavorable political environment, significant emissions reduc-tions can be achieved if countries exploit at least part of the potential of emissions trading under Article 6.2 of the Paris Agreement and conclude bilateral trading agreements. Using a numerical meta-analysis based on empirical data, we analyzed such bilateral trading clubs under the assumption that participating countries choose their tradable emissions reduction contributions non-cooperatively as mutual best-response strategies.

The most effective clubs link a country that has high benefits of abatement but also high abatement costs, with a country that has the opposite pattern and also ac-counts for a sufficiently large share of global CO_2 emissions. Pairing South Korea or Europe with China reduces global emissions by 30% respectively 29% (vs. BaU emissions levels), whereas current NDCs reduce emissions by only 17%. Moreover, each of these two bilateral clubs can already achieve 80% of the emissions reduc-tions that a global trading agreement would achieve. This number rises to 93% if several bilateral clubs with non-overlapping members are formed. Therefore, even with non-cooperative choices of emissions reduction contributions, bilateral emis-sions trading has the potential to bring global emissions reductions close to the path required to stay within the 2°C climate target.

Bilateral trading clubs only equalize marginal abatement costs between club mem-bers and therefore do not fully exploit the potential of emissions trading. But in a non-cooperative setting, smaller clubs are less susceptible to free-rider incentives, which explains their surprisingly good performance. This also explains why the NDC constraint that emissions reduction contributions must not fall below NDC levels does not bind for any of the top 10 bilateral clubs with the highest emissions reductions. By contrast, in a comprehensive trading club of all strategic countries, the absence of the NDC constraint would reduce overall emissions reductions from 37% to 30% compared to BaU. This matters as NDCs are neither legally binding nor enforceable.

The political message from our analysis is that countries should intensify their ef-forts to conclude bilateral agreements on emissions trading under Article 6.2 of the Paris Agreement. They should combine this with more ambitious NDCs, which is in their own interest given that trading makes abatement more efficient. From this perspective, the finalization of rules for global carbon markets under Article 6 of the Paris Agreement—and in particular Article 6.2, which regulates bilateral car-bon trading—at the COP 29 climate negotiations in 2024 is reassuring. Now every effort must be made that the Article 6 Technical Expert Review process ensures the accuracy, completeness, consistency, and comparability of the data submitted by the trading clubs (Dossi & Crook, 2025). In addition, trading club members must agree on a robust enforcement mechanism to prevent any weakening of commitments, which could ultimately jeopardize even well-functioning domestic emissions trading systems such as the EU-ETS.
In its NDC communication, the EU stated that it "is continuing to explore the possi-bilities to link the EU-ETS with other robust emissions trading systems" (European Commission, 2023, p. 20). In line with its self-perception as a pioneer in cli-mate policy, the EU—but also other countries—should intensify these efforts, as our analysis showed that even bilateral trading clubs can achieve a great deal. This experience will also improve our understanding of how international emissions trad-ing can be implemented in practice, which is crucial for

expanding to larger trading clubs over time.

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Appendix A: Data sources

The EMF36 study is based on quantitative analysis from several computable general equilibrium (CGE) models operated by established international expert groups. For our meta-analysis we selected those nine models that feature multi-region trade across the 14 regions that had been identified by EMF36 as both geopolitically important and amenable to parameterization with publicly available data – see Table 3 for the list of models by acronym, institutional hosts, and respective modeling experts.

Table 3: EMF36 models used in the meta-analysis

Model Institution Experts

CEPE Swiss Federal Institute of Technology (ETH) Zürich

Florian Landis, Gustav Fredriksson, Sebastian Rausch

DREAM Fudan University Haoqi Qian, Shuaishuai Zhang, Libo Wu

ENVISAGE Purdue University Maksym Chepeliev, Israel

Osario-Rodarte, Dominique van der Mensbrugghe

GEM-E3 European Commission - Joint

Research Centre (JRC)

ICES Euro-Mediterranean Center on Climate Change (CMCC)

PACE Centre for European Economic Research (ZEW)

Toon Vandyck, Matthias Weitzel, Krzysztof Wojtowicz, Luis Rey Los Santos, Anamaria Maftei, Sara Riscado

Ramiro Parrado Sebastian Rausch

SNOW Statistics Norway Taran Fæhn, Hidemichi

Yonezawa TUB Technical University (TU) Berlin Mohammad M. Khabbazan, Christian von

Hirschhausen UOL University of Oldenburg Chrish Böhringer, Jan Schneider Source: EMF36

(Böhringer et al., 2021).

The expert teams used their multi-region CGE models to derive marginal abatement cost curves for the 14 geopolitical regions. More specifically, the marginal abate-ment cost functions are generated through a sequence of emissions prices taxes starting from \$0 to \$200 per ton of CO_2 in steps of \$1. At each CO_2 price, the CGE models quantify the induced emissions reduction by region. As in Böhringer et al. (2025), we have used these data to obtain reduced-form representations of regional MAC curves based on a least-square fit to polynomial functions of third degree (see section 3). Table 6 summarizes all the region-specific coefficients of the least-square approximation by CGE model. Table 5 reports the region-specific BaU emissions by model aligned to projections of the International Energy Outlook (EIA, 2017) on GDP growth and fossil fuel demands in 2030.

Note that the information on NDCs contained in Table 1, together with the coeffi-cients of marginal abatement cost curves (Table 6) and the BaU emissions in 2030 (Table 5), is sufficient to reproduce all of our simulation results.

Table 4: Regions in the dataset

Regions

Composite regions 3-letter code *consisting of*

Africa AFR Egypt, Morocco, Tunisia, Rest of North Africa, Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Ghana, Guinea, Nigeria, Senegal, Togo, Rest of Western Africa, Central Africa, South Central Africa, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe, Rest of Eastern Africa, Botswana, Namibia, South Africa, Rest of South African Customs Union

Australia and New Zealand ANZ Australia, New Zealand

Europe EUR Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Croatia, Cyprus, Latvia, Lithuania, Malta, Romania, Switzerland, Norway, Rest of EFTA, Albania, Belarus, Bulgaria, Ukraine, Rest of Eastern Europe, Rest of Europe

Middle East MEA Bahrain, Iran, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Rest of Western Asia, Israel, Turkey Other Americas OAM Mexico, Chile, Rest of North America, Argentina, Bolivia, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Rest of South America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Rest of Central America, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, Caribbean Other Asia OAS Rest of Southeast Asia, Rest of East Asia, Mongolia, Nepal,

Countries

Brazil BRA

Canada CAN

China CHN

India IND

Japan JPN

Russia RUS

South Korea KOR

United States USA Source: Böhringer et al. (2025).

Pakistan, Sri Lanka, Taiwan, Kazakhstan, Kyrgyzstan, Rest of Former Soviet Union, Armenia, Azerbaijan, Georgia, Rest of the World

Table 5: Regional Business-as-Usual (BaU) emissions by EMF36 models

BaU emissions in 2030 in Mt CO_2

	CEPE	DREAM TUB	ENVISAGE UOL	GEM-E3	ICES	PACE	SNOW	
AFR	1256.67	1264.47	1275.06	1264.39	1264.51	1305.57	1261.13 1260.28	949.32
ANZ	452.54	452.64	460.38	451.97	452.22	440.19	451.33 451.67	411.62
BRA	467.25	464.12	462.17	469.55	464.25	484.58	463.98 463.90	371.80
CAN	559.58	563.75	553.63	562.30	563.35	527.83	562.02 562.67	522.60
CHN	8062.37	8308.35	8532.27	8316.32	8318.13	8344.19	8296.04 8295.64	7083.08
EUR	3677.40	3756.51	3765.57	3714.42	3752.80	4035.59	3744.07 3744.46	4202.14
IND	3292.95	3300.52	3259.58	3301.96	3292.22	2832.30	3291.18 3291.42	1771.16
JPN	899.33	928.21	939.03	925.03	927.36	885.05	900.27 900.09	998.37
KOR	602.61	605.96	607.14	605.64	604.71	577.72	604.48 604.32	501.74
MEA	2185.64	2320.07	2402.06	2313.76	2312.54	1770.91	2182.46 2185.03	1709.23
OAM	1356.14	1342.76	1370.50	1363.68	1342.31	1292.30	1323.92 1325.00	1153.14
OAS	3221.46	3157.91	3166.18	3190.76	3152.70	3048.34	3139.00 3138.65	2119.20
RUS	1419.2	1427.44	1396.12	1430.26	1429.2	1317.0	1424.08	1499.6

	1				7	3	1425.14	7
USA	4562.3 2	4554.63	4716.87	4554.01	4554.2 5	4587.1 3	4553.09 4553.18	5107.3 7
Source: EMF36 (Böhringer et al., 2021). Column labels refer to modeling teams								
and row labels refer to model regions. For regional 3-letter codes see Table 4.								

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