A multi-level climate club with national and sub-national members: theory and application to US states

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A multi-level climate club with national and sub-national members: theory and application to US states

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Abstract

The minilateral approach of a climate club of countries has been suggested as an intermediate phase in a transition towards a global agreement that enforces national climate policies through harmonization. To garner critical mass, we propose an extended club configuration including sub-national states or provinces, resulting in a multi-level club. This would allow considerable contributions from important emitters like the US to be brought on board, relevant given its intended withdrawal from the Paris Agreement. We elaborate this idea and clarify potential roles of participants at distinct levels. The concept is operationalized by developing a method for identifying suitable entities at each level that uses a set of likelihood-of-involvement indicators capturing existing carbon dependence, public opinion, government policy and climate coalition membership. Application at the national level identifies a subset of seven of the highest emitting countries representing 21% of global emissions. This rises to 51% assuming that China, the dominant global emitter, could be enticed into the group. Given that US involvement remains unlikely for now, we illustrate selection at the sub-national level for US states. Here, an initial group of 21 states appear as potential members, jointly accounting for 36% of national emissions. An additional group, representing a further 34% of emissions, are potentially receptive to enticement via trade dependencies on four key countries identified within the group of national members. Accordingly, some 70% of US emissions, representing 11% of global totals, may be subject to climate club involvement via a combination of these pathways. While the implementation of such a club requires various political and legal hurdles to be overcome, the ongoing threat of climate change and inadequacies of the Paris Agreement suggest that novel solutions of this kind deserve serious attention from scientists and politicians.

1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) has now been widely accepted as the default facilitator of global negotiations on climate issues (Karlsson-Vinkhuyzen and McGee 2013). However, the multilateral approach it employs has been slow to address the ongoing threat of global warming, primarily owing to the logistical limitations of large groups and the voluntary nature of involvement (Nordhaus 2015). Indeed, the two most ambitious initiatives undertaken by the UNFCCC thus far—the defunct Kyoto Protocol and the current Paris Agreement—have both relied on voluntary actions, meaning that levels of commitment and compliance among member countries have not been uniform in nature. Accordingly, the incentive for self-interested parties to free-ride continues to be present.

Acknowledging the limitations of this approach, many are now suggesting the importance of alternative solutions. One of the more promising of these is the minilateral approach of a climate coalition or club of ambitious countries that implements a uniform policy, most likely some form of carbon pricing. This

so-called 'climate club' would offer exclusive trade benefits or club goods to members and seek to attract further membership by imposing penalties on imports from non-members to limit unfair competition from unregulated production sources. By creating moral and economic pressure on other countries, the club would likely expand over time. Once critical mass is achieved, it could grow to cover the bulk of global emissions and potentially influence post-Paris UNFCCC negotiations to focus on global policy coordination rather than mere targets (Eckersley 2012, Nordhaus 2015).

Attempting to affect environmental change in smaller groups outside of the UNFCCC framework has a number of key benefits. Firstly, it is thought that smaller groups enable negotiations to be undertaken more efficiently, which may result in faster and more streamlined responses (Biermann *et al* 2009, Weischer *et al* 2012). This is especially critical when mitigating a problem such as climate change, where time is a decisive factor. Secondly, smaller groups of like-minded participants are able to tackle 'narrow-but-deep' goals and achieve much more focused and ambitious outcomes than larger disparate groups (Aldy *et al* 2003). Additionally, the relatively simple and egalitarian nature of climate clubs that results from homogeneous market policies presents less barriers and encourages entry to a broader spectrum of stakeholders (Biermann *et al* 2009, Weitzman 2014). Lastly, countries which have consistently blocked ambitious proposals at UNFCCC Conference of the Parties meetings—particularly oil exporters such as Russia and Australia—will continue to do so, meaning that the current mechanisms of the UNFCCC are unlikely to lead to global policy harmonization (King and van den Bergh 2019). It is particularly telling in this respect that the Nationally Determined Contributions of the ten largest fossil fuel producers under the Paris Agreement lack any policy limiting fossil fuel supply, with the exception of India (Piggot *et al* 2017).

Notwithstanding such observations, another compelling aspect of climate club membership lies in the economic benefits it provides. Empirical modeling that tested four target carbon prices and 11 tariff rates for non-members for a range of club configurations found that net gains in welfare were achieved for the club under all regimes, even using lower carbon prices and tariff rates (Nordhaus 2015). Higher benefits were reaped as the prices and tariffs increased. And, while not all members benefitted under all combinations tested, individual net gains were achieved 88% of the time. Tellingly, many of the simple regimes tested resulted in all seven major emitters achieving simultaneous benefits. As such, climate clubs are not only capable of providing a feasible reduction in emissions but are thought to offer more immediate financial benefits to members under the majority of configurations.

2. Climate clubs beyond countries

Interest in minilateral solutions to climate change has increased in recent years and a great deal of discussion regarding the characteristics and potential benefits of climate club arrangements can be found in the literature (Leycegui and Ramírez 2015, Nordhaus 2015, Victor 2015, Falkner 2016, Gampfer 2016, Hovi *et al* 2016, Keohane *et al* 2017, Nordhaus 2017, Victor 2017, Sprinz *et al* 2018, Hagen and Eisenack 2019, Paroussos *et al* 2019). Nevertheless, discussions on the subject to date have tended to assume that membership would be limited to national actors. Yet, in countries with considerable spatial variation in terms of economic activities and climate policies, membership could also be offered to sub-national governments who wish to deviate from national actions by implementing their own, more ambitious climate policies. Indeed, a growing number of such government bodies are mobilizing to address climate change and implement stricter emissions targets within coalition groups, often as a direct reaction to weak policy or inaction at the national level.

As the effectiveness of a climate club is largely determined by the share of emissions and economic influence of its members, we contend that a multi-level club could target motivated potential members with high economic pull and emissions reduction capacities regardless of the strata of government they occupy. Furthermore, the participation of significant sub-national entities may ultimately also be capable of imposing critical pressure on national governments to consider club membership.

Nevertheless, as club members, sub-national governments are unlikely to be capable of imposing trade barriers on imports from non-members. For example, it is doubtful that individual states within the United States (US) could legally impose trade restrictions on other countries as members of a climate club. Theoretically, Article 1, section 10 of the US Constitution prevents states from imposing their own trade policies on other states or foreign countries unless permitted to do so by Congress. Such actions have proven difficult in the past and would seem very unlikely to be approved by the current legislative branch of the federal government, particularly for purposes that directly challenge the policies of the current administration.

However, sub-national members such as US states would still be able to implement the uniform climate policies of the club internally, be exempted from carbon border tariffs on trade with national club members, benefit from club goods such as R&D cooperation and, in the case of high-profile sub-national members, provide legitimacy to the club as a whole. This introduces a club design consisting of two types of members: (1) countries that can enjoy club goods and both employ and avoid penalties; and (2) sub-national governments that can enjoy club goods and

Table 1. Criteria used for assessing likelihood-of-involvement of 15 countries with the highest carbon emission rates.

Criteria	Description	Relevance	Source
Carbon independence	'Cleanliness' or lack of dependence on carbon-intensive industries in generating income. Defined as GDP earned per tonne of CO_2 emitted	Reflects ability to conform to club emission standards or integrate other carbon-related mechanisms into local economy. A lower value of this indicator increases the likelihood of considering club membership	World Bank (2017a, 2017b)
Public opinion regarding climate change	Composite of data from two public opinion polls relating to climate change issues	Reflects voter concern about climate change and support of mitigation strategies. Indicates likelihood of prioritizing climate change and considering club membership	Pugliese and Ray (2009) and Stokes *et al* (2015)
Government policy position	Quantified assessment of Nationally Determined Contribution (NDC) pledge under the Paris Agreement.	Reflects current government policy on climate change. Indicates likelihood of considering club membership	Climate Action Tracker (2017), Robiou du Pont and Meinshausen (2018)
Climate coalition membership	Involvement of governments in current climate-focused coalitions	Reflects current policy on climate change. Indicates likelihood of considering club membership	Individual coalition membership records

be enticed into clubs to avoid penalties imposed by existing members.

At the receiving end, the application of trade penalties within a multi-level climate club arrangement may indeed be complicated by the fact that sub-national members are positioned within the trade borders of a non-member country and are thus liable to pay the penalties that apply to the country as a whole. Administratively, it would seem complex for a climate club to only apply penalties to certain regions of a non-member country. A simpler solution could be to apply penalties to all sales from non-member countries and then return those penalties to sub-national members as part of a 'refund' scheme.

3. Assessing potential club members

In order to predict the 'likelihood-of-involvement' for governments at multiple levels, we developed a method that utilizes four complementary criteria: (1) carbon independence; (2) public opinion regarding climate change; (3) government policy position; and (4) climate coalition membership. The first criterion quantifies the lack of dependence on carbon-intensive industries by comparing the gross domestic product (GDP) or gross state product (GSP) earned per tonne of CO_2 emitted. The second criterion captures the level of localized voter support for action on climate change and, thus, the likelihood of governments implementing more stringent climate policies. The third criterion considers the current political leanings or policy positions of government bodies with respect to climate issues. The fourth and final criterion assesses the extent of local involvement in the growing number of climate-related coalition groups. While these criteria may correlate, they are largely complementary in scope and are believed to provide a good indication of a location's ambitions regarding climate policy and hence its potential willingness to be involved in an international climate club.

As a first step, the maximum score for each criterion was used to normalize individual scores on a scale from 0 to 1. Where more than one source exists for a given criterion, normalized scores were initially calculated for the individual sources and then averaged to generate an overall score for the criterion. The final likelihood-of-involvement scores were then derived by aggregating the normalized scores for all criteria. This was achieved by calculating a geometric mean as this method is believed to deliver a more meaningful outcome for indicators of this kind than using an arithmetic mean (Ebert and Welsch 2004). A higher final aggregated score is interpreted as indicating that a country or state is more motivated to undertake climate action and, therefore, more likely to consider membership in a climate club. A full description of the data, method and sensitivity analysis used is provided in the supplementary materials available online at stacks.iop.org/ERL/14/124049/mmedia.

4. Potential national members

Likelihood-of-involvement scores were first calculated for the 15 countries[4] with the highest carbon emission rates utilizing the data sources listed in table 1. The results, as shown in figure 1, suggest that two distinct groups of countries exist. A group of seven 'likely' club members—including the EU, Japan, South Korea, Canada, Brazil, Mexico and Australia–were deemed to be the most receptive to club membership. These countries represent approximately 20.5% of global

[4] The term 'countries' is used hereafter for all potential national members, including the European Union (EU).

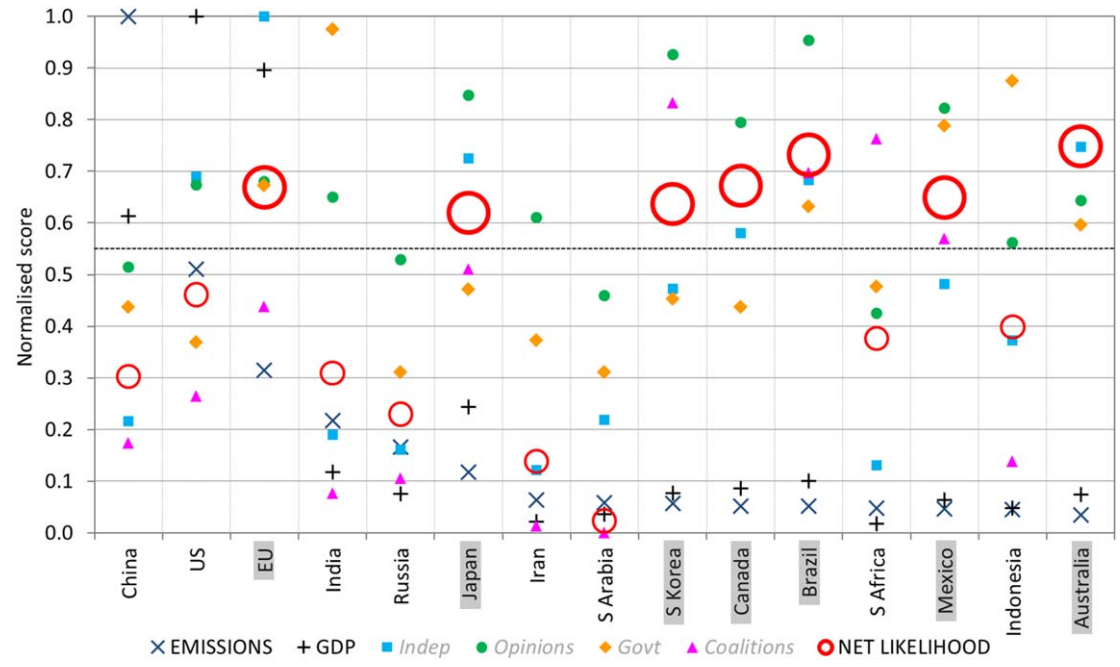

Figure 1. Normalized indicators and final 'net likelihood' scores for top 15 carbon emitting countries in order of current CO_2 emission levels (World Bank 2017a). Large red rings denote seven 'likely' countries and small-sized rings denote eight 'not likely' countries. A threshold line delineating the two categories is also shown.

carbon emissions. It is also noted that this group includes all Group of Seven (G7) members except the US.

A relative gap of some 25.5% then exists between Japan (0.606) and the US (0.451) as the seventh and eighth highest scoring countries, respectively. This represents a significant increase compared to the intervals observed within the 'likely' group, where changes were generally around 2%–3% and all were less than 9%. Accordingly, this acts as the delineation point between the 'likely' group and a second group of eight 'not likely' club members. This group consists of China, the US, India, Russia, Iran, Saudi Arabia, South Africa and Indonesia.

Because these results were derived by taking the geometric means of four normalized indicators, equal weighting was implicitly applied. As a sensitivity test, six alternative combinations using two weightings at 10% and another two at 40% were examined (see supplementary materials). Although slight variations occurred in their order, the countries within each group remained constant for all combinations suggesting a consistency and robustness in the delineation between the two groups.

As the third-highest emitter with the second-highest GDP, the EU is the most desirable potential club member within the group of more 'likely' countries in terms of potential emissions reduction and economic influence. Four EU countries—France, Germany, Italy and the United Kingdom—alongside Canada and Japan represent six of the seven members of the G7, a group considered by the International Monetary Fund to represent the world's seven largest 'advanced economies'. Moreover, the EU currently has active trade agreements with three other members of the 'likely' group—Japan, South Korea and Mexico—and only one member of the 'not likely' group (South Africa). This suggests that a substantial level of influence and existing affiliations exist within the identified 'likely' countries, with the EU as the member with the highest apparent level of potential influence.

The capacity of the EU to guide initiatives of this kind is not only demonstrated by empirical data. It also has a long history of leadership within the sphere of climate change mitigation activities (Parker and Karlsson 2010, Schmidt and Fleig 2018) and has traditionally shown greater commitment to UNFCCC programs than either China or the US (Keohane and Victor 2011, Sommer and Hain 2017). Following a period of reinvention in the UNFCCC following the 2009 Copenhagen Summit, the EU adopted the additional role of both leader and mediator by attempting to reconcile the growing concern of the developing world with the apparent reticence of the US and China (Bäckstrand and Elgström 2013). As such, it played a key role in the coordination of what was to become the Paris Agreement (Oberthür and Groen 2017).

5. Challenges at the national level

Notwithstanding the elevated likelihood of EU membership, the second 'not likely' group includes both the US and China—the two highest emitters with the highest and third-highest GDPs. Two such high-profile countries remaining outside such a club is likely

to greatly limit its chances of success. Indeed, previous modeling simulations found that climate clubs are far more likely to be successful with US involvement (Hovi *et al* 2019, Sprinz *et al* 2018).

It is nevertheless worth noting that previous modeling simulations also suggest that it would be relatively easy for others to entice China into a club (Hovi *et al* 2019) and that, alongside India, China has the most to gain from club membership (Paroussos *et al* 2019). This is predominantly the result of the high volume of emissions it produces, the high cost of energy transitions and its vulnerability to the ongoing impacts of global emissions. As the world's highest emitter of carbon—producing some 30.4% of global totals—China imposes a huge cost on its own future, and should be less sensitive to free-rider temptation than smaller players. What is more, it already appears to be implementing more sustainable domestic energy policies (Green and Stern 2017) and to be making greater efforts to raise its profile on the international climate stage. Furthermore, China and the EU have recently announced a joint commitment to intensify implementation of the Paris Agreement and strengthen their ties on climate change and clean energy issues (European Commission 2018). In light of this evidence, it is assumed that, in reality, China is more likely to consider club membership than our calculations suggest. This is especially true if the EU were to initiate such a club. As a result, 50.9% of global carbon emissions would be encompassed within this group of eight countries.

In any case, what remains clear is that, considering the Trump administration's ongoing intention to withdraw from the Paris Agreement in 2020, US membership in a climate club regime would appear unlikely for now. That leaves it as the 'odd one out' of the three key countries highlighted as preferred members of a potential climate club situation. Being the second-highest emitter with the highest GDP, the non-inclusion of the US would represent a major challenge for the feasibility of implementing a truly effective global climate club.

Although Trump's decision to step away from the Paris Agreement came as no surprise, the news was greeted with widespread condemnation in the US and abroad (Diringer 2017). Perhaps the most visible reaction to the announcement was the rapid mobilization of coalitions of companies and sub-national government bodies specifically denouncing the decision and vowing to uphold the spirit of the Paris Agreement and prioritize climate change mitigation efforts. Two of the most significant—the Under2 Coalition, a global alliance spearheaded by California governor Jerry Brown, and the Mayors National Climate Action Agenda ('Climate Mayors')—were organized in advance of the 2015 Paris conference but subsequently revitalized by Trump's statement (Alvarez 2017, Henderson 2017, State of California 2017). The most notable others—We Are Still In and the United States Climate Alliance—were formed as a direct reaction to Trump's election and expected withdrawal (Crooks 2017, Worland 2017).

Despite this apparent gridlock at the national level, the proliferation and consolidation of determined sub-national governments suggests that US involvement in international climate clubs could take the form of membership by motivated states as part of a multi-level configuration. Existing coalitions may even be capable of building upon their present relationships to negotiate with—or even aid in initiating—burgeoning clubs as a collective unit. Furthermore, as a notably decentralized country, where individual states are able to enact relatively high levels of political decision-making at the local level, the US is an ideal candidate for operationalizing the multi-level club notion.

As many states control significant economies with high emissions in their own right—some exceeding those of many of the top 20 countries in both of these dimensions—such an arrangement could offer a pathway for more enthusiastic governments to sidestep the current administration and achieve significant reductions in overall US emissions. This could be achieved via involvement of single states, or integration of regional coalitions of states, in pre-existing international clubs. Operational climate clubs may also prove capable of using the market-based mechanisms that drive them to entice otherwise reluctant US states towards a climate club arrangement, particularly where strong trade dependencies with member countries exist.

6. Potential US state members

In order to estimate the likelihood of individual US states to consider membership in an international climate club the previous method for assessing potential members was applied to US states utilizing the data sources listed in table 2. Recognizing the complexity of political mechanisms in the US, it is acknowledged that one cannot fully capture the myriad factors that determine the likelihood of state involvement in a climate club. Nevertheless, the chosen data is thought to provide a reasonable indication of the general public and governmental tendencies of each state.

The assessment ultimately assigns each state as being 'very likely', 'moderately likely' or 'not likely' to consider involvement in a climate club situation. While classifying groups is always somewhat arbitrary, three groups were defined based on the size of the relative gaps between scores.

Ultimately, 12 of the 50 states were selected as being 'very likely' to consider club membership. The relative gap between the lowest ranked state in this first group, New Jersey (12th, 0.838), and the next state, New Hampshire (13th, 0.803), corresponds to a change of 4.2%, the highest of the first 12 intervals

Table 2. Criteria used for assessing likelihood-of-involvement of US states.

Criteria	Description	Relevance	Source
Carbon independence	'Cleanliness' or lack of dependence on carbon-intensive industries in generating income. Defined as GSP earned per tonne of CO_2 emitted	Reflects ability to conform to club emission standards or integrate other carbon-related mechanisms into local economy. A lower value increases the likelihood of considering club membership	Bureau of Economic Analysis (2017) and US Energy Information Administration (2018)
Public opinion regarding climate change	Public opinion poll data relating to climate change issues	Reflects voter concern about climate change and support of mitigation strategies. Indicates likelihood of prioritizing climate change and considering club membership	Howe *et al* (2015)
Government policy position	Composite indication of political position (Republican or otherwise) based on presidential voting and composition of legislative branches at federal and state level	Reflects current government composition considering the increasingly partisan division on climate issues in US politics. States with lower Republican Party influence are broadly assumed to be more likely of consider club membership	Federal Election Commission (2016), United States Senate (2019), United States House of Representatives (2019), Ballotpedia (2019a, 2019b)
Climate coalition membership	Involvement of governments in current climate-focused coalitions	Reflects motivation to undertake action on climate change. Indicates likelihood of considering club membership	Individual coalition membership records

(most others are less than 2%). Observation of the data for these states also reveals a notable consistency in high scoring across most or all categories when compared to the states that follow. The resulting group of 'very likely' states collectively cover a total of 17.8% of the total emissions and 36.6% of GDP.

New York and California are the key candidates for climate club membership in this group; their likelihood scores occupy the second and fourth rankings, while they control the third-largest and largest state economies, respectively, jointly accounting for 22.1% of total GDP. In fact, as countries, California and New York would represent the fifth and eighth largest economies in the world. What is more, California is the second-highest emitting state while New York sits at number nine.

Almost all gaps between scores for the remaining 38 states are less than 2%. The only notable exceptions are the 5.6% interval between Virginia (14th, 0.786) and Maine (15th, 0.742), the 4.6% interval between Florida (21st, 0.699) and New Mexico (22nd, 0.667) and the 5.2% interval between Arizona (27th, 0.641) and Ohio (28th, 0.608). As the gap between Virginia and Maine occurs only two positions after the previous group this interval is not deemed suitable. Meanwhile, the individual characteristics of states as far down the list as Arizona indicate diminishing tendencies towards climate action and these could not realistically be considered 'likely' states. Accordingly, the interval between Florida and New Mexico is thought to provide the most suitable delineation between the 'moderately likely' and 'not likely' groups based on the size and location of the observed gaps and trends observed in the data for the individual states within this range.

So, while the nine states within the final 'moderately likely' group display less noteworthy results than the former ('very likely') group, they do nevertheless offer some suggestion of a willingness to consider membership in initiatives such as climate clubs when compared to the 29 remaining states. This group of 'moderately likely' states collectively account for 18.2% of emissions and 19.8% of GDP. Considering their emissions and GSP, the two most significant states in this list are Illinois and Florida, among states the fourth and sixth highest emitters with the fifth and fourth largest economies, respectively.

The final results for each state, in order of CO_2 emissions, are shown in figure 2. All 'very likely' and 'moderately likely' states are further summarized in table 3 while a complete listing of the indicator data is provided in the supplementary materials.

As a sensitivity test, six alternative combinations using two weightings at 10% and another two at 40% were again examined (see supplementary materials). While slight variations occurred in the order, the states contained within each group remained largely constant with a small number of exceptions. The top 12 'very likely' group members remained within the group for all combinations tested with the exception of Delaware and New Jersey which transferred out of the

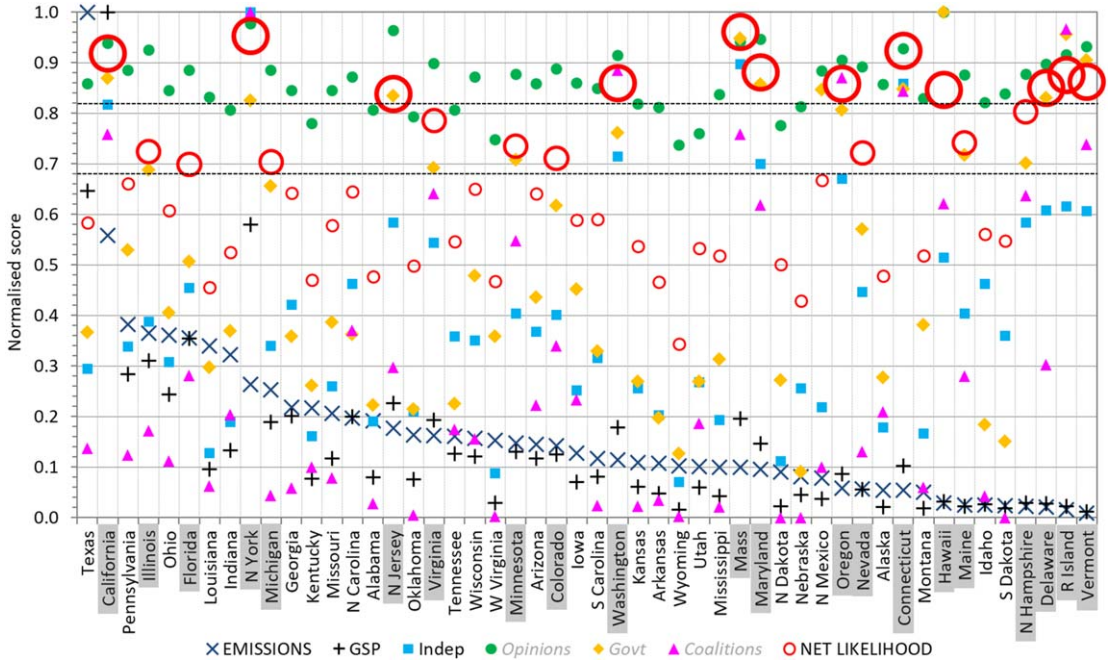

Figure 2. Normalized indicators and final 'net likelihood' scores for US states in order of current CO_2 emission levels (US Energy Information Administration 2018). Large red rings denote 12 'very likely' states, medium-sized rings denote nine 'moderately likely' states and small rings denote 29 'not likely' states. Threshold lines delineating the three categories are also shown. The names of all states identified as 'very likely' and 'moderately likely' are highlighted in gray.

Table 3. Indicator scores for 12 'very likely' states and nine 'moderately likely' states, ranked in final order of likelihood.

State	% of total US CO_2 emissions	% of total US GDP	Likelihood-of-involvement		
			Score	Ranking	Rating
Mass	1.2	2.7	0.961	1	Very likely
N York	3.1	8.1	0.953	2	
Connecticut	0.6	1.4	0.924	3	
California	6.6	14.0	0.919	4	
Maryland	1.1	2.1	0.882	5	
R Island	0.2	0.3	0.876	6	
Vermont	0.1	0.2	0.862	7	
Washington	1.4	2.5	0.859	8	
Oregon	0.7	1.2	0.858	9	
Delaware	0.2	0.4	0.850	10	
Hawaii	0.3	0.5	0.847	11	
N Jersey	2.1	3.2	0.838	12	
N Hampshire	0.3	0.4	0.803	13	Moderately likely
Virginia	1.9	2.7	0.786	14	
Maine	0.3	0.3	0.742	15	
Minnesota	1.8	1.8	0.735	16	
Illinois	4.3	4.3	0.725	17	
Nevada	0.7	0.8	0.721	18	
Colorado	1.7	1.8	0.711	19	
Michigan	3.0	2.6	0.704	20	
Florida	4.2	5.0	0.699	21	

top group during four scenarios. Both states possess high public opinion and government scores and moderate carbon dependence but are sensitive to variations in coalition membership weighting as a result of their low scores in this category.

Similar observations pertain to Michigan, Nevada and Illinois within the 'moderately likely' group. All three states have exceptionally low membership in coalitions despite scoring well in public opinion and government categories. As a result, they fell out of the group during six, three and one of the sensitivity scenarios, respectively. However, as the groupings were generally shown to be resilient to these changes, and the observed substitutions all related to the coalition

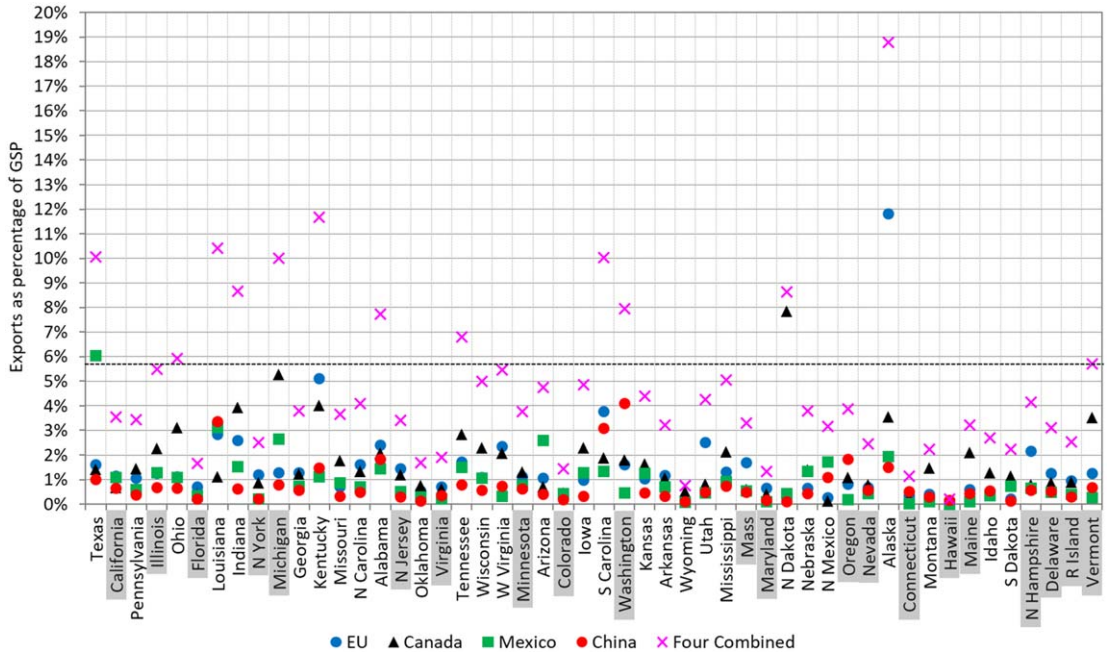

Figure 3. US state exports sold to four key countries and combined sum of all four as percentage of gross state product (GSP). Threshold line representing the 75th percentile of combined scores is also shown. States previously identified as 'very likely' and 'moderately likely' climate club members are highlighted in gray.

criterion, we can conclude that the results are consistent and robust overall.

To summarize, a total of 21 states were found to display tendencies that mark them as more likely candidates for considering club membership, representing a total of 36.0% of national emissions and 56.3% of GDP. The remaining 29 states were deemed to be 'not likely' in the analysis. Significantly, ten of the highest 15 emitters are in this group, including Texas as the highest overall emitter with the second-highest GSP. As we demonstrate in the following section, a functional climate club could entice some of these states into membership via a trade-related mechanism.

7. State-country trade as a push force for additional state membership

The ability of operational multi-level climate clubs to entice new members can be further understood by examining existing international trade links with US states. The previous analysis attempted to identify states with higher likelihoods of considering climate club membership solely based on their individual characteristics. However, once a club is in operation, member nations may be capable of enticing even the less 'likely' US states via the power of existing trade dependencies. States with particularly high dependencies on club member countries may consider membership simply in order to maintain beneficial trade relationships and avoid the imposition of trade penalties on non-members.

Examining international exports from individual US states (United States Census Bureau 2018) identified the top four US trading partners as the EU, Canada, Mexico and China. Since the previous analysis of potential members at the national level found the involvement of three of these to be likely, and provided additional reasons for China to be included, the four key US trading partners could potentially exert pressure on certain US states to join the climate club. With this in mind, figure 3 reports data on state exports to each of these countries and their sum ('Four Combined') as a percentage of the GSP for that state (see supplementary materials for full listing). Previously identified 'likely' states are highlighted in gray.

Considering all 50 states, the third quartile (75th percentile) of these scores is some 5.7% of GSP. The results indicate that exports from several states—many of which are among the highest emitters—are well above this level. What's more, a total of 10 previously 'not likely' states—accounting for 33.9% of national emissions and 21.4% of GDP—are among those with trade dependencies on the EU, Canada, Mexico and China that are well above the national average. This includes five of the seven highest emitting 'not likely' states, all of whom are within the country's top 12 highest emitting states overall.

The most notable state in this list is Texas—the top carbon emitter with the second-highest GSP—which sells 61.4% of its total exports to these four countries and 37.0% to Mexico alone. These exports account for some 10.6% of the state's total GSP, making it the fourth highest of all 50 states in this category. Indeed, Texas was highlighted as being particularly vulnerable to revenue losses when Donald Trump threatened to withdraw from the North American Free Trade Agreement in 2018 for this very reason (Roberts 2018).

Other notable states in the list include Louisiana and Kentucky—the seventh and twelfth highest carbon emitting states—which have the third and second-highest proportion of exports to GSP, respectively.

On the strength of such results, it seems plausible that the EU, Canada, Mexico and China could be capable of using the power of these trade dependencies to entice additional high-profile US states into considering membership in club arrangements. This is especially likely if all four are able to apply club mechanisms in unison.

8. Discussion and conclusions

The climate club is emerging as a promising alternative for mitigating global climate change. Recognizing the urgency of addressing climate change and the shortcomings of the all-inclusive UNFCCC approach, a climate club prioritizes deeper reductions in carbon emissions by smaller groups of more motivated governments. However, the chances of such a club succeeding would appear to be greatly improved by US involvement, an unlikely scenario for the time being. Acknowledging the potential of sub-national government involvement in minilateral actions of this kind, it was demonstrated that climate club arrangements that include US states may be able to maximize US participation in lieu of involvement at the national level.

Based on various motivation-level indicators, 12 of the 50 US states were found to be 'very likely' to consider club membership while a further nine states were deemed to be 'moderately likely' to do so. In total, these states account for 36.0% of national emissions and 56.3% of GDP. Even so, 29 states were found to be 'not likely' to join a climate club based on these indicators. Tellingly, ten of the 15 highest emitting states are in this group, including Texas as the highest overall emitter with the second-highest GSP.

Further investigation revealed that even less motivated US states could potentially still be enticed into an operational climate club via strong export dependencies, particularly with the four key US trading partners—the EU, Canada, Mexico and China. In fact, five of the seven highest emitting 'not likely' states, and 10 'not likely' states in total, were found to be among the highest quarter of states when considering their individual export dependencies in relation to total GSP. Collectively, these states represent some 33.9% of emissions and 21.4% of GDP, suggesting that a club including the four key US trading partners may be capable of augmenting club membership significantly via trade influences. This is consistent with one important role of a climate club recognized in the literature, namely to put pressure on exports of non-members so as to encourage them to become club members. In all, the analysis suggests that states representing a total of 69.9% of national emissions, 10.8% of global emissions and 77.7% of total US GDP may be amenable to club membership.

The method devised for assessing likely members within the study provides a broad first analysis of the architectures that could evolve should climate clubs become a reality and offers an example of trade-related mechanisms that could influence further club growth. Nevertheless, we fully recognize the legal and political hurdles that climate clubs could face, including those employing a multi-level structure. Such hurdles have already received much attention in the literature, and still merit further research, particularly in the context of the ongoing discussion regarding environmental policy and protection measures permitted by the World Trade Organization (Cottier *et al* 2009). Here we merely intended to offer a new angle on the composition of climate clubs and the selection of potential members at multiple levels.

While it is easy to judge proposals for genuinely solving climate change as politically difficult, considering the limitations of the Paris Agreement and the urgency of implementing effective climate action sooner rather than later, the time is ripe for debating daring solutions. More ambitious policies within a small coalition of powerful and motivated countries and sub-national governments already promise significant emissions reduction in the short run. More importantly, through moral and economic pressure exerted on non-members, such a climate club could expand over time and thus significantly contribute to a transition towards a global policy level playing field. This would allow for harmonized and gradually more stringent climate policies worldwide.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available for legal and/or ethical reasons.

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