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Preprint

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Suggested Citation: Best, Frank; Tang, Anita (2024) : Assessing the Effectiveness of EU Countries in Implementing the Paris Agreement, ZBW - Leibniz Information Centre for Economics, Kiel, Hamburg

This Version is available at:
https://hdl.handle.net/10419/302321

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Assessing the Effectiveness of EU Countries in Implementing the Paris Agreement

Frank Best* & Anita Tang

Abstract

Climate change, a transnational issue, necessitates international collaboration for effective mitigation. Despite the progress achieved by the Paris Agreement of 2015, a significant milestone in global cooperation, its implementation remains a challenge for both the international community and individual countries. Because of the agreement's optional nature, there are significant differences in terms of the ambition and achievement levels among signatories. The European Union (EU) stands out because of its unique structure and common policies, yet there is a lack of empirical research into their impact on climate policy effectiveness. This paper aims to fill this gap by comparing the effectiveness of the implementation between EU and non-EU countries in terms of policy output, achieving climate targets and an economically sustainable transition. Quantitative regression models show no significant differences concerning policy output and the achievement of climate targets, while they demonstrate greater ambition and success in economically sustainable transition. Our findings contribute to a better understanding of effective climate policies, highlight the positive impact of EU leadership in this regard, and stress the importance of international cooperation.

Introduction

Human-induced greenhouse gas emissions (GHG), driven primarily by fossil fuel consumption, industrial agriculture, and deforestation, are elevating global temperature, resulting in serious environmental, social and economic repercussions[1,2]. These changes threaten millions of lives globally through heightened mortality rates, loss of biodiversity, and exacerbation of natural disasters which are likely to induce food and water shortages, forced migrations, and conflicts, particularly impacting poorer nations[3,4,5]. The state of the research highlights the severe impacts that can be expected with a temperature increase beyond 2°C, necessitating urgent global action to mitigate these effects[2,6].

The Paris Agreement is a critical step in coordinating global climate action with the goal of "holding the increase in the global average temperature to well below 2°C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels"[7,8]. The agreement encourages countries to mitigate the causes and adapt to the effects of climate change through Nationally Determined Contributions (NDC)[9]. 168 NDCs have been submitted to the UNFCCC Secretariat by the end of 2023, representing all 195 parties[10]. As of today, there is a significant gap between the commitments and the real-life mitigation efforts[11,12]. In addition, the effectiveness of the NDCs varies greatly[13,14]. Climate policy effectiveness is defined as the extent or degree to which policies, measures and actions address climate change and the extent to which their objectives and measures are achieved[8,9]. Effective climate policy reduces GHG emissions and enhances resilience to climate impacts through international cooperation, financial investments, and enforcement mechanisms that promote compliance and innovation[15,16].

While the Paris Agreement proposes a general transformation pathway, the drafting and implementation of NDCs depends on the individual countries[8]. Previous studies on the effectiveness of climate policy in regard to implementing the Paris Agreement's goals have shown that a high level of political ambition leads to effective implementation[14,17,18]. Achieving the 1.5°C / 2°C targets is hindered by both gaps in ambition and implementation among

countries[13,14]. The ambition gap refers to the shortfall between current commitments and the reductions needed to mitigate climate change effectively[19]. Closing this gap requires stronger national commitments and increased global cooperation[20–23]. The implementation gap, more complex to address, involves aligning actual policy measures with committed targets, which demands significant political, economic, and social shifts within countries[14,21]. In order to close the implementation gap, national political institutions and the accompanying resources, such as political and administrative resources, are a key driver in reducing the implementation gap[13,14].

Among industrialized countries, the EU climate policy approach stands out with its unique political and economic integration, which facilitates coordinated climate action among its members[24]. The EU's climate strategy, bolstered by the European Green Deal, sets ambitious targets for reducing emissions and enhancing renewable energy use, aiming for carbon neutrality by 2050[25]. This comprehensive approach integrates economic, environmental, and social policies to achieve long-term sustainability goals.

The effects of EU policies on climate policy effectiveness and decoupling economic growth from emissions have been scrutinized in the research literature, e.g. with regards to environmental policy[26–29], energy policy[30–32], economic policy[33,34], or in the form of overviews of different policies[35,36]. A vast literature overview of the effectiveness of global policies has been collected by Hoppe et al. (2023)[37]; a comparison of the effectiveness of ~1500 climate policy measures implemented over the past 2 decades across 41 countries from six continents has been published by Stechemesser et al. (2024)[38].

However, to the best of our knowledge, no empirical contributions deal with the effects of the EU's special political structure on climate policy effectiveness. The goal of this study is to compare the effectiveness of implementing the Paris Agreement across EU and non-EU countries to explain variation in climate action and to increase our understanding of effective climate policies.

This paper investigates whether the unique characteristics of the EU benefit its climate policy effectiveness compared to non-EU countries in terms of:

- Policy output
- Achieving climate targets, and
- Economically sustainable transition.

Results

We tested the strength of the influencing factors listed above using a multivariate regression. Our analysis covers the whole population of each of the countries that ratified the Paris Agreement, excluding the UK. The summary statistics in *Table 1* displays substantial variation in the analyzed population, with the variable GDP per capita highlighting the existing imbalance in economic means worldwide.

The independent variable - EU membership - is clearly defined for all 194 countries as a binary variable with a mean of 0.139, where the standard deviation obviously indicates fewer EU countries than non-EU countries.

The composition of the dependent variables shows significant variation, where the mean of the adopted climate-related policies is almost nine, with a maximum of policies at 69. The range

of relative change in GHG is also remarkable, from Iceland pledging 70% reduction per capita emissions by 2030 to Nicaragua's 229% increase. The relative changes in GHG emissions per capita and per GDP draw a mostly similar picture showing a slight decrease on average but with high variability. Again, the range of observed values and the standard deviation is remarkably high.

Taking the included set of control variables into account, it is notable that the fewest observations exist for the Climate Risk Index, missing for 15 countries.

Table 1: Summary Statistics World Sample

Statistic	**N**	**Mean**	**St. Dev.**	**Min**	**Max**
EU Membership	194	0.139	0.347	0	1
Climate-Related Policies	182	8.901	10.379	1	69
NDC Pledges	194	11.696	48.370	-70	229
GHG/Capita Change	181	-1.120	14.271	-51.446	43.839
GHG/GDP Change	180	-6.766	19.395	-58.132	108.025
Population	194	38.019	142.429	0.011	1,379.860
GDP/Capita	183	21.325	22.324	0.708	115.542
Climate Risk Index	178	81.684	35.511	5.500	125.000
GHG/Capita Base	181	7.427	9.766	0.602	75.601
GHG/GDP Base	180	0.521	0.463	0.089	3.827

Table 1. Summary statistics for all 194 countries in the sample.

Due to the very heterogeneous structure of the overall population, we decided to create a subset that serves better comparability. This subset includes only countries that are members of the EU, the G20 or the OECD (EGO).

Table 2: Summary Statistics EGO

Statistic	N	Mean	St. Dev.	Min	Max
EU Membership	48	0.729	0.449	0	1
Climate-Related Policies	48	16.938	15.260	2	69
NDC Pledges	48	-24.917	26.425	-70	81
GHG/Capita Change	48	-5.286	11.911	-41.592	21.277
GHG/GDP Change	48	-17.892	10.617	-53.914	4.163
Population	48	97.715	272.752	0.331	1,379.860
GDP/Capita	48	43.246	20.963	7.096	115.542
Climate Risk Index	48	65.955	29.425	5.500	125.000
GHG/Capita Base	48	10.548	5.262	2.590	24.940
GHG/GDP Base	48	0.316	0.153	0.089	0.775

Table 2. Summary of the vital statistical indicators of this sample composition across all variables. Most notably, the number of observations remains constant at 48 for all variables. This indicates that recorded observations on all variables exist for each of the 48 countries in the sample.

Compared to the sample covering the whole population, this subset has a higher mean for the independent variable, which indicates that the sample consists of a majority of EU countries. EGO countries have a significantly higher mean of adopted climate-related policies.

This is in line with the characteristics of the observed values for the other dependent variables. There is a clear indication of higher average reduction in GHG emissions according to their NDC pledges as well as the recorded GHG emissions per capita and per GDP. However, the mean base value of GHG per capita is higher than in *Table 1*.

The emission intensity per GDP for the EGO countries is lower on average, which confirms the ongoing decoupling of GDP from GHG emissions in industrialized countries[39–41]. Overall, the subset is more balanced, with a narrower range of observed values for most explanatory variables except the Climate Risk Index.

Model 1: Policy output. In our first empirical model, we estimate the effect of EU membership on the number of adopted climate-related policies since the Paris Climate Conference 2015. The results, presented in *Table 3* below, indicate the estimates for the effect of the GHG per capita base value in 2015 counterintuitively suggest that countries with higher GHG emissions per capita adopted less climate-related policies. The first two baseline models (1.1 and 1.2) include only the dependent and independent variables. Model 1.1 is the baseline model for the sample covering all ratifying countries, and Model 1.2 is the baseline model for the reduced EGO sample. In Model 1.3, the set of control variables is included for the world sample, and in Model 1.4, respectively, for the reduced sample.

Table 3: Estimated Regression Results Model 1

	Dependent variable:			
	Number of adopted climate-related Policies 2015-2023			
Model No.	**(1.1)**	**(1.2)**	**(1.3)**	**(1.4)**
EU Membership	7.466***	-3.836	1.314	-2.712
	(2.098)	(4.452)	(2.422)	(4.786)
Population			0.018***	0.008
			(0.005)	(0.009)
GDP/Capita Base			0.178***	0.174
			(0.050)	(0.119)
Climate Risk Index			-0.096***	-0.238***
			(0.022)	(0.072)
GHG/Capita Base			-0.201*	-0.238
			(0.107)	(0.472)
Constant	7.794***	19.095***	13.684***	28.337***
	(0.808)	(3.339)	(2.094)	(8.387)
Sample	**World**	**EGO**	**World**	**EGO**
Observations	182	48	159	48
R^2	0.066	0.016	0.309	0.280
Adjusted R^2	0.061	-0.006	0.286	0.194
Residual Std. Error	10.059	15.302	9.172	13.699
	(df = 180)	(df = 46)	(df = 153)	(df = 42)
F Statistic	12.665***	0.742	13.685***	3.264**
	(df = 1; 180)	(df = 1; 46)	(df = 5; 153)	(df = 5; 42)

Note: *p<0.1; **p<0.05; ***p<0.01

The Models 1.3 and 1.4 indicate the goodness-of-fit attribute for both samples to explain the observed variance in adopting climate policies, which can be seen by a higher R^2 value.

Looking at the independent variable, EU membership, in the baseline Model 1.1 the estimated regression coefficient is positively significant at the 99 percent level but becomes insignificant at the 90 percent level in the more comprehensive Model 1.3, which indicates limited explanatory power.

The estimated coefficient for the reduced sample, Models 1.2 and 1.4, suggest that EU members adopt less climate-related policies, but the high standard error and weak model fit undermine these findings. This also explains the diverging estimated effect directions and sizes between the two samples.

The control variables in Models 1.3 and 1.4 indicate similar tendencies, but the estimates are mostly insignificant at the 90 percent level in Model 1.4 due to a small sample size that hampers statistical significance.

Notably, the Climate Risk Index is highly significant and negative for both models, suggesting that countries more vulnerable to climate change adopt more climate-related policies.

Model 2: Achieving climate targets. While Model 1 considered only the quantitative dimension of policy output, Model 2 evaluates the qualitative impact of EU membership on the relative change in GHG per capita emissions from 2015-2030, based on current NDC pledges for each country. The estimated regression results are displayed in *Table 5*.

Once again, Models 2.1 and 2.2 serve as the baseline models for each sample, while Model 2.3 (for the global sample) and 2.4 (for the EGO sample) consider the influences of potential confounding variables. The model statistics, especially the R^2 Value, attribute a better fit to those models that include the set of control variables. Even though the F Statistic for Model 2.1 is higher in comparison to Model 2.3, the number of observations is also higher, with 193 compared to 165. The difference stems from missing values for some control variables.

Table 4: Estimated Regression Results Model 2

	Dependent variable:			
	Relative Change in GHG/Capita according to NDC pledges 2015-2030			
Model No.	**(2.1)**	**(2.2)**	**(2.3)**	**(2.4)**
EU Membership	-48.265***	-11.280	-27.074**	-7.289
	(9.437)	(7.592)	(10.816)	(7.513)
Population			0.012	0.025*
			(0.022)	(0.013)
GDP/Capita Base			-0.550**	-0.325*
			(0.225)	(0.187)
Climate Risk Index			0.210**	0.016
			(0.095)	(0.113)
GHG/Capita Base			-0.373	-1.543**
			(0.479)	(0.741)
Constant	18.413***	-18.571***	12.259	5.971
	(3.521)	(5.694)	(9.203)	(13.165)
Sample	**World**	**EGO**	**World**	**EGO**
Observations	194	48	165	48
R2	0.120	0.046	0.247	0.408
Adjusted R2	0.115	0.025	0.223	0.338
Residual Std. Error	45.496 (df = 191)	26.092 (df = 46)	40.984 (df = 159)	21.504 (df = 42)
F Statistic	26.158*** (df = 1; 191)	2.208 (df = 1; 46)	10.430*** (df = 5; 159)	5.795*** (df = 5; 42)
Note:				*p<0.1; **p<0.05; ***p<0.01

Regarding the explanatory variable of interest, EU membership, the estimated coefficient is strongly negative in all four models. This suggests that the NDC pledges of EU countries are more ambitious regarding the targeted reduction of GHG emissions. Nevertheless, the estimated effect is statistically significant at the 99 percent and 95 percent levels for the world sample Models 2.1 and 2.3, but not for the models using the reduced sample, due to the high standard error of the estimated regression coefficients. This further restricts empirically profound conclusions.

Among the coefficients for the control variables in Model 2.3, the Climate Risk Index is positive and significant at the 95 percent level. The NDC pledges suggest that countries facing higher climate change risks have stronger ambitions to reduce their GHG per capita emissions, although this effect is not significant in Model 2.4 (0.016). Besides, the coefficient for the GDP per capita base value in 2015 is negative and significant throughout Models 2.3 and 2.4. This shows that, on average, countries with a better economic performance have more ambitious GHG reduction targets according to their NDC pledges (Quelle). For Model 2.4, the GHG per capita value in 2015 is also negatively correlated to the forecasted relative change in GHG emissions per capita. The statistically significant coefficient thus suggests that economies with a higher emission intensity in 2015 have more ambitious NDC pledges in terms of reducing emissions.

Models 3 & 4: Economically sustainable transition. In contrast to Models 1 and 2, Models 3 and 4 consider actual achievements made since the Paris Agreement. Model 3 estimates the effect of EU membership on the relative change in per capita GHG emissions between 2015 and 2022, which are shown in *Table 5*. Just as with the previous models, Models 3.1 and 3.2 form the baseline models, while Models 3.3 and 3.4 include a set of control variables.

Table 5: Estimated Regression Results Model 3

	Dependent variable:			
	Relative Change in GHG Emissions per Capita 2015-2022			
Model No.	**(3.1)**	**(3.2)**	**(3.3)**	**(3.4)**
EU Membership	-7.625**	-5.306	-6.455*	-5.110
	(2.931)	(3.415)	(3.430)	(3.571)
Population			0.009	0.007
			(0.007)	(0.006)
GDP/Capita Base			-0.030	-0.120
			(0.071)	(0.089)
Climate Risk Index			0.015	0.049
			(0.030)	(0.054)
GHG/Capita Base			-0.221	-0.771**
			(0.152)	(0.352)
Constant	0.018	-2.301	1.151	6.994
	(1.132)	(2.561)	(2.918)	(6.257)
Sample	**World**	**EGO**	**World**	**EGO**
Observations	181	48	165	48
R^2	0.036	0.050	0.096	0.342
Adjusted R^2	0.031	0.029	0.068	0.264
Residual Std. Error	14.048 (df = 179)	11.736 (df = 46)	12.997 (df = 159)	10.220 (df = 42)
F Statistic	6.768** (df = 1; 179)	2.415 (df = 1; 46)	3.379*** (df = 5; 159)	4.368*** (df = 5; 42)

Note: *p<0.1; **p<0.05; ***p<0.01

It is striking that the model statistics here paint a clear picture regarding the model fit and the explanatory power of the models. Except for the last model, 3.4, all models are rather unsuitable for explaining the variance in the relative change of per capita GHG emissions. The model fit is generally weak, with low explanatory power in Models 3.1, 3.2, and 3.3.

In contrast, Model 3.4 shows a better fit and explanatory power (R^2 of 0.342), indicating that EU members have been more successful in reducing per capita GHG emissions. However, the standard error of the estimated coefficient is so high that the result is statistically insignificant at the 90 percent level for the limited sample size.

The only significant coefficient in Model 3.4 is the base value of GHG per capita emissions in 2015, suggesting that the countries in the EGO sample, which previously had higher per capita emissions, have reduced their emissions more strongly.

The relative change in GHG emissions per GDP as a measure of emission intensity is the dependent variable in Model 4. Once again, Models 4.1 and 4.2 constitute the baseline models, while Models 4.3 and 4.4 include control variables (see *Table 6*).

Regarding the overall model statistics, Model 4 provides a better fit for the observed values than Model 3. This is particularly true for 4.4, which explains about half the variation in the dependent variable. The relatively high explanatory power of the baseline Model 4.2 indicates the strong relationship between EU membership and the relative change in GHG emissions per GDP following the Paris Agreement (R^2 of 0.285 and an adjusted R^2 of 0.269).

Analyzing the estimated effects of the explanatory variables, it is striking that EU membership shows a significant negative effect at the 99 percent level throughout all four models. This suggests that EU members are better at decreasing the emission intensity of their economies.

Table 6: Estimated Regression Results Model 4

	Dependent variable:			
	Relative Change in GHG Emissions per GDP 2015-2022			
Model No.	**(4.1)**	**(4.2)**	**(4.3)**	**(4.4)**
EU Membership	-18.903***	-11.298***	-11.567***	-12.576***
	(3.805)	(2.641)	(3.806)	(2.758)
Population			-0.011	-0.012**
			(0.008)	(0.005)
GDP/Capita Base			-0.218***	-0.159**
			(0.079)	(0.069)
Climate Risk Index			0.010	-0.056
			(0.033)	(0.042)
GHG/Capita Base			0.356**	-0.468*
			(0.168)	(0.272)
Constant	-3.931***	-11.536***	-4.644	5.903
	(1.474)	(1.981)	(3.238)	(4.833)
Sample	**World**	**EGO**	**World**	**EGO**
Observations	180	48	165	48
R^2	0.122	0.285	0.210	0.506
Adjusted R^2	0.117	0.269	0.185	0.447
Residual Std. Error	18.227 (df = 178)	9.078 (df = 46)	14.421 (df = 159)	7.895 (df = 42)
F Statistic	24.686*** (df = 1; 178)	18.298*** (df = 1; 46)	8.465*** (df = 5; 159)	8.600*** (df = 5; 42)

Note: *p<0.1; **p<0.05; ***p<0.01

The control variables in Models 4.3 and 4.4 show that the base value for GDP per capita in 2015 is estimated to be significantly negatively related to the change in GHG emissions per capita. Thus, higher GDP per capita in 2015 correlates with reduced carbon intensity.

For the GHG per capita base value, the estimated relationship for Model 4.3 is positively significant at the 95 percent level, whereas the regression coefficient in Model 4.4 is negative at the 90 percent level. Consequently, the model suggests that on average a higher previous emission rate is related to an increase in the emission intensity in the past years, whereas for the countries that are members of EGO higher GHG emissions are related to a decrease in emission intensity.

Discussion

Our first hypothesis claims that EU countries are more effective in implementing the Paris Agreement in terms of policy output, from both a qualitative and quantitative perspective.

Figure 1 below shows the number of climate-related policies adopted by each country from December 2015, when the Paris Agreement was drafted, to 2023.

Figure 1: Adopted Climate-Related Policies 2015-2023

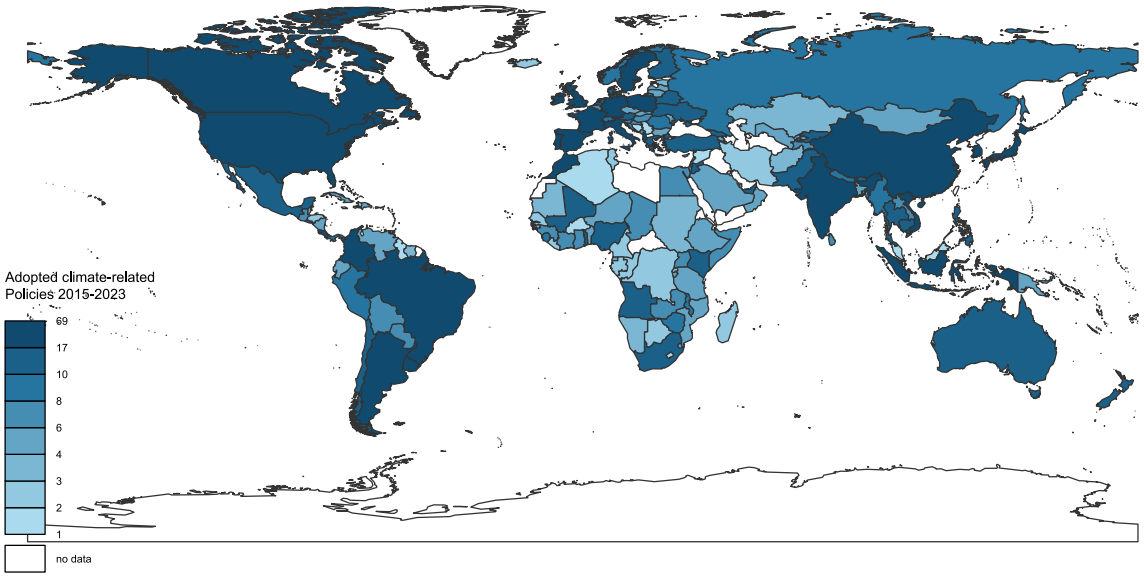

Figure 1. Number of climate-related policies adopted by each country since the Paris Agreement, covering the period when the Agreement was drafted in December 2015 to 2023. Data: CPR

This figure indicates that EU countries are among the countries that adopted the most climate-related policies. France has the highest number of adopted policies. Other EU countries also produced a double-digit number of climate related policies, with some exceptions like the Czech Republic or Estonia. The regression analysis of the baseline model indicates that, while EU membership appeared positively related to the number of adopted policies, the significance diminishes when controlling for possible confounding factors such as GDP per capita. The findings of our first model show that quantitative policy output seems to be affected more by economic development and factors such as vulnerability to climate change than by EU membership status. While this provides some support to our argument regarding supranational capacity and public awareness, it also shows that those characteristics are not necessarily unique EU phenomena but, in general, create a divide in policy output between developing and developed countries.

Other dimensions of policy output which are analyzed in our second regression model are NDC pledges and their forecasted effect on GHG per capita emissions (*Figure 2*). Most EU countries are among the group with the most ambitious NDC pledges; however, other countries like Australia, the US or Angola also have ambitious targets. There seem to be notable differences between the number of adopted policies and NDC ambitions. While China, India, or Turkey rank high in adopting climate-related policies, their NDC pledges are less ambitious compared to other countries. The results of our regression analysis in Model 2 are confirmed by the visual

depiction in Figure 2. The findings show that EU membership is significantly associated with more ambitious NDC pledges, though this was not significant for the OECD sample.

Figure 2: Relative Change in per capita GHG Emissions based on NDC Pledges 2015-2030

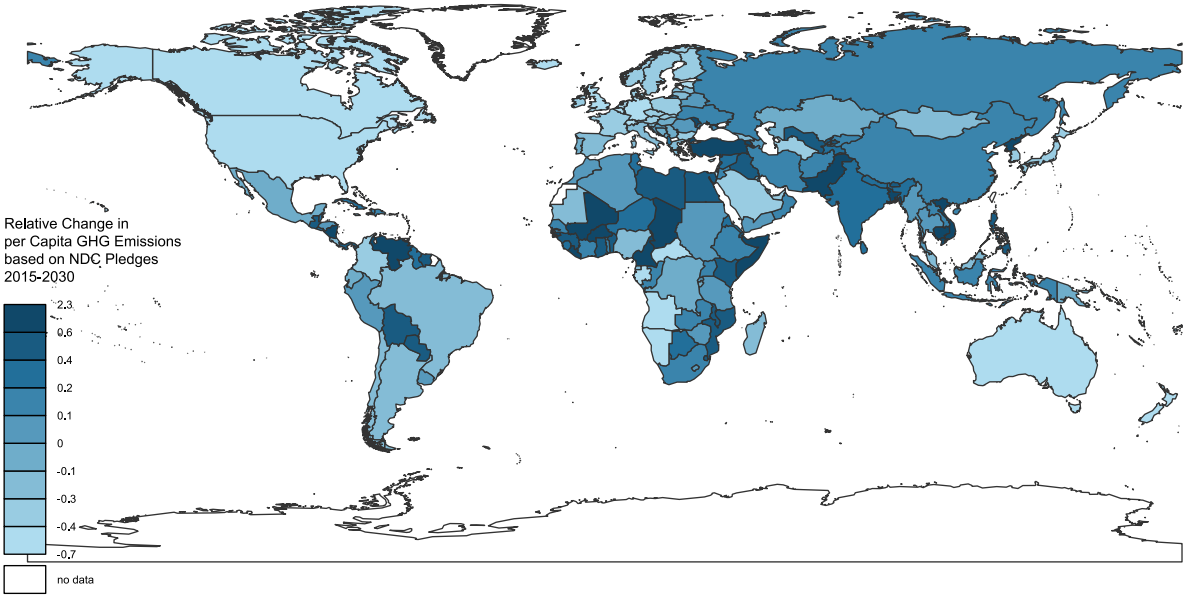

Figure 2. Overview of projected relative changes in annual GHG emissions per capita based on each country's NDC pledges and their forecasted effect on GHG per capita emissions. Data: Meinshausen et al.

Based on the evidence provided, we can partly confirm the first hypothesis. On the one hand, EU membership does not significantly correlate with a higher number of adopted policies but does correlate with more ambitious NDC pledges. This underlines our previous assumptions regarding the EUs institutional and capacity advantages to close the ambition gap to achieve an effective implementation of the Paris Agreement. On the other hand, it could not be clearly examined whether the ambition gap diverges between developed and developing countries or between EU countries and non-EU countries.

Our second hypothesis was that EU countries are more efficient in implementing the Paris Agreement in terms of achieving the climate targets (*Figure 3*).

While most EU countries have been able to reduce their GHG emissions, the variation between them is higher compared to the previously analyzed indicators. For example, Finland was able to reduce GHG per capita emissions by 25 percent since 2015, and yet the emission rate of Bulgaria increased by 10 percent. This heterogeneity is also portrayed by the described results of our model. Although the regression model estimates that on average EU countries reduced their emissions more compared to non-EU countries, the membership status only explains a very small fraction of the observed variance and lacks explanatory power in comparison to the OECD and G20 members. The model especially falls short in regard to the variation of GHG emission change for all ratifying countries, failing to identify the significant determinants for emission changes.

Figure 3: Relative Change in per Capita GHG Emissions 2015-2022

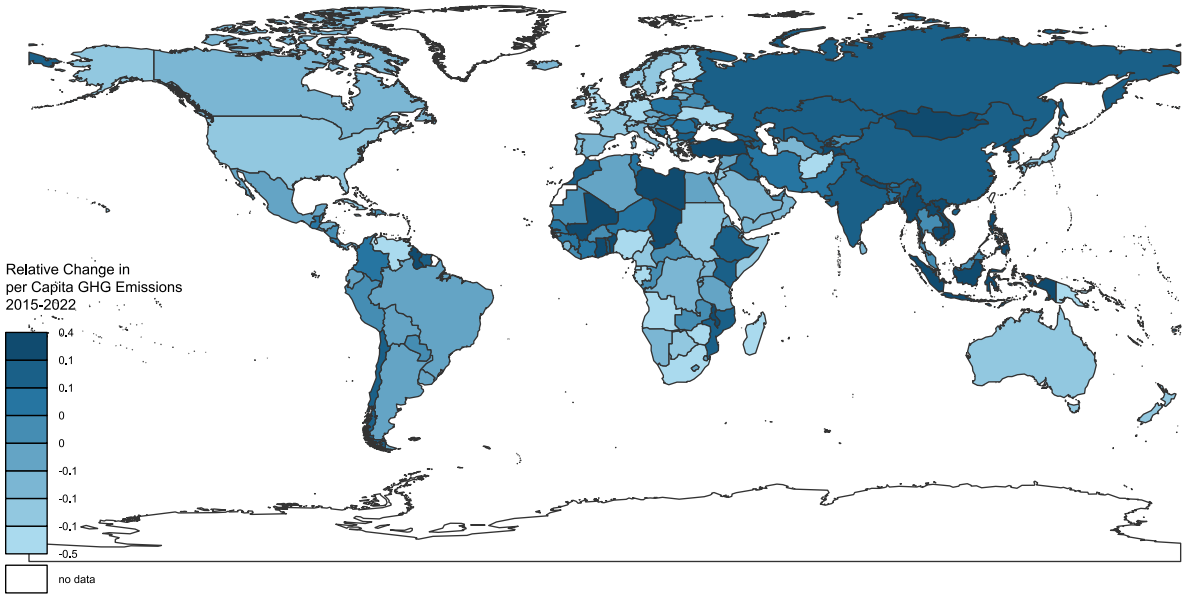

Figure 3. Overview of relative changes in annual GHG emissions per capita since the Paris Agreement. The graph presents each country's individual change in achieving climate targets. Data: EDGAR

Based on the analyzed data, the second hypothesis cannot be confirmed. Furthermore, the analysis underlines the complex nature of successfully implementing the Paris Agreement, with many interconnected factors causing variation in terms of reaching the targets.

In contrast, the results of our analysis provide strong evidence regarding the third hypothesis. One key aspect in successfully implementing of the Paris Agreement involves decoupling economic performance and growth needs to be decoupled from GHG emissions[42,43]. With the third hypothesis we assumed that EU countries are more effective in implementing the Paris Agreement in terms of economic sustainability, as we can see in the relative change in annual GHG emissions per GDP since 2015 (*Figure 4*).

Figure 4: Relative Change in GHG Emissions per GDP 2015-2022

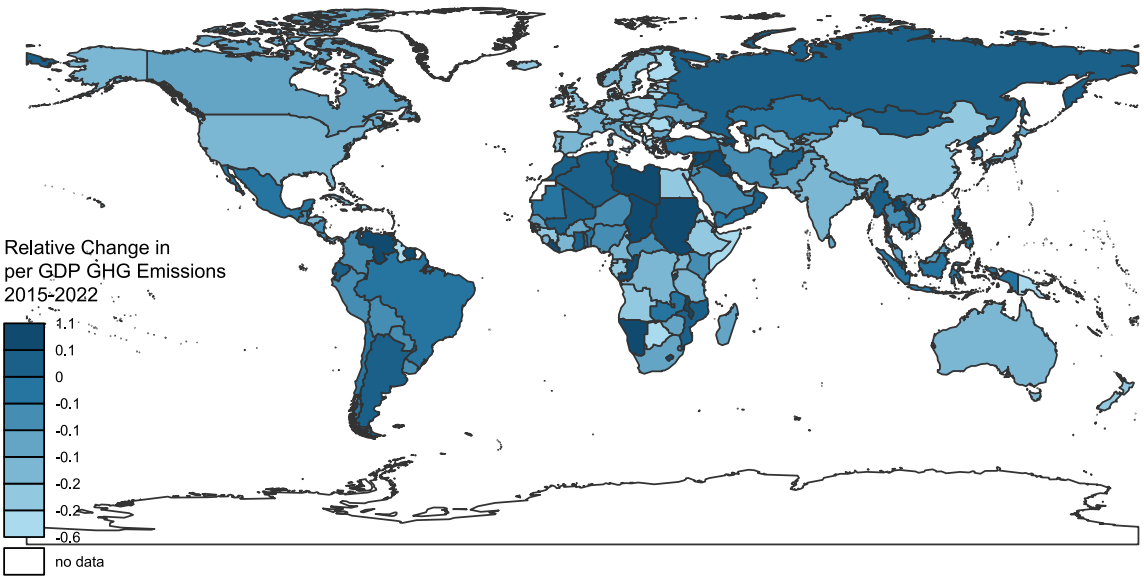

Figure 4. Overview of each country's change relative to their emission intensity rate in 2015. Each countries relative change in annual GHG emissions per GDP since 2015 is presented. Data: EDGAR

This impression is confirmed by the results of the regression analysis in Model 4. All EU members uniformly reduced their emission intensity compared to 2015 and are among the countries that achieved the strongest relative reduction globally. The analysis estimated a strong and significant relationship between EU membership and the reduction of emission intensity. This was consistent across all models, indicating that EU members have successfully decoupled economic growth from GHG emissions more effectively than non-EU countries. The effect is also robust when taking possible confounding variables and alternative explanations into consideration.

Figure 5 (below) plots the relative change in GHG emission per GDP since 2015 for both EU countries and non-EU countries in the OECD and G20. Again, the difference between EU countries and non-EU countries in reducing emission intensity becomes apparent.

Figure 5: Relative Change in GHG Emissions per GDP 2015-2022 by EU Membership

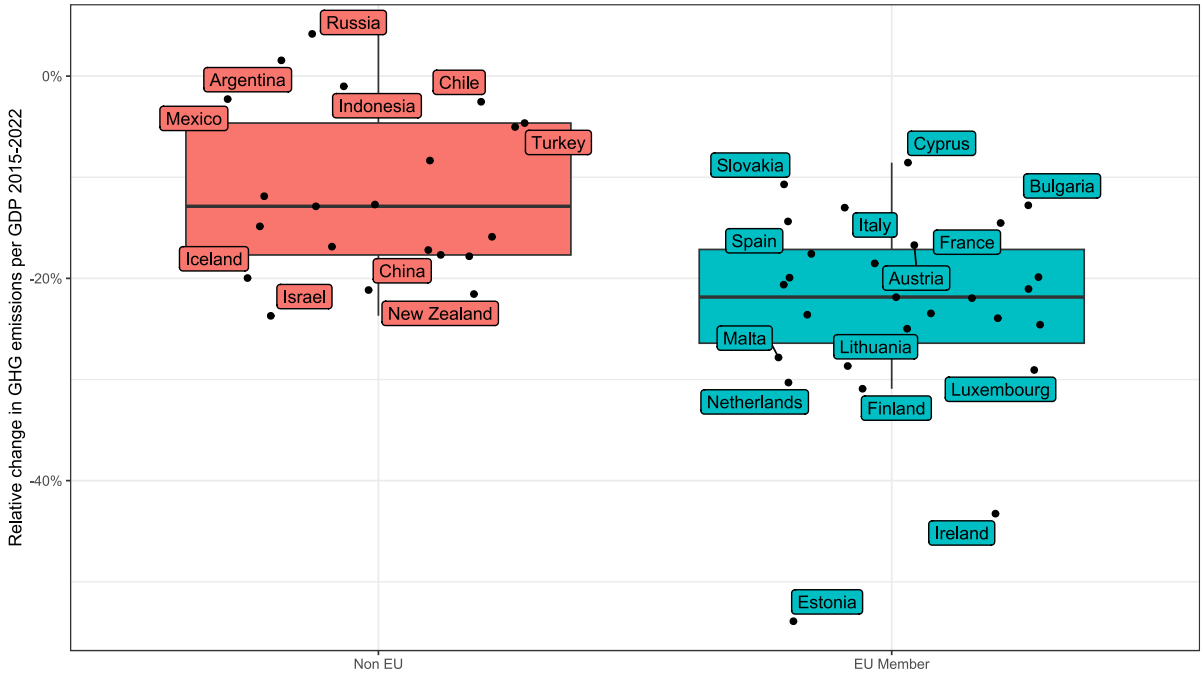

Figure 5. Overview of the relative change in GHG emissions per GDP from 2015 to 2022 for OECD/G20 members (without EU members) and EU members. The thick black line represents the median for both groups, and the colored boxes show the interquartile range, marking the area between the 25th and 75th percentile. Data: EDGAR

Our results show that between 2015 and 2022, EU members have been more effective in implementing the Paris Agreement in an economically sustainable way. We attribute the effect to supranational capacities, such as common markets, policies, tools and standards, as well as public awareness that encourages companies and governments alike to accelerate the green transition.

The results of our analysis confirm previous theoretical debates on the concept of ambition and implementation gaps[20,42,44]. The worldwide variation in the extent of both gaps differs. While the ambition gap seems to show a divergence between developing and developed countries, the actual implementation of the climate goals seems to be unrelated to a country's economic development.

The EU's role is different regarding both gaps. While EU members are at the forefront when it comes to ambiguous targets and effective NDC pledges, we could not identify a significant effect of EU membership on achieving those targets. Regarding economic sustainability, our findings show that the EU members already managed to lay a solid foundation by decoupling economic performance from GHG emissions.

These findings have general implications regarding our theoretical considerations but also for the practical aspects of implementing the Paris Agreement. By identifying the EU's success in this dimension, we also showcase the described EU policy tools, such as the ETS, as promising tools that could be applied to other countries or even in a global context to reach the goals of the Paris Agreement and limit global warming. The results thus provide more evidence for the significance of international cooperation when it comes to an economically viable decarbonization[45].

Among others, it adds to the body of knowledge concerning the justification of climate clubs[45–50]. The G7 climate club is a first step towards a more sustainable transnational economy. In addition, the expansion of the club concept to the G20 countries could accelerate a cooperative green transition[45]. Seeing that the G20 account for roughly 80% of all emissions[51], a cooperation of the group would be a strong lever for international decarbonization and prevent free-riding of single actors[48]. Our results strengthen the concept of climate clubs by providing evidence that cooperation in climate action yields better results than non-cooperative strategies.

Methods

The case selection and the level of analysis are explained as follows. As our research question concerns the impact of EU membership on the implementation of the Paris Climate Agreement, our level of analysis is the country level. In addition, countries are the legal entities subject to the Paris Climate Agreement and are responsible for its implementation[8,52] The analysis on the country level also contributes to a valid measurement of the theoretical construct, as our argumentation is mainly based on the policy level, which primarily operates at the national level.

To obtain the most precise estimation of the analyzed effects of EU membership and mitigate a possible selection bias in the sample, it would be best to consider the whole population. In the case of the analysis, this population would refer to all signatories of the Paris Agreement. We considered all 195 countries that have ratified the Paris Agreement in our hypothesis tests, providing that the respective data was available for all countries.

As EU members do not only differ geographically in many aspects from other countries in the world, a sample of all ratifying countries makes it harder to isolate the effect of EU membership. Such a substantial divergence between the treatment and control groups leaves space for a possible omitted variable bias. Thus, we performed additional analyses with a sample of countries that are members of EGO. The OECD, as a coalition of developed, democratized, and liberal market-oriented countries, serves as a suitable control group with similar characteristics to EU countries. Moreover, the G20 include a diverse set of developed and economically powerful as well as internationally influential countries.

Another crucial dimension of the case selection is the time period of the analysis. In general, we use 2015 as a baseline period against which we compare changes in the aftermath of the Paris Agreement. Moreover, since the implementation of the agreement is an ongoing process, our strategy is to consider the most recent available data to capture the latest possible implementation stage. While this describes our overall approach regarding the case selection, the exact time periods differ between the models. For each model, the time period among other model specifications can be found in the summary table (*Table 7*).

Given the complex nature of the concepts under scrutiny, the operationalization of the selected variables is crucial regarding the internal and external validity. This section discusses the measurement of the independent and dependent variables. Moreover, we introduce a set of control variables to avoid any omitted variable bias while estimating the regression coefficients.

Independent Variable

The operationalization of our independent variable for each hypothesis test is straightforward. As we compare the implementation of the Paris Agreement between EU countries and non-EU countries, the independent variable is EU membership. Consequently, we code the independent variable as *1* if a country is an EU member and *0* if not.

For the majority of countries, this measurement is uncontested. There is, however, the exceptional case of the United Kingdom (UK) and the country's Brexit in 2020. As the membership status of the UK changed during the study period, the country does not distinctively fall under one of the coded categories of our independent variable. Thus, we decided to drop the UK from the sample.

Dependent Variables

Regarding the dependent variables, the measurement is of a more complex nature. Since the analyzed dependent variables differ between the hypotheses, this part discusses the operationalization for each hypothesis separately.

Policy Output

Our first hypothesis concerns the effect of EU membership on the policy output regarding the implementation of the Paris Agreement. We identify two dimensions in which policy output can be measured. At first, a quantitative perspective acknowledges the number of policies on a particular issue that the national legislative has adopted. While the number of adopted policies of a country is arguably easy to record, mapping a specific topic that is affected by the policy is more difficult. To this end, we draw on an existing database from the Grantham Research Institute on Climate Change and the Environment[53]. Their open-data and open-source "Climate Policy Radar" (CPR) uses machine learning algorithms to record climate legislation covering all national-level policies worldwide. The scope of the included policies is broadly defined as "legal documents that are directly relevant to climate change mitigation, adaptation, loss and damage or disaster risk management". A more detailed overview of the methodology can be found on the project website. Since the adoption of the Paris Agreement in 2015, the CPR has recorded over 5,000 policy documents. As some documents refer to the same policy, the CPR also defines policy families under which several policy documents that all concern one unique law or policy are combined. We thus use the family ID variable of the CPR to measure the number of adopted climate-related policies in the aftermath of the Paris Agreement. In total, we obtain 1756 adopted policies from 187 different countries.

While the number of adopted policies indicates the quantity of a country's implementation efforts, the sole measurement of adopted policies comes short in accounting for different scopes of policies. For example, Country A adopted multiple policies on subsidizing renewable energy compared to Country B, which passed a single law on exiting fossil fuel energy generation. Although Country A yields a higher quantity of policy output, the measures by Country B would be more ambitious in reducing GHG emissions. Thus, we also introduce a measure for the quality of a country's policy output that accounts for differences in the ambitiousness of policies. To this end, we draw on the previously mentioned NDCs. Meinshausen et al. developed a statistical model to quantify NDC pledges and their effect on the country's per capita GHG emissions in 2030[54]. In total, the data set covers the NDC pledges of all countries that ratified the Paris Agreement. We thus use the NDC-based projected change in per capita GHG emissions relative to the base value of 2015. That way, we also obtain a qualitative measure of each country's ambitions in implementing the Paris Agreement.

GHG Reduction

With regards to our second hypothesis, we aim to measure the actual achievements made regarding the Paris Agreement's overall goal to limit global warming. To this end, we focus on the GHG emissions of each country as the main drivers of global warming. As the critical leverage point in limiting global warming and as the cornerstone of most NDC pledges, we use the reduction of GHG emissions per capita as the dependent variable for our second hypothesis.

The European Commission's Emissions Database for Global Atmospheric Research (EDGAR) provides global past and present-day information on GHG emissions[55]. The EDGAR database uses a technology-based emission factor approach to estimate the GHG emissions of each country for the period from 1970 to 2022 in CO2-equivalent. Based on the EDGAR estimates, we calculate the relative difference in GHG emissions between 2022 and 2015.

Emission intensity

For our third and last hypothesis we analyze the economic dimension of implementing the Paris Agreement. More narrowly, we aim to measure to what extent countries achieve the agreed goal of limiting global warming in a way compatible with economic prosperity. In this regard, we draw on the previously mentioned concept of economic decoupling. This concept refers to achieving economic growth without increasing environmental impact[56].

A standard measurement of economic decoupling is a country's carbon intensity or emission intensity[41,57–59]. The emission intensity indicates the level of emissions needed to achieve an economic output. In macroeconomic analyses, the emission intensity is typically measured as the ratio of GHG emissions to GDP[60–62]. The EDGAR database also provides data on GHG emissions measured in CO2-equivalent per GDP, adjusted for USD Power Purchase Parity (PPP) in constant 2017. We use the relative change from 2015 to 2022 as the dependent variable to measure if EU member countries are more successful in implementing the Paris Agreement in an economically sustainable way.

Control Variables

Since the EU membership status is arguably not randomly distributed among the countries in the sample, there is room for possible confounding variables affecting both the dependent and independent variables. If these variables are not conditioned, an omitted variable bias could distort the estimation of the analyzed effect. Thus, we introduce a set of control variables that condition on possible confounding factors.

Population

We consider the population size as a possible confounding factor and thus include it as a control variable. In contrast to other countries, the population size of EU countries ranges between 500,000 and 80 million people. Moreover, we argue that population can also be related to the different dependent variables. Especially the number of adopted policies could be higher for bigger countries. However, also the domestic and international pressure to limit global warming could be higher for larger countries as they have more leverage due to their population size. We use the World Bank's World Development Indicators database to retrieve the population for each country in millions of people[63].

GDP per Capita

We include the economic status of a country as a control variable. The EU consists mainly of highly developed countries with strong economic performance. Additionally, higher economic means offer pathways to mitigate climate change. Arguably, economic performance can affect the implementation of the Paris Agreement in multiple ways[20]. We therefore include the GDP per capita from 2015 in USD PPP constant 2017 as a measure of economic performance and development as a control variable. Again, we derive the data from the World Bank's World Development Indicators.

Climate Risk Index

An additional potentially confounding factor is the vulnerability to climate change. The exposure to climate-related risks can also affect the implementation of the Paris Agreement[20]. EU countries are endangered by climate change and global warming to a different extent compared to non-EU countries[21]. We argue that higher exposure to climate change increases pressure to successfully implement the goals of the Paris Agreement.

To measure a country's exposure to climate change, we draw on the Climate Risk Index from the independent Germanwatch Institute[64]. The index combines ecological, humanitarian, and economic indicators to calculate a country's risk of climate change-related events. The index ranges from zero to 125, whereby lower values indicate a higher climate-related risk.

GHG emissions per capita

Every EU country emits more GHGs per capita than the worldwide country average[65]. We argue that GHG emissions per capita also affect the implementation of the Paris Agreement. They increase a country's responsibility to reduce emission rates in order to implement the Paris Agreement successfully[66]. Therefore, we introduce the per capita GHG emissions in CO_2-equivalents in tons from the baseline period of 2015 as a control variable. As for the dependent variables, we obtain the data from the EDGAR database.

Method

The goal of estimating a precise and unbiased effect of EU membership on the different dependent variables lays the foundation for methodological considerations. This allows us to formulate an evidence-based evaluation of the hypotheses and reject possible alternative explanations. This section elaborates on the method selected for the research design.

In general, we assume that the relationship between EU membership and the dependent variables follows a linear trend and can be represented by the following equation:

$$Y_i = \alpha + \beta_1 EU_i$$

Where Y_i represents the value of the dependent variable for country i, α is the intercept or the constant, and β_1 is the regression coefficient of the independent variable EU_i, a binary variable indicating whether country i is an EU member or not. Adding the mentioned control variables, we obtain the following equation for our regression analysis:

$$Y_i = \alpha + \beta_1 EU_i + \beta_2 X_i$$

In this equation, β_2 represents a vector of regression coefficients, and X_i represents a matrix containing the observed values of the control variables for each country i. We estimate the regression coefficients β_1 and β_2. We use the least square method that fits the estimates to minimize the residuals for the observed values. The estimated regression coefficients are tested for statistical significance using a two-sided t-test. The significance levels are indicated at the 90, 95, and 99 percent confidence intervals.

Table 7: Summary of Regression Models

	Dependent Variable(s)	**Data**	**Sample**	**Time period**
Model 1	Number of climate-related policies	Climate Policy Radar	All ratifying countries/ All EGO members	December 12 2015 - today
Model 2	Change in GHG emissions	Meinshausen et al.	All ratifying countries/	2015-2030

	according to NDC pledges		All EGO members	
Model 3	Relative change in per capita GHG emission	EDGAR	All ratifying countries/ All EGO members	2015-2022
Model 4	Relative change in GHG emissions per GDP	EDGAR	All ratifying countries/ All EGO members	2015-2022

Table 7. Overview of the different models for each hypothesis.

Data availability

The datasets generated and analyzed during this study, including data shown in the figures, are available from the authors upon request.

Code availability

The code used in this study is available from the authors upon request.

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Ethics declarations

The authors declare no competing interests.

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