The net zero wave: identifying patterns in the uptake and robustness of national and corporate net zero targets 2015-2023

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Abstract

Since the 2015 Paris Agreement, a growing number of states and firms have adopted targets to reach net zero emissions. These pledges vary significantly both in the timing of adoption and in robustness – measured by the procedural best practices that they adopt or not. We introduce a novel timeseries dataset that measures both the uptake and robustness of net zero targets of states and the world's largest listed firms between 2015 and 2023. The new data allow us to identify patterns that speak to a key debate in the literature: what explains the rapid uptake of net zero targets by firms and countries? Descriptive inference yields several insights. First, the timing of net zero adoption by both states and firms strongly tracks international mobilization efforts, highlighting the importance of the United Nations (UN) process for target setting. Second, on average, firms set targets before countries. Third, there is a rise in some best practices for companies, such as setting interim targets and including Scope three emissions in targets, alongside a lack of progress in others, such as safeguards on the use of offsetting. Significantly, we do not find significant variation in timing or robustness of net zero pledges across firms in different sectors. For countries, early adopters tend to have more robust targets from the beginning than late adopters, suggesting the latter may be adopting more symbolic targets. In sum, our results show the rapid growth of the net zero wave, but also its limits in driving robust targets.

Key Policy Insights:

- The timing of the adoption of net zero targets by both firms and countries closely mirrors the multilateral negotiations of the Paris Agreement, highlighting the importance of international organizations for target setting.

- While the adoption of some best practices grows over time, including setting interim targets and including all emissions, others, such as transparent and appropriate use of offsetting, are not.
- Additional focus on these areas is therefore needed, for example: clear guidance on the use of offsets in target-setting frameworks.
- The UN and non-governmental organizations should use the requirements of the Paris Agreement to increase ambition to further define best practices for net zero, and incentivize states to submit more robust pledges, moving beyond targets to specific plans for how to operationalize and implement them.

Keywords: Net zero; Paris Agreement; Nationally Determined Contributions, climate neutrality; firms; robustness

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Introduction

The 2015 Paris Agreement sets the goal of reaching a balance between sources and sinks of greenhouse gasses - "net zero," though the treaty does not include those words—by the second half of the 21st century. At the Paris Conference of the Parties (COP), only four member states of the United Nations Framework Convention on Climate Change (UNFCCC) and 26 Forbes500 firms had a net zero target. By mid-2023, 149 countries had net zero targets, accounting for 92 percent of global gross domestic product (GDP). Thousands of cities, regions, businesses, investors, and other actors also now have targets, though they vary in robustness . In a remarkably short period of time, a "net zero wave" made the concept the dominant organizing principle of climate mitigation policy. Analyzing this wave is important for understanding both the present international climate policy landscape as well future prospects for climate policy diffusion.

In this article, we take a first step toward explaining the net zero wave. Our analysis speaks to three categories of explanation that are common in the political science literature on climate. First, we consider theories that highlight how actors' behavior can be influenced by other actors, particularly how international organizations can drive the timing of country commitments and

mobilize actors around governance goals and how corporate and national actions may support each other via an "ambition loop" (Abbott & Snidal, 2021; Eskander et al., 2024; Hale & Roger, 2014; Manulak, 2022). Second, we explore the idea that commitments may be merely symbolic "cheap talk" or greenwashing (de Freitas Netto et al., 2020; Downs et al., 2008). Finally, we examine correlates of countries' and firms' adoption of net zero targets, including timing, robustness and strengthening of pledges over time. We also probe whether costs of behavioral change and institutional context are correlated to actor targets.

Our goal is not to assess the dominance of one logic over another (since in all likelihood, there are multiple explanations), but rather to evaluate the extent to which patterns in the data are compatible with these motivations. This descriptive analysis contributes to theoretical discussions around the uptake of sustainability targets and net zero targets specifically, and also lays the groundwork for causal theory testing in future research.

The article makes another important contribution, extending the Net Zero Tracker (Lang et al., 2023) back in time to create a new dataset of net zero targets from all UNFCCC member states, as well as the Forbes500 largest firms from 2015 to the present (over 700 firms in total, as companies enter and leave the Forbes500 over the period of analysis). While previous work has examined the rise of net zero (J. F. Green & Reyes, 2023; Van Coppenolle et al., 2023) and presented important snapshots of the net zero wave (Eskander et al., 2024; Hale et al., 2022)our new time series data allow for the first quantitative assessment of the spread of net zero targets since the concept's entry into the climate policy system.

The data record the quantity of net zero targets, the timing of their adoption, as well various features such as whether interim targets or implementation plans are included. Such features are commonly viewed as best practice, and so to facilitate comparison, we summarize them in a simple index of robustness that documents their presence or absence. However, we do not provide a deeper assessment of the ambition of individual targets or the level of effort they represent (Fankhauser et al., 2022).

The paper proceeds as follows. We first describe the methods for creating the new dataset, including how we construct and code the robustness index. Second, we present our results, tracking overall trends in the timing and robustness of net zero targets. Third, we examine the actor-level correlates of net zero target adoption, robustness, strengthening and institutional

context. We also explore the correlation *between* firm and government targets. We conclude with a discussion of the implications for net zero policy going forward.

Methods

Study population

This article extends the Net Zero Tracker dataset that has been described in previous work (Hale et al., 2022; Lang et al., 2023). Here we do not repeat, but instead briefly summarize, the data collection strategy and explain how we have extended the data. While previously published versions begin in 2020, this new, extended dataset begins on 1 January 2015, allowing us to study diffusion dynamics. The study population is defined as follows:

For countries, we include all UNFCC member states (193 countries) and four self-governing territories and dependencies, for a total of 197 entities. For corporations, we included the top 500 publicly traded companies included in the Forbes Global 2000 list in each year from 2015 to 2022. A total of 774 firms were recorded, as companies enter and leave the Forbes Global 2000 list over the period of analysis. The inclusion criterion for analysis is that companies must be included twice in the list over the study period. This criterion was added so that we can cover a large number of companies given feasibility constraints in coding information. Of total, 628 firms that appeared at least twice in the list over the study period are included in the dataset. The remaining 146 firms that appeared only once in the list were excluded. The Net Zero Tracker already has records for 603 of the 628 firms. Twenty-five firms were added in the process of extending the data. Table S1 lists the breakdown of these firms according to industry, region, and country.

Data collection

For each entity we collected various descriptive data on climate mitigation targets (see codebook (Hale et al., 2022; Lang et al., 2023)), creating a panel data set with entity-day as the unit of analysis. As detailed in the Net Zero Tracker methodology (Hale et al., 2022), we include both commitments for CO_2 only or multiple greenhouse gases, and include targets explicitly described as “net zero” or other terms that mean net zero or net negative emissions.

The collection process involved a team of five trained student data collectors, supervised by the paper authors. The information collected on the entities was based on publicly available sources. For countries, we relied on NDCs and Long-Term Strategies from 2015 onwards, as well as published documentation and data from Climate Change Laws of the World (CCLW) and Climate Action Tracker, amongst other sources.

We obtained corporations' information from annual reports such as Environmental, Social and Governance (ESG), Corporate Social Responsibility (CSR), and sustainability reports starting from 2015. The coders were given instructions to prioritize primary material whenever available. However, they were advised to use relevant web pages or Google Search as a means of complementing and verifying the information as required. The data collection activities were carried out from April 2022 to March 2023.

The data collection covers national and corporate commitments that pertain to CO_2 or other greenhouse gas emissions, and targets related to achieving net zero or other closely associated concepts such as carbon neutral, zero carbon, or net negative emissions.

Robustness index

The dataset tracks the timing of pledges by both countries and Forbes500 firms between 2015 and 2022. We measure the robustness of these pledges using a common set of criteria, primarily based on the UN Race to Zero campaign criteria, which includes target status, target year, gasses covered, presence of interim target, presence of mitigation plan, gasses covered, reporting mechanism, accountability, scope, and use offset mechanisms (Table 1). These attributes were combined into an index to assess the completeness of the net zero pledges.

The robustness index is an aggregate of the nine criteria into a simple additive index and calculated using Equation 1. Each criterion is provided with a score following an ordinal scale, e.g., a net zero target with an annual reporting mechanism has a score of 2 (highest score in the scale) while a target with no reporting mechanism has a score of 0 (lowest score in the scale). We normalize each criterion with the highest possible score (e.g., a score of 2 for a 3-scale criterion has a normalized value of 67%) and then aggregate the normalized values of the nine criteria by weighting them equally. As such, the index has a final score that ranges from 0 to 100. Table 2 provides information on the normalization and weighting factors of each criterion. Robustness indices are calculated for every entity at a daily interval.

$$Robustness\ index_{e,d} = \frac{\sum_{1}^{i=9} \frac{criteria_i}{n}}{9} \qquad \text{(Equation 1)}$$

where e denotes an entity, d denotes the day of interest, i denotes a robustness criterion, and n denotes the normalization factor in Table 1."

This index should be interpreted not as an overall benchmark of a target's ambition or quality, but rather as a description of how many best practices a given target includes. Putting this information into a simple additive index facilitates comparison across actors and across time, but it should not be interpreted as an indicator of the overall quality of an actor's target, which would require additional analysis. The Robustness index is better understood as a measure of the extent to which an entity's target-setting methodology aligns with best practice.

Table 1. Description of the attributes used in the robustness index.

Attributes	Characteristics	
	National targets	**Corporate targets**
Target status	Target is achieved, prescribed in legislation, set in national policy documents (including NDCs in the UNFCCC), pledged but not yet institutionalized, or being considered.	Target is achieved, set in corporate policy documents, pledged but not yet institutionalized, or being considered.
Target year	Pledge to reach net zero by mid-century at the latest.	
Interim target	Commit intermediate targets through absolute emission target, emission intensity target, or other forms.	
Gasses coverage	Cover carbon dioxide only or all greenhouse gases.	
Plan	Explain the steps taken to advance toward achieving net zero, including a timeframe in which they will be taken.	
Reporting	Commit to a regular review of measures and report progress.	
Accountability	Government held accountable through legislature, courts, higher level of government, or other bodies for the target.	Executives held accountable, e.g., pay linked to climate deliverables.

Attributes	Characteristics	
	National targets	**Corporate targets**
Scope	Cover all emissions including territorial emissions, international aviation, and international shipping.	Cover direct emissions from operations (scope 1), purchase of electricity, heating, and cooling (scope 2) and all emissions from across the value chain (scope 3).
Offsets	Immediate mitigation measures are prioritized, and the use of carbon credits to neutralize emissions is limited.	

Table 2. Characteristics, normalization, and weighting factors in assessing the robustness of national and corporate net zero targets.

Criteria for Robustness (i)	Characteristics		Normalization factor (n)	
	National Targets	Corporate Targets	National Targets	Corporate Targets
Target status	In law/achieved = 3 In policy document = 2 Pledged/proposed = 1 None = 0	In planning documents/achieved = 2 Pledged/proposed = 1 None = 0	3	2
Target year	<2050 = 3 2050 = 2 >2050 = 1 No target year = 0	<2050 = 3 2050 = 2 >2050 = 1 No target year = 0	3	3
Interim target	Yes =1 No = 0	Yes =1 No = 0	1	1
Gasses coverage	All GHGs = 2 CO_2 only = 1 Not specified = 0	All GHGs = 2 CO_2 only = 1 Not specified = 0	2	2
Plan	Detailed plan = 2 Has plan = 1 No = 0	Detailed plan = 2 Has plan = 1 No = 0	2	2
Reporting	Annual = 2 Less than annual = 1 None/not specified = 0	Annual = 2 Less than annual = 1 None/not specified = 0	2	2
Accountability	Has mechanisms = 1 No mechanism = 0	Has mechanisms = 1 No mechanism = 0	1	1

Criteria for Robustness (i)	Characteristics		Normalization factor (n)	
	National Targets	Corporate Targets	National Targets	Corporate Targets
Scope	All territorial + aviation and/or shipping = 2 All territorial only = 1 None/not specified = 0	All scopes = 3 Scopes 1+2 and partial scope 3 = 2 Scopes 1+2 only = 1 Not specified = 0	2	3
Offsets	No offsets used = 3 Using with conditions = 2 Using with no conditions = 1 Not specified = 0	No offsets used = 3 Using with conditions = 2 Using with no conditions = 1 Not specified = 0	3	3

Limitations

The dataset used in the analysis is limited by the defined populations of entities. While all countries are included, we restrict the firms included to the top 500 of the 2000 largest publicly traded companies by revenue from 2015 to 2022. This cut-off allows us to cover as many entities as possible while considering feasible resource constraints. Data is also limited by what is publicly available: NDCs for countries and annual reports for corporations.

The simplicity of the robustness index also creates limitations. Using ordinal scales lacks precise quantitative measures to represent every robustness criterion. For example, having detailed plan (a score of 2) can be the threshold for a normalized score of 100%, but simply having a plan (a score of 1) may or may not be directly equivalent to 50%. Equal weighting factors assumes that all criteria have equal value, but in theory, some criteria may be more important than others.

Correlates

Considering the picture of increasing quantity and heterogenous robustness, we examined countries and companies' target-setting behavior regarding 1) timing of adoption, 2) robustness of pledges at the end of study period (i.e. 2023), and 3) strengthening of robustness. Drawing on the climate policy literature, we seek to identify the correlates of each group. Specifically, we consider geography (World Bank regions), income level (World Bank income groups), industry (International Standard Industrial Classification of All Economic Activities classifications), link

to fossil fuels (the Organization of Petroleum Exporting Countries membership and coal dependence), regime type (Varieties of Democracy categories), and whether countries are part of the UNFCCC's "Annex 1" group, meaning the 1990s-era industrialized countries that have traditional been seen has having relatively higher mitigation responsibilities under the UN convention. The correlates are summarized in Table 3, while full results are given in Supplementary Information.

Results

Timing of net zero targets

The data show a clear net zero "wave:" very few initial net zero pledges followed by rapid growth around COP26. There is a significant lag between the signing of the Paris Agreement, which sets a goal of balancing sources and sinks of emissions in the second half of the century, and the adoption of net zero pledges (Figure 1). National net zero targets (ranging from proposals to laws) covered less than 10% of global GDP until 2020, the majority in the realm of soft law (Figure 1a). Even today, only about 25% of global GDP is covered by binding legislation, though nearly the entire world is covered by targets of varying degrees of legalization – ranging from proposal to fully executed legislation (Abbott et al., 2000). Most net zero pledges were made between COP25 and COP26, when countries were due to submit both new or updated NDCs and Long-Term Strategies to the UNFCCC.

Strikingly, Forbes 500 firms moved more quickly on net zero than countries (Figure 1b).[1] By 2020, just as the big surge in national pledges was beginning, 40% of total revenue of Forbes 500 corporations were already covered by net zero pledges. During this time there was a concerted push to mobilize net zero targets, which emerged from both orchestration efforts by UN leaders, and the hosts (termed "Presidencies") of COPs 25 and 26, as well as advocacy of other countries advocating for "ambition" and civil society. These efforts began in the lead up to the September 2019 UN Secretary General's climate action summit. Later that year, COP25 host Chile announced a Climate Ambition Alliance that included aspirational long-term net zero targets, or,

[1] The "staircase" pattern in Figure 1b is an artifact of retrospective data collection. While net zero targets were sourced from annual corporate reports, it was not always possible to obtain the exact date a new target was first announced. When specific dates were not associated with corporate pledges, we used January 1 as the default date for a given year.

more ambiguously, "advancing consultations on a long-term strategy for climate-neutrality in line with the Paris Agreement," from 120 countries, 786 companies, 398 cities, and 15 regions (*Climate Ambition Alliance*, 2019). The UK, which served as the COP president in 2021, actively embraced the Climate Ambition Alliance and worked with Chile to launch the Race to Zero campaign--an effort to mobilize further net zero targets from non-state actors—in June 2020. In parallel, the UK worked to secure net zero pledges from countries in advance of COP26 in Glasgow. G7 and G20 statements in these years affirmed these goals.

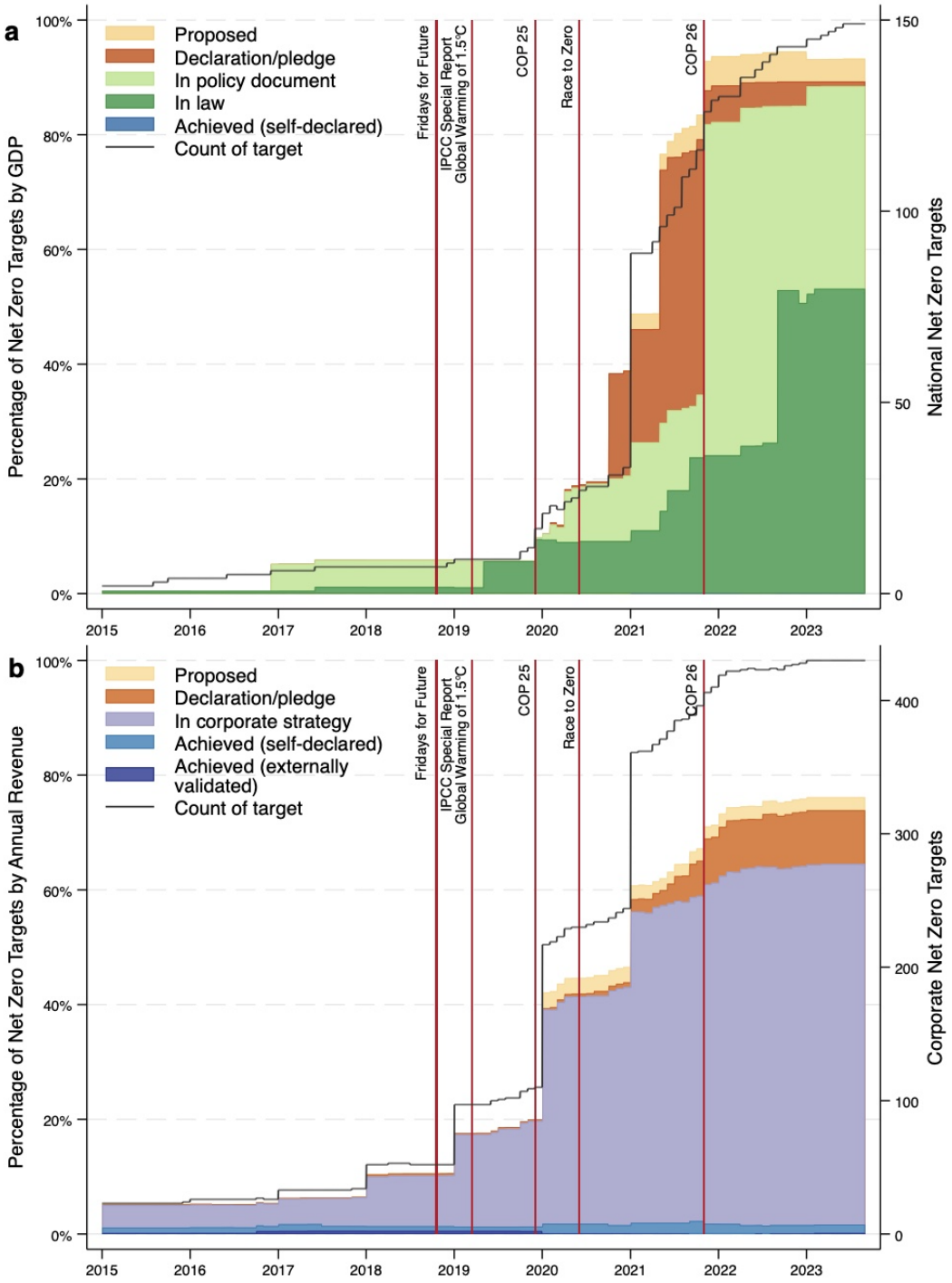


Figure 1. Adoption of net zero targets over time. Shaded regions show the percentage of global GDP covered by national net zero targets (a) and the percentage of the Forbes500 firms annual review covered by corporate net zero targets (b). Solid black lines represent the count of net zero targets (secondary y axis) for each entity. Vertical red lines mark important events.

Robustness of net zero targets

Figure 2 shows trends in the degree of variation in robustness over time. For countries, robustness increases in the initial period when there were very few targets and then plateaus until net zero takes off in 2020 (Figure 2a, c). As the number of targets increases, average robustness dips modestly. In addition, variance in robustness declines in the last three years of the sample, with fewer targets significantly above or below the average.

Changes in robustness over time could be due to either 1) existing targets becoming more/less robust or 2) more recent targets being more/less robust. In comparing the robustness between early and later adopters (see Figure S1a in Supplementary Information), we find that early adopters (both countries and firms) have moderate increases in robustness during the period of analysis. In contrast, later country adopters tend to adopt less robust targets, outweighing the improvements in early adopters' targets and resulting in the overall dip of average robustness. Later firm adopters are less likely to have implementation plans, more likely to have a narrower scope of emissions covered, and more likely to use offset mechanisms with underspecified terms (Figure 2c).

In general, most countries have an interim target, which is an important indicator for evaluating progress. However, this robustness feature may not be as consequential, since interim goals and targets are typically part of a country's national pledge under the Paris Agreement, known as its NDC. Very few countries have an accountability mechanism in place, which means few governments can be held to account by the legislature, courts, or other bodies for failing to meet their target.

By contrast, companies demonstrate more consistency in robustness across time, with a marginal increase over the whole period of analysis (Figure 2b, Figure S1b in Supplementary Information). Unlike with countries, the rapid increase in target adoption is not associated with a diminution of quality. Meanwhile, variation across targets reduces over time. In particular, there appears to be some convergence around features including implementation plans, interim reporting and emissions scopes included, and the adoption of these features increases over time (Figure 2d). Later adopters tend to adopt very slightly less robust targets than earlier adopters. Overall, however, we do not observe significant differences in the robustness of targets between earlier and later adopters, and the combined robustness rises marginally over time (Figure 2b).

There are, however, some noteworthy gaps. There is little specification about whether and how firms use offsets in their net zero pledges. And as with countries, there is scant use of accountability mechanisms – which are defined as the linking of executive pay to net zero achievement. Moreover, there is variation in target year, with later adopters setting targets farther in the future. This pattern suggests that later adopters may be hedging, hoping that future technological improvements will help them meet their net zero goals (J. Green et al., 2022).

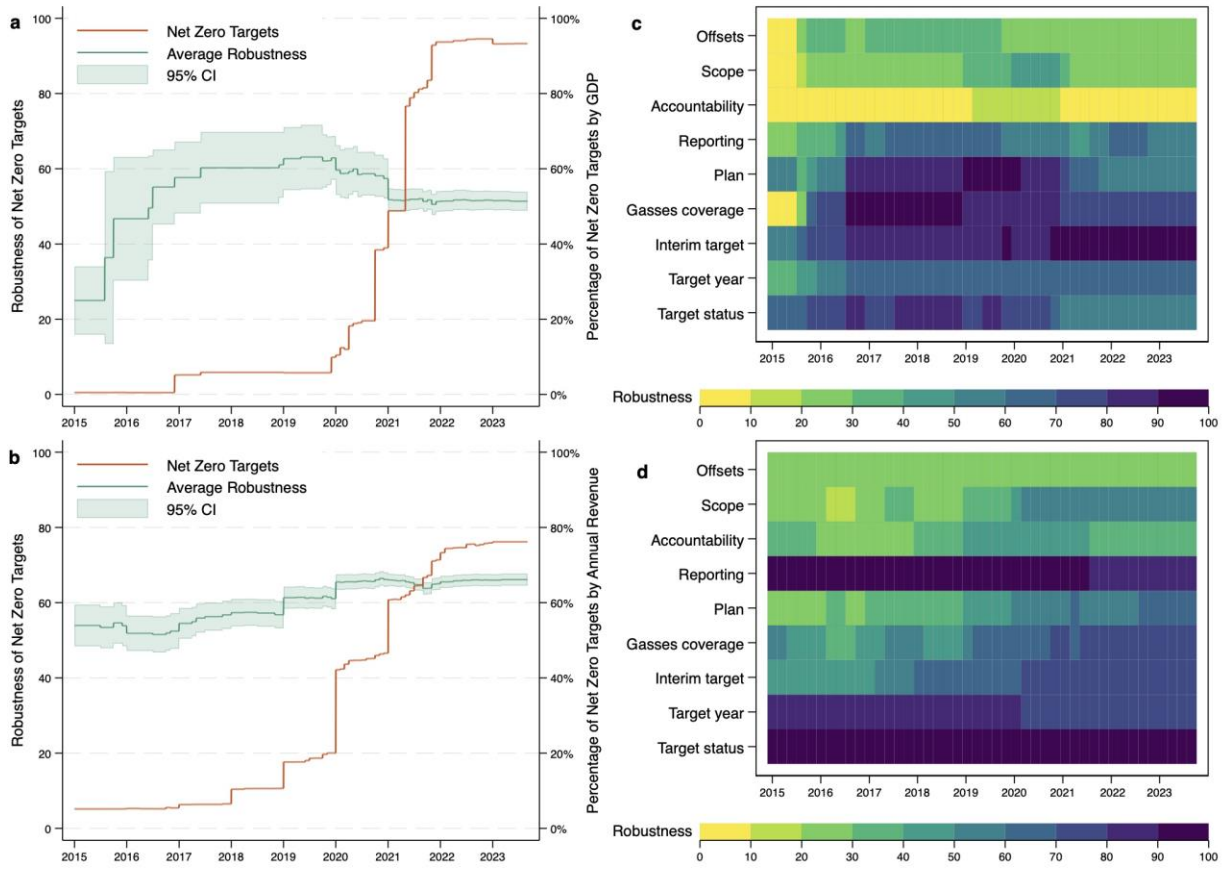


Figure 2. Robustness of net zero targets over time. a-d, Aggregated robustness index of national (a) and corporate net zero targets (b); Robustness index broken down into attributes for national (c) and corporate net zero targets (d). Solid green lines represent the robustness of net zero targets (unweighted). Shaded green areas represent variation in robustness index at 95% confidence interval (unweighted). Solid orange lines represent net zero targets weighted by GDP in (a) and annual revenue in (b).

Actor-level correlates of net zero target adoption, robustness, and strengthening

Work in political science and related disciplines provides baseline expectations about the conditions under which countries and companies are more or less likely to adopt climate targets of varying robustness (Bernauer & Bo, 2012; Hsueh, 2017, 2019; Lachapelle & Paterson, 2013; Prakash, 2000; Tørstad et al., 2020). We investigate two sets of factors that help explain climate policy: distributional costs and institutional characteristics of countries and firms.

Since politics is about who gets what, the material costs of decarbonization are often viewed as a key driver for climate policy (Aklin & Mildenberger, 2020; Colgan et al., 2021). For instance, countries that are highly dependent on fossil fuel production are less likely to have ambitious climate policy, since the costs of decarbonization will be greater than those where renewable energy is more available (Lamb & Minx, 2020). Similarly, we expect that these countries will be less likely to have net zero pledges and that if they do, they will be less robust than their less fossil-fuel dependent counterparts. For firms, we expect those in high-emitting sectors will be less likely to have net zero pledges and that they will be less robust than firm pledges in lower-emitting sectors (Meckling et al., 2022).

Institutional factors are also critical for understanding the uptake and robustness of net zero pledges. For example, countries with proportional representation and corporatist institutions are more likely to produce more ambitious climate policy than those without, since there is greater electoral competitiveness (Finnegan, 2022), more opportunities for green voters and established pathways for compensating losers (Meckling & Nahm, 2022). In general, and following previous research, we expect that democratic countries and firms headquartered in democratic countries are more likely to have net zero pledges, and that those pledges will be more robust than non-democratic countries, and firms headquartered in non-democracies.

We acknowledge that there are many other factors which may influence the adoption and robustness of net zero pledges – such as the presence of civil society, normative pressure, the need for brand or reputation management, among others. However, this is beyond the scope of our paper.

In this section, we probe these expectations by examining national and corporate groups' target-setting behavior regarding timing of adoption, robustness of pledges, and strengthening of robustness, as summarized in Table 3. Full results are given in Tables S3 and S4 in Supplementary Information.

Table 3. Correlates of net zero target adoption, robustness, and strengthening by national and corporate categories.

Category		Adoption	Robustness	Strengthening
National category				
World Bank income group	High income	∅	+	+
	Upper middle income	∅	–	∅
	Lower middle income	∅	–	–
	Low income	∅	–	–
World region	Americas	∅	–	∅
	Europe and Central Asia	+	+	∅
	Middle East and Africa	–	–	∅
	S. and E. Asia and Pacific	∅	–	∅
V-Dem world regime	Closed autocracy	–	–	+
	Electoral autocracy	–	–	–
	Electoral democracy	–	–	–
	Liberal democracy	+	+	+
Fossil fuel - OPEC	OPEC member	–	∅	∅
	Non-OPEC	+	∅	∅
Fossil fuel - coal dependent	Coal dependent	∅	∅	+
	Non-coal dependent	∅	∅	–
Corporate category				
Industry	Biotech, health care & pharma	∅	∅	∅
	Food, beverage & agriculture	∅	∅	∅
	Fossil Fuels	∅	∅	∅
	Infrastructure	∅	∅	∅
	Manufacturing	∅	∅	∅
	Materials	∅	∅	∅
	Power generation	∅	∅	∅
	Retail	∅	∅	∅
	Services	∅	∅	∅
	Transportation services	∅	∅	∅
Firm headquarters	Americas	–	+	∅
	Europe and Central Asia	+	+	∅
	Middle East and Africa	–	–	∅
	S. and E. Asia and Pacific	–	–	∅

Note: + denotes that the category is statistically significantly faster to adopt net zero or has statistically significantly more robust or stronger targets over time compared with the other categories in the group. – denotes the opposite interpretation from +. ∅ is neither + nor –.

Adoption

Our data indicate that net zero adoption among countries follows some expected patterns. First adopters of net zero are northern European states who are traditionally climate leaders (Sweden, Germany, Norway), extremely vulnerable states (Marshall Islands, Fiji, Grenada), and those whose significant natural carbon sinks and low emission levels allow them to achieve net zero with relatively little policy change (e.g., Bhutan, Liberia). Also, early adoption correlates with liberal democracies, consistent with the literature that democracies tend to be greener than their less-free counterparts (Bättig & Bernauer, 2009). At the opposite side of the spectrum, latecomers to net zero include OPEC countries, which is unsurprising given their economic dependence on fossil fuels.

Strikingly, there is no statistically significant variation in the timing of adoption across industries. This runs contrary to the intuition that hard-to-abate industries with higher emissions would take longer to adopt climate-friendly policies[2] (see e.g. Cheon & Urpelainen (2013); Colgan et al. (2021); Geels (2014)). By contrast, geography matters in the adoption of firms. Corporations headquartered in Europe, and Central Asia are faster to adopt than those in America, Middle East, Africa, South and East Asia and Pacific.

Robustness

We find significant variation in the robustness of net zero targets across both countries and companies. For countries, robustness was high for high-income countries, European and Central Asian nations, and liberal democracies. Meanwhile robustness was neither low nor high for OPEC and coal dependent countries.

For companies, robustness also mirrors the speed of adoption, with some subtle differences. Firms in the Americas and Europe and Central Asia make more robust pledges than companies in South and East Asia and Pacific and Middle East and Africa. In other words, while companies in the Americas were not early adopters compared to Asian and African companies, they have reached a higher level of robustness, on average. As with speed of adoption, we find no statistically significant differences in net zero target robustness across industries.

[2] While we find no significant variation in the timing of adoption across industries, the 2023 Global Climate Action report shows that industries with more consumer facing operations such as manufacturing, retail, and services lead in total net zero target setting. We find this same trend in our sample, even though we used a different and smaller sample size than the Global Climate Action report.

Figure 2(c)-(d) disaggregate the robustness index by category. Several findings are particularly noteworthy. First, there is very little specification about whether and how firms use offsets in their net zero pledges. States also tend not to provide much information about offsets, though they fare somewhat better than firms. Second, as with firms, accountability mechanisms are scarce. Third, there is variation in target year, with later adopters setting later targets. This pattern suggests that later adopters may be hedging, in the hopes that changing regulations or technology will lessen the costs of meeting net zero targets. Finally, both states and firms expand the scope of their net zero pledges over time, an indication of increasing robustness.

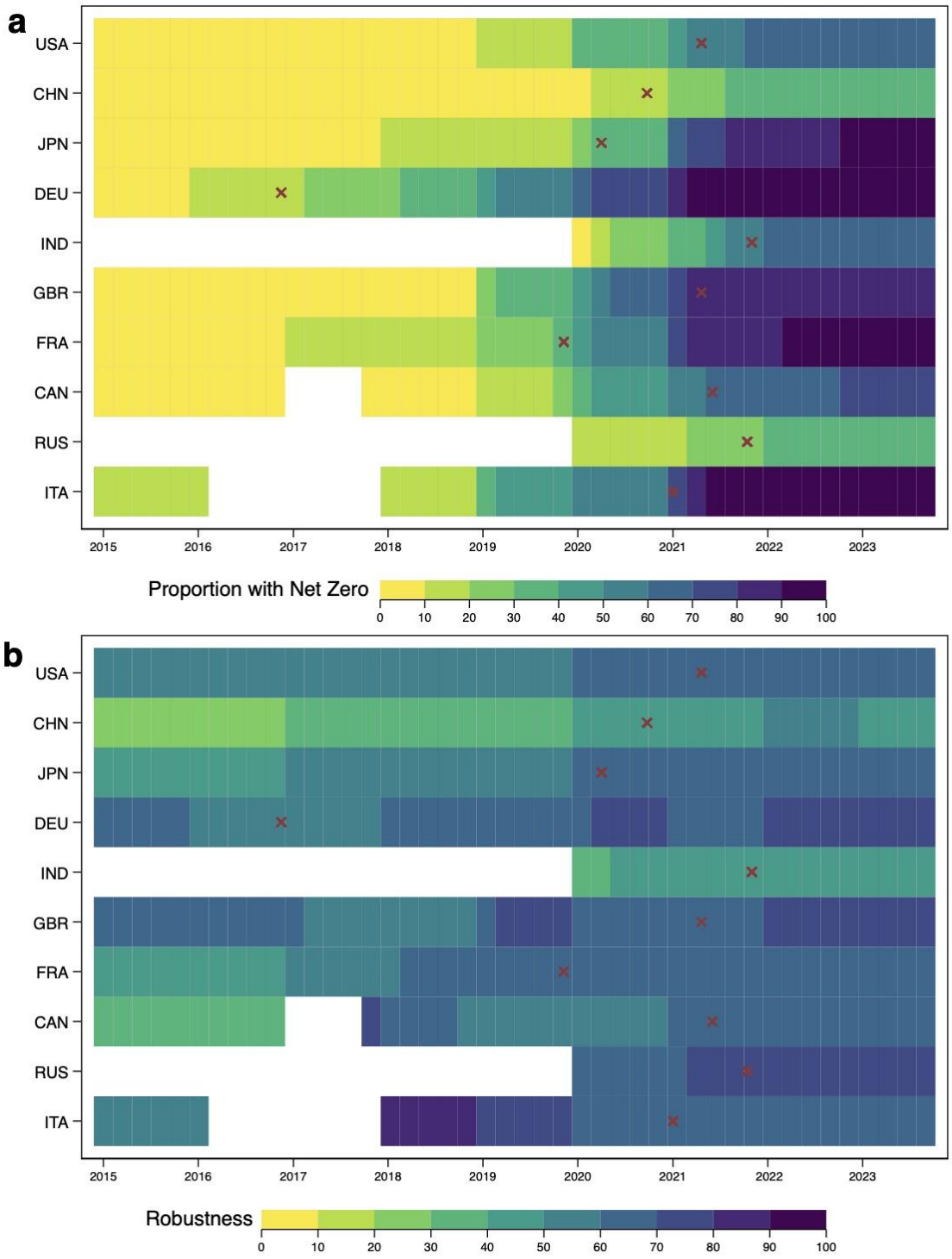
Strengthening

Wealthier nations and liberal democracies have statistically significant strengthening of net zero target robustness. Counterintuitively, coal dependent nations and closed autocracies increased target robustness over the analysis period. Coal dependent nations have a record of opposing climate regulations, making them unlikely candidates for increasingly robust net zero pledges (International Energy Agency, 2022). Similarly, autocracies tend to have less ambitious climate policies than democracies (Bättig & Bernauer, 2009). Strengthening of pledges' robustness over time could reflect the low level at which these nations started.

We find no correlation between strengthening and sectors or geography. This uniformity across firms appears to contravene conventional wisdom that high-emitting sectors are more likely to be climate-laggards.

Correlates of net zero target adoption and robustness between countries and corporations

Figure 3 shows trends in the degree of adoption and robustness over time of corporate net zero targets in the ten largest economies. We note that corporations move more quickly on net zero than countries (Figure 1), but we find that corporate adoption of net zero increases as the countries in which companies are headquartered also adopt (Figure 3a), highlighting a potential mutual influence in line with the "ambition loop" (Eskander et al., 2024). However, this increase does not similarly correlate with improvements in robustness. Corporations demonstrate consistent increases in robustness across time – even before countries where they are headquartered adopt net zero (Figure 3b).



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371 **Figure 3.** Net zero targets of corporations headquartered in ten largest economies. a,b.
372 Proportion of corporations with net zero targets (a) and mean robustness index of corporations
373 with targets (b). Red markers denote national net zero adoption.

Discussion

This new timeseries data enables descriptive inference of key patterns in the "net zero wave," identifying novel patterns that build on existing understandings of the spread of net zero while also raising new questions for further research. First, while actors have diverse motivations to set net zero targets (Boykoff & Pearman, 2019; J. F. Green & Reyes, 2023), the wave of net zero targets is closely clustered in time alongside key moments in the UN climate process, notably the submission of new Nationally Determined Contributions (NDC) and Long-term Strategies at COP26, as well as the UN Climate Champions' Race to Zero campaign. This synchronization suggests a key role for the UN process in target setting, in line with theoretical treatments of major international summits as "temporal focal points" (Manulak, 2022) and with theories of orchestration by international organizations (Abbott & Snidal, 2021).

Second, on average, Forbes500 firms adopted net zero targets earlier and more widely than countries, providing suggestive evidence of a catalytic "ambition loop" in which target-setting by one set of actors encourages others to act as well (Eskander et al., 2024; Hale et al., 2022). Third, firms show a pattern of convergence on best practices for some robustness features – including implementation plans, interim reporting, and emission scopes.

Countries, however, vary more widely in the timing and robustness of their pledges, though variation in robustness narrows over time. Early country adopters tend to have more robust pledges, suggesting that many later adopters are merely following the trend of setting targets, though with less effort. In both groups of actors, there is little constraint on the use of offsets, and relatively little in the way of accountability mechanisms. These findings suggest that for many actors net zero targets remain superficial. Finally, the data identify a number of empirical puzzles that warrant further investigation. Notably, we do not find evidence that firms' net zero pledges vary significantly across sectors, despite the differential decarbonization costs they face (Colgan et al., 2021).

In this section, we consider how these findings speak to the three categories of explanation for climate policy ambition: relations between actors, the role of substantive versus symbolic commitments, and how country and company characteristics affect their propensity to adopt net zero targets.

First, the data suggest that the UNFCCC played an important role in catalyzing net zero pledges for both countries and firms. National net zero target setting is clustered between COP25 and COP26 of the UNFCCC, when as part of the first "ratchet" of the Paris Agreement countries were due to submit updated NDCs and encouraged to submit Long-Term Strategies. Large summits seem to serve as temporal focal points for target setting (Manulak, 2022).

Corporate targets also show their greatest growth during this period, consistent with theories of orchestration (Abbott & Snidal, 2021; Hale & Roger, 2014). Ongoing efforts by the UNFCCC, successive COP Presidencies, and the UN Secretary-General to mobilize net zero targets from non-state actors and to promote good practices around those targets are reflected in both the "wave" of country pledges, as well as their convergence on a set of best practices.

At the same time, the earlier start to the corporate net zero wave, compared to countries, suggests that different factors likely drive firm versus country adoption. The beginning of the corporate wave in 2018-2019 coincides with events like the publication of the IPCC Special Report on Global Warming of 1.5C, which laid out the scientific case for reaching net zero by mid-century, as well as the first global "Fridays for Future" school strike. Certain companies, such as those with pro-social brands that are sensitive to consumer sentiments, may be more immediately responsive to these kinds of scientific and social event, both of which garnered significant media attention, than countries (Boykoff & Pearman, 2019). Others may be motivated by the "shadow of regulation" – adopting net zero pledges in anticipation of tightening national regulations (J. F. Green, 2014).

Moreover, the fact that corporate targets precede national targets indicates that firms were not simply responding to regulatory mandates, or the threat of such mandates. However, the fact that early net zero pledges tended to be less robust in terms of scope, the use of offsets, or plans, suggests that these targets were relatively low cost to adopt. This, in turn, could be consistent with firms seeking to shape the regulatory landscape in favor of greater flexibility. This finding highlights a key ambiguity with the "ambition loop" concept: action by one set of actors may increase the likelihood of other to act, but, if it is merely symbolic, it may also weaken or even forestall subsequent action.

Related, the slight increase in robustness of corporate pledges over time, and the fact that late corporate adopters do not adopt significantly weaker targets than early adopters, may suggest that efforts by NGOs and the UN to define best practices for net zero may have some effect on

the design of corporate targets. Such measures include the promulgation of voluntary standards like the Science Based Targets Initiative, the Race to Zero campaign, or the UN Secretary General's High-Level Expert Group on the Net-Zero Emissions Commitments of Non-State Entities, and related efforts by civil society to name-and-shame companies that fail to meet such standards. However, ongoing areas of weakness, such as appropriate use of offsetting, also point to the potential limits of these soft governance tools.

By contrast, while a greater number of countries have adopted net zero pledges, the gap between the number of pledges and their robustness is much larger than for firms. A political-economic explanation of countries' lackluster efforts often points to firm preferences as a key driver for country (in)action (Aklin & Mildenberger, 2020; Bayer & Genovese, 2020; Genovese, 2019). However, the data show that firms' have a greater commitment to net zero, as evidenced by greater average robustness and a smaller gap between number of pledges and robustness (albeit, among a slightly smaller subset of actors). This finding provides some evidence *against* the standard political-economic explanation, since countries have less robust net zero pledges on average.

Finally, the striking finding that the timing and robustness of net zero targets do not correlate across industries speaks precisely to the multi-causal nature of the net zero wave we probe in this research. Firms' motivations for adopting net zero targets are diverse, suggesting that scholars should eschew overly reductive frameworks.

Conclusions and future research

Descriptive inference of new timeseries data on the net zero wave confirms some existing understandings in the literature, generates new insights, and raises questions. To conclude we highlight two puzzling patterns that require future research.

First, Table 3 shows that there is no inter-industry variation in net zero target setting. Given variation in the ease of decarbonization across sectors, this is surprising (Kelsey, 2018). We expect that those sectors with fossil-free alternatives, or that are well on the way to the diffusion of those technologies (like the automotive industry) would be more likely to adopt net zero targets, and that these targets would be more robust (Victor et al., 2019). However, we do not observe such a pattern.

Second, there is little evidence of increasing robustness among national pledges over time, suggesting that there may be limits to the UN process to compel governments to decarbonize. Moreover, the shrinking variance in robustness among country pledges indicates that states may have converged around a set of best practices that is less than optimal, since it hovers at around 50%. A central part of the "catalytic" logic of the Paris Agreement is that governments will strengthen targets over time (Hale, 2020). While there has been growth of the number of nationally determined contributions (NDCs) since 2015, the robustness of net zero targets shows more limited progress.

More generally, our findings indicate three key areas where policymakers could intervene to accelerate ambition and decarbonization. First, the next "ratchet" mechanism of the Paris Agreement, in which countries are required to submit more ambitious national pledges every five years, is a critical moment to enhance robustness, particularly for countries' net zero targets – and therefore the likelihood of more rapid decarbonization. Policymakers should consider requiring new national pledges to specify how individual components will be made more stringent, including in key overlooked areas such as offsets and accountability. Second, given the myriad problems with offsets, both in the compliance and voluntary markets, all net zero pledges should specify the amount of offsets they are using and their source. Firms should severely limit their reliance on the voluntary market, ideally using only permanent offsets (J. F. Green, 2023). Third, the convergence in robustness among firms hides important variation in costs. A robust net zero pledge will be much more costly for a mining company than a technology company, and yet, both types appear to have similarly robust pledges. This indicates that there is considerable room for improvement for those sectors facing lower costs. Sectoral standards for net zero pledges can help raise ambition for lower-emissions sectors.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Author Contributions

J.F.G. and T.N.H. conceptualized the overarching research goals and aims. A.A. was responsible for data curation and visualization. All authors contributed to analyzing the data and writing the paper.

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