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ABSTRACT
What effect does extreme weather have on climate policy? Existing studies show that weather shocks have negative economic impacts and increase public awareness of climate change. These findings help identify the impacts of climate change on economic and social systems, and provide reasons for governments to adopt climate policy reforms. However, questions remain about the overall link between local extreme weather shocks and government climate policy. I investigate the effect of temperature shocks and natural disasters on a range of national, international, and subnational climate policies in samples spanning 1990–2018. I find that neither temperature shocks nor natural disasters generate climate mitigation reforms. Given that climate policy is currently insufficient to manage climate change and climate impacts are expected to increase this century, these findings suggest that future climate shocks are unlikely to catalyze meaningful climate action.

KEYWORDS Climate change; climate mitigation; environmental politics; external shocks; natural disasters; policy responsiveness

1. Introduction

In 2019/2020 Australia experienced its worst wildfire season in history. The wildfires gripped international news media as an area roughly the size of Syria burned, over a billion animals died, and billions of dollars of economic damages were realized. In Australian newspapers, climate scientists explained that anthropogenic climate change made wildfires worse (Mann 2020), while activists pushed the government to adopt more stringent climate policies to forestall future disasters (Mullins 2020). 2019 was also Australia's hottest year on record, with temperatures +1.5°C above the country's long-term average, a clear sign of global warming's local effects. Yet, months later in May 2020, the Australian government announced it would not augment its already 'insufficient' climate policy targets under the Paris Agreement on Climate Change (Climate Action Tracker 2021) ahead of the Glasgow climate summit, despite the treaty's obligation for states to do so. The wildfires created enormous damages and focused attention on Australia's climate policy record, but even these unprecedented impacts were insufficient to spur reforms.

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Global climate policy is not on track to prevent dangerous climate change.[1] Nonetheless, some jurisdictions have enacted stringent climate policies. Existing research explains cross-national differences through factors like natural resource endowments and political institutions (Bättig and Bernauer 2009, Harrison and Sundstrom 2010). But, these are slow to change and strong climate policy is increasingly urgent. Other research explores how interest groups and public opinion shape policy (Genovese 2019, Mildenberger 2020, Stokes 2020). These factors may be more dynamic, but have produced gridlock to date. Given that climate policy remains insufficient, questions persist over which factors could kickstart reforms.

Extreme weather may provide a catalyst for climate reforms. Extreme weather events are readily related to climate change rhetorically (Mann 2020), shift public opinion (Egan and Mullin 2012, Bergquist and Warshaw 2019), and create economic damages that could unite disparate interests around climate reforms (Burke *et al.* 2015). Collective action often requires an external impetus and extreme weather may act as a focusing event for organizing pro-climate groups (Birkland 1998). Extreme weather's effects on domestic political economy can activate mechanisms for generating climate reforms.

What effect does extreme weather have on climate policy? Do local impacts from climate change lead governments to adopt more stringent climate policies? Existing research yields conflicting results. Peterson (2021) finds that expert perceptions of national climate policies improve following natural disasters, but only in high-income democratic countries. Giordono *et al.* (2020) and Cohen (2021) both study US subnational contexts and find an adaptation response following natural disasters, while Nohrstedt *et al.* (2021) find a null adaptation effect globally. Despite this recent work, the overall effect of extreme weather on climate mitigation policy outcomes has not been studied systematically for a large and representative set of jurisdictions and policy measures. In this paper, I study how temperature shocks and natural disasters affect a wide range of climate mitigation policy outcomes. I collect climate policy data across national, international, and subnational levels. Given the effects of temperature shocks on domestic political economy that have already been established in the literature, I expect that governments will respond to these shocks by adopting more stringent climate policies.

I find, however, that temperature shocks and natural disasters are not associated with climate reforms. I use fixed effects regression models that identify the effect of extreme weather on climate policy through year-on-year deviations in extreme weather from local means and common global shocks. This estimation technique is well-established in the empirical climate literature because it isolates the independent effect of weather shocks from local confounders, long-run averages, and common global trends (Dell *et al.*

2014). Across many climate policy outcomes, weather measures, estimation techniques, and samples, I consistently find that weather shocks have no effect on climate mitigation policy. I also find no effect of cumulative shocks or their intensification over time.

Climate change-induced impacts are expected to increase because current climate policies allow further greenhouse gas emissions. I show that local temperature shocks – many of which are of the same magnitude as a + 1.5-°C uniform shift in global average temperatures – have not induced climate policy changes historically. Neither have natural disasters. While the past is not necessarily prelude, these findings suggest that we should be skeptical about arguments that future climate change will lead governments to adopt reforms to prevent dangerous climate change. Australia's experience of extreme climate impacts followed by climate policy stasis appears indicative of a more general disconnect between local impacts from climate change and policy responsiveness.

2. Climate impacts should influence climate policy

Climate politics research contends with two stylized facts. First, damages from unchecked climate change are much larger than the costs of mitigation or adaptation to severe climate impacts (Stern 2007). However, the benefits of climate mitigation policy accrue mostly in the future, while costs are borne mostly in the present, and these kinds of policy programs have weak political constituencies (Finnegan 2022). Second, domestic publics express support for much stronger climate policy than has been enacted in almost every jurisdiction. Early research explained this gap through international cooperation problems (Keohane and Victor 2016), while recent research often emphasizes how vested interests block reforms (Mildenberger 2020, Stokes 2020). One of the key tasks of climate research, then, is to identify mechanisms that could cut through these problems and facilitate stronger climate action.

Many governments have enacted climate reforms, even if climate policy remains under-provided globally. Scholars have explained cross-national differences through electoral institutions (Harrison and Sundstrom 2010), the strength of carbon-polluting industries (Genovese 2019), partisan politics (Trachtman 2020), and trust in politicians (Levi *et al.* 2020), among other factors, though mostly to highlight how attributes of the high-carbon status quo obstruct climate reforms. A growing body of research examines whether alternative mechanisms, such as mass mobilization (Sisco *et al.* 2021) or policy sequencing (Breetz *et al.* 2018), could cut through existing gridlock and jumpstart climate action.

One under-explored mechanism is whether physical impacts from climate change itself could unlock reforms. The information from extreme weather and its effects on domestic political economy provide strong reasons to think climate impacts should influence policy. First, extreme weather events make climate change vivid. They translate the abstract phenomenon of global climate change into local lived experiences (Weber 2010). It has become nearly automatic that pro-climate action groups seize upon extreme weather events as 'wake-up calls' for reforms (Mann 2020, Mullins 2020). The media has also become more active in attributing extreme weather to climate change (Stecula and Merkley 2019). For example, *The Guardian* ran editorials over the span of two weeks in July 2021 following a heat wave in the Pacific Northwest and flooding in western Germany arguing that these events necessarily 'intensif[y] the pressure on policymakers to act' (The Guardian 2021). These statements reflect a widespread belief in the media, amongst activists, scientists, and political leaders that negative impacts from climate change can act as catalysts for reforms.

There is some evidence that extreme weather changes public attitudes and political behaviour on climate change. Bergquist and Warshaw (2019) estimate that a + 1 °C increase in local average temperature increases public concern about climate change by 0.12–0.16 standard deviations in the United States (Egan and Mullin 2012, Boudet *et al.* 2020). Similar effects on public attitudes have been documented from exposure to other extreme weather events (Konisky *et al.* 2016). Recent studies go further and show that exposure to extreme temperatures, wildfires, or flooding can increase pro-environment voting (Hazlett and Mildenberger 2020, Baccini and Leemann 2021). Hoffmann *et al.* (2022) find that a one standard deviation increase in local temperature increases votes for Green parties in European Parliament elections by 0.11–0.19 standard deviations. Governments are sensitive to public opinion, even in authoritarian political contexts, because public opposition can constrain governments (Alkon and Wang 2018). As climate impacts can shift public attitudes and voting behaviour, governments may enact reforms to meet heightened public demands. Indeed, Bromley-Trujillo and Poe (2020) show that changes in public attitudes precede climate reforms in American states, and Schaffer *et al.* (2021) find similarly in six wealthy countries.

A second reason why negative impacts from climate change should lead to policy changes stems from extreme weather's negative economic consequences. Hsiang *et al.* (2017) show that a + 1 °C increase in average annual temperature in the United States shaves roughly 1.2% off annual economic growth. Other studies find similar macroeconomic effects in global samples (Burke *et al.* 2015), and within economic sectors (Zhang *et al.* 2018, Shew *et al.* 2020). Governments monitor economic conditions closely because governments that preside over economic downturns struggle to maintain public support, especially if these can be linked to government inaction. Indeed, in a similar context of financial crises where governments preside over economic losses, Calca and Gross (2019) find that governing parties respond with high levels of policy responsiveness. Crucially, domestic publics continue to support environmental protection even during recessions (Mildenberger and Leiserowitz 2017).

Ultimately, natural disasters could act as focusing events that help pro-climate action groups mobilize to demand policy reforms. Birkland (1998, p. 72) argues that natural disasters are 'important opportunities' for pro-reform interest groups because they help groups 'mobilize to press for policies that would prevent future such events and to ameliorate the immediate disaster.' Environmental groups tend to be less well-organized than fossil fuel groups (McAdam 2017), but climate-related natural disasters could bring pro-climate action groups together into a broader advocacy coalition. Environmental disasters, historically, have helped organize opposition to nuclear energy (McAdam 2017) and push for more stringent regulation on oil infrastructure (Birkland 1998). Mobilization around extreme weather may elevate climate policy in national discussions and allow it to break through gridlocked political processes.

How could an adverse impact from climate change affect policy in practice? Consider a country that experiences a particularly hot summer – a temperature shock, where the local temperature is substantially above that jurisdiction's long-term average. Agricultural yields fall precipitously for each hour that crops spend exposed to extremely high temperatures (Shew *et al.* 2020). Poor crop yields directly affect farmers, a geographically-concentrated interest group that provides them a mobilization advantage to pressure public officials. Temperature shocks also decrease labour productivity (Zhang *et al.* 2018). Agricultural and labour productivity losses ultimately aggregate up to closely monitored macroeconomic statistics. Meanwhile, high temperatures are also associated with heightened public climate concerns (Bergquist and Warshaw 2019). Pro-climate groups organize at this crucial moment to press for reforms (McAdam 2017). These multiple effects of weather shocks on economic and social systems generate a set of pathways through which climate impacts can put pressure on governments to react (Bromley-Trujillo and Poe 2020, Schaffer *et al.* 2021). Governments are not compelled to act, but the adverse impacts of climate change raise the political costs of inaction and raise the political benefits of action (Hoffmann *et al.* 2022).

This theoretical argument makes little reference to how political contexts may influence the likelihood that extreme weather events lead to policy reforms. Existing research suggests that the relationship may be stronger in specific circumstances. First, if changes in public opinion and mobilization are important drivers, then the effects may be stronger in democracies than autocracies, which would fit with findings that democracies have stronger climate policy (Bättig and Bernauer 2009). Second, wealthier countries may be more responsive because they tend to have stronger states that can undertake more reforms in parallel. Existing research has produced diverging estimates of the effect of national wealth on climate policy (Dolphin *et al.* 2020, Levi *et al.* 2020), so negative economic impacts should not inherently undermine costly climate reforms. Third, characteristics of an extreme weather event, such as its type and intensity, may influence its ability to act as a focusing event (Birkland 1998). Similarly, the effects of extreme weather events may be stronger at smaller spatial scales, such as in subnational units compared to national ones, especially given the very local impacts of many extreme weather events (Giordono *et al.* 2020). In the empirical sections, I consider each of these possible heterogeneities in the effect of extreme weather on climate policy as scope conditions.

The argument above illustrates a theoretically-informed perspective for a plausible link between extreme weather and policy reforms. However, there are many steps in the causal chain and therefore many opportunities for the process to break down. Although many studies find an effect of extreme weather on public attitudes (Egan and Mullin 2012, Bergquist and Warshaw 2019) and on voting behaviours (Baccini and Leemann 2021, Hoffmann *et al.* 2022), other studies find modest and short-lived effects that depend on prior beliefs and context (Konisky *et al.* 2016, Hazlett and Mildenberger 2020). As such, it may take large weather shocks to generate reform pressure, and these may vary across political contexts. Furthermore, even if public attitudes change, there remains a persistent disconnect in climate policy – as on other issues – between public preferences and policy outcomes. As Gilens and Page (2014) demonstrate, policy outcomes more often reflect the preferences of unrepresentative, well-organized interest groups. Even if climate shocks can lead to new alignments between pro-climate action groups, they may still be weaker than the anti-climate groups that have opposed policy historically. Extreme weather may focus the agenda on policy reforms, but as Birkland (1998) notes, while focusing events can trigger interest group mobilization, they can also prompt countermobilization. Pro-climate groups still face an uphill battle. Other mechanisms could further undermine climate policy, such as, to the extent that climate impacts increase political violence, they also decrease state capacity, though existing research disagrees about the scope of this mechanism (Koubi 2019).

A final consideration is that governments may compensate impacted groups or invest in adaptation following extreme weather. Healy and Malhotra (2009) show that citizens do not reward incumbents for preparedness spending and instead reward disaster relief. Similarly, Cohen (2021) and Giordono *et al.* (2020) demonstrate that governments may prioritize local adaptation measures over mitigation. Damages from climate change increase until global emissions reach zero, and governments may find themselves trapped repeatedly protecting groups from escalating damages rather than investing those resources in mitigation. However, as public understanding of climate change has increased, domestic publics should demand higher levels of climate action, not only disaster relief. I do not consider the protection versus reform choice, though future research may find this to be productive. With this caveat, I now discuss operationalizing the key variables and the identification strategy.

3. Data and estimation

3.1 Climate policy outcomes

Climate policy's key objective is to reduce emissions, but policy has relatively weak leverage over emissions in the short-term. As physical impacts from climate change have negative economic effects, the former will have indirect effects on emissions that pass through direct economic effects. This suggests studying climate policy reforms rather than emissions levels. There is no single, best measure of climate policy because governments set climate policy in many ways. Therefore, I evaluate 11 measures that have been analyzed in the existing literature (listed in table APP-1).[2]

Carbon pricing is the most prominent climate policy, and has been adopted in thirty countries. Carbon pricing varies in terms of price levels ($/tonne of carbon dioxide) and sectoral coverage (prices across polluting sectors). As an outcome variable, I construct an emissions-weighted carbon price that aggregates sectoral prices into a continuous annual national carbon price. Economic damages and heightened public attitudes resulting from climate impacts could pressure regulators to tighten the cap on emissions or change market actors' beliefs about future cap tightening, and thereby increase the financial value of permits leading to a higher carbon price. The emissions-weighted carbon price could also rise if regulators expand the scope of a carbon pricing scheme to cover more sectors. Of course, extreme weather might lower economic growth and, with it, demand for electricity, thereby diminishing the value of pollution permits.

Governments often eschew carbon pricing to set other kinds of legislation, such as energy efficiency or technology standards. The Grantham Research Institute on Climate Change tracks national climate change policies, and catalogues climate-specific national laws.[3] I take an annual count of the number of operating national climate laws, including amendments, as an outcome. I supplement this data with binary measures of renewable energy policies, such as whether a country has a national renewable electricity standard or a feed-in tariff (Baldwin *et al.* 2019). Since many of these policies will aggregate into a greater role for renewable energy in electricity generation, I also examine as a policy outcome each country's annual share of electricity generated from renewable sources.

Designing, drafting, and adopting new climate regulations necessarily takes time, so the link between climate impacts and policy may not be contemporaneous. Nonetheless, some climate reforms can be initiated more quickly, especially in international policy. The long intervals between international negotiations over GHG mitigation targets (roughly, once a decade) place them outside the scope of this study. However, annual public climate finance flows provide a timely, and possibly more responsive, policy outcome. Part of climate finance's promise is that mitigation projects in developing countries provide more cost-effective abatement than projects in developed countries. Developed countries are also expected to provide increasing amounts of climate finance under global climate treaties. Developing countries that experience climate impacts may advocate for more climate finance. Even if developing countries are frequently restricted by aid allocation rules, there has been a concerted push since the mid-2000s to have donors provide aid that is aligned with recipients' development priorities. Extreme weather, by causing economic damage and changing public opinion, can act as a focusing event in developing countries leading them to upgrade climate finance within their aid priorities. Donors may provide climate finance for mitigation or adaptation projects in foreign countries, and these projects are categorized as either 'principally' related to addressing climate change, the more inclusive category of 'significantly' related, or not climate -related. I evaluate four measures of climate finance – provision by donors and receipt by recipients separately, and principal and total finance flows separately at the country-year level.

Other aspects of international climate policy may be adjusted even more quickly. Countries experiencing negative physical impacts from climate change may choose to send a larger delegation to the annual United Nations climate summits, as a reflection of climate change's heightened domestic salience. States may also reform their climate policies through participation in the myriad climate institutions states have created outside of the UN process to address climate change. The majority of these institutions are less formal than the UN climate treaties, and therefore allow for quicker participation because they do not require domestic ratification. To measure these international outcomes, I take annual counts of the size of national UN climate delegations and membership in climate institutions from published research (Kaya and Schofield 2020, Rowan 2021).

Climate policy presents a range of opportunities for reforms. These policy outcomes vary in their complexity, costs, and national versus international orientation. Some policies, such as designing a new carbon pricing system, may require substantial adjustments of local regulations, while others, such as adopting a feed-in tariff, are more incremental. More complex policies may seem more costly, but this is not necessarily always the case, as choosing to provide more climate finance could increase financial commitments, but not necessarily complexity, particularly if using existing multilateral institutions. Furthermore, governments may hesitate to adopt policies that impose domestic costs while creating diffuse international public goods, such as carbon pricing; however, other policies generate more local benefits in comparison, such as the capacity-building and expertise developed through membership in climate institutions. The latter policy outcomes may be more responsive to weather shocks, as governments adopt policies to address climate change, while also minimizing domestic costs. This allows for an examination of policy reforms across several important dimensions, though inevitably some topics are neglected, particularly climate adaptation measures, which scholars have struggled to measure across jurisdictions.

3.2 Climate impacts

Physical impacts from climate change manifest in many ways, such as flooding, heat waves, and storms. Natural scientists are increasingly able to attribute changes in the frequency and intensity of these events to anthropogenic climate change. To understand the effect of physical impacts from climate change on climate policy, I examine temperature shocks and natural disasters separately.

For temperature, I use temperature reanalysis data to obtain a population-weighted measure of average daily national temperature (Hersbach *et al.* 2020). The spatial distribution of weather stations leaves gaps in coverage, especially in poorer and warmer countries, such that the observation record alone omits a crucial part of the temperature distribution. Climate scientists fit climate models to the fully-observed data and then estimate the local weather conditions to fill these spatial gaps. This yields a continuous and consistent measure of temperature at the local-day level, which I aggregate to the country-level using population weights. Using population weights rather than equal area weights is common practice, and leads weather measures to better reflect the conditions where most people live and most economic activity takes place (Dell *et al.* 2014).

For natural disasters, I use the Emergency Events Database (EM-DAT). I subset the natural disaster data to include only events affected by climate change in the 'meteorological' (e.g., storm), 'climatological' (e.g., wildfire), and 'hydrological' (e.g., flood) categories. I take a count of the total number of annual natural disasters within a country, and a second measure of the number of persons affected by disasters. While a measure of direct economic costs may be more consonant with the theoretical mechanisms outlined above, nearly two-thirds of natural disaster events in EM-DAT have missing cost figures. This missing data is concentrated in developing countries and, therefore, relying on cost measures would introduce measurement error.

3.3 Research design and estimation

How can we estimate the effect of extreme weather on climate policy? Consider first a cross-sectional research design, predicting climate policy outcomes as a function of national average temperatures. In this setup, any regression coefficient for temperature would be biased to the extent that average temperature is correlated with unobserved factors that also influence policy – a familiar case of confounding. For example, if hotter climates influence the quality of local political institutions and institutions affect policy outcomes, then not controlling for institutions produces omitted variable bias, yet controlling for institutions in the cross-section will eliminate the effect of temperature, even if temperature is the fundamental cause of both – an instance of over-controlling.

We might instead compare a country that experiences a single extreme weather event to one that does not to estimate the effect of extreme weather on climate policy. However, risk from extreme weather varies across countries, and risk covaries with many unobservable factors that also influence policy. The precise timing and severity of a temperature shock may be random – a draw from the (shifting) distribution of local climate – but if the treated unit is consistently exposed to these impacts while the controls are not, then units will have different potential outcomes that need to be accounted for. Places that do and do not experience climate impacts differ systematically in many ways that we cannot observe, which returns us to the prior endogeneity problem.

The key empirical task is to identify exogenous variation in extreme weather. The two-way fixed effects estimator solves this problem by comparing each country to itself over time. Consider the following econometric model:

$$\text{Policy}^k_{i,t} = \beta\text{Temperature}_{i,t} + \gamma_i + \delta_t + \theta_i t + \rho\mathbf{W}\text{Temperature shock}_{i,t} + \in_{i,t}$$

where k indexes a measure of climate policy (described above), \$i\$ indexes countries, t indexes years, γ_i are country fixed effects (dummies), and δ_t are year fixed effects. Temperature enters the model as a measure of local temperature levels (e.g., annual average, etc. – discussed below), while γ_i nets out that country's mean temperature from that observed temperature, and \$ \gamma_t\$ nets out global temperature trends. The remaining variation in temperature used to explain policy outcomes is year-on-year local temperature anomalies, which are temperature shocks. This estimation strategy allows the effect of temperature to be identified through deviations in national temperature from country- and year-specific means.

Concurrently, γ_i absorbs all unit-specific time-invariant factors that influence climate policy – such as, uneven vulnerability to climate impacts – while

δ_t controls for all time-varying unit-invariant common shocks – such as, the adoption of global climate treaties. I add unit-specific linear time trends $\theta_i t$ to allow weather and climate policy to trend together via unobserved unit-specific, time-varying factors. I also include a spatial term $\rho\mathbf{W}\text{Temperature shock}_{i,t}$ built from an $N \times N$ row-standardized connectivity matrix that measures the annual weather shocks in state i's contiguous neighbours. As weather shocks are correlated in space, failing to include a spatial term could bias estimates by mistakenly attributing unmeasured regional shocks to global annual shocks. Now, ρ controls for spillovers from common regional shocks and isolates the independent effect of local weather shocks on local climate policy. Dell *et al.* (2014) provide an overview of this technique's strengths for studying the effects of climate change on economic and social outcomes. The estimation is the same for natural disasters, replacing measures of temperature with natural disasters.

Figure 1 illustrates the identification of temperature shocks. I plot average annual temperature from 1900 to the present for all countries, with annual values demeaned from their pre-1980 country-specific means. The left-axis gives the deviation in Celsius, while the right-side benchmarks observed values to the standard deviation of within-country temperature in the pre-1980 period. Many of the recent temperature shocks are substantively large, up to 5 and 6 standard deviations. Global mean temperature is given in black – note that the standard deviation of global temperatures is much smaller than that within countries ($\sigma_{Global} = 0.17; \sigma_{Country} = 0.48$) such that current global mean temperatures are already over 5 standard deviation

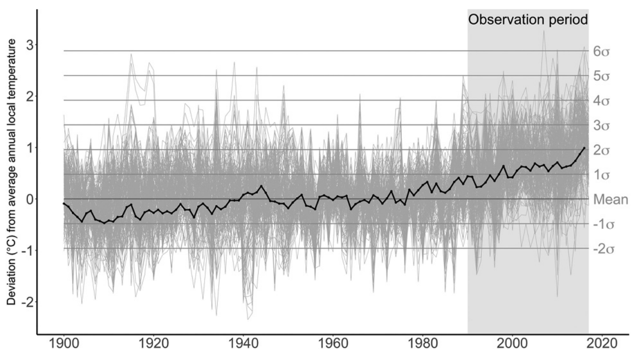

Figure 1. Global and national temperatures rise over time. Tracings are each country's average annual temperature, demeaned from their pre-1980 historical period. Standard deviations of within-country annual temperature are given on the right-hand side (σ = 0.48 °C), calculated on the pre-1980 period. Recent country-level annual temperature shocks have exceeded 6 standard deviation changes from local historical averages. Global average temperature is plotted in black. Identification of temperature shocks with the two-way fixed effects estimator is obtained through the within-country annual anomaly, netting out global trends.

increases compared to the pre-1980 period. The two-way fixed effects estimator converts measured annual temperature levels into ‘temperature shocks’ by demeaning temperature from national averages and global trends.

I use versions of equation 1 to estimate the effect of temperature shocks on climate policy. The observation period runs from 1990 to 2019, but the sample of years varies slightly across models due to data availability for each policy outcome. The number of countries also varies across samples, with some measures tracking outcomes for 190 countries, but others are more limited. I calibrate a power analysis to detect an effect of the same size as a high-quality study published in *Science* by Hsiang *et al.* (2017), which found a + 1 $^{\circ}$C annual temperature shock cuts 1.2 percentage points off annual economic growth in the United States, which implies a standardized effect of −0.238. This power analysis calls for a minimum of 555 observations, which is exceeded for eight of eleven outcome variables.[4] Models are estimated separately for each of the $k \in \{1, \ldots, 11\}$ policy outcomes. Adjustments for multiple comparisons are presented in every analysis. Binary policy outcomes are estimated as a linear probability model. I analyze several extensions of this baseline model to consider different functional forms, heterogeneous effects, levels of analysis, and measures of extreme weather.

4. Results

4.1 Effect of temperature shocks on national policy

Table 1 presents the results from statistical tests of the effect of temperature shocks on climate policy. I begin with a one-year lag of temperature, two measures of temperature (average annual temperature and average hottest season temperature), and 11 measures of climate policy. Dependent variables are standardized before the estimation to facilitate comparison across indicators, while the temperature variables are measured in Celsius.

I find little evidence that national governments reform their climate policies following local temperature shocks. I find a mix of positive and negative coefficients that are not statistically significant at conventional standards. Columns 3 and 5 report standard p-values. Since I evaluate a large number of outcomes, the probability of finding at least one statistically significant result is high even if no underlying relationship exists. Applying a Bonferroni correction to account for multiple comparisons lowers the critical threshold from nominal $\alpha = 0.05 \rightarrow 0.0045$. The coefficients for annual temperature shocks on climate finance that developing countries receive are statistically significant at this threshold. Note that these coefficients take the opposite direction than expected, as temperature shocks lead to less climate finance. A one standard deviation

Table 1. No systematic average treatment effect of temperature shocks on national climate policy. Results for 11 OLS models with country and year fixed effects; temperature shocks lagged by one year; and standard errors clustered by country. Outcome variables are standardized prior to estimation. Temperature levels measured in Celsius. Uncorrected p-values reported; Bonferroni adjusted nominal $\alpha = 0.05 \longrightarrow 0.0045$ for 11 outcome variables.

	Annual		Hottest season			
Climate policy outcome	β Temp.	p-value	β Temp.	p-value	Countries	Years
Climate laws	0.018	0.129	0.003	0.713	187	1990–2018
Emissions-weighted carbon price	−0.070	0.045	0.023	0.121	27	1990–2018
Renewable electricity generation	−0.011	0.247	−0.001	0.817	188	1990–2015
Feed-in tariff	0.021	0.492	0.016	0.379	61	1991–2013
Renewables quota	0.053	0.419	0.055	0.189	19	1991–2013
COP delegates	0.031	0.394	−0.022	0.089	183	1995–2015
Climate institutional memberships	−0.009	0.336	−0.004	0.505	188	1990–2015
Climate finance provided	−0.059	0.383	−0.033	0.413	43	2012–2017
Climate finance (principal) provided	0.014	0.726	0.010	0.706	43	2012–2017
Climate finance received	−0.115	0.001	−0.042	0.070	142	2000–2017
Climate finance (principal) received	−0.160	0.000	−0.047	0.062	142	2000–2017

temperature shock, after considering the within-unit and within-year variation that the two-way fixed effects estimator removes and the log-transformation of the climate finance measure, is associated with a 19% decline in finance received [−8%, −29%; Bonferroni-corrected 95% confidence intervals]. This is a large substantive effect, but it is not robust across lags and temperature specifications (Figure 2). In later analysis with natural disasters, the coefficient switches sign.

One concern with these findings may be that reforming policy takes time. A model that only allows for a one-year lag between shocks and policy outcomes may poorly represent slower data generating processes. Therefore, I substitute the one-year temperature lag with two- and three-year lags. Figure 2 shows that only three of the 66 ($\approx 0.045\%$) estimates (11 outcomes $\times$ 2 temperature measures $\times$ 3 lags) are statistically different from zero, and all are negatively signed.

The null findings in Table 1 are not driven by insufficient time between temperature shocks and policy outcomes. Another possibility may be that climate policy reforms may be influenced by existing policy levels. I investigate this possibility by including a lagged dependent variable into the models, and find that the results are consistent across both specifications (see figure APP-1). One important limitation of these models arises from the

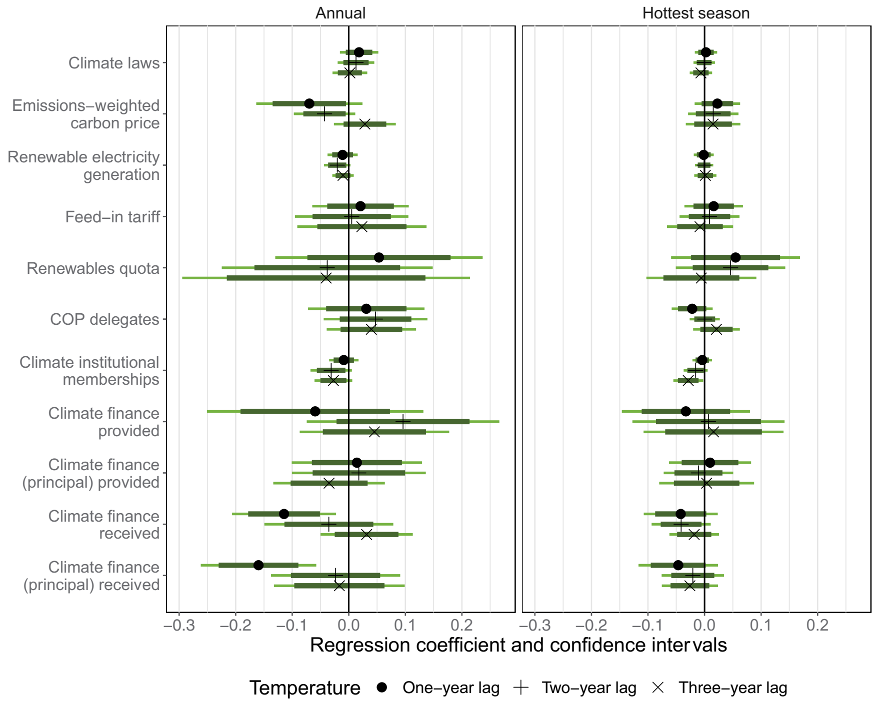

Figure 2. No systematic average treatment effect of temperature shocks on national climate policy for different lag structures. Dependent variables are standardized prior to estimation, and effect sizes are for a + 1 °C temperature shock. Point estimates are coefficients from OLS models with country and year fixed effects, lagging temperature by 1, 2, and 3 years. Horizontal bars are uncorrected 95% confidence intervals (thicker, dark green) and Bonferroni-corrected confidence intervals for 11 comparisons (thinner, light green).

need to use high-dimensional time fixed effects for identification, which means they do not capture long-term adaptations.

Another consideration with these findings may be that, while the estimates may not be statistically distinguishable from zero, they could nonetheless be consistent with large substantive effects. If the effect of temperature shocks is imprecisely estimated (i.e., large confidence intervals), that may indicate causal heterogeneity and model misspecification. I interpret the substantive effects by benchmarking the effects to existing findings in Hsiang *et al.* (2017), where a + 1 °C shock cuts GDP growth by −0.58 standard deviations. In Figure 2, temperature is measured on the same scale and the outcomes variables are all standardized, so the effect of temperature shocks can be compared across papers directly. The largest substantive coefficient estimate in the analyses in Figure 2 is −0.160 and the largest positive estimate is 0.096, roughly one-quarter or one-sixth the size of the effect recovered in Hsiang *et al.* (2017). This suggests that the estimates presented here are relatively precisely estimated negligible effects of temperature shocks on climate policy.

Some readers may also question whether focusing on temperature averages discards useful, more granular information about temperature extremes. I address this by replacing average temperature with a set of counts of the number of days a country spends in different temperature bins, highlighting extremely hot days. I re-code hottest season daily temperature into a count of days within 5 ˚C intervals (i.e., days below 10 ˚C, 10–15 ˚C, etc., up to >35 ˚C.). This measure allows for a non-linear effect of temperature and an independent effect of extremely hot days. The estimating equation is given in the appendix (equation APP-2).

Figure 3 presents this model where individual hot days can affect the number of climate laws adopted and climate institutional memberships – two indicative outcomes. I find no systematic evidence that climate policy responds non-linearly to temperature extremes. The point estimates summarize the effect that one additional day in a temperature bin has on climate

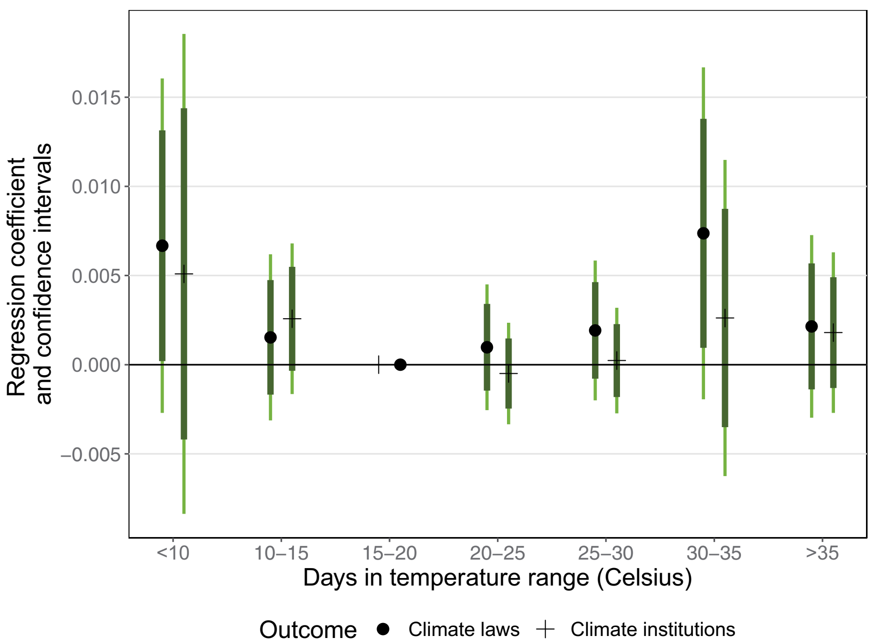

Figure 3. Non-linear effect of temperature across different realizations of temperature within countries. Point estimates are coefficients from OLS models with country and year fixed effects, lagging temperature by one year. Interpretation is the effect of an additional day in a temperature bin compared to a day in the 15–20 ˚C bin. Outcomes are for the number of climate laws and climate institutional memberships; standardized prior to estimation.

policy compared to an additional day between 15–20 °C (the omitted reference category). We see that the point estimates hover close to zero for most temperatures, but fluctuate at higher temperatures. The estimates are relatively consistent across both outcomes, suggesting that there is no meaningful heterogeneity in the effect of temperature on each policy. In figure APP-2, I plot the *t*-statistics for all 11 outcome variables. Only 2 of the 66 (≈ 3%) coefficients are statistically significant, and there is no obvious trend in the distribution of *t*-statistics across temperature bins.

A single adverse temperature shock may not have much of an impact on policy, but the effect of a temperature shock could be larger if a jurisdiction has experienced several recent shocks. I investigate this possibility with a new cumulative temperature shocks indicator, that first standardizes annual temperature at the national-level as *z*-scores, then cumulatively sums positive scores since 1990. Following the guidance of Dell *et al.* (2014, eq. 7), I interact this cumulative shock indicator with last year's temperature to allow the effect of a temperature shock to depend on recent temperature shocks (equation APP-3).

Figure APP-3 plots the linear marginal effect of last year's hottest season's temperature across values of the cumulative temperature shock moderator. First, the overall effect is negative: temperature shocks decrease policy reforms when there is a large amount of accumulated temperature hazard. Second, there is large uncertainty in the estimates. Figure APP-4 presents the binning estimator results for all outcome variables, and only 2 of the 33 (≈ 6%) coefficients have a marginal effect different from zero. Consistent with the main findings in Figure 2, I find little evidence that governments respond to cumulative temperature shocks or to past realizations of temperature by strengthening their climate policies.

In the appendix, I extend this analysis to the subnational level in American states' climate policies. Many underlying differences across countries are eliminated in this subnational design that only allows within-case variation – or 'within–within-case' variation, given the country fixed effects. Extreme weather events may also have stronger local effects than national ones, given that weather shocks can be highly local. However, I find no consistent effect for temperature shocks on three subnational climate policies.

4.2 Natural disasters and climate policy

The findings for temperature shocks are not necessarily indicative of the effect of all kinds of physical impacts from climate change. While research on temperature shocks is the most developed empirically, recent studies find that other extreme weather, such as wildfires and flooding, can influence climate behaviour (Hazlett and Mildenberger 2020, Baccini and Leemann

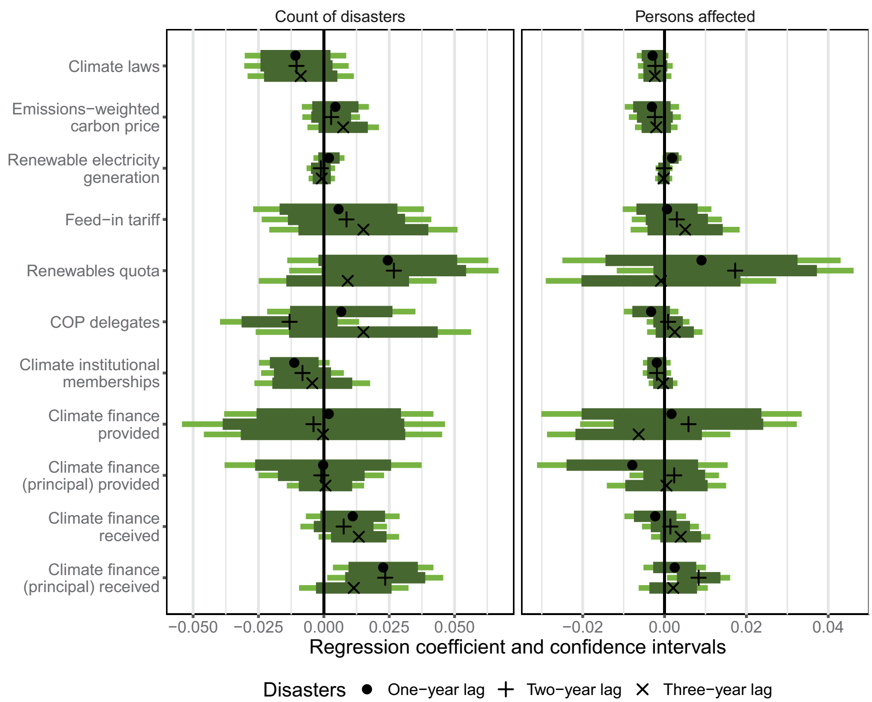

Figure 4. No effect of natural disasters on climate policy. Left facet counts the number of natural disasters annually within a country, while right facet counts the number of persons affected by natural disasters. Models as per Figure 2

2021, Peterson 2021). The physical impacts of other forms of extreme weather may be more disruptive and vivid than annual temperature shocks, potentially creating a stronger focal point for leveraging policy reforms.

I use the same estimating equation as for temperature shocks (equation 1), replacing temperature levels with a count of natural disasters and a measure of the number of persons affected by disasters annually. Figure 4 shows that neither measure of natural disasters is consistently related to climate policy reforms. The only statistically significant effect is for climate finance received (principal definition), where a one standard deviation increase in local natural disasters appears to increase the climate finance that developing countries receive by roughly 14% [2%, 27%], but the effect is not consistent across specifications, and is of the opposite sign as for temperature shocks in Figure 2.

4.3 Heterogeneous effects

The theoretical argument provides reasons to think the effect of extreme weather may be stronger in some political contexts. Previous studies have found that democracies have stronger climate policies than non-democracies, perhaps because democracies are more responsive to broad-based political demands (Bättig and Bernauer 2009, Peterson 2021). Wealth may also moderate the effect of temperature shocks, wherein richer countries are capable of absorbing negative economic effects of extreme weather to reform at the same time, but poorer ones are not. The average treatment effect in a global sample may mask causal heterogeneity if certain types of countries are more responsive. Accordingly, I investigate whether there are heterogeneous treatment effects by splitting the data using country-level covariates (equation APP-4). I distinguish democratic countries from non-democratic countries using a binary indicator of political regimes that allow for both political contestation and participation. I dichotomize GDP per capita at roughly the 70th percentile in 1990, near the wealth levels of Argentina, South Korea, and Turkey to investigate heterogeneous effects in rich and poor countries.

Figure 5 presents effects separated by regime type and wealth. Overall, there is no consistent heterogeneous effect of temperature shocks on climate policy. Note that since poorer and autocratic countries have less climate policy generally, and with these relationships being imprecisely estimated on small samples, I remove analyses with fewer than 5 countries leading to some empty cells. Results are similar for continuous moderators in the appendix (see figure APP-5).

Overall, I find no indication that democracies are responsive to adverse climate impacts, and this divergence from existing findings merits closer explanation. The closest study to mine is Peterson (2021), on the effect of natural disasters on climate policy. Both studies use similar two-way estimation techniques. The sample populations differ slightly due to data availability, but in common samples, the null findings presented here persist (figure APP-6). Therefore, the main difference should lie in the outcome variables. Peterson (2021) uses an expert survey on national climate policy that is a subindicator from the Climate Change Policy Index. While expert opinion may be better able to account for local nuance, it may also be subjective, have uneven coverage across countries based on variation in expertise and access, and may be inconsistent as respondents, questions, and methodologies change over time. Indeed, the Climate Change Policy Index acknowledges changing their methodology over time, and that they use different questions for Group of 20 countries than others. The outcome measures that I use in this paper are generally available for a wider range of countries and years, derive from more transparent methodologies and public agencies, and link more closely to climate policy measures considered by the literature. This is not to say that the expert survey outcome measure is ‘wrong’, but it may capture a different dimension of climate mitigation policy than the adoption of specific climate programs.

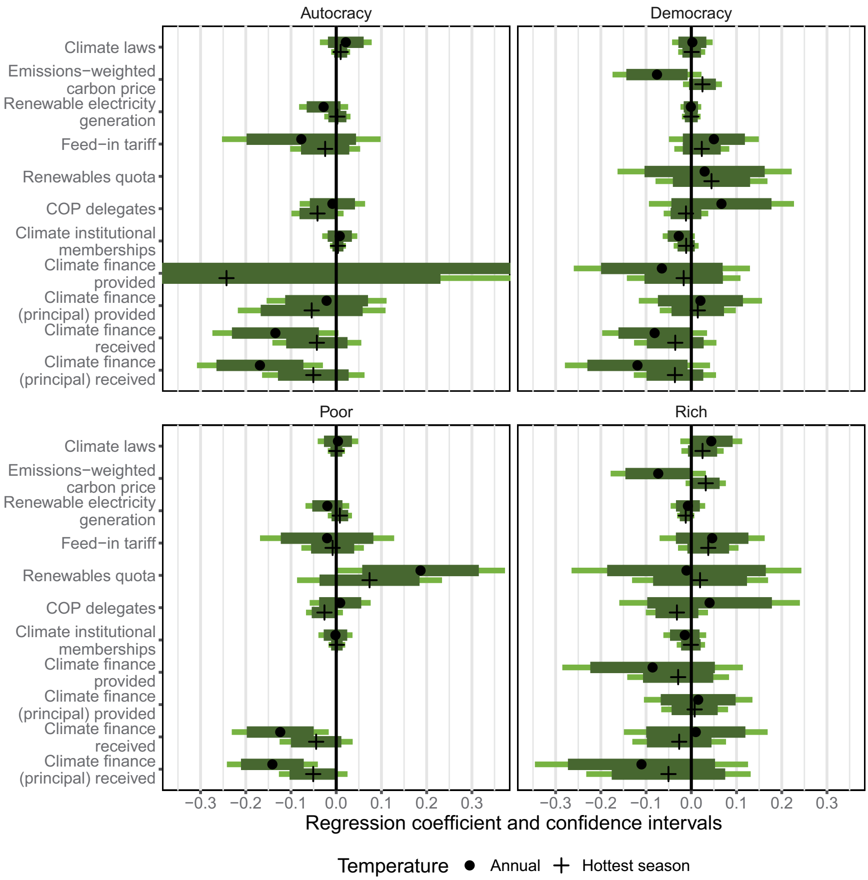

Figure 5. Heterogeneous effects of temperature by regime type. OLS models as in Figure 2, estimated on datasets stratified by.

5. Conclusion

Negative climate change-induced impacts are expected to increase this century because current policies allow high levels of future emissions. Climate politics have been gridlocked for decades. Accordingly, researchers are interested in identifying drivers that could cut through fractious climate politics and catalyze greater climate action. I argued that extreme weather events may be good candidates. They are external shocks to local politics that translate the abstract problem of global warming into the present, shift public attitudes on climate change, and induce myriad economic damages. As such, they may act as focal points that help disparate groups in society recognize their common pro-climate interests and mobilize for reforms.

However, I find no systematic evidence that climate impacts enable climate mitigation policy. This holds across a range of (1) climate policy outcomes at the international, national, and subnational levels, (2) empirical specifications, (3) samples, and (4) measures of climate impacts. Figure APP-7 plots the t-statistics from the estimates in Figures 2 and 4, and APP-8. Only 6 of 150 (4%) coefficients for temperature or natural disasters are statistically significant at the Bonferroni-corrected thresholds: three on the lower tail and three on the upper tail, roughly in line with the $\approx$ 8 we would expect under a null hypothesis with 95% confidence intervals. Even in contexts where we would expect the strongest demands for climate action – in jurisdictions with recent negative experiences of climate damages and democratic political institutions that allow for voice and accountability – reforms are not forthcoming. These findings contribute to a growing body of evidence showing the limits of external shocks for policy reforms. However, it is worth drawing attention to three important limitations of the analysis: the method's strengths for estimating short-term effects does not negate the possibility of long-term adaptations, the focus on average effects does not preclude a consideration of necessary and sufficient conditions, and the focus on mitigation policy does not necessarily imply a null relationship for other climate policy topics.

Given this serious gap in policy responsiveness, it is important to identify where in the causal chain the relationship breaks down. Given that the public opinion literature is already well-developed, the most useful future research might explore the relationship between weather shocks and interest group mobilization. How successful are pro-climate action groups at using extreme weather as focusing events? Does extreme weather also enable anti-climate groups to mobilize? A range of intermediate outcomes, such as legislative speech, policy proposals, and lobbying could shed light on this process. The null effects reported here matter because they help to characterize the disconnect between climate damages and climate policies, and open onto a range of inquiries into why.

Notes

1. Climate policy is often characterized into 'mitigation' policy to reduce greenhouse gas emissions or 'adaptation' policy to increase local resilience to climate impacts. I focus on mitigation policy and further references to climate policy refer to mitigation unless stated otherwise.
2. All variables and data sources are described in more detail in the appendix.

3. Note that executive actions from American presidents, such as President Obama's 2015 Clean Power Plan, are included.
4. The under-powered analyses are for the renewable electricity generation quota, and both measures of climate finance provided.

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