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# Climate Change and Political Participation: Evidence from India*

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**Abstract**

We study the effects of temperature shocks on electoral outcomes in Indian elections. Taking advantage of localized, high-frequency data on temperatures, we find that exposure to extreme temperatures the year before an election increases voter turnout, changes the composition of the candidate pool, and leads to different electoral outcomes (e.g. winning candidates are more likely to have an agricultural background). The effects are driven by reductions in agricultural productivity and are strongest in rural areas. We also show that temperature shocks increase the value voters place on agricultural issues and on policies which mitigate the effects of extreme temperatures, such as irrigation.

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# 1 Introduction

The earth's climate is warming, bringing with it an increase in the frequency and severity of extreme weather events, such as droughts, floods and periods of extreme heat. These shocks have been shown to reduce productivity (Somanathan et al., 2021) - especially in the agricultural sector (Burke et al., 2015) - and increase mortality - especially in rural areas (Burgess et al., 2017). Rural inhabitants of poor countries are particularly vulnerable due to their reliance on agriculture for employment and income and their relative lack of access to institutions and markets that can mitigate risk and smooth consumption, such as financial and insurance markets (Langsdorf et al., 2022).

Nevertheless, even poor inhabitants of rural areas have ways of responding to climate change-induced shocks to agricultural productivity. For example, farmers have been shown to respond to shocks by altering their choice of crops, adjusting their use of inputs, and disposing of assets in order to smooth consumption (Aragón et al., 2021; Garg et al., 2018; Liu et al., 2021). What is not well understood is the extent to which citizens in developing countries may be responding to climate change related weather shocks through the political process. Put differently, can electoral democracy provide a means for responding constructively to the pressures of climate change in developing countries? These are the questions we aim to address in this paper.

We focus on the case of India, the largest democracy in the world and a country with very high levels of political participation (Kasara and Suryanarayan, 2015, Pande, 2003). Our measure of climate change-related weather shocks is based on an area's degree of exposure to high temperature events, which are particularly bad for agricultural outcomes. We take advantage of localized, high-frequency (i.e. daily) data on land surface temperatures to measure the number of "harmful degree days" (HDDs) in the previous year or agricultural season, thus capturing an area's cumulative exposure to extreme temperatures. We construct these measures for State Legislative Assembly (SLA) Constituencies in India between 2008 and 2018.[1] We then regress various political outcomes (e.g. voter turnout) against our measures of HDDs along with a variety of controls, including location and time fixed effects.

Our methodology follows the climate change literature and allows us to estimate non-linear effects of temperature on agricultural productivity (Burke et al., 2015, Hsiang et al., 2016, Schlenker and Roberts, 2006a, 2009), which in turn allows us to test for non-linear behavioral responses to extreme temperatures (Aragón et al., 2021, Carleton and Hsiang, 2016,

[1] India currently has about 4,000 SLA constituencies.

Jessoe et al., 2018, Taraz, 2018). We study three main types of outcomes: i) the behaviour of voters (in particular, voter turnout), ii) the behaviour of political candidates (e.g. decisions to run and subsequent changes in the composition of the pool of political candidates), and iii) electoral outcomes (e.g. election results, including which types of candidates are more likely to win in response to such weather shocks). In order to understand the mechanisms behind our results, we also look at the effects of extreme temperature shocks on stated voter preferences, using data from a large survey of Indian voters.

Our results first confirm the existence of a sharp, non-monotonic effect of temperatures on agricultural productivity: warmer temperatures - up to a point - boost productivity, but more days with average temperatures above a threshold (roughly 36°C) sharply lower it. That is, more HDDs have a negative effect on agricultural productivity - a result that has been documented in the literature previously. Next, we turn to our analysis of political outcomes, showing that the effect of HDDs on voter turnout exactly mirrors the effect of HDDs on agricultural productivity, with harmful weather over the previous year/growing season driving voters to the polls in an identically non-monotonic fashion. We also show that HDDs affect the composition of the candidate pool by, for example, inducing marginal candidates to drop out. Finally, we document an effect of HDDs on political outcomes, with, among other things, incumbents being penalized and candidates from agricultural backgrounds being more likely to win.

Our results are consistent with a very simple conceptual framework wherein high temperatures reduce incomes, which - in a context of diminishing marginal utility of consumption and political candidates providing pecuniary benefits to certain segments of citizens if elected - induces more citizens to vote. At the same time, given that contesting for elections in India involves a potential pecuniary cost - namely, candidates must stake a deposit[2] which is not returned unless they obtain at least one sixth of the vote - the decrease in incomes due to high temperatures is expected to reduce the incentives of marginal candidates to run for election.

Turning to mechanisms, we provide evidence that the effects we observe are due to the fact that high temperatures negatively affect agricultural productivity. This is suggested first by the aforementioned fact that the effect of HDDs on turnout precisely mirrors the specific non-monotonic pattern observed between HDDs and agricultural productivity. In addition, we show that the effect of HDDs on turnout is larger in areas that are more dependent on agriculture, whether measured by the share of rural population or the share of

[2]Deposits are 10,000 Rs., approximately 125 USD.

non-farm employment. Since 90% of the elections in our sample take place in constituencies where the share of the rural population is larger than 50%, this means that elections are effectively decided in rural areas, by voters who suffer most directly from the effects of high temperatures on their economic activities. We then conduct a mediation analysis to decompose the total effect of high temperatures on political outcomes into a direct effect and an indirect effect through agricultural productivity. For all three of our primary outcomes (turnout, the number of candidates standing, whether an agricultural candidate wins), the percentage of the total effect of HDDs that can be attributed to the effect of HDDs on agricultural productivity is between 72% and 88%.

Finally, we investigate whether our findings can be explained by the role that politicians play in helping to mitigate the effects of temperature shocks on agriculture. First, we use data from a large scale survey of voters in 2014 to test whether temperature shocks affect voters' preferences regarding environmental issues, agricultural policies and candidate characteristics. We find that they do: an increase in HDDs makes voters more likely to list irrigation programmes, agricultural loan availability, electricity for agriculture and "environmental issues" as being highly important. These results establish the fact that extreme temperature shocks changes voters' preferences and increase the salience of agricultural issues.

So what can politicians do for their constituents? One option is to invest in irrigation, which has been shown to moderate the effects of high temperatures on agricultural productivity (Tack et al., 2017 and Zaveri and B. Lobell, 2019). We compute the percentage of area that is irrigated at the assembly constituency level using data from Ambika et al. (2016), and find that, as expected, irrigation does mitigate the effects of HDDs - not only on agricultural productivity but also on turnout. We then take advantage of the fact that some agricultural candidates win in close elections against candidates with other backgrounds to show - through a regression discontinuity design - that constituencies with agricultural candidates are more likely to invest in irrigation after these candidates are elected. This may explain why HDDs increase the likelihood of agricultural candidates winning: voters care more about agricultural issues like irrigation, and they know that agricultural candidates are more likely to make the relevant investments.

With this paper we contribute to a growing literature analyzing the effects of climate change and climate change related weather shocks on various outcomes in developing countries (Dell et al., 2014, Guiteras, 2009, Burgess et al., 2017, Aragón et al., 2021, Colmer, 2020, Garg et al., 2018, and Somanathan et al., 2021). Another strand of literature has studied the effects of climate change related shocks on the behaviour of politicians regarding environmental policies, but the findings vary - and the literature has been largely focused on developed countries (Gagliarducci et al., 2019, Sambrook et al., 2021, Herrnstadt and Muehlegger, 2014, Peterson, 2021). For example, Gagliarducci et al. (2019) show that US members of Congress whose districts are hit by a hurricane are more likely to support bills promoting climate change related regulation in the following year. In contrast, Rowan (2022) conducts a cross-country analysis and finds that weather shocks at the country level don't seem to impact national level climate policy.

Our paper adds to the literature by showing evidence of the extent to which democratic politics may provide an effective means for responding to climate change. We provide estimates of the political responses to climate change related shocks in a developing country and by analyzing the mechanisms behind these political responses. This is significant because India is the largest democracy in the world and shares many characteristics with other developing countries, such as a warmer climate and a greater reliance on agriculture, both of which make it more exposed to temperature shocks.

Perhaps the two most closely related papers are Besley and Burgess (2002) and Tarquinio (2023), even if they do not focus on the effects of extreme temperatures or analyze outcomes such as political participation (e.g., turnout, candidate selection). Besley and Burgess (2002) show that Indian state governments are more responsive to weather-related economic shocks when facing greater electoral accountability and media scrutiny. Relatedly, Tarquinio (2023) finds that government interventions such as drought relief are distorted by the political incentives of the state's ruling party: again, greater electoral competition in an area increases the probability that it will receive drought relief.

There is a separate literature which has explored the effects of other economic shocks on voter turnout in elections. These studies - which mainly focus on developed countries and use unemployment to measure shocks - find that the effect is context dependent Burden and Wichowsky, 2014, Guiso et al., n.d.). One exception is Cole et al. (2012), which shows that in India voters punish incumbent politicians for negative economic shocks due to rainfall, but do so less if the government responds vigorously to the crisis.

The rest of the paper proceeds as follows. Section 2 discusses the background and conceptual framework. Section 3 discusses the data and methodology. Section 4 presents the results, while Section 5 discusses the mechanisms. Section 6 concludes.

# 2 Background

## 2.1 Indian Elections

India is the world's largest democracy, with a parliamentary style of administration at both the federal and state levels. In our analysis we will focus on elections to the State Legislative Assemblies (SLA). In single-member seats of the SLAs, elections are held every five years using a first-past-the-post method. Each candidate for the state elections is elected in an electoral constituency, with borders drawn by the Election Commission of India. We use data from 2008, when the last delimitation order was implemented, so that constituency borders remain fixed throughout our period of analysis. While state elections take place every five years, they happen at different points in time, and in different months, which allows us to account for temporal variation in a flexible manner.

State governments are in charge of various development policy areas in India's federal system, including law and order, health and education, agricultural development, and village council financing. Party and independent candidates run for elections and while there are many political parties in India, there is no specific political party which exclusively represents the needs of those working in agriculture. Party leaders choose their candidates in each constituency in a selection process that is not transparent, but parties tend to value the candidates' recognition within the constituency, prior service to the party, financial resources, caste identity and internal party support (Bhalotra et al., 2018).

## 2.2 Conceptual Framework

In this section of the paper, we provide a brief sketch of the conceptual framework which undergirds our empirical analysis. Our framework aims to aid in understanding how a climate shock such as an increase in harmful degree days (HDDs) might affect 1) a citizen's decision regarding whether or not to turn out to vote, and 2) a politician's decision regarding whether or not to run for office. We consider each aspect of the problem separately and in partial equilibrium. In both cases, the mechanism we focus on is driven by diminishing marginal utility of consumption: a reduction in income (as a result of more HDDs) will increase the marginal benefit of pecuniary payoffs, leading to greater turnout among voters and fewer candidates running for office – under the assumptions sketched out below.

First let us consider the decision of citizens regarding whether or not to participate in the political process through voting. We assume that voting is costly - and that the cost is non-pecuniary - but that it can entail certain (perceived) pecuniary benefits. The cost of voting includes not only the cost of physically going to vote, but also the intellectual effort involved in learning about who is running and about how the candidates' platforms differ from one another. We imagine that there might be a perceived benefit of voting if a) voters believe that their vote has some positive probability of being influential, and b) their preferred candidate will implement financially beneficial policies (e.g. an investment in irrigation that will improve agricultural outcomes).

In other words, we imagine that the (perceived) marginal benefit of voting is fundamentally pecuniary, while the marginal cost of voting is non-pecuniary. Assuming voters' preferences are characterized by diminishing marginal utility of consumption, the marginal (net) benefit of voting will be declining in income, since the (pecuniary) marginal benefit is declining while the marginal cost is constant in income (as the cost is non-pecuniary).[3] Thus, if an increase in HDDs has the effect of reducing incomes for a given voter (due to a loss in agricultural output or a reduction in agricultural productivity), the marginal benefit of voting (and thus the likelihood of casting a vote) for such a voter would go up. There are two other testable implications of this argument: 1) An increase in HDDs should impact voters' rankings over various policies (e.g. it should increase the importance voters place on policies that improve agricultural outcomes, and especially those which mitigate the negative effects of HDDs), and 2) an increase in HDDs should increase the vote share for candidates who are perceived as being able to improve economic outcomes for those adversely affected (this could include candidates with agricultural backgrounds if they are the ones who are most likely to implement such policies, as we later show is the case).

Next, we consider the decision of a politician regarding whether or not to run for office. We imagine that gaining office may entail certain benefits (potentially pecuniary and non-pecuniary in nature), and that running carries an explicit pecuniary cost. In particular, political candidates in our empirical context must provide a 10,000 Rs. deposit, which is forfeited if they lose with less than one sixth of the vote.

Again assuming standard curvature of the pecuniary component of a politician's utility function, a reduction in income will increase the marginal benefit from pecuniary payoffs and increase the marginal cost of a pecuniary loss (such as the expected cost of losing one's deposit). This means that, for marginal candidates (who are more likely to lose their deposit), the net marginal cost of running increases when facing a shock - such as an increase in HDDs

[3] We provide evidence that turnout is higher in more "backward" (i.e. poorer) areas in Table 4. See also Kasara and Suryanarayan (2015).

- that reduces their incomes (which may occur if their incomes are based on agriculture or are otherwise tied to the conditions of the local economy in a rural area). If the effect is large enough, it may lead to a reduction in the number of marginal candidates running for office. On the other hand, an increase in HDDs may increase the net marginal benefit of running for candidates who are more likely to win, if the expected pecuniary benefit of winning is high enough.[4]

Thus, the main takeaways from the frameworks sketched above are the following: an increase in HDDs which reduces incomes may be expected 1) to increase voter turnout by increasing the marginal benefit of voting (i.e. the expected pecuniary payoff is more valuable), and 2) to decrease entry of marginal political candidates by increasing the marginal cost of losing one's deposit. Two additional implications are: an increase in HDDs should impact the importance that voters place on 1) certain agricultural policies, and 2) candidates who are likely to implement the relevant agricultural policies.

# 3 Data and Methodology

## 3.1 Data

In order to conduct this study we combine data on political outcomes in Indian State Legislative Assemblies (SLAs) at the constituency level with satellite imagery data (containing information on agricultural and weather-related variables) and information on socioeconomic and population characteristics at the constituency level. The data on political outcomes in State Legislative Assemblies cover the period between 2008 and 2017 and come from Lok Dhaba (Ananay Agarwal et al., 2021). These data provide information on electoral outcomes and turnout, but also include some candidate characteristics such as political party, incumbency status and gender. We combine these data with affidavit information from SHRUG (Asher et al., 2020 and Prakash et al., 2019) and ADR (Association for Democratic Reforms). The latter provides information on other candidate characteristics such as criminal convictions, education, age and occupation.

We combine the data on political outcomes with high resolution satellite imagery data on climatic outcomes. There are two principal advantages of using satellite imagery data instead of monitoring station data: 1) their geographical coverage is broader and finer, allowing us to exploit variation at a very micro level, and 2) they are available at a high frequency, which is

[4] However, in this case the effect is unlikely to increase the number of such candidates running (since they are not likely to be marginal).

particularly important when calculating the effect of temperature shocks. The main variable we are interested in is Land Surface Temperature (LST), obtained from the MODIS tool aboard the Terra satellite.[5] The readings are processed to obtain *daily* measures of daytime temperature on a grid of 0.05 x 0.05 degrees, which is around 5.6 km squared at the Equator. These data are available from 2008 to 2017.

We also use data on agricultural yields (Annual Net Primary Production, NPP), which also come from the MODIS tool. These are provided at 30 arcseconds (approximately 1 km) and we use information on this outcome from 2008 to 2015. In most of our empirical specifications we control for local precipitation, which comes from the Climate Hazards Group Infra-Red Precipitation with Station data (CHIRPS) (Funk et al. (2015)) and is also available on a grid of 0.05 x 0.05 degrees between 2008 and 2017. All of these measures are aggregated at the Assembly Constituency level before being merged with the data on political outcomes.

In our exploration of mechanisms, we supplement our primary analysis with data on voter preferences and irrigation. Data on voter preferences are taken from the ADR-Daksh National Voters Survey, which is a survey of more than 250,000 respondents in 525 Parliamentary constituencies and was conducted in 2014, prior to the Lok Sabha elections of that year. The survey asks respondents about issues such as their priorities as voters and their perceptions regarding the Members of Parliament representing their constituencies. These data are averaged at the Parliamentary constituency level before being merged with the main data set at the State Legislative Assembly constituency level.

The data on irrigation are satellite-based measures taken from Ambika et al. (2016). Again, satellite based measures of irrigation are used because they offer the greatest scope, range and frequency. Some descriptive statistics - for all main variables - are provided in Table 1.

## 3.2 Non-linear effects of temperature

Several papers document non-linear effects of hot temperatures on agricultural productivity in rural India (Burgess et al., 2017, Costa et al., 2020, Taraz, 2017). To explore how this shock to rural incomes affects electoral outcomes we use daily Land Surface Temperature (LST) from MODIS in order to construct two measures of *cumulative exposure to heat*, as in Aragón et al. (2021), Deschênes and Greenstone (n.d.), Schlenker and Roberts (2006a,b). The first measure captures the harmful effect of extreme temperatures by aggregating the

[5] Moderate Resolution Imaging Spectroradiometer on NASA's Terra satellite.

Table 1: Descriptive Statistics

| | Mean | SD |
|---|---|---|
| Degree Days | 19.37 | (3.80) |
| Harmful Degree Days | 0.40 | (0.65) |
| Log median yields | 8.51 | (1.14) |
| Turnout | 71.25 | (12.21) |
| Number of candidates | 10.94 | (5.32) |
| Number of candidates with lost deposits | 6.56 | (5.16) |
| Proportion candidates Independent | 0.28 | (0.21) |
| Proportion candidates Congress | 0.11 | (0.12) |
| Proportion candidates BJP | 0.11 | (0.12) |
| Proportion candidates Other parties | 0.50 | (0.20) |
| Number new candidates | 1.91 | (1.77) |
| Number female candidates | 0.29 | (0.69) |
| Number of agricultural candidates | 0.87 | (1.30) |
| Number of candidates with experience | 1.01 | (0.83) |
| The incumbent contests | 0.53 | (0.50) |
| Average age of candidates | 49.04 | (6.65) |
| Average education of candidates | 11.79 | (1.85) |
| Average number of crimes of candidates | 0.86 | (1.93) |
| Average number of serious crimes candidates | 1.52 | (4.50) |
| Log asseets | 16.50 | (1.59) |
| Log liabilities | 11.08 | (6.85) |
| Age winner | 50.93 | (10.49) |
| Education winner | 11.96 | (2.28) |
| Log assets winner | 16.36 | (2.03) |
| Major crime winner | 0.07 | (0.26) |
| Years punishment winner | 2.08 | (8.60) |
| Winner agricultural candidate | 0.24 | (0.43) |
| Log liabilities winner | 7.84 | (9.00) |
| Female winner | 0.08 | (0.28) |
| Number crimes winner | 1.03 | (2.84) |
| Winner Congress | 0.25 | (0.44) |
| Winner BJP | 0.25 | (0.43) |
| Winner other parties | 0.46 | (0.50) |
| Incumbent won | 0.26 | (0.44) |
| Winner was new candidate | 0.49 | (0.50) |
| Vote share incumbent | 44.87 | (10.10) |
| Vote share new candidate | 42.23 | (11.66) |
| Vote share candidate who contested before | 43.65 | (10.60) |
| Percentage area irrigated | 0.26 | (0.19) |
| Observations | 8173 | |

cumulative exposure to daily temperatures above a threshold ($\tau$) over a certain period of time (Harmful Degree Days, $HDD$). The second measure captures the cumulative exposure to "good" temperatures ($> 8$°C and $\leq \tau$) over some period (regular degree days, $DD$).

These two measures require very high frequency (i.e. daily) data, and are defined by equations (1) and (2), where $h_x$ is the average daytime temperature on day $x$ , and $n$ is the total number of days over some period (for example, a growing season, or the year before an election).

$$HDD = \frac{1}{n}\sum_{x=1}^{n}(h_x - \tau)1(h_x > \tau) \tag{1}$$

$$DD = \frac{1}{n}\sum_{x=1}^{n}(min(h_x, \tau) - 8)1(h_x > 8) \quad (2)$$

In order to analyze the effect of very high temperatures on agricultural productivity and political outcomes, we first estimate the relationships semi-parametrically, in order to determine the value of $\tau$. For this we compute the proportion of days that the average daily temperature in an electoral constituency falls in a particular temperature bin, $b$. For example, $bin_b$ in equation (3) captures the proportion of days that fell in the bin between 9℃ and 10℃ over some period:

$$bin_b = \frac{1}{n}\sum_{x=1}^{n} 1(10 \geq h_x \geq 9) \quad (3)$$

We begin by estimating semi-parametric regressions of agricultural productivity at the assembly constituency (AC) level against average daily temperature by bin - using the full set of temperature bin dummies - along with a set of controls including precipitation and its square, and location and time fixed effects:

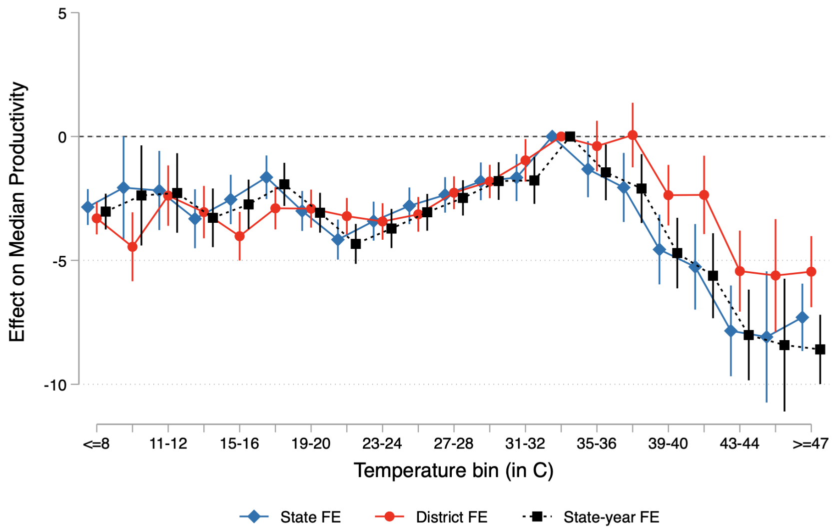
$$y_{idt} = \sum_{b=B_{min}}^{B_{max}} \gamma_b bin_{bidt} + \beta_3 PP_{idt} + \beta_4 PP_{idt}^2 + \delta_d + \sum_{m=1}^{12} \mu_m * \lambda_t + \varepsilon_{idt} \quad (4)$$

In the above regression, $y_{idt}$ denotes outcome $y$ in AC $i$, district $d$, in election year $t$, $b$ indexes the temperature bins, running from $B_{min}$ ($\leq$ 8℃) to $B_{max}$ ($\geq$ 47℃) in increments of 2, $bin_{bidt}$ denotes the proportion of days in that temperature bin in the past year/growing season (in that AC), $PP_{idt}$ denotes precipitation over the previous year/growing season, $\delta_d$ denotes district fixed effects, state or state-year fixed effects (depending on the specification), $\lambda_t$ denotes year fixed effects and $\mu_m$ denotes month of year fixed effects.

Figures 1 and 2 plot the coefficients for the temperature bins ($\gamma_b$) from the bin regressions when using alternative regional fixed effects and different definitions of the growing season. From visual inspection it becomes clear that the incidence of temperatures beyond 36℃ lead to a reduction in our measure of agricultural productivity. While the specific threshold is sensitive to the measurements of temperature (e.g. land surface temperature from remote sensing instruments, reanalysis or ground-level monitoring stations) and agricultural productivity, this non-linear effect of hot temperatures has been documented in a variety of contexts across the developing world, including in India (Burgess et al., 2017, Costa et al., 2020, Taraz, 2017).

We subsequently use our threshold to compute measures of $HDD$ and $DD$ in the previous

Figure 1: Temperature in the Previous Growing Season and Agricultural Productivity




*Notes:* Figure displays the estimates of the effect of an increase of 1 percentage point in the proportion of growing-season days in a given temperature bin on a State Assembly's median ln(output per ha). Shapes represent points estimates, while lines indicates 90% confidence intervals using robust standard errors. All specifications include month-year fixed effects and either state, district or state-year fixed effects.

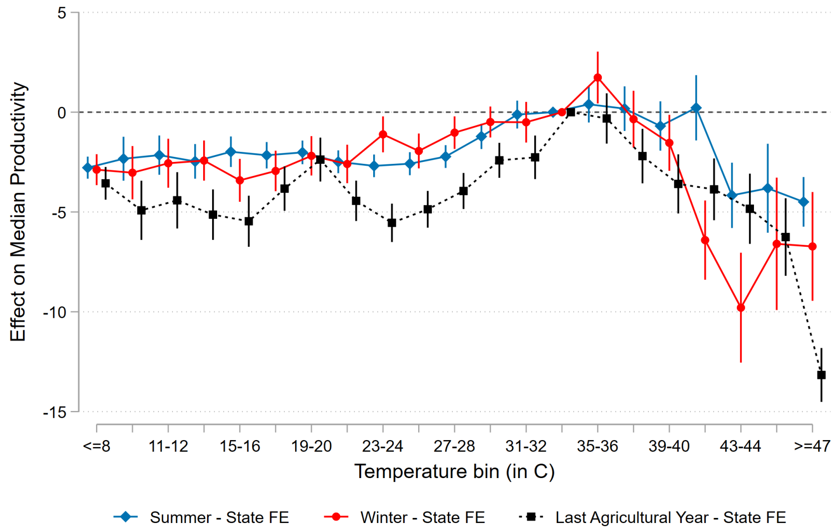
growing season as defined in equations (1) and (2) to run the following regressions:

$$y_{idt} = \beta_1 DD_{idt} + \beta_2 HDD_{idt} + \beta_3 PP_{idt} + \beta_4 PP^2_{idt} + \delta_d + \sum_{m=1}^{12} \mu_m * \lambda_t + \varepsilon_{idt} \tag{5}$$

Here, $y_{idt}$ denotes outcome $y$ in AC $i$, district $d$, and election year $t$, $DD_{idt}$ denotes the proportion of "good" degree days in the past year, and $HDD_{idt}$ denotes the proportion of "harmful" degree days in the past year. The coefficient $\beta_2$ provides the estimated effect of a larger proportion of harmful degree days during the time period under consideration on the outcome of interest. As before the specification also includes precipitation over the previous period, $PP_{idt}$ and its square, in addition to location fixed effects ($\delta_d$, denoting either district, state or state-year fixed effects), and time fixed effects ($\lambda_t$ denotes year fixed effects, and $\mu_m$ denotes month fixed effects). Standard errors are clustered at the constituency level.

There is a considerable amount of within- and between-constituency variation in HDDs over time. Figure 3 shows the minimum and maximum average HDDs in a growing season in each Assembly Constituency between 2008 and 2017. In many ACs in most parts of the

Figure 2: Previous Temperatures on Agricultural Productivity by Growing Season

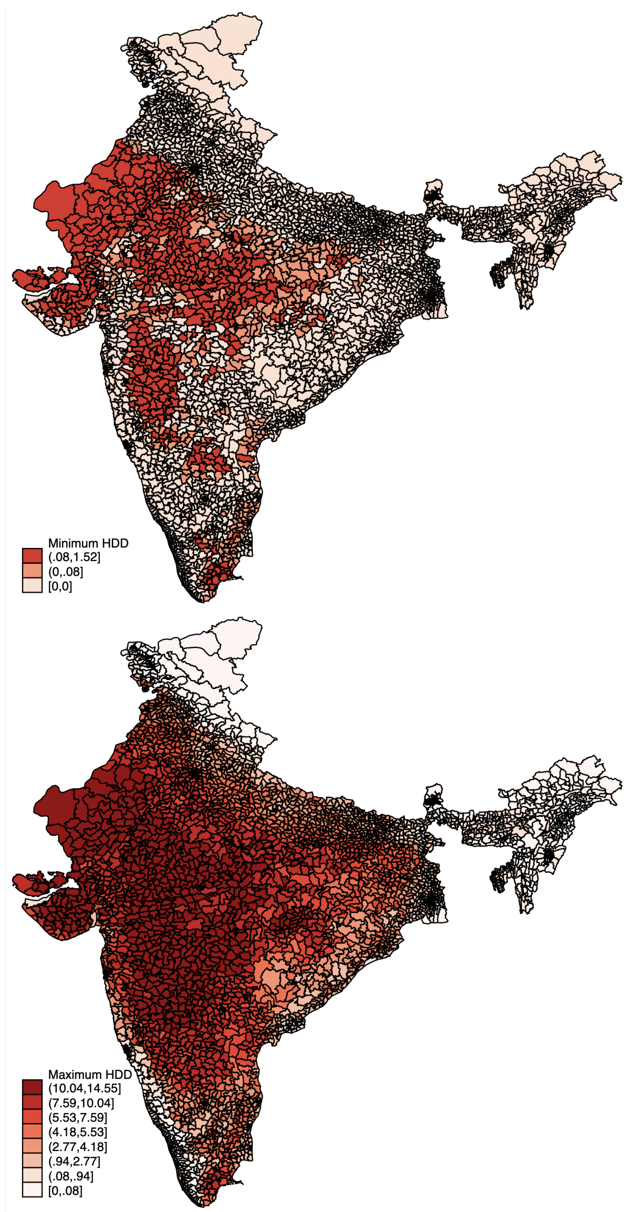



*Notes:* Figure displays the estimates of the effect of an increase of 1 percentage point in the proportion of days in a given temperature bin over a specified period on a State Assembly's median ln(output per ha). Shapes represent points estimates, while lines indicates 90% confidence intervals using robust standard errors. All specifications include month-year and district fixed effects.

country, there are years when the average HDD in a growing season is quite low (top panel), as well as years in which the average HDD is very high (bottom panel).

Table 2, using variations of our main specification (equation (5)), shows the negative effects of HDDs on agricultural productivity. We see from columns 1 to 6, that the effects are robust to different specifications. In particular, results are the same whether we focus on the summer or winter seasons, although the effect of extreme temperatures is more harmful for productivity during the winter season. Given that rainfall is always lower during the winter season, high temperatures are going to be more harmful during that season, and this is what we find. Even after adding rainfall as a control, the negative effect of HDDs on agricultural productivity is almost four times higher in the winter season. We can also see this in Figure 2, where a much larger decrease in median productivity is observed after the proportion of days with higher temperatures increase. As shown in column 6, results also hold if we use the whole year before the election, instead of just the previous growing season.

Figure 3: Minimum and Maximum HDD in sample years by Assembly Constituency




*Notes:* Top (bottom) shows the the minimum (maximum) average harmful degree days (HDD) in a growing season for each Assembly Constituency between 2008 and 2017

Table 2: Extreme Temperatures and Agricultural Productivity

| | Log Agricultural Productivity (Median) | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Growing Season: | Previous | Previous | Previous | Summer | Winter | Previous Agricultural Year |
| DD | 0.074*** | 0.129*** | 0.030*** | 0.103*** | 0.132*** | 0.137*** |
| | (0.010) | (0.011) | (0.008) | (0.008) | (0.012) | (0.012) |
| HDD | -0.497*** | -0.311*** | -0.120*** | -0.188*** | -0.650*** | -0.546*** |
| | (0.051) | (0.049) | (0.021) | (0.046) | (0.049) | (0.055) |
| Regional FE | State | District | AC | District | District | District |
| N | 6,120 | 5,901 | 3,985 | 5,901 | 5,274 | 5,901 |
| R2 | 0.464 | 0.632 | 0.987 | 0.630 | 0.615 | 0.637 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36°C. All specifications include month-year fixed effects and control for rainfall and rainfall squared.

# 4 Results

In this section we analyze the effect of exposure to extreme temperatures on political participation by looking separately at voters' behaviour, candidates' participation (including the resulting composition of the candidate pool), and election outcomes.

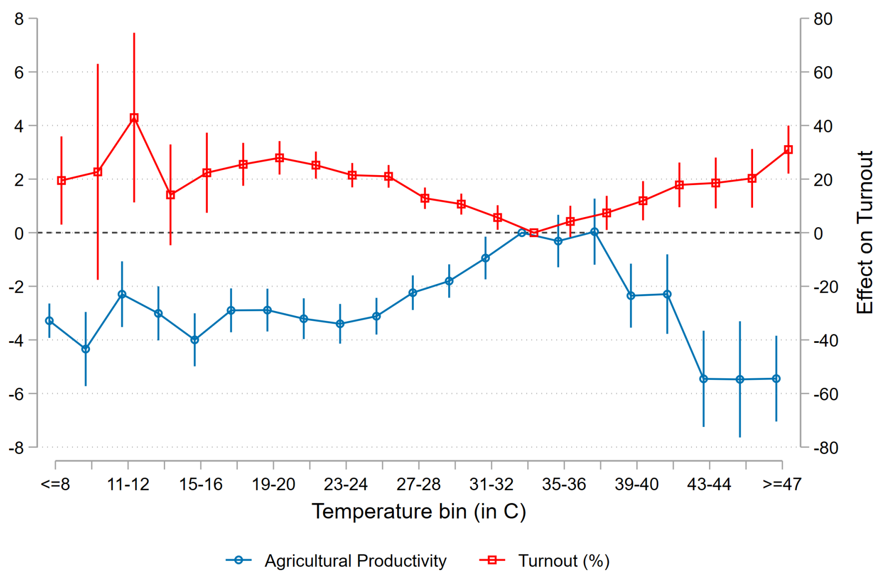
## 4.1 Voter Turnout

We begin by investigating the response of voters in Assembly Constituency elections to extreme temperature realisations in the previous growing season. Figure 4, which plots the $\gamma_b$ coefficients from equation 4, summarizes the key result: the effect of temperature on turnout mirrors the effect of temperature on agricultural productivity. Within the range of "good" degree days (i.e., those that positively affect agricultural production), warmer temperatures decrease voter turnout. For temperatures above the threshold (i.e., when warmer temperatures start to reduce agricultural productivity), higher temperatures increase turnout.

In Table 3 we show regression results of turnout on temperatures for different specifications. Column 1 confirms the negative effect on turnout of good degree days (DD) and the positive effect on turnout of harmful degree days (HDD) - i.e., days with extremely high average temperatures. An additional unit of harmful degree days (i.e. the equivalent of an increase of one degree every day throughout the previous growing season) increases turnout by 1.44 percentage points. The result is statistically significant at the 1% level, and represents almost 12% of a standard deviation. Column 2 restricts the sample to those assembly constituencies that also have information on agricultural productivity, and we see that the effect is undiminished. Column 3 regresses voter turnout on agricultural productivity alone, demonstrating that there is a strong and direct negative relationship between agricultural productivity and voter turnout. Columns 4, 5 and 6 show that the results hold whether we focus on the summer growing season, the winter growing season, or the whole agricultural year prior to the election. Just as we saw with agricultural productivity in Table 2, the effect of extreme temperatures on turnout during the winter season is much larger than during the summer season. Given that rainfall is much lower during the winter season, and the damaging effect of high temperatures on agricultural productivity is more important then, we find a correspondingly larger increase if high temperatures occur during the winter season.

If agricultural productivity is the mechanism through which temperature affects political outcomes, we would expect the effects of temperature on political participation to be stronger

Figure 4: Temperatures, Agricultural Productivity and Turnout




*Notes:* Figure displays the estimates of the effect of an increase of 1 percentage point in the proportion of growing-season days in a given temperature bin on a State AC's mean ln(output per ha) and share of electors that voted. Shapes represent point estimates. Both specifications include month-year and district fixed effects and use temperatures for the previous growing season.

Table 3: Extreme Temperatures and Turnout

| | Turnout (%) | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Growing Season: | Previous | Previous | Previous | Summer | Winter | Previous Agricultural Year |
| DD | -1.003*** | -1.033*** | | -0.645*** | -0.940*** | -1.010*** |
| | (0.124) | (0.136) | | (0.095) | (0.154) | (0.158) |
| HDD | 1.439*** | 1.791*** | | 0.432** | 1.841*** | 1.361*** |
| | (0.278) | (0.304) | | (0.220) | (0.424) | (0.355) |
| log Median Yields | | | -2.582*** | | | |
| | | | (0.144) | | | |
| Regional FE | District | District | District | District | District | District |
| N | 7,532 | 5,806 | 5,804 | 7,532 | 6,902 | 7,532 |
| R2 | 0.778 | 0.767 | 0.778 | 0.775 | 0.784 | 0.776 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: ** p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36°C. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared. Column (2) restricts the sample to Assembly Constituencies that also have information on agricultural productivity.

in areas where a shock to agriculture is more damaging. In Table 4 we look at heterogeneous effects along dimensions correlated with agricultural activities. Column 1 shows that HDDs are associated with larger increases in turnout, the larger the share of rural population in the assembly constituency. Columns 2 and 5 show that the effects are stronger in areas with lower levels of literacy and non-farm employment, respectively.[6] While the point estimates have the expected signs in Columns 3 and 4, we do not find significantly different effects for constituencies with larger shares of Scheduled Caste or Scheduled Tribe populations (SC/ST), or for constituencies with more land area classified as rural in population censuses, even though the coefficient for the latter is quite large.

## 4.2 Candidates' behavior and characteristics

Next we explore the effect of exposure to harmful temperatures on politicians' decisions to run for election in the State Legislative Assembly (SLA). In Table 5 we find that the realisation of extreme temperatures over the year preceding an election reduces the number

[6] Also note that, consistent with the hypotheses in our conceptual framework, turnout tends to be greater in more rural, agricultural and illiterate areas.

Table 4: Extreme Temperatures and Turnout - Heterogeneous Effects

| | Turnout (%): Heterogeneous Effects | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| HDD | -0.450 | 4.208*** | 0.588 | -1.479 | 1.704*** |
| | (0.625) | (0.867) | (0.484) | (1.528) | (0.379) |
| indicator | 7.198*** | -14.585*** | 1.507 | 12.648*** | -13.162*** |
| | (0.682) | (1.906) | (1.522) | (1.485) | (4.131) |
| HDD x Indicator | 1.254* | -7.060*** | 0.188 | 2.028 | -16.238*** |
| | (0.641) | (1.566) | (1.830) | (1.523) | (4.309) |
| Population Indicator | Rural | Literate | SC/ST | Rural Area | Non farm emp |
| N | 5,291 | 5,284 | 5,284 | 3,546 | 4,660 |
| R2 | 0.817 | 0.811 | 0.803 | 0.835 | 0.846 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36°C. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

of candidates running to be Members of the SLA. An additional average harmful degree day (HDD) decreases the number of candidates running by 0.44, which is 8% of a standard deviation. The effects are larger in elections with more than 10 or 15 candidates (columns 3 and 5), suggesting that marginal candidates choose not to run after a bad agricultural year. This is confirmed in column 6, which shows that an increase in HDDs reduces the number of candidates that have lost their deposits due to insufficient support from voters; in India, candidates that obtain less than one-sixth of the total vote share forfeit the deposit (10,000 Rs, which is approximately 125$) they must pay in order to contest in the election.

This reduction in the number of candidates seems to affect the party composition of candidates. Table 6 shows a slight reduction in independent and traditional parties at the expense of regional parties. The reduction in the proportion of independent candidates is consistent with our finding that marginal candidates choose not to contest, given that independent candidates tend to have a lower probability of winning elections.

One logical follow-up question is the following: do characteristics of the candidate pool change substantially after this reduction in the number of candidates? Specifically, we look at whether extreme temperatures affect the number of candidates that are new (versus having contested before), female, work in agriculture, and if they have won before. We also look at whether the incumbent re-contests, as well as average age, education, assets, liabilities,

Table 5: HDDs and Number of Candidates

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Dependent variable: | Number of candidates | | | | | Candidates w/ lost deposits |
| DD | 0.329*** | 0.039* | 0.481*** | 0.125*** | 0.327** | 0.256*** |
| | (0.044) | (0.023) | (0.081) | (0.031) | (0.143) | (0.048) |
| HDD | -0.439** | 0.137 | -0.671*** | 0.039 | -0.640* | -0.519*** |
| | (0.183) | (0.119) | (0.227) | (0.128) | (0.382) | (0.172) |
| Number of candidates | all | less 10 | more 10 | less 15 | more 15 | |
| N | 7,533 | 3,156 | 4,230 | 5,804 | 1,654 | 7,599 |
| R2 | 0.601 | 0.586 | 0.345 | 0.627 | 0.350 | 0.519 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36°C. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

Table 6: HDDs and Political Parties

| | Proportion of candidates | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Dependent variable: | Independent | INC | BJP | other |
| DD | 0.005*** | -0.001 | -0.000 | -0.004* |
| | (0.002) | (0.001) | (0.001) | (0.002) |
| HDD | -0.016** | -0.003 | -0.007* | 0.026*** |
| | (0.007) | (0.004) | (0.004) | (0.007) |
| Regional FE | District | District | District | District |
| N | 7,599 | 7,599 | 7,599 | 7,599 |
| R2 | 0.466 | 0.473 | 0.350 | 0.369 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36°C. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

number of crimes they have been charged with, and the likelihood of being charged with a serious crime. The results, which can be found in Tables 7 and 8, suggest that the pool of candidates remains broadly similar in elections following extreme temperatures, both in terms of socio-demographic characteristics, criminal activities, and incumbency status.

There does seem to be an increase in the probability that the candidate is experienced and poorer.

Table 7: HDDs and Characteristics of the Candidate Pool (1)

| | number of | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| Dep var: | new cand | female cand | agr cand | cand won before | incumbent contests |
| DD | -0.032*** | -0.018** | -0.068*** | -0.021*** | 0.005 |
| | (0.012) | (0.009) | (0.012) | (0.005) | (0.007) |
| HDD | -0.049 | 0.003 | -0.024 | 0.058** | 0.008 |
| | (0.061) | (0.026) | (0.045) | (0.028) | (0.022) |
| Regional FE | District | District | District | District | District |
| N | 7,668 | 7,668 | 7,668 | 7,668 | 5,457 |
| R2 | 0.552 | 0.125 | 0.482 | 0.565 | 0.294 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36°C. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

Table 8: HDDs and Characteristics of the Candidate Pool (2)

| | average | | | average prob | ln average | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Dep var: | age | education | num crimes | serious crimes | assets | liabilities |
| DD | 0.178** | 0.078*** | 0.042** | 0.006 | 0.072*** | -0.080 |
| | (0.090) | (0.024) | (0.017) | (0.036) | (0.022) | (0.082) |
| HDD | -0.228 | -0.049 | -0.072 | -0.103 | -0.228*** | -0.020 |
| | (0.269) | (0.096) | (0.086) | (0.172) | (0.073) | (0.273) |
| Regional FE | District | District | District | District | District | District |
| N | 7,634 | 7,527 | 7,573 | 7,409 | 7,573 | 7,573 |
| R2 | 0.197 | 0.183 | 0.206 | 0.265 | 0.402 | 0.259 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36°C. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

## 4.3 Electoral Outcomes

The fact that temperature shocks affect political participation among voters and candidates could translate into different voting behaviour and political outcomes. We know that political participation has increased for voters and decreased for candidates, and that the composition of the candidate pool is only slightly different. This suggests that any change in the characteristics of winners will be mainly driven by changes in the political preferences of voters.[7]

In Tables 9 and 10, we document the effect of extreme temperature realisations on the characteristics of election winners, using the same specification as above. The results show that election winners tend to have fewer assets, are less likely to have a criminal record, and are more likely to work in agriculture - following a temperature shock. While the vote share of incumbents does drop after extreme temperature realisations, we do not find that the swing in votes is large enough to negatively affect the likelihood that an incumbent wins.

Table 9: HDDs and Winner Characteristics (1)

| | Winner characteristics | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Dependent variable: | Age | Edu | Assets(log) | Major crime | Punishment | Agri |
| DD | 0.349** | 0.048 | 0.076** | 0.002 | 0.022 | -0.022*** |
| | (0.136) | (0.033) | (0.033) | (0.002) | (0.062) | (0.004) |
| HDD | -0.576 | -0.080 | -0.259*** | -0.023** | -1.327*** | 0.036** |
| | (0.447) | (0.118) | (0.097) | (0.011) | (0.336) | (0.016) |
| Regional FE | District | District | District | District | District | District |
| N | 7,517 | 7,055 | 7,242 | 6,980 | 6,980 | 7,594 |
| R2 | 0.156 | 0.155 | 0.325 | 0.235 | 0.191 | 0.367 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36℃. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

[7] We explicitly analyze the effect of HDDs on voters' preferences using voter survey data in Section 5.

Table 10: HDDs and Winner Characteristics (2)

| | Winner characteristics | | | Vote Share | | |
|---|---|---|---|---|---|---|
| Dep. var.: | (1) Incumbent Won | (2) Incumbent Won (if contest) | (3) New Cand Won | (4) Incumbent | (5) New candidate | (6) Contested Before |
| DD | 0.006 | 0.008 | -0.011 | 0.590 | -0.198 | -0.025 |
| | (0.007) | (0.013) | (0.007) | (0.375) | (0.297) | (0.132) |
| HDD | 0.013 | 0.015 | -0.004 | -2.201** | 0.996 | 0.258 |
| | (0.022) | (0.034) | (0.023) | (1.030) | (0.799) | (0.434) |
| Regional FE | District | District | District | District | District | District |
| N | 5,456 | 2,867 | 5,456 | 1,320 | 2,574 | 7,530 |
| R2 | 0.180 | 0.201 | 0.227 | 0.503 | 0.434 | 0.345 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36°C. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

# 5 Mechanisms

## 5.1 Mediation Analysis

We have shown above that an increase in HDDs affects political participation on a variety of outcomes, including voter turnout, candidate participation, and election outcomes. We have also seen that an increase in HDDs leads to a sharp reduction in agricultural productivity - a result that is widely corroborated in the literature (Aragón et al., 2021, for example). Moreover, Figure 4 shows that these two effects closely mirror one another, suggesting that HDDs reduce agricultural productivity and it is this reduction in agricultural productivity that leads to greater turnout and changes in other political outcomes. This hypothesis is corroborated by some of our heterogeneity analysis - in particular those results which show that the effect of HDDs on turnout is concentrated in areas with a larger rural population or a smaller share of non-farm employment (Table 4). Assuming this mechanism is at work, how much of the total effect of HDDs on political outcomes can be explained by agricultural productivity? In this subsection, we perform a mediation analysis to decompose the total effect of HDDs on political outcomes (e.g. turnout) into a direct effect and an indirect effect (i.e. the part of the total effect that is mediated through agricultural productivity), which allows us to quantify the relevance of this mechanism.

The indirect effect or ACME (for Average Causal Mediation Effect) can be identified under two main assumptions (Imai et al., 2010): 1) sequential ignorability and 2) no-interaction. In our case, the sequential ignorability assumption requires the following two conditions to hold: i) that HDDs are independent of potential outcomes and potential agricultural productivity, conditional on the controls, and ii) that agricultural productivity is independent of potential outcomes conditional on the controls and the realization of HDDs. Condition i) is already required for all of our main results to be unbiased. Condition ii) implies, *inter alia*, that there are no omitted variables that influence both agricultural productivity and political outcomes (such as turnout), conditional on HDDs and other controls (including precipitation and geographic fixed effects). The no-interaction assumption requires the effect of agricultural productivity on political outcomes to be independent of the realization of HDDs (i.e. poor agricultural productivity should have the same effect on political outcomes whether HDDs are high or low).

Given these assumptions, we run the following regressions for each of our main political outcome variables: i) voter turnout, ii) the number of candidates running, and iii) whether an agricultural candidate is elected.

$$y_{idt} = \gamma_1 HDD_{idt} + \gamma_2 \boldsymbol{X}_{idt} + u_{idt} \tag{6}$$

$$NPP_{idt} = \beta_1 HDD_{idt} + \beta_2 \boldsymbol{X}_{idt} + \epsilon_{idt} \tag{7}$$

$$y_{idt} = \alpha_1 HDD_{idt} + \alpha_2 \boldsymbol{X}_{idt} + \alpha_3 NPP + \varepsilon_{idt} \tag{8}$$

where $y_{idt}$ denotes a political outcome variable, $NPP_{idt}$ denotes agricultural productivity, $\boldsymbol{X}_{idt}$ denotes all controls (including fixed effects), and all other variables are defined as above. The coefficient $\gamma_1$ in Equation 6 - which takes the same form as our main results - provides an estimate of the (total) effect of HDDs on political outcomes, while $\beta_1$ from equation 7 provides an estimate of the effect of HDDs on agricultural productivity, and equation 8 regresses political outcomes on HDDs while controlling for agricultural productivity (and our other controls).

The average causal mediation effect (ACME) - which is the part of the effect of HDDs on political outcomes that is mediated via agricultural productivity - is then the product of $\beta_1$ and $\alpha_3$ (Imai et al., 2010; Reuben M. Baron and David A. Kenny, 1986), while the ACME as a fraction of the total effect (of HDDs on political outcomes) is $\frac{\beta_1 \alpha_3}{\gamma_1}$.

Both of these quantities are reported in the bottom panel of Table 11 for each of our three primary outcomes of interest (voter turnout, the number of candidates, and whether an agricultural candidate is elected). In every case, the fraction of the total effect of HDDs which can be attributed to the indirect effect of agricultural productivity is in excess of .7 (and is sometimes as large as .88). In other words, the primary way in which HDDs seem to effect political outcomes is via their negative effect on agricultural productivity.

Table 11: Average Causal Mediation Effects

| | NPP | Turnout (%) | | Number of Candidates | | Agricultural Winner | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| DD | 0.137*** | -1.145*** | -0.816*** | 0.359*** | 0.258*** | -0.023*** | -0.018*** |
| | (0.012) | (0.185) | (0.185) | (0.051) | (0.049) | (0.004) | (0.004) |
| HDD | -0.546*** | 1.836*** | 0.505 | -0.463** | -0.058 | 0.025 | 0.003 |
| | (0.055) | (0.398) | (0.399) | (0.202) | (0.198) | (0.016) | (0.016) |
| Ln Median Yields | | | -2.425*** | | 0.739*** | | -0.040*** |
| | | | (0.145) | | (0.090) | | (0.006) |
| Indirect Effect (ACME) | | | 1.324 | | -.403 | | .022 |
| Indirect Effect (fraction) | | | .721 | | .87 | | .884 |
| N | 5,901 | 5,796 | 5,796 | 5,797 | 5,797 | 5,863 | 5,863 |
| R2 | 0.637 | 0.766 | 0.782 | 0.614 | 0.622 | 0.411 | 0.414 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: *$p<0.10$, ** $p<0.05$, *** $p<0.01$.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36℃. All regressions include only those observations for which agricultural productivity data are available. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

## 5.2 The Effect of HDDs on Stated Voter Preferences

The evidence so far suggests that temperature shocks lead to negative agricultural/economic shocks, which in turn affect election outcomes by changing the way voters value different policies and the candidates that will provide them. In particular, we hypothesize that an increase in HDDs increases the weight that rural voters place on agricultural issues such as irrigation, because an improvement in such issues might mitigate the negative effects of HDDs on agricultural productivity. In this section, we provide concrete evidence to support this hypothesis by leveraging data from a survey of Indian voters.

In 2014, Daksh India and ADR (Association for Democratic Reforms) conducted a national survey of 250,000 respondents in 525 constituencies of the Lok Sabha (i.e. the main national legislative body), asking voters - among other things - to rank the importance of a range of issues on a 3 point scale (i.e. low, medium, high). The topics included agricultural issues (e.g. the availability of agricultural loans, irrigation programmes, electricity for agriculture), environmental issues more generally, and issues related to efficacy and transparency (e.g. accessibility, eradication of corruption, and trustworthiness). For each outcome, we generated a measure capturing the share of respondents in a parliamentary constituency (PC) who gave that outcome "high" importance.

We then regressed these outcome measures (which capture the average importance of various issues to respondents in a constituency) against HDDs in the assembly constituency during the previous year [8], as in our previous specifications. There are two main differences between this analysis and our previous analysis: 1) we cluster standard errors at the PC level, because the outcomes are measured at the PC level, and 2) this analysis is purely cross-sectional, since we only observe voter preferences in a single year: 2014. As we did in Table 4, we also interact HDDs with the share of the population in an assembly constituency that lives in a rural area, under the assumption that HDDs should have a greater impact on voters' preferences regarding agricultural issues in more rural areas.

The results of this analysis are shown in Tables 12 and 13, for i) agricultural issues and ii) issues related to accessibility and corruption, respectively. In Table 12 we see that HDDs increase the share of voters who report each of the following outcomes as highly important: the availability of agricultural loans, irrigation programmes, and electricity for agriculture. In the case of agricultural loans, the effect is significantly stronger in more rural areas. We also find that an increase in HDDs in more rural areas increases the likelihood that voters report "environmental issues", broadly speaking, as being highly important. This implies that voters see temperature shocks as an "environmental issue" and suggests that voters may connect these events with the wider environmental phenomenon of climate change.

In Table 13 we find that HDDs increase the importance that voters *in rural areas* put on the eradication of corruption and on having an MP who is accessible (we fail to find an effect on trustworthiness of MPs). This suggests that, not only do voters desire more agricultural resources and investments (like loans, irrigation and electricity), they expect politicians to be accessible and responsive, and to do something about their wishes (rather than relying

[8] Each Parliamentary Constituency contains several Assembly Constituencies, allowing us to make a clear match between the two.

on private provision exclusively). It is also intuitive that tolerance of corruption should go down, since the negative income shock implied by an increase in HDDs will also tend to increase the opportunity cost of wasted funds.[9]

Table 12: The Effect of HDDs on Voter Attitudes Regarding Agricultural and Environmental Issues

| | Irrigation Programmes | | Agr. Loan Availability | | Electricity for Agr. | | Environmental Issues | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| DD | -0.030** | -0.023* | -0.030** | -0.034* | -0.032** | -0.029** | 0.011 | -0.002 |
| | (0.012) | (0.013) | (0.015) | (0.018) | (0.014) | (0.014) | (0.011) | (0.011) |
| HDD | 0.092*** | 0.046** | 0.082** | 0.049* | 0.100*** | 0.081** | -0.003 | -0.010 |
| | (0.029) | (0.023) | (0.033) | (0.029) | (0.032) | (0.033) | (0.026) | (0.025) |
| share rural | | -0.069 | | -0.118** | | -0.068 | | -0.060 |
| | | (0.051) | | (0.059) | | (0.053) | | (0.046) |
| HDD x share rural | | 0.028 | | 0.053** | | 0.018 | | 0.039** |
| | | (0.021) | | (0.022) | | (0.024) | | (0.019) |
| Regional FE | District | District | District | District | District | District | District | District |
| Time Period | 2014 | 2014 | 2014 | 2014 | 2014 | 2014 | 2014 | 2014 |
| N | 889 | 692 | 889 | 692 | 889 | 692 | 889 | 692 |
| R2 | 0.770 | 0.795 | 0.734 | 0.760 | 0.734 | 0.757 | 0.750 | 0.790 |

*Notes:* Standard errors (in parenthesis) are clustered at the *parliamentary* constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* All specifications include district fixed effects, month fixed effects, rainfall and rainfall squared.

## 5.3 Irrigation

In this subsection we dig deeper into the mechanism highlighted above (i.e. agricultural productivity) and explore some of the further implications. Irrigation has been shown to mitigate the effects of high temperatures on agricultural productivity.[10] If our results for political outcomes are indeed driven by agricultural productivity, we would thus expect irrigation to also affect the relationship between high temperatures and political outcomes such as turnout.

In Table 14 we test whether this is the case by interacting HDDs with the percentage of irrigated area at the assembly constituency level (from Ambika et al., 2016). Columns 1 and 2 include district fixed effects, while columns 3 and 4 include assembly constituency

[9]That is, public funds should be more valuable if private incomes and consumption go down.
[10]See, for example, Tack et al. (2017) and Zaveri and B. Lobell (2019).

Table 13: The Effect of HDDs on Voter Attitudes Regarding Corruption and Accessibility of MPs

| | Accessibility of MP | | Eradication of Corruption | | Trustworthiness of MP | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| DD | 0.004 | -0.007 | 0.021 | 0.005 | 0.013 | 0.002 |
| | (0.012) | (0.014) | (0.013) | (0.012) | (0.012) | (0.012) |
| HDD | -0.025 | -0.016 | -0.032 | -0.019 | -0.015 | 0.007 |
| | (0.029) | (0.033) | (0.029) | (0.027) | (0.027) | (0.025) |
| share rural | | -0.113** | | -0.068 | | -0.057 |
| | | (0.055) | | (0.050) | | (0.040) |
| HDD x share rural | | 0.054** | | 0.037* | | 0.023 |
| | | (0.022) | | (0.021) | | (0.017) |
| Regional FE | District | District | District | District | District | District |
| Time Period | 2014 | 2014 | 2014 | 2014 | 2014 | 2014 |
| N | 889 | 692 | 889 | 692 | 889 | 692 |
| R2 | 0.747 | 0.772 | 0.738 | 0.773 | 0.753 | 0.783 |

*Notes:* Standard errors (in parenthesis) are clustered at the *parliamentary* constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* All specifications include district fixed effects, month fixed effects, rainfall and rainfall squared.

fixed effects. In columns 1 and 3 we attempt to confirm the finding from the previous literature that irrigation serves to mitigate the harmful effects of extreme temperatures on agricultural productivity. The effect is large and significant in column 3 with the inclusion of AC fixed effects, but is smaller and insignificant in column 1 when only district fixed effects are included.[11] Regardless of which level of fixed effects are included, we find that irrigation also mitigates the effect of HDDs on voter turnout (columns 2 and 4) - which is again in line with our mechanism, since there is no reason that irrigation should attenuate the effects of HDDs unless the effects are mediated through agricultural productivity.

Next we aim to use the findings above regarding irrigation to better understand some of our other results - in particular our results on election outcomes and the characteristics of election winners. In the previous section we found that, following extreme temperatures, election winners tended to be poorer, with fewer alleged crimes, and were more likely to come from agricultural occupations. In what follows we focus on the last of these outcomes, as candidates' occupations are likely to be known by voters, and it is reasonable to think that

[11] One explanation for this discrepancy could be the presence of within district omitted variables which affect both irrigation and agricultural productivity and respond to HDDs.

Table 14: The Effect of Irrigation

| | NPP and turnout: Mechanisms | | | |
|---|---|---|---|---|
| | (1)<br>Log NPP | (2)<br>Turnout | (3)<br>Log NPP | (4)<br>Turnout |
| DD | 0.142*** | -1.105*** | 0.033*** | -0.413 |
| | (0.010) | (0.135) | (0.008) | (0.332) |
| HDD | -0.363*** | 2.457*** | -0.204*** | 2.725*** |
| | (0.080) | (0.378) | (0.029) | (0.319) |
| Irrigation | -1.720*** | 8.187*** | 0.007 | 5.342*** |
| | (0.126) | (0.843) | (0.045) | (0.797) |
| HDD × Irrigation | 0.084 | -1.791** | 0.241*** | -4.382*** |
| | (0.161) | (0.753) | (0.047) | (0.504) |
| Constant | 6.182*** | 88.089*** | 7.179*** | 72.977*** |
| | (0.185) | (2.783) | (0.154) | (6.392) |
| Regional FE | District | District | AC | AC |
| N | 5,899 | 5,805 | 3,983 | 3,899 |
| R2 | 0.665 | 0.772 | 0.988 | 0.904 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* All specifications include AC fixed effects, month-year fixed effects and control for rainfall and rainfall squared.Irrigation data from Ambika et al. (2016).

voters may prefer candidates with agricultural backgrounds *if* they believe such candidates will better understand the consequences of temperature shocks for agricultural outcomes and be more willing to implement policies to address such shocks.

The question is then: are candidates from agricultural backgrounds more likely to invest in policies - such as irrigation - that help citizens mitigate the effects of temperature shocks? The identification challenge in this case is the existence of omitted variables that may affect both who is elected and irrigation levels (e.g. perhaps agricultural candidates are more likely to be elected in ACs with more farmers, which also tend to have more irrigation). To get around this problem we take advantage of the fact that some agricultural candidates win in close elections against non-agricultural candidates, which allows us to use a sharp regression discontinuity design (RDD), following the methodology in Cattaneo et al. (2019). In our data we have 1,580 AC elections with an agricultural and a non-agricultural candidate as winner and runner-up. We also have information on the margin of victory, the running variable. As expected, there is a sharp discontinuity in the probability of being elected at the zero vote margin, since winning candidates have a positive margin of victory.

Results in Table 15 show that a victory by an agricultural candidate increases the percentage of irrigated area in the following year by 7.6 percentage points, which is 35% of a standard deviation. The coefficient increases slightly when adding a second order polynomial of the vote margin as a control variable (column 2), and when adding controls for the winner's political party and the share of the population that is rural (column 3). A graphical representation of the result can be found in Figure 5. Finally, we test whether agricultural candidates who win in close elections generate higher agricultural productivity in general, but we fail to find such an effect (last column of Table 15).

In order to be able to use RDD as an identification strategy, several conditions must be met. First, there should be no manipulation of the running variable at the discontinuity. This is shown in Figure B2 of the appendix, where the estimated discontinuity is both small and not significantly different from zero. Second, covariates and pre-determined variables should also be balanced around the discontinuity. Results in Table A3 show that this is indeed the case, using variables such as past irrigation, past vote margins, and whether the profession of the previous winner was agricultural. Finally, we note that our estimates capture the effect of electing an agricultural candidate - *including* any compensating differentials if they exist (i.e. individual characteristics that could affect the outcome variables along with the likelihood that these candidates are in close elections (Marshall, 2022).

The upshot of this analysis is the following: agricultural candidates who win in close elections seem to be more likely to invest in irrigation in their constituencies. If voters know this, along with the fact that irrigation tends to mitigate the effect of high temperatures on agricultural productivity, they may be more likely to vote for agricultural candidates in response to extreme temperature realisations (especially if they believe that recent extreme temperature realisations are indicative of more frequent or more extreme temperature realisations in the future).

## 5.4 Discussion

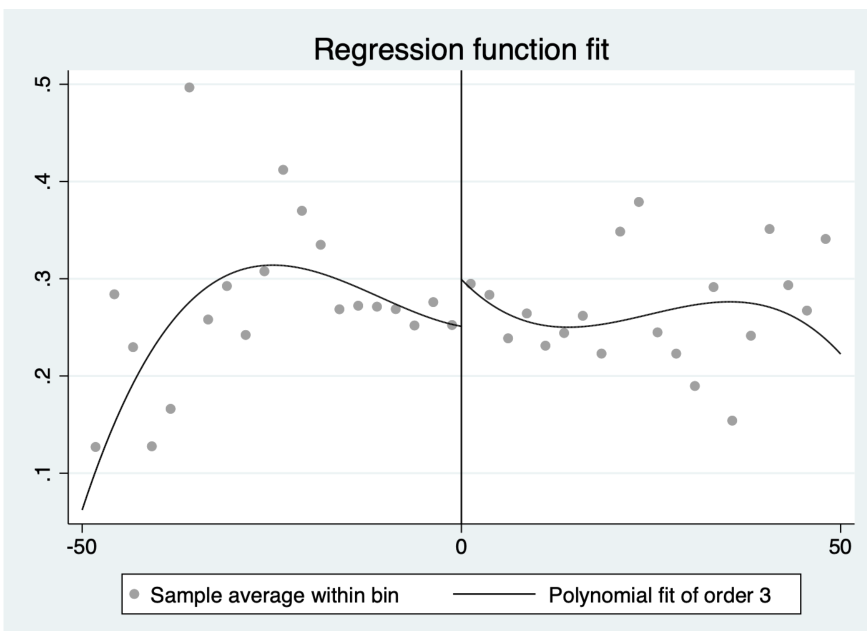
In Section 2.2, we sketched a simple conceptual framework in which citizens' decisions to vote hinged on the possibility of obtaining pecuniary benefits from the electoral process. Under standard preferences (i.e. diminishing marginal utility of consumption), this set-up implies not only that voter participation should be greater in poorer areas but also that shocks which reduce income should *increase* turnout (by increasing the marginal benefit of

Table 15: Agricultural candidates in Close Elections

| VARIABLES | (1) Irrigation | (2) Irrigation | (3) Irrigation | (4) Log NPP |
|---|---|---|---|---|
| Won in close elections | 0.0762*** (0.0294) | 0.0942*** (0.0344) | 0.0895*** (0.0302) | -0.0153 (0.0944) |
| | | 2nd order | Controls | |
| Obs | 996 | 996 | 736 | 725 |
| Bandwidth | 8.309 | 12.01 | 8.013 | 13.09 |
| Robust p val | 0.00941 | 0.00614 | 0.005 | 0.871 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* Estimates produced using "rdrobust". Irrigation data from Ambika et al. (2016).

Figure 5: RD estimates: The Effect of Agricultural Candidates on Irrigation




*Notes:* Whole sample and a 3rd order polynomial.Produced using "rdplot".

political participation). We provide evidence consistent with both phenomena in Section 4.1, as voter turnout i) is larger in rural, less literate areas and ii) increases when the constituency is exposed to a harmful temperature shock.

We find evidence suggesting that stronger preferences for agricultural support that would directly benefit agricultural voters after difficult agricultural years may explain this increase in political participation. In section 5.2 we show, using different data from a survey of voters, that extreme temperatures change voters' stated preferences in favour of topics related to agricultural inputs (such as irrigation, agricultural loans and electricity for agriculture) and politician quality (such as accessibility and attitudes towards corruption).

At the same time we find that the temperature shock in a context of diminishing marginal utility of consumption decreases the propensity of marginal candidates to run for office (Section 4.2). Together with the change in voter behavior, this affects electoral outcomes. In Section 4.3 we show that winning candidates tend to be less corrupt and are more likely to have an agricultural background when elections take place after a temperature shock.

Finally, in Table 14, we provide evidence that access to irrigation, a primary means of adaptation (as documented in Tack et al., 2017, Zaveri and B. Lobell, 2019), mitigates the effects of extreme temperatures on both productivity and turnout. Consistent with this result, we also find that candidates with an agricultural background tend to invest more in irrigation (Table 15). This suggests that adaptation measures that decouple temperature shocks from agricultural productivity or income realisations could also attenuate the link between climate shocks and political participation. An important take-away is that, at a local level over the short-term, the (democratic) political process may provide an effective way of responding to climate change.

One competing story that could also explain why turnout increases after extreme temperature realizations is the following: perhaps negative agricultural productivity shocks reduce the opportunity cost of agricultural workers' time. With more free time, workers might use it to participate more in the political process. While this explanation is intuitive, we think it is unlikely based on our reading of the literature. In particular, Aragón et al. (2021) show that farmers in Peru respond to heat-induced negative productivity shocks by *increasing* their labour input - not decreasing it. This occurs because of 1) high levels of poverty (leading to a high marginal utility of consumption) and 2) incomplete markets (for inputs, insurance and finance). While the setting in Aragón et al. (2021) (i.e. rural Peru) is not the same as India, the conditions needed for this result (i.e. widespread poverty and incomplete markets) are at least as likely to apply in India's rural areas.

Another explanation for our findings regarding turnout is related to the movement of workers/voters in response to a negative income shock. In particular, a negative shock in agriculture could cause farmers to leave rural areas, which could decrease the number of registered voters. If those who move are less likely to vote than those who stay, the turnout rate could increase. While we do not measure this potential behaviour directly, it is in conflict with previous findings: Liu et al. (2021) show that, in the long-run, exposure to extreme temperatures *increases* the share of employment in the agricultural sector in India. In addition, they find no discernible changes in migration patterns in districts exposed to more temperature shocks between census years. This suggests that out-migration does not provide a likely alternative mechanism.[12]

# 6 Conclusion

We find that extreme temperatures reduce agricultural yields and increase voter turnout, with almost identical (but opposite) effects. These effects are more pronounced in assembly constituencies that depend more on agriculture, suggesting that citizens react to temperature shocks which affect their livelihoods by increasing their political participation. Regarding politicians' behavior, we find that temperature shocks reduce the number of candidates who stand for election, in particular by dissuading marginal candidates from running (i.e. those who would *ex-ante* have a lower probability of winning, such as candidates who are likely to lose their deposit or independent candidates). These effects translate into changes in the political equilibrium, with an increase in the success rates of poorer candidates, candidates with better criminal records, and candidates with an agricultural background.

Our mediation analysis suggests that the decrease in agricultural productivity caused by extreme temperatures is quantitatively important and can account for nearly all of these effects. Our investigation of the mechanism finds that 1) high temperatures impact voters' preferences regarding agricultural policies such as irrigation programmes, 2) agricultural candidates tend to improve irrigation, and 3) irrigation tends to mitigate the negative effects of high temperatures on agricultural productivity, as well as the effects on turnout.

This paper provides a first attempt at understanding the political implications of climate change in democratic developing countries, as climate change is likely to bring an increase in the frequency and severity of temperature shocks - especially in warmer countries close to the equator, which also tend to be poorer. We focus on India, the largest democracy in the world, but future research could use evidence from other countries to explore how the effects may or may not differ given different political institutions and environments. Further research should also dig deeper into the tools that politicians and bureaucrats have at their

[12] In addition, we find that electors as a proportion of the 2001 population increased with high temperatures (coefficient 0.029 and standard error 0.126, which is small, 3% of the mean. AC population numbers vary considerably).

disposal to mitigate the effects of climate change in low- and medium-income countries.

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# A Appendix Tables

Table A1: Extreme Temperatures and Turnout: Robustness

| | Turnout (%): Robustness | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| DD | -0.998*** | -0.820*** | -0.760*** |
| | (0.121) | (0.130) | (0.215) |
| HDD | 1.438*** | 0.990*** | 0.973*** |
| | (0.272) | (0.290) | (0.246) |
| Lagged DD | | -0.214* | |
| | | (0.123) | |
| Lagged HDD | | 0.760*** | |
| | | (0.267) | |
| Spec | No rainfall | Lags | AC FE |
| N | 7,816 | 7,532 | 7,211 |
| R2 | 0.778 | 0.778 | 0.932 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p <0.10, ** p <0.05, *** p <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36℃. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

Table A2: HDDs and Winner Characteristics (Other results)

| | Winner characteristics | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Dependent variable: | Liab(log) | Female | Number crimes | INC | BJP | Others |
| DD | -0.128 | -0.003 | 0.048* | -0.003 | 0.006 | -0.005 |
| | (0.111) | (0.003) | (0.026) | (0.005) | (0.004) | (0.004) |
| HDD | 0.281 | -0.017 | -0.187 | -0.003 | 0.014 | -0.009 |
| | (0.388) | (0.013) | (0.141) | (0.019) | (0.018) | (0.016) |
| Regional FE | District | District | District | District | District | District |
| N | 7,242 | 7,468 | 7,242 | 7,594 | 7,594 | 7,594 |
| R2 | 0.216 | 0.103 | 0.162 | 0.271 | 0.386 | 0.474 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p* <0.10, ** *p* <0.05, *** *p* <0.01.* DD and HDD are the average good and harmful degree days, respectively, using a threshold of 36℃. All specifications include district fixed effects, month-year fixed effects and control for rainfall and rainfall squared.

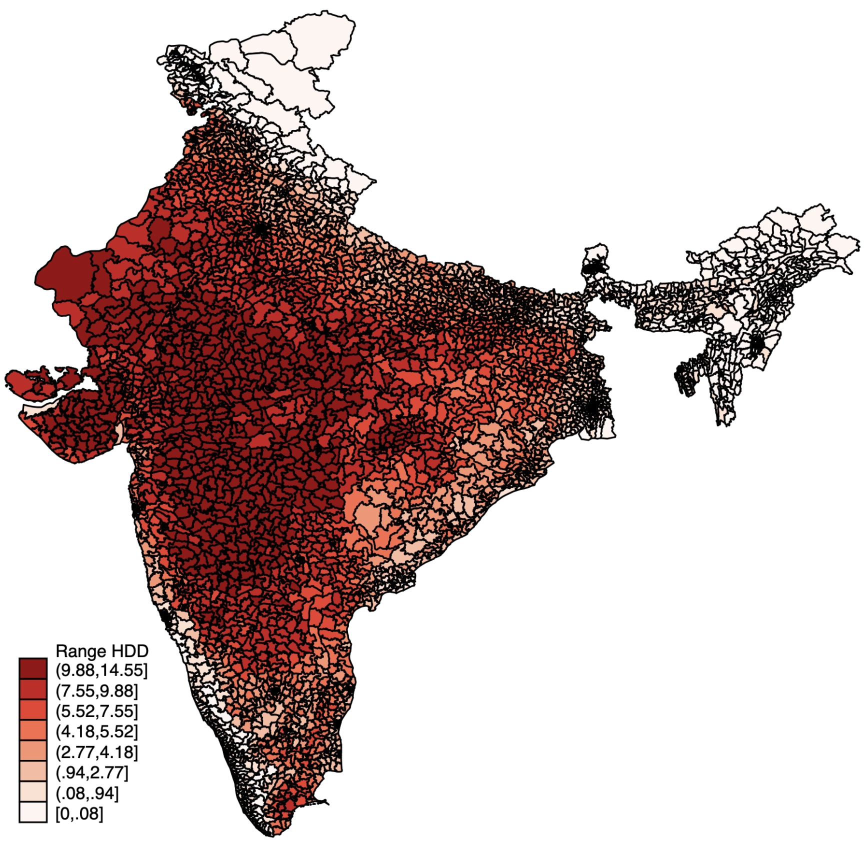
Table A3: Covariate Balance Around the Discontinuity

| | (1) | (2) | (3) |
|---|---|---|---|
| VARIABLES | Past irrigation | Past margin | Previous proff agri |
| RD_Estimate | -0.0123 | 0.0581 | -0.0173 |
| | (0.0240) | (0.0556) | (0.0590) |
| Observations | 1,099 | 174 | 1,101 |
| Bandwidth | 16.56 | 10.09 | 14.33 |
| Robust p value | 0.660 | 0.319 | 0.772 |

*Notes:* Standard errors (in parenthesis) are clustered at the constituency level. Stars indicate statistical significance: **p* <0.10, ** *p* <0.05, *** *p* <0.01.*

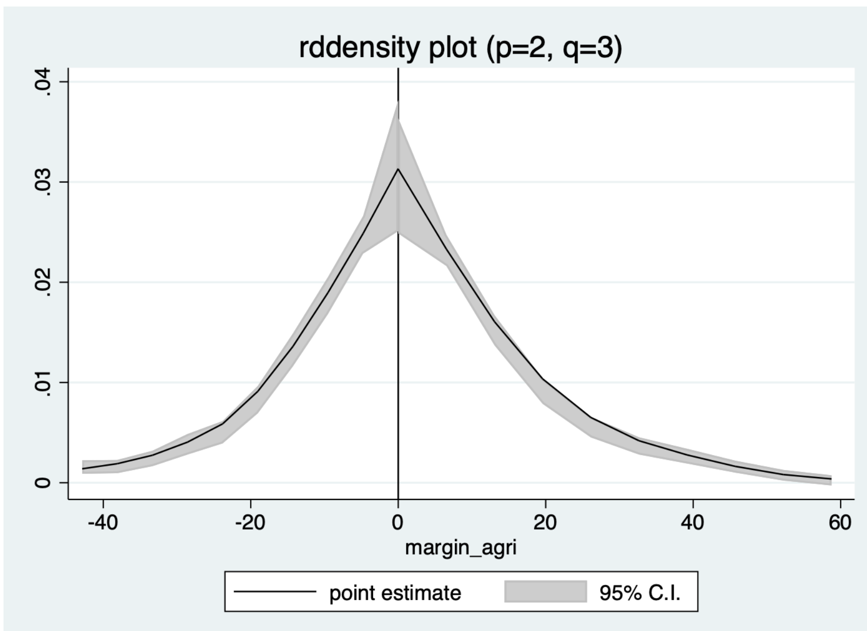
# B Appendix Figures

Figure B1: Range of HDD in sample years




*Notes:* Difference between the maximum and the minimum average harmful degree days (HDD) in a growing season for each Assembly Constituency between 2008 and 2017

Figure B2: Test: Manipulation of the Running Variable




*Notes:* Discontinuity:0.245, p-value: 0.8065 , estimated using "rd-density"