When the Temperature Drops, Perceptions Worsen: Effects of Extreme Cold on Perceptions of Government and Civic Participation in the Peruvian Highlands

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Abstract

Perceptions of government and political institutions can have important effects on a wide range of outcomes, such as compliance with laws and demand for public goods. We examine how extreme weather affects individuals' belief of how well democracy functions in Peru. We construct a unique dataset containing spatially and temporally specific cold temperature shocks and find that extreme cold reduces positive perceptions of democracy. This translates into reductions in civic engagement in formal democratic institutions (as measured by participation in national elections) but increased involvement in local associations. We provide evidence that these effects work through several mechanisms: decreased income, assets, and expenditure as well as increased incidence of illness and some types of crime. Finally, we find that the negative effects of extreme cold are mitigated by government provision of goods and services, namely, social programs, public hospitals, and police resources.

1 Introduction

A growing body of empirical evidence illustrates the role of trust and confidence in government in determining a myriad of important political economy outcomes, such as policy preferences (Fairbrother, 2019; Marien and Hooghe, 2011), compliance with laws (Citrin and Stoker, 2018), political participation (Grönlund and Setälä, 2007; Bélanger and Nadeau, 2005; Bélanger, 2017), voting behavior (Dalton and Weldon, 2005; Citrin and Stoker, 2018; Guiso et al., 2020; Bélanger, 2017), and the use of public goods and services (Christensen et al., 2021; Alsan and Wanamaker, 2018; Lowes and Montero, 2021; Martinez-Bravo and Stegmann, 2022; León-Ciliotta et al., 2022). However, much of the current literature focuses on the consequences of political trust in rich countries; few study the context of low- and middle-income countries (LMICs). Moreover, less is known about what determines sentiments towards government and political systems at the individual level.[1]

In this paper, we study the effect of extreme cold spells on the belief that democracy works well in Peru. This outcome captures an overall perception of the way democracy functions in Peru, both in terms of "diffuse" attitudes towards the political system (i.e., democracy as a regime) and "specific" satisfaction with or confidence in government in practice (i.e., citizens' evaluation of the performance of government bodies).[2] In many ways, weather shocks test the capacity and efficacy of the government system. Extreme weather has adverse consequences for agricultural income, assets, and consumption (Dell et al., 2012; Skoufias et al., 2012; Zhang et al., 2017; Schlenker et al., 2009; Aragón et al., 2021); health (Deschenes and Moretti, 2009; Deschênes and Greenstone, 2011); and crime (Simister and Cooper, 2005; Simister, 2001; Miguel, 2005; Ranson, 2014; Iyer and Topalova, 2014; Blakeslee and Fishman, 2013). In the context of the Peruvian Highlands — the main agricultural region of Peru — extreme cold is particularly important. Frost and cold waves have become increasingly common and devastating, highlighting the vulnerability of the region to weather volatility (Painter, 2008; Tambet and Stopnitzky, 2021; Keller and Echeverría, 2013; FAO,

[1] We are aware of only four economics papers that study the determinants of political trust. Stevenson and Wolfers (2011) document the strong pro-cyclicality of confidence in public institutions. Blanco and Ruiz (2013) and Blanco (2013) show that crime and insecurity can affect trust in democracy and institutions in Colombia and Mexico, respectively. Malásquez and Salgado (2023) finds that perceptions of democracy is affected by exposure to the Peruvian Conflict.

[2] We discuss the interpretation of this variable in more detail in Section 3.1.

2008). Thus extreme cold spells represent a broad negative shock that tests the capacity of the state in a meaningful way for citizens. Intuitively, we expect that negative shocks worsen perceptions of government and democracy in circumstances where citizens' needs are not met by government programs and services.

We begin by showing that extreme cold temperature shocks significantly lower the belief that democracy works well using a large repeated cross-section of agricultural households in the Peruvian Highlands over a period of 12 years. In particular, we use the 2007-2018 rounds of the Peruvian National Household Survey (ENAHO), which collects individuals' perceptions of government and democracy. We match these data to local weather data collected at the hourly level from the European Centre for Medium-Range Weather Forecasts (ECMWF). To do so, we use the GPS location of each household and the specific date each household is interviewed.[3] Our primary measure of extreme cold is the cumulative degree hours (CDH) below a given temperature threshold, which captures the number of hours in the relevant window that a household experienced temperatures below a specific threshold and the extent to which the temperature was below the threshold.

Conditional on district, year, and month-of-interview fixed effects, an additional ten hours below the threshold of -9°Celsius (C) over the course of the previous year lowers the probability that an individual sees democracy as functioning well in Peru by about 0.4 percentage points. Given the sample average for this measure is 0.51, we see these results as illustrating that extreme weather can meaningfully impact perceptions of government and democracy. The point estimates are larger in magnitude and statistically significant for colder temperature thresholds. Our main results are robust to using samples from other data sources (i.e., the Americas Barometer (LAPOP) and the Latinobarómetro), testing alternative measures of frost shocks, including fixed effects at more disaggregated levels, and accounting for potential endogenous migration.

Cold shocks affect critical downstream outcomes, namely measures of civic participation. First, we find that extreme cold reduces participation in national elections. The share of absent voters (registered voters who do not show up at the polling stations) and blank votes (votes that are

[3] The recorded GPS location of each household is specific to the village centroid in rural areas and the neighborhood block in urban areas.

cast but are left blank) is higher in districts that experience cold weather shocks leading up to presidential elections. This suggests that, as cold weather erodes the belief that democracy functions well, individuals are less likely to participate in national electoral institutions directly linked to democracy. Second, we also show that individuals are more likely to engage with local institutions (such as community-based associations) in the wake of cold shocks.[4] Thus, our results are consistent with negative shocks resulting in citizens turning away from formal national institutions to less formal and more local institutions.

We then explore several possible mechanisms through which extreme cold shocks worsen perceptions of government and democracy. We first confirm that extreme cold acts as a significant negative shock to income in our setting. Cold shocks occurring during the growing season lower agricultural income as well as total income and expenditure: ten additional degree-hours below the threshold of -9°C reduce agricultural income by 4.4%, total income by 1.5%, and total expenditure by 1.4%. Moreover, we find supporting evidence that extreme cold shocks lead to losses in livestock assets and worsen subjective perceptions of the economy. Second, we show that extreme cold increases illness experienced by the household. Ten degree hours below -9°C increase the probability that a young child in the household has been ill in the past 4 weeks by 2.7 percentage points and has been "severely ill" (requiring a medical consultation) by 2 percentage points. Third, we use a district-level yearly panel to show that frost shocks lead to an increase in certain types of crime. 10 CDH below -9°C increases economic crimes (e.g., burglary, theft, fraud, sales of illicit goods, etc.) per capita by 2% and overall crime by 1.2% but does not lead to more violent crime (e.g., assaults, murder, kidnapping, rapes, etc.). Additionally, extreme cold shocks increase intimate partner violence (as reported in the Peruvian Demographic and Health Survey (DHS)). Ten CDH below -9°C in the previous year increases the likelihood that a woman had experienced domestic violence by 0.5 percentage points.

Based on this evidence about the multiple ways in which extreme cold affects households' well-being, we posit that frosts highlight the extent to which government institutions can (or cannot) effectively serve their citizens in times of need. In other words, we argue that negative shocks are

[4] These results are consistent with recent work by Buggle and Durante (2021), who find that historical climate variability fostered interpersonal trust in Europe with lasting impacts on norms and institutions.

detrimental to perceptions of how democracy functions in circumstances where citizen needs are not met by government programs and services. Conversely, government-led programs that help smooth or ease negative shocks could be key in weakening the effect of cold shocks on political mistrust.[5]

To substantiate this claim, we conduct several heterogeneity analyses that focus on the role of government institutions in serving citizens in the presence of extreme cold shocks. We first study whether the effect of cold weather shocks on political trust is mediated by access to government-led social assistance schemes. Indeed, in provinces that have historically high shares of social program coverage (at baseline), the effect of a cold weather shock on political trust is small and statistically indistinguishable from zero. However, the effect is large and negative in areas with low baseline coverage. We find similar patterns when assessing the heterogeneity in the effects of cold weather shocks by access to public health facilities. Given that cold weather worsens health, we expect the negative effect on political trust to be mitigated in places where the government provides access to quality health care. Accordingly, we find that the effect of an extreme cold shock is attenuated in provinces that have more public hospitals per capita at baseline. Finally, we find that access to public safety also matters. In areas with low baseline police stations per capita, the negative effects of frost shocks are large and significant, whereas they are near zero and statistically insignificant in areas with high baseline police station coverage.

It is worth noting that though we study extreme cold as a relevant weather shock for our context, our results are useful for understanding the effects of other extreme weather conditions. This is because our results indicate that the mechanisms of interest — income, health, and crime — respond similarly to extreme cold as they do to other measures of extreme weather, such as extreme heat, drought, and floods (see, for example, Dell et al., 2012; Skoufias et al., 2012; Zhang et al., 2017; Schlenker et al., 2009; Aragón et al., 2021; Deschenes and Moretti, 2009; Deschênes and Greenstone,

[5]Previous literature has explored the role of public policy in attenuating the negative consequences of weather shocks on citizenship-related outcomes. For example, Fetzer (2014) shows that public workfare programs like the National Rural Employment Guarantee Act (NREGA) weakened the relationship between rainfall shocks and conflict in India, primarily by providing an option for income smoothing. Sarsons (2015) finds that public infrastructure (i.e., dams) attenuates the impact of rainfall shocks on Hindu-Muslim violence in India. Garg et al. (2020) find a positive relationship between heat waves and homicides in Mexico. However, homicide rates in locations that benefit from conditional cash transfers are less sensitive to higher temperatures, suggesting a role for income-support programs to reduce violence.

2011; Simister and Cooper, 2005; Simister, 2001; Miguel, 2005; Ranson, 2014; Iyer and Topalova, 2014; Blakeslee and Fishman, 2013). Thus we expect perceptions of government and downstream outcomes to be similarly impacted by events like heat waves and extreme rain episodes.

Our research makes important strides in understanding both the causes and consequences of changes in the way citizens view democracy and government. Evidence on the determinants of confidence and trust in government institutions in economics is scarce and outside of economics, the evidence is heavily skewed toward rich economies (Citrin and Stoker, 2018; Zmerli and Van der Meer, 2017). Our results yield novel insight into one factor that is important for determining beliefs about how democracy functions in LMICs: extreme cold. We are able to explore the pathways through which extreme cold impacts perceptions of democracy and government and illustrate the extent to which government provision of goods and services mitigates the impact of negative shocks on positive perceptions. Moreover, we demonstrate the importance of perceptions in key, tangible outcomes, such as voter participation, and highlight the potential for participation in national institutions to trade off with participation in local, community-based institutions. As such, these results provide policy insights into improving political trust and civic participation in unstable democracies or regions with high political mistrust, like Peru.

Our results also complement the extensive body of work linking extreme weather to conflict and political instability.[6] Though previous work has examined the roles of income and health as mediating factors through which weather impacts conflict and instability (see, for example, Miguel et al., 2004; Burke et al., 2009; Dell et al., 2012; Hsiang et al., 2011; Harari and La Ferrara, 2018; Ranson, 2014; Maystadt and Ecker, 2014; Sarsons, 2015; Hsiang et al., 2013), our findings shed light on the role of perceptions of and participation in democracy, which are thus far largely unstudied. We show that weather shocks erode the beliefs that democracy functions well at the individual level and that this, in turn, translates into changes in electoral behavior at an aggregate level, with potential implications for political instability and conflict.[7]

[6]While the research relating climate change and conflict is relatively recent, evidence suggests that weather has affected governance and political stability throughout human history. A growing strand of the literature analyzes long-term historical consequences of changes in climatic patterns on conflict in ancient civilizations (Chaney, 2013; Kung and Ma, 2014; Jia, 2014; Yancheva et al., 2007).

[7]For example, Engvall (2010) shows that low pre-conflict trust in government is a strong determinant of contemporaneous incidence of violence and casualties in Southern Thailand while Buhaug et al. (2015) argues that

Finally, we build on the previous literature evaluating the effects of extreme weather by focusing on a novel measure: extreme cold. Though the adverse effects of floods, droughts, and extreme heat have been well documented, to our knowledge we are the first to establish the effects of extreme cold on economic and political outcomes in a low-income setting. Interestingly, though average temperatures are expected to rise globally with climate change, there is evidence that extreme cold events may also become more common. In the northern hemisphere, this is attributed to the polar vortex or the "accelerated Arctic warming", which has induced more severe cold-air outbreaks in North America and Eurasia (Cohen et al., 2018; Kim et al., 2017).[8] In the southern hemisphere, the recent surge in extreme cold events is attributed to episodes of La Niña, which are projected to increase in both frequency and duration (Cai et al., 2015).[9]

2 Background

Formally, Peru is a democracy, where the president and members of Congress are elected by popular vote every five years. However, its political system has been plagued by individualistic leaders and unstable environments in the last three decades. These circumstances have led The Economist Intelligence Unit (2023) to classify Peru as a *hybrid regime*, somewhere between a "flawed democracy" and an "authoritarian regime". Political parties collapsed in the 1990s — a phenomenon that Tanaka (2005) coined as a "party-less democracy" — and have remained weak. Clashes between the executive and legislative branches have prevented the implementation of any meaningful reforms during the last decades. In the last six years (2016-2022), tensions between the two branches have escalated: Congress has impeached three presidents, one president dissolved Congress, and another one staged a failed *coup d'état*.

Furthermore, Peruvian politics have been deeply entrenched in systemic corruption: every elected president since 1985 has either faced jail time for corruption or has had credible corruption

preexisting political mistrust could provide "breeding ground" for political violence.

[8]It is hypothesized that Artic amplification or "accelerated Arctic warming" is a key underlying mechanism behind increased extreme cold weather events in the northern hemisphere. In other words, "as the Arctic warms the continent becomes colder" (Cohen et al., 2018).

[9]La Niña is a weather pattern characterized by cooler sea-surface temperatures in the southern Pacific off the coast of South America. It is the "opposite" phase of the El Niño, which increases the sea temperature in this region.

allegations against them (Bristow, 2022). Former president Fujimori (who ruled Peru between 1990 and 2001) has been ranked as one of the most corrupt leaders in the world, having embezzled an estimated $600 million (Transparency International, 2004). Peru has continued to be plagued by subsequent corruption scandals. One case — considered to be the "largest foreign bribery case in history" (US Department of Justice, 2016) — involved millions of dollars in bribes to Peruvian political leaders, including large campaign donations to several presidential candidates. Members of Congress have also faced corruption accusations. They are perceived to favor powerful lobbies, act based on personal economic interests, and shield themselves from accountability through congressional immunity (Wall Street Journal, 2020). The judiciary has not been exempt from corruption either. In 2018, wiretap transcripts uncovered a vast corruption network where judges in high courts and members of the National Board of Justice (a council that appoints and removes judges from office) received bribes and political favors from businessmen and politicians in exchange for favorable sentences (IDEHPUCP, 2020; La República, 2021). Thus, it is not surprising that Peru is one of the countries with the lowest levels political trust in Latin America. Figure A1 shows that, in a sample of 17 Latin American countries, Peruvians' trust in democratic institutions (i.e., the national congress, political parties, and the government) is the lowest, with the exception of Ecuador.

Despite this political instability, Peru's economy has experienced considerable and sustained economic growth; in 20 years (2000-2019), GDP per capita doubled. Economic growth allowed for a large reduction in poverty (which dropped from 48.4 % to 20.5% during this period). While there was some reduction in inequality (the Gini index reduced by 15%, from 49.1 to 41.6), Peru is still a country with large inequalities. While the top 10% of the population concentrates 31.6% of total income in Peru, the share of the bottom 10% is only 1.8%. There are also significant regional gaps in Peru. In this paper, we focus on the rural highlands of Peru, a region that has been left behind despite the significant overall progress that Peru experienced in the last decades. By 2018, 13.1% of the population in Metropolitan Lima was poor. In contrast, the poverty rate in the rural highlands (the poorest region in the country) was 49% (INEI, 2019). There are also large regional gaps in terms of access to public services: while access to sanitation is almost universal in Metropolitan Lima

(97%), only about half of households in the rural highlands (54.1%) have access to such utilities.[10]

Compounding this vulnerable situation, the rural highlands in Peru are also subject to considerable weather shocks (e.g., droughts, floods, frosts, cold waves, etc.; World Bank 2008). Most experts argue that this situation will continue to worsen in the future, as Peru is one of the most vulnerable countries to climate change (Stern, 2007; Tambet and Stopnitzky, 2021). Frosts and extreme cold events have become increasingly common in Peru over the last two decades, affecting millions of Peruvians (Keller and Echeverría, 2013; FAO, 2008), particularly those in the highlands, which are located at elevated altitudes (between 500 and 6,798 meters above sea level). In recent years, extreme cold temperatures have dipped as low as -20°C in some areas, affecting close to 200 thousand inhabitants (Centre for Research on the Epidemiology of Disasters, 2023).

Extreme cold can have particularly severe consequences on agricultural output, an important economic activity in the highlands. The extent of the damage induced by frosts depends on the intensity of the frost (i.e., how much below 0°C the temperature drops), the frequency of these events, the type of crops, and the phenological state of the plants (Snyder and Melo-Abreu, 2005). More intense frost episodes can induce crop failure and significant economic losses. For example, a frost in 2008 destroyed 45% of potato production in several high-altitude Peruvian provinces (FAO, 2008). Frost damage is not limited to Peru. A 2021 frost caused an estimated US$ 1 billion losses to coffee farmers in the Brazilian state of Minas Gerais (Samora, 2021), while another frost in 2021 generated around € 2 billion in losses in French wine production (The Guardian, 2021). The continued threat of frosts is a concern for much of the highlands; CENEPRED (2021) estimates that there are 823 districts (encompassing around 1 million farmers and 3.3 million hectares of agricultural land) under high or very high risk of experiencing frosts.

Extreme cold can also have detrimental effects on livestock. Livestock are valuable assets for rural households in the Peruvian Andes (Kristjanson et al., 2007). They are sources of food, energy, fiber, fertilizer, and transport (León-Velarde and Quiroz, 2003). Additionally, they "can be sold to finance investments such as school fees or in time of need such as illness or drought" (Herrero et al., 2013). For example, *alpacas* (a South American camelid) are one of the most important types

[10]Calculations based on the 2018 Peruvian National Household Survey (ENAHO).

of livestock in the Peruvian highlands. Alpacas can be directly affected by frosts, as they can experience hypothermia and frostbite when subject to sudden reductions in temperature. The effects of frosts can be quite severe: during 2015, temperatures in the state of Puno reached -20°C. The extreme cold shock killed 170 thousand alpacas and had negative impacts on the livelihoods of several communities that depend upon sales of alpaca fiber (BBC News, 2015).

In addition to its negative impact on farm income, extreme cold weather can potentially also have severe health consequences. Previous research has found a significant association between cold weather and the incidence of respiratory tract infections (Zhao et al., 2021; Kephart et al., 2022; Sheridan and Allen, 2015). In 2010, extreme cold temperatures related to a *La Niña* event killed 250 children (mostly under the age of 5) in Peru due to "cold-related respiratory diseases, mostly pneumonia" (Kirkland, 2012).

A less-explored channel through which extreme cold can affect rural households is a potential increase in crime and violence. Previous literature has found that *hotter* temperatures can increase violence and crime (Blakeslee and Fishman, 2018; Mukherjee and Sanders, 2021; Colmer and Doleac, 2022; Mares and Moffett, 2019; Garg et al., 2020; Simister, 2001; Simister and Cooper, 2005). Income losses and physiological responses to extreme weather shocks can lead to increases in crimes. However, there is scant research testing whether *colder* temperature can also affect crime rates. Additionally, if individuals avoid cold outdoor temperatures by staying home, it is possible that frosts can increase the extent of domestic violence (Agüero and Frisancho, 2022). Peru is a country with high levels of Intimate Partner Violence (IPV). 63% of women aged 15–49 report having experienced violence from their partner/spouse throughout their lives (INEI, 2019). Anecdotal evidence suggests that, because individuals experience "cabin fever" when they stay home during cold weather, it is more likely that perpetrators and victims spend more time in confined spaces (ABC News, 2014).

All in all, the Peruvian highlands are vulnerable to frosts that can have negative impacts on agricultural production, incomes, productive assets (such as livestock), health outcomes, and violence. We hypothesize that such shocks can potentially translate into political mistrust, in a country that has faced long-standing governance crises.

3 Data and Variables

Our analysis uses two main data sources: the Peruvian National Household Survey (*Encuesta Nacional de Hogares* - ENAHO) and weather data from the European Centre for Medium-Range Weather Forecasts (ECMWF) and the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS).

3.1 Encuesta Nacional de Hogares (ENAHO)

The ENAHO is a detailed household survey collected annually by the National Statistics Office (Instituto Nacional de Estadística e Informática 2018c - INEI). We use twelve rounds of the ENAHO (2007-2018) and focus on several dimensions of the survey. The first is a module on households' perceptions of governance, which solicits individuals' confidence in democracy, political parties, and institutions. Only one randomly chosen adult (18 years or older) in each household is sampled for this module.

Our primary outcome variable measures whether citizens believe that democracy works well in Peru. Specifically, we focus on a question that asks the following: "In Peru, does democracy work..?" We code our variable as one to those who believe democracy works "well" or "very well" and zero otherwise.[11]

$$Y_{idt} = \begin{cases} 1 & \text{if response is "very well" or "well"} \\ 0 & \text{if response is "very poorly" or "poorly"} \end{cases} \quad (1)$$

We believe that this variable represents an overall perception of the way democracy functions in Peru, both in terms of so-called "diffuse" attitudes towards the political system (i.e., democracy as a principle or as a broad institution) and "specific" satisfaction with or confidence in the current or recent government regimes (i.e., how democracy works in practice and citizens' evaluation of the performance of government bodies).

[11]The questionnaire includes an option for "do not know". About 24% of individuals respond with "do not know". In our main analysis, we drop these observations from our sample; in Section 8, we show that our results are robust including these observations as a neutral, middle category.

Indeed, we find empirical support for both interpretations of this measure. Table 1 displays conditional correlations between our primary outcome measure (the belief that democracy works well in Peru) and a battery of other measures of political trust and confidence in specific institutions.[12] We find that the belief democracy works well is most highly correlated with evaluations of how well different levels of government (central, regional, provincial, and district) are managed. Our outcome variable is also correlated with confidence in specific government bodies, such as the national Congress, the Judiciary, and Political parties. However, it also reflects more general beliefs about democracy as a system: it is highly correlated with the belief that democracy is always the most preferred form of government and the belief that democracy is important.

In this way, we see our outcome as being similar to the widely used "satisfaction with democracy" (SWD) measure. SWD is typically elicited with questions very similar to the one included in the ENAHO, along the lines of: "On the whole, are you very satisfied, fairly satisfied, not very satisfied, or not at all satisfied with the way democracy works in [country]?" SWD has been interpreted as a measure of either support for democratic principles (for example, see Norris 2011) or for specific support (for example, see Linde and Ekman 2003), or both (Kölln and Aarts, 2021; Clarke et al., 1993; Christmann, 2018; Kosec and Mo, 2023). Along these lines, SWD can be interpreted as "an expression of citizen's evaluation of how the democratic regime procedures function in practice, so it reflects a rational response to the working and outputs of political systems" (Christmann, 2017, p. 10). The ENAHO does not explicitly ask about citizens' SWD, but instead has a similar question about how democracy "works".

The ENAHO also collects detailed information about households' socioeconomic characteristics, such as demographics, education, expenditures, and dwelling characteristics. Importantly, INEI provides households' approximate GPS location: in rural areas, the ENAHO reports GPS coordinates for the village in which the household lives, and in urban areas, it reports coordinates for the centroid of the neighborhood block.

We use ENAHO's health module to collect information about child health status. In particular, we focus on illnesses and medical consultations of children below five years of age (an age group

[12] The correlations in Table 1 are coefficients from separate regressions that include district, year, and month-of-interview fixed effects.

Table 1: Conditional Correlations between Evaluation of Democracy and Evaluation and Confidence in Specific Institutions

	Dep. Variable: Believes democracy works well
Supports management of central government †	0.235***
	(0.006)
Supports management of regional government †	0.224***
	(0.007)
Supports management of provincial government †	0.225***
	(0.006)
Supports management of district government †	0.211***
	(0.006)
Confidence in political parties	0.140***
	(0.007)
Confidence in Congress	0.129***
	(0.005)
Confidence in regional government	0.119***
	(0.005)
Confidence in municipal government	0.116***
	(0.005)
Confidence in provincial government	0.106***
	(0.005)
Confidence in the Judiciary	0.110***
	(0.005)
Believes democracy is preferable	0.102***
	(0.006)
Confidence in Police	0.101***
	(0.005)
Confidence in Armed Forces	0.050***
	(0.005)
Confidence in the Catholic Church	0.042***
	(0.005)

Note: Each coefficient comes from separate regressions with district, year, and month-of-interview fixed effects and "Believes Democracy Works Well" as the dependent variable. The sample in the regressions includes the 2007-2018 rounds of ENAHO. † However, due to lack of data availability, the top four variables (management of the central, regional, provincial, and district governments) are only analyzed for the 2012-2018 rounds of the ENAHO. District-level clustered standard errors in parentheses. Significance levels denoted by: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

that is particularly vulnerable to respiratory infections when exposed to frosts). We also use the ENAHO to collect information about household members' membership in local associations. Lastly, we use the ENAHO agricultural module, where households report their crop income, input usage, and other relevant agricultural information in the twelve-month period before their interview. Appendix Figure A2a shows the location of all farming households surveyed within the Peruvian Highlands in the ENAHO between 2007-2018, the sample which we use for our study. Importantly, these households are located precisely in the regions of Peru that are more susceptible to experiencing frosts (Appendix Figure A2b).

3.2 Weather Data

We collect detailed hourly temperatures (i.e., at midnight, 1 AM, 2 AM,..., 11 PM) for every day between 2011 and 2018 from the European Centre for Medium-Range Weather Forecasts (2018) (ECMWF).[13] The ECMWF estimates temperatures from weather stations, satellites, and sondes, and processes this information at a geographic resolution of 0.25 degrees. We match household data from the ENAHO with the ECMWF weather data using two critical pieces of information: households' approximate GPS location (provided at the level of the primary sampling unit or the survey block) and each household's month and year of interview. This allows us to construct a household-specific measure of extreme cold exposure throughout the year prior to interview (the standard recall period for most survey questions), which takes into account both the location of the household and the timing of the interview.

We build on the widely used cumulative degree days measure from Schlenker and Roberts (2006) and estimate the number of cumulative degree *hours* in which a household experienced extreme cold temperatures. This measure aims to combine both the amount of time and the severity of a climatic shock — i.e., for how long and by how much a household experienced temperatures below a certain threshold. Therefore, this measure combines both the duration and intensity of frost events. Denote the temperature threshold λ, where λ= 0°C, -1°C, -2°C,... , -12°C. We begin by

[13] In particular, we use the ERA5 dataset, which provides the latest reanalysis data on global climate and weather for the past several decades.

defining harmful degree hours (i.e., hours of exposure to temperatures below the threshold λ) as:

$$DegreeHours(DH_{itmdh}) = \begin{cases} \lambda - h_{itmdh} & \text{if } h_{itmdh} < \lambda \\ 0 & h_{itmdh} \geq \lambda \end{cases} \tag{2}$$

where h_{itmd} is the temperature in household i's location, on year t, month m, and hour h. For example, if λ=-1°C, an hour of temperature at -3°C represents 2 degree hours; while an hour at a temperature of -2°C would lead to only 1 degree hour. Because there is no clear definition of a "harmful" threshold, we show our results using a wide range (from 0°C to -12°C) of temperature thresholds.

Our primary measure of extreme cold exposure is the *cumulative* degree hours (CDH) below threshold λ that household i interviewed in month m and year t experienced over the 12 months prior to the survey.

$$CumulativeDegreeHours(CDH_{it}) = \sum_{m=-12}^{-1} \sum_{d=1}^{30} \sum_{h=1}^{24} DH_{itmdh} \tag{3}$$

In some of our regressions, we use a shorter window of time instead of a 12-month period (e.g., for morbidity outcomes, which have a shorter recall period). When we consider agriculture-related outcomes, we calculate a modified version of this index where we weight exposure based on the provincial crop calendar (described below in 3.4). More precisely, we weigh each the number of degree hours below our threshold temperature in a month (i.e., $\sum_d \sum_h DH_{itmdh}$) by the share of farmers in household i's province growing crops in month m (ω_{md}). The weighted index not only captures the intensity and duration of the frost shocks but also reflects potentially different effects of these events depending on local cropping cycles.

$$WeightedCumulativeDegreeHours(WCDH_{it}) = \sum_{m=-12}^{-1} \omega_{md} \sum_{d=1}^{30} \sum_{h=1}^{24} DH_{itmdh} \tag{4}$$

Finally, we extract rainfall data from the Weather Hazards Group InfraRed Precipitation with

Station Data (CHIRPS).[14] CHIRPS is a global dataset that provides high-resolution estimates of rainfall for 0.05 X 0.05 degree pixels. We match rainfall to households using GPS coordinates and interview dates from the ENAHO using the same procedure as we use for the temperature data.

3.3 Main Estimation Sample

In this paper, we pool 12 survey rounds of the ENAHO (2007-2018). Due to the nature and geographic scope of cold weather shocks in Peru, we restrict our sample to farming households in the highlands. With these restrictions, we obtain a sample of 57,159 households across 938 districts in the Peruvian highlands.[15] Table 2 presents the summary statistics for our sample.

About 63% of the sample has completed at most primary school and over half of the sample speaks Quechua (the most prominent indigenous language in Peru) at home (column 1). Though the average household has experienced less than one harmful degree hour at the threshold of -9°Celsius, this is because only 5% of households experience temperatures below this threshold (Appendix Figure A3). Conditional on having been exposed to temperatures below this threshold, the average CDH in the sample is about 15.

Strikingly, only about half of the individuals in our full sample believe that democracy works well in Peru. When we break down the sample into households that face and do not face frost shocks (columns 2 and 3), we see that those who face frost shocks are about 2.5 percentage points less likely to report that democracy works well. Households facing frost shocks also tend to have lower agricultural and total income, and they are more likely to have sick children in the household. In terms of predetermined individual and household characteristics, households that have and have not faced frost shocks are largely similar, with the exception that those facing frost shocks are more likely to speak Quechua as their mother tongue.

3.4 Other Data Sources

Encuesta Nacional Agropecuaria (ENA). We complement the ENAHO with data from the Peruvian ENA (National Agriculture Survey), also collected by the Instituto Nacional de Estadística e

[14]For a discussion of the CHIRPS dataset, please see Funk et al. (2015).

[15]There are 1,873 districts in Peru, so our sample covers around half of all districts in the country.

Table 2: Descriptive Statistics

	Full Sample (1)	Households Facing Frost Shocks (2)	Households Not Facing Frost Shocks (3)
Believes Democracy Works Well	.511	.487	.512
Weather Variables			
CDH (λ = -9°C)	.755	14.981	0
Average Temperature	9.542	5.318	9.766
Average Rainfall	65.303	65.314	65.302
Mechanisms			
Total Agricultural Income	3039.5	1696.8	3110.7
Total Income	9209.4	8776.4	9232.3
Total Expenditure	6799.3	6826.6	6797.8
Value of Livestock Losses	751.6	242.2	781.3
Livestock Death (dummy)	.342	.488	.334
Biggest Problem: No Agric. Support	.083	.069	.084
Biggest Problem: Lack of Employment	.076	.09	.075
Child Has Been Ill (prev. 4 weeks)	.333	.387	.332
Child Required Medical Attention	.316	.319	.316
Individual and Household Characteristics			
Male	.509	.498	.51
Age	46.724	47.632	46.676
Household Size	4.014	3.88	4.021
Education			
Primary or Less	.628	.626	.628
Secondary	.285	.286	.285
Technical	.05	.057	.049
College	.037	.032	.038
Mother Tongue			
Quechua	.518	.830	.501
Spanish	.428	.096	.445
Amarya or Other Indig.	.055	.075	.054
Observations	57159	2880	54279

Notes: All monetary variables are expressed in 2007 soles using the GDP deflator published by World Bank (2023). The main sample (column 1) includes individuals in all farming households in the Highlands in the ENAHO 2007-2018 . We further split the sample into households that have experienced frost shocks (column 2) and those that have not (column 3). The exception is the sample for child health variables, which are reported for a restricted sample of children ages 0-5 living in the main sample households.

Informática (2018b). The ENA is a yearly cross-sectional dataset of agricultural households. Importantly, the ENA contains information about the timing of cultivation (sowing and harvesting). Information about when households grow crops is important because cold weather shocks could have a larger effect — at least in terms of agricultural income — during the months in which households grow their crops. We pool five rounds of the ENA (2014-2018) to build an agricultural calendar for each province. In particular, we calculate the share of households growing crops in each calendar month in each province, where we consider any months between sowing and final harvest as the growing period.

Organismo Nacional de Procesos Electorales (ONPE). We obtain data on voting outcomes at the district level from the Peruvian National Elections Commission (2016). We focus on the 2011 and 2016 Peruvian presidential elections, the two presidential elections that occur during our sample period. Presidential elections in Peru proceed in two rounds; all parties/candidates openly compete in the first round, and if no party claims an overall majority (50 % or higher), the two parties with the highest first-round votes compete in a run-off in the second round. Our data capture voting participation in both rounds. For each district, we are able to observe the number of registered voters and the number of votes cast. Within the votes cast, we observe how many of them are valid or blank/invalid.

Registro Nacional de Denuncias de Delitos y Faltas. The Registro Nacional de Denuncias de Delitos y Faltas (National Registry of Crimes and Misdemeanors) collects crime-level information from each police station in Peru (Instituto Nacional de Estadística e Informática, 2017). Importantly, the registry includes information on the type of crime (e.g., violent versus economic crimes) and the district where each crime occurs. We use this to create a district-level panel of crimes per 10,000 residents for the years in which the Registro is available (2011, 2013, 2014, 2016, and 2017).[16]

Encuesta Demográfica y de Salud Familiar (Peruvian DHS). The Peruvian Demographic and Health Survey (also referred to as the ENDES) is the first continuous (i.e., annual) DHS survey, starting in 2004 (Instituto Nacional de Estadística e Informática, 2018a). We use the Peruvian DHS to study the effect of extreme cold on intimate partner violence. The DHS data is a rich source of nationally representative, repeated cross-sectional data on various types of domestic violence like emotional, physical, and sexual violence. We focus primarily on a summary measure of domestic violence: whether a woman has experienced any physical, emotional, or sexual violence from her partner in

[16]District population data is taken from the 2007 National Census.

the past year. Our estimation sample is made up of ever-married women (aged 15-49) living in the Peruvian highlands. The DHS provides geographical coordinates of the households at the level of the survey clusters starting 2010 onwards, so for our domestic violence analyses, we restrict our sample to the years 2010-2018.

Registro Nacional de Municipalidades (RENAMU). The RENAMU (Municipality Registry) is an annual survey that collects information on the universe of municipalities (districts) in Peru (Instituto Nacional de Estadística e Informática, 2007). We use it to compute the number of public hospitals per 10,000 residents at the province level in 2007, the baseline year of our main estimation sample.

Censo Nacional de Comisarías (CENACOM). The CENACOM (National Census of Police Stations) is an annual census that collects information on police stations throughout Peru Instituto Nacional de Estadística e Informática (2012). We use the CENACOM to measure the number of police stations per 10,000 residents at the province level in 2012, the earliest available round of the census.

Latin American Public Opinion Project (LAPOP) and Latinobarómetro. We use data covering Peru from two similar, nationally representative surveys: the AmericasBarometer of the LAPOP (LAPOP Lab, 2017) and Latinobarómetro (Latinobarómetro Corporation, 2017). Both collect information on a variety of topics, including citizens' satisfaction with democracy. We use the 2014 and 2017 rounds of the LAPOP and the 2008-11, 2013, and 2015-2017 rounds of the Latinobarómetro. For both surveys, we restrict our attention to individuals in the Highlands as we do in our main regression sample.

4 Empirical Strategy

To estimate the causal effects of extreme cold shocks on political trust, we employ a fixed effects strategy. Specifically, we estimate the following regression:

$$Y_{idmt} = \beta_1 CDH_{idmt} + \beta_2 AvgTemp_{idmt} + \beta_3 AvgRain_{idmt} + \beta_4 Z_{idmt} + \alpha_d + \gamma_t + \theta_m + \varepsilon_{idmt} \quad (5)$$

where Y_{idmt} is a measure of political trust for a randomly chosen individual from household i in district d interviewed in calendar month m of year t. CDH_{idmt} is the number of degree hours below threshold λ that a household experienced in the 12-month period before being interviewed (as described in Section 3.2). Avg Temp$_{idmt}$ and Avg Rain$_{idmt}$ are the average temperatures and rainfall that household i experienced in the 12 months prior to the survey, respectively. Z_{idmt} is a vector of predetermined individual characteristics (i.e., respondent sex, age, education level, mother tongue, relationship to the head of the household, and household size).

We include fixed effects at the district level (α_d), which account for any time-invariant spatial heterogeneity in the incidence of cold shocks and political trust. We also include fixed effects at the interview year (γ_t) and month level (θ_m), which accounts for seasonality and general trends in political trust and cold shocks.

The coefficient of interest in is β_1. Our identification strategy assumes that — conditional on district, year, and month fixed effects (and other individual and household controls) — the incidence and intensity of cold shocks are exogenous with respect to political trust. While households might select into different districts (for example, wealthier households might choose to live in warmer areas), we exploit *within-district* variation in the intensity of cold shocks over time. In essence, we compare households within the same district who are interviewed at different times — and thus who are subject to different temperature fluctuations that vary randomly by the date of interview[17] — while netting out general trends and seasonality in weather. As long as households are unable to anticipate fluctuations in the intensity of cold shocks, $\hat{\beta}_1$ will capture the causal effect of cold shocks. We report our results for this specification below. To simplify their interpretation, we have multiplied the coefficients and standard errors in the tables below by 100 (so they directly reflect changes in terms of percentage points).

5 Results

We find that cold weather shocks negatively affect individuals' perceptions of democracy. Exposure to an additional 10 degree hours below -9°C in the previous year reduces the probability an individual believes democracy works well (or very well) by 0.39 percentage points (Table 3). The effects of cold weather shocks are larger if we consider more extreme thresholds of harmful

[17]It is worth noting that the ENAHO is not collected during particular months. Instead, it is collected continuously throughout each survey year, in such as way that each quarterly dataset provides a nationally representative sample. This provides us with random variation in the survey dates.

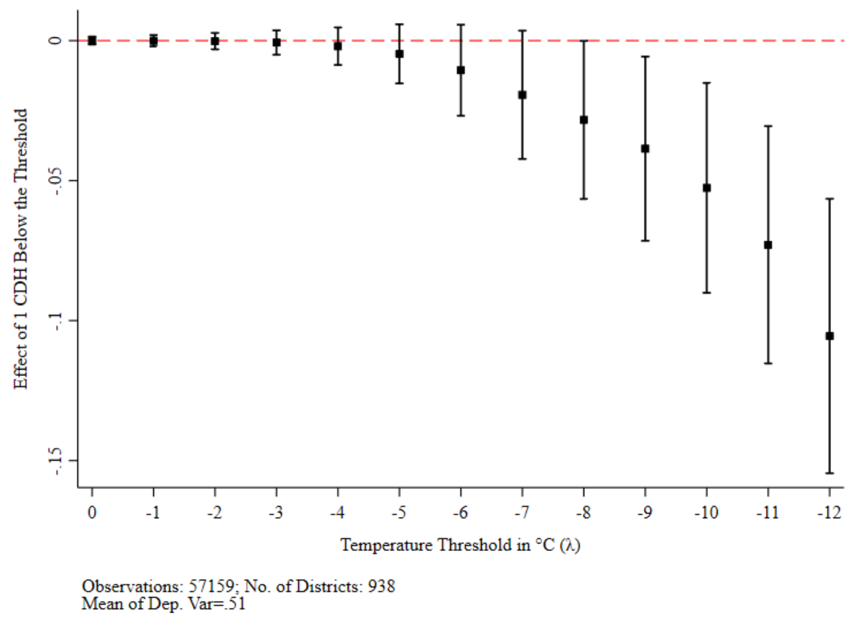
temperatures (see Figure 1). For example, 10 degree hours below -12°C over the period of previous one year reduces the likelihood that a respondent believes democracy works well by 1.2 percentage points.

Table 3: Effects of Frost Shocks on the Belief that Democracy Works Well

	Dep. Var.: Believes Democracy Works Well
Cumulative Degree Hours (λ = -9°C)	-0.039**
	(0.017)
Observations	57159
No. of Districts	938
Mean of Dep. Var	0.511

Notes: The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, age squared, education level, and mother tongue), and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Figure 1: Effect of Sub-zero Temperature Shocks on the Belief that Democracy Works Well



Notes: The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, and age squared as well as education level, mother tongue fixed effects, and household size). All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation.

We next investigate whether the reduction in political trust has consequences for aggregate electoral participation. We focus on two indicators of electoral participation at the district-level: the share of absent votes (i.e., the share of eligible voters in a district that did not cast a vote)[18] and the share of votes that are either absent or blank (where blank votes are those that are cast but that are left blank).[19] Both voting behaviors capture disengagement with the most basic democratic institution (i.e., voting) and previous research suggests that they might reflect protest voting (Alvarez et al., 2018).

[18]One important characteristic of the Peruvian political system is that voting is mandatory for all citizens aged 18–70. Those who do not show up to the polling stations on election day face a monetary fine that ranges from approximately US$ 6 (in poorer districts) to approximately US$ 25 (in wealthier districts). Therefore, absenteeism imposes economic costs on those that decide not to participate in elections.

[19]In the results below, we do not consider spoilt votes (null votes where individuals choose more than one presidential candidate, make drawings in their ballot, physically deforms the ballot, etc.). While some spoilt votes may reflect protest voting, others might have unintentionally voided their ballots. In any case, our results are robust to including spoilt votes in our measure of civic disengagement.

For this purpose, we use district-level voting data from ONPE for the 2011 and 2016 Presidential Elections (the two races during our study period). As mentioned previously, the Peruvian Presidential election typically includes two rounds: a general election (with several candidates) and a run-off race between the two top candidates (when no candidate reaches more than 50% of the votes in the general election). Therefore, we focus on four different voting rounds. We match weather data to district-level voting data using the GPS location of the district centroid. We measure extreme weather shocks as those that occur in the year previous to the election, taking into account the date at which each voting round occurs. As in our main specification (equation 5), we include district- and year-fixed effects.

We find that extreme cold shocks in the year before a presidential election decreases voter participation: 10 degree hours below -9°C in the 12 months prior to the election increases the share of absent voters by 0.08 percentage points in the 1st round, and by 0.12 percentage points in the 2nd round of the elections (Table 4, columns 1 and 2). These results are robust to including blank votes as an additional measure of non-participation (columns 3 and 4).[20] Though the effect size is modest, we believe that these results have important implications for voting outcomes for Peru, where the margin of victory in national elections tends to be very small. For example, a 10 degree hour shock translates into an increase in 25,474 absent voters in the second round.[21] The margin of victory in the 2016 presidential elections was only 41,057, suggesting that the effect of extreme cold on absent voters could potentially play a meaningful role in election outcomes.

Consistent with our results for political trust, we find that the effects of extreme cold shocks on the share of absent voters are much larger for more extreme temperature thresholds (Appendix Figure A4). For example, 10 degree hours below -12°C in the year before the election leads to an increase in the share of absent voters in the district of 0.27 percentage points (second round). This translates to more than 58 thousand fewer voters in the 2016 presidential elections, much more

[20]Recent literature has interpreted blank, null, or spoiled ballots as a manifestation of disillusionment with the existing political system, rejection of incumbent politicians, and/or discontent with current conditions (Alvarez et al., 2018, p. 144). To demonstrate that blank votes can be interpreted as intentional "protest votes" rather than accidental errors in casting votes, Cohen (2017) compares self-reported null votes cast in ex-post surveys' to official electoral results in 14 Latin American countries. She finds that a large proportion of official null votes corresponds to self-reported ones, suggesting that these votes are intentional.

[21]The total number of eligible voters in 2016 was 22,016,988.

Table 4: Effects of Frost Shocks on Electoral Participation

	Share of Absent Votes		Share Absent & Blank	
	First Round	Second Round	First Round	Second Round
	(1)	(2)	(3)	(4)
CDH (λ = -9°C)	0.008***	0.012***	0.007***	0.011***
	(0.002)	(0.003)	(0.002)	(0.003)
Observations	2536	2536	2536	2536
No. of Districts	1268	1268	1268	1268
Mean of Dep. Var	0.235	0.263	0.363	0.273

Notes: Shares are calculated with respect to the total eligible voters in each district. The sample includes all districts in the Highlands and covers the 2011 and 2016 presidential elections. Weather variables are measured at the district centroid and measures weather in the year prior to the date of each election. All specifications include year and district fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

than the margin of victory.

We interpret these results as indicating the extent to which extreme cold can worsen perceptions of democracy, which in turn reduces participation in national political institutions, such as voting. One question is whether extreme cold lowers the evaluation of all institutions, or whether the effects are specific to political institutions. One possibility is that, as individuals experiencing extreme cold move away from national and formal institutions, they may reallocate their participation towards other, non-political or informal institutions. We draw the motivation for this relationship from prior work that suggests that in the face of economic shocks, agricultural households may use alternative strategies to cope with economic uncertainties and consumption losses when state and market-led opportunities for consumption smoothing are lacking (Bhattamishra and Barrett, 2010; Buggle and Durante, 2021). Though some of the alternative strategies can be household-specific (like diversifying own income channels), others can involve a higher degree of engagement both within and outside local communities. Higher cooperation, interaction, and participation in neighborhood and nearby communities are seen as key pathways for risk coping as well as mutual insurance.

To investigate this possibility, we examine whether extreme cold shocks impact engagement in local institutions. Namely, we use data from ENAHO where individuals report whether they participate (as leaders or members) in different types of local associations and groups. We classify these institutions into three categories[22]: political (e.g., political parties, municipal management committees, citizen round tables, etc.), professional and agricultural (e.g., worker associations, trade guilds, professional associations, agricultural associations, etc.), and community-based (e.g., peasant communities in charge of communal land administration, *Rondas Campesinas* or rural self-defense groups[23], *Juntas de Regantes* or local irrigation management boards, neighborhood associations, etc.). We regress an indicator of whether (at least one member of) a household reports participation in any of these local organizations on CDH as well as the fixed effects and similar controls as in equation 5.

We find that overall participation in local associations increases by 0.23 percentage points when households face 10 degree hours below -9°C (Table 5, column1). This estimated effect does not appear to be driven neither by participation in political (column 2) nor professional and agricultural associations (column 3), but rather by community-based associations (column 4). As with our main results, we find that the effects of cold weather shocks on participation in local organizations are larger in magnitude when we consider more extreme temperature thresholds (see Appendix Figure A5). This evidence is consistent with the possibility that, on average, extreme cold shocks tend to push individuals away from engaging with formal, national institutions (such as voting) and toward more local, informal institutions related to identity, kinship, and social proximity.

6 Mechanisms

Thus far, we have shown that extreme cold shocks worsen individuals' perceptions of democracy, lower participation in formal government institutions such as voting, and increase participation in local associations. We now consider the potential pathways through which cold shocks influence these outcomes. We focus on three broad mechanisms: lower economic standing (income, assets, and expenditure), adverse health consequences (such as illness), and increased crime.

[22]Our measure of participation in local organizations aims to highlight the way in which citizens self-organize to cope with negative shocks. Therefore, our variable excludes participation in government-run social assistance programs (such as *Vaso de Leche* and *Comedores Populares*), which require communities' in-kind provision of labor.

[23]Prior to the 2012 round of the ENAHO, participation in *Comunidades Campesinas* (a historical and widespread community-based group) was not asked about directly, but was included in the category "Other". As a result, we include the "Other" category prior to 2012 in the community-based definition.

Table 5: Effects of Frost Shocks on Participation in Local Associations

	All Local Assoc. (1)	Political & Government (2)	Professional & Agricultural (3)	Community-Based (4)
CDH (λ = -9°C)	0.023**	0.000	0.005	0.029**
	(0.010)	(0.001)	(0.016)	(0.013)
Observations	76471	76471	76471	76471
No. of Districts	944	944	944	944
Mean of Dep. Var	0.816	0.012	0.182	0.703

Notes: The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, household head characteristics (sex, age, age squared, education level, and mother tongue), and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

6.1 Income, Assets, and Expenditure

Extreme cold can have severe consequences for agricultural output. Anecdotal evidence suggests that episodes of extreme cold can result in crop failures and livestock death, entailing significant economic losses in a variety of settings (Samora, 2021; Barbier, 2010; The Guardian, 2021; FAO, 2008; BBC News, 2015). This is further substantiated in the agronomy literature, which highlights that crops — including those that are most commonly grown in Peru, such as maize, potatoes, and *mashua* (a popular Andean tuber) — suffer when exposed to cold temperatures, especially for longer periods of time or during critical stages of growth (Lee and Herbek, 2012; Carter and Hesterman, 1990; Hijmans et al., 2001; Burrows, 2019; Janssen, 2004; Romero et al., 1989).

We estimate the effects of extreme cold shocks on income, livestock assets, and expenditure using the strategy outlined in equation 5. For crop-related outcomes, we use a version of CDH that gives higher weight to incidences of extreme cold that occur during the growing season, outlined in equation 4 (along with similarly weighted versions of average temperature and rainfall). This is to reflect the seasonal nature of agricultural activities and to allow that seasonality to vary spatially within the Highlands. We transform all monetary outcomes using an inverse hyperbolic sine transformation (IHST) to interpret the effects of extreme cold in terms of percentage changes while accounting for zero-valued observations.

Income and Expenditure. Table 6 shows that extreme cold substantially lowers agricultural income, total income, and consequently, expenditure. An additional 10 degree hours below -9°C in the past year lowers annual agricultural income by 4.4% (column 1) and total income by 1.4% (column 2). Total expenditure also falls significantly by 1.5%. Consistent with earlier literature, we find that the effects of extreme weather shocks are smaller for total income and expenditure than for agricultural income, likely because households are able to mitigate the loss in agricultural income through secondary sources of employment in the non-farm sector, wage labor, credit access, migration and other consumption-smoothing mechanisms (Kubik and Maurel, 2016; Newman and Tarp, 2020). Nonetheless, even in light of these potential mitigation strategies, the net effects of cold shocks on income and expenditure are large.

Table 6: Effects of Frost Shocks on Agricultural Income, Total Income, and Expenditure

	Agricultural Income	Total Income	Total Expenditure
	(1)	(2)	(3)
Weighted CDH (λ = -9°C)	-0.439***	-0.154**	-0.143**
	(0.100)	(0.077)	(0.061)
Observations	76642	76642	76642
No. of Districts	944	944	944
Mean of Dep. Var	2747	8136	6117

Notes: All income and expenditure variables have been transformed using the inverse hyperbolic sine function. The sample includes all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include (weighted) average temperature, average rainfall at the household level for over the same reference period as the frost shock, household head characteristics (sex, age, and age squared as well as education level and mother tongue fixed effects), log of total land (owned + rented), and household size fixed effects. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1. Mean of dependent variables are expressed in 2007 soles using the GDP deflator published by World Bank (2023).

Productive Assets. While farming households in developing countries own several types of productive assets (e.g., land, housing, agricultural equipment, etc.), we focus on livestock. Livestock represents one of the most important assets in rural areas of Peru (Escobal et al., 1999). Livestock provides households with meat, milk, cheese, leather, fiber, manure, and other byproducts for sale or self-consumption. They can also provide transportation and help with plowing equipment. Additionally, livestock is relatively liquid and can be sold to cushion unexpected negative shocks (Herrero et al., 2013). Therefore, any shocks that affect livestock can have potentially serious consequences on the livelihoods of households in the highlands.

We estimate the effect of extreme cold temperature shocks on the reported incidence of large livestock (i.e., cows, sheep, pork, goat, native camelids, and horses). We focus on both the impact of frosts on both the intensive (i.e., an indicator variable indicating whether households have experienced any deaths of animals) and the intensive margin (i.e., households' self-reported monetary value of dead animals). We find that 10 degree hours below a threshold of -9°C in the previous 12 months increases the likelihood of a reported livestock death by 0.44 percentage points (column 1, Appendix Table A1). This same shock translates into a 2.5 percent increase in monetary losses due to livestock deaths (column 2, Appendix Table A1).

Subjective Perceptions of the Economic Environment. While the results in Table 6 and Appendix Table A1 illustrate that extreme cold substantially reduces objective measures of households' economic standing, we are also interested in the extent to which these effects translate into issues that households are concerned with and for which they may hold governments accountable. The governance module of the ENAHO collects citizen sentiments on a variety of areas through the question *"What are the main problems of the country?"*. Respondents rank several issues in order of importance. We test whether extreme cold impacts the likelihood that individuals report *lack of agricultural support* or *lack of employment opportunities* as the top-priority issue for the country. We find that 10 degree hours below -9°C in the previous 12 months increases the likelihood that individuals report lack of agricultural support and lack of employment as the main problems in Peru by 0.17 and 0.14 percentage points respectively (Appendix Table A2). Thus, it appears that extreme cold influences citizens' perceptions of the state of the country in ways that align with the estimated effects of extreme cold on household economic standing, which may have important consequences for individuals' evaluation of the government and the democratic system.

6.2 Health

Extreme cold can also be harmful to health in terms of both population morbidity (Zhao et al., 2021; Kephart et al., 2022; Sheridan and Allen, 2015) and mortality (Deschenes and Moretti, 2009; Deschênes and Greenstone, 2011). To the extent that cold weather shocks induce affect health, we might expect that they lower individuals' trust in the government's ability to aid citizens in times of need. This is especially salient in low-income settings, where public health facilities and access to quality medical care are often scarce or insufficient. Indeed, Costello et al. (2015) find that child mortality rates were a significant predictor of violent and non-violent protests that took place as part of the "Arab Awakening".

To examine this possibility, we investigate the effect of extreme cold shocks on two indicators of health: the incidence of child illness (due to flu, fever, cough, etc.) and the severity of child illness as captured by illnesses that requires a medical consultation (both of which are dummy variables in the ENAHO). Our focus on child health is motivated by evidence from Peru which suggests that children are a particularly vulnerable population to extreme cold exposure. In 2010, extreme cold events reportedly resulted in increases in infant mortality due to cases of chronic pneumonia and cold-related respiratory diseases (Kirkland, 2012). We restrict our analysis to the subset of households in our main sample from Table 3 that contain children aged five and younger. Illness is reported within the 4 weeks prior to the survey interview, so we match the household's weather data from the 8 weeks prior to the interview date to allow for extreme cold conditions to affect health with a lag.

Our results confirm earlier findings that extreme cold adversely impacts health (Table 7). 10 degree hours below a harmful threshold of -9°C increases the likelihood of any child illnesses by 2.7 percentage points. It also increases the likelihood of more "severe" illness — which we measure as sickness episodes that results in a medical consultation — by 2 percentage points. These are meaningful effects on infant health, given that about a third of households in our sample have a child who has been ill in the past month.

6.3 Crime and Violence

While previous work has shown that extreme heat can spur violence and crime (see for example Blakeslee and Fishman (2018); Mukherjee and Sanders (2021); Colmer and Doleac (2022); Mares and Moffett (2019); Garg et al. (2020); Simister (2001); Simister and Cooper (2005)), less is known about the effects of extreme cold. Extreme cold may affect violence and crime through at least two mechanisms: income and exposure.[24] As illustrated in Section 6.1, cold shocks significantly

[24]Some studies find that extreme heat affects crime through an additional channel, namely that heat can heighten aggression (e.g., see Anderson et al. (2000); Ranson (2014)). However, cold spells have not been shown to have the same link to aggressive impulses.

Table 7: Effects of Frost Shocks on Child Health

	Child Has Been Ill	Child Has Required Medical Attention
	(1)	(2)
Cumulative Degree Hours (λ = -9°C)	0.268***	0.197***
	(0.055)	(0.064)
Observations	29240	29240
No. of Districts	887	887
Mean of Dep. Var	0.333	0.316

Notes: The sample includes all children under the age of 5 living in farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, household head characteristics (sex, age, age squared, education level, and mother tongue), child sex and age fixed effects, and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

lower household income and expenditure. This drop in income can lead to a spike in crimes by increasing the value of crime as an alternative source of income or in violence if individuals are more likely to be violent when under financial stress (e.g., Iyer and Topalova (2014); Blakeslee and Fishman (2018); Mehlum et al. (2006)). On the other hand, cold spells may affect crime and violence through opportunity and exposure. If individuals are more likely to stay home to avoid cold outside temperatures, this may reduce their opportunities to commit crimes outside their home while increasing the potential for violence inside the home (Dugan et al., 2003; Bhalotra et al., 2021; Agüero, 2021; Ranson, 2014).[25] Moreover, experiencing crime and victimization has been shown to shape (mis)trust in democracy and institutions (Blanco and Ruiz, 2013; Blanco, 2013).

To assess the impact of extreme cold on crime, we construct a panel of district-level annual crimes per 10,000 residents for the years in which the National Registry of Crimes and Misdemeanors (see Section 3.4) was conducted (2011, 2013, 2015, and 2017).[26] We focus mainly on two types of crime, which we believe are most likely to respond to extreme weather based on prior work: economic crimes (such as robbery and theft, extortion, fraud, and the sale of illicit goods) and violent crimes (such as murder, assaults, kidnapping, and rape). We transform all crime variables

[25]The theory that weather can affect crime and violence through its impact on the probability of social interactions is sometimes referred to as "routine activity" (RA) theory (Rotton and Cohn, 2003).

[26]The National Registry of Crimes and Misdemeanors does not include information about population. To calculate our measure of crimes per capita, we use district-level population from the 2007 National Census in the denominator.

using the inverse hyperbolic sine function to account for zeros (which are common for crime counts in smaller districts). We match weather data to the National Registry of Crimes and Misdemeanors using the GPS coordinates of each district's centroid and consider frost shocks in the calendar year prior to the calendar year of the crimes. We find that economic crimes rise by 2% and total crimes by 1.2% for an additional 10 degree hours below -9°C (column 1). In contrast, we find no discernible effects on violent crimes (column 2), though the point estimate is positive. We expect that crimes are likely to be underreported; given this additional noise in the (reported) crime data, we expect that the estimates in columns 1-3 are likely to represent lower bounds of the true effects of frost shocks on crime.

Table 8: Effects of Frost Shocks on Crime and Violence

	Economic Crimes	Violent Crimes	Total Crimes	IPV (DHS)
	(1)	(2)	(3)	(4)
CDH (λ = -9°C)	0.204***	0.089	0.121**	0.052**
	(0.063)	(0.075)	(0.058)	(0.023)
Observations	5390	5390	5390	54584
No. of Districts	1072	1072	1072	918
Mean of Dep. Var	19.70	14.55	40.28	0.69

Notes: District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1. Columns 1-3: Weather variables are measured at the district centroid and measures weather in the previous year. All crime variables have been transformed using the inverse hyperbolic sine function. The sample includes all districts in the Highlands using all available crime data from the 2011, 2013, 2015, 2016, and 2017 rounds of the National Registry of Crimes and Misdemeanors. All specifications include year and district fixed effects as well as province-specific time trends. Means of crime variables are expressed in annual crimes per 10,000 district residents. Column 4: The sample includes all ever-partnered women (aged 15-49) in the Peruvian highlands who have responded to the domestic violence module of the DHS dataset between 2010-2018. Controls include average temperature and average rainfall at the household level in the 12 months prior to the interview date. We control for individual characteristics (age, age squared, mother tongue, education fixed effects, number of children under five); household head characteristics (age and sex), household size, household wealth group fixed effects, rural status, and husband education fixed effects. All specifications include year, district, and month of interview fixed effects.

In column 4, we estimate the effects of extreme cold on intimate partner violence (IPV) using data from the Peruvian Demographics and Health Survey (DHS). As in our main specification (equation 5), we match weather data to households using the approximate GPS locations of households and the date of interview and include district-, year-, and month-fixed effects.[27] We measure IPV with a summary indicator for whether a woman aged 15-49 has faced violence from a husband

[27] The DHS data contain approximate GPS locations from 2010 onward, so we use data from 2010-2018 for this analysis.

or a partner in the year prior to the survey, including violence in three general forms: emotional (e.g., humiliation, threats, insults), physical (e.g., pushing, slapping, punching, kicking, dragging, strangling, hair pulling), and sexual (i.e., any form of being forced to participate in unwanted sexual acts). We find that 10 degree hours below -9°C in the past year increases the likelihood that a woman experiences IPV by 0.5 percentage points (Table 8, column 4).

Taken together, the results in Table 8 indicate that extreme cold increases some dimensions of crime. If citizens hold the government responsible for curtailing crime — for example, by reducing the need to resort to crime, providing resources for the police, or funding other public safety measures — then an increase in crime may partly explain why frost shocks negatively impact their evaluation of democracy.

7 Examining the Roles of Access to Social Assistance Programs, Public Health Care Facilities, and Public Safety

In the previous section, we show that extreme cold affects several important proximate causes of lower evaluations of democracy: economic standing, health, and crime/violence. To provide further evidence that these mechanisms at least partly explain our main findings, we now examine the extent to which the effects of extreme cold on political trust are heterogeneous by access to government-provided means of mitigation. If government-provided programs, facilities, and other resources protect households from the adverse effects of cold weather, then we expect that the effects should be strongest for those who lack access. With this in mind, we now explore heterogeneous impacts of frost shocks by access to social assistance programs, public hospitals, and police stations.

7.1 Access to Social Assistance Programs

How can the government maintain the confidence of its citizens amid extreme weather shocks? Several studies find that redistributive programs such as cash transfers can foster support for government (Evans et al., 2019; Kosec and Mo, 2023), though effects may be short-lived (Zucco Jr, 2013). To the extent that social assistance programs can mitigate the negative impacts of extreme cold on households, they may also temper the effects of cold shocks on political trust.Many social programs are targeted at poor and marginalized populations and act as important sources of both steady income and "safety net" income in the case of adverse shocks. Thus access to these programs can be essential in facilitating income and consumption smoothing, potentially inspiring confidence in public institutions and increasing political trust.

To investigate the degree to which social assistance programs attenuate the effect of cold weather shocks on political trust, we construct a measure of social program coverage from the ENAHO. Specifically, we calculate the share of households in each province in which at least one member has been a beneficiary of a government-sponsored social program. Because public programs can respond endogenously to frost shocks (or even shift due to low levels of government approval), we construct a baseline measure of coverage of social programs. Unfortunately, the ENAHO did not collect information about access to social programs prior to 2012. Thus, we estimate our measure of access to social programs based on this round.

As social program coverage data is only available starting in 2012, we restrict our analysis to the 2013–2018 rounds of the ENAHO (using 2012 coverage as our measure of baseline coverage). Thus, we begin by demonstrating that our main results in this restricted sample period (column 1 of Table 9) are nearly identical to those using the full sample period (column 1 of Table 3). In column (2), we add an interaction between CDH and the baseline share of social assistance beneficiaries. We find that, in provinces with low (10th percentile) social program coverage at baseline, extreme cold lowers political trust considerably: 10 degree hours below -9°C in the previous 12 months reduces political trust by 1 percentage point (significant at the 95% level of confidence). In contrast, among households in provinces high (90th percentile) baseline coverage, frost shocks appear to have an effect very close to zero.

One potential concern with the results in column 2 is that social assistance programs are targeted to poor households, so that baseline social program coverage may simply proxy for poverty. To account for this possibility, we use the baseline share of *poor* (as opposed to all) households that receive government-sponsored social assistance in column 3. This measure automatically takes into account the underlying share of poor households. Using this measure of baseline coverage, the estimated effects of cold shocks are large and negative for households in provinces with low coverage; the effect is similar in magnitude as in column 2, though it is only marginally significant (p-value=0.101). Again, the effect is small and not statistically different from zero in areas that

Table 9: Heterogeneous Effects by Baseline Social Program Coverage

	Dep. Var.: Believes Democracy Works Well		
	(1)	(2)	(3)
CDH (λ = -9°C)	-0.037**	-0.110*	-0.122
	(0.018)	(0.056)	(0.078)
CDH × Baseline Coverage (w.r.t. all HHs)		0.167	
		(0.112)	
CDH × Baseline Coverage (w.r.t. poor HHs)			0.077
			(0.062)
Effect at the ... percentile of baseline coverage			
10th		-0.101**	-0.102
		(0.050)	(0.062)
90th		-0.001	-0.013
		(0.021)	(0.014)
Observations	34131	34131	34131
No. of Districts	885	885	885
Mean of Dep. Var	0.555	0.555	0.555

Notes: The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Baseline coverage is defined as the share of households in the province receiving assistance from social programs in 2012. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, and age squared, education level, and mother tongue), and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

already had high access to social programs at baseline.

7.2 Access to Public Health Care Facilities

Does access to government-provided health facilities mitigate the negative effect of extreme cold? To explore this possibility, we examine heterogeneity by access to public hospitals. To measure access to public hospitals, we calculate the number of public hospitals per 10,000 residents at the provincial level using the 2007 Peruvian Municipality Registry (RENAMU). Since we consider 2007 as the baseline year, our analytical sample period spans 2008-2018. In column (1) of Table 10 we show that the estimated effect of a frost shock is similar to our baseline result (column 1 of Table 3) when we restrict the sample period to 2008 and onward. In column (2), we include the interaction term of the frost shock with baseline public hospitals per capita. We find that households which were located in provinces without any public hospitals in the baseline year are more likely to evaluate democracy less favorably. Specifically, a 10 degree hour shock below -9°C in the previous

12 months in provinces with no public hospitals in 2007 reduces the belief that democracy works well by 0.8 percentage points. This effect is close to double the estimate in column (1). This is particularly relevant, as more than 47% of provinces in the sample lack a public hospital. On the other hand, the effect of frost shocks for households in provinces in the 90th percentile of baseline public hospitals per capita is near zero and statistically insignificant. These results show that access to public hospitals can mitigate political mistrust due to extreme cold temperature shocks.

Table 10: Heterogeneous Effects by Baseline Access to Public Hospitals

	Dep. Var.: Believes Democracy Works Well	
	(1)	(2)
CDH (λ = -9°C)	-0.038**	-0.072***
	(0.017)	(0.018)
CDH $\times$ Baseline Public Hospitals pc		0.223***
		(0.061)
Effect at the ... percentile of baseline coverage		
10th		-0.072**
		(0.018)
90th		-0.002
		(0.021)
Observations	53696	53696
No. of Districts	938	938
Mean of Dep. Var	0.521	0.521

Notes: The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Baseline hospitals per capita is defined as the number of public hospitals per 10,000 provincial residents in 2007. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, and age squared, education level, and mother tongue), and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

7.3 Access to Public Safety

To complement the results on crime (6.3) and illustrate that public safety is another potential mediating factor between frost shocks and political trust, we use data from the 2012 CENACOM, the earliest available census of police stations. Specifically, we calculate the number of police stations per 10,000 province-level residents in 2012 and estimate whether the effects of extreme cold are less intense where residents are more likely to have access to a police station. As the earliest measure of police stations is from 2012, we restrict our sample to the years 2013-2018 to avoid capturing potentially endogenous changes in police station access.

Our results appear in Table 11. In Column 1, we first show that our baseline results are robust to restricting our sample to 2013-2018. In Column 2, we find that qualitatively, the negative effects of frost shocks are meaningfully different for areas with higher and lower baseline police station presence. Though the interaction term is not statistically significant, the magnitude is substantial. For example, for individuals in a province with the 10th percentile number of police stations per capita at baseline, the effect of a 10 degree hour shock below -9°C in the previous 12 months reduces the belief that democracy works well by 0.43 percentage points, and the effect is significant at the 10% level. On the other hand, for those in a province with 90th percentile baseline police stations per capita, the effect is only 0.17 percentage points and is not statistically significant.

Table 11: Heterogeneity in Effects by Baseline Access to Police Stations

	Dep. Var.: Believes Democracy Works Well	
	(1)	(2)
CDH (λ = -9°C)	-0.037**	-0.046
	(0.018)	(0.032)
CDH $\times$ Baseline Police Stations pc		0.011
		(0.037)
Effect at the ... percentile of Baseline Police Stations pc		
10th		-0.043*
		(0.024)
90th		-0.017
		(0.070)
Observations	34295	34295
No. of Districts	890	890
Mean of Dep. Var	0.555	0.555

Notes: Baseline police stations per capita are measured as the province-level number of police stations per 10,000 residents in 2012. The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, age squared, education level, and mother tongue); and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

8 Robustness Checks

8.1 Alternative samples and measures of political trust

Our primary outcome measures whether individuals believe democracy works well based on the responses to the question "In Peru, does democracy work ...?" with five potential responses: very well, well, poorly, very poorly, and "don't know". Our preferred measure is a simple dummy variable that classifies those who responded with "very well" and "well" as 1 and those who responded with "poor" or "very poor" as 0. To retain the full variation in the potential responses, we estimate an ordered probit and report the marginal effects of this regression in Appendix Table A3. In the first set of regressions (Panel A), we include four categories in the dependent variable (i.e., in increasing order: whether democracy works very poorly, poorly, well, very well). Our results illustrate that frost shocks significantly lower the probability of reporting "well" and "very well" and increase the probability of reporting "poor" or "very poorly". In Panel B (columns 6-10), we again estimate an ordered probit but now we include individuals who responded "don't know" in a neutral, middle category (i.e., between poorly and well). Similar to Panel A, these results also indicate that frost shocks reduce the likelihood of reporting "well" or "very well" and increase the likelihood of reporting "poorly" or "very poorly". Our results suggest that frost shocks increase the probability of reporting "don't know", but the effect is small (with a marginal effect that is smaller than those of other categories by at least an order of magnitude).

To demonstrate that our results are robust beyond our particular sample and definition of confidence in democracy, we employ two additional datasets that collect information about perceptions of democracy: the Latin American Public Opinion Project (LAPOP) and the Latinobarómetro. Both surveys ask respondents about their satisfaction with democracy, a commonly used measure of confidence and trust in government and political institutions. Neither dataset collects geo-locations of surveyed households, so we match weather data using the centroid of the district where survey participants reside and the year and month of interview (considering shocks in the previous 12 months to the interview).[28] Consistent with our earlier findings, we find that

[28] Additionally, the LAPOP and Latinobarómetro are much smaller surveys that with lower coverage of districts (about 5% or less of districts in our main sample).

frost shocks substantively reduce satisfaction with democracy in both datasets. In the LAPOP data, an additional 10 degree hours below -9°C lowers the probability that an individual in the Highlands is satisfied with democracy by 8.6 percentage points (Appendix Table A4 column 1). The effect is 7.4 percentage points using the Latinobarómetro data (column 2). Finally, we demonstrate that our voting results are robust by using an individual-level indicator for whether a respondent abstained from voting in the presidential election prior to the survey using the LAPOP data (column 3). Consistent with the results using official district level voting data in Section 5, we find that individuals are more likely to report that they did *not* vote if they experienced frost shocks in the year prior to the election; an additional degree hour below -9°C lowers the probability that an individual in the Highlands abstains from voting by 2.2 percentage points.

8.2 Alternative measures of frost shocks

Throughout the paper, we generally focus on the effects of cumulative degree hours below -9°C in the 12 months prior to the date of interview. We discuss robustness to other temperature thresholds in Figure 1. As already discussed, we find larger reductions in citizens' evaluation of democracy when we use colder temperature thresholds (λ) in our calculation of cumulative degree hours.

Additionally, we examine robustness to alternative windows of frost shocks in Appendix Table A5. Column 1 is our baseline result using the 12 months prior to the date of interview. Columns 2 and 3 illustrate that the estimated effects are larger if we consider frost shocks over more recent windows (6 months and 3 months, respectively). In column 4, we show that our results are robust to using a coarser though more common measure of frost shocks: cumulative degree days, i.e., the number of degree days in the previous year that the household experienced temperatures below -9°C.[29] We find that each additional degree day below -9°C lower the belief that democracy works well by close to 0.2 percentage points. Finally, in column 5, we show that our results are also similar when we consider a binary indicator for whether a household has experienced any frost shocks over the year prior to the survey [30]. Experiencing a frost shock (regardless of the magnitude of the

[29]Similar to our primary measure (cumulative degree hours), cumulative degree days capture both the number of days temperatures dipped below a given threshold and by how much below the threshold the temperature fell.

[30]In other words, this binary measure assigns a value of one to households that have experienced *any* positive values of CDH; and zero otherwise.

shock) lowers the probability of believing democracy works well by 3.2 percentage points.

8.3 Conglomerate and Household Fixed Effects

Our main estimating equation includes district-level fixed effects to control for (time-invariant) spatial variation in weather and our outcomes. Districts are typically small in Peru, so we believe that district-level fixed effects capture much of the potentially endogenous variation in frost incidence. However, to further control for unobserved spatial heterogeneity, we include conglomerate fixed effects column 2 of Appendix Table A6. Conglomerates are generally smaller than districts (though they constitute primary sampling units and not official administrative areas); our sample includes 2,985 conglomerates (compared to 938 districts). The estimated effects of frost shocks are even larger when we include conglomerate fixed effects.

Finally, in column (3) we include household fixed effects, which restricts our identifying variation to differences in frost shocks that occur over time within a household (i.e., within the same GPS location). The ENAHO contains a subsample made up of an unbalanced panel of households. This sample includes 7,291 households and covers only about a third of our baseline observations and 200 fewer districts. Our estimate using household fixed effects is smaller but still negative and meaningful in magnitude. The standard errors are larger (arguably due to the dramatic reduction in our sample size), and thus the estimate with household fixed effects is not statistically significant.

8.4 Endogenous migration and changes in sample composition

A final potential concern is that even if households cannot perfectly predict future frost shocks, they may migrate in response to past shocks. This would mean that households who remain in areas experiencing relatively more frost shocks may be systematically different from those who live in areas with fewer shocks. To investigate this possibility, we begin by assessing whether household characteristics vary systematically with frost shocks. In Table Appendix Table A7, we find that there are no meaningful differences in predetermined, observable characteristics according to frost shocks. Though there is a statistically significant relationship between frost shocks and having a primary education or less (column 4), the magnitude of the relationship is very small. In other words, there is no evidence that sample composition responds endogenously to frost shocks.

Next, we show that endogenous migration is unlikely to explain our results. In column 2 of Appendix Table A8, we show that the results are robust to restricting the sample to those who are currently living in their district of birth (so-called "non-movers"). In column 3, we assess whether households are likely to move in response to frost shocks (most likely to warmer areas with less extreme temperatures). We find no evidence that areas with fewer frost shocks have a larger proportion of migrant households.

8.5 Falsification exercise

As a final way to ensure that our measure of frost shocks captures exogenous weather shocks rather than systematic unobserved determinants of or prexisting trends in perceptopns of democracy, we perform a simple falsification test where we estimate the "effect" of future cold weather events. Specifically, we estimate a version of equation 5 where instead of focusing on CDH in the past 12 months to the survey, we include CDH in the 12 months *after* the interview date.

The results of this falsification exercise are displayed in Appendix Table A9. Because we estimate the "effects" of a 12-month lead of CDH and have weather data only through 2018, we begin by running our baseline specification (using shocks over the past 12 months) for the restricted sample period 2010-2017 in column 1. For this restricted time period, we confirm that frost shocks significantly decrease the belief that democracy works well in Peru; if anything, the estimate is slightly larger for this restricted sample period. In column 2, we replace CDH over the past 12 months with CDH over the following (i.e., future) 12 months after the interview date. Here, we find no statistically significant relationship between perceptions of democracy and future realizations of extreme cold temperatures. This null result helps us rule out the possibility that households can anticipate (and respond to) future frost shocks as well as the possibility that frost shocks simply capture unobserved determinants of perceptions of democracy that vary systematically across households and/or geographic areas. They also help to dispel concerns about differential pre-trends in perceptions of democracy that are related to frost shocks. Thus, we view the results in Appendix Table A9 as evidence that our main estimates capture the causal effect of extreme cold on the belief that democracy works well.

9 Conclusion

This study sheds light on the impact that extreme weather conditions have on individuals' perceptions of democracy. Extreme cold temperature shocks significantly decrease in the belief that democracy functions well in Peru. This, in turn, reduces civic engagement in formal, national institutions, as reflected by lower participation in national elections. However, we also observe an increase in participation in local associations, suggesting a shift towards alternative forms of civic involvement.

Furthermore, our research explores the underlying mechanisms through which extreme cold affects perceptions. We find that decreased income, assets, and expenditure, along with an increased incidence of illness and certain types of crime, contribute to the negative effects on individuals' beliefs about democracy and government.

Importantly, our findings indicate that government provision of goods and services can mitigate the adverse effects of extreme cold. Access to social programs, public hospitals, and police resources play a crucial role in buffering the negative impact of extreme weather shocks on individuals' confidence in political institutions.

Overall, these results emphasize the importance of considering weather-related factors when examining the dynamics of citizens' beliefs about how well democracy functions. These findings underscore the need for governments to be attentive to extreme weather events and to prioritize the provision of essential services during such periods, as this can help maintain or restore confidence in democratic processes and institutions.

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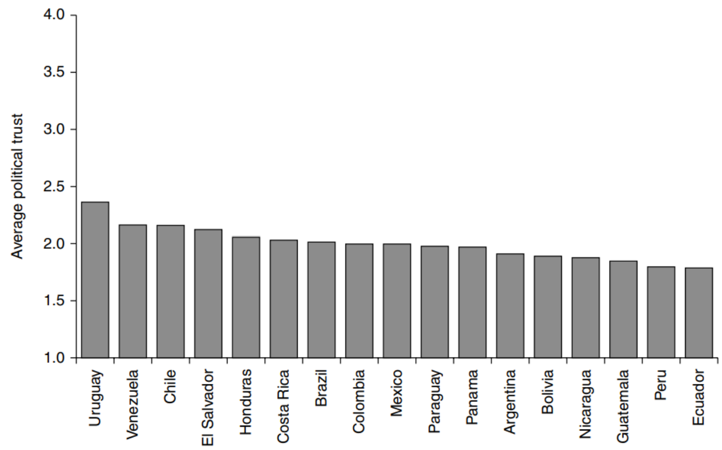
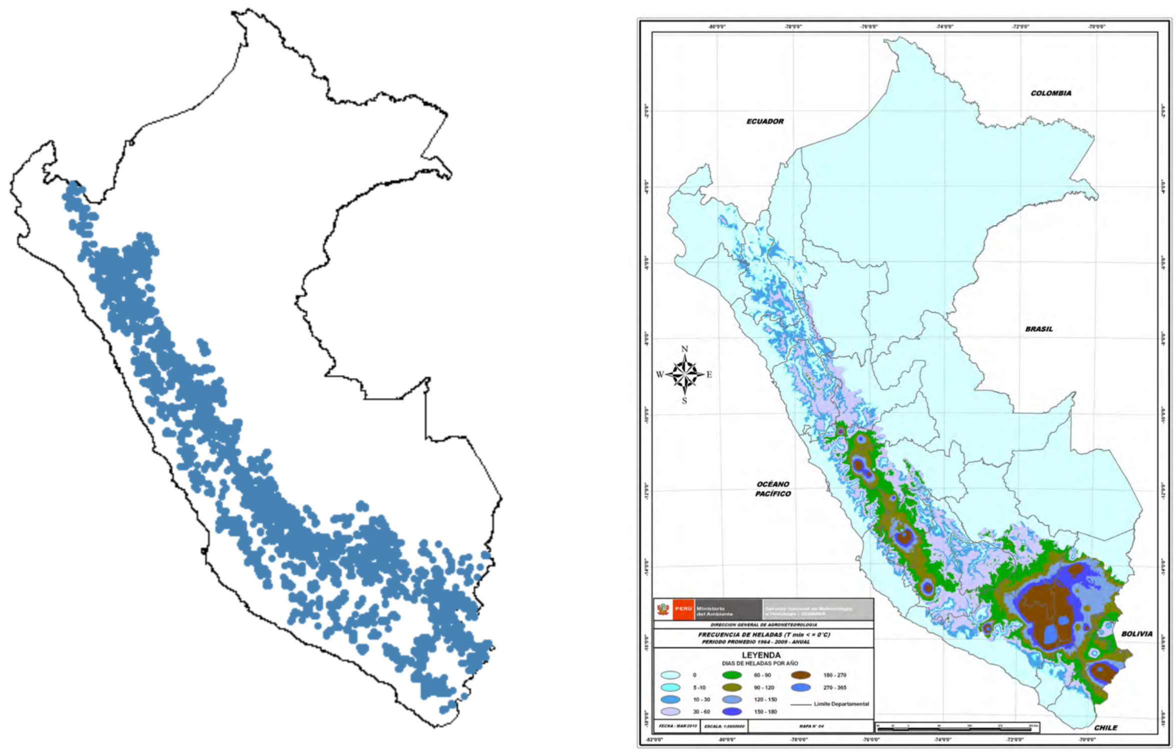
A Appendix: Figures and Tables

Figure A1: Trust in political institutions by country in Latin America (average, 1996-2011)



Source: Bargsted et al. (2017) , Handbook of Political Trust. The index is an average of trust in three political institutions: the national congress, political parties, and the government.

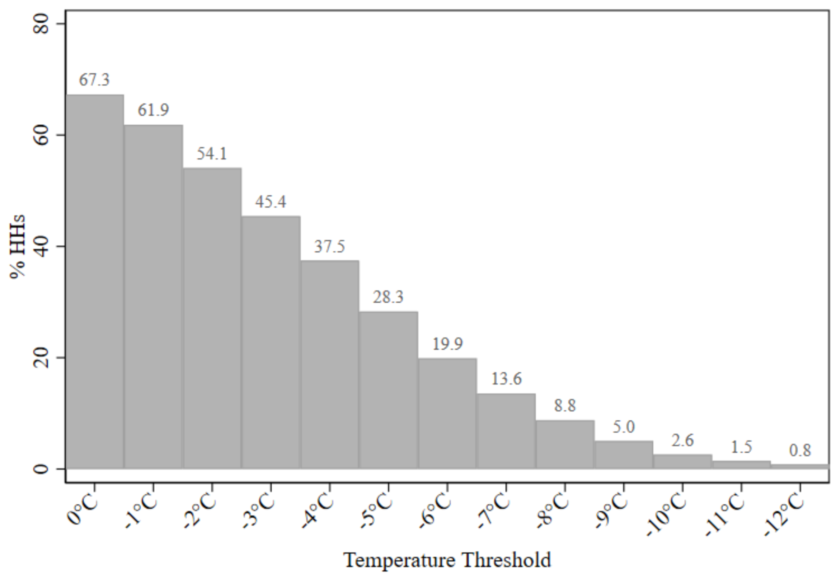
Figure A2: Location of the ENAHO observations across the Peruvian Highlands used in this study



(a) Location of Households in this Study, from ENAHO (b) Incidence of Frosts in Peru (1964–2009)

Notes: The left panel (Figure A2a) presents the location of the sample of rural households from the Peruvian highlands in this study (2007-2018). The right panel (Figure A2b) was taken from SENAMHI (2010) (p.47). It presents the average number of frost days per year between 1964 and 2009.

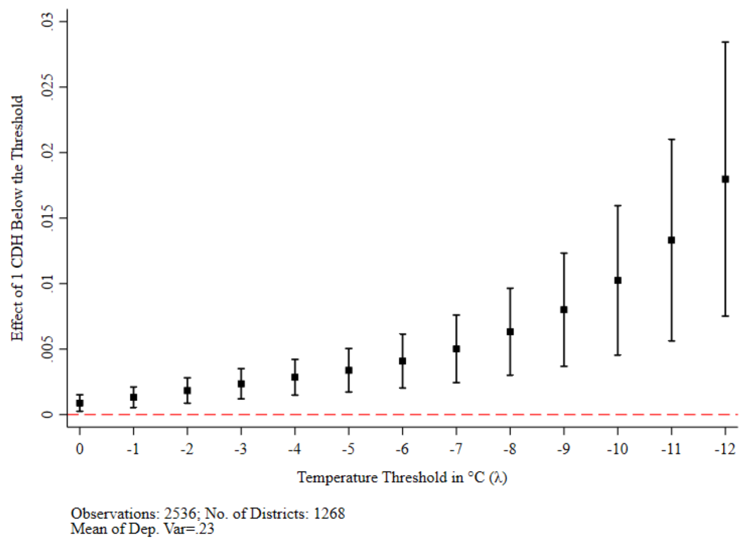
Figure A3: Percentage of Households Facing Shocks at Different Temperature Thresholds



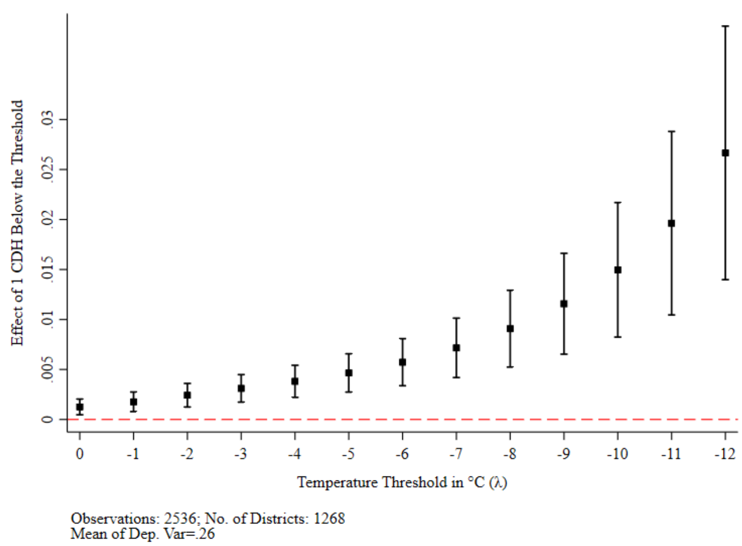
No. of observations: 57159; No. of Districts: 938

Figure A4: Effect of Sub-zero Temperature Shocks on the Share of Absent Voters in Presidential Elections

(a) First Round

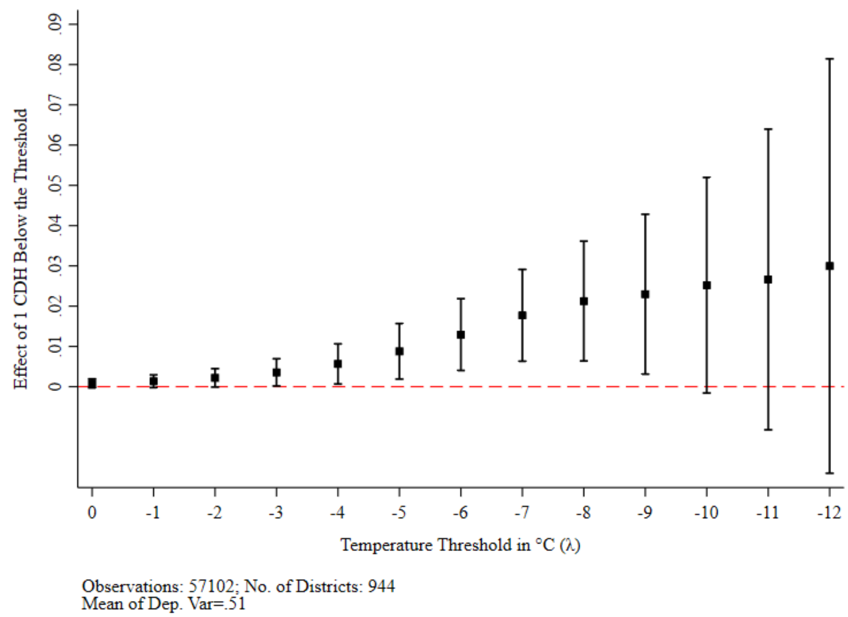


(b) Second Round



Notes: Shares are calculated with respect to the total eligible voters in each district. The sample includes all districts in the Highlands and covers the 2011 and 2016 presidential elections. Weather variables are measured at the district centroid and measures weather in the year prior to the date of each election. All specifications include year and district fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation.

Figure A5: Effect of Sub-zero Temperature Shocks on Participation in Local Associations



Notes: The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, household head characteristics (sex, age, age squared, education level, and mother tongue), and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation.

Table A1: Effects of Frost Shocks on Livestock Assets

	Any Livestock Death (1)	Log Value of Livestock Deaths (2)
CDH (λ = -9°C)	0.044*	0.246*
	(0.024)	(0.135)
Observations	63028	63028
No. of Districts	922	922
Mean of Dep. Var	0.339	582.943

Notes: Value of livestock deaths has been transformed using the inverse hyperbolic sine function. The sample includes all farming households using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, household head characteristics (sex, age, and age squared, education level and mother tongue), log of total land (owned + rented), and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1. Mean value of livestock deaths are expressed in 2007 soles using the GDP deflator published by World Bank (2023).

Table A2: Effects of Frost Shocks on Subjective Perceptions of Economic Environment

	The country's highest priority problem is ...	
	Lack of Agricultural Support (1)	Lack of Employment (2)
CDH (λ = -9°C)	0.017***	0.014**
	(0.005)	(0.006)
Observations	75632	75632
No. of Districts	940	940
Mean of Dep. Var	0.076	0.063

Notes: The sample includes individuals in all farming households in the Highlands with agricultural revenue over the previous year using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, and age squared, education level, and mother tongue), and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A3: Ordered Probit Models (Marginal Effects)

	A. Dep. Var.: Believes Democracy Works Well (categories)				
	Very Poorly	Poorly	Don't Know	Well	Very Well
	(1)	(2)	(3)	(4)	(5)
CDH (λ = -9 °C)	0.010***	0.025***	–	-0.004***	-0.001***
	(0.003)	(0.001)	–	(0.001)	(0.0003)
N. of obs.			57159		

	B. Dep. Var.: Believes Democracy Works Well (categories)				
	Very Poorly	Poorly	Don't Know	Well	Very Well
	(6)	(7)	(8)	(9)	(10)
CDH (λ = -9 °C)	0.005*	0.014*	0.0002*	-0.018 *	-0.002*
	(0.003)	(0.008)	(0.0001)	(0.009)	(0.0013)
N. of obs.			75632		

Notes: Columns 1-5: Dependent variable is categorical and takes 4 distinct values (omitting "Don't Know"). Columns 6-10: Dependent variable is categorical and takes 5 distinct values (including "Don't Know" as a "middle" category). The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, age squared, education level, and mother tongue), and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Marginal Effects and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A4: Using Alternative Datasets

	Is Satisfied with Democracy		Did Not Vote in Last Presidential Election
	LAPOP	Latinobarometer	LAPOP
	(1)	(2)	(3)
CDH (λ = -9°C) in Year Prior to Survey	-0.861***	-0.739***	
	(0.238)	(0.212)	
CDH (λ = -9°C) in Year Prior to Election			2.174*
			(1.143)
Observations	1053	2819	1544
No. of Districts	47	33	84
Mean of Dep. Var	0.324	0.199	0.087

Notes: Sample is restricted to districts in the Highlands and includes the 2014 and 2017 rounds of the LAPOP in column 1; the 2008-2011, 2013, 2015-2017 rounds of the Latinobarometer in column 2; and the 2006, 2012, and 2017 rounds of the LAPOP in column 3. Weather variables are measured at the district centroid and measures weather in the year prior to the interview month and year in columns 1 and 2 and in the year prior to the election month and year in column 3. Controls include respondent sex, age, and age squared as well as education level fixed effects. Columns 1 and 2 include year, district, and month of interview fixed effects; column 3 includes election year and district fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A5: Effects Using Alternate Measures of Frost Shocks

	Dep. Var.: Believes Democracy Works Well				
	(1)	(2)	(3)	(4)	(5)
CDH over past 12 months (λ = -9°C)	-0.039**				
	(0.017)				
CDH over past 6 months (λ = -9°C)		-0.056***			
		(0.018)			
CDH over past 3 months (λ = -9°C)			-0.042***		
			(0.015)		
Cumulative Degree Days (λ = -9°C)				-0.192*	
				(0.110)	
Any shock over past 12 months (λ = -9°C)					-3.248*
					(1.678)
Observations	57159	57159	57159	57159	57159
No. of Districts	938	938	938	938	938
Mean of Dep. Var	0.511	0.511	0.511	0.511	0.511

Notes: The sample includes all individuals in farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, and age squared as well as education level and mother tongue fixed effects), and household size fixed effects. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A6: Effects Using Alternate Fixed Effects

	Dep. Var.: Believes Democracy Works Well		
	District FE (Baseline)	Conglome FE	Household FE
	(1)	(2)	(3)
Cumulative Degree Hours (λ = -9°C)	-0.039**	-0.066***	-0.022
	(0.017)	(0.019)	(0.022)
Observations	57159	56823	20934
No. of Districts	938	932	748
No. of Groups for FE	938	2985	7291
Mean of Dep. Var	0.511	0.512	0.513

Notes: The sample includes all individuals in farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, household head characteristics (sex, age, age squared, education level, and mother tongue), and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A7: Frost Shocks and Sample Composition

	Male	Age	Household Size	Primary Education	Speaks Quechua
	(1)	(2)	(3)	(4)	(5)
CDH (λ = -9°C)	0.0000	-0.0004	0.0005	0.0003***	0.0000
	(0.0001)	(0.0033)	(0.0004)	(0.0001)	(0.0001)
Observations	57159	57159	57159	57159	57159
No. of Districts	938	938	938	938	938
Mean of Dep. Var	0.509	46.724	4.014	0.628	0.518

Notes: The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO. Except when used as an outcome, controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, age squared, education level fixed effects, mother tongue); and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A8: Assessing Endogenous Migration

	Dep. Var.: Believes Democracy Works Well		Dep. Var.: Migrated
	Full Sample	Non-movers	Full Sample
	(1)	(2)	(3)
CDH (λ = -9°C)	-0.039**	-0.034*	-0.007
	(0.017)	(0.018)	(0.011)
Observations	57159	46907	57151
No. of Districts	938	913	938
Mean of Dep. Var	0.511	0.518	0.179

Notes: The sample includes individuals in all farming households in the Highlands using the 2007-2018 rounds of the ENAHO; in column 2, the sample is further restricted to individuals who reside in their district of birth (non-movers). Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, age squared, education level fixed effects, mother tongue); and household size. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.

Table A9: Falsification Test: Effects of Future Frost Shocks

	Dependent Variable: Believes Democracy Works Well	
	(1)	(2)
CDH (λ = -9°C) in the *Previous* 12 Months	-0.044***	
	(0.016)	
CDH (λ = -9°C) in the *Next* 12 Months		0.010
		(0.012)
Observations	50701	50701
No. of Districts	902	902
Mean of Dep. Var	0.515	0.515

Notes: The sample includes all individuals in farming households in the Highlands using the 2007-2017 rounds of the ENAHO. Controls include average temperature, average rainfall at the household level for over the same reference period as the frost shock, individual characteristics (respondent sex, age, and age squared as well as education level and mother tongue fixed effects), and household size fixed effects. All specifications include year, district, and month of interview fixed effects. District-level clustered standard errors in parentheses. Coefficients and standard errors have been multiplied by 100 for ease of interpretation. Significance levels denoted by: *** p<0.01, ** p<0.05, * p<0.1.