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Maladaptive Household Responses to Extreme Weather in Colombia

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Abstract
Climate change can trigger household adaptations that unintentionally worsen environmental impacts. This study examines how extreme weather events influence appliance ownership in Colombia, using data from the Integrated Household Survey conducted by the National Administrative Department of Statistics and climate records from the Institute of Hydrology, Meteorology, and Environmental Studies. Probability models with fixed effects show that extreme temperatures increase the likelihood of households acquiring fans and air conditioners, while extreme precipitation raises heater ownership. These patterns reflect maladaptive responses that intensify energy demand and emissions. Effects differ across socioeconomic groups, gender, and regions, underscoring inequalities in adaptive capacity. The findings highlight the importance of policies that encourage sustainable and equitable adaptation strategies in urban contexts.

Keywords: climate change; households adaptation; appliance ownership.

Respuestas inadecuadas de los hogares ante fenómenos meteorológicos extremos en Colombia

Resumen
El cambio climático puede provocar adaptaciones en los hogares que, sin quererlo, empeoran el impacto medioambiental. Este estudio analiza cómo los fenómenos meteorológicos extremos influyen en la adquisición de electrodomésticos en Colombia, utilizando datos de la Encuesta Integrada de Hogares realizada por el Departamento Administrativo Nacional de Estadística y registros climáticos del Instituto de Hidrología, Meteorología y Estudios Ambientales. Los modelos probabilísticos con efectos fijos muestran que las temperaturas extremas aumentan la probabilidad de que los hogares adquieran ventiladores y aires acondicionados, mientras que las precipitaciones extremas aumentan la adquisición de calefactores. Estos patrones reflejan respuestas inadecuadas que intensifican la demanda de energía y las emisiones. Los efectos difieren entre los distintos grupos socioeconómicos, géneros y regiones, lo que resalta las desigualdades en la capacidad de adaptación. Los resultados destacan la importancia de las políticas que fomentan estrategias de adaptación sostenibles y equitativas en contextos urbanos.

Palabras clave: cambio climático; adaptación de los hogares; posesión de electrodomésticos.

Respostas inadequadas das famílias diante de fenômenos meteorológicos extremos na Colômbia

Resumo
As mudanças climáticas podem provocar adaptações nos domicílios que, sem querer, agravam o impacto ambiental. Este estudo analisa como os fenômenos meteorológicos extremos influenciam a aquisição de eletrodomésticos na Colômbia, utilizando dados da Encuesta Integrada de Hogares (No Brasil: Pesquisa Nacional por Amostra de Domicílios) realizada pelo Departamento Administrativo Nacional de Estatística e registros climáticos do Instituto de Hidrologia, Meteorologia e Estudos Ambientais. Modelos probabilísticos com efeitos fixos mostram que temperaturas extremas aumentam a probabilidade de as famílias adquirirem ventiladores e aparelhos de ar condicionado, enquanto precipitações extremas aumentam a aquisição de aquecedores. Esses padrões refletem respostas inadequadas que intensificam a demanda por energia e as emissões. Os efeitos diferem entre os diferentes grupos socioeconômicos, gêneros e regiões, o que destaca as desigualdades na capacidade de adaptação. Os resultados destacam a importância das políticas que promovem estratégias de adaptação sustentáveis e equitativas em contextos urbanos.

Palavras-chave: mudança climática; adaptação das famílias; posse de eletrodomésticos.

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1. Introduction

Climate change[1] is perhaps the greatest threat to health, well-being, and productivity today. Its harmful effects on humans have been observed worldwide and include diseases, natural disasters, forced displacement, food insecurity, and deteriorating mental health.[2] Each year, around 13 million people worldwide die from disasters related to extreme temperatures (heatwaves or cold spells) or extreme climate events (cyclones, tornadoes, hurricanes, or intense storms). It has also been observed how heatwaves impact morbidity in cardiorespiratory disease (Cheng et al., 2019) and kidney disease (Lee et al., 2019), as well as mortality rates (Calleja-Agius et al., 2021) in vulnerable city dwellers. Also, studies in Latin America have systematically shown losses in agriculture due to extreme events (Lozano-Povis et al., 2021). These events also lead to the destruction of public and private infrastructure, generating high economic and social costs that typically fall on governments.

With frequent extreme weather events, the adaptation processes of individuals and systems are revealed. Much of the literature focuses on adaptations in vulnerable agricultural communities in developing countries (Makondo & Thomas, 2018) and adaptative processes of rural dwellers as shown by Williams et al. (2019) in Ghana, Dube et al. (2018) in Zimbabwe, and Taraz (2017) in Asia, where the main goal is to safeguard the income sources of vulnerable households. In developed countries, studies focus on the implications of climate change in agricultural markets (Costinot et al., 2016), adaptation of agricultural production (Burke & Emerick, 2016), and carbon emissions of agriculture (Moore et al., 2017). Generally, climate change influences rising prices of primary goods, which are then transferred and covered by consumers. Another branch of literature focuses on variations in consumption and ownership, especially of appliances, in urban areas to counteract the adverse effects imposed by climate change.

Much of the literature reveals the rise of consumption of conditioning systems, in situations of extreme weather events (heat or cold) and the corresponding increased electricity consumption (Levesque et al., 2018), although this is still debated in energy-specialized literature (Birol, 2018). Besides, in large cities, high-temperature events are exacerbated by the presence of heat islands (Kim, 1992), which, along with high construction density, increase average temperatures compared to rural areas (Zeleňáková et al., 2015). In fact, a higher demand for heating and cooling systems has been observed for a set of developed countries (Mishra et al., 2015). Likewise, it is observed that individuals in response to extreme events may consume more sunscreen, sunglasses, protective clothing against the sun, and bottled water in greater quantities (Zapata, 2021).

These changes in consumption as a response to extreme weather events can lead to exacerbate pollution and electricity consumption, which in turn can worsen or accelerate the climate emergency in response to extreme events. This is called maladaptation (Pelling, 2010) and has become a recurring process to analyze and observe in climate change mitigation processes by individuals, households, and communities (Lee et al., 2023). Processes of good adaptation within cities due to climate change are also an issue that has been highlighted by Huang-Lachmann (2019).

In Colombia, as in the rest of the countries, adaptation processes can vary from those in developed countries with seasons. First, in tropical zones, there are no seasons, and therefore, the extreme and prolonged temperature variations typical of countries in temperate zones are not observed. Second, in tropical zones and specifically in Colombia, rainfall is much more frequent and intense, and consequently, extreme events are expected more frequently. It is also important to consider that the material capacities of both households and governments to respond to extreme weather events are more limited in countries like Colombia. Moreover, following Brink et al. (2023), there are settlements in the city where households are inserted in "contextual factors, which may precede or have little to do with climate adaptation processes." Thus, at first glance, it does not seem that these households can easily adapt to change, and if they do, they must do so assuming significant costs in terms of consumption of essential goods. Not only that, but part of the adaptation would occur through the purchase of appliances that have lower quality standards in developed countries and therefore would lead to more polluting and inefficient consumption.

To provide evidence of the particularities of climate change adaptation in Colombia, this article estimates how extreme temperatures and rainfalls modify the ownership of air conditioning, fans, and heaters in households. Perhaps the most significant difficulty in credibly identifying the effect of climate change on appliance ownership is the likely reverse causality between variables. As mentioned earlier, appliance consumption generates pollution and increased electricity consumption, which in turn contributes to worsening climate change.[3] Thus, a simple regression of appliance ownership versus the presence of extreme events does not accurately reflect the magnitude and direction of the effect of interest. Another significant identification problem is related to the presence of confounding factors such as electricity consumption or variations in appliance prices, which, if absent in the regression analysis, would lead to biased estimates of the effect of interest.

To mitigate these concerns, we use monthly household survey data (GEIH) combined with climate information at the municipality level and include a set of municipality and time

1 As defined by NASA climate change is "the change in the average conditions such as temperatures and rainfalls in a region over a long period of time." Seen at https://climatekids.nasa.gov/climate-change-meaning/

2 World Health Organization (WHO), Fact Sheet on Climate Change (2022). https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health

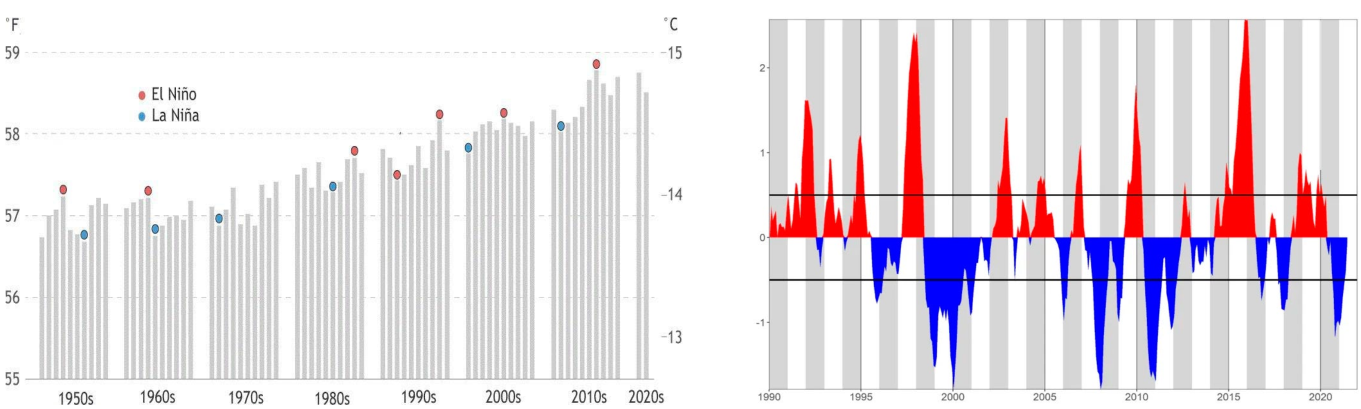
3 The energy consumption of cooling and heating appliances varies considerably. A typical ceiling fan uses between 10 and 75 watts, while pedestal or high-speed fans can reach up to 120 watts. In contrast, residential air conditioners commonly consume between 500 and 3500 watts, depending on the model, capacity, and efficiency. Electric space heaters often operate at 1500 to 2000 watts. These large differences imply that increases in air conditioner or heater ownership—compared to fans—can result in much greater electricity demand and, in fossil-fuel-dependent grids, higher greenhouse gas emissions. As such, fan ownership may represent a low-impact or efficient adaptation, whereas increased use of energy-intensive appliances could be more maladaptive, especially without accompanying energy-efficiency or decarbonization measures.

fixed effects in our household-level regressions to control for time-invariant differences across locations and common shocks over time. While our approach does not permit household fixed effects due to the repeated cross-sectional design, these specifications help isolate variation in climate conditions within municipalities over time. Our results show how extreme temperature events are related to a higher probability of households having fans and air conditioning (and a lower probability of having heaters). Meanwhile, events of extreme precipitation increase the probability of households having a heater. The results are consistent with those of the maladaptation literature. This paper is divided into a first part that exhibits the context of adaptation and changes in consumption; a second part presents the literature review; in the third part, the data are described, and some descriptive statistics are presented; finally, the identification strategy is described, and the results are presented.

2. Climate Change and Adaptation: A Context

The concept of adaptation to climate change is broad and heterogeneous and can include cognitive adaptation, genetic adaptation, social adaptation, environmental adaptation, etc. According to Lee et al. (2023), climate change is the process of adjusting to the current climate or adjusting to climate expectations. In human systems, adaptation seeks to moderate damage or take advantage of beneficial opportunities. Meanwhile, Williams (2018) asserts that adaptation to climate change arises when the effects of an adverse exogenous process affecting survival in any aspect are mitigated. As a natural process, it is considered a process of selection in humans throughout history and reflects the resilience and endurance capacity of ecosystems and individuals. Now, some responses to extreme weather events can be considered maladaptation actions that, in the long term, worsen the problem being mitigated. For example, when appliance ownership increases in response to extreme events, it can lead to higher electricity consumption, resulting in higher emissions (depending on the type: hydro, thermal, nuclear, wind, solar, etc.) and increased amounts of pollutant waste in landfills. However, there are other actions promoting no maladaptation processes, such as regulations governing the ownership of heating systems in new buildings to reduce electricity consumption and associated pollution (Hallegatte et al., 2007), or the usage of green materials to reduce the impact of heat island (Irfeey et al., 2023). This is also relevant for middle-income countries where climate change has already led to increased electricity consumption due to higher appliance usage (Davis & Gertler, 2015). In fact, the International Energy Agency (IEA) in 2018 anticipated an increase in consumption in conditioning systems because of the El Niño Southern Oscillation (ENSO) phenomenon.

In Colombia, maladaptation resulting from increased appliance consumption is plausible since it is one of the countries strongly affected by the ENSO phenomenon. ENSO is defined as an interannual cycle in the central-western Pacific region where a change in atmospheric pressure near the ocean surface (eastern and western) is observed. ENSO causes surface waters to become warmer, leading to low precipitation (El Niño) or causes cooler temperatures, leading to high precipitation (La Niña) (Bocanegra, 2014). In Figure 1, it can be seen how, since 1950, these two major climate disturbances, La Niña or El Niño, alternate in cycles, even when the average temperature is rising (Graph a, Figure 1). The duration of these events varies from three months to two or more years. According to their intensity, they are classified as weak, moderate, or strong. The occurrences of El Niño or La Niña events shown in the graph (b) belong to those of small, medium, or strong intensity since 1990. Furthermore, they generally begin in the middle of the year, reach their maximum intensity at the end of the same year, and dissipate by the middle of the immediately following year; although this pattern can vary between one event and another, as was the case at the end of 2017. It is important to clarify that a cooling of the waters of the Tropical Pacific does not necessarily give rise to the 'La Niña' phenomenon, although it does increase rainfall in



(a) Average temperature and Extreme ENSO

(b) ENSO events

Figure 1. Global Average Temperature and El Niño-La Niña Events
Note: Average temperature available at: https://report-2023.global-tipping-points.org/; and ENSO events at: https://www.worldclimateservice.com/2021/08/25/what-is-el-nino/
Source: own elaboration.

Colombia. Figure 1 also shows a steady increase in average temperature over the last 70 years.

Projections for Colombia by IDEAM (2024) indicate that by 2050, temperatures may rise between 1.5 and 2°C with an increase in extreme precipitation variability by 10%. These changes are expected to intensify heatwaves and droughts, affecting urban energy demand and adaptation decisions.

Both in the El Niño and La Niña periods, extreme events are reported as heatwaves (days exceeding 29.5°C for three or five consecutive days) or extreme levels of precipitation in short periods of time, causing landslides, tree falls, river surges, and creek overflow. It is expected that, in response to these phenomena, households will incur private costs that the State does not subsidize, which would describe adaptation actions. It is also expected that consumption responses vary with income, specifically where households with low incomes do not frequently engage in adaptation actions. Thus, climate change in our study is when monthly temperature and rainfall levels are above the annual average. We explain this in detail in the data section.

3. Literature Review

The study of adaptation processes to climate change is not new in academic literature and has largely focused on the case of communities in rural areas that are more frequently, strongly, and directly affected by extreme weather events. These communities are significantly affected in both their well-being levels and their means of sustenance, such as crops and livestock (Mertz et al., 2009). In urban areas, there is literature that has discussed the co-benefits and synergies between adaptation and mitigation measures leading to resilience and good adaptation within cities (Sharifi, 2021), while other research focused on household adaptation processes leading to the rise in consumption or ownership of goods that mitigate the effect of climate change (such as conditioning or heater systems) which in turn have led to a rise in electricity usage. This has been verified in countries like Germany (Kussel, 2018),[4] the United States (Doremus et al., 2022), and China (Zhang et al., 2022),[5] with greater repercussions for low-income households, which are usually the most vulnerable and are being limited by monetary resources, thus, they cannot counteract the effects of extreme weather (Park et al., 2018).[6]

Other studies for OECD countries (Johnstone & Serret, 2012) and Ecuador Zapata (2015, 2021) show that temperature increases are related to increases in demand for bottled drinking water.[7] Meanwhile, for Buenos Aires, Argentina, Rabassa et al. (2021) show maladaptation when people stop using bicycles for transportation on hot days.[8] For the Chinese case (Garg et al., 2020), longitudinal data from 1989 to 2011 show that households reallocate time use in their daily activities in response to extreme weather events. The authors estimate that extreme temperatures reduce working time,[9] with a greater effect for agricultural work and women (especially those engaged in household chores), and reduce time spent on childcare (by more than four hours per week).[10]

In Colombia, studies have mainly focused on agricultural adaptation to climate change. Camargo (2022) analyzes strategies in agricultural contexts, while Eise et al. (2021) study adaptation in the coffee sector. Similarly, Marchant-Santiago et al. (2021) examine how farming families respond to climatic variability. Córdoba-Vargas et al. (2020) show that ancestral knowledge plays a crucial role in building rural community resilience. However, Bonilla & Quesada (2024) note that climate change is not yet central in the education of students in rural schools, and Howland and LeCoq (2022) argue that adaptation policies remain limited beyond the National Disaster Risk Management Plan 2015–2025.

In the urban context, Pardo-Martínez et al. (2018) demonstrate that Bogotá's citizens are aware of mitigation practices but do not associate extreme events with changes in household behavior, particularly regarding ownership of durable goods and environmentally certified food consumption. These changes tend to be privately assumed without government subsidies. Despite this, Cali and Medellín have been recognized by the Rockefeller Foundation among the 100 resilient cities for their inclusive urban planning processes.[11]

Beyond these perspectives, McRae (2023) provides empirical evidence that higher temperatures increase the use of air conditioning and consequently household electricity consumption. However, this analysis focuses only on the temperature–electricity relationship, omitting the influence of extreme precipitation and household appliance ownership decisions. Other research addresses the economic impacts of climate events, such as Abril-Salcedo et al.,(2020), who document the nonlinear effects of strong El Niño events on food inflation, while Julio et al. (2020) and Melo et al. (2020) assess the forecasting of food price shocks due to extreme climate shocks, estimating the costs of the 2015 El Niño on the Gross Domestic Product (GDP) and ecosystem services for Colombia.

Further evidence comes from Restrepo (2020), who explores household responses to climate stress in water and energy use, and Ramirez-Villegas (2012), who examines agricultural adaptation strategies to long-term precipitation and temperature shifts. Mendoza Ledezma (2024) reports local adaptation strategies in rural Cauca, while Villegas-Palacio (2020) analyzes household adaptive capacity in degraded Andean ecosystems. While prior research either addresses electricity consumption (McRae, 2023) or the economic impacts of climate variability, no one has investigated how extreme temperatures and

4 The author estimates panel households with random effects using a Probit model.

5 Both studies estimate linear panel models with fixed effects. In China, results differ in the annual distribution of mean daily temperatures that authors divide into 10 mutually exclusive subsets.

6 Authors find that, for 52 countries, low-income individuals are more exposed to climate change.

7 Both studies use surveys that inquire about consumption on days with high temperatures.

8 The authors estimate an OLS linear regression model to analyze the correlation between weather events and individuals' transportation modes, controlling for multiple characteristics.

9 Using panel models with fixed effects, they calculate that an additional day with temperatures above 80 degrees Fahrenheit reduces weekly work by more than one hour.

10 The result is not replicable for households that do possess cooling technologies

11 Report reviewed from the link: https://resilientcitiesnetwork.org/downloadable_resources/Network/Cali-Resilience-Strategy-Spanish.pdf

precipitation jointly influence urban household appliance ownership. Unlike McRae's work, this paper incorporates precipitation extremes and examines heterogeneous responses across socioeconomic groups, revealing maladaptive dynamics absent in previous studies. Thus, it contributes to understanding that adaptation in tropical urban contexts involves not only increased electricity use but also broader patterns of appliance adoption shaped by multiple climatic stressors and social disparities.

4. Data Sources

Part of climate change manifests through extraordinary variations in temperature and precipitation. To identify these extraordinary climate events, this study will use information provided by the Institute of Hydrology, Meteorology, and Environmental Studies of Colombia (IDEAM). IDEAM offers daily information on temperatures and precipitation at the municipal level from 2007 to 2021. Data on maximum precipitation, maximum temperatures, minimum temperatures, and accumulated precipitation are captured. This study uses monthly information for 11 out of 13 metropolitan areas of Colombia due to missing data.[12] With the daily information, we calculate the average and standard deviation of the last 10 years for maximum temperature (*MaxTemp*) and accumulated (or maximum) daily precipitation (MaxPrec). Then we sum to the average its standard deviation, and then calculate a binary variable, taking a value of one if the daily maximum temperature exceeds the sum of the 10-year average maximum temperature plus its standard deviation, and zero otherwise (a similar procedure is followed for accumulated precipitation).[13] In short, our measurements indicate that an extreme event occurs when the maximum value recorded for the day surpasses the ten-year average by more than one standard deviation. Finally, a variable indicating low temperatures is calculated when the daily minimum temperature is below its 10-year average for three consecutive days.

We also calculate the Standard Temperature Index (STI) and Standard Precipitation Index (SPI) using in both variables the ten-year records of maximum temperature and precipitation to account for high levels as we do. Table 2 (Appendix A) presents values for the correlation of the STI and SPI with our climate measures for temperature and precipitation. In both cases, the variables are highly correlated. Figure 10 in Appendix A presents an evolution of the indexes by metropolitan area from 2009 to 2019 to see their pattern over ten years. We observe that, besides the seasonality of the values with some peaks, there is an increase in STI Max in almost every metropolitan area except Bogotá, Manizales, and Villavicencio (Graph a, Figure 10, Appendix A). The SPI Max also presents a seasonal pattern, and it seems not to have an increasing tendency in any metropolitan area (Graph b, Figure 10, Appendix A).

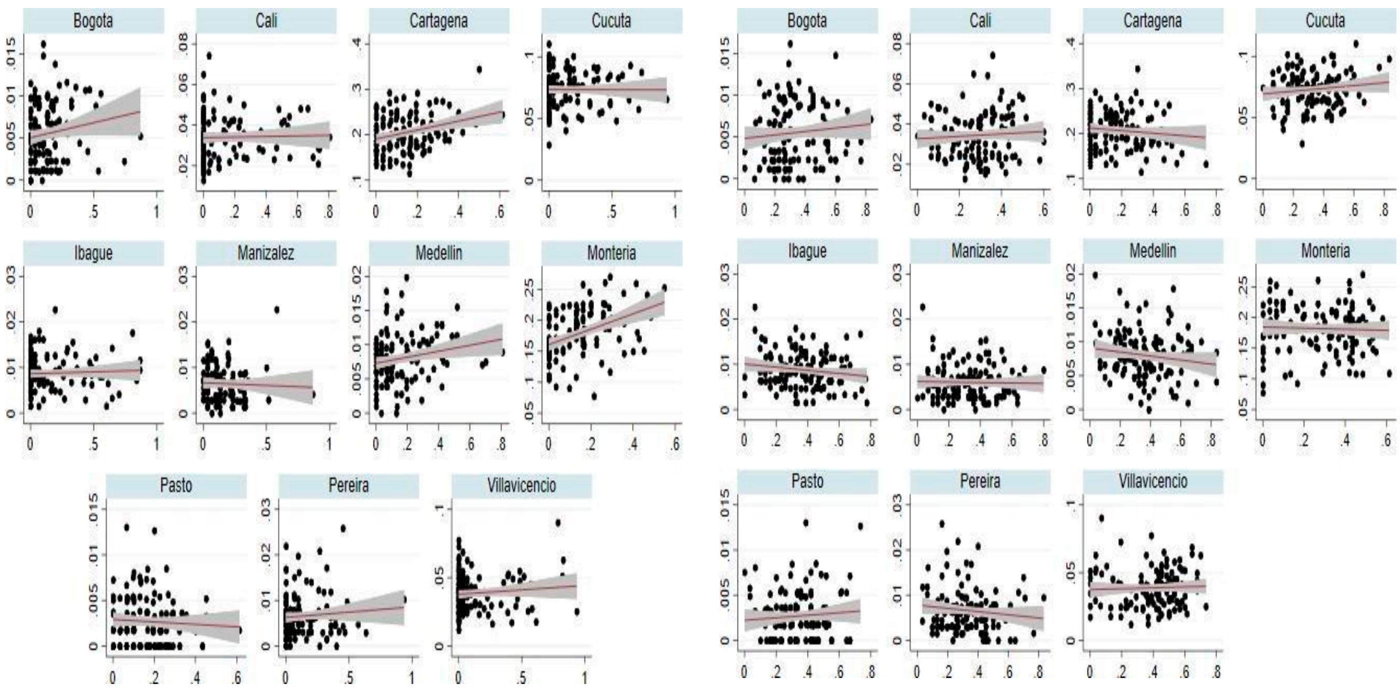
Information on household appliance ownership, such as air conditioning, fans, or heaters, is obtained from the Integrated Household Survey (GEIH) operated by the National Administrative Department of Statistics (DANE) of Colombia. This survey collects information for a set of households in the 13 main metropolitan areas of Colombia monthly from January 2007 to the present. The fan ownership indicator is constructed as a binary variable, taking a value of one if the household reports ownership of a fan and zero otherwise. Similar indicators are constructed for air conditioning and heater ownership. Figure 11, Appendix A shows the tendency of ownership of fans, air conditioners, and heaters by households for each metropolitan area. We observe a strong correlation between altitude and climate appliance, meaning metropolitan areas located at higher altitudes, presenting a larger percentage of households reporting owning a heater (also with an increasing tendency of ownership), while small percentages of households report having a fan or an air conditioner. A similar pattern appears when looking at metropolitan areas at lower altitudes with a bigger proportion of households owning an air conditioner or a fan (the tendency of ownership is increasing in these metropolitan areas, except for households owning an air conditioner in the metropolitan area of Cucuta).

Control variables related to household characteristics and the characteristics of the household head are also obtained from GEIH. For our analysis, two datasets are built. The database used for the empirical strategy is a repeated cross-section (GEIH collects monthly information of a sample of households since January 2007) consisting of 985,470 households from 11 cities. The second data set is obtained by aggregating household information by metropolitan area and month, resulting in a panel of cities with a total of 1,452 observations.

Figure 2 shows the relationship between the proportion of households with air conditioning (vertical axis) and extreme weather events (horizontal axis), summarized either by the percentage of days in the month where the maximum temperature exceeded one standard deviation its 10-year average (panel a of Figure 2) or by the proportion of days that exceeded the accumulated precipitation of the last 10 years (panel b of Figure 2). These aggregations are made by metropolitan area and consider all months between 2010 and 2019. From this figure, it can be observed that for most cities, months with a higher proportion of extreme temperatures show a higher proportion of air conditioning ownership (panel a of Figure 2), while the results are mixed by metropolitan areas for extreme events related to high precipitation (graph b, Figure 2). Similar results are observed for fan ownership (see Figure 12, Appendix A). Finally, heater ownership seems to reveal a negative correlation with high temperature events (graph a, Figure 13, Appendix A), and a positive correlation with high precipitation events (graph b, Figure 13, Appendix A).

12 Only 2 metropolitan areas, Barranquilla and Bucaramanga, are excluded from the sample due to a lack of environmental information over long periods of time.

13 We calculate the following: Alta temperatura =1 si $MaxTemp > \overline{Maxtemp + SD}$ y Alta temperatura =0 si $MaxTemp < \overline{MaxTemp + SD}$. Similarly, it is calculated for accumulated precipitation.



(a) Temperature

(b) Rainfall

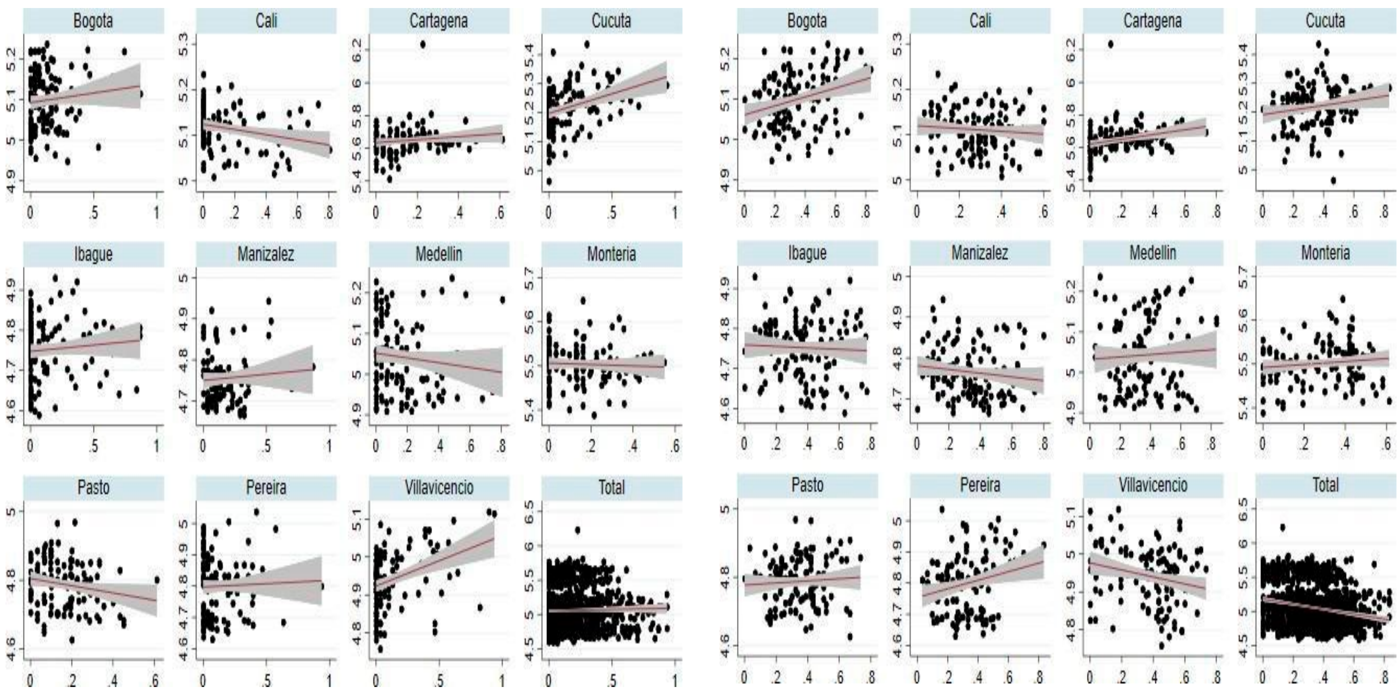
Figure 2. Correlation between the probability of households owning air conditioning and high temperature and precipitation events by metropolitan area, 2009-2019
Source: own elaboration.

While the main objective of this study is to analyze how household appliance ownership changes in response to extreme temperatures and precipitation, it is also important to identify how electricity consumption changes, as this variable is directly involved in maladaptation processes. Information on electricity consumption is obtained from the Single Information System for Household Public Services (SUI), from the Superintendence of Public Utility Services. SUI provides municipal-level information on total energy consumption in kilowatt-hours (KWH), average KWH consumption, average household socioeconomic strata, and the number of subscribers. Electricity consumption data has been obtained since January 2009. Panel a of Figure 3 shows that, except for Cali, Montería, and Pasto, high temperatures coincide with an increase in electricity consumption, confirming what has already been documented for other countries. On the other hand, high precipitation events seem to increase electricity consumption, except for Cali, Ibagué, Manizales, and Villavicencio, while in the aggregate of all cities, it is observed that high precipitation decreases electricity consumption (graph b, Figure 3).

Finally, Appendix A, Table 3 presents some descriptive statistics by metropolitan area. In general, it is observed that municipalities are heterogeneous in most of the characteristics used as controls, which emphasizes the usage of fixed effects and cluster errors at the municipality level in our model specification.

5. Empirical Strategy

Our main specification is conducted at the household level, using a repeated cross-section of 985,470 households across eleven metropolitan areas between 2007 and 2019. As previously mentioned, there are significant challenges in identifying the effect of climate change on appliance ownership. Firstly, since appliance ownership can exacerbate the climate change process, there is a possibility of seeing a reverse causality bias. Second, there are confounding factors that, if absent from the regression analysis, could lead to a selection bias in the estimates. A list of possible confounding factors is household electricity consumption, appliance price variation, relative humidity levels, and air pollution emissions. To mitigate these identification problems, we begin by including a broad set of control variables in the household-level regression analysis. These controls include the consumer price index (CPI) for appliances and monthly electricity consumption at the city level, which help account for variation in appliance affordability and energy demand. Next, to account for unobserved heterogeneity, we include municipality (metropolitan area) fixed effects and time fixed effects at the month-year level in our household-level regressions. The municipality fixed effects control all time-invariant characteristics specific to each location—such as long-run climate baselines, infrastructure quality,



(a) Temperature (b) Rainfall

Figure 3. Correlation between high temperature (and precipitation) events and electricity consumption (logarithm of the average) by metropolitan area, 2009-2019
Source: own elaboration.

economic structure, or cultural factors—that might otherwise confound the results. Time fixed effects, in turn, absorb national shocks or seasonal trends that affect all municipalities simultaneously, such as changes in national energy policy, inflation cycles, or climate anomalies like El Niño. This two-way fixed effects specification strengthens the internal validity of our estimates by ensuring that comparisons are made within municipalities over time, effectively leveraging variation in extreme weather events relative to each location's baseline. However, this strategy does have limitations. First, it does not control unobserved, time-varying confounders at the municipality level, such as changes in local enforcement, electricity pricing, or unmeasured socioeconomic shocks. Second, since our data comes from repeated cross-sections rather than a panel of households, we cannot account for unobserved heterogeneity at the household level, which may still bias our results if such unobservables correlate with both climate exposure and appliance ownership. Therefore, while the fixed effects framework improves our ability to approximate causal effects, we remain cautious in interpreting the results as fully causal. Our baseline specification is given by:

$$\begin{aligned}\mathrm{Owner_{hmt}} &= \mathrm{Temp_{mt}} + \mathrm{Prec_{mt}} + \mathrm{X_{hmt}} \\ &+ \mathrm{Eneg_{mt}} + \mathrm{IPCEle_{mt}} + \mathrm{Mun_m} + \mathrm{T_t} + \varepsilon_{\mathrm{mt}}\end{aligned} \quad (1)$$

where the dependent variable $Owner_{hmt}$ can be: (*i*) ownership of a fan; (*ii*) ownership of an air conditioner, or (*iii*) ownership of a heater for household *h*, in municipality *m*, and in period *t*. As mentioned earlier, the ownership indicator takes the value one if the household has a certain appliance and zero otherwise. The variables $Temp_{mt}$ and $Prec_{mt}$ represent our measures of extreme temperature and precipitation events, respectively at the municipality level; X_{hmt} is a vector of household characteristics; $Eneg_{mt}$ is the logarithm of average electricity consumption; $IPCEle_{mt}$ is the consumer price index for climate change-related appliances; Mun_m denotes municipality fixed effects, and denotes time fixed effects (month-year), as previously described. These parameters capture unobserved, time-invariant characteristics across municipalities and common temporal shocks, respectively.

It is important to notice that in our empirical design there is a spatial mismatch between climate exposure and household location. Because the GEIH survey does not include GPS coordinates or sub-municipal identifiers, we are constrained to using municipality-level climate data to represent exposure for all households in that area. This assumption may not hold in all cases, particularly in geographically diverse municipalities where climate conditions can vary significantly over short distances. As a result, our measures of exposure to extreme temperatures or precipitation events may suffer from measurement error, which—if classical in nature—would likely attenuate the estimated effects and bias our coefficients toward zero.

To reduce this risk, we take several steps: (i) we restrict the analysis to urban households in 11 metropolitan areas, where weather conditions are more likely to be homogenous; (ii) we use data from a network of 23 IDEAM weather stations, selecting only municipalities with high reporting completeness and reliable monthly coverage; and (iii) we aggregate daily climate data to the monthly level to better match the behavioral time frame of appliance ownership decisions.

6. Results

6.1 Household-Level Analysis

Next, we present the results of estimating Equation 1 specifying a Probit model and a Logit model. When using a binary outcome variable, a linear probability is best estimated using a probabilistic model (Probit or Logit) rather than a linear estimation (OLS). In our estimation, we use a probabilistic model (Probit) as a baseline, in this case compared to the coefficients of a Logistic estimation. In Figure 4, it can be observed that an increase in the proportion of days with extreme temperatures in a month increases the probability that households own a fan or an air conditioner by 0.02 and 0.015 percentage points, respectively, while reducing the probability of owning a heater by 0.013 percentage points.

It is also observed that a higher proportion of extraordinary precipitation in a month is related to increases in the probability of heater ownership by up to 0.025 percentage points. It is clear then that households do adapt (or maladapt) to extreme weather events with a higher ownership of fans, air conditioners, and heaters. In terms of energy consumption, owning a fan could not be seen as a maladaptive process, although owning an air conditioner or a heater is. We also estimate equation 1 using the STI and SPI instead of our measures of temperature and precipitation, and the results are similar to those found in Figure 4 (see Figure 14, Appendix A)

Since the adaptation process may take time, we also perform estimations using extreme weather events in the immediate previous month or period as the treatment variable. The results in Table 1 again show that in the face of extreme events, there are positive and statistically significant increases in the probability of fan ownership, while the probability of air conditioner ownership decreases.

Next, possible heterogeneous effects by socioeconomic strata and gender are explored. To do so, we introduce dummy variables into equation one (1) to identify household socio-economic strata, gender of the head of household, and metropolitan area, to estimate differentiated results (we did not subsample the data for these estimates). By strata level, it is observed that the effect of extreme temperatures on the probability of air conditioner ownership is greater for households in strata one (up to 0.13 percentage points) than for the group of households in strata higher than one (panel (a), Figure 5). It is also observed that the effect of extreme temperatures on the probability of heater ownership is greater for households in strata two, three, and four (up to 0.1 percentage points) than for households in stratum one, although this difference seems to be significant only for households in stratum three and four (panel (a), Figure 5). On the other hand, the effect of extreme rainfall on the probability of air conditioner ownership is lower for households in strata two (0.12 pp) and three (0.2 pp) compared to households in strata one, while the effect of extreme rainfall on the probability of heater ownership is greater for households in strata two compared to households in strata one (panel (b), Figure 5).

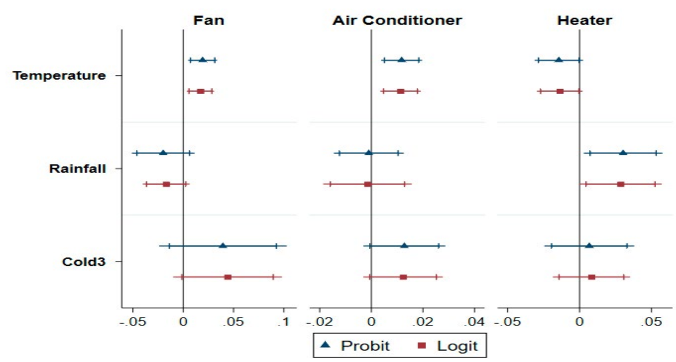


Figure 4. Estimates of the relationship between extreme weather events and ownership of fans, air conditioning, or heaters in households in 11 major cities, 2009-2019.
Source: own elaboration.

When considering the sex of the head of household, it is observed in panel (a) of Figure 6 that the effect of extreme rainfall events on the probability of owning a fan, air conditioner, and heater is lower for households with a

Table 1. Estimates of the relationship between extreme weather events occurred one month before and ownership of fans, air conditioning, or heaters in households in 11 major cities, 2009-2019

Variables	Fan		Air Conditioner		Heater	
	(1)	(2)	(3)	(4)	(5)	(6)
	Probit	Logit	Probit	Logit	Probit	Logit
Lag temperature	0.018**	0.017***	-0.007***	-0.006**	-0.007	-0.007
	(0.008)	(0.006)	(0.002)	(0.003)	(0.013)	(0.012)
Lag rainfall	0.025*	0.018*	0.003	0.006	-0.024*	-0.021
	(0.014)	(0.010)	(0.007)	(0.008)	(0.014)	(0.014)
Lag cold	0.055**	0.058***	0.006	0.008	0.011	0.015
	(0.025)	(0.019)	(0.008)	(0.008)	(0.023)	(0.020)
Observations	935,251	935,251	936,160	936,160	936,160	936,160

Note: PROB: margins from Probit estimates with errors adjusted by cluster of metropolitan area; LOG: margins dy/dx from Logit model, with errors adjusted by cluster of metropolitan area. Control variables used in equation 1 from Table 2, Appendix A.
Source: own elaboration.

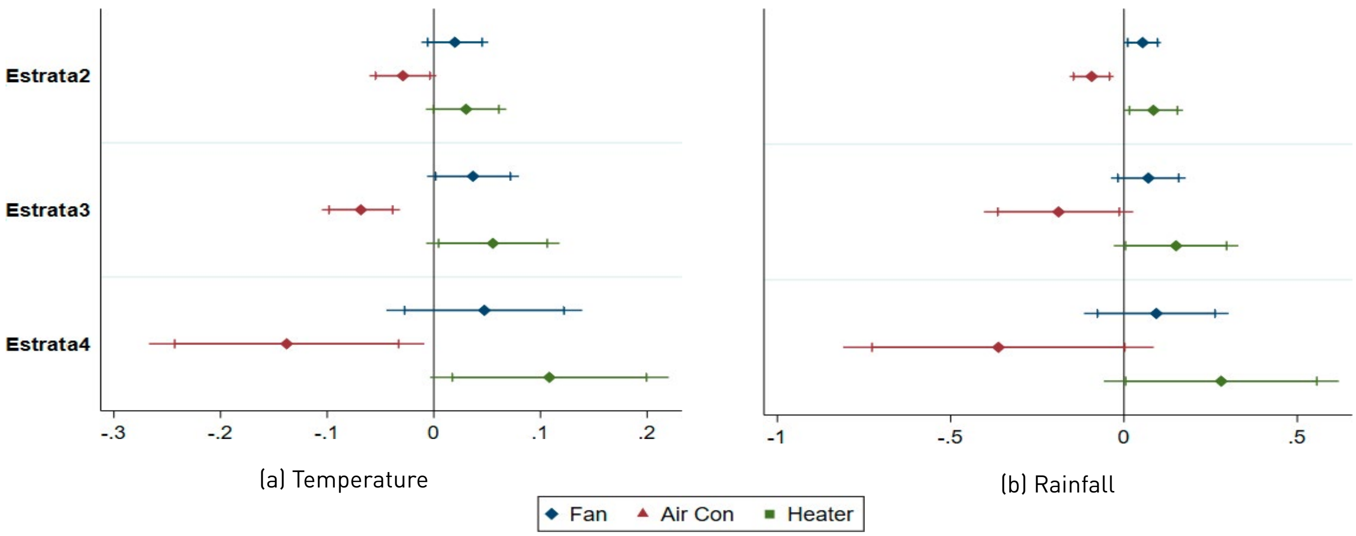


Figure 5. Estimates for extreme weather events and ownership of fans, air conditioning, or heaters, differentiated by socioeconomic stratum of the household, 11 major cities, 2009-2019
Source: own elaboration.

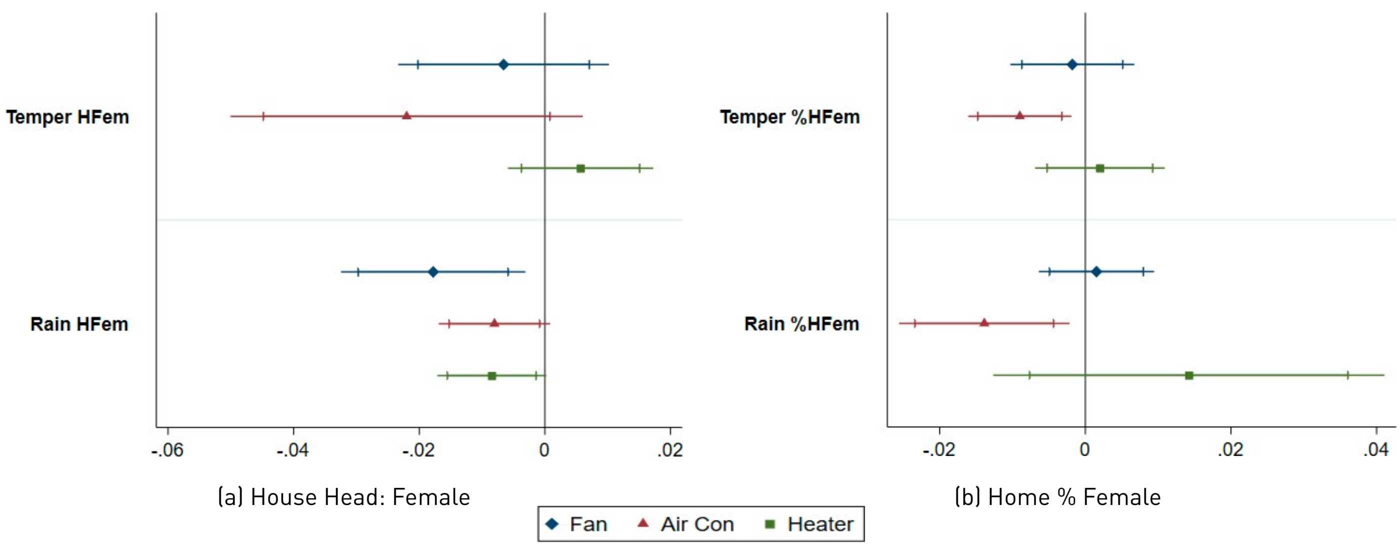


Figure 6. Estimates of extreme weather events and ownership of fan, air conditioning, or heater, differentiated by gender of the household head, in 11 major cities, 2009-2019
Source: own elaboration.

female head compared to households with a male head (by 0.02 percentage points). Additionally, no differentiated effects are found for high temperatures. Considering the predominant sex in the household (a household is considered female if the majority of household members are female, male if the majority are male, while it is considered balanced if there are equal numbers of men and women), it is observed that the effect of both extreme temperatures and extreme rainfall on the probability of owning an air conditioner is lower for female-headed households (until 0.015 percentage points) compared to male-headed (or balanced households) (panel (b), Figure 6)

When considering the number of children within the household, it is observed for households with two or more children that the effect of extreme high temperatures on the probability of owning an air conditioner (0.018 and 0.04 percentage points) is higher compared to households without children and the effect of extreme high temperatures on the probability of owning a heater (0.02 and 0.038 percentage points) is lower compared to households without children (graph (a), Figure 7). For events of heavy precipitation, for households with two or more children the effect of extreme high temperatures on the probability of owning a heater (0.05 and 0.11 percentage points) is lower compared to households without children (graph (b), Figure 7).

Heterogeneous effects are also identified by geographical area. In cities such as Cali, Medellín, and Villavicencio, the effect of extreme temperatures on the probability of owning a fan is higher when compared to Bogotá, while in Cartagena, Montería, and Villavicencio, the effect of extreme temperatures on the probability of owning an air conditioner (0.11, 0.09, and 0.01 percentage points) is higher when compared to Bogotá. Also, in all cities in the sample (except Pasto), the effect of extreme temperatures on the probability of owning a heater is lower (up to 0.08 percentage points) compared to Bogotá. Additionally, in Pasto, the effect of extreme temperatures on the probability of owning a fan is lower compared to Bogotá (graph (a), Figure 8).

Heterogeneity analysis also shows that in Ibagué, Montería, and Pereira, the effect of extreme precipitation on the probability of owning a fan (0.03, 0.1, and 0.01 percentage points) is lower compared to Bogotá. Meanwhile, the effect of extreme precipitation on the probability of owning an air conditioner is higher in Cali, Cúcuta, and Pasto (0.03, 0.2, and 0.2 percentage points), and lower in Cartagena (0.04 percentage points) compared to Bogotá. In Cúcuta, Pasto, and Pereira, the effect of extreme precipitation on the probability of owning a heater (households in Ibagué have a lower probability) is higher compared to Bogotá (graph (b), Figure 8).

6.2 Metropolitan-Level Analysis

Finally, we aggregate household information by metropolitan area and month, resulting in a panel of cities with a total of 1,452 observations to gauge how municipal-level electricity consumption is related, first, to our measures of climate change, and second, to the average ownership of climate-related goods: fan, air conditioning, and heater.

We estimate the following equation, $pOw_{nmt} = Temp_{mt} + Prec_{mt} + X_{mt} + Eneg_{mt} + IPCEle_{mt} + Mun_{m} + T_{t} + \vartheta_{mt}$ where the variable pOw_{nmt} is the proportion (percentage) of households reporting ownership of a heater, fan, or air conditioning in municipality m, in month-year t. The rest of the variables

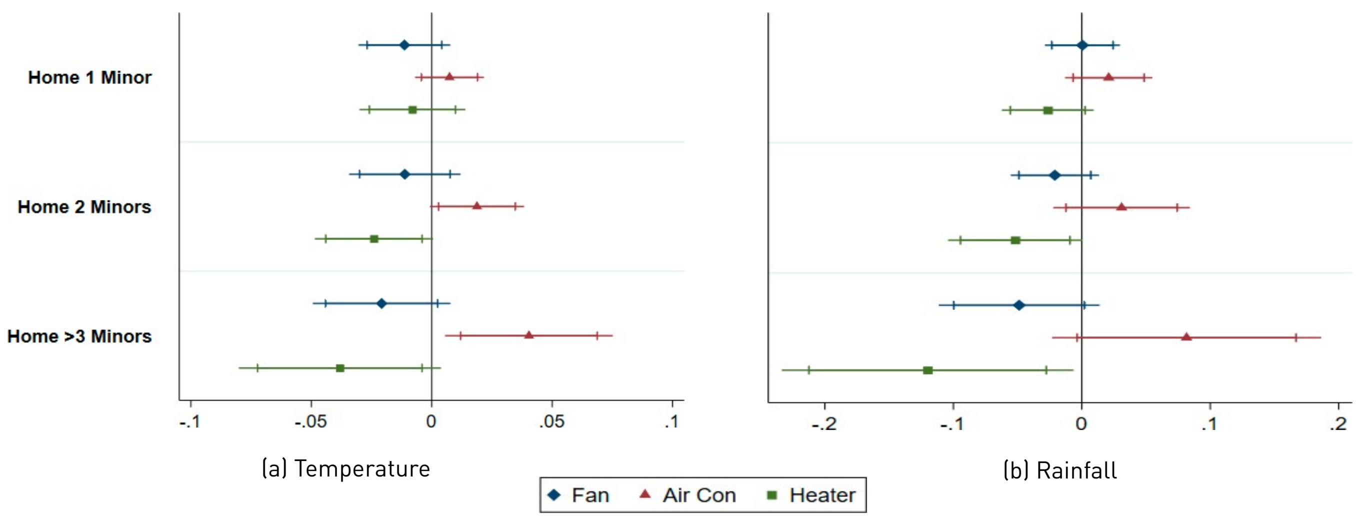


Figure 7. Estimates for extreme weather events and ownership of fan, air conditioning, or heater, differentiated by the number of children in the household, 11 major cities, 2009-2019
Source: own elaboration.

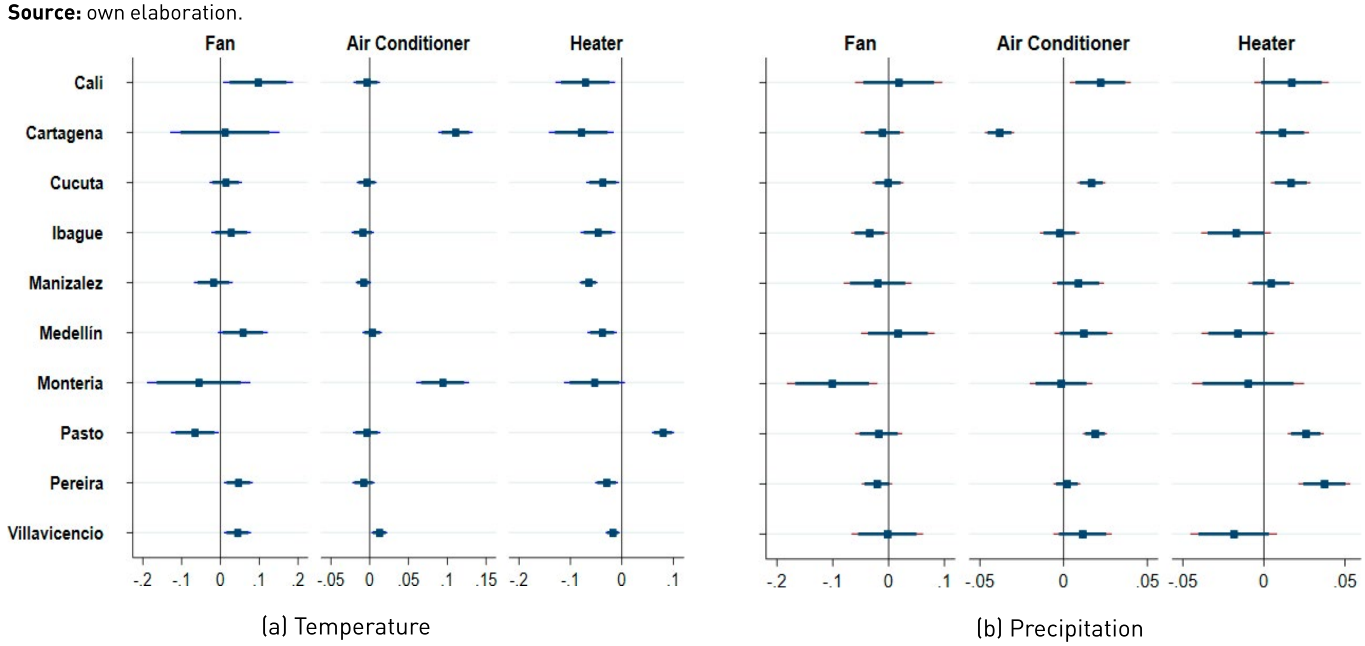


Figure 8. Estimates of extreme weather events and ownership of fan, air conditioning, or heater, differentiated by metropolitan area, 2009-2019
Source: own elaboration

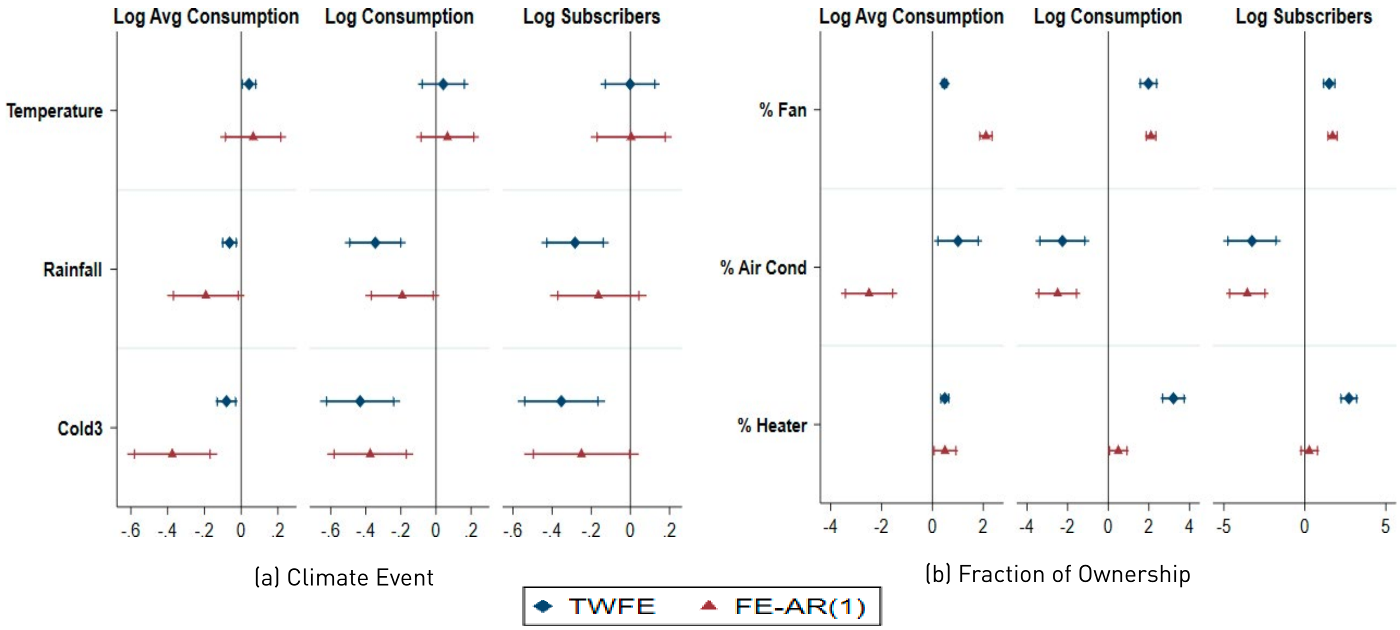


Figure 9. Estimates of the relationship between electricity consumption, extreme weather events, and average ownership of fans, air conditioning, or heaters at the municipal level, 11 major cities, 2009-2019
Source: own elaboration

are defined similarly as in equation 1, but the aggregation is the average by city, month, and year. In this specification, the terms Mun_m and T_t refer to city and time fixed effects, so we have a traditional two-way fixed effects model (TWFE). Given the long panel structure ($T > N$), it is necessary to consider correcting for serial autocorrelation of errors. For estimation, two types of models are used: a panel linear model with two-way effects (TWFE) and a model that corrects for autocorrelated errors (FE-AR(1)). This correction allows obtaining robust and unbiased estimators.

Results in Figure 9 show that extreme precipitations lead to lower electricity consumption. Similarly, when drought events are reported, electricity consumption increases. When a higher percentage of ownership of heaters is observed, a higher electricity consumption at the municipal level is observed. Also, when a high percentage of air conditioning ownership is observed, electricity consumption decreases, which seems counterintuitive. Thus, even though greater ownership of goods implies their use, it seems that for weather events, the ownership of fans and heaters drives electricity consumption.

7. Discussion and Conclusions

The findings of our study shed light on the intricate dynamics of maladaptation within households in response to extreme weather events in eleven metropolitan areas of Colombia. While adaptation is evident through changes in appliance ownership, particularly in response to temperature and precipitation extremes, there are also indications of maladaptive behaviors that warrant attention.

We observe an increase in the probability of owning fans and air conditioners during periods of extremely high temperatures, similar to those found for New York by Lane et al. (2014) and other cities in developed countries by De-Cian et al. (2019). Furthermore, extreme precipitations are associated with lower ownership of air conditioning and higher ownership of heaters, a result that, to the best of our knowledge, has not been highlighted in the literature by any other study, showing how maladaptation also occurs for households when taking actions against extreme rainfall events.

The increased consumption of heating and cooling systems highlights a maladaptive response when temperatures are high. While it reflects an action to mitigate, it may inadvertently exacerbate energy consumption or costs for households. This maladaptation process is consistent with results found by McRae (2023), Doremus et al. (2022), and Randazzo et al. (2020), where it is evident that the consequences of extreme climate events (and heat islands) increase the electricity consumption of cities. Besides, it seems that ownership and the adaptation process can lead to greater pressure on resource use and, in turn, increase the effect of climate change, as evidenced by Zapata (2015, 2021) for Ecuador, and Johnstone & Serret (2012) and Mehiriz et al. (2018) for developed cities, and Ashraf and Faruk (2018) for Argentina. Thus, an action previously seen as an adaptation (solution) becomes a catalyst over time.

Disparities in adaptive capacity are also evident, as lower strata households may lack the resources to invest in more sustainable adaptation strategies, leading to dependence on less efficient or costly solutions. The observed lower probabilities of owning climate appliances during periods of extreme rainfall for female-headed households highlight potential challenges in accessing and utilizing adaptive technologies, indicating gender-specific vulnerabilities or adaptation strategies. Variations across cities suggest the influence of local climate conditions, infrastructure, and socio-economic factors in shaping maladaptation dynamics. These findings emphasize the importance of tailored adaptation strategies that consider local contexts and vulnerability.

While adaptation responses are evident, the implications of maladaptive behaviors require consideration. Sustainable adaptation strategies that address both immediate needs and long-term resilience are essential to mitigate the risks associated with maladaptation and promote household wellbeing, such as the use of more friendly and energy efficient construction materials, as highlighted by Rezvani et al. (2023) with the use of urban resilience standards (Urban Resilience Evaluation System), in addition to improving access to efficient and environmentally friendly energies. Other solutions include promoting communication and information to individuals about the risks of mitigation processes that turn into maladaptation (Nitschke et al., 2017).

Addressing maladaptation requires a comprehensive approach that considers socioeconomic disparities, gender dynamics, and geographic variations. Policy interventions aimed at promoting sustainable adaptation strategies and enhancing resilience at the household level are crucial for mitigating the adverse impacts of extreme weather events and building climate-resilient communities. Further research is needed to deepen our understanding of maladaptation dynamics and inform targeted interventions to reduce vulnerability and enhance adaptive capacity.

Conflict of interest

The authors declare no conflict of interest.

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Statement on the Use of AI

The authors declare that they used generative artificial intelligence (AI) tools solely as support in the manuscript writing process. Platforms such as (e.g., ChatGPT) were used for writing suggestions, idea organization, and style editing. All content was subsequently reviewed, validated, and edited by the authors, who assume full responsibility for the accuracy, originality, and validity of the work presented.

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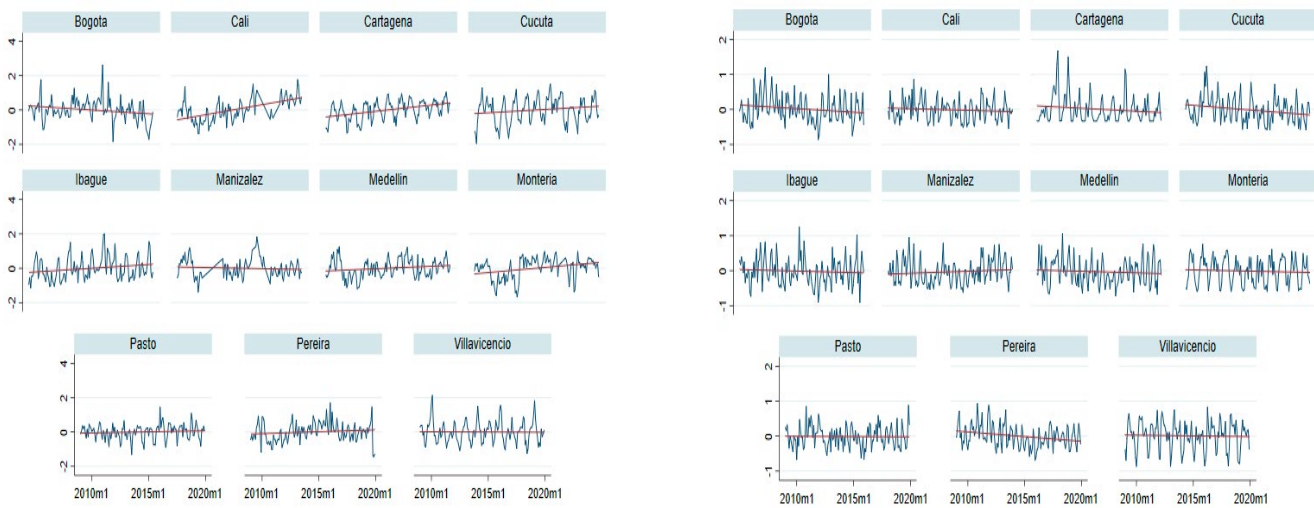
Appendix A

Table 2. Correlation between STI and SPI, and binary variables indicating if the maximum temperature and precipitation are above one standard deviation of the 10-year maximum average.

Variables	STI Max	Temp Max	SPI Max	Prec Max
STI Max	1			
Temp Max	0,8437	1		
SPI Max	-0,421	-0,3799	1	
Prec Max	-0,3114	-0,2723	0,9055	1

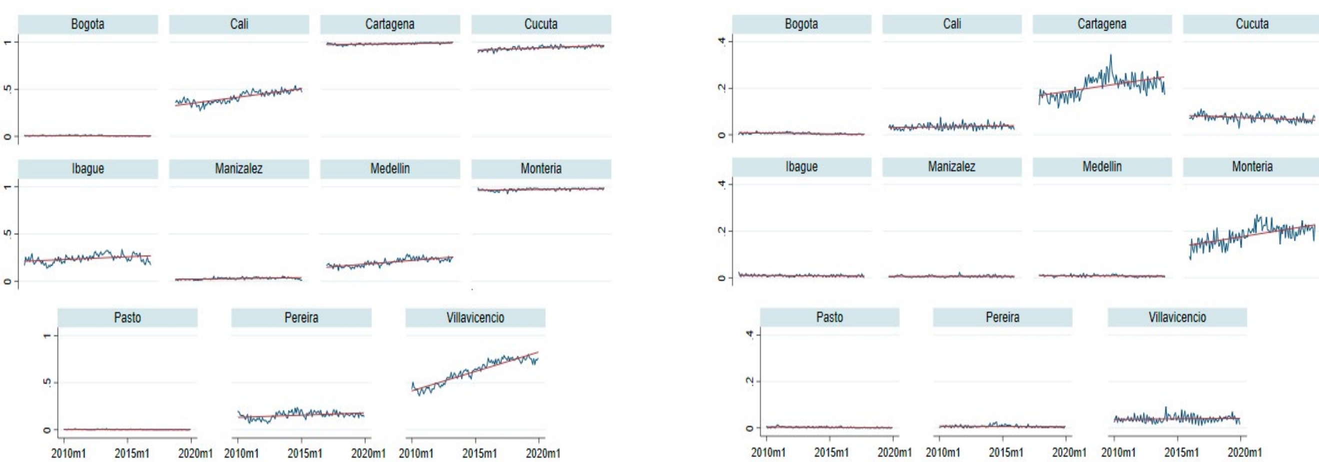
Source: own elaboration.



(a) STI Max

(B) SPI Max

Figure 10. Standard Temperature and precipitation Indexes (STI and SPI) by metropolitan area, 2009-2019.
Source: own elaboration.

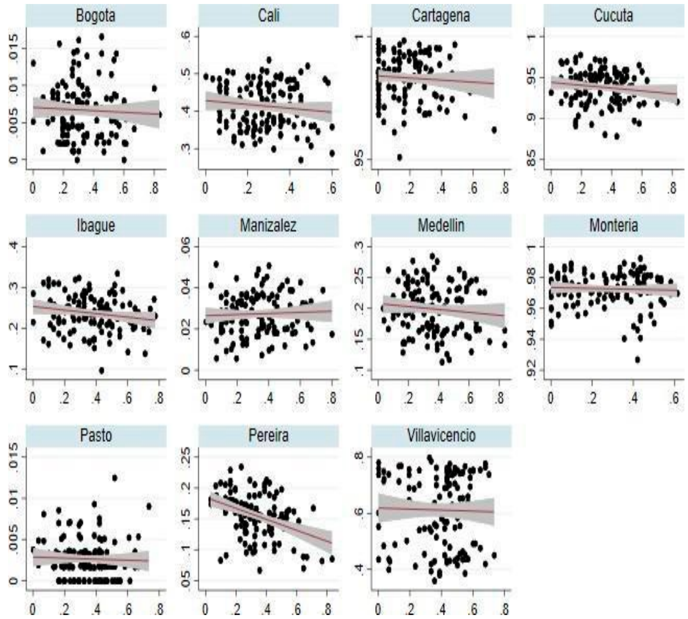


(a) Owning a fan

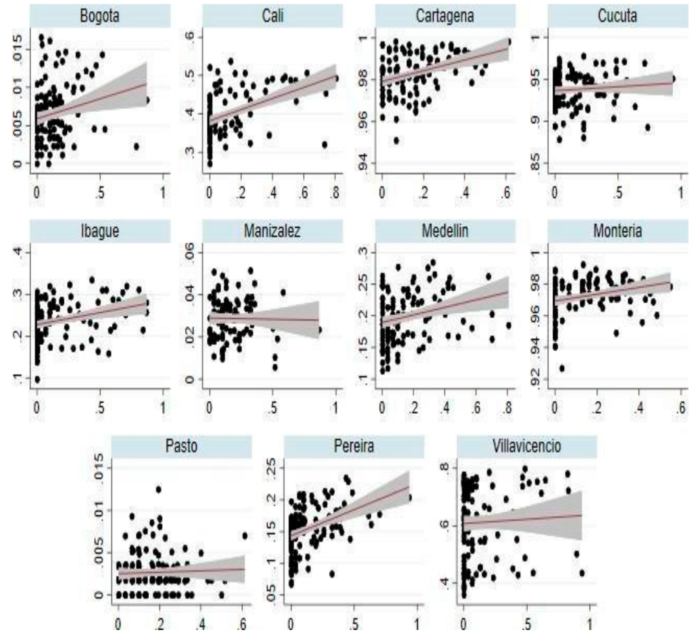
(b) Owning an air conditioner

(C) Owning a heater

Figure 11. Proportion of households owning a fan, an air conditioner, or a heater by metropolitan area, 2010-2019
Source: own elaboration.

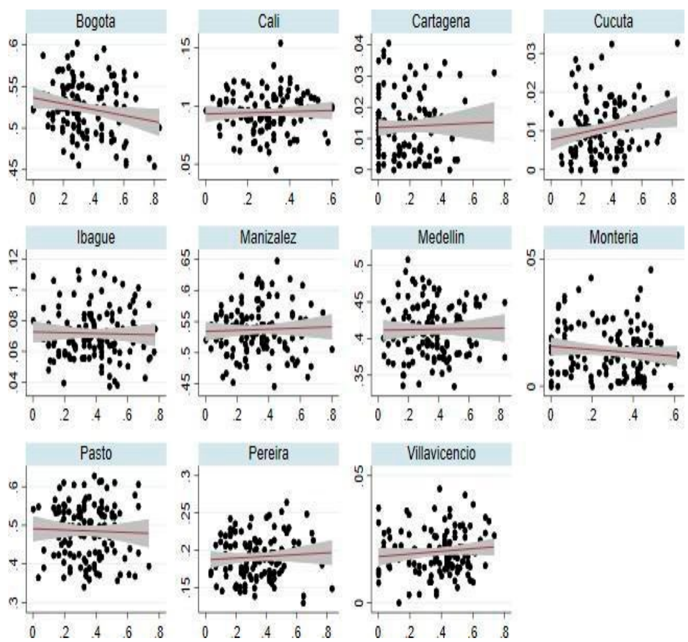


(a) Temperature

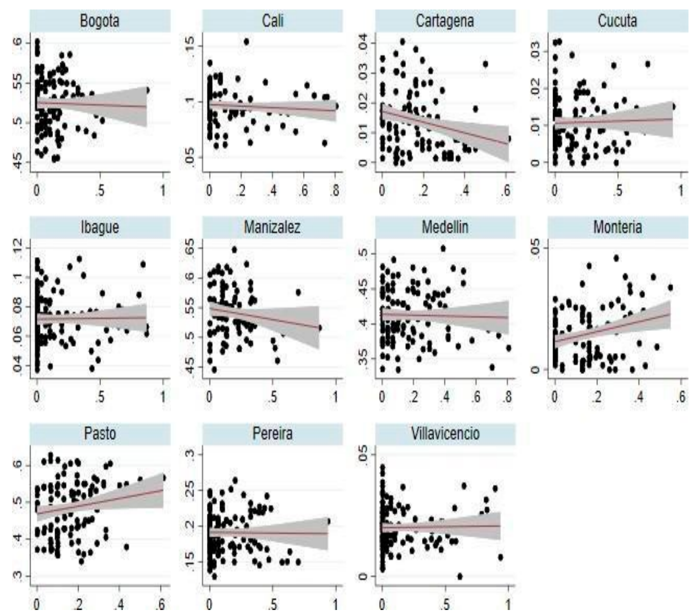


(b) Rainfall

Figure 12. Correlation between the probability of a household owning a fan and high temperature and precipitation events by metropolitan area, 2009-2019
Source: own elaboration.



(a) Temperature



(b) Rainfall

Figure 13. Correlation between the probability of households owning heaters and high temperature and precipitation events by metropolitan area, 2009-2019
Source: own elaboration.

Table 3. Variables used as controls in Equation 1. Information from the GEIH Survey

Metropolitan Area	Bogotá	Calí	Cgena	Cucuta	Ibague	Mzalez	Mllín	Mtería	Pasto	Peira	Vcencio	Total
Sewage serv	0.99	0.99	0.91	0.97	0.99	0.99	0.97	0.50	0.99	0.99	0.98	0.95
(0.07)		(0.10)	(0.29)	(0.18)	(0.10)	(0.08)	(0.17)	(0.50)	(0.08)	(0.11)	(0.16)	(0.22)
Trash serv	1.00	1.00	0.99	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00
(0.02)		(0.05)	(0.10)	(0.06)	(0.05)	(0.03)	(0.03)	(0.12)	(0.03)	(0.03)	(0.04)	(0.06)
Water serv	1.00	1.00	0.98	0.98	1.00	1.00	0.99	0.98	1.00	1.00	0.96	0.99
(0.06)		(0.06)	(0.14)	(0.12)	(0.06)	(0.06)	(0.07)	(0.15)	(0.05)	(0.05)	(0.20)	(0.10)
# People house	2.28	2.29	2.86	2.56	2.28	2.23	2.32	2.82	2.37	2.26	2.29	2.45
(1.95)		(1.95)	(2.35)	(2.14)	(1.94)	(1.89)	(1.97)	(2.37)	(2.05)	(1.93)	(1.99)	(2.11)
# Rooms 1.98		2.04	2.06	1.95	2.00	2.09	2.11	2.07	2.04	2.07	1.99	2.06
(0.94)		(0.94)	(0.85)	(0.88)	(0.89)	(0.95)	(0.97)	(0.90)	(0.98)	(0.93)	(0.88)	(0.93)
Married 0.56		0.57	0.70	0.63	0.58	0.55	0.53	0.69	0.56	0.55	0.58	0.60
(0.50)		(0.50)	(0.46)	(0.48)	(0.49)	(0.50)	(0.50)	(0.46)	(0.50)	(0.50)	(0.49)	(0.49)
Single 0.68		0.64	0.67	0.67	0.64	0.70	0.72	0.68	0.75	0.66	0.63	0.68
(0.47)		(0.48)	(0.47)	(0.47)	(0.48)	(0.46)	(0.45)	(0.47)	(0.43)	(0.47)	(0.48)	(0.47)
Health Paid	0.81	0.76	0.66	0.55	0.75	0.83	0.82	0.60	0.61	0.75	0.68	0.72
(0.39)		(0.43)	(0.47)	(0.50)	(0.43)	(0.37)	(0.39)	(0.49)	(0.49)	(0.43)	(0.47)	(0.45)
Bachelor 0.54		0.40	0.57	0.39	0.50	0.53	0.54	0.47	0.53	0.42	0.36	0.49
(0.50)		(0.49)	(0.50)	(0.49)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.49)	(0.48)	(0.50)
House owner	0.40	0.38	0.50	0.53	0.43	0.45	0.46	0.53	0.41	0.38	0.41	0.45
(0.49)		(0.49)	(0.50)	(0.50)	(0.49)	(0.50)	(0.50)	(0.50)	(0.49)	(0.49)	(0.49)	(0.50)
House/aptment	0.39	0.37	0.47	0.35	0.41	0.45	0.45	0.50	0.41	0.37	0.39	0.42
(0.49)		(0.48)	(0.50)	(0.48)	(0.49)	(0.50)	(0.50)	(0.50)	(0.49)	(0.48)	(0.49)	(0.49)
Walls	0.98	0.95	0.92	0.93	0.97	0.89	0.97	0.92	0.94	0.96	0.96	0.95
(0.13)		(0.22)	(0.26)	(0.25)	(0.17)	(0.32)	(0.16)	(0.26)	(0.23)	(0.20)	(0.19)	(0.22)
Read and write	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
(0.07)		(0.08)	(0.07)	(0.11)	(0.09)	(0.08)	(0.08)	(0.11)	(0.08)	(0.09)	(0.11)	(0.09)
Highschool student	0.57	0.52	0.67	0.61	0.58	0.53	0.55	0.65	0.60	0.51	0.57	0.58
(0.50)		(0.50)	(0.47)	(0.49)	(0.49)	(0.50)	(0.50)	(0.48)	(0.49)	(0.50)	(0.50)	(0.49)
Telephone	0.59	0.57	0.31	0.33	0.49	0.54	0.78	0.26	0.32	0.53	0.26	0.48
(0.49)		(0.50)	(0.46)	(0.47)	(0.50)	(0.50)	(0.42)	(0.44)	(0.47)	(0.50)	(0.44)	(0.50)
Electricity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
(0.02)		(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.02)	(0.04)	(0.02)	(0.03)	(0.04)	(0.03)
Natural gas	0.87	0.82	0.93	0.52	0.90	0.77	0.65	0.91	0.09	0.77	0.87	0.77
(0.33)		(0.38)	(0.26)	(0.50)	(0.31)	(0.42)	(0.48)	(0.28)	(0.28)	(0.42)	(0.34)	(0.42)
Single mother	0.37	0.40	0.41	0.39	0.41	0.40	0.43	0.40	0.39	0.44	0.39	0.40
(0.48)		(0.49)	(0.49)	(0.49)	(0.49)	(0.49)	(0.50)	(0.49)	(0.49)	(0.50)	(0.49)	(0.49)
% Females Home	0.39	0.41	0.41	0.41	0.42	0.41	0.42	0.43	0.43	0.41	0.40	0.41
(0.49)		(0.49)	(0.49)	(0.49)	(0.49)	(0.49)	(0.49)	(0.49)	(0.49)	(0.49)	(0.49)	(0.49)
Log(Week working hours) 10.70		9.39	9.21	8.70	7.99	7.53	9.45	8.47	8.08	8.18	8.14	8.93
(3.94)		(4.00)	(3.06)	(3.60)	(3.72)	(3.75)	(4.05)	(2.71)	(3.26)	(3.75)	(3.47)	(3.70)
Log(Income)	13.95	12.44	9.51	11.21	11.73	11.44	13.24	12.53	11.66	12.05	11.52	12.15
(10.69)		(10.25)	(9.92)	(9.76)	(9.54)	(9.45)	(10.21)	(9.00)	(9.29)	(9.56)	(9.54)	(9.90)
Log(Mortage)	1.44	0.94	0.21	0.62	1.12	1.57	1.25	0.25	1.06	0.68	0.82	0.92
(5.40)		(4.25)	(1.95)	(3.40)	(4.51)	(5.19)	(4.93)	(2.18)	(4.35)	(3.58)	(3.87)	(4.19)
Log(Rent) 10.86		9.50	6.23	6.10	8.78	8.12	8.98	5.45	8.68	9.55	9.49	8.44
(10.69)		(10.10)	(9.10)	(8.96)	(9.43)	(9.23)	(10.18)	(8.44)	(9.16)	(9.53)	(9.40)	(9.73)
Log(Electricity)	5.11	5.12	5.64	5.27	4.76	4.78	5.06	5.49	4.80	4.82	4.95	5.11
(0.07)		(0.06)	(0.09)	(0.44)	(0.08)	(0.08)	(0.10)	(0.05)	(0.08)	(0.11)	(0.08)	(0.33)
Price variation	0.30	0.28	0.30	0.28	0.29	0.31	0.32	0.29	0.28	0.29	0.27	0.30
(0.34)		(0.40)	(0.35)	(0.42)	(0.34)	(0.36)	(0.30)	(0.36)	(0.34)	(0.31)	(0.33)	(0.35)
Estrata 1 0.11		0.21	0.37	0.25	0.13	0.09	0.12	0.59	0.21	0.15	0.20	0.22
(0.31)		(0.41)	(0.48)	(0.43)	(0.34)	(0.29)	(0.33)	(0.49)	(0.41)	(0.36)	(0.40)	(0.41)
Estrata 2 0.41		0.29	0.30	0.48	0.52	0.29	0.37	0.23	0.44	0.36	0.32	0.36
(0.49)		(0.46)	(0.46)	(0.50)	(0.50)	(0.45)	(0.48)	(0.42)	(0.50)	(0.48)	(0.47)	(0.48)
Estrata 3 0.35		0.32	0.21	0.17	0.25	0.43	0.34	0.10	0.24	0.29	0.37	0.28
(0.48)		(0.46)	(0.41)	(0.38)	(0.43)	(0.50)	(0.47)	(0.30)	(0.43)	(0.45)	(0.48)	(0.45)
Estrata 4 0.08		0.06	0.05	0.06	0.07	0.10	0.09	0.02	0.07	0.11	0.05	0.08
(0.27)		(0.24)	(0.22)	(0.25)	(0.25)	(0.30)	(0.28)	(0.15)	(0.26)	(0.31)	(0.22)	(0.27)

Metropolitan Area Bogotá	Calí	Cgena	Cucuta	Ibague	Mzalez	Mllín	Mtería	Pasto	Peira	Vcencio	Total
Estrata 5 0.02	0.05	0.02	0.01	0.01	0.03	0.05	0.02	0.02	0.05	0.02	0.03
(0.13)	(0.22)	(0.15)	(0.08)	(0.09)	(0.18)	(0.22)	(0.13)	(0.14)	(0.22)	(0.13)	(0.16)
Estrata 6 0.02	0.02	0.01	0.00	0.00	0.04	0.02	0.01	0.00	0.03	0.01	0.02
(0.14)	(0.13)	(0.12)	(0.01)	(0.05)	(0.20)	(0.15)	(0.09)	(0.01)	(0.17)	(0.07)	(0.13)

Source: own elaboration.

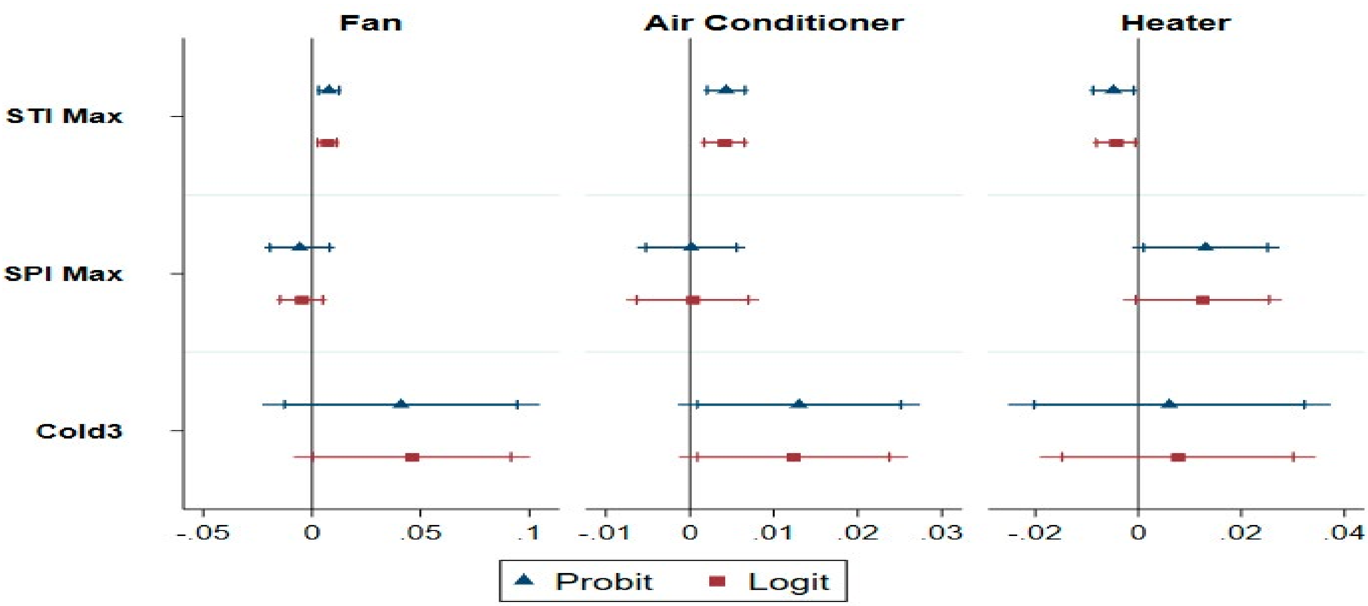


Figure 14. Estimates of the relationship between temperature and precipitation indexes (STI and SPI), and ownership of fans, air conditioning, or heaters in households in 11 major cities, 2009-2019
Source: own elaboration.