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Temperature, climate change, and household financial behaviour

Evidence from Viet Nam

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Abstract: We examine the impact of temperature shocks and climate change on household financial behaviour in Viet Nam. To do so, we first estimate the effect of temperature on household borrowing and savings using Vietnamese longitudinal data that matches satellite reanalysis temperature data with household information over the period 2008 to 2016. We find that an additional day with an average temperature of greater than 30°C, relative to the number of days in the 18–22°C range, is associated with a 6.3 per cent decrease in household savings and a 1.4 per cent increase in household borrowing. In the case of household savings, we find that the effects of temperature shocks are more pronounced on informal savings than formal savings. Further, total agricultural production and rice production are mechanisms through which temperature shocks influence household savings and borrowing. Specifically, by reducing the level of agricultural production, (hot) temperature shocks decrease household savings and increase household borrowing. Our estimates suggest that over the next century, under the conventional trajectory in which countervailing measures are not adopted to address climate change, climate change will be responsible for an additional 0.124 standard deviation decrease in household savings and a 0.102 standard deviation increase in household debt.

Key words: temperature, weather, climate change, savings, borrowing, Viet Nam

JEL classification: Q51, Q54, G02, D14

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1 Introduction

With evidence showing that the average temperature of the globe is increasing over time, weather shocks are becoming a common occurrence around the world, evidenced by droughts, heatwaves, bushfires, floods, tsunamis, cyclones, and snowstorms (Dell et al. 2014; Deschênes and Greenstone 2011; Meierrieks 2021). An established body of literature has, therefore, examined the impact of temperature shocks and climate change on a range of outcomes. In addition to the noted impact of weather shocks on loss of lives and property, various research has shown that weather shocks also have negative effects on physical health and can lead to heat stress and heat strokes, negatively affect the body's normal thermoregulation and sleep quality, and increase problems with the cardiovascular, nervous, respiratory, and digestive systems (Deschênes 2014; Deschênes and Moretti 2009; Ebi et al. 2004; Hajat et al. 2006; Meierrieks 2021; Morabito et al. 2005; Obradovich et al. 2017). Weather shocks and climate change have also been linked to poor mental and psychological wellbeing (see, e.g., Charlson et al. 2021; Keller et al. 2005; Li et al. 2020; Mullins and White 2019; Palinkas and Wong 2020).

What is the effect of temperature shocks and climate change on household financial behaviours? To explain variations in household savings and borrowing patterns, an established body of literature has examined myriad factors driven by different theoretical models. For household savings, this literature has focused on policy interventions and factors such as social norms, labour market outcomes, political shocks, homeownership, and insurance (see, e.g., Aaberge et al. 2017; Al-Awad and Elhiraika 2003; Ceritoğlu 2013; Chen et al. 2019; Cheung and Padieu 2015; Rodgers 2020; Tovar and Urrutia 2017; Zhu et al. 2012). For household borrowing, studies have examined the impact of factors such as macroeconomic conditions, house prices, mortgage rates, and inequality (see, e.g., Coibion et al. 2020; Martins and Villanueva 2006; Meng et al. 2013; Oikarinen 2009). However, we know very little about the relationship between temperature shocks, climate change, and household financial behaviours. We contribute to the literature by examining the impact of temperature shocks and climate on household savings and borrowing.

The relationship between weather and financial behaviours and outcomes has long been acknowledged (see, e.g., Hirshleifer and Shumway 2003; Krämer and Runde 1997; Saunders 1993). Studies in this area of research argue that weather patterns tend to be correlated with moods, personalities, and skills, which influence trading decisions and, subsequently, stock returns. As Hirshleifer and Shumway (2003: 1013) put it, 'if people are more optimistic when the sun shines, they may be more inclined to buy stocks on sunny days'. More recently, Awaworyi Churchill et al. (2023b) show theoretically that temperature shocks influence risk preference and time preference, which act as channels to explain the impact of temperature shocks on savings and net worth. Using longitudinal data from Australia, they find support for their theoretical predictions.

We use longitudinal data from the Viet Nam Access to Resources Household Survey (VARHS), covering the period 2008 to 2016, which we merge with ERA5 satellite reanalysis data taken from the European Centre for Medium-Range Weather Forecasts (ECMWF) using district identifiers. Viet Nam makes for an interesting case study given that it is among the five countries in the world that have been most affected by climate change and is well known for its highly heterogeneous climatic conditions (Dasgupta et al. 2009; Nguyen and Scrimgeour 2022). Since the 1970s, the average temperature for Viet Nam has increased by 0.26 ± 0.10°C per decade, approximately double the rate of global warming for the same period (Nguyen et al. 2014). Between 1958 and 2007, the annual average temperature increased by 0.5–1°C and thus, hot temperature shocks have been typical of Viet Nam for decades (Trinh et al. 2021). Thus, from a policy perspective, understanding the impact of temperature shocks and climate change in Viet Nam is important.

While a well-established literature focused on Viet Nam has examined the impact of temperature shocks and different dimensions of climate change on a wide range of outcomes, no studies have examined the effects on financial behaviours, including household savings and borrowing. The focus on household financial behaviours, in particular household saving, is important given that household savings rates are indicators of financial wellbeing and are increasingly considered targets for public policy interventions (Beverly and Sherraden 1999; Borsch-Supan 2003; Borsch-Supan and Brugiavini 2001; Borsch-Supan et al. 2001).

We argue that by influencing agricultural production, temperature shocks are likely to influence household savings and borrowing in Viet Nam. Agricultural production is arguably one of the sectors most affected by climate change given its direct reliance on climatic factors (Duc et al. 2019; Huong et al. 2019; Trinh 2018; Trinh et al. 2021). Temperature shocks can directly influence crop production by altering the soil and atmospheric environment in which crops grow. Indirectly, temperature shocks can affect agricultural production through changes in irrigation, evapotranspiration, and water availability (Trinh et al. 2021). According to the World Bank, climate change affects agricultural productivity through increased climate variability and changes in precipitation, temperature, carbon dioxide fertilization, and surface water run-off, with temperature shocks and precipitation expected to have the most direct influence on crop production (World Bank 2008). Precipitation and temperature determine the level of soil moisture and availability of fresh water, which are critical for crop growth (Calzadilla et al. 2013). Thus, temperate and precipitation extremes could reduce production yields by causing either flooding, which results in excessive inputs of production, or lower moisture than required in soil (Falloon and Betts 2010). Similarly, temperature shocks can influence crop development and water requirements by altering the characteristics of various crop growing seasons. For instance, (hot) temperature shocks could promote agricultural production in cool-climate marginal croplands by shortening frost periods. The opposite effect can be expected in relation to agricultural production in arid and semi-arid areas, where temperature shocks or extreme heat could shorten the typical crop cycle (Calzadilla et al. 2013). For a country like Viet Nam where agriculture contributes significantly to economic growth and the livelihood of most households (Trinh et al. 2021), agricultural production is expected to influence household savings and borrowing decisions. We argue that the effect of temperature shocks on agricultural production could be to worsen livelihood conditions for households, which could limit their ability to save and increase the need for borrowing (Irz et al. 2001; Warr and Suphannachart 2021).

Using data from the VARHS, we measure household savings using information on household savings balance held across formal and informal institutions, while household borrowing is measured as the value of household loans. In addition to total household savings, we consider informal and formal savings separately. We find that hot temperature shocks decrease household savings and increase household borrowing by reducing the level of agricultural production. Specifically, our results suggest that an additional day with an average temperature of greater than 30°C, relative to the number of days in the 18–22°C range, is associated with a 6.3 per cent decrease in household savings and a 1.4 per cent increase in household borrowing. In the case of household savings, we find that the effects of temperature shocks are more pronounced on informal savings than formal savings. Our estimates suggest that over the next century, under the conventional trajectory in which countervailing measures are not adopted to address climate change, climate change will be responsible for an additional 0.124 standard deviation decrease in household savings and a 0.102 standard deviation increase in household debt.

Our study makes multiple contributions to the literature. First, it relates to the literature that has examined the link between weather and stock returns (see, e.g., Chang et al. 2008; Hirshleifer and Shumway 2003; Lu and Chou 2012; Saunders 1993; Trombley 1997). However, we make a distinct contribution in that we focus not on stock returns but on household savings and borrowing. Our findings are based on longitudinal household data that track financial behaviours of the same households over time, as opposed to stock returns drawn from the stock exchange. In this regard, our study is closely related to Awaworyi Churchill et al. (2023b), which demonstrates, using longitudinal data from Australia, that by influencing risk preference and time preference, temperature shocks impact on savings and net worth. We differ from Awaworyi Churchill et al. (2023b) in several ways. In addition to the focus on a different country and different set of outcomes, we make a unique contribution by focusing on agricultural production as an important channel through which temperature shocks are likely to influence household savings and borrowing. Our focus on agricultural production has at least two motivations. First, as noted earlier, the agricultural sector is considered one of the most vulnerable to temperature shocks and climate change (Carter et al. 2018; Smit and Cai 1996). Second, the agricultural sector is a major contributor to the Vietnamese economy, including being the largest employment sector in the country (Appau et al. 2021; Giang et al. 2019). Accordingly, agricultural productivity is an important mediator to consider when examining the impact of temperature shocks and climate change in Viet Nam. Our study therefore relates to those that examine the relationship between extreme weather events, climate change, and agricultural production (see, e.g., Duc et al. 2019; Huong et al. 2019; Trinh 2018; Trinh et al. 2021).

2 Data and variables

We use panel data from the VARHS, an initiative facilitated by UNU-WIDER (2017) in partnership with various Vietnamese institutions. The overarching objective of the VARHS—biennially conducted in a dozen provinces of Viet Nam, namely Ha Tay, Phu Tho, Lao Cai, Dien Bien, Lai Chau, Nghe An, Quang Nam, Khanh Hoa, Dak Lak, Dak Nong, Lam Dong, and Long An—is to garner an in-depth understanding of the socioeconomic circumstances of rural households in Viet Nam. The VARHS aims to yield a representative sample of these rural households, offering a thorough examination of pertinent demographic, economic, and social facets of rural life. These include, but are not limited to, characteristics specific to farms and farmers, resource allotment, agricultural production and consumption, economic endeavours, welfare indicators, savings, and borrowing patterns. Our analysis focuses on the five waves of VARHS from 2008 to 2016, comprising a sample of 2,920 households.

The temperature data employed are derived from ERA5 satellite reanalysis provided by the ECMWF (2018). The ERA5 system amalgamates information from a variety of sources—including ground stations, weather balloons, and satellites—with a climate model. This provides hourly estimates of multiple climate-related variables, offering a global grid spacing of approximately 31 km, with data extending back to 1979. For the purposes of this study, we collect daily air temperature data and apply them to the district level in Viet Nam. The granular climate data allow us to draw more precise correlations between temperature fluctuations and household financial behaviours, providing a more robust analysis of the impact of climatic shocks on savings and borrowing patterns in rural Viet Nam.

2.1 Household financial behaviours

We focus on two indicators of household financial behaviour, namely household savings and household borrowing. Given that the VARHS does not incorporate total expenditure data, a conventional measure of savings—calculated as income minus expenditure—is absent. However, an alternate credible measure of savings is derived from households' self-reported savings data. Households are questioned about their savings balance at the time of the interview, the balance a year prior, and the amount saved over the preceding year. The questionnaire also delves into the specifics of the savings, categorizing them as formal (such as postal savings or savings in state-owned or commercial banks, private banks, and credit organizations) and informal (such as cash, gold, or jewellery kept at home, participation in rotating savings and credit associations/ROSCAs, or money borrowed from private lenders). Details on borrowing are obtained by asking about the value of the three most substantial loans.

2.2 Temperature shocks

We measure temperature shocks using the binning approach (Awaworyi Churchill et al. 2022; Trinh et al. 2022). This involves dividing the daily average temperature into one of seven temperature bins: bin 1 is below 10°C, bin 2 is 10–11°C, bin 3 is 14–18°C, bin 4 is 18–22°C, bin 5 is 22–26°C, bin 6 is 26–30°C, and bin 7 is 30°C. The bin excluded as the reference category typically depends on the climate of the geographic location under consideration (Awaworyi Churchill et al. 2022; Karlsson and Ziebarth 2018; White 2017; Yu et al. 2019), with the most comfortable temperature range often excluded as the reference employed category (Yu et al. 2019). In the case of Viet Nam, we exclude bin 4 (18–22°C) as the reference category. In robustness checks, however, we also consider alternative bin classification to examine the robustness of our results.

In additional checks, we also use alternative measures of temperature shocks defined as the difference between observed temperature at time t and the long-run mean for each district d, divided by the long-run standard deviation for the district (see, e.g., Awaworyi Churchill et al. 2023a; Graff Zivin et al. 2020; Hirvonen 2016; Letta et al. 2018). This indicator captures the deviation in actual temperature from the historical mean for district d at time t, standardized by the standard deviation. This measure therefore reflects both cold and hot temperature shocks. We further consider hot and cold temperature shocks separately. In this case, we define extreme hot shocks as a temperature of greater than one standard deviation above the mean and extreme cold shocks as a temperature of less than negative one standard deviation below the mean (Awaworyi Churchill et al. 2022).

2.3 Mediators

We focus on agricultural production as a potential mechanism that explains the relationship between temperature shocks and household financial behaviour. In addition to total agricultural production we use an indicator of rice production, given that rice is Viet Nam's largest agricultural product and is critical for food security (Appau et al. 2021; Kompas et al. 2012). Importantly, Viet Nam is the world's second-largest exporter of rice, with rice production contributing significantly to economic growth, foreign exchange, and rural employment (Trinh et al. 2021). Agricultural productivity is measured as total household agricultural production per unit of agricultural land.

2.4 Covariates

While the existing temperature shocks literature emphasizes the importance of not 'over-controlling' by including control variables that are likely to be influenced by temperature shocks, it is relevant to control for a set of covariates that are likely to be correlated with financial behaviours. Specifically, we control for various characteristics of the household head, including age, education level, health status, marital status, and household size. Consistent with the literature that has examined the impact of temperature shocks, we also control for rainfall at the district level.

Table A1 presents descriptions and summary statistics for the variables used in our analysis.

3 Methodology

We estimate the following empirical specification:

$$FB_{idt} = \gamma_0 + \sum_{j=1}^{7} \beta_j T_{dt} + \delta_d R_{dt} + \varphi_i + \mu_r + \delta_t + \varepsilon_{it} \quad (1)$$

where FB_{it} is the indicator of household financial behaviour for household i living in district d in year t. *FB* is the measure of either household savings or household borrowing. T_{djt} is our indicator of temperature shock for district d in the period t and represents the number of days that fall into each of the seven average temperature bins, excluding bin 4, which is the reference category. R_{dt} measures the amount of rainfall for district d in period t. We control for household fixed effects (φ_i), province fixed effects (μ_r), and time fixed effects (δ_t) to absorb the potential effects of unobservable household, time-invariant province, and time characteristics. ε_{it} denotes the error term.

We cluster standard errors at the district level. Controlling household and time fixed effects allows for the identification of the impact of temperature shocks from location-specific deviations in temperature, while controlling for annual shocks common to all districts.

4 Results

Table 1 presents results for the effects of temperature on household financial behaviour. Columns 1 and 2 report results for effects on household savings, while Columns 3 and 4 report results for household borrowing. In Columns 1 and 3 we report results from parsimonious models that do not control for household characteristics, while in Columns 2 and 4 we present results from a more complete model that includes all covariates. We find that temperature shocks are negatively associated with household savings but positively associated with household borrowing. Focusing on the most complete models in Columns 2 and 4, the number of days when daily average temperatures are below 10°C and the number of days in the 10–14°C and 14–18°C ranges have no significant effect on household savings and borrowing. However, the number of days in the 26–30°C relative to the number of days in the 18–22°C range has a negative effect on household savings and borrowing. Here, an additional day with an average temperature of 26–30°C is associated with a 3.3 per cent decrease in household savings and a 0.9 per cent decrease in household borrowing. Similarly, an increase in the number of days of extreme heat (greater than 30°C) is associated with a decline in household savings and an increase in household borrowing, with effect sizes relatively larger than in the previous bin. Here, an additional day with an average temperature of greater than 30°C is associated with a 6.3 per cent decrease in household savings and a 1.4 per cent increase in household borrowing. These findings, viewed together, suggest that temperature shocks (in this case defined as extreme heat) are associated with a decline in household savings and an increase in house borrowing.

Table 1: Impact of temperature shocks on savings and borrowing—main results

Dependent variable		Saving		Borrowing
	(1)	(2)	(3)	(4)
Reference: [18°C, 22°C)				
Days below 10°C	0.010	0.018	0.001	−0.000
	(0.020)	(0.020)	(0.011)	(0.012)
[10°C, 14°C)	0.003	0.005	−0.000	−0.000
	(0.007)	(0.007)	(0.004)	(0.004)
[14°C, 18°C)	−0.000	0.003	0.000	0.000
	(0.005)	(0.005)	(0.003)	(0.003)
[22°C, 26°C)	−0.002	−0.004	0.006***	0.006***
	(0.004)	(0.005)	(0.002)	(0.002)
[26°C, 30°C)	−0.032***	−0.033***	0.009***	0.009***
	(0.006)	(0.006)	(0.004)	(0.003)
Days above 30°C	−0.064***	−0.063***	0.013**	0.014***
	(0.009)	(0.009)	(0.006)	(0.005)
Other controls	No	Yes	No	Yes
Household and year fixed effects	Yes	Yes	Yes	Yes
Observations	11,408	11,408	2,881	2,881

Note: robust standard errors in parentheses; standard errors clustered at household level; saving and borrowing measured in thousand dong (VND) (in log); control variables include rainfall, household head characteristics (gender, age, education), and household size; results with control variables presented in Appendix Table A2; *** p<0.01, ** p<0.05, * p<0.1.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

In Table 2, we focus on the distinction between informal and formal savings. We find that the negative effects of temperature shocks are more pronounced in the case of informal savings than formal savings. Specifically, while we find no effect in the case of formal savings, an additional day with an average temperature of greater than 30°C is associated with a 6.2 per cent decrease in informal savings. In the case of days in the 26–30°C range, we find that the effect is relatively stronger for informal savings than for formal savings. Here, an additional day with an average temperature of 26–30°C is associated with a 1.4 per cent decrease in formal savings and a 2.8 per cent decrease in informal savings. Given that informal finance systems are more prevalent in low-income settings, including Viet Nam (Barslund and Tarp 2008; Carpenter and Jensen 2002; Khoi et al. 2013), our findings suggest that temperature shocks tend to diminish reliance on existing informal networks, which are critical for informal savings.

Table 2: Formal saving vs informal saving

	Formal	Informal
	(1)	(2)
Reference: [18°C, 22°C)		
Days below 10°C	0.005	0.008
	(0.004)	(0.021)
[10°C, 14°C)	−0.008	0.010
	(0.009)	(0.007)
[14°C, 18°C)	−0.016***	0.009*
	(0.006)	(0.005)
[22°C, 26°C)	−0.006*	0.003
	(0.004)	(0.005)
[26°C, 30°C)	−0.014**	−0.028***
	(0.006)	(0.006)
Days above 30°C	−0.008	−0.062***
	(0.008)	(0.009)
Other controls	Yes	Yes
Household and year fixed effects	Yes	Yes
Observations	11,408	11,408

Note: robust standard errors in parentheses; standard errors clustered at household level; saving measured in thousand VND (in log); control variables include rainfall, household head characteristics (gender, age, education), and household size; *** p<0.01, ** p<0.05, * p<0.1.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

In Table 3, we examine the robustness of our results to alternative measures of temperature shocks. Our main results in Table 1 are based on temperature shocks measured using the temperature binning approach. In Panel A of Table 3, we examine the robustness of our results to an alternative measure of temperature shocks, defined as the deviation of actual temperature from the historical mean standardized by the standard deviation. We calculate this as the difference between observed temperature and the long-run average for each district, divided by the long-run standard deviation for the district. In Panels B and C of Table 3, we use measures of temperature shocks that consider extreme hot and cold temperatures. In Panel B, we define extreme hot temperature as temperature deviation of greater than one standard deviation, while in Panel BC we define extreme cold temperature as temperature deviation of less than negative one standard deviation. From Panel A, we find that our findings are robust to the alternative measure of temperature shocks. Specifically, we find that temperature shocks are associated with a decrease in savings but an increase in household borrowing. The results from Panels B and C suggest that the findings from Panel A are driven largely by extreme hot shocks. Specifically, from Panel B, our result show that, consistent with our main results, extreme hot temperature is associated with a decrease in savings and an increase in household borrowing. However, in Panel C, while we observe the opposite effect for extreme cold temperature, the estimates are statistically insignificant.

Table 3: Alternative measures of temperature shock

	Saving	Borrowing
	(1)	(2)
Panel A: Temperature deviation from the mean (absolute value)		
Temperature deviation	−0.370***	0.303***
	(0.118)	(0.021)
Panel B: Extreme hot temperature (deviation > 1sd)		
Hot temperature	−2.298***	0.481***
	(0.078)	(0.040)
Panel C: Extreme cold temperature (deviation < −1sd)		
Cold temperature	0.417	−0.178
	(0.313)	(0.143)
Other controls	Yes	Yes
Household and year fixed effects	Yes	Yes
Observations	11,408	2,881

Note: robust standard errors in parentheses; standard errors clustered at household level; saving and borrowing measured in thousand VND (in log); control variables include rainfall, household head characteristics (gender, age, education), and household size; *** p<0.01, ** p<0.05, * p<0.1.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

Our main results examine the impact of contemporary temperature shocks (i.e., shocks in time t) on household savings and borrowing. In an additional check, we estimate a distributed lag model that captures the cumulative effect of temperature on household savings and borrowing. We do this by imposing a lag structure on the temperature bins, and thus, in addition to the contemporaneous effect of temperature, we also include the lag of each temperature bin for the last period (Agarwal et al. 2021; Chen and Yang 2019). The results, which are reported in Table 4, show that temperature shocks are negatively associated with household savings. Focusing on the cumulative effects, we find that each temperature bin relative to the reference category 18–22°C has a negative effect on household savings. The most pronounced effect is for temperatures of greater than 30°C. Specifically, an additional day with an average temperature of greater than 30°C is associated with an 8.1 per cent decrease in household savings. For household borrowing, the effects are significant only for bins with temperatures within the ranges of 22–26°C and 26–30°C. Here, an additional day with an average temperature 22–26°C or 26–30°C, relative to the reference category, is associated with a 0.8 per cent and a 1.1 per cent increase in household borrowing, respectively.

Table 4: Cumulative effects of temperature shocks

	Saving	Borrowing
	(1)	(2)
Temperature at time (t)—reference: [18°C, 22°C)		
Days below 10°C	−0.007	0.012
	(0.029)	(0.013)
[10°C, 14°C)	−0.005	−0.000
	(0.007)	(0.004)
[14°C, 18°C)	−0.012**	0.004
	(0.005)	(0.003)
[22°C, 26°C)	−0.016***	0.005**
	(0.004)	(0.002)
[26°C, 30°C)	−0.022***	0.005*
	(0.006)	(0.003)
Days above 30°C	−0.055***	0.004
	(0.010)	(0.004)
Temperature at time (t−1)—reference: [18°C, 22°C)		
Days below 10°C	−0.071***	−0.005
	(0.015)	(0.005)
[10°C, 14°C)	−0.015***	−0.005
	(0.006)	(0.003)
[14°C, 18°C)	−0.033***	0.003
	(0.007)	(0.002)
[22°C, 26°C)	−0.022***	0.006**
	(0.005)	(0.003)
[26°C, 30°C)	−0.014**	0.007
	(0.006)	(0.005)
Days above 30°C	−0.026***	−0.018
	(0.007)	(0.013)
Cumulative effects—reference: [18°C, 22°C)		
Days below 10°C	−0.077***	−0.006
	(0.022)	(0.023)
[10°C, 14°C)	−0.020***	−0.006
	(0.009)	(0.008)
[14°C, 18°C)	−0.045***	0.010
	(0.008)	(0.006)
[22°C, 26°C)	−0.038***	0.008**
	(0.008)	(0.003)
[26°C, 30°C)	−0.036***	0.011**
	(0.009)	(0.005)
Days above 30°C	−0.081***	0.011

	(0.014)	(0.007)
Other controls	Yes	Yes
Household and year fixed effects	Yes	Yes
Observations	11,408	2,881

Note: robust standard errors in parentheses; standard errors clustered at household level; saving and borrowing measured in thousand VND (in log); control variables include rainfall, household head characteristics (gender, age, education), and household size; *** p<0.01, ** p<0.05, * p<0.1.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

4.1 The mediating effects of agricultural productivity

We perform a mediation analysis consistent with the literature (Alesina and Zhuravskaya 2011; Awaworyi Churchill et al. 2019). We empirically examine the role of total agricultural production and rice production as channels through which temperature shocks influence household savings and borrowing. In the first stage, for total production and rice production to qualify as mediators, they need to be significantly correlated with temperature shocks. Second, they should also be significantly correlated with household savings and borrowing, and their inclusion as additional covariate in the regression linking temperature shocks to household savings and borrowing should either render the coefficient of temperature shocks statistically insignificant (i.e., full mediation) or decrease its magnitude (i.e., partial mediation).

We report the results for the effects of temperature shocks on total and rice production in Table 5, Columns 1 and 2, respectively. From Columns 1 and 2, we find that except for bin 5, the coefficients on all temperature bins are statistically insignificant. Focusing on extreme heat, which we have found to be the most pronounced influence and to be driving our results, we find that an increase in the number of days on which the average temperature is greater than 30°C, relative to the comfortable temperature range, is associated with a decline in both total agricultural production and rice production. Thus, extreme heat is associated with a decline in agricultural productivity. We find similar results for extreme cold temperature.

Table 5: The impact of temperature shocks on mediators

	Total production	Rice production
	(1)	(2)
Reference: [18°C, 22°C)		
Days below 10°C	−0.015**	−0.012**
	(0.006)	(0.006)
[10°C, 14°C)	−0.007**	−0.006**
	(0.003)	(0.003)
[14°C, 18°C)	−0.005**	−0.005**
	(0.002)	(0.002)
[22°C, 26°C)	−0.002	−0.002
	(0.002)	(0.002)
[26°C, 30°C)	−0.006**	−0.007**
	(0.003)	(0.003)
Days above 30°C	−0.014***	−0.011***
	(0.004)	(0.004)
Other controls	Yes	Yes
Household and year fixed effects	Yes	Yes
Observations	10,409	10,409

Note: robust standard errors in parentheses; standard errors clustered at household level; total production and rice production measured in log; control variables include rainfall, household head characteristics (gender, age, education), and household size; *** p<0.01, ** p<0.05, * p<0.1.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

In Table 6, we include total agricultural production and rice production as additional covariates in alternative models for household savings and borrowing. In Columns 1 and 4, we report the baseline effect of temperature shocks on household savings and borrowing without total production and rice production, for comparison. In Columns 2 and 3 we include total production and rice production, respectively, as additional covariates in the household saving model, while in Columns 5 and 6 we include them as additional covariates in the household borrowing model. We find that total production and rice production are associated with an increase in household savings and a decrease in household borrowing. We find evidence of partial mediation, as the inclusion of total production and rice production as additional covariates reduces the magnitude of the coefficient on our focal temperature shock variable, extreme hot temperature (i.e., greater than 30°C). Overall, these results suggest that total agricultural production and rice production are mechanisms through which temperature shocks influence household savings and borrowing. Specifically, by reducing the level of total agricultural production and rice production, (hot) temperature shocks decrease household savings and increase household borrowing.

Table 6: The impact of mediators on savings and borrowing

			Saving			Borrowing
	(1)	(2)	(3)	(4)	(5)	(6)
Total production		0.604***			−0.114***	
		(0.068)			(0.027)	
Rice production			0.040***			−0.025*
			(0.013)			(0.013)
Reference: [18°C, 22°C)						
Days below 10°C	0.020	0.030	0.004	0.016	0.020**	0.016*
	(0.022)	(0.022)	(0.012)	(0.010)	(0.010)	(0.010)
[10°C, 14°C)	−0.015**	−0.017***	0.011**	−0.002	−0.003	−0.002
	(0.006)	(0.006)	(0.005)	(0.002)	(0.002)	(0.002)
[14°C, 18°C)	0.004	0.005	-0.007**	0.013***	0.013***	0.013***
	(0.006)	(0.006)	(0.003)	(0.003)	(0.003)	(0.003)
[22°C, 26°C)	−0.003	−0.002	0.002	0.011***	0.010***	0.011***
	(0.005)	(0.005)	(0.002)	(0.001)	(0.001)	(0.001)
[26°C, 30°C)	−0.033***	−0.033***	0.004***	0.021***	0.019***	0.020***
	(0.006)	(0.006)	(0.001)	(0.002)	(0.002)	(0.002)
Days above 30°C	−0.075***	−0.061***	−0.005*	0.030***	0.028***	0.021***
	(0.010)	(0.010)	(0.003)	(0.002)	(0.002)	(0.002)
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Household and year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,402	9,402	9,402	2,881	2,881	2,881

Note: robust standard errors in parentheses; standard errors clustered at household level; saving and borrowing measured in thousand VND (in log); control variables include rainfall, household head characteristics (gender, age, education), and household size; *** p<0.01, ** p<0.05, * p<0.1.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

4.2 Climate change, household savings, and household borrowing

We simulate changes due to climate change in future household savings and borrowing in Viet Nam. To do this, we combine estimates from Panel A of Table 3 with data on simulated climate conditions at the district level for 2021 to 2099. Simulated climate change data are obtained from the NASA Earth Exchange (NEX) Global Daily Downscaled Projections (GDDP) and the CMIP6 Project. The NEX-GDDP-CMIP6 data use nine global climate models (GCMs) to model average temperature projects over multiple horizons—namely, short term (2021–40), medium term (2041–60), and long term (2061–99).[1] We focus on Representative Concentration Pathway 4.5 (RCP4.5) and Representative Concentration Pathway 8.5 (RCP8.5), which are two divergent emission pathways that encompass contrasting outcomes based on the adoption of renewable energy.[2] Considering that the effects of climate change are susceptible to variations depending on the specific GCM used (Burke et al. 2015), to ensure robustness we use future projections from eight of the nine GCMs at 2.5-minutes spatial resolution.[3]

Following Burke et al. (2009), we generate monthly mean temperature projections in three steps. First, we construct monthly mean temperature and probability distribution functions using daily average temperatures for the period 2001 to 2020. Second, we estimate projected changes in monthly mean temperatures as the difference between the projected monthly mean temperatures and the historical mean temperatures. Third, we work with the assumption that the distribution of the projected daily mean temperatures closely mirrors that of historical temperature and, accordingly, we construct the distribution of mean temperatures in the short, medium, and long term for the two emission pathways (RCP4.5 and RCP8.5).

Table 7 presents estimates of the projected changes for temperature and household savings for each of the eight GCMs for both emission pathways in the short, medium, and long term, while Table 8 presents similar results for the effects of temperature changes on household borrowing. Under the RCP4.5 pathway the average change in temperature peaks at 1.472 standard deviations in the long term, while under the RCP8.5 pathway, in which countervailing measures are not adopted to address climate change, the average change in temperature in the long term peaks at 1.807 standard deviations.

In Table 7, using the maximum temperature projection across each of the eight GCMs under the RCP4.5 pathway, mean temperature increases are associated with up to a 0.468, 0.504, and 0.545 standard deviation decrease in household savings in the short, medium, and long term, respectively. Under the RCP8.5 pathway, mean temperature increases are associated with up to a 0.488, 0.556, and 0.669 standard deviation decrease in household savings in the short, medium, and long term, respectively. Thus, without implementing any mitigating measures to tackle climate change, between 2021 and 2099 we can expect up to an additional 0.124 standard deviation

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[1] The nine global climate models are BNU-ESM, CCSM4, CNRM-CM5, CanESM2, GFDL-ESM4, IPSL-CM5A-MR, MIROC-ESM, MIROC-ESM-CHEM, and MRI-CGCM3. Details are available at: https://www.nasa.gov/nex/gddp.

[2] RCPs capture future trends in climate change under alternative scenarios of human activities. RCP8.5 tracks emissions under the 'business as usual' scenario in which greenhouse gas emissions follow current or ongoing trends, while RCP4.5 considers an alternative scenario with less reliance on coal-fired power and increased reliance on renewable energy.

[3] GFDL-ESM4 is excluded because future projections are not available for this under the RCP8.5 pathway.

decrease in household savings as a result of climate change, compared with the more ideal scenario under the RCP4.5 pathway.[4]

Table 7: Simulated effect of temperature change on saving, 2021–99

	RCP4.5					
	Short term (2021–40)		Medium term (2041–60)		Long term (2061–99)	
GCM Models	∆Temperature	∆Saving	∆Temperature	∆Saving	∆Temperature	∆Saving
BNU_ESM	1.246	−0.461	1.297	−0.480	1.400	−0.518
CCSM4	1.266	−0.468	1.314	−0.486	1.384	−0.512
CNRM_CM5	1.180	−0.437	1.245	−0.461	1.326	−0.491
CanESM2	1.261	−0.467	1.356	−0.502	1.448	−0.536
IPSL_CM5A_MR	1.279	−0.473	1.361	−0.504	1.472	−0.545
MIROC_ESM	1.286	−0.476	1.313	−0.486	1.441	−0.533
MIROC_ESM_CHEM	1.257	−0.465	1.327	−0.491	1.447	−0.535
MRI_CGCM3	1.142	−0.423	1.181	−0.437	1.269	−0.470
	RCP8.5					
	Short term (2021–40)		Medium term (2041–60)		Long term (2061–99)	
GCM Models	∆Temperature	∆Saving	∆Temperature	∆Saving	∆Temperature	∆Saving
BNU_ESM	1.246	−0.461	1.297	−0.480	1.400	−0.518
CCSM4	1.264	−0.468	1.396	−0.517	1.620	−0.599
CNRM_CM5	1.189	−0.440	1.352	−0.500	1.554	−0.575
CanESM2	1.318	−0.488	1.503	−0.556	1.793	−0.663
IPSL_CM5A_MR	1.296	−0.480	1.454	−0.538	1.807	−0.669
MIROC_ESM	1.260	−0.466	1.346	−0.498	1.643	−0.608
MIROC_ESM_CHEM	1.233	−0.456	1.351	−0.500	1.668	−0.617
MRI_CGCM3	1.161	−0.430	1.275	−0.472	1.489	−0.551

Note: change in temperature and net worth measured in standard deviation; data on simulated weather conditions at postcode level are from the NEX-GDDP; the projection is estimated using the coefficient on temperature deviation of −0.370 reported in Column 1, Table 3.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

In Table 8, under the RCP4.5 pathway, mean temperature increases are associated with up to a 0.390, 0.412, and 0.446 standard deviation increase in household borrowing in the short, medium, and long term, respectively. Under the RCP8.5 pathway, mean temperature increases are associated with up to a 0.399, 0.455, and 0.548 standard deviation increase in household borrowing in the short, medium, and long term, respectively. Thus, without any mitigating measures to deal with climate change, there would be an additional 0.102 standard deviation increase in household

[4] Under the RCP4.5 scenario in which the government actively promotes renewables, we can expect at most a 0.504 standard deviation decrease in household savings, while under the RCP8.5 scenario, in which current trends are maintained without interventions, we can expect at most a 0.669 standard deviation decrease household savings. The difference in outcomes under the two pathways is 0.124 (i.e., 0.669−0.545) standard deviations.

borrowing as a result of climate change compared with the more ideal scenario under the RCP4.5 pathway.

Table 8: Simulated effect of temperature on borrowing, 2021–99

	RCP4.5					
	Short term (2021–40)		Medium term (2041–60)		Long term (2061–99)	
GCM Models	∆Temperature	∆Borrowing	∆Temperature	∆Borrowing	∆Temperature	∆Borrowing
BNU_ESM	1.246	0.378	1.297	0.393	1.400	0.424
CCSM4	1.266	0.384	1.314	0.398	1.384	0.419
CNRM_CM5	1.18	0.358	1.245	0.377	1.326	0.402
CanESM2	1.261	0.382	1.356	0.411	1.448	0.439
IPSL_CM5A_MR	1.279	0.388	1.361	0.412	1.472	0.446
MIROC_ESM	1.286	0.390	1.313	0.398	1.441	0.437
MIROC_ESM_CHEM	1.257	0.381	1.327	0.402	1.447	0.438
MRI_CGCM3	1.142	0.346	1.181	0.358	1.269	0.385
	RCP8.5					
	Short term (2021–40)		Medium term (2041–60)		Long term (2061–99)	
GCM Models	∆Temperature	∆Borrowing	∆Temperature	∆Borrowing	∆Temperature	∆Borrowing
BNU_ESM	1.246	0.378	1.297	0.393	1.400	0.424
CCSM4	1.264	0.383	1.396	0.423	1.620	0.491
CNRM_CM5	1.189	0.360	1.352	0.410	1.554	0.471
CanESM2	1.318	0.399	1.503	0.455	1.793	0.543
IPSL_CM5A_MR	1.296	0.393	1.454	0.441	1.807	0.548
MIROC_ESM	1.260	0.382	1.346	0.408	1.643	0.498
MIROC_ESM_CHEM	1.233	0.374	1.351	0.409	1.668	0.505
MRI_CGCM3	1.161	0.352	1.275	0.386	1.489	0.451

Note: change in temperature and savings measured in standard deviation; data on simulated weather conditions at the postcode level are from the NEX-GDDP; the projection is estimated using the coefficient on temperature deviation of 0.303 reported in Column 2, Table 3.

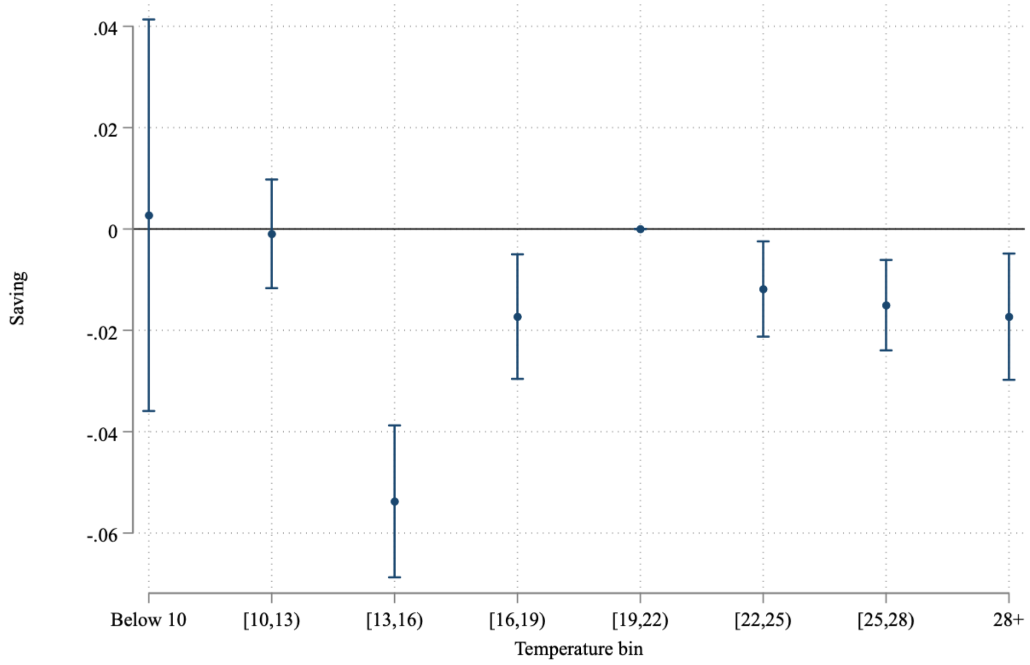
Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

4.3 Additional checks

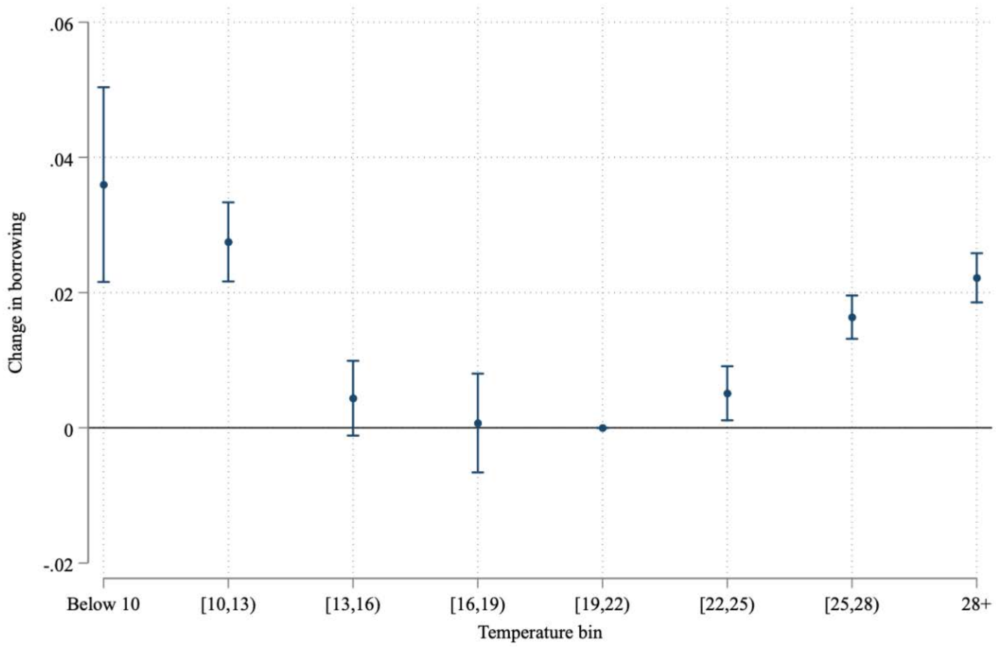
We conduct a series of checks to examine the robustness of our results. In Figure 1, we examine the robustness of our results to alternative temperature bins, which involve different reference groups. We consider temperatures below 10°C as bin 1, 10–13°C as bin 2, 13–16°C as bin 3, 16–19°C as bin 4, 19–22°C as bin 5, 22–25°C as bin 6, 25–28°C as bin 7, and above 28°C as bin 8. Results for the alternative bins are presented in Panels A and B of Figure 1 for household savings and borrowing, respectively. Leaving out bin 5 as the reference category, we find that our results remain robust.

Figure 1: Alternative temperature bins

Panel A: Saving



Panel B: Borrowing



Note: the figure presents the cumulative effects of temperature bins in which the outcome variables are saving (Panel A) and borrowing (Panel B); each estimate comes from a separate regression of outcomes on temperature bins and other control variables, and household/year fixed effects; robust standard errors clustered at the household level.

Source: authors' illustrations based on ECMWF (2018) and UNU-WIDER (2017).

Next, we examine the robustness of our results to the use of spatial regressions. Our main specification allows for arbitrary serial correlation of errors across household from each district. This approach works with the assumption that there are no correlations between the error structure in different districts, although they may be proximate in space. We relax this assumption and control for spatial autocorrelation in Table A3. We use the Conley standard errors (Conley 1999) and the procedure from Colella et al. (2019), and we find that our results remain robust.

In a final check, we examine the robustness of our results to attrition, which is a common concern when using household longitudinal survey data. In Table A4, we use weighted regressions to address attrition bias, using the inverse probability weighting approach (Fitzgerald et al. 1998). Again, we find that our results remain robust.

5 Conclusion

Previous studies in behavioural finance and related disciplines show that weather has an impact on stock returns. By focusing on one or more stock exchanges, this literature tends to explain the relationship between weather and stock market returns via the mood effects of weather (Goetzmann et al. 2015; Saunders 1993). The idea of mood as a channel through which weather influences stock returns is based on the premise that people who are in a good mood tend to be more optimistic and this translates into the decisions they make. Thus, by showing that psychological responses to temperature variations or weather changes affect investor behaviour, this literature challenges the traditional finance theory of efficient markets, which suggests that stock markets are rational and tend to reflect economic fundamentals. This literature, however, sheds light on only one aspect of the relationship between weather and financial decision-making. We build on the literature by examining the impact of temperature shocks on household financial behaviour.

Using longitudinal data from the VARHS, we find that an additional day with an average temperature of greater than 30°C, relative to the number of days in the 18–22°C range, is associated with a 6.3 per cent decrease in household savings and a 1.4 per cent increase in household borrowing. We also find that the effects of temperature shocks are more pronounced on informal savings than formal savings. Our findings from the mechanism analysis demonstrate that hot temperature shocks decrease household savings and increase household borrowing by reducing the level of agricultural production (both total agricultural production and rice production). Drawing on simulated future climate change data, our estimates suggest that over the next century, under the conventional trajectory in which countervailing measures are not adopted to address climate change, climate change will be responsible for an additional 0.124 standard deviation decrease in household savings and a 0.102 standard deviation increase in household debt.

By focusing on the impact of temperature shocks on savings, our study presents insights that help to inform an understanding of the mechanisms underlying the relationship between temperature shocks and growth, given the role of savings in economic growth. Given the importance of savings, our findings contribute to a growing body of literature that highlights the detrimental effects of temperature shocks and climate change. While several policies have emerged over the years to address climate change and curb its implications, in the case of Viet Nam the findings from our mediation analysis suggest the need for policies that allow households to adapt to challenges from climate change and promote agricultural production. Given Viet Nam's reliance on the agricultural sector, our findings suggest that targeted interventions that help with adaptation can help in enhancing productivity in the agricultural sector. Such policies would also have significant implications for financial behaviours that promote household savings and reduce borrowing.

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Appendix

Table A1: Variable descriptions and summary statistics

Variables	Description	Mean	Standard deviation
Saving behaviours			
Saving	Total saving (in log)	7.939	3.942
Borrowing	Total loan (in log)	10.106	1.386
Temperature variables			
Days below 10°C	Number of days temperature below 10°C	1.613	3.353
[10°C, 14°C)	Number of days temperature from 10˚C to 14°C	12.108	13.506
[14°C, 18°C)	Number of days temperature from 14°C to 18°C	29.574	24.765
[18°C, 22°C)	Number of days temperature from 18°C to 22°C	52.682	32.088
[22°C, 26°C)	Number of days temperature from 22°C to 26°C	111.090	74.116
[26°C, 30°C)	Number of days temperature from 26°C to 30°C	135.323	85.320
Days above 30°C	Number of days temperature from 30°C	23.217	22.554
Temperature deviation	Temperature deviation divided by standard deviation (absolute value)	−0.191	0.885
Rainfall			
Rainfall	Average daily rainfall (metres)	0.006	0.001
Other variables			
Age	Age of household head	52.606	14.192
Gender	Gender of household head (female = 1)	0.222	0.416
Education	Years of education	7.063	3.669
Health	Having illness = 1	0.179	0.383
Marital status	Married = 1	0.803	0.398
Household size	Number of members in household	4.202	0.536

Note: monetary units are adjusted for inflation.

Source: authors’ construction based on ECMWF (2018) and UNU-WIDER (2017).

Table A2: Controlling for other covariates

Dependent variable		Saving		Borrowing
	(1)	(2)	(3)	(4)
Reference: [18°C, 22°C)				
Days below 10°C	0.010	0.018	0.001	−0.000
	(0.020)	(0.020)	(0.011)	(0.012)
[10°C, 14°C)	0.003	0.005	−0.000	−0.000
	(0.007)	(0.007)	(0.004)	(0.004)
[14°C, 18°C)	−0.000	0.003	0.000	0.000
	(0.005)	(0.005)	(0.003)	(0.003)
[22°C, 26°C)	−0.002	−0.004	0.006***	0.006***
	(0.004)	(0.005)	(0.002)	(0.002)
[26°C, 30°C)	−0.032***	−0.033***	0.009***	0.009***
	(0.006)	(0.006)	(0.004)	(0.003)
Days above 30°C	−0.064***	−0.063***	0.013**	0.014***
	(0.009)	(0.009)	(0.006)	(0.005)
Female		−0.006		−0.175
		(0.267)		(0.169)
Age		−0.001		0.001
		(0.009)		(0.006)
Education		0.005		0.016
		(0.021)		(0.015)
Illness		−0.391***		−0.144**
		(0.104)		(0.060)
Married		0.202		0.037
		(0.224)		(0.165)
Household size		0.277***		0.041
		(0.085)		(0.050)
Rainfall		−326.440***		−83.690**
		(57.422)		(34.272)
Household and year fixed effects	Yes	Yes	Yes	Yes
Observations	11,408	11,408	2,881	2,881

Note: robust standard errors in parentheses; standard errors are clustered at household level; saving and borrowing measured in thousand VND (in log); *** p<0.01, ** p<0.05, * p<0.1.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

Table A3: Spatial (Conley) regression

Dependent variable	Saving	Borrowing
	(1)	(2)
Reference: [18°C, 22°C)		
Days below 10°C	0.018	−0.000
	(0.027)	(0.012)
[10°C, 14°C)	0.005	−0.000
	(0.011)	(0.004)
[14°C, 18°C)	0.003	0.000
	(0.008)	(0.004)
[22°C, 26°C)	−0.004	0.006**
	(0.006)	(0.002)
[26°C, 30°C)	−0.033***	0.009***
	(0.009)	(0.003)
Days above 30°C	−0.063***	0.014**
	(0.012)	(0.005)
Other controls	Yes	Yes
Household and year fixed effects	Yes	Yes
Observations	11,408	2,881

Note: robust standard errors in parentheses; standard errors clustered at household level; saving and borrowing measured in thousand VND (in log); control variables include rainfall, household head characteristics (gender, age, education), and household size; *** p<0.01, ** p<0.05, * p<0.1.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).

Table A4: Weighted regression

Dependent variable:	Saving	Borrowing
	(1)	(2)
Reference: [18°C, 22°C)		
Days below 10°C	0.016	0.006
	(0.020)	(0.010)
[10°C, 14°C)	0.004	−0.003
	(0.007)	(0.003)
[14°C, 18°C)	0.001	−0.000
	(0.005)	(0.003)
[22°C, 26°C)	−0.004	0.002
	(0.005)	(0.002)
[26°C, 30°C)	−0.034***	0.005**
	(0.006)	(0.002)
Days above 30°C	−0.067***	0.008*
	(0.009)	(0.004)
Other controls	Yes	Yes
Household and year fixed effects	Yes	Yes
Observations	11,408	2,881

Note: robust standard errors in parentheses; standard errors clustered at household level; saving and borrowing measured in thousand VND (in log); control variables include rainfall, household head characteristics (gender, age, education), and household size; *** p<0.01, ** p<0.05, * p<0.1.

Source: authors' construction based on ECMWF (2018) and UNU-WIDER (2017).