Effects of weather on the health of individuals: Comparative evidence from Cambodia, Laos, and Vietnam

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Although there is no doubt about the harmful effects of extreme weather and climate events, there is no consensus on the magnitude of these effects on health and disease infection. This study aims to evaluate the effect of temperature and precipitation on the health of individuals in Cambodia, Laos, and Vietnam using district fixed-effects regression. It finds that exposure to high temperature not only causes sickness and fever but also increases the risk of getting diarrhoea – an infectious disease. High precipitation also increases the probability of getting diseases. However, the effect of precipitation is remarkably lower than that of temperature. The effects of temperature and precipitation differ for different population groups. In Laos and Vietnam, urban and highly educated individuals are less likely to be affected by temperature and precipitation than rural and less educated ones.

Keywords:
temperature,
precipitation,
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Cambodia,
Laos,
Vietnam

Introduction

There is a broad consensus that extreme weather and climate events have been and will be the biggest challenge to humankind (e.g. Stern 2008). One of the direct effects of extreme weather and climate events is the deterioration of the health of individuals. High temperature is also found to be associated with cardiovascular, respiratory, cerebrovascular, and blood cholesterol problems (Huynen et al. 2001, Barreca et al. 2016, Mullins–White 2020, Pottier et al. 2021). Climate variability can affect the survival rate and transmission of viruses and bacteria. There is extensive evidence on the positive association between temperature and infectious diseases (e.g. Jahani–Ahmadnezhad 2011, Levy et al. 2016, Wu et al. 2016). Extreme weather can increase mortality and malnutrition in children (e.g. Deschênes–Moretti 2009, Anderson–Bell 2011, Deschênes–Greenstone 2011, Simeonova 2011, Barreca et al. 2016, Karlsson–Ziebarth 2018, Mullins–White 2020, Pottier et al. 2021).

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Although the harmful effects of extreme weather and climate events are certain, there is no consensus on the magnitude of these effects on health and disease infection (e.g. see a review from Nichols et al. 2009, Jahani–Ahmadnezhad 2011, Phalkey et al. 2015, Levy et al. 2016, Jaber 2022). The effect of climate events differs for different nations, regions, communities, and individuals owing to the differences in their exposure and resilience to climate events (Phalkey et al. 2015, Nagy–Veresné Somosi 2022). Climate change and extreme weather events cause more human and economic losses in developing than developed countries (e.g. Dell et al. 2008, World Bank 2010, Mitsis 2021, Khedhiri 2022). Exposed to the same extreme weather events, households and individuals with high resilience can suffer less damage than those with low resilience (Briguglio et al. 2009, Davies 2013, Phalkey et al. 2015, Carleton et al. 2020, Lee–Li 2021). Existing studies show a wide diversity of empirical results, calling for more empirical findings to better understand the effects of climate on health status.

This study aims to evaluate the effect of temperature and precipitation on the incidence of illness, fever, coughs or colds, and diarrhoea among the people of Cambodia, Laos (or Lao PDR), and Vietnam. This study is expected to make the following contributions: First, it provides empirical findings on the effects of climate on health status and diseases in Cambodia, Laos, and Vietnam. Although there are relatively many studies on the effects of climate change and weather extremes on health in Vietnam (e.g. Dao et al. 2013, Giang et al. 2014, Phung et al. 2016, Dang et al. 2019, Tran et al. 2020, Nguyen et al. 2022), there are only a few studies on this topic in Cambodia (e.g. McIver et al. 2016). To the best of our knowledge, there are no quantitative studies on the effects of climate change as well as weather extremes on health in Laos. This study examines how weather extremes influence different diseases to identify which one is more vulnerable to weather events. Second, this study compares the effect between temperature variation and precipitation variation in the three countries. There can be different effects of temperature and precipitation on different types of illness and diseases.

There are several reasons why Cambodia, Laos, and Vietnam are interesting cases to examine. First, located in South East Asia, these countries are highly exposed to climate change and extreme weather events such as typhoons, floods, and droughts. There are increasing climate problems in Laos, including higher-than-usual intensity rainfall events during the rainy season and extended dry. As they have coastlines, Cambodia and Vietnam are likely to be seriously affected by sea level rise. All three countries have a tropical climate. Moreover, high temperature and humidity can increase the risk of waterborne diseases such as diarrhoea, dysentery, and typhoid fever (WHO 2008, UNICEF 2012). Second, there have been large household surveys in Cambodia, Laos, and Vietnam over time, allowing us to analyse the effects of temperature and precipitation on the health of individuals.

The reduction of the adverse effects of climate change has been set up as one of the Millennium Development Goals as well as Sustainable Development Goals in Cambodia, Laos, and Vietnam. This study's findings are expected to provide useful information for policy makers as well as other related organisations on the effects of climate. In the case of a large climate effect on people's health, the government should have more effective policies and programmes to manage climate change. As we also separate the effects of temperature and precipitation, our findings can also help provide pertinent policy recommendations to manage different kinds of weather events. The findings can be useful for not only the three countries in this study but also for other countries, especially Asian countries with similar economic and climate contexts such as Indonesia, Myanmar, the Philippines, and Thailand.

This paper is organised as follows. The following sections presents a review of related literature, the datasets used in this study, the descriptive analysis of the pattern of temperature and precipitation, health, and diseases of individuals in Cambodia, Laos, and Vietnam, the estimation method and empirical results, respectively. The final section summarize the main conclusions.

Literature review

In recent decades, there has been growing attention on climate change by not only academic researchers but also policy makers. At the individual level, empirical studies tend to focus on the effect of temperature fluctuation, particularly heat stress, on labour and health. High temperatures are also found to be associated with cardiovascular, respiratory, cerebrovascular, and blood cholesterol problems (Huynen et al. 2001, Barreca et al. 2016, Jay et al. 2021). Heat waves are further found to increase healthcare contacts of exposed people (Mullins–White 2020, Lee–Li 2021, Pottier et al. 2021). Recently, Zhao et al. (2021) have estimated that temperature extremes are associated with approximately 5 million deaths worldwide yearly, of which 90% are cold-related and 10% are heat-related. Burkart et al. (2021) show a positive correlation between daily temperature and different diseases including ischaemic heart disease, stroke, cardiomyopathy and myocarditis, hypertensive heart disease, diabetes, chronic kidney disease, lower respiratory infection, and chronic obstructive pulmonary disease.

There are several studies on the adverse effect of extreme temperature on mortality (e.g. Curriero et al. 2002, Anderson–Bell 2011, Deschênes–Greenstone 2011, Barreca et al. 2016, Guo et al. 2017, Cohen–Dechezleprêtre 2022, Ebi et al. 2021). Exposure to cold and hot days can also cause mortality (e.g. Deschênes–Moretti 2009, Karlsson–Ziebarth 2018, Mullins–White 2020, Ebi et al. 2021, Pottier et al. 2021). Simeonova (2011) concludes that exposure to weather events during pregnancy can decrease gestational age and birth weight of children in the United

States. In-utero exposure to extreme weather results in low birth weights (e.g. Deschênes et al. 2009) and under-nutrition in children (Phalkey et al. 2015).

The epidemiological literature examines the effects of climate and weather on the probability of getting diseases. Climate variability can affect the survival rate and spread of viruses and bacteria. There is extensive evidence on the positive association between temperature and waterborne diseases (e.g. Jahani–Ahmadnezhad 2011, Levy et al. 2016). Higher temperature and heavy rainfall can increase the incidence of diarrheal diseases (Levy et al. 2016). Temperature, humidity, and precipitation are found to strongly influence the spread of dengue, cholera, malaria, diarrhoea, vector, water, food borne diseases, and several other infectious diseases (e.g. Kuhn et al. 2005, Naish et al. 2014, Burkart et al. 2021).

Compared with the effect of temperature, there are fewer studies on the effect of rainfall on health. Sharon–Yang (2009) evaluated the effect of early-life rainfall on the health, education, and socio-economic outcomes in Indonesian adults. They found that higher early-life rainfall has large positive effects on outcomes of women, but not of men. A reason for the positive effect of rainfall is the increase in agricultural production. There are several studies on the effect of precipitation extremes, including floods, and on economic growth, which mainly noted an adverse effect (e.g. Brown–Lall 2006, Brown et al. 2011, 2014).

Compared with Cambodia and Laos, there are more studies on the effects of weather on health in Vietnam. Several studies noted negative effects of extreme weather events and natural disasters on household consumption and health in Vietnam (e.g. Bui et al. 2014, Arouri et al. 2015, Noy–Vu 2010). Dao et al. (2013) found that heat exposure caused health problems for workers, especially poor, female, unregistered outdoor workers in Da Nang city, Vietnam. Giang et al. (2014) and Phung et al. (2016) showed that high temperature increased hospital admissions for cardiovascular diseases in Vietnam. Recently, Dang et al. (2019) and Nguyen et al. (2022) have concluded that heat waves increase the mortality rate, especially among older people in Vietnam. Regarding Cambodia, Davies et al. (2015) showed an association between floods and diarrhoeal disease incidences among children. McIver et al. (2016) found a positive correlation between diarrhoeal disease incidences and temperature in Cambodia. In Laos, to the best of our knowledge, there have been no quantitative studies on the effects of climate change as well as weather extremes on health.

Data sets

Household survey data

This study relies on household surveys from Cambodia, Laos, and Vietnam. We use the Cambodian Socio-Economic Surveys (CSES) in 2004 and 2010. These surveys were conducted by the National Institute of Statistics of the Ministry of Planning to collect data on the living standards of households and individuals. The sample sizes in the 2004 CSES and the 2010 CSES were 12,000 and 3,840 households, respectively. The corresponding number of household members covered in these surveys was 59,750 and 16,510, respectively.

Regarding Laos, we use the Lao Expenditure and Consumption Survey 3 (LECS 3) in 2002/03 and the LECS 4 in 2007/08. The LECSs covered all the provinces of Lao PDR. The LECS 3 was undertaken from March 2002 to February 2003 (12 months), while the LECS 4 was undertaken from April 2007 to March 2008. The LECS is aimed at estimating the expenditure and consumption of household production, investment, accumulation, and other socio-economic aspects of households. It contains both household-level and individual-level data. The number of sampled households in LECS 3 and LECS 4 is 8,100 households with 47,715 individual members and 8,296 households with 48,745 individual members, respectively.

Regarding Vietnam, we use data from the Vietnam Living Standard Surveys (VLSS) which were conducted in 1992/1993 and 1997/1998. These data sets were collected by the General Statistics Office (GSO) of Vietnam with technical support from the World Bank. The GSO has conducted the Vietnam Household Living Standard Surveys (VHLSS) every two years since 2002; however, there are no data on health and diseases from these surveys. Therefore we do not use the VHLSS in this study. The 1992/1993 VLSS was undertaken between October 1992 and October 1993, with the sample covering 4,800 households with 23,454 household members. The 1997/98 VLSS was started in December 1997 and completed by November 1998. The sample size in this survey was extended to 6,000 households with 28,430 household members.

All the household surveys used in this study are designed using the survey design from the Living Standards Measurement Study (LSMS) of the World Bank. Therefore, they are relatively comparable in terms of sampling and survey instruments. The sample sizes are nationally and regionally representative.

Climate change data

Regarding climate change data, there are different sources of data on monthly temperature and precipitation, for example, the data from Willmott–Matsuura (2015). This dataset provides worldwide (terrestrial) monthly mean temperature and precipitation data at high resolution. We can use geospatial software to compute the district-level data of monthly temperature and precipitation over the period 2003–2014. Cambodia, Laos, and Vietnam are diverse countries including different agro-ecological zones such as delta, mountain, and coastal terrain. All three countries have similar administration divisions. They are divided into provinces and cities, which are further divided into districts. The number of provinces and districts in Cambodia is 24 and 171, respectively. There are 63 provinces and 684 districts in Vietnam. The number of provinces and districts in Laos is 18 and 143, respectively. There are large variations in temperature and precipitation among regions and provinces. However, we expect little variation within a district. More detailed geographic data on temperature and precipitation are better for estimation; however, these data are not available for us.

Descriptive analysis

This section presents the descriptive analysis of temperature and precipitation in the districts over time, and illness and diseases of individuals in Cambodia, Laos, and Vietnam. Table 1 presents some basic information on geographic and economic levels of the three countries. Cambodia is one of the least developed countries in Southeast Asia with a per capita annual GDP of 1,084 USD in 2014. The land area of Cambodia covers approximately 181,000 km^2. The population of Cambodia in 2014 was 15.41 million people. Laos is also a developing country covering a land area of 237,000 km^2 with a population of 6.89 million people in 2014. Laos is a landlocked country without coastal zones or a coastline. It has a terrain of mostly rugged mountains with some plains and plateaus. The per capita GDP of Laos was approximately 1,708 USD in 2014. Among the three countries, Vietnam is the richest, with a GDP per capita of 2,052 USD in 2014. Vietnam also has the largest area and population. In 2014, there were 90.73 million people living in 331,000 km^2.

It is worth noting that Cambodia, Laos, and Vietnam are now classified as lower-middle income. However, the data used in this study were collected when the three countries were considered low-income countries.

Table 1

Country background in 2014

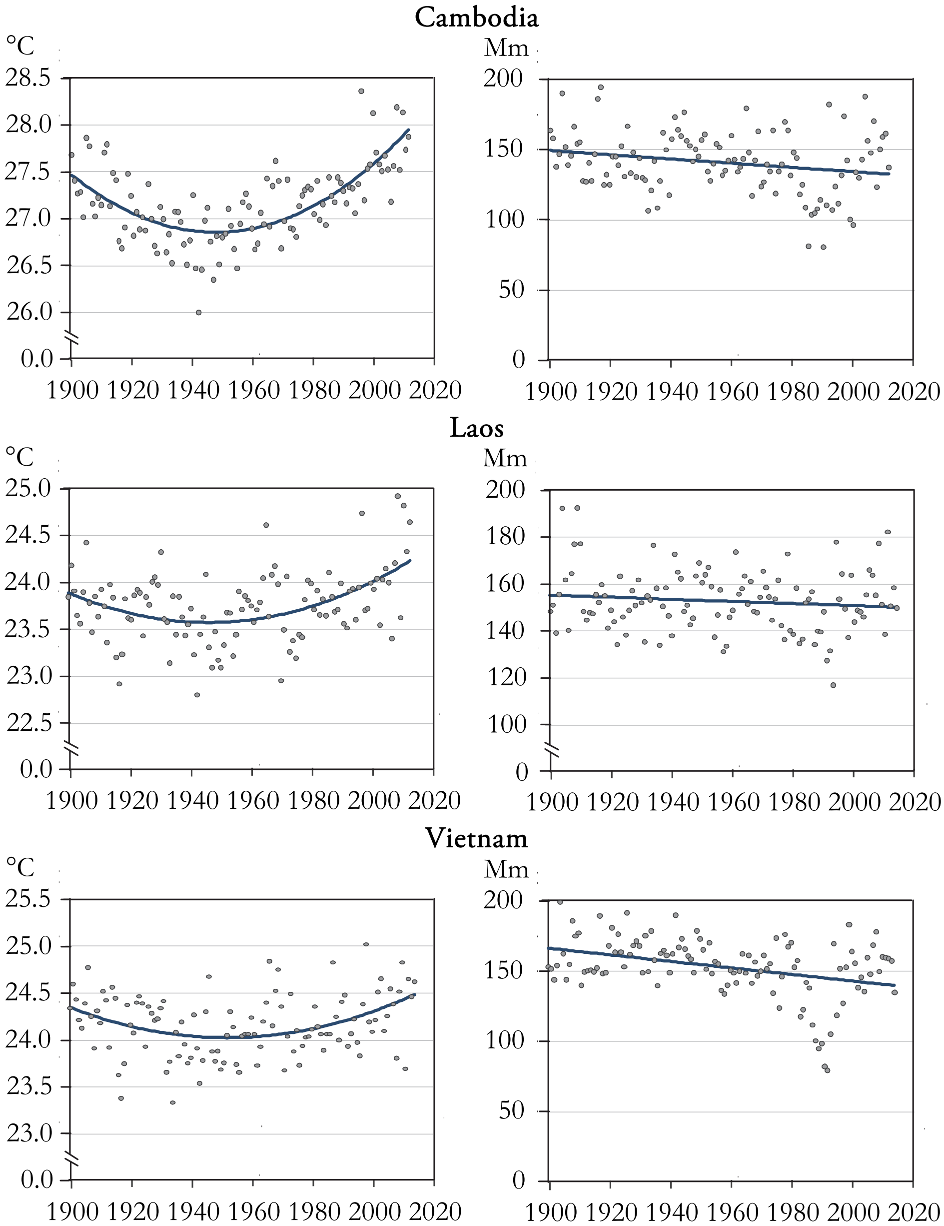
Country	Area, thousand km^2	Population, thousand people	GDP per capita, current USD	GDP per capita, PPP, USD, 2005 (international)
Cambodia	181	15,408	1,084	3,242
Laos	237	6,894	1,708	5,162
Vietnam	331	90,730	2,052	5,629

Source: Authors' preparation using World Development Indicators Database of the World Bank (2009, 2010).

Figure 1

Average monthly temperature and precipitation over 1900–2014

Average monthly temperature (°C) Average monthly precipitation (mm)



Source: Authors' preparation using data from Willmott–Matsuura (2015).

Cambodia, Laos, and Vietnam have a tropical climate. Using climatic data from Willmott–Matsuura (2015), we compute the monthly precipitation and temperature at the district level for the three countries over the period from 1900 through 2014. Figure 1 shows the average of monthly precipitation and temperature over this period. Each dot represents the average of monthly precipitation or temperature in one year. It is computed as the average across districts and months. The temperature was the lowest in the 1950s and 1960s but has recently increased. In 2014, the average temperature of Cambodia, Laos, and Vietnam was 27.9°C, 24.6°C, and 24.6°C, respectively. The average precipitation tended to decrease over time, especially in Vietnam. In 2014, the average monthly precipitation of Cambodia, Laos, and Vietnam was 137.1, 150.1, and 133.7 mm (millimetre per square metre), respectively.

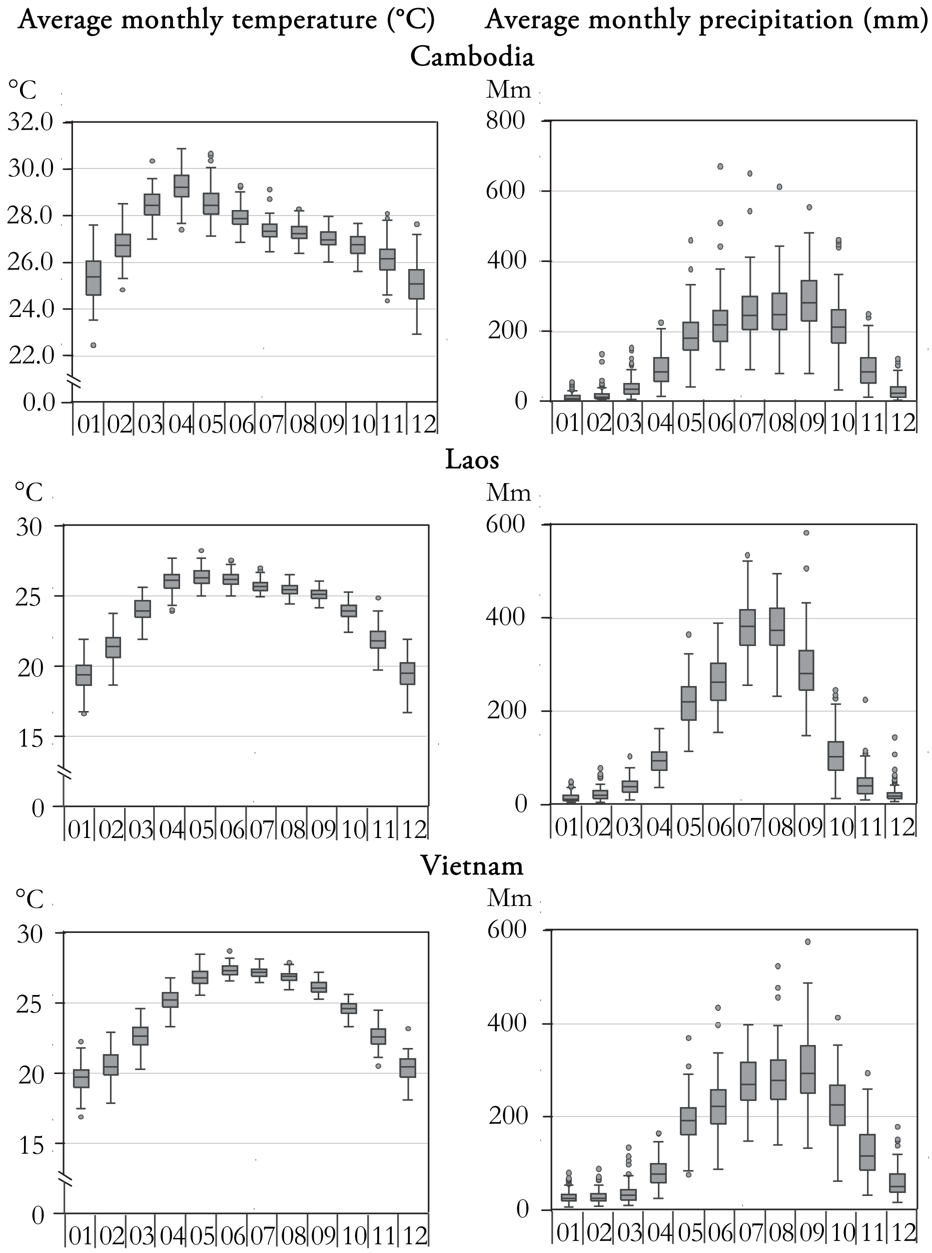
There are climate differences between these countries. Moreover, there is a large geographic variation in the climate within each country. Figure 2 presents the median of temperature and precipitation of months over time. The estimates are averaged across years from 1900 to 2014 and across districts. In Cambodia, there are two seasons governed by the monsoon: dry and rainy seasons. The dry season lasts from mid-November to mid-May and the rainy season lasts from mid-May to mid-November. The annual average temperature in Cambodia is about 27°C. In some days in April or May, the temperature increases up to 38°C. The lowest temperature occurs in January or December, decreasing to approximately 14°C. The precipitation is highest in September.

Laos also has two main seasons that are influenced by the tropical monsoon: dry and rainy seasons. The dry season lasts from November to April and the rainy season lasts from May to October. In December and January, the temperature is the lowest, ranging between 16°C and 18°C, while in May and June, the temperature is the highest, with a range between 27°C and 34°C. Regarding precipitation, it is highest in May and June.

South Vietnam has two seasons, and its climate is quite similar to that of Cambodia and Laos. The dry season lasts from November to April and the rainy season lasts from May to October. In North Vietnam, there are four seasons. Temperature and precipitation are much lower in winter than in summer.

Figure 2

The median temperature and precipitation by months



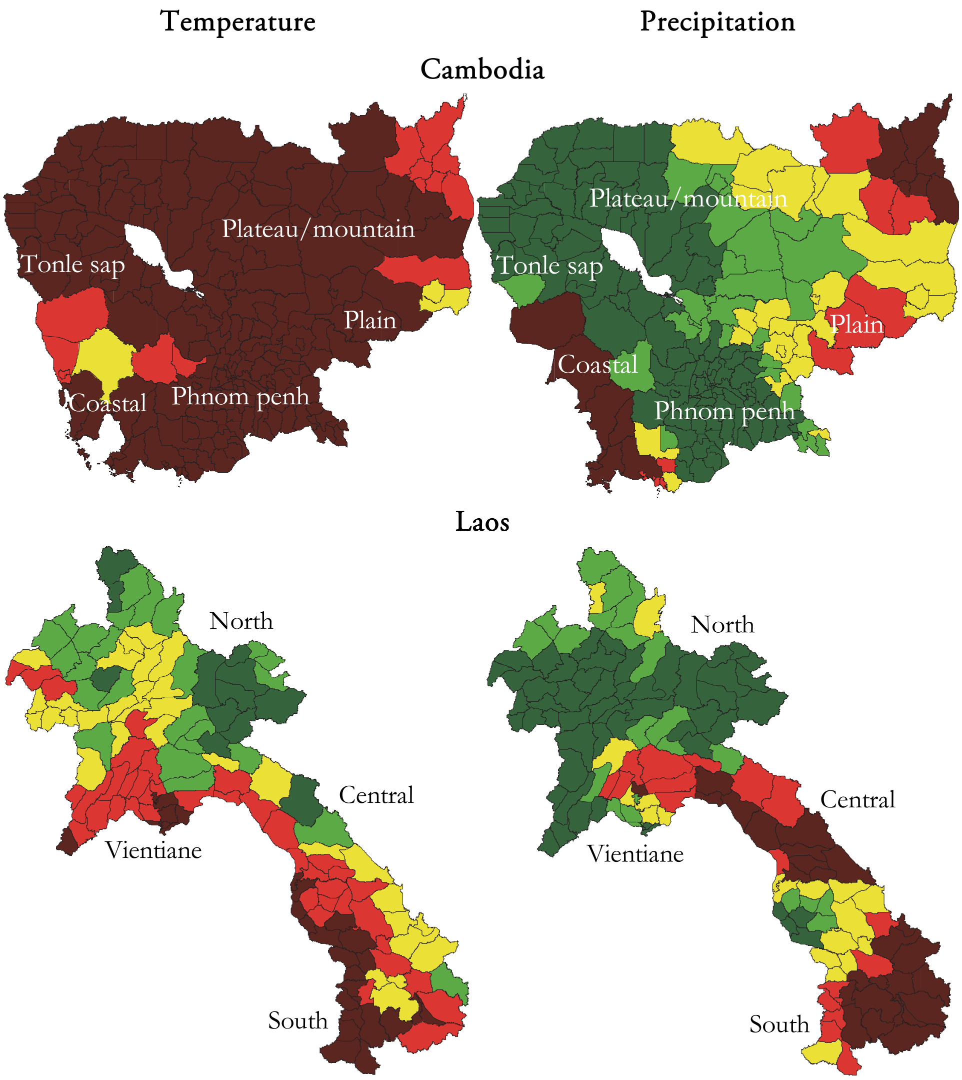
Note: This figure presents the box plot of the average of temperature and precipitation over years. The median and variation (upper quartile, lower quartile, and adjacent values) is estimated for over time from 1900 to 2014.

Source: Authors' preparation using data from Willmott–Matsuura (2015).

Figures 3 show the average monthly precipitation and temperature of the districts. For comparison, we use the same scale and legend for the three countries. Overall, the three countries have rather similar levels of temperature and rainfall. The average temperature of Cambodia is higher than that of Laos or Vietnam. Evidently, there is a large geographic variation in both precipitation and temperature within each country. There are a large proportion of mountainous areas in the North of Laos and Vietnam. Moreover, the temperature in the mountains is lower than that in other areas.

Figure 3

The average precipitation and temperature during 1900–2014



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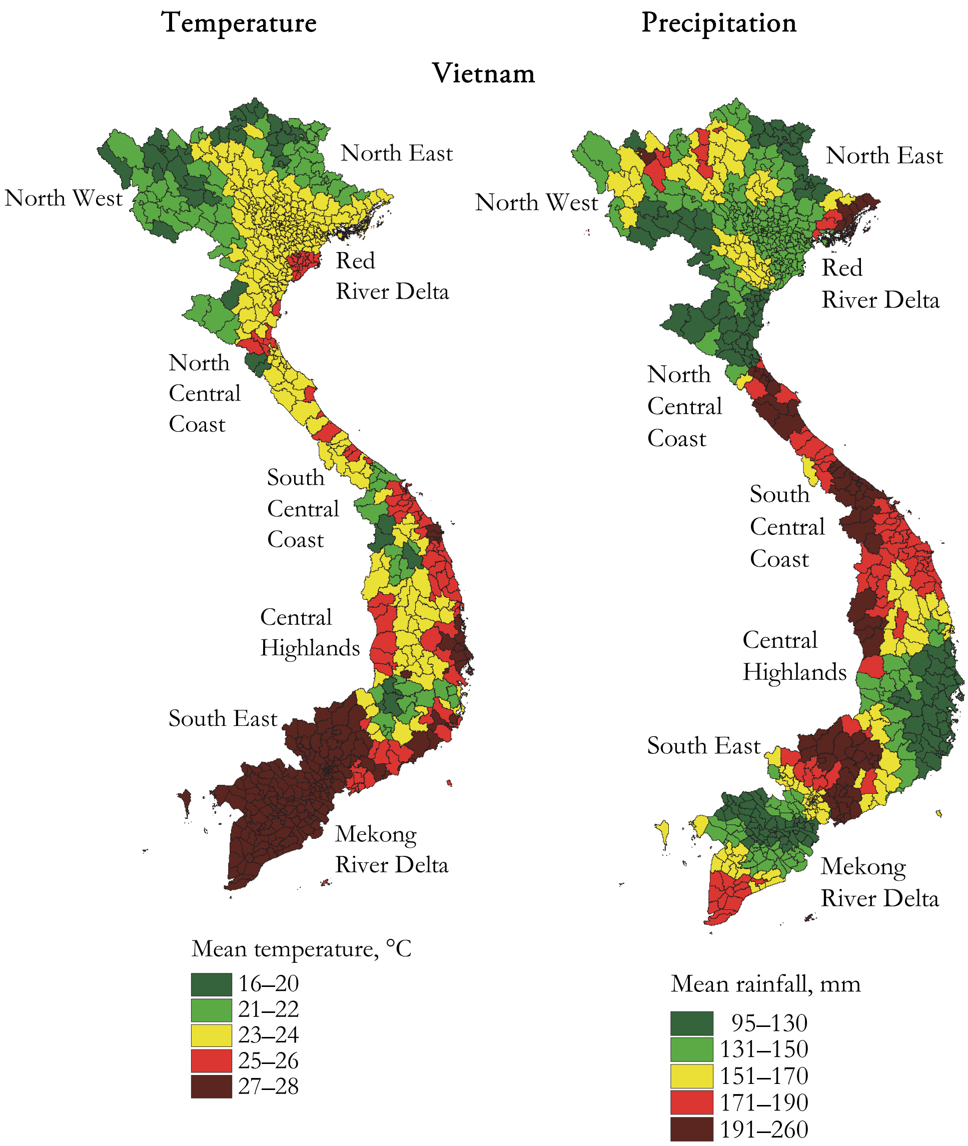

Note: The while-color polygon inside the country denotes the water surface.
Source: Authors' preparation using data from Willmott–Matsuura (2015).

In Table 2, we examine the health variables. The surveys contain data on illness and diseases that individuals have suffered over the past four weeks. There were approximately 18% and 10% of people reporting disease incidences over the past four weeks in Cambodia and Laos, respectively. In Vietnam, 27.5% of people reported they had diseases in 1993. However, this figure increased to 35.6% in 1998. The proportion of people with illnesses was higher in Vietnam than in Laos or Cambodia; possibly, the surveys in Vietnam were conducted in earlier years when Vietnam had a lower GDP and health care services.

Table 2

The percentage of individuals having illness symptoms and diseases over the past four weeks

(%)

Variables	Cambodia		Laos		Vietnam	
	2004	2010	2003	2008	1993	1998
Illness/sickness/diseases	18.20	18.28	10.10	10.41	27.52	35.58
Fever	3.40	4.29	2.30	2.10	1.49	4.86
Coughs and colds	5.34	8.61	4.34	5.31	9.91	16.07
Diarrhea	0.64	1.25	0.49	0.27	0.70	1.90
Other diseases	8.82	4.13	4.14	3.78	15.42	12.98

Source: Author's estimation using Cambodia, Laos, and Vietnam Household Surveys.

Questionnaires on health differ between countries. To have comparable variables on health, we examine only three types of illness symptoms and diseases: fever, coughs or colds, and diarrhoea. Other diseases and illness symptoms are grouped into 'other diseases'. It is important to note that there is a difference between Cambodia's surveys (CSES) and the surveys of the other two countries (LECS and VLSS). In the CSES, respondents could report only one disease or symptom of illness that they had over the past four weeks, while in the LECS and VLSS, respondents could mention more than one disease or symptom of illness.

Estimation methods

We adopted econometric methods to evaluate the effect of temperature and precipitation on the health of individuals. According to the health capital model of Grossman (1972, 2000), health is considered an individuals' demand for the commodity 'good health'. The main factors determining the demand for 'good health' are inherited stock of health, the shadow price of the 'good health' commodity, household income, and price of other commodities. Extreme weather events can affect health through inherited stock of health. In Deschênes–Greenstone's (2011) study, temperature is an exogenous factor that directly affects the survival function of individuals.

This study evaluates both short-term and long-term effects of weather events. First, we assume a health indicator is a reduced-function of characteristics of individuals and weather variables as follows:

$$Y_{ijmt} = \beta_0 + X_{ijt}\beta_1 + Month\_C_{jmt}\beta_2 + Year\_C_{jt}\beta_3 + T_t\beta_4 + v_j + u_{ij} + \tau_{jmt} + \varepsilon_{ijmt}, \quad (1)$$

where Y_{ijmt} is a welfare indicator of individual *i* in district *j* in month *m* of year *t*. We use different indicators of sickness and diseases over the past four weeks to evaluate the health of individuals (see Table 2). We further use similar specifications as equation (1) for different dependent variables. X_{ijt} is a vector of characteristics of individuals and households such as demography and household composition. $Month\_C_{jmt}$ denotes temperature and precipitation of district *j* in month *m* of year *t*. $Year\_C_{jt}$ is the average of temperature and precipitation over the 12 months before the interview month of individuals. We tried log of temperature and log of precipitation; the results are very similar but less significant. Therefore, in this study, we do not use the dependent variable in the log form. T_t is the dummy variable of years. u_{ij} and v_j are time-invariant unobserved variables of individuals and districts, respectively. ε_{ijmt} and τ_{jmt} are time-variant unobserved variables of individuals and districts, respectively.

Estimation of the effect of weather can be biased owing to the endogeneity problem, as unobserved variables are correlated with the weather variables. For example, people living in hot areas might be more resilient to high temperature. People who are not able to adapt might migrate to areas with lower temperature. Consequently, people in high temperature areas might be less likely to suffer from diseases. In equation (1), unobserved variables include both district-level and individual-level variables. As the weather variables are district-level variables, they are more likely to be correlated with unobserved district-level variables. Using the district fixed-effects regression, we can eliminate unobserved time-invariant district-level variables, v_j. It is expected that the endogeneity bias is negligible after eliminating the unobserved time-invariant variables and the control of observed variables.

The short-term effect of temperature and precipitation is measured by β_2, that is, a vector of coefficients of temperature and precipitation of the interview month in equation (1). Once the district dummies and the average temperature and precipitation during the past 12 months are controlled for, we expect the monthly temperature and precipitation to be more exogenous.

To evaluate the long-term effect of weather, we use the following model:

$$Y_{ijmt} = \beta_0 + X_{ijt}\beta_1 + Variation_{jt}\beta_2 + Year\_C_{jt}\beta_3 + T_t\beta_4 + v_j + u_{ij} + \tau_{jmt} + \varepsilon_{ijmt}, \quad (2)$$

where the monthly temperature and precipitation are replaced by variables $Variation_{jt}$, indicating whether temperature and precipitation in the previous 12 months were remarkably higher or lower than the average trend. Exposure to high or low precipitation and temperature than the average level in a given year can cause health problems for individuals. In this study, the climate shocks or weather extremes are evaluated based on monthly variation within the past 12 months in comparison with the average trend over time. It reflects unusually high or low amounts of precipitation and temperature in the district-year-month (e.g., Deschênes et al. 2009, Deschênes–Greenstone 2011). More specifically, the variables 'low temperature' and 'high temperature' in a district are evaluated based on the number of months (in the prior 12 months) that have a temperature below the 5th percentile and above the 95th percentile of the distribution of monthly temperature in the same district during the period from 1900 through 2014, respectively. Similarly, the variables 'low precipitation' and 'high precipitation' are evaluated based on the number of months in the previous 12 months having precipitation below the 5th percentile and above the 95th percentile of the distribution of monthly precipitation, respectively. The explanatory variables are presented in Table A1 in the Appendix.

Temperature and precipitation are correlated. To examine their joint effect, we also tried to include interaction between these two variables in regressions. Most interactions are not statistically significant. Hence, in this study, we present regressions without the interactions.

It is important to note that all the dependent variables in this study are binary. Although binary dependent variables are often estimated using a logit or probit model, we use linear probability models as we estimate equations (1) and (2) using district fixed-effects regression, and there are no available fixed-effects probit estimators.[1] A fixed-effects logit regression is available, but it is not efficient, as observations with the constant dependent variable within a district are eliminated. An alternative way is to run probit on a set of district dummies. However, this method has a computational burden and sometimes is not convergent. Linear probability models are extensively used in cases where there are no available non-linear probability models (e.g., Angrist 2001, Angrist–Krueger 2001). Additionally, interpretation of coefficients in the linear probability model is straightforward compared with that in probit or logit models.

Empirical studies

Effects of temperature and precipitation on health

Tables A2–A7 in the Appendix show the district fixed-effects regression of illness variables on temperature and precipitation variables. The control variables include age, sex, ethnicity, urban variable, and year dummy. We use more exogenous variables. Variables that might be affected by climatic events are not used. Endogenous variables that are caused by treatment variables should not be used as controls (e.g. Heckman et al. 1999, Angrist–Pischke 2008). For example, although income can strongly affect the health of individuals, it should not be controlled as it is also affected by climate events. However, to examine the sensitivity of the estimates of the effects of weather on health, we still attempted to use regression models, which

[1] This is attributed to a so-called incidental parameter problem in maximum likelihood methods (Greene 2004).

include log of household income, education of household head, household size, and the proportion of children and elderly in households. We found that almost all the estimates from the models with these extended control variables have the same sign and very similar magnitudes as the models without the extended control variables. This implies that the effect of climate on health and diseases does not happen through income or education level. For interpretation in this study, we use the estimates from the models without the extended control variables.

In Table A2 in the Appendix, the short-term effects of temperature and precipitation on health in Cambodia are evaluated by the coefficients of monthly temperature and precipitation. It is important to note that temperature is evaluated in °C and precipitation is evaluated in thousand millimetres (mm) per square metre per month. Although precipitation is often evaluated in mm, we rescale the precipitation to thousand mm (equivalent to one metre) in regressions so that the coefficients are greater. Table A2 in the Appendix shows that the effect of temperature and precipitation on illness over the past four weeks is positive, but only the effect of precipitation is statistically significant. If the monthly precipitation level increases by 1000 mm, the probability of being sick increases by 0.0248. To compute the elasticity at the mean of precipitation, we note that a 1% of precipitation mean in 2010 is equal to 0.00114 m (see Table A1 in the Appendix). Therefore, a 1% increase in the precipitation increases the probability of being sick by 0.00002827 (equal to 0.00114*0.0248). The increase of 0.00002827 is equivalent to 0.015% of the average proportion of sickness in 2010, which accounts for 0.1828 (Table 2).[2] Therefore, the elasticity of the incidence of sickness to precipitation is 0.015. Higher precipitation also results in an increase in the incidence of fever and other diseases.

Although temperature does not have a significant effect on the risk of illness, it significantly influences symptoms of some diseases. A 1°C increase in temperature increases the probability of suffering fever, diarrhoea, and other diseases by 0.0027, 0.0008, and 0.0016, respectively. We can compute the elasticity of the probability of getting diseases with respect to temperature using the same way of computing elasticity to precipitation. This shows that a 1% increase in monthly temperature increases the probability of getting fever, diarrhoea, and other diseases by 1.7%, 1.8% and 1.1%, respectively. Compared with precipitation, temperature has a remarkably higher effect on health. Interestingly, higher temperature results in a reduction in the incidence of coughs and colds.

Table A3 in the Appendix examines the effects of extremes in temperature and precipitation in Cambodia. As aforementioned, temperature and precipitation variables are evaluated based on the number of months over the past 12 months in which monthly temperature and precipitation are below the 5th percentile or above the 95th percentile of the distribution of monthly temperature and precipitation over

[2] 0.015 is equal to 0.00002827*100/0.1828.

the period from 1900 through 2014. Although the number of high temperature months does not have a significant effect on health, the number of low temperature months has an adverse and significant effect. An increase of one month with temperature below the 5th percentile of distribution increases the probability of sickness, coughs/colds, and other diseases by 0.047, 0.023, and 0.018, respectively.

High precipitation also increases the probability of being sick in Cambodia. An additional month with precipitation above the 95th percentile of the distribution increases the probability of being sick by 0.0173, the probability of having coughs/colds by 0.0099, and other diseases by 0.0072. Low precipitation reduces the probability of fever but increases the probability of other diseases.

Table A4 in the Appendix shows clear evidence of the harmful effects of hot weather on health in Laos. A 1°C increase in temperature increases the probability of sickness, fever, diarrhoea, and other diseases by 0.0032, 0.0011, 0.0005, and 0.0023, respectively. We can compute elasticities: a 1% increase in temperature results in increases of 0.74%, 1.26%, 4.44%, and 1.46% in the incidence of sickness, fever, diarrhoea, and other diseases, respectively. Regarding the precipitation, there are no significant effects on health and diseases of individuals.

Generally, variations in temperature and precipitation do not have significant effects on health in Laos. Only high rainfall significantly influences the incidence of diarrhoea. An additional month with high precipitation increases the probability of diarrhoea by 0.0025, which is approximately equal to 1% of the average incidence of diarrhoea in 2008.

In Vietnam, the health of individuals is affected by not only high temperature but also high precipitation. A 1°C increase in temperature increases the probability of sickness, fever, diarrhoea, and other diseases by 0.0051, 0.0009, 0.0006 and 0.0041, respectively. For comparison with Cambodia and Laos, we also calculate the elasticity in Vietnam. If temperature increases by 1%, the probability of sickness, fever, diarrhoea, and other diseases will rise by 0.37%, 0.48%, 0.82%, and 0.82%, respectively. People who are exposed to higher precipitation are more likely to suffer from illnesses and diarrhoea. Like Cambodia, the magnitude of the precipitation effect is small in Vietnam.

Table A7 in the Appendix shows the effect of extreme temperature and precipitation on illnesses among individuals in Vietnam. People who experience a greater number of months with high temperature are more likely to suffer fever but less likely to get coughs or colds. The number of low temperature months does not have a significant effect on health. People are sensitive to variations in precipitation. Exposure to high precipitation increases the probability of getting diseases. In contrast, lower precipitation reduces the probability of getting diseases.

Overall, there is a consistent finding on the harmful effects of high temperature on health in the three countries. High precipitation also increases the probability of getting diseases in these countries. Extreme low temperature negatively affects health in Cambodia but not in Laos and Vietnam. This may be attributable to the fact that Cambodia has a higher average temperature than Laos and Vietnam. People in Cambodia might not be familiar with cold weather. Consequently, they are more vulnerable in the case of extreme low temperature.

Heterogeneous effects of temperature and precipitation on health

The effects of weather events can differ for different communities and individuals owing to the differences in their exposure and coping capacity during the weather events (Phalkey et al. 2015). At the national level, empirical evidence shows that low-income countries are more affected by climate change and extreme weather events than high-income countries (e.g. Dell et al. 2008, World Bank 2010). At the individual level, Phalkey et al. (2015) note that socio-economic and demographic factors significantly contribute to mitigating the effect of climate change on nutrition.

To examine the heterogeneous effects of weather, we include interactions between monthly temperature and precipitation with several control variables in the regression of the diseases of individuals (Tables A8 and A9 in the Appendix). The interacted variables consist of a dummy variable of ethnic minorities, an urban dummy, and a dummy variable indicating whether household heads completed college or university. We do not interact weather variables with household income as income is very endogenous and can be strongly affected by weather events.

It is important to note that we do not include interactions between control variables with the numbers of months with low or high temperature and precipitation, as there will be a large number of interactions and interpretation is very complicated.

Most interactions between the weather variables and ethnic minorities are not statistically significant; therefore, we do not report the results from this analysis. Table A8 in the Appendix presents the estimates of interactions between monthly temperature and precipitation and urban dummy. Urban areas have higher living standards and health care services than rural areas. In Cambodia, most interactions are not statistically significant. Only the interaction between temperature and urban dummy in regression of other diseases is negative and statistically significant. Regarding Laos and Vietnam, there are more significant interactions in the regressions. Most interactions have a negative sign. This means that individuals in urban areas are less affected by temperature and precipitation than those in rural areas.

In conclusion, Table A9 in the Appendix shows the estimates of interactions between education of household heads and the weather variables. No interactions are significant in Cambodia. However, several interactions are significant and have a negative sign in Laos and Vietnam. Individuals in households with higher education heads are less likely to be affected by high temperature and precipitation. Having better education and knowledge might help households better cope with extreme weather events and mitigate the adverse effects.

Conclusions

This study aims to estimate the short-term and long-term effects of temperature and precipitation on the health of individuals in Cambodia, Laos, and Vietnam using the district fixed-effects regression. The short-term effects are evaluated based on the effect of current monthly temperature and precipitation on the diseases of individuals over the past four weeks, while the long-term effects are evaluated based on the effect of the number of months with too low or too high temperatures and precipitation during the previous 12 months. Although there are some differences in the weather effect on health between the three countries, the pattern is fairly consistent. The current weather as well as the variation in weather during the previous 12 months can influence the incidence of diseases. Exposure to high temperature not only causes sickness and fever in people but also increases the risk of getting diarrhoea – an infectious disease. However, high temperature reduces the incidence of coughs and colds. Compared with hot weather, cold weather has a smaller effect on health. We find the number of months with low temperature tends to increase the incidence of sickness and coughs/colds in Cambodia but not in Laos and Vietnam. High precipitation also causes diseases, while low precipitation tends to be better for health. The effect of precipitation on health is remarkably lower than the effect of temperature.

We find some evidence of a heterogeneous effect of temperature and precipitation. In Laos and Vietnam, urban and high-education individuals are less likely to be affected by temperature and precipitation than rural and less educated ones.

This study's findings suggest several policy implications. First, extreme weather events, especially high temperature ones, have an adverse effect on health. Therefore, governments should provide health care services to reduce the adverse effects of weather events. Second, people in rural areas and those with less education are more affected by weather events. This implies that better living conditions and education might be important mitigating factors of the effects of weather on the health of individuals. In conclusion, there can be differential effects of weather on health in different countries; therefore policies that manage climate change and extreme weather events should be tailored to different countries. For example, high temperature causes health problems in the three countries in this study, but extreme low temperature increases the incidence of sickness and coughs/colds only in Cambodia. Therefore, Cambodia needs policies and measures to manage not only extremely high but also extremely low temperatures.

Appendix

Table A1

Mean and standard deviation of the explanatory variables

Explanatory variables	Cambodia		Laos		Vietnam	
	CSES 2004	CSES 2010	LECS 2002/2003	LECS 2007/2008	VLSS 1992/1993	VLSS 1997/1998
Temperature of interview month (°C)	28.014	28.447	24.492	24.543	25.243	25.956
	(1.541)	(1.603)	(3.280)	(3.620)	(3.578)	(3.558)
Precipitation of interview month (1000 mm)	0.120	0.114	0.145	0.152	0.085	0.166
	(0.129)	(0.111)	(0.149)	(0.148)	(0.088)	(0.167)
Average temperature of the past 12 months (°C)	28.149	28.285	24.404	24.605	24.678	25.399
	(0.634)	(0.694)	(2.516)	(2.528)	(2.210)	(2.290)
Average precipitation of the past 12 months (1000 mm)	0.122	0.133	0.143	0.154	0.066	0.118
	(0.032)	(0.040)	(0.036)	(0.047)	(0.029)	(0.040)
Number of months with temperature above the 95th percentile	1.777	1.760	0.650	0.587	0.662	1.385
	(0.957)	(1.325)	(0.477)	(0.549)	(0.777)	(1.113)
Number of months with temperature below the 5th percentile	0.011	0.080	0.279	0.047	0.641	0.032
	(0.106)	(0.271)	(0.448)	(0.211)	(0.518)	(0.184)
Number of months with precipitation above the 95th percentile	0.256	1.010	0.427	0.771	0.027	0.212
	(0.448)	(0.695)	(0.557)	(0.803)	(0.162)	(0.447)
Number of months with precipitation below the 5th percentile	1.079	0.522	0.706	1.228	2.227	1.441
	(0.653)	(0.685)	(0.660)	(0.853)	(1.651)	(1.428)
Age	25.250	26.857	23.913	25.682	25.432	28.226
	(18.698)	(19.239)	(18.747)	(19.184)	(19.827)	(20.350)
Male (male=1, female=0)	0.480	0.478	0.496	0.494	0.483	0.484
	(0.500)	(0.500)	(0.500)	(0.500)	(0.500)	(0.500)
Khmer (yes=1, other ethnic groups=0)	0.961	0.961				
	(0.194)	(0.194)				
Mon, Khmer (yes=1, other ethnic groups=0)			0.200	0.212		
			(0.400)	(0.409)		
Laos (yes=1, other ethnic groups=0)			0.679	0.664		
			(0.467)	(0.472)		
Ethnic minorities (yes=1, Kinh=0)					0.127	0.134
					(0.333)	(0.341)
Urban	0.204	0.194	0.264	0.288	0.225	0.227
	(0.403)	(0.395)	(0.441)	(0.453)	(0.418)	(0.419)

Note: Standard deviations in parentheses.
Source: Author's estimation using Cambodia, Laos, and Vietnam Household Survey Data.

Table A2

Regression of sickness on monthly temperature and precipitation in Cambodia

Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
Temperature of the interview month (°C)	0.0003	0.0027***	–0.0048***	0.0008***	0.0016**
	(0.0011)	(0.0006)	(0.0007)	(0.0003)	(0.0008)
Precipitation of the interview month (1000 mm)	0.0248*	0.0109*	–0.0091	–0.0003	0.0233***
	(0.0129)	(0.0063)	(0.0083)	(0.0027)	(0.0088)
Average temperature of the 12 months prior to the interview (°C)	0.0196***	–0.0006	0.0066*	–0.0027**	0.0163***
	(0.0050)	(0.0026)	(0.0034)	(0.0011)	(0.0031)
Average precipitation of the 12 month prior to the interview (1000 mm)	–0.3240***	–0.1219**	–0.2355***	–0.0090	0.0424
	(0.1149)	(0.0573)	(0.0820)	(0.0316)	(0.0683)
Age	–0.0068***	–0.0035***	–0.0029***	–0.0011***	0.0008***
	(0.0003)	(0.0001)	(0.0002)	(0.0001)	(0.0002)
Age squared (× 1000)	0.1401***	0.0457***	0.0459***	0.0147***	0.0337***
	(0.0041)	(0.0021)	(0.0025)	(0.0011)	(0.0031)
Male (male=1; female==0)	–0.0297***	–0.0047***	–0.0065***	–0.0003	–0.0183***
	(0.0027)	(0.0013)	(0.0017)	(0.0006)	(0.0019)
Khmer (yes=1, other ethnic groups=0)	0.0026	–0.0006	0.0066	0.0014	–0.0048
	(0.0083)	(0.0040)	(0.0053)	(0.0017)	(0.0060)
Urban (urban=1, rural=0)	–0.0107*	–0.0045	0.0032	–0.0057***	–0.0038
	(0.0063)	(0.0029)	(0.0041)	(0.0015)	(0.0043)
Dummy year 2010 (year 2004=0)	–0.0043	0.0116***	0.0338***	0.0069***	–0.0565***
	(0.0039)	(0.0020)	(0.0028)	(0.0010)	(0.0022)
Constant	–0.2932**	0.0385	0.0583	0.0722**	–0.4623***
	(0.1387)	(0.0733)	(0.0937)	(0.0317)	(0.0873)
Observations	76,259	76,259	76,259	76,259	76,259
R-squared	0.074	0.025	0.026	0.013	0.071

Note: Control variables include age, age squared, gender, ethnicity, urban, and dummies of years.

Robust standard errors in parentheses. Standard errors are corrected for sampling weight and within-district correlation.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Source: Author's estimation using Cambodia Household Survey Data.

Table A3

Regression of sickness on temperature and precipitation variations in Cambodia

Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
Number of months with temperature above the 95th percentile	–0.0050	–0.0028	0.0003	0.0001	–0.0025
	(0.0031)	(0.0019)	(0.0020)	(0.0008)	(0.0021)
Number of months with temperature below the 5th percentile	0.0473***	0.0017	0.0233**	0.0047	0.0177**
	(0.0129)	(0.0065)	(0.0093)	(0.0038)	(0.0074)
Number of months with precipitation above the 95th percentile	0.0173***	–0.0012	0.0099***	0.0013	0.0072**
	(0.0045)	(0.0024)	(0.0030)	(0.0011)	(0.0028)
Number of months with precipitation below the 5th percentile	0.0053	–0.0044**	0.0019	0.0019	0.0060**
	(0.0038)	(0.0019)	(0.0027)	(0.0015)	(0.0024)
Average temperature of the past 12 months (°C)	0.0325***	0.0093**	0.0013	–0.0018	0.0237***
	(0.0076)	(0.0040)	(0.0049)	(0.0019)	(0.0049)
Average precipitation of the past 12 months (1000 mm)	–0.9278***	–0.0633	–0.5750***	–0.0453	–0.2442***
	(0.1537)	(0.0785)	(0.1075)	(0.0438)	(0.0928)
Age	–0.0068***	–0.0035***	–0.0029***	–0.0011***	0.0008***
	(0.0003)	(0.0001)	(0.0002)	(0.0001)	(0.0002)
Age squared (× 1000)	0.1400***	0.0457***	0.0459***	0.0147***	0.0336***
	(0.0041)	(0.0021)	(0.0025)	(0.0011)	(0.0031)
Male (male=1; female=0)	–0.0298***	–0.0047***	–0.0065***	–0.0003	–0.0183***
	(0.0027)	(0.0013)	(0.0017)	(0.0006)	(0.0019)
Khmer (yes=1, other ethnic groups=0)	0.0032	–0.0011	0.0071	0.0015	–0.0043
	(0.0084)	(0.0040)	(0.0053)	(0.0017)	(0.0060)
Urban (urban=1, rural=0)	–0.0110*	–0.0039	0.0023	–0.0056***	–0.0039
	(0.0063)	(0.0029)	(0.0041)	(0.0015)	(0.0043)
Dummy year 2010 (year 2004=0)	–0.0145***	0.0082***	0.0282***	0.0071***	–0.0580***
	(0.0055)	(0.0029)	(0.0037)	(0.0015)	(0.0033)
Constant	–0.5748***	–0.1625	0.1064	0.0741	–0.5928***
	(0.2099)	(0.1099)	(0.1359)	(0.0526)	(0.1359)
Observations	76,259	76,259	76,259	76,259	76,259
R-squared	0.074	0.025	0.026	0.013	0.071

Note: Robust standard errors in parentheses. Standard errors are corrected for sampling weight and within-district correlation.

*** p<0.01, ** p<0.05, * p<0.1.

Source: Author's estimation using Cambodia Household Survey Data.

Table A4

Regression of sickness on monthly temperature and precipitation in Laos

Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
Temperature of the interview month (°C)	0.0032**	0.0011*	0.00001	0.0005**	0.0023***
	(0.0013)	(0.0007)	(0.0010)	(0.0002)	(0.0006)
Precipitation of the interview month (1000 mm)	–0.0178	0.0074	–0.0134	–0.0016	–0.0084
	(0.0228)	(0.0093)	(0.0147)	(0.0020)	(0.0140)
Average temperature of the 12 months prior to the interview (°C)	–0.0286	–0.0131	–0.0215	–0.0028	–0.0077
	(0.0198)	(0.0083)	(0.0131)	(0.0027)	(0.0085)
Average precipitation of the 12 months prior to the interview (1000 mm)	–0.4895***	–0.1113	–0.0899	–0.0418*	–0.2442***
	(0.1676)	(0.0758)	(0.1281)	(0.0218)	(0.0896)
Age	–0.0020***	–0.0011***	–0.0024***	–0.0003***	0.0010***
	(0.0003)	(0.0001)	(0.0002)	(0.0001)	(0.0001)
Age squared (× 1000)	0.0604***	0.0163***	0.0377***	0.0050***	0.0122***
	(0.0041)	(0.0019)	(0.0030)	(0.0009)	(0.0023)
Male (male=1; female==0)	–0.0093***	–0.0029**	0.0005	0.0005	–0.0079***
	(0.0026)	(0.0012)	(0.0014)	(0.0004)	(0.0017)
Mon, Khmer (yes=1, other ethnic groups=0)	0.0368***	0.0102**	0.0163**	–0.0003	0.0135***
	(0.0098)	(0.0050)	(0.0071)	(0.0017)	(0.0040)
Laos (yes=1, other ethnic groups=0)	0.0058	–0.0039	–0.0012	–0.0037**	0.0105***
	(0.0094)	(0.0039)	(0.0060)	(0.0015)	(0.0040)
Urban (urban=1, rural=0)	–0.0051	–0.0058*	0.0073	0.0001	–0.0086*
	(0.0086)	(0.0033)	(0.0054)	(0.0010)	(0.0048)
Dummy year 2007 (year 2002=0)	0.0060	0.0066**	–0.0031	0.0033***	0.0048
	(0.0080)	(0.0029)	(0.0062)	(0.0012)	(0.0034)
Constant	0.7829	0.3424*	0.6080*	0.0722	0.1669
	(0.4825)	(0.2039)	(0.3241)	(0.0640)	(0.2062)
Observations	96,448	96,448	96,448	96,448	96,448
R-squared	0.042	0.015	0.022	0.011	0.040

Note: Robust standard errors in parentheses. Standard errors are corrected for sampling weight and within-district correlation.

*** p<0.01, ** p<0.05, * p<0.1.

Source: Author's estimation using Laos Household Survey Data.

Table A5

Regression of sickness on temperature and precipitation variations in Laos

Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
Number of months with temperature above the 95th percentile	0.0083	0.0013	0.0036	0.0006	0.0022
	(0.0062)	(0.0024)	(0.0047)	(0.0009)	(0.0026)
Number of months with temperature below the 5th percentile	0.0063	0.0010	0.0042	–0.0021	–0.0016
	(0.0137)	(0.0066)	(0.0109)	(0.0015)	(0.0045)
Number of months with precipitation above the 95th percentile	–0.0012	–0.0001	–0.0006	0.0025**	–0.0015
	(0.0084)	(0.0025)	(0.0057)	(0.0011)	(0.0032)
Number of months with precipitation below the 5th percentile	–0.0004	0.0029	–0.0000	0.0004	–0.0028
	(0.0060)	(0.0019)	(0.0045)	(0.0007)	(0.0027)
Average temperature of the past 12 months (°C)	–0.0410*	–0.0103	–0.0286*	–0.0036	–0.0121
	(0.0208)	(0.0081)	(0.0145)	(0.0034)	(0.0098)
Average precipitation of the past 12 months (1000 mm)	–0.4154	–0.0737	–0.0557	–0.0722**	–0.2115
	(0.2803)	(0.1014)	(0.1974)	(0.0341)	(0.1343)
Age	–0.0020***	–0.0011***	–0.0024***	–0.0004***	0.0010***
	(0.0003)	(0.0001)	(0.0002)	(0.0001)	(0.0001)
Age squared (× 1000)	0.0604***	0.0163***	0.0376***	0.0050***	0.0123***
	(0.0041)	(0.0019)	(0.0030)	(0.0009)	(0.0023)
Male (male=1; female==0)	–0.0093***	–0.0029**	0.0005	0.0005	–0.0079***
	(0.0026)	(0.0012)	(0.0014)	(0.0004)	(0.0017)
Mon, Khmer (yes=1, other ethnic groups=0)	0.0386***	0.0111**	0.0161**	0.0002	0.0148***
	(0.0098)	(0.0050)	(0.0071)	(0.0017)	(0.0041)
Laos (yes=1, other ethnic groups=0)	0.0072	–0.0031	–0.0012	–0.0033**	0.0112***
	(0.0095)	(0.0040)	(0.0060)	(0.0014)	(0.0040)
Urban (urban=1, rural=0)	–0.0041	–0.0055	0.0072	0.0002	–0.0078
	(0.0087)	(0.0034)	(0.0054)	(0.0010)	(0.0048)
Dummy year 2007 (year 2002=0)	0.0112	0.0044	–0.0002	0.0024*	0.0075
	(0.0109)	(0.0040)	(0.0087)	(0.0013)	(0.0051)
Constant	1.1430**	0.2946	0.7714**	0.1042	0.3253
	(0.5097)	(0.1960)	(0.3602)	(0.0839)	(0.2362)
Observations	96,448	96,448	96,448	96,448	96,448
R-squared	0.042	0.015	0.022	0.012	0.039

Note: Robust standard errors in parentheses. Standard errors are corrected for sampling weight and within-district correlation.

*** p<0.01, ** p<0.05, * p<0.1.

Source: Author's estimation using Laos Household Survey Data.

Table A6

Regression of sickness on monthly temperature and precipitation in Vietnam

Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
Temperature of the interview month (°C)	0.0051***	0.0009*	–0.0005	0.0006**	0.0041***
	(0.0013)	(0.0005)	(0.0009)	(0.0003)	(0.0010)
Precipitation of the interview month (1000 mm)	0.0379*	0.0032	–0.0286	0.0201***	0.0443**
	(0.0227)	(0.0089)	(0.0181)	(0.0071)	(0.0174)
Average temperature of the 12 months prior to the interview (°C)	–0.1130***	–0.0111*	–0.0212*	–0.0099**	–0.0749***
	(0.0163)	(0.0067)	(0.0119)	(0.0042)	(0.0124)
Average precipitation of the 12 months prior to the interview (1000 mm)	–0.7748***	0.0692*	–0.5585***	0.0039	–0.2900***
	(0.1079)	(0.0388)	(0.0776)	(0.0264)	(0.0820)
Age	–0.0037***	–0.0005***	–0.0038***	–0.0012***	0.0017***
	(0.0004)	(0.0001)	(0.0003)	(0.0001)	(0.0003)
Age squared (× 1000)	0.0918***	0.0045***	0.0523***	0.0164***	0.0207***
	(0.0048)	(0.0017)	(0.0035)	(0.0016)	(0.0038)
Male (male=1; female==0)	–0.0406***	0.0047***	–0.0157***	0.0007	–0.0300***
	(0.0039)	(0.0016)	(0.0029)	(0.0010)	(0.0029)
Ethnic minorities (yes=1, Kinh=0)	0.0252**	0.0137***	0.0089	0.0084***	–0.0054
	(0.0105)	(0.0048)	(0.0080)	(0.0029)	(0.0077)
Urban (urban=1, rural=0)	0.0164	–0.0004	–0.0172	–0.0021	0.0382***
	(0.0156)	(0.0071)	(0.0111)	(0.0050)	(0.0115)
Dummy year 1993	–0.0554***	0.0055	–0.0352***	–0.0056**	–0.0201**
	(0.0102)	(0.0038)	(0.0073)	(0.0026)	(0.0079)
Dummy year 1997	0.1475***	0.0441***	0.0791***	0.0118**	0.0159
	(0.0175)	(0.0069)	(0.0129)	(0.0047)	(0.0133)
Dummy year 1998	0.1592***	0.0449***	0.0838***	0.0138***	0.0223**
	(0.0147)	(0.0058)	(0.0108)	(0.0037)	(0.0112)
Constant	3.0344***	0.2609	0.7541***	0.2497**	1.8670***
	(0.3952)	(0.1624)	(0.2877)	(0.1007)	(0.2986)
Observations	51,884	51,884	51,884	51,884	51,884
R-squared	0.079	0.042	0.049	0.017	0.059

Note: Robust standard errors in parentheses. Standard errors are corrected for sampling weight and within-district correlation.

*** p<0.01, ** p<0.05, * p<0.1.

Source: Author's estimation using Vietnam Living Survey Data.

Table A7

Regression of sickness on temperature and precipitation variations in Vietnam

Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
Number of months with temperature above the 95th percentile	0.0024	0.0093***	–0.0064*	–0.0005	0.0005
	(0.0050)	(0.0019)	(0.0036)	(0.0012)	(0.0037)
Number of months with temperature below the 5th percentile	0.0024	–0.0006	–0.0039	–0.0028	0.0089
	(0.0082)	(0.0032)	(0.0060)	(0.0022)	(0.0062)
Number of months with precipitation above the 95th percentile	0.0770***	0.0072*	0.0433***	0.0003	0.0262***
	(0.0101)	(0.0039)	(0.0073)	(0.0027)	(0.0076)
Number of months with precipitation below the 5th percentile	–0.0127***	–0.0008	–0.0052**	–0.0015*	–0.0049*
	(0.0033)	(0.0012)	(0.0025)	(0.0008)	(0.0025)
Average temperature of the past 12 months (°C)	–0.1038***	–0.0423***	–0.0163	0.0009	–0.0516***
	(0.0234)	(0.0096)	(0.0171)	(0.0060)	(0.0174)
Average precipitation of the past 12 months (1000 mm)	–1.1030***	0.0082	–0.6741***	–0.0408	–0.4025***
	(0.1224)	(0.0453)	(0.0887)	(0.0310)	(0.0938)
Age	–0.0037***	–0.0005***	–0.0038***	–0.0012***	0.0017***
	(0.0004)	(0.0001)	(0.0003)	(0.0001)	(0.0003)
Age squared (× 1000)	0.0916***	0.0045***	0.0522***	0.0164***	0.0206***
	(0.0048)	(0.0017)	(0.0035)	(0.0016)	(0.0038)
Male (male=1; female==0)	–0.0406***	0.0046***	–0.0157***	0.0007	–0.0301***
	(0.0039)	(0.0016)	(0.0029)	(0.0010)	(0.0029)
Ethnic minorities (yes=1, Kinh=0)	0.0263**	0.0132***	0.0103	0.0083***	–0.0051
	(0.0105)	(0.0048)	(0.0080)	(0.0029)	(0.0077)
Urban (urban=1, rural=0)	0.0130	0.0006	–0.0171	–0.0033	0.0348***
	(0.0156)	(0.0070)	(0.0111)	(0.0049)	(0.0115)
Dummy year 1993	–0.0450***	0.0082**	–0.0411***	–0.0035	–0.0080
	(0.0096)	(0.0036)	(0.0069)	(0.0024)	(0.0074)
Dummy year 1997	0.1414***	0.0588***	0.0695***	0.0076	0.0100
	(0.0197)	(0.0078)	(0.0144)	(0.0052)	(0.0148)
Dummy year 1998	0.1589***	0.0685***	0.0685***	0.0083*	0.0208
	(0.0197)	(0.0079)	(0.0144)	(0.0050)	(0.0148)
Constant	2.9762***	1.0505***	0.6476	0.0087	1.4038***
	(0.5768)	(0.2363)	(0.4213)	(0.1468)	(0.4281)
Observations	51,884	51,884	51,884	51,884	51,884
R-squared	0.080	0.042	0.050	0.017	0.059

Note: Robust standard errors in parentheses. Standard errors are corrected for sampling weight and within-district correlation.

*** p<0.01, ** p<0.05, * p<0.1.

Source: Author's estimation using Vietnam Living Survey Data.

Table A8

Regression of sickness on temperature and precipitation with interactions between climate variables and urban dummy

Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
	Cambodia				
Temperature of the interview month (°C)	0.0027	0.0032*	–0.0056***	0.0011**	0.0040
	(0.0055)	(0.0016)	(0.0020)	(0.0005)	(0.0027)
Precipitation of the interview month (1000 mm)	–0.0027	0.0026	–0.0132	–0.0027	0.0106
	(0.0598)	(0.0152)	(0.0278)	(0.0049)	(0.0278)
Temperature of the interview month (°C) × Urban dummy	–0.0080	–0.0017	0.0030	–0.0007	–0.0086**
	(0.0079)	(0.0020)	(0.0039)	(0.0009)	(0.0037)
Precipitation of the interview month (1000 mm) × Urban dummy	0.1012	0.0306	0.0162	0.0088	0.0456
	(0.0921)	(0.0283)	(0.0466)	(0.0072)	(0.0395)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	76,259	76,259	76,259	76,259	76,259
R-squared	0.074	0.025	0.026	0.013	0.071
	Laos				
Temperature of the interview month (°C)	0.0036***	0.0008***	0.0002	0.0004***	0.0028***
	(0.0006)	(0.0003)	(0.0004)	(0.0001)	(0.0004)
Precipitation of the interview month (1000 mm)	–0.0069	0.0151***	–0.0058	0.0006	–0.0112
	(0.0117)	(0.0055)	(0.0081)	(0.0020)	(0.0080)
Temperature of the interview month (°C) × Urban dummy	–0.0019*	0.0010**	–0.0007	0.0002	–0.0019***
	(0.0011)	(0.0005)	(0.0007)	(0.0002)	(0.0007)
Precipitation of the interview month (1000 mm) × Urban dummy	–0.0438**	–0.0269***	–0.0295**	–0.0075*	0.0073
	(0.0212)	(0.0094)	(0.0148)	(0.0041)	(0.0144)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	96,448	96,448	96,448	96,448	96,448
R-squared	0.042	0.015	0.022	0.011	0.040

(Table continues the next page.)

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Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
	Vietnam				
Temperature of the interview month (°C)	0.0065***	0.0008	0.0007	0.0006*	0.0044***
	(0.0013)	(0.0005)	(0.0010)	(0.0004)	(0.0010)
Precipitation of the interview month (1000 mm)	0.0535**	0.0196*	–0.0515***	0.0291***	0.0578***
	(0.0251)	(0.0101)	(0.0171)	(0.0079)	(0.0196)
Temperature of the interview month (°C) × Urban dummy	–0.0121***	–0.0006	–0.0072***	–0.0005	–0.0035
	(0.0029)	(0.0011)	(0.0021)	(0.0007)	(0.0021)
Precipitation of the interview month (1000 mm) × Urban dummy	–0.0622	–0.0660***	0.0526	–0.0365***	–0.0544*
	(0.0435)	(0.0153)	(0.0352)	(0.0127)	(0.0320)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	51,884	51,884	51,884	51,884	51,884
R-squared	0.079	0.042	0.049	0.018	0.060

Note: This table only reports the coefficients of monthly temperature and precipitation and the interactions between these variables and urban dummies. Control variables are the same as Tables A2 to A7 in the Appendix.

Robust standard errors in parentheses. Standard errors are corrected for sampling weight and within-district correlation.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Source: Author's estimation using Cambodia, Laos, and Vietnam Household Survey Data.

Table A9

Regression of sickness on temperature and precipitation with interactions between climate variables and education of household head

Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
	Regressions for Cambodia				
Temperature of the interview month (°C)	0.0000	0.0026*	–0.0051***	0.0008*	0.0017
	(0.0044)	(0.0014)	(0.0017)	(0.0004)	(0.0021)
Precipitation of the interview month (1000 mm)	0.0248	0.0107	–0.0087	–0.0001	0.0229
	(0.0492)	(0.0131)	(0.0222)	(0.0038)	(0.0230)
Temperature of interview month (°C) × Head with college, university	0.0118	0.0031	0.0112	0.0023	–0.0048
	(0.0077)	(0.0024)	(0.0081)	(0.0017)	(0.0045)
Precipitation of interview month (1000 mm) × Head with college, university	0.0076	0.0114	–0.0085	–0.0048	0.0095
	(0.1017)	(0.0300)	(0.0580)	(0.0120)	(0.0579)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	76,259	76,259	76,259	76,259	76,259
R-squared	0.074	0.025	0.026	0.013	0.071
	Regressions for Laos				
Temperature of the interview month (°C)	0.0036***	0.0012***	0.0001	0.0005***	0.0026***
	(0.0006)	(0.0003)	(0.0004)	(0.0001)	(0.0004)
Precipitation of the interview month (1000 mm)	–0.0160	0.0101*	–0.0094	–0.0014	–0.0118
	(0.0109)	(0.0052)	(0.0075)	(0.0020)	(0.0074)
Temperature of interview month (°C) × Head with college, university	–0.0062***	–0.0012*	–0.0005	–0.0002	–0.0051***
	(0.0017)	(0.0007)	(0.0012)	(0.0003)	(0.0012)
Precipitation of interview month (1000 mm) × Head with college, university	–0.0072	–0.0295**	–0.0493**	–0.0013	0.0545**
	(0.0323)	(0.0132)	(0.0230)	(0.0037)	(0.0221)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	96,448	96,448	96,448	96,448	96,448
R-squared	0.042	0.015	0.022	0.011	0.040

(Table continues the next page.)

(Continued.)

Explanatory variables	Having sickness, illness	Having fever	Having coughs or colds	Having diarrhea	Having other sickness or illness symptoms
	yes=1, no=0				
	Regressions for Vietnam				
Temperature of the interview month (°C)	0.0055***	0.0009*	–0.0004	0.0007**	0.0044***
	(0.0013)	(0.0005)	(0.0009)	(0.0003)	(0.0010)
Precipitation of the interview month (1000 mm)	0.0465**	0.0062	–0.0282*	0.0215***	0.0480***
	(0.0230)	(0.0091)	(0.0163)	(0.0072)	(0.0176)
Temperature of interview month (°C) × Head with college, university	–0.0064***	–0.0005	–0.0012	–0.0008	–0.0041**
	(0.0024)	(0.0007)	(0.0017)	(0.0006)	(0.0018)
Precipitation of interview month (1000 mm) × Head with college, university	–0.1237**	–0.0495***	0.0040	–0.0247	–0.0533
	(0.0599)	(0.0142)	(0.0438)	(0.0185)	(0.0426)
Control variables	Yes	Yes	Yes	Yes	Yes
Observations	51,884	51,884	51,884	51,884	51,884
R-squared	0.080	0.042	0.049	0.017	0.060

Note: This table only reports the coefficients of monthly temperature and precipitation and the interactions between these variables and urban dummies. Control variables include head with college and university and the same variables as Tables A2 to A7 in the Appendix.

Robust standard errors in parentheses. Standard errors are corrected for sampling weight and within-district correlation.

*** p<0.01, ** p<0.05, * p<0.1.

Source: Author's estimation using Cambodia, Laos, and Vietnam Household Survey Data.

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