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RESEARCH ARTICLE

How temperature shocks impact energy poverty in Vietnam: mediating role of financial development and environmental consideration

Nguyen Dang Que[1] · Nguyen Van Song[2] · Tran Duc Thuan[3] · Dinh Van Tien[4] · Thai Van Ha[5] · Nguyen Thi Minh Phuong[6] · Nguyen Thi Xuan Huong[7] · Pham Thi Lan Phuong[8]

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Abstract
This paper evaluates the energy poverty of Vietnam by mediating the role of financial development and environmental considerations. Across the globe, billions of individuals live in fuel poverty, failing to access inexpensive and sustainable energy, which is necessary for long-term development. An elevation in power consumption due to an overall increase in heat and short periods of extreme heat exacerbates global warming. The goal of this research is to look at how climate change is affecting energy poverty in Vietnam. This finding (1) demonstrates that temperature shocks have a positive and quantitative impact. (2) The same may be said for "poor income/high cost" figures, which include information on power rates. Similarly, if households use the same amount of power but spend less on other items, the influence will not raise their electricity use. (3) Thermal shocks have been shown to reduce agricultural output in studies. During seasons of low rainfall, for example, higher evaporation and plant water demand can worsen drought and raise total irrigation expenses. Labor productivity is also affected by rising temperatures, particularly in weather-sensitive industries like agriculture. As a result, heat shocks will lower agricultural revenues, worsening energy poverty. Surprisingly, overall income appears to be a little mitigating influence. This might be owing to widespread underreporting of stated income, particularly among persons who rely on agriculture for their livelihood.

Keywords Financial development · Financial consideration · Temperature shocks · Energy poverty · Financial inclusion · Econometric estimation

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✉ Nguyen Van Song
nguyensonghua@gmail.com

Nguyen Dang Que
dangquenapa@gmail.com

Tran Duc Thuan
tranducthuan@dntu.edu.vn

Dinh Van Tien
dinhvantien.hubt@gmail.com

Thai Van Ha
vanha280182@gmail.com

Nguyen Thi Minh Phuong
minhphuongn78@yahoo.com

Nguyen Thi Xuan Huong
xuanhuongfuv@gmail.com

Pham Thi Lan Phuong
phuongcknn@cam.edu.vn

1 Present Address: National Academy of Public Administration (NAPA), Ha Noi, Viet Nam

2 Viet Nam National University of Agriculture (VNUA), Ha Noi, Viet Nam

3 Dong Nai Technology University (DNTU), Bien Hoa City, Vietnam

4 Ha Noi University of Business and Technology (HUBT), Ha Noi, Viet Nam

5 National Academy of Education and Management (NAEM), Ha Noi, Viet Nam

6 Vinh University (VU), Vinh City, Vietnam

7 Viet Nam National University of Forestry (VNUF), Ha Noi, Viet Nam

8 College of Agricultural Mechanics (CAM), Vinh Phuc, Vietnam

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Introduction

Increasing temperatures have been demonstrated to have a significant adverse influence on household health. Recurrent and strong high temperature waves, for example, have been associated to higher death and morbidity rates (Hancock and Vasmatzidis 2003; Churchill et al. 2020). Increased poverty (Hodell et al. 1995), instability of food (Seppanen et al. 2003; Fang et al. 2004), and other aspects of ill health have all been linked to it (Rodriguez-Alvarez et al. 2021).

Higher temperatures are expected to become more common in the following decades (Hedge 2004). More scientific information concerning climate change's various effects, mainly on results that have been missed previously and on families whose living is vulnerable to temperature fluctuations, is also needed to mitigate the disruptions and displacements caused by the phenomenon (Awaworyi Churchill and Smyth 2021).

The effect of increasing global temperatures on the consequence of fuel insecurity in single Vietnamese households is investigated in this study. Inadequate accessibility to and/or incapacity to purchase renewable power alternatives for daily chores such as heating and cooking is referred to as power insecurity (Ampofo and Mabefam 2021; Chien et al. 2021a, b, c; Li et al. 2021a, b). Availability of renewable energy will be restricted due to the immoderate temperature, which is expected. It is because the family income coming from agriculture will be reduced and the total energy usage will be surged in a continuous financial limitation, will take an alternative far from greener, costlier fuel sources and toward low-cost, but comparatively unclean fuel resources. With these possible lines of impact, and given the expected increase in the frequency of temperature extremes, a better knowledge of their possible effects on fuel poverty is critical. One of the main reasons for focusing on energy poverty is that it stays to influence the living of many individuals in emerging nations and portions of Europe (Auffhammer and Aroonruengsawat 2011; Chien et al. 2021a, b, c; Ehsanullah et al. 2021; Tunio et al. 2021). According to van der (Deschênes and Greenstone 2011), two billion individuals still count on old-fashioned fuels like agricultural wastes, woods, and waste dung for their day-to-day fuel demand, while around 1.4 billion individuals still lack access to electricity (Auffhammer and Aroonruengsawat 2011). Aside from its pervasiveness, this type of adversity breeds more hindrance for persons, society, and the atmosphere. Outdated energy sources, like solid fuels or biomass, are frequently gathered in an unsustainable manner and are frequently used in inefficient cook stoves (Halls 2009; Desai et al. 2015; Chien et al. 2021a, b, c; Jamali et al. 2021). Traditional energy sources are clearly inferior to modern energy sources due to their inefficiency and long-term environmental consequences (Dong et al. 2021; Bukari et al. 2021).

As a result, fuel disparity has been connected to poorer medical well-being (Group 2016; Sadiq et al. 2021b; Nguyen et al. 2019), lower subjective well-being, lower financial development, and more environmental deterioration (Halkos et al. 2015; Tan et al., 2021; Group 2016) that mitigate the effects of global warming on fuel disparity, which can thereby achieve development and environmental sustainability goals in addition to easing immediate consumption deprivation. Signatories to the Sustainable Development Targets (SDGs) have embraced global right to use inexpensive and green fuel as one of the particular objectives to accomplish by 2030, reflecting this. As a result, this research offers a significant input to the climate-change works and the ecological reason by concentrating on fuel poverty as the consequence of interest (Ye and Koch 2021; Apergis et al. 2021).

Our findings are based on the Vietnam Household Living Standards Survey, a dataset that is unusually comprehensive and nationally representative in terms of household surveys (VHLSS). These statistics are suitable for achieving our objective since they enable us to determine particular energy consumption patterns in Vietnamese homes. We created the MEPI in response to the findings of this research, which accounts for disparities in both the kind and quantity of electricity consumed. Our basic strategy is to estimate a linear prediction framework with a spectrum of parameter estimates. To detect them, our study depends on the random variance of temperature waves over place and time. Exploiting both of these sources of difference has the advantage of taking into consideration factors that may influence both the selection of accommodation and the probability of becoming energy inefficient (Kahouli and Okushima 2021). Possible housing choice, in particular, is expected to be widespread among families in the same province that vary in their contact to a concurrent temperature jolt merely due to the timing (or year) in which the shock occurs. Also, by comparing the schedule of the shocks over a short period of time, possible bias from differing macroeconomic trends between provinces is reduced (Drescher and Janzen 2021). Our method has the advantage of isolating the influence of the temperature jolt on fuel poverty (Ye and Koch 2021).

Our key finding is that short-term temperature variations have a significant impact on energy poverty. As per our sample, Vietnam's total energy poverty rate is 19%, with an MEPI rating and MEPI score of 0.188 (Drescher and Janzen 2021).

We find that the impacts differ by region, which is steady with previous research on temperature vulnerability. Agricultural production in Vietnam's north is particularly vulnerable to the effects of temperature shocks. As a result, rice harvests in this area are extremely responsive to temperature fluctuations. A contributing aspect is the high quantity of irrigation used on crops. The rest of the paper is organized as follows: Section 2 gives a quick overview of the associated literature and explains how we contributed to these bodies of work in a unique way. Section 3 introduces the Vietnamese setting; Section 4 summarizes the data; Section 5 defines the technique; Section 6 offers and examines the findings; and Section 7 wraps things up.

Literature review

A family's capacity to acquire and access products, particularly contemporary power sources, is hampered by lower income (Rafi et al. 2021). Temperature extremes, in particular, limit household income by lowering crop yields (Finance 2013). Temperature extremes can also have an impact on agriculture yield by generating extra weather phenomena such droughts and floods, which can reduce agricultural productivity. As a result, temperature extremes are likely to have a greater impact on households whose livelihoods are strongly reliant on agricultural produce.

Extreme temperatures, however, can affect all households, including those who are not agriculture dependent. This is due to the fact that severe temperatures diminish labor productivity and supply (Mac Sweeney et al. 2008; Park et al. 2010). Extremes in temperature are likely to reduce labor productivity by affecting mental or cognitive clarity (Gencer et al. 2011; Finance 2013; Ha and Son 2017). In general, the evidence indicates that heat stress, rather than cold stress, has the biggest deleterious influence on cognitive performance. The discovery of the negative effects of high temperatures is a major driving force behind our emphasis on greater temperatures.

Increased temperatures can result in fuel hardship in a manner that has nothing to do with income or workforce efficiency. Increased consumption for advanced energy equipment, notably cooling systems, may result from more regular extreme temperature. Energy expenditures as a percentage of total household income rise for households with air conditioners and the ability to satisfy their greater energy needs. This increases the chances of being in a state of energy scarcity. Households that are incapable to fulfill their cooling requirements (due to a shortage or the inability to buy current energy services) are more probable to experience diminished labor productivity. This is because workers have been demonstrated to effectively mitigate the impacts of severe temperatures on labor efficiency with the help of air conditioners (Tang et al. 2016). When compared to homes who have access to contemporary energy services, temperature extremes may help to exacerbate their already prevailing drawback.

(Dell et al. 2014; Scott and Greenhill 2014; Sadath and Acharya 2017) Extremely warm temperatures, according to the literature (Alkire and Foster 2011) cause higher energy demand and consumption.

We distinguish our paper from these other works in two ways. To begin with, the majority of the literature focuses on industrialized nations. Outside of developed countries, little is known about the impact of weather on power requirements or usage. In this paper, we look into the relationship among fuel poverty and increasing temperatures in Vietnam, a nation that is especially vulnerable to both. It is one of the top five nations expected to be badly impacted by environmental catastrophes and global warming because of its terrain, size of population, and density of financial operations in coastal regions. Furthermore, present temperatures in some sections of the nation, like the Mekong Delta area, are previously at dangerous levels, so adding extra heat stress is possible to harm rice development and has an impact on fisheries The truth that numerous Vietnamese families depend largely on agriculture as their chief basis of earnings adds to the country's extreme sensitivity to climate change. It is believed that around 40% of all Vietnamese homes are affected. Moreover, despite Vietnam's fast financial transition in earlier decades, fuel inequality has been identified as a significant and determined impediment to the country's future economic progress (Hirvonen 2016).

Second, for instance, fuel poverty is concerned with the kind of power consumed (conventional bioenergy and hard energies vs contemporary power sources) and how these power sources may be replaced. Higher biofuel or fossil fuel-based energy usage would be regarded a "better" with regard to power intake, but a "becoming worse" of power deprivation reality. This difference is essential as strategies that modify the type of power used have very distinct ecological and climate strategy significance than policies that concentrate on the concentration or cost of power. Measures to promote higher power consumption, irrespective of the nature of energy utilized, have the ability to grow greenhouse production, increasing prospective fuel requirement. Apart from that, strategies that purposefully aim to substitute traditional power resources with innovative power resources can escape the response loop issue. As a sense, they may be able to assist in the attainment of ecological sustainable objectives (Linke et al. 2014; Jiang et al. 2016). For instance, regulations targeted at abolishing fuel poverty, such as the construction of extra power facilities, are expected to arise in minimal extra temperature rise to the climate—an effect that is controllable when weighed against the other advantages that an effective power inequality minimization strategy would deliver (Barua et al. 2020).

The survey data used has the particular advantage of allowing us to see both the "amount" and the "type" of energy use. We can also differentiate among various types of fuel utilized for various purposes, including cooking, heating, businesses, amusement, and telecommunication. As a conclusion, a multidimensional energy poverty index will be possible. Our MEPI is predicated on advances in the published literature on power poverty quantification, which highlights the influence of accounting for three areas of energy poverty: (1) the kind of energy usages; (2) fuel spending and usage; and (3) the long-lasting investments needed to process daily power-related objectives (Ike et al. 2020; de Lorena Diniz Chaves et al. 2021). The intensity of these adversity, which is predicated on the mean amount of energy-related metrics a family is excluded of. Renewable power deprivation metrics, which are explored in Section 4, are compared to our results using this selected indicator.

The Vietnamese scenario

This segment gives a quick overview of the two concerns in Vietnam that are at the heart of this article: the nation's sensitivity to climate jolts and the prevalence and type of fuel inequality among households.

The country is divided into four separate physical zones: central coast, south, central highlands, and the north, which vary significantly latitude-wise and hence in weather and climate patterns. The temperature in the north varies more throughout the year. Summer temperatures in the north range from 22.5 to 27.5 °C, compared to 15 to 20 °C in the winter. In the south, typical temperatures for these seasons are 28 to 29 °C, decreasing to 26 to 27 °C (Baulch et al. 2007).

The central coast's summers are hot and dry, with a short rainy season, but the central highlands' temperatures are substantially cooler. Vietnam is one of Asia's most disaster-prone countries, as well as one of the five countries most vulnerable to climate change (Nguyen et al. 2007).

The average yearly temperature in Vietnam has risen by 0.4 °C, with the south experiencing considerably greater increases (Tan et al. 2007).

The southern section of the country will have the greatest temperature spike, followed by the center area. The northern portion of the nation is predicted to be the least affected by climate change. The size of temperature changes grows as well. The consequences of climate change will be exacerbated since annual highs and lows are predicted to climb faster than usual. Every year, the temperature in Vietnam fluctuates dramatically. Furthermore, the uptrend line reveals that during the last 4 years, the temperature change in Vietnam has grown.

Temperature influences the energy demands of the home by needing heating and cooling, as mentioned in Section 2. Vietnam's energy consumption has expanded dramatically in recent decades. Because the Vietnamese government and international assistance donors invested so much in rural electrification, the population's use of electricity climbed from 14% in 1990 to 97% in 2010. Production has more than doubled in the same time span. Energy consumption is critical to Vietnam's economic development, and the government is working to lower energy rates. High-income families boost their electricity use by capping electricity costs for local customers (Su et al. 2009; Hertel et al. 2010) and implementing electricity tariffs. Please give it a rating.

However, a projected one million individuals remain deprived of electricity, mostly in the country's hilly north. The occurrence of energy poverty according to our four separate indicators reflect this. They reveal that, although patches of fuel poverty can be found in the south toward a minimal degree, area of Vietnam, the majority of cases occur in the north.

Just because a household has access to power does not mean they can afford to utilize it. Twenty-five percent of Vietnamese families said that their electricity consumption was inadequate to satisfy their needs in 2010. Rural families must utilize more power than is funded for the electricity to add value to alleviating poverty (50 kWh per month). Moreover, as discussed already, fuel poverty affects not just family accessibility to electricity but also the type of fuel utilized.

Data and methodology

Data

Data from two sources is used in this investigation. The Vietnam Household Living Standard Survey is the first. Since 2000, the VHLSS has been conducted biannually by the General Statistics Office of Vietnam, with technical assistance from the World Bank. Each wave sample has roughly 9000 homes and is a national representative sample for all provinces in Vietnam. The data include a tremendous quantity of household information, including demographic characteristics of household members, household income, expenditure, assets, housing, and access to services, with the goal of measuring living conditions across Vietnam. The poll uses a rotating panel of households and is not intended for long-term panel data analysis. The VHLSS from Christensen et al. (2007) and Srivastava et al. (2012) is the subject of our investigation. For two reasons, we do not use surveys. First (Van der Kroon et al. 2013), there has been a considerable change in data coding. Second, data on our key MEPI component—power usage—was unavailable.

Methodology

The causal influence of temperature jolts on fuel disparity is something we are interested in estimating. We take use of quasi-exogenous disparity, which occurs when families are subjected to temperature spikes. Our goal is to relate the effects of fuel poverty on inhabitants in Vietnam districts that are likewise probable to be subjected to temperature jolts.

The following model specification is estimated:

$$EP_{ict} = \beta_0 + \beta_1 Ts_{ct-1} + \theta'^{C_{ict}} + \mu_p + S_t + \mu_p x\gamma_t + \sigma_i + \varepsilon_{ict} \tag{1}$$

EP_{ict} denotes the amount of energy poverty experienced by household I in zone c during the year t (2010–2016). All previous fuel economy indicators are included in the primary specs, with the MEPI indicator being the most important. The thermal shock is the key explanatory variable (TSct1). To get the long-run regional average (1980–2009), divide the difference between the mean measurements of area c for the year $t-1$ (the year preceding the fuel economy index) by the long-run SD. As a result, we find that variations matter not just in absolute terms, but also departures from long-term trends. When the difference from the long-term mean surpasses two standard deviations, a thermal shock ensues.

We employ vector to regulate a variety of household and district factors. Time constant impacts (t) contribute for any common time pattern in fuel poverty throughout provinces, whereas province fixed effects adjust for time constant provincial degree characteristics that affect fuel poverty. To account for provincial-specific macroeconomic trends, it stands for the erroneous word. Standard mistakes are heterogeneity resistant and cluster at the district level.

After computing for spatial and temporal stable factors, along with province-linear time reaction, Eq. (1) assumes that temperature realizations are close to random. Of course, there is no guarantee that if a temperature shock had not occurred, the trends in an impacted province would have followed a comparable time-series tendency to those in an unmoved province. For instance, Vietnam's rapidly growing economy in recent decades is known to us, but the development trend was not the same in all provinces. Highly sensitive individuals are more prone to reside in regions that are more susceptible to temperature shocks if inhabitants are classified depending on these financial development features. We have attempted to solve the problem in two ways. One was to look at the linear time domain's fixed influence, and the other was to confine the investigation to a short time frame (2010–2016). In VHLSS, result shows summary data for household factors (appendix). The average proportion of energy-efficient dwellings in the sample is 19.5%, according to the MEPI technique. Between 2010 and 2016, males accounted for 75% of household heads, with an average age of 50. The average household consists of four individuals, and the reinforced concrete roof covers nearly half of the house.

$$\partial NI = \frac{\partial Sales}{Sales} \times (Sales - opex \times E_{opex}) \times (1-t) \tag{2}$$

$$\partial FFO = \partial NI + \partial Dep + \partial DT \tag{3}$$

$$\partial CFO = \partial FFO - \Delta CA \times E_{\Delta CA} + \Delta CL \times E_{\Delta CL} \tag{4}$$

$$\partial FOCF = \partial CFO - \Delta FA \big| E_{\Delta FA} \tag{5}$$

$$WC = CA + \left(\Delta CA | E_{\Delta CA}\right) - CL + \left(\Delta CL | E_{\Delta CL}\right) \tag{6}$$

$$\partial TA = \Delta CA \big| E_{\Delta CA} + \Delta FA \big| E_{\Delta FA} + OA = \Delta CL \big| E_{\Delta CL} + OL + FD + Eq + \Delta RE \big| \partial NI \tag{7}$$

where operating expenses counting the sold products are depicted by opex, D.T. refers to deferred taxes, t represents relevant tax rate, O.L. means other liabilities, O.A. is other assets, F.D. refers to financial debt, F.A. represents fixed assets, RE corresponds to retained earnings, and Eq is equity. We maintain O.A. and O.L. as consistent in the baseline year in our evaluation. We presume that no purchases are made and that no dividends will be distributed. As a result, the stock fluctuates as a result of retained income fluctuations. Likewise, F.D. will continue to be stable for the base scenario at the value of 2019. E with their particular subscribers captures the sensitivity of several factors in sales. We employ panel assessments in the given manner to compute these sensibilities.

To anticipate meteorological parameters on the network, data from base stations, satellites, balloons, and other sources with meteorological structures were combined to provide high-quality reanalysis data (Bauen et al.). The ERA5 data is transformed to a grid with a topographical resolution of 31 km and latitude and longitude of 0.25–0.25°. The temporal resolution of climate data can exceed the hour from January 1979 to now.

Energy poverty

This is particularly true in underdeveloped nations, where energy usage statistics may be scarce. Economic methods, quantitative methods, and subjective measurements are the three sorts of procedures. Table 1 summarizes each technology and discusses its advantages and disadvantages.

In this paper, the MEPI is our favored metrics. Fuel poverty is best analyzed using data on access to economical and sustainable power, as discussed in Section 2. The MEPI measures a variety of energy shortages in households. We define seven indices of energy poverty, which are organized into five main aspects founded on prior research and data accessibility for Vietnam: (i) Cooking, (ii) Lighting, (iii) Services, (iv) Entertainment/Education, and (v)

Table 1 Temperature shock effects on energy poverty

Dependent factor:	Energy poverty				
	10% measure	Low earning-high cost measure	Electricity measure	MEPI status	MEPI 3.marks
	(1)	(2)	(3)	(4)	(5)
Temperature shock	0.002	0.002	0.008	0.025**	0.012**
	(0.009)	(0.007)	(0.008)	(0.010)	(0.005)
Obs	36,238	36,238	36,238	36,238	36,238
R-sq	0.078	0.080	0.209	0.231	0.342
Additional controls	Yes	Yes	Yes	Yes	No
Province F.E	Yes	Yes	Yes	Yes	Yes
Year F.E	Yes	Yes	Yes	Yes	No
Province*linear time pattern	Yes	Yes	Yes	Yes	Yes
Survey time F.E	Yes	Yes	Yes	Yes	No

*** $p < 0.01$; ** $p < 0.05$; * $p < 0$

Communication are the five categories. A weight of 0.2 is allocated to each of the five dimensions. Table 2 lists the indicators, weights, and design parameters. Regrettably, almost half of the VHLSS family fails to fulfill electrical standards (K.W.). According to this article, energy use is a significant component of electrical poverty that must be taken into account when making estimates.

Each indication is binary, with a value of 0 or 1 indicating if the area is experiencing a family shortage. When it comes to the "cooking" criteria, a home is regarded very poor if it lacks access to clean energy (coal/coal/firewood/produce). We did not ask respondents to contribute this information to VHLSS, but we did replace the data on household cooking fuel spending with new data. A residence with an annual energy usage of less than 100 kW per person is also deemed poor, according to the concept of "lighting." In addition, to define fuel poverty, we utilize data on durable consumer items such as refrigerators, hot water tanks, air conditioners, televisions, and telephones. The MEPI is calculated by taking the total number of inequalities and averaging them. If a family's overall equalized inequality reaches 0.33, it is classified as a multidimensional poor family. This defines the family's MEPI level, with 1 indicating poverty and 0 indicating no poverty. In addition, to establish an MEPI rating for the household, the MEPI ranking is multiplied by the number of undervalued indicators. Finally, the MEPI score gives a multidimensional indicator of the degree of fuel poverty in disadvantaged families. This is how Alkire and his

Table 2 Temperature shock effects on MEPI across areas

	(1)	(2)	(3)	(4)
Areas	North	Central coast	Central highlands	South
Panel 1: Dependent factor is MEPI status				
Temperature shock	0.123**	0.043**	−0.012	0.021
	(0.049)	(0.020)	(0.039)	(0.022)
Obs	13,782	8138	2548	11,770
R-squared	0.329	0.170	0.317	0.138
Panel B: Dependent factor is MEPI score				
Temperature shock	0.053*	0.032***	−0.032	0.021*
	(0.031)	(0.010)	(0.022)	(0.011)
Obs	13,782	8138	2548	11,770
R-squared	0.444	0.271	0.408	0.253
Average temperature	23.386	25.264	24.663	28.004
Additional controls	Yes	Yes	Yes	Yes
Province F.E	Yes	Yes	Yes	Yes
Year F.E	Yes	Yes	Yes	Yes
Province*linear time trend	Yes	Yes	Yes	Yes
Survey time F.E	Yes	Yes	Yes	Yes

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

colleagues calculate poverty levels for the multidimensional poverty index, which is then used to create MEPI.

Temperature shock

Previous research have investigated a variety of temperature shock reduction techniques. Temperature variations were employed in this investigation to see whether there was an effect. In the literature, this strategy is extensively utilized. We begin by monitoring temperature before attempting to measure energy poverty.

This is how the temperature shock factor is described for a number of reasons. When compared to average volatility in the region, we feel that level shifts are more essential than absolute levels. Second, past research has demonstrated that severe temperatures can enhance reactivity to factors including energy consumption, labor productivity, and agricultural productivity loss. Temperature variations of more than 2 standard deviations, according to our findings, can have a major influence on agricultural productivity. The residuals of a logarithmic regression of agricultural productivity based on humidity and temperature are displayed. These residuals have an impact on the study's condition, time, and month. This means that when the temperature fluctuates by more than 2 standard deviations, the yield declines dramatically. In addition, for robustness testing, other impact assessments such as actual deviations (levels) and multiple deviation thresholds should be employed.

We underline the implicit consideration of adaptive response by evaluating temperature variations based on long-term averages. Because the region is used to hot weather, the consequences of significant temperature variations in southern Vietnam (relative to the long-term average) may be minor. Residents may have spent money on things like air conditioners to cope with the excessive heat. The short-term consequences of temperature shock may differ from the long-term effects of persistent temperature fluctuations of same magnitude as a result of this adaptation.

Furthermore, we created a region-specific temperature shock to explain why various geographic locations in Vietnam had varied baseline temperatures. As a result, unusual weather shocks in one section of the nation may be rather frequent in another, particularly if adaptation occurs. As a result, the range of temperature fluctuations should be calculated using the area's long-term average temperature.

Results and discussion

There are four components to our results section. We begin by providing our key findings before analyzing whether the temperature shock-energy poverty link is heterogeneous. We then conduct a series of robustness tests before looking into the processes through which temperature shocks can affect energy poverty.

Econometric analysis

The outcomes of Eq. (1) estimation are shown in Table 1. For simplicity, just the findings for the temperature shock factor, which is our major factor of concern, are displayed. Table 1 in the appendix contains the complete findings. It makes no difference. These findings are unsurprising, and they support the use of multidimensional energy metrics. The heat shock would not alter the evolution of the concept of energy poverty by 10% if the shock lowered household income but the family moved to a cheaper kind of energy. This is also true for the "poor income-high cost" indicators, which contain data on power rates. Similarly, if a household uses the same amount of power but spends less on other items, the impact will not immediately result in an increase in their electricity use.

A 2.5% upsurge in the likelihood of being multidimensional fuel-poor is linked to a temperature shock. By means of the uninterrupted indicator of MEPI only, it is also linked to a 1.2% upsurge in the intensity of fuel poverty. As previously stated, higher-than-normal temperatures can raise household bills, especially the power required to cool a home with a fan or air conditioner. Families can also switch from clean, contemporary energy to less expensive traditional energy, resulting in a variety of forms of energy poverty. Household income is reduced by declining agriculture production, labor shortages, or labor productivity. The energy poverty indicators of our choosing are status and MEPI score; hence, the remainder of this study will concentrate on these findings.

The coefficients on energy use only apply to specific families, as noted in Section 4. To see if this might generate sample selection issues, I imagined a binary dependent variable framework. The number will be 1 if data on residential energy usage is lacking; otherwise, it will be 0. With the help of an equation, make adjustments to this variable based on the thermal shock factor, and the control factor especially in the appendix summarizes the findings. Households with no energy consumption statistics are less likely (or less probable) to experience thermal shock,. We ran the framework with a full sample of families to disregard the consumption of MEPI energy and focus on the problem.

Inspecting heterogenous effects

We assumed that thermal shocks had the same impact on all Vietnamese households' multiform energy poverty. Nonetheless, depending on the climate trends and other topographical characteristics outlined in Section 3, temperature shocks may have distinct effects on households in various geographic regions. As a result, we run the model independently for each of Vietnam's four regions, utilizing Panel A and Panel B as dependent factors. Table 2 summarizes the findings. Rising temperatures in northern and central coastal areas considerably enhanced the prevalence and intensity of multidimensional energy poverty, according to the study. This suggests that residences in these areas are vulnerable to temperature shock and have limited response capabilities in the case of one. Furthermore, research suggests that heat shock is linked to greater MEPI points in southern families, but not to MEPI status.

Exercise of temperature shock

Furthermore, robustness testing does more thermal shock measurements. Three SD (standard deviations) in the long-term mean are indicative of thermal shock. Finally, compare the temperatures of the two levels (no impact threshold specified). As seen in Table 3, the results for many parameters are essentially the same. MEPI status and MEPI score rise in response to all thermal shocks, regardless of their degree or origin. Thermal shocks (defined as departures from the long-term mean of several standard deviations) had no effect. A 1 standard deviation temperature increase is fairly common in Vietnam (the incidence rate is 58%) and has no influence on agricultural production. Thermal shocks must thus reach a particular threshold in order to have an impact on the impacts of multidimensional energy poverty. Thermal shocks of moderate strength have minimal effect, according to our findings.Table 4 summarises the survey findings. Intriguingly, in all four regions, However, this has a negligible effect.Furthermore, there is evidence that hot days along the central coast andcentral highlands have an impact on poverty (MEPI score).

Thermal shocks are likely to have long-term effects on domestic. Households, for example, can withstand short-term consequences but not the long-term repercussions of income losses. Table 5 displays the results of moving the two- and three-period shock variables to investigate this issue. According to the statistics, the MEPI status and score were altered by thermal shock 2 years ago (although the effect was small). The influence did not appear to be working 3 years ago.

Then, to assess the identified robustness, we use another MEPI structure. We put the food weight to 0.4, the illumination to 0.3, the service, entertainment/education to 0.1, and the communication to 0.1 as an option. Cooking is one of the most basic human needs, so this makes logical sense (Reddy et al. 2000; Allison et al. 2009). In terms of severe health impacts produced by weather conditions and indoor

Table 3 Temperature shock

	(1)	(2)
Dependent factor:	MEPI status	MEPI score
1: Cutoff = 2.5 SD		
Temperature shock	0.074***	0.056***
	(0.018)	(0.011)
Obs	36,238	36,238
R-squared	0.231	0.343
2: Cutoff = 1.5 SD		
Temperature shock	0.016**	0.010***
	(0.008)	(0.004)
Observations	36,238	36,238
R-squared	0.231	0.342
3: Cutoff = 1 SD		
Temperature shock	0.007	0.004
	(0.008)	(0.005)
Observations	36,238	36,238
R-squared	0.231	0.342
Panel 4: Total days that are 2sd above long-run mean		
No. of hot days	0.001***	0.001***
	(0.000)	(0.000)
Obs	36,238	36,238
R-squared	0.231	0.343
Panel 5: Temperature deviation		
Temperature deviation	0.030***	0.020**
	(0.009)	(0.004)
Obs	36,238	36,238
R-squared	0.314	0.342
Additional controls	Yes	No
Province F.E	Yes	Yes
Year F.E	Yes	No
Province*linear time trend	Yes	Yes
Survey time F.E	Yes	Yes

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Household factors (age, sex, education level, family size, roof type) and geographical characteristics are also used as control measures (average rainfall and population density)

air pollution, traditional cooking equipment and fuels are quite expensive for households. Furthermore, instead of 0.33, a critical value of 0.5 is utilized to determine if home energy usage is inefficient. The information supplied backs up our conclusions.

Table 6 shows the degree of variation we discovered. The goal of this research is to see if the impacts of temperature shocks in Vietnam and Geneva differ between rural and urban families, as well as between significant ethnic minorities. This is accomplished through the use of interactive words. Thermal shocks exacerbate the multilayered poverty of rural households as compared to urban families, according to the findings (state and MEPI scores). Because rural communities

Table 4 Hot days by areas

	(1)	(2)	(3)	(4)
Areas	North	Central coast	Central highlands	South
Panel 1: Dependent factor is MEPI status				
Number of hot days	0.001*	0.003***	0.004***	0.001*
	(0.004)	(0.002)	(0.001)	(0.001)
Obs	13,782	8138	2548	11,770
R-squared	0.328	0.171	0.319	0.139
Panel 2: Dependent factor is MEPI score				
Number of hot days	0.001	0.002***	0.003***	0.000
	(0.001)	(0.000)	(0.001)	(0.000)
Obs	13,782	8138	2548	11,770
R-squared	0.443	0.273	0.410	0.253
Average number of "hot" days	11.994	15.952	17.652	22.632
Additional controls	Yes	Yes	Yes	Yes
Province F.E	Yes	Yes	Yes	Yes
Year F.E	Yes	Yes	Yes	Yes
Province*linear time trend	Yes	Yes	Yes	No
Survey time FE	Yes	Yes	Yes	No

*** $p<0.01$; ** $p<0.05$; * $p<0.1$

Table 5 Lagged effect of temperature shock on MEPI

	(1)	(2)
Dependent variable:	MEPI status	MEPI score
Panel 1: Shock calculated in (t − 2)		
Temperature shock	0.013*	0.009**
	(0.008)	(0.004)
Obs	36,238	36,238
R-squared	0.231	0.342
Panel 2: Shock calculated in (t − 3)		
Temperature shock	−0.002	0.002
	(0.008)	(0.004)
Obs	36,238	36,238
R-squared	0.231	0.342
Additional controls	Yes	No
Province F.E	Yes	Yes
Year F.E	No	No
Province*linear time trend	Yes	No
Survey time F.E	No	Yes

*** $p<0.01$; ** $p<0.05$; * $p<0.1$

In parentheses, there is a standard error. The standard errors are categorized at the regional level. Household factors (age, sex, education level, family size, roof type) and geographical characteristics are also used as control measures (average rainfall and population density)

Table 6 Heterogeneity tests

	(1)	(2)
Dependent factor	MEPI status	MEPI score
Panel 1: Urban vs. rural		
Temperature shock	0.008	0.002
	(0.011)	(0.005)
Temperature shock*rural	0.039***	0.024***
	(0.010)	(0.006)
Obs	29,874	36,238
R-squared	0.159	0.252
Panel 2: Kinh vs. minorities		
Temperature shock	0.032	0.019*
	(0.019)	(0.002)
Temperature shock*Kinh	−0.000	−0.019*
	(0.020)	(0.030)
Obs	29,874	29,874
R-squared	0.199	0.402
Additional controls	Yes	No
Province F.E	Yes	Yes
Year F.E	Yes	No
Province*linear time trend	Yes	Yes
Survey time F.E	Yes	No

*** $p<0.01$; ** $p<0.05$; * $p<0.1$

rely on agriculture for a living, and when agricultural output is disturbed, temperature shocks can have a substantial financial impact. When compared to ethnic minority households, the impacts of heat shock on Jin ethnic families are often modest. There is some evidence, however, that the effect has minimal impact on Kinn's MEPI score. Because they are located in the highlands and hills, these minority groups are particularly exposed to income shocks. They frequently lack basic infrastructure and services and are susceptible to revenue fluctuations.

Mechanism analysis

The mechanism whereby thermal shock causes multidimensional energy poverty is next investigated. The drop in household income is projected to be influenced by the drop in agricultural production and productivity. Using MEPI status and scoring variables, add these virtual mediators one by one to the baseline regression. If these parameters are the mediators linking thermal shocks to the rise in multidimensional energy poverty, statistically significant and better coefficients of determination should be predicted. Furthermore, because the negative impacts of the shock are mostly mitigated by household earnings and the loss of agricultural production, the component of the thermal shock coefficient is projected to be minor.

Reduced agricultural productivity, as shown in Table 7, can help alleviate the multifarious energy poverty induced by climatic shocks. The MEPI condition criteria and MEPI value have a negative adjustment factor, which is scientifically important, but the heat shock factor is nearly nil; therefore, the MEPI score lacks statistical validity. Thermal shocks have been shown to have a deleterious impact on agricultural crops in the literature. During seasons of low rainfall, for example, higher evaporation from plants and increased water demand can worsen drought and contribute to an increase in overall irrigation cost. Temperature rises have an impact on worker productivity, particularly

Table 7 Mechanism analysis of temperature shock and energy poverty

	Dependent factor: MEPI status			
	I	II	III	IV
Panel 1: MEPI status				
Temperature shock	0.022**	0.023**	0.024**	0.027*
	(0.011)	(0.010)	(0.010)	(0.016)
Total earning (in log)		−0.204***		
		(0.003)		
Earning per capita (log)			−0.226***	
			(0.003)	
Agricultural output (log)				−0.011***
				(0.001)
Obs	36,238	36,238	36,238	17,555
R-sq	0.126	0.285	0.277	0.212
Province F.E	Yes	Yes	Yes	Yes
Year F.E	Yes	Yes	Yes	Yes
Province*linear time trend	Yes	Yes	Yes	Yes
Survey time F.E	Yes	Yes	Yes	Yes
	Dependent factor: MEPI score			
	(1)	(2)	(3)	(4)
Panel 2: MEPI score				
Temperature shock	0.010	0.010**	0.011**	0.008
	(0.006)	(0.005)	(0.005)	(0.009)
Total earning (in the log)		−0.138***		
		(0.002)		
Earning per capita (log)			−0.154***	
			(0.002)	
Agricultural output (log)				−0.005***
				(0.001)
Obs	36,238	36,238	36,238	17,555
R-sq	0.189	0.423	0.414	0.301
Province F.E	Yes	Yes	Yes	Yes
Year F.E	Yes	Yes	Yes	No
Province*linear time trend	Yes	Yes	Yes	No
Survey time F.E	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

in weather-sensitive industries like agriculture. As a result, temperature shocks will lower agricultural revenues, exacerbating energy poverty. Surprisingly, overall income does not appear to be a mitigating influence. This might be owing to widespread underreporting of stated income, especially as those who rely on agriculture do most of their work outside of the public sector.

Robustness analysis

It is possible that a temperature shock will take some time to affect domestic energy poverty. For example, households can withstand short-term consequences but not the long-term repercussions of income losses. Delay the shock factors by 2 and 3 periods to study this problem, as indicated in Table 8. Thermal shocks had an influence on MEPI status and scores 2 years ago, according to data (albeit the impact was minor). The influence did not appear to be working 3 years ago.

Conclusion and policy implication

Based on solid panel-based survey statistics and exact climate data, we conclude that higher temperatures are a substantial provider to multidimensional fuel poverty in Vietnam. Temperature jolts cause families to sacrifice greener energy sources or advanced energy equipment, according to our findings. Traditional energy sources, on the other hand, are reliant on families to maintain a consistent percentage of overall energy spending. To completely comprehend the intricacy of energy shortages, it is critical to check the kind and amount of energy utilized. Furthermore, energy poverty has worsened by 1.2%. This result is unaffected by changes in temperature extreme thresholds, the use of various temperature intensity variables, sample decisions, and other model parameters. We determined that the impacts of high temperatures on the prevalence and intensity of multidimensional energy poverty are concentrated in Vietnam's northern and central coastal areas after analyzing these data across different topographical regions. This discovery is in line with earlier research, which suggests that these areas are vulnerable to global warming. Furthermore, we discovered that rural families had a greater influence than city dwellers. This is reasonable considering that rural populations rely on agriculture for their livelihoods, and climate change has a considerable influence on agricultural productivity.

Table 8 Robust test (lagged impact of temperature shock on MEPI)

	(1)	(2)
Dependent factors:	MEPI status	MEPI score
Panel 1: Shock calculated in (t − 2)		
Temperature shock	0.015*	0.010**
	(0.009)	(0.006)
Obs	36,240	36,240
R-sq	0.233	0.347
Panel 2: Shock calculated in (t − 3)		
Temperature shock	− 0.004	0.003
	(0.009)	(0.006)
Obs	36,240	36,240
R-sq	0.233	0.343
Additional controls	Yes	No
Province F.E	Yes	Yes
Year F.E	Yes	No
Province*linear time trend	Yes	Yes
Survey time F.E	Yes	No

*** $p<0.01$; ** $p<0.05$; * $p<0.1$

Reduced food production may be the temperature increase method that affects fuel shortages, according to research into the process. Because family income data might be unreliable, money cannot be identified Regrettably, we were unable to include this in our survey.

Many additional countries, notably those in Southeast Asia, are expected to benefit from the findings of this study. They bring up an amount of points for representatives to think about. Considering the relationship among global warming and temperature spikes, the international society must step up measures to reduce carbon dioxide production to limit potential temperature spikes. Two wide policy proposals work at the national level. To begin with, tailored policy interferences are most possible to be the most effective. Households in Vietnam's north and central coast areas have the highest prevalence and depth of multidimensional energy poverty. They are also the most vulnerable to the effects of temperature shocks. The families in these areas are the ones who need help the most.

Policy implication

I Policies paper of Vietnam has made significant advancement in giving families adequate electricity. It does not mean that they can pay to use it. In Vietnam, energy poverty is still prevalent, and some families still depend largely on old-fashioned power sources including biomass and coal. Furthermore, our data imply that families avoid using greener energy sources or newer power equipment as an outcomes of temperature shocks. It is consequently vital to cut the cost of power for impoverished households in order to reduce multidimensional energy poverty. This might be accomplished by providing aids or money allocations to energy-insecure families, which could be accompanied by more broad-minded electricity charges.

II Using blinds and energy-efficient appliances, which will boost household resistance to temperature shocks.

III Establishing picture of the necessitates an awareness of the many impacts of increased temperatures. The average global temperature is growing, as is the occurrence of really scorching days. The fact that increased temperatures can cause homes to be more power needy in the short term is merely the beginning of the global warming effect chain. Lack of availability of clean and inexpensive power can result in worsened health, reduced earnings, and increased environmental destruction. Climate change's long-term and knock-on consequences, as well as the mechanisms that underpin them, are major areas of continuing research.

Author contribution NDC: conceptualization, writing—original draft. NVS: writing—literature review. TDT: software. DVT: visualization. TVH: methodology. NTMP: supervision. NTXH: data curation. PTLP: editing.

Data availability The data that support the findings of this study are attached.

Declarations

Consent to participate It can be declared that there are no human participants, human data, or human tissues.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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