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A Comprehensive Analysis of the Dynamic Space-time Impacts of Climate Change on Poverty in Egypt

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ECONOMIC RESEARCH FORUM 30 years

منتدى البحوث الاقتصادية

2024

A comprehensive analysis of the dynamic space-time impacts of climate change on poverty in Egypt

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Abstract

This paper explores the relationship between climate conditions and poverty in Egypt at a sub-national level, considering various factors and estimation techniques. Using a functional data analysis (FDA) this paper explores the long-term effects of summer, winter temperature and precipitation on poverty across Egypt. FDA results highlight the evolving relationship between temperature changes and poverty, emphasizing the heightened influence of summer temperature on poverty rates over the past three decades. Additionally, the contrast in temperature dynamics before and after 1985 emerges as a significant predictor. With the aid of geographically weighted regression modelling, distinct patterns in different areas of the relationship between climate and poverty are revealed, with urban areas demonstrating more resilience and rural regions facing increased vulnerabilities. The paper contributes to understanding the climate-poverty nexus and emphasizes the need for tailored strategies at the local level for climate resilience and poverty alleviation.

JEL-Classification: C21, I30, Q51

Keywords: Climate Change, Egypt, Functional Data Analysis, Geographically Weighted Regression, Poverty

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1. Introduction and Background:

In response to the escalating threats of climate change, a substantial body of research has emerged across various sectors such as agriculture (Birkman et al, 2022; Hallegate and Rozenberg, 2017; Jacoby et al, 2011; Kandeel, 2019; Schlenker and Roberts, 2009; Tull 2020), human health (Deschênes and Greenstone, 2011; Elayouty et al. 2022) and labor productivity (Abou-Ali et al., 2022; Skoufias et al, 2011; and Somanathan et al., 2021). The central concern evolves around the potential impact of climate change on economic growth and its subsequent implications on poverty, highlighting the importance of understanding the dynamics of this relation (Diffenbaugh and Burke, 2019; Hsiang et al, 2019; Lankes et al. 2022; Newell et al. 2021). The relationship between poverty and climate change is bidirectional. Poor households, with limited resources, face heightened vulnerability to climate-related shocks, while poverty can drive activities intensifying climate change (Birkman et al, 2022; Lankes et al, 2022). Factors governing this relationship include social, economic, and institutional elements, with consistency in the poverty-climate link highlighted by Awad and Warsame (2022).

A warming climate is expected to affect the availability of and accessibility to necessities, such as food, fresh water, and energy (Dagnachew and Hof, 2022). Individuals with lower economic means are likely to encounter greater challenges in dealing with and recovering from extreme climate events, disrupters, and crises, such as epidemics, economic downturns, health hazards and natural disasters. The impacts of climate change on household welfare demonstrate intricate variations, particularly evident within a single country and exacerbated in regions experiencing pre-existing poverty and health inequalities. This scenario is pertinent in countries like Egypt. Effectively addressing the interrelationship between climate change and poverty requires comprehensive strategies that acknowledge their inherent linkages. These approaches must be adapted to the specific socioeconomic, environmental, and health dynamics of each region. Only through such tailored approaches equitable progress can be achieves steering countries toward a sustainable future. Recognizing the unique challenges faced by vulnerable populations is crucial for developing interventions that not only mitigate climate-related risks but also uplift communities economically and enhance their resilience in the face of multifaceted adversities.

Global warming and adverse climate conditions exacerbate poverty through various channels, affecting land, labor, and food prices, leading to health crises and economic losses (Assunção and Chein Feres, 2009; Jacoby et al, 2011; Skoufias et al, 2011). Climate-related shocks, like floods and droughts, disproportionately impact poor households, prompting coping strategies that perpetuate poverty (Hallegate and Rozenberg, 2017). Agriculture, a key sector for poor households, is highly vulnerable to climate-related shocks, threatening local production, employment, and food security. Climate change contributes to intergenerational poverty transmission, impacting women economic opportunities and children's development. Moreover, policies such as carbon pricing, designed to mitigate climate change, may raise energy and food costs, potentially increasing poverty. The redistributive nature of such policies influences their impact on poverty rates (Kandeel, 2019; Tull 2020; Lankes et al, 2022). In addition, the impacts of climate change are not evenly distributed across countries and within the one country, in the sense that the less affluent groups are possibly the ones to bear the most harmful consequences (Dang et al, 2023). Geographical disparities exist within the one country, with rural communities, dependent on agriculture, more susceptible to poverty due to climate-related shocks. Ignoring subnational variations could easily mask the dynamic effects of climatic conditions on poverty. Therefore, studying the effects of climate change on poverty using data at the district level within the one country can reveal the true effects of climate change on economic growth and helps in understanding the poverty roots in the context of environmental challenges (Azzarri and Signorelli, 2020; Garafa et al, 2021; Hansen et al, 2019; Soergel et al, 2021). In sum, a holistic approach considering these complex linkages is essential for addressing poverty and climate change challenges, ensuring sustainable and equitable progress (Lankes et al, 2022; Awad and Warsame, 2022).

The scarcity of empirical evidence on the global warming and poverty nexus can be attributed to the challenges of obtaining accurate measures (Dang et al, 2023). The significant variations in poverty within and across countries underscores the importance of more refined analysis that considers subnational variations (Damania et al. 2020; Kalkuhl and Wenz, 2020; Dang et al, 2023). This paper seeks to fill this gap by examining the correlation between climate conditions and poverty across Egypt. Despite contributing minimally to global CO2 emissions (less than 0.6%), Egypt is severely impacted by extreme weather due to its geographical location and arid climate. The vulnerability of the Nile River to heatwaves and rising sea levels compounds challenges for a population with a 30% poverty rate, ranking Egypt as the 87th most vulnerable nation to climate change (World Bank, 2021). The consequences of heatwaves extend across various sectors of the Egyptian economy, from water scarcity and biodiversity disturbance to tourism fluctuations to public health challenges.

The objective of this paper is to understand the long-term effects of climate change on poverty rates in Egypt and to disentangle the complex spatial dynamics between climate conditions and poverty across diverse geographical regions and household characteristics in Egypt. The paper contributes with fresh insights to the body of existing literature on the distributional effects of climate change, with a specific emphasis on understanding the impacts of both hot and cold temperature deviations, on poverty across Egypt. This research also seeks to understand and quantify geographical inequalities in the distribution of poverty, pinpointing areas most susceptible to environmental hazards.

Beyond its scholarly merit, this paper carries profound policy implications. By identifying specific geographic areas most vulnerable to climate change, policymakers can strategically channel resources and interventions in the fight against poverty. This research serves as a bridge between theoretical insights and actionable policy, enabling Egypt to make informed decisions that safeguard its marginalized citizens from the far-reaching impacts of climate change. The paper is organized as follows. Section 2 describes the data and Section 3 explains the analytical framework employed for studying the cumulative effects of temperature changes on poverty as well as the geographic disparities in the impacts of climate conditions on poverty across Egypt. In Section 4, the data analysis and modelling results are presented and discussed. Finally, Section 5 concludes with the main findings and policy recommendations and highlights important directions for further research.

2. Data:

The paper aims at offering insights into the dynamic implications of temperature fluctuations spanning the period 1950 to 2020 on poverty in Egypt. To achieve this objective, the paper relies on aggregated estimates of poverty as well as socio-economic characteristics at the second administrative (Kism/Shyakha) level across Egypt. These estimates are obtained from the 2019/2020 Egypt Household Expenditure, Income and Consumption Survey (HEICS). The Egypt HEICS presents a large database for the socio-economic and demographic differentials and provides a large amount of data for measuring the living standards of households and individuals and hence estimating poverty rates at various administrative levels. The data used in the study cover 365 subnational units across Egypt referred to as Kism in urban areas and Shyakha in rural areas. The poverty rate at a subnational unit is measured based on the national poverty line, set at 736 EGP per capita per month.

The socio-economic and demographic variables employed in this study include the percentage of individuals with secondary education or higher, the percentage of households residing in owned property, the percentage of female headed households, the average household size and an aggregated index reflecting the average percentage of household ownership of assets such as cars, fridges, microwaves, water heaters, air conditioners, motorbikes, bicycles, and washing machines at the second administrative level of the country (Kism/Shyakha).

To assess the relationship between climate change and poverty in Egypt, the above HEICS data are matched with monthly averages of $0.5^o \times 0.5^o$ climate gridded satellite time series data obtained from the Climate Research Unit (CRU) at the University of East Anglia. This climate data cover the period from 1950 to 2020 and are aggregated at the Kism/Shyakha level. The climate data are used to calculate the annual average maximum temperatures during summer and winter months, and annual total precipitation at each subnational unit.

All demographic and socio-economic variables exhibit large disparities across the country; see Table 1. The percentage of individuals with secondary education or higher across Egypt ranges between 0 and 66 percent, while the percentage of households living in owned flats extends between 21 and 99.7 percent and the percentage of female headed households varies from 0 to 90.42 percent. Figure 1 – panel (a) provides a geographical map of poverty across Egypt, which displays substantial variation of poverty ranging from below 20 percent in Greater Cairo and the Delta region to above 60 percent in Upper Egypt. Simultaneously, Figure 1 – Panels (b) and (c) depict spatial variation in temperatures across Egypt, with summer temperatures ranging from 31 to 42 degree Celsius and winter temperature from 19 to 25 degree Celsius. In general, temperatures are increasing towards the south of Egypt, whereas precipitation levels increase in the Delta and coastal regions; see Figure 1 – Panel (d).

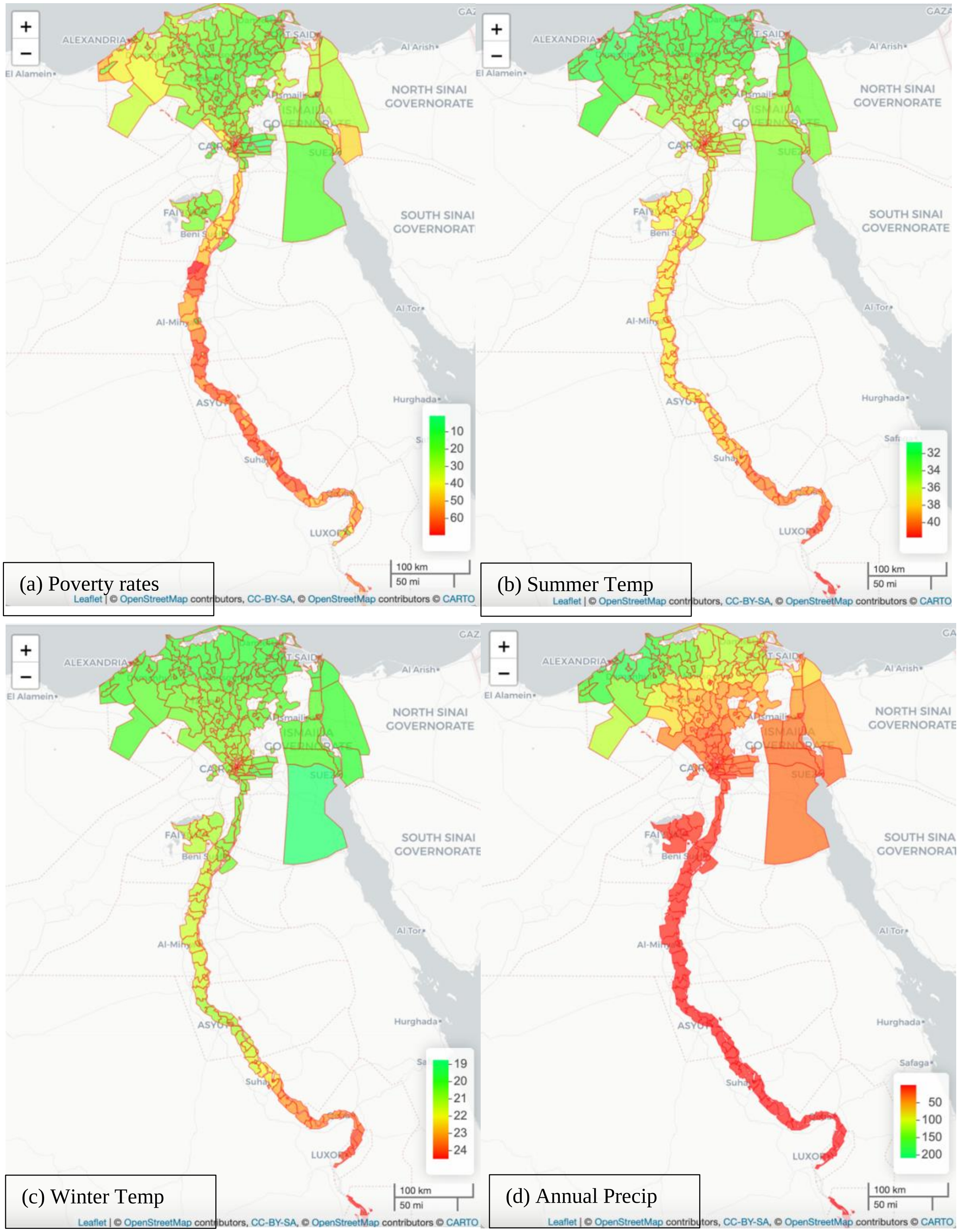

Figure 1: Map of poverty in percent (top left) and climate variables - average maximum summer temperature (top right), average maximum winter temperature (bottom left) and total precipitation (bottom right) across Egypt districts (second administrative level – Kism/Shyakha), excluding the frontier governorates.

Figure 2 illustrates a slight increasing trend in the average temperature in Egypt over the study period that is more pronounced in the summer months relative to the winter months. This sheds the light on the importance of examining the cumulative effects of changes in climate on economic growth and poverty at the subnational level of Egypt. The wide-ranging subnational variations in both poverty and climate conditions emphasize the importance of studying the relationship between global warming and poverty, recognizing that these dynamics may vary across different regions.

Table 1: Summary statistics of the response and explanatory variables

Variable	Min.	Q1	Median	Q3	Max.	Mean	St. dev
Poverty rate	1.03	16.71	22.45	34.68	69.43	27.29	15.52
Average max summer Temp	30.73	33.01	35.13	36.84	41.68	34.89	2.57
Average max winter Temp	18.78	20.00	20.67	21.14	24.45	20.78	1.12
Total Precipitation	0.39	10.80	31.40	83	2017.1	56.57	56.73
% Secondary education	0	30.94	37.60	41.89	66.10	34.60	12.13
% living in owned flat	20.82	72.08	90.02	96.80	99.71	82.18	18.39
% Possession	13.99	21.97	27.53	34.74	62.15	29.19	9.39
Average household size	2.05	3.79	4.01	4.23	4.86	3.99	0.38
% female headed households	0	12.08	14.86	18.75	90.42	19.93	18.39

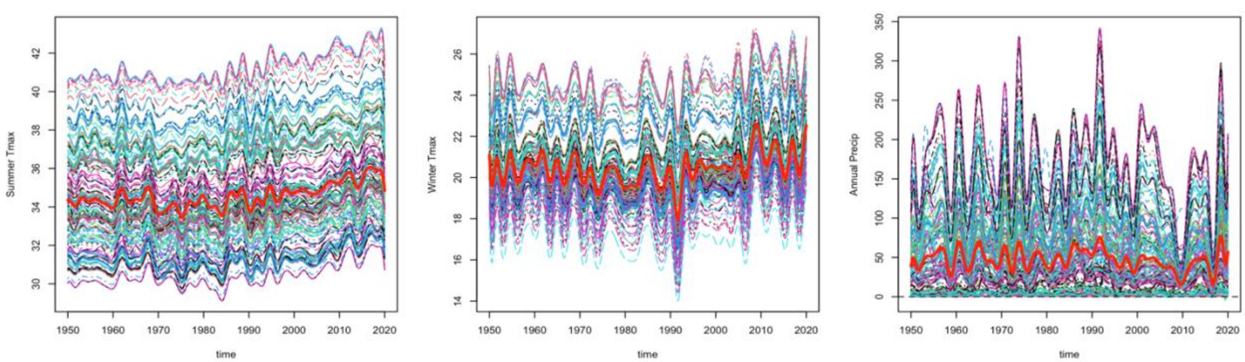

Figure 2: Temporal trends of summer temperature (left), winter temperature (middle) and precipitation (right) over the period 1950-2020 across the different districts (Kism/Shyakha) in Egypt along with the overall mean in red.

3. Methodology:

As mentioned above, this paper pursues two main objectives. The first objective is to understand the cumulative temporal impacts of global warming over the period 1950-2020 on poverty in Egypt. This analysis is conducted while controlling for several socio-economic and demographic variables known to influence poverty. The second objective involves investigating whether and how the impacts of climate conditions on poverty may vary spatially within Egypt, discerning differences from one region to another.

To analyse the cumulative impacts of climate and the pattern of temperature variation through the period 1950 to 2020 on current poverty rates in Egypt, a functional linear model is employed. In this model, poverty serves as the scalar response and climate profiles act as functional covariates. The methodology draws upon Functional Data Analysis (FDA), as a field of statistics that has received much attention in the last two decades. This approach proves to be one very useful technique for the analysis of data collected as multiple time series, providing a sensible alternative to panel data analysis. In FDA, each time series is viewed as one realisation of a continuous smooth function. Hence, the fundamental idea of FDA is to express discrete observations arising from a time series in the form of a smooth function. This representation encapsulates the entire measured function as a single observation, enabling a more nuanced understanding of the complex dynamics between climate variables and poverty over the specified time frame.

In this paper, a fundamental unit of interest is the entire smooth function of climate variable (summer temperature – winter temperature - precipitation) over the period 1950 – 2020. Following from this, the first step in the analysis involves constructing smooth functions or climate profiles from the discrete annual climate measurements obtained for each Kism/Shyakha, using a basis function expansion. This makes 365 continuous functions, for each of the summer mean annual temperature, winter annual mean temperature and total annual precipitation, that can be expressed by the following linear combination:

$$x_{ji}(t) = \sum_{k=1}^{K_j} c_{jik}\, \phi_{jk}(t) = \boldsymbol{c}_{ji}^{\top}\boldsymbol{\phi}_j(t), \quad j = 1,2,3 \; and \; i = 1,2,\ldots,365$$

where $\boldsymbol{\phi}_j(t) = \left(\phi_{j1}, \dots, \phi_{jK_j}\right)^\top$ is the vector of K_j basis functions used to approximate the profiles of the j-th climate variable and $\boldsymbol{c}_{ji} = \left(c_{ji1}, \dots, c_{jiK_j}\right)^\top$ is the corresponding vector of basis coefficients to be estimated for the i-th subnational unit (Kism or Shyakha) and j-th climate variable using the least squares method. The functions/profiles of a certain variable share the same basis functions, but different variables may have different basis functions based on the nature and the characteristics of the variable. There are multiple choices for the basis functions including polynomials, splines, Fourier series and wavelets (Ramsay and Silverman, 2005). In this paper, cubic B-splines, which are characterized by their flexibility and computational efficiency are used for approximating the profiles of the 3 climate variables. However, different degrees of freedom and complexities are permitted for the basis system of each variable.

After obtaining the climate profiles for each Kism or Shyakha, a functional linear model with scalar response and a mix of scalar and functional covariates are fitted. The model regresses the poverty rates on the climate profiles, in addition to other socio-economic and demographic explanatory variables, and can be formulated as follows:

$$Y_i = \beta_0 + \int_t \beta_1(t) STemp_i(t)\, dt + \int_t \beta_2(t) WTemp_i(t) dt + \int_t \beta_3(t) Precip_i(t) dt + \sum_j \gamma_j z_{ji} + \epsilon_i, \quad \epsilon_i \sim N(0, \sigma^2)$$

where Y_i is the poverty rate in area i, $STemp_i(t), WTemp_i(t)$ and $Precip_i(t)$ are the smooth summer temperature, winter temperature and precipitation profiles over the period 1950-2020 for area i and z_{ji} are the scalar covariates including the socio-economic and demographic characteristics for area i and ϵ_i is the random error. In the above model, $\beta_1(t), \beta_2(t)$ and $\beta_3(t)$ are the functional regression coefficients measuring the cumulative effects of the climate variables' profiles on poverty and γ_j are the coefficients of the scalar explanatory variables in the model. The functional regression coefficients are expressed in terms of a basis functions expansion and estimated using the penalized least squares method. More details about the estimation of this model are provided by Ramsay and Silverman (2005).

To achieve the second objective of the paper, the geographical differences in poverty are modelled in a way that allows the relationship between the percentage of poverty and the different climatological and socio-economic variables at the Kism/Shyakha level to flexibly vary from one area to another. This can be performed using the Geographically Weighted Linear Regression (GWR) model, introduced by Brunsdon et al. (1996), given by

$$Y_i = \alpha_0(u_i, v_i) + \sum_{k=1}^{p} \alpha_k(u_i, v_i)\, x_{ik} + \varepsilon_i,$$

where (u_i, v_i) are the geographical coordinates of location i within the region $D \in R^2$, that can possibly be the coordinates of the district's centroid, and ε_i is the error term with mean zero and common variance σ^2. α_k's are the local regression coefficients at location i, estimated using the geographically weighted least squares method on a pointwise basis using kernel-based methods. That is, the $(p+1) \times 1$ coefficients vector $\widehat{\boldsymbol{\alpha}}(u_i, v_i)$ at the point of geographic coordinates (u_i, v_i) is estimated by minimizing a weighted sum of squares resulting in the following estimate:

$$\widehat{\boldsymbol{\alpha}}(u_i, v_i) = \left(\boldsymbol{X}^T \mathbf{W}_{(u_i,v_i)} \mathbf{X}\right)^{-1} \mathbf{X}^T \mathbf{W}_{(u_i,v_i)} \mathbf{Y},$$

where $\boldsymbol{X}$ is the $n \times (p+1)$ design matrix and $\mathbf{W}_{(u_i,v_i)}$ is an $n \times n$ weighting diagonal matrix that contains the weight of each observation $j = 1, \dots, n$ according to its distance to the regression point i with coordinates (u_i, v_i). The observations closer to point i are assumed to have more influence over the estimated parameters at location i than more remote observations, and hence the weights' values in the matrix decrease as the distance to the point i increases. The decrease in the weight of each observation with the distance to the regression point i is determined according to a weighting kernel function $K(.)$. Among the most popular continuous weighting kernels is the Gaussian Kernel defined as follows:

$$K(d_{ij}) = \exp\left(-\frac{{d_{ij}}^2}{2h^2}\right),$$

where d_{ij} is the distance between the locations of observations i and j, and h is the kernel bandwidth defining the extent beyond which the weight is minimal that is chosen based on goodness of fit criterion such as the Akaike Information Criterion (AIC).

4. Results and Discussion:

The analysis started by examining the long-term effects of climate change on poverty across Egypt by fitting the above functional linear model with the Kism/Shyakha average poverty rate as the response variable. Figure 3 visually represents the estimated average cumulative impacts of summer temperature, winter temperature and precipitation on poverty in Egypt. The results indicate that the summer temperature is positively associated with poverty rates and that the effect of summer temperature on poverty have been increasing significantly over the past three decades. In contrast, colder temperature exhibits a negative effect on poverty. These results are consistent with those of Dang et al. (2023) based on subnational data from 134 countries. The estimated effects of temperature indicate that an increase in the average summer temperature by a one-degree Celsius increases the percentage of poverty by an average of 4% across Egypt. Conversely, a one-degree Celsius decrease in winter temperature in Egypt is associated with between 4% and 6% average increase in poverty rate, a trend that appears to be on the rise in recent years. It is also evident that the contrast between both the average summer and the average winter temperature before and after 1985 is a significant predictor of the poverty rates across Egypt. As for precipitation, its effect on poverty is mainly negative but minimal relative to temperature effects. This result is expected since Egypt is generally not characterized by large amounts of rainfalls.

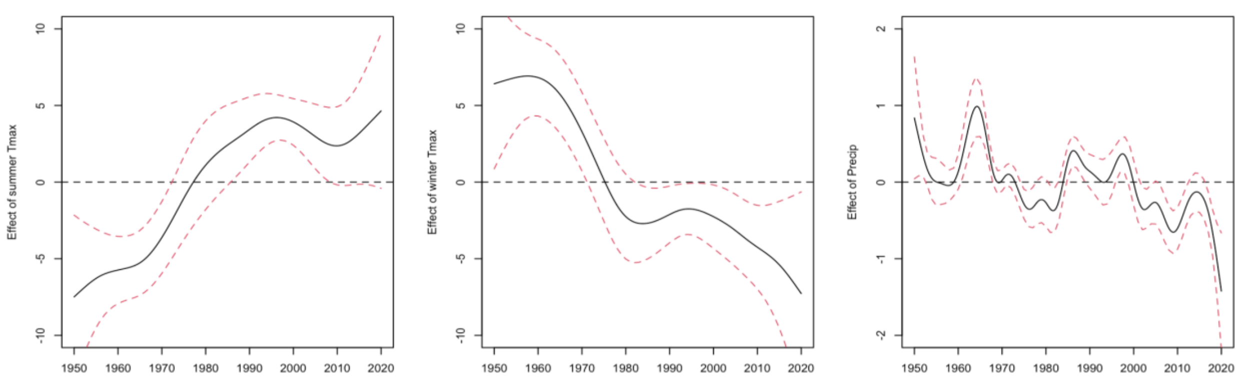

Figure 3: The estimated regression coefficients reflecting the effects of summer temperature, winter temperature and precipitation on the poverty rates across Egypt, along with 95% confidence intervals.

The remaining model results regarding the other scalar variables and their significance are displayed in Table 2. The results indicate that the poverty rate within a certain district is significantly inversely related with the average percentage of individuals with assets such as cars, fridges, microwaves, air conditioners, motorbikes, and washing machines in the same area. Another notable observation that aligns with expectation is the significant rise in the average percentage of poverty as family size increases. The other socio-economic variables in the model are negatively correlated with poverty but they do not seem to exhibit significant relationships with the presence of the other variables in the model. Overall, the fitted model represents a good fit to the data as shown in Figure 4 depicting the observed versus the fitted values. The comprehensive examination of these scalar variables provides valuable insights into the relationship of socio-economic factors influencing poverty dynamics in Egypt. The nuanced relationships revealed in the model contribute to a more holistic understanding of the multifaceted determinants of poverty.

Table 2: Estimated regression coefficients of the scalar covariates in the functional linear model.

Variable	Coefficient Estimate	Standard Error	Lower Limit of 95% C.I.	Upper Limit of 95% C.I.
Intercept	0.3947	0.5417	-0.6887	1.4781
% Secondary education	-0.0016	0.0009	-0.0035	0.0003
% living in owned flat	-0.0006	0.0006	-0.0017	0.0005
% Possession	-0.0043	0.001	-0.0063	-0.0023
Average household size	0.2115	0.0246	0.1623	0.2607
% female headed households	-0.0005	0.0007	-0.0019	0.0008

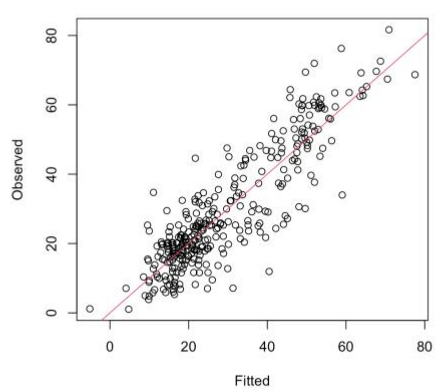

Figure 4: A scatter plot of the observed poverty rates versus the corresponding fitted values from the functional linear model.

The model outlined above assumes constant relationships between response and covariates across various districts in Egypt. However, this assumption might not hold true due to the wide-ranging disparities in environmental conditions and substantial heterogeneities in socio-economic variables across different regions in Egypt. Recognizing this, a geographically weighted regression (GWR) approach is adopted. This approach allows for the acknowledgment of the variations in response-covariate relationships across different geographical areas, enabling a more accurate representation of the complex dynamics underlying poverty's relationship with environmental and socio-economic factors.

GWR model effectively accounts for approximately 70% of the variability in the percentage of poverty across Egypt. It is important to note that the model was applied after excluding the frontier governorates, ensuring a focused and accurate analysis. Visual representations of the coefficients' geographic distributions are presented in Figures 5 and 6. Figure 5 - Panel (a) illustrates disparities in the connection between summer temperature and poverty across Egypt. Upper Egypt, namely Asyut, Al-Minya, and Benisuef, experiences hotter and drier climates compared to Greater Cairo, contributing to immediate and pronounced impacts on livelihoods, especially for vulnerable populations. Agricultural activities, prevalent in Upper Egypt, are sensitive to temperature fluctuations, further affecting income and poverty rates. Greater Cairo, as a major urban hub, benefits from enhanced infrastructure, services, and economic diversification, providing a buffer against temperature shocks (Jacoby et al, 2011; Angelson and Dokken, 2018).

Panel (b) of Figure 5 reveals a negative correlation between average winter temperatures and poverty. Urban settings, particularly in Greater Cairo, demonstrate this inverse relationship, indicating the impact of urbanization on poverty dynamics. Urban areas typically offer better access to services, employment opportunities, and resources, contributing to improved living conditions and lower poverty rates. Regional disparities in poverty and vulnerability are influenced by governance and policy decisions. The literature shows that social policies play a significant role in mitigating the adverse effects of climate hazards (Garafa et al, 2021). The implementation of social safety nets and targeted poverty alleviation programs can vary between regions, impacting their resilience to climate variation. Panel (c) of Figure 5 highlights limited variability in the impact of precipitation on poverty across Egypt, attributed to the low rainfall across Egypt. Figure 6 illustrates the negative correlation between socio-economic variables and poverty, with variations across regions. Greater Cairo and the delta region exhibit a subdued influence, potentially due to higher urbanization levels moderating the relationship between socio-economic factors and poverty.

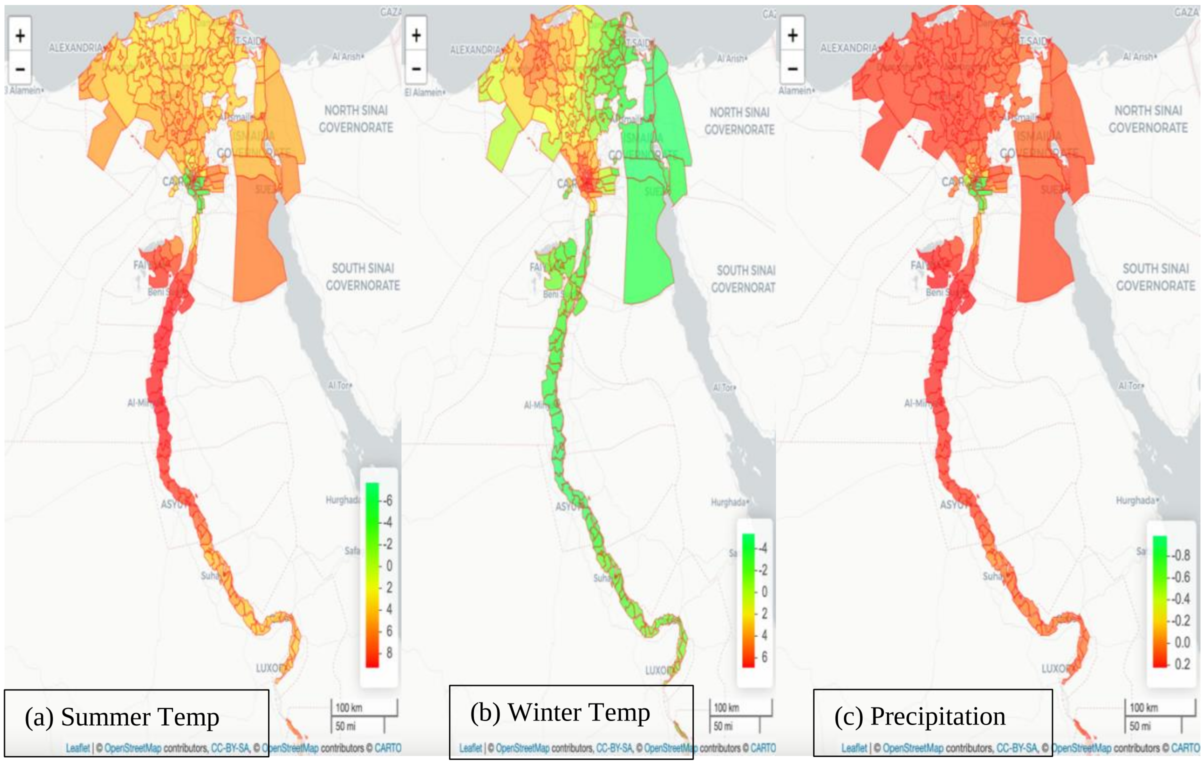

Figure 5: Map of the coefficient estimates of climate variables - average maximum summer temperature (top left), average maximum winter temperature (top right) and total precipitation (bottom left) - obtained from the GWR fitted to the data of Egypt, excluding the boundary governorates.

As for average household size in Panel (d) of Figure 6, a positive relationship with poverty holds true across the country, intensifying in Upper Egypt. This can be attributed to a combination of socio-economic, demographic, and geographic factors unique to the region, such as traditional family structures, limited access to job opportunities, and larger rural and agricultural communities. These interrelated factors underscore the complex relationship between socio-economic dynamics and regional disparities in poverty across Egypt. Understanding these nuances is crucial for targeted and effective policy interventions aimed at reducing poverty and enhancing resilience in the face of environmental challenges. It is essential to recognize that the above factors are interrelated, potentially reinforcing each other, thereby culminating in the observed pattern where the influence of socio-economic factors on the percentage of poverty becomes more pronounced in Upper Egypt. For instance, educational attainment emerges as a pivotal determinant of income and poverty levels, as evident in Figure 6 - Panel (a). In regions with lower educational levels, families may possess limited awareness of family planning methods and the potential advantages of smaller family sizes. This can result in larger household sizes, which in turn can strain available resources and contribute to higher poverty percentages. Such interrelations can be masked if the geographic location is not accounted for.

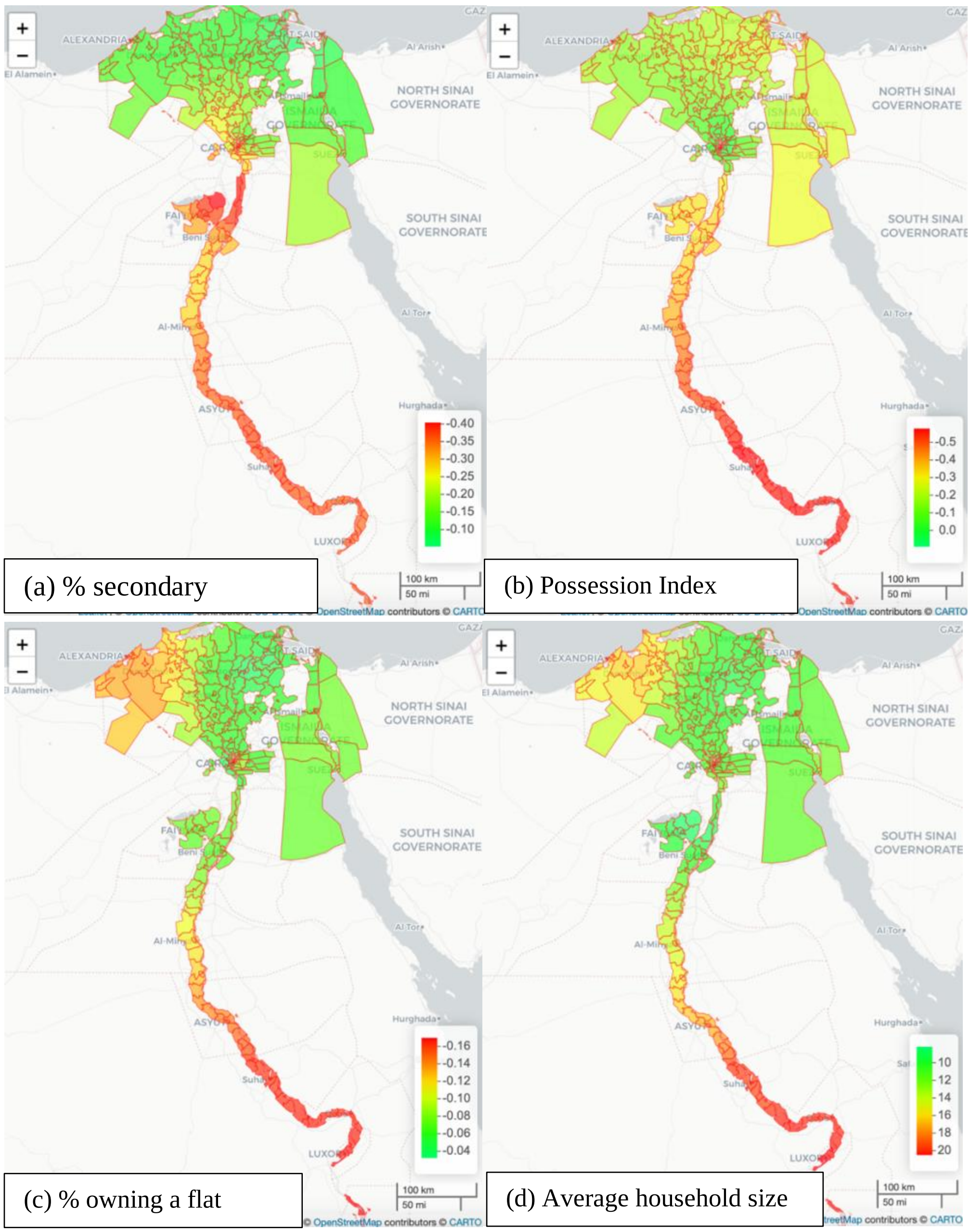

Figure 6: Map of the coefficient estimates of socio-economic and demographic variables – percentage of individuals with secondary education (top left), average possession index (top right), percentage of

households owning a flat total (bottom left) and the average household size (bottom right)- obtained from the GWR fitted to the data of Egypt, excluding the boundary governorates.

5. Conclusions

Egypt, facing the challenges of extreme weather due to its geographical location and arid climate, stands at the crossroads of climate vulnerability and poverty. The Nile River, vital to the nation, is susceptible to heatwaves and rising sea levels, compounding challenges for a growing population with a significant poverty rate. In the face of escalating climate change threats, understanding its complex relationship with poverty is essential. This paper contributes to the existing literature by exploring the relationship between climate conditions and poverty at a subnational level in Egypt. By utilizing data spanning from 1950 to 2020, the study employs a functional linear model, incorporating Functional Data Analysis (FDA), to disentangle the cumulative temporal impacts of global warming on poverty rates. The analysis also investigates spatial variations, recognizing the diverse socio-economic and environmental dynamics across different regions in Egypt.

Key findings indicate that rising summer temperatures are positively associated with poverty rates, with a notable increase in the last three decades. Conversely, colder temperatures exhibit a negative impact on poverty. Precipitation, while having a mainly negative effect on poverty, proves minimal relative to temperature variations. The relationships between climate variables and poverty are further highlighted through a geographically weighted regression (GWR) approach, capturing the nuances across different geographical areas. This model shows the vulnerability of North Upper Egypt relative to Lower Egypt and the Delta region to climate warming, especially to increases in summer temperatures. By identifying specific geographic areas most vulnerable to climate change, policymakers can strategically channel resources and interventions to combat poverty effectively.

Developing and implementing localized climate mitigation strategies, including measures to address rising summer and falling winter temperatures that consider the distinct climate conditions in various regions, is essential. Policymakers must consider unique challenges in different regions and across time to design timely interventions that enhance adaptability and reduce vulnerabilities to address the climate change-poverty nexus. Policies should address educational attainment, asset ownership, and housing status, focusing on regions with lower development levels. Public awareness campaigns and educational programs should be implemented to inform communities about climate change, its potential impacts on poverty, and adaptive measures. Increasing awareness can empower communities to adopt sustainable practices, mitigate climate risks, and actively participate in resilience-building initiatives.

Bridging theoretical insights with actionable policy recommendations, this study guides policymakers in formulating targeted and effective strategies and to make informed decisions that safeguard Egypt marginalized citizens from the far-reaching impacts of climate change. In conclusion, this paper underscores the critical need for a holistic approach that considers the complex spatio-temporal linkages between climate conditions and poverty. By doing so, Egypt can pave the way for sustainable and equitable progress, ensuring the well-being of its population and enhancing resilience in the context of environmental challenges.

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