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Climate Change Impacts on Household Income in Pakistan: An Empirical Analysis

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Abstract

As climate change continues to pose a significant challenge globally, this study examines its impact on household income, delineating the differential impacts across agricultural and non-agricultural sectors in Pakistan. Utilizing household data from 2020 for 156,440 households across 126 districts of Pakistan, along with climate variable data spanning from 1961 to 2020, the research employs multiple regression analysis with robust standard errors to explore these impacts. The findings reveal that changes in the mean values of temperature and precipitation, as well as the variability of these climate variables, have a statistically significant impact on household income. Specifically, a one-degree Celsius rise in average temperature leads to a 3.3% decrease in income for households in the agricultural sector and a 0.4% decrease for those in non-agricultural sectors. The variability in temperature, indicated by a one-degree increase in its standard deviation, similarly results in a 4% income reduction for households across both sectors. Conversely, a one-decimeter increase in average precipitation is associated with a modest income increase of 0.33% and 0.19% for the agricultural and non-agricultural sectors, respectively. However, greater variability in precipitation adversely affects income in both sectors. The research highlights the vulnerability of households, especially those in agriculture, to climate change and shows non-agricultural sectors are also affected. It offers insights into climate change's economic impacts and suggests developing targeted policies to improve adaptation and resilience.

Keywords: *climate change, climate variability, household income, agricultural sector, Pakistan*

JEL Classification: I38, P36, Q54

1. Introduction

Climate change is a global challenge with profound implications for both natural and human systems. The repercussions of climate change are particularly acute for developing countries, where a significant portion of the population relies on climate-sensitive sectors such as agriculture for their livelihoods (Noack, 2015). Agriculture is highly vulnerable to climatic changes, as weather variables, including temperature and precipitation, are direct inputs into agricultural production (Deschenes & Greenstone, 2007). Many industries, such as textiles and food processing, are agro-based and either directly or indirectly linked to agriculture. Furthermore, many other sectors may also be affected because household consumer demand is dependent on agro-based income. Notably, climate change adversely affects both agricultural and industrial sectors, as its repercussions extend beyond the agricultural sector, influencing assets and workers' productivity through a variety of channels (Skoufias et al., 2011; IPCC, 2014). While the agricultural sector's vulnerability to climate change is well-documented, the impacts on non-agricultural sectors are less understood. Studies such as those by Dercon (2004) argue that climate

change has a broad economic impact, affecting not only agriculture but also manufacturing, services, and other sectors through complex channels.

Recent studies have increasingly focused on the economic vulnerabilities induced by climate change, highlighting the direct and indirect impacts on livelihoods. For instance, Hallegatte et al. (2016) discuss the pathways through which climate change exacerbates poverty, stressing the importance of analyzing the impact on household income. Among classes of welfare measures, income is considered the most important. As a result, examining the welfare implications of climate change across household and sectoral levels is critical. We need to understand more about the relationship between climatic and economic repercussions at the household level to quantify the effects of climate change. Furthermore, it is recognized that not only the mean values of temperature and precipitation but also the variability of these climate variables can have impacts on economic sectors (van der Wiel and Bintanja, 2021; Panda and Sahu, 2019).

Pakistan is one of the most vulnerable countries in the world to climate change (UNDP, 2015). According to the Global Climate Risk Index 2021 report, Pakistan has been ranked as the eighth most affected country in the world (Eckstein et al., 2021). As a predominantly agrarian economy, Pakistan is highly vulnerable to the adverse effects of climate variability. This vulnerability underscores the need for an in-depth examination of how climate change impacts household income across different economic sectors. Climate variability, particularly in terms of temperature and precipitation, has garnered significant global attention due to its continuous increase and detrimental effects on agriculture (van der Wiel and Bintanja, 2021; Panda and Sahu, 2019).

Previous studies have explored the relationship between climate conditions and household income, generally revealing adverse effects from heightened temperatures (Palanisami et al., 2008; Mendelsohn et al., 1994, 1996; de Medeiros Silva et al., 2019). Some investigations have delved into the influence of average climate variables on income, indicating that certain weather factors pose an increased risk (Isik and Devadoss, 2006; Ranganathan, 2009; McCarl et al., 2008). Despite the growing body of literature on the economic impacts of climate change and climate variability, there remains a gap in sector-specific analyses, especially in the context of Pakistan. This study aims to fill this gap by examining the differential impacts of climate change and climate variability on household income across agricultural and non-agricultural sectors in Pakistan. By utilizing household-level data from 2020 for 156,440 households across 126 districts and climate variable data from 1961 to 2020, this research employs a multiple regression analysis to explore the nuanced impacts of climate change.

The rest of the paper is organized as follows: Section 2 presents the literature review, while Section 3 describes the data and specifies the empirical model. Section 4 presents and discusses the results. Finally, Section 5 concludes with policy implications.

2. Literature Review

The Intergovernmental Panel on Climate Change defines climate change as “a statistically significant variation in either the mean state of the climate or in its variability, persisting over a wide range of time scales” (IPCC, 2001). Consequently, climate change refers to a shift in the average, standard deviation, and occurrence of extremes in climate parameters like precipitation and temperature that has been documented for at least 30 years. These are termed “long-term phenomena”, while anomalies (deviations from long-run averages) are termed “short-term phenomena”.

Climate change affects agricultural and industrial production negatively. Its effects are not limited to agriculture but also have adverse impacts on assets and workers’ productivity (Skoufias et al., 2011; IPCC, 2014). Climate change poses major threats to household incomes, especially in developing

countries. As developing countries have fewer resources, it is therefore challenging for them to cope with the adverse effects of climate change (Noack, 2015). The effects of climate change, such as drought and flooding, as well as increases in temperature and precipitation, could harm the livelihoods of these households (McSweeney, 2005; Robinson, 2016). This harm can occur directly by reducing agricultural output and revenue or indirectly by influencing resource utilization and environmental conditions. According to Dasgupta et al. (2022), the extensive consequences of climate change are expected to result in more areas in poor countries becoming unsuitable for agricultural development. This could impact the number of individuals residing in rural areas. Another study (Ayindea et al., 2011) discovered that temperature changes have a detrimental influence on agricultural productivity in Nigeria, while precipitation changes have either a positive or negative effect, depending on the region. According to Skoufias (2011), the consequences of climate change on household welfare and deprivation can be felt through a variety of channels.

Extensive research has been conducted globally to investigate the effects of weather and climate change on agriculture, with a predominant focus on mean values of temperature and precipitation (Kumar et al. 2011; Cline 2007; Mendelsohn 2008; Kavi Kumar 2011; Mendelsohn et al. 1994). However, this approach may not fully capture the impacts on agricultural production, as weather variability has a more significant impact on crops (Thornton et al. 2014). Weather variability throughout crop growing seasons is likely to increase in the future, according to the IPCC Fifth Assessment Report (Kirtman et al. 2013), with more severe deleterious effects than changes in baseline weather variables. There is a wealth of literature on the influence of climate change on agriculture, different crops, and cropping patterns, both globally and in Pakistan. Climate change affects different industries in various ways (World Bank, 2015). It has an immediate impact on agriculture, but it also indirectly affects other sectors. Despite the growing body of literature on the economic impacts of climate change and climate variability, there remains a gap in sector-specific analyses, especially in the context of Pakistan.

3. Data and Methodology

In this section, we discuss the data sources and variable construction, followed by a discussion of the empirical model.

3.1 Data

For our analysis, we use household-level data and climate data. We utilize household-level data from the Pakistan Social and Living Standards Measurement (Government of Pakistan, 2020). This dataset comprises a sample of 156,440 households with positive income from 126 districts across Pakistan. Climate data on temperature and precipitation have been compiled from various provincial development statistics and environmental compendiums (Government of Pakistan, 2004, 2010, 2015, 2020). These government publications provide district-representative climate data using station-wise data provided by the Pakistan Meteorological Department. To construct the long-run climate variables, we use climate variable data spanning a 60-year period from 1961 to 2020.

3.2 Model and estimation methods

To analyze how climate change affects household income, we develop an economic model following the approach of Azzarri and Signorelli (2020). Our model is specified as follows.

$$Income = f(Climate, Human\ capital, Physical\ capital, Household\ characteristics, \varepsilon) \quad (1)$$

This model shows that household income depends on climate, human capital, physical capital, and household characteristics. The econometric model of this equation is specified as follows.

$$Y_{id} = \alpha + \beta_1 Temp_d + \beta_2 {Temp_d}^2 + \beta_3 Prec_d + \beta_4 {Prec_d}^2 + \beta_5 Tempsd_d + \beta_6 Precsd_d + \beta_7 Temp_d \times Agri_{id} + \beta_8 {Temp_d}^2 \times Agri_{id} + \beta_9 Prec_d \times Agri_{id} + \beta_{10} {Prec_d}^2 \times Agri_{id} + \beta_{11} Tempsd_d \times Agri_{id} + \beta_{12} Precsd_d \times Agri_{id} + \beta_{13} Agri_{id} + \gamma X_{id} + \varepsilon_{id} \quad (2)$$

The dependent variable is the natural logarithm of household income, which represents the total household income from various sources. Among the explanatory variables, climate variables include average temperature, average temperature squared, average precipitation, average precipitation squared, standard deviation of temperature, and standard deviation of precipitation. *Agri* is a dummy variable, which equals 1 if at least one of the household members earns income from the agriculture sector, and 0 otherwise. *X* includes human capital, physical capital, and other household characteristics. Human capital is the average education level of earning members, while physical capital is the market value of household assets. Household characteristics encompass household size, average age of earning members, average age squared, the number of earning persons in the household, and a region dummy variable, which equals 1 if the household lives in a rural area, and 0 otherwise. Short definitions of these variables are provided in Table 1.

Based on the specified model, we estimate the multiple linear regression model using the ordinary least squares (OLS) method. Given indications of heteroskedasticity in the error term, we employ robust standard errors for statistical inferences.

4. Results and Discussion

Table 1 presents descriptive statistics and definitions for each variable used in the regression model. The average household income is PKR 426 thousand, with a relatively high standard deviation of PKR 670 thousand, indicating income inequality among households. The average temperature is 23.41 degrees Celsius, and annual precipitation averages 45.12 decimeters. Earning members of households have an average education level of 5.5 years. The average market value of household assets is PKR 3.6 million, but with a notable standard deviation of PKR 11.69 million, reflecting wealth inequality. The average family size is 5.44 members, with a standard deviation of 2.6. The average age of household members who earn income is 39 years old. On average, households have 1.41 earning members. Additionally, 29 percent of households have at least one member working in the agriculture sector.

We use regression analysis to isolate the impact of climate change from other variables because there are many factors that may affect household income. Table 2 presents the regression results for two models. Model 1 is a base model without interactions between climate variables and dummy indicating household from agriculture sector. As the impact of climate change may be different in the agricultural sector and the non-agriculture sector, we estimate model 2 by including the interaction between climate variables and dummy variable indicating household from agriculture. As the coefficient estimates of the interaction terms are statistically significant, model 2 is a complete model without omitting the interaction variables. Therefore, we interpret below only the regression results of model 2.

The regression results illustrate how variables such as climate, human capital, physical capital, and household characteristics influence household income. The findings reveal that changes in the mean values of temperature and precipitation, as well as the variability of these climate variables, have a statistically significant impact on household income. We find that the relationship between household income and temperature is quadratic, which means that as temperature rises, household income rises initially, peaks, and then falls. For this nonlinear relationship, we compute the marginal effect of temperature on household income by taking the derivative of equation (2) with respect to temperature. The results show that, on average, a one-degree Celsius rise in average temperature leads to a 3.3%

decrease in income for households in the agricultural sector and a 0.4% decrease for those in non-agricultural sectors. The variability in temperature, indicated by a one-degree increase in its standard deviation, similarly results in a 4% income reduction for households across both sectors.

We find that the relationship between household income and precipitation is quadratic, which means that as precipitation rises, household income rises initially, peaks, and then falls. For this nonlinear relationship, we compute the marginal effect of precipitation on household income by taking the derivative of equation (2) with respect to precipitation. Results show that a one-decimeter increase in average precipitation is associated with a modest income increase of 0.33% and 0.19% for the agricultural and non-agricultural sectors, respectively. This shows precipitation is beneficial for households that are working in the agriculture sector. The quadratic relationship between revenue and climate variables is shown in previous studies, and these results are consistent with the theory (Lohano, 2018; Felbermayr et al., 2015; Ayindea et al., 2011). However, the results show that greater variability in precipitation, indicated by a one-decimeter increase in its standard deviation, adversely affects income in both sectors.

Both human capital and physical capital contribute significantly to household income. One-year increase in education of earning household members leads to 5 percent increase in household income, on average. Similarly, one percent increase assets value results in 1.1 percent increase in household income. Results show that the average age has statistically significant effect on household income. Family size has a positive and statistically significant impact on household income, which shows that as the number of family members increases, more pressure is placed on adult earning members to earn more to fulfill family needs. There is a positive and statistically significant relationship between the number of employed family members and household income. As the number of employed people in the household increases, the flow of income also goes up. On average, rural household earn 15.5 percent less than urban households. Urban area is used as a reference category, and rural area is a dummy variable in 0/1 form.

Diagnostic tests for the model have been performed. In Table 2, F-test values show that models are significant overall. The value of R-squared shows how much of the model's variation can be explained. This ranges from 0.305 to 0.308. Further tests for heteroskedasticity and normality are also performed, and their results are as follows. For heteroskedasticity, we use the Breusch-Pagan test. The Chi-Square statistics with p-value 0.000 indicate the presence of heteroskedasticity. To tackle this issue, we use heteroskedasticity robust standard errors. Further testing for normality (Jarque-Bera test) shows that the probability values of 0.121, and 0.122 for each of the two models show that the error term is normally distributed.

Table 1: Descriptive statistics

Variable	Definition of variables	Mean	Std. Dev.
Income			
Household income (thousand PKR) (annual)	Household income from all sources[1]	426.20	670.05
Climate			
Temperature (°C)	Average temperature of last 60 years	23.41	3.71
Precipitation (decimeters)	Average annual precipitation of last 60 years	45.12	39.45
Human capital			
Education (years)	Average education level of all earning members in household	5.50	5.21

[1] Household income includes income from all sources, such as income from a job, agricultural income, non-agricultural income, rent from shops, a house or agricultural land, and local and foreign remittances.

Physical capital			
Assets value (million PKR)	Market value of household assets	3.60	11.69
Household characteristics			
Family size (numbers)	Total number of family members in the household	5.44	2.60
Age (years)	Average age of earning members in the household	39.52	11.43
Earning persons in household (number)	Total number of earning persons in household	1.41	0.76
Agriculture (dummy variable)	It is defined as a dummy variable. Equals 1 if at least one of the family members earns from agriculture sector otherwise 0.	0.291	0.454
Rural (dummy)	1 if household lives in rural area, 0 otherwise	0.687	0.464
Observations		156,440	

Source: Authors' computations using data from Government of Pakistan (2020)

Table 2: Regression results

Model:	**(1)**	**(2)**
Dependent variable: ln (Household income)		
Climate		
Temperature	0.0809***	0.0624***
	(0.00789)	(0.00963)
Temperature squared	-0.00200***	-0.00141***
	(0.000184)	(0.000223)
SD of temperature	-0.0273***	-0.0401***
	(0.00206)	(0.00256)
Precipitation	0.00380***	0.00299***
	(0.000336)	(0.000393)
Precipitation squared	-0.00183***	-0.00123***
	(0.000212)	(0.000248)
SD of precipitation	-0.000455***	-0.000512***
	(0.00429)	(0.00522)
Temperature × Agriculture		0.0579***
		(0.0166)
Temperature squared × Agriculture		-0.00186***
		(0.000389)
Precipitation × Agriculture		0.00370***
		(0.000743)
Precipitation squared × Agriculture		-0.00252***
		(0.000469)
SD of temperature × Agriculture		0.00341
		(0.00914)

SD of precipitation × Agriculture		0.0363***
		(0.00432)
Human Capital		
Education	0.0502***	0.0499***
	(0.000572)	(0.000564)
Physical Capital		
Asset's value	0.0109***	0.0108***
	(0.00130)	(0.00129)
Household Characteristics		
Family size	0.0409***	0.0412***
	(0.000868)	(0.000867)
Age		
	0.0410***	0.0407***
Age squared	(0.00108)	(0.00107)
	-0.000392***	-0.000390***
Employed persons in household	(0.00129)	(0.00129)
	0.314***	0.312***
Household's earning members share in non-agriculture sector (reference)	(0.00248)	(0.00248)
Agriculture		
Rural (dummy) (urban reference)		
	-0.0544***	-0.496***
Constant	(0.00575)	(0.164)
	-0.171***	-0.155***
Observations	(0.00458)	(0.00457)
R-squared	10.00***	10.15***
Diagnostic tests	(0.0811)	(0.0990)
Overall significance	156,440	156,440
F-stat	0.305	0.308
p-value		
Jarque-Bera test for normality of error term		
p-value	4712.35	3326.22
Breusch-Pagan heteroskedasticity test	0.000	0.000
Chi-square stat		
p-value	0.121	0.122

Notes: The t-statistics based on robust standard errors are in parentheses. *, ** and *** denote significance at 10%, 5% and 1%, respectively.
Source: Authors' computations using data from Government of Pakistan (2020)

5. Conclusions and Policy Implications

The study reveals that climate change has a discernible impact on household incomes in Pakistan. Changes in the mean values of temperature and precipitation, as well as the variability of these climate variables, have a significant impact on household income. A one-degree Celsius increase in average temperature results in a 3.3% income reduction for agricultural sector households and a 0.4% decrease for non-agricultural sectors. Increase in temperature variability similarly reduces income by 4 percent across both sectors. Changes in precipitation patterns show a modest income increase for agricultural

and non-agricultural households. However, greater variability in precipitation adversely affects income in both sectors. These findings highlight the differential vulnerability of sectors to climate change, underscoring the need for sector-specific adaptation strategies to mitigate these impacts. In light of these results, it is imperative for policymakers to devise and implement targeted policies that bolster the resilience of households, particularly those within the agricultural sector. Strategies should focus on promoting climate-resilient agricultural practices, enhancing infrastructural resilience, and facilitating income diversification to reduce climate-related income volatility. Engaging a broad range of stakeholders in the policy development process will ensure that these measures are effectively aligned with the needs of those most impacted by climate change, thereby contributing to the economic stability of Pakistan in the face of ongoing environmental challenges.

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Data Availability Statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

Disclosure statement
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