CLIMATE CHANGE IN SOUTH AFRICA: IS THERE A DISPROPORTIONATE EFFECT ON POORER MUNICIPALITIES?

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Abstract

Climate change represents a profound and escalating challenge, disproportionately burdening the world's most vulnerable populations. The complex relationship between poverty and climate change is increasingly recognized, however, much of the existing research has concentrated on national or global scales, often overlooking the detailed, specific effects on smaller, more localized areas, such as individual municipalities within a country. This study seeks to bridge this gap by focusing on the municipal level in South Africa, a country marked by stark socio-economic inequalities and pronounced climate vulnerabilities. Utilizing a panel dataset from 234 municipalities, based on the 2011 municipal boundaries, this research employs a fixed-effects model to examine how climate shocks influence poverty dynamics across different socio-economic contexts. The findings reveal a significant divergence in the impact of climate shocks, with the poorest municipalities experiencing a markedly higher increase in poverty rates compared to their wealthier counterparts. This heightened vulnerability underscores the limited adaptive capacity of these communities, exacerbated by their dependence on climate-sensitive sectors and a lack of diversified economic opportunities. The findings underscore the importance of spatially differentiated climate adaptation strategies that are not only responsive to the immediate needs of the most vulnerable but also address the underlying structural inequalities that perpetuate their susceptibility to climate-induced economic shocks. Moreover, this research contributes to the broader discourse on climate justice, offering critical insights into the mechanisms through which climate change amplifies existing socio-economic disparities. The implications extend globally, providing a foundation for policy interventions that prioritize the protection and empowerment of the most disadvantaged communities in the face of an increasingly volatile climate.

1. Introduction

Climate change is currently one of the biggest existing global threats to humanity. It is an environmental phenomenon that continues to result in socio-economic consequences (Sahoo and Rath, 2023). While the effects it has had in different parts of the world have been different, they are substantial (Lai et al, 2021). The world's poorest countries feel the impacts most sharply. These populations have felt the impact more, in part because they depend mostly on agriculture, and this economic sector is extremely vulnerable to climate change. They are also faced with sub-standard public services (Das Gupta, 2013) which hinder their ability to recover from the impacts of climate change. Climate change is defined as the fluctuations in a region's typical weather patterns, it can encompass changes in annual rainfall amounts, deviations from average monthly or seasonal temperatures (Luo 2020). It can also present as variations in global temperatures. According to Fiordelisi et al. (2021) it is responsible for climate shocks, whose definition broadens the concept of natural disasters to encompass extreme weather events (De la Fuente, 2007).

The effects of climate change are overarching throughout the globe, affecting all of humanity. Conversely, poverty is unevenly distributed with its effects more pronounced across low-income and middle-income countries (Echendu, 2022). Climate change and poverty are, however, intricately linked and cannot be separated. This is a view that is held by Khine and Langkulsen (2023). They cite that the effects of climate change on poverty rates are intensifying due to the resulting extreme weather conditions that are occurring more frequently. It is further echoed by Hope (2009) who expands that climate change will affect the poorest communities the most, and highlights that the lack of access to safety nets and limited access to assets that can be sold or used to enable recovery and progression following natural disasters, are some of the factors that cause the poor to be disproportionately affected by climate change. Hallegate et al (2018) agree with this view, specifying that climate change increases the flow of people falling into poverty and hampers trajectory of those trying to escape it. They argue that many shocks that drive people into poverty are related to climate change and that the risks of natural disasters keep the poor trapped in poverty by affecting the way they behave: for example, people who are exposed to climate risks will be averse to making investments such as agriculture, property and other infrastructure as the

risk of losses is high. This lack of investments leads to a limited capacity to recover from climate shocks (Hallegate et al, 2018) and this in turn makes it even more difficult for them to escape poverty. Adaptation to the effects of climate change is therefore mandatory for there to be economic and social development in the affected communities, and the efforts to improve the capacity of a community's adaptation capacity (Abbass et al, 2022). There needs to be efforts to improve the level of a community's adaptation capacity such as increased household income and bettering education levels are therefore necessary if the communities are going to escape the poverty cycle.

Bose (2017) describes climate change adaptation as the change in practices, processes and structures in order limit the potential destruction from climate change, and possibly even benefit from the opportunities that may arise from it. Society therefore needs to adapt societal, economic and institutional practices in order to protect its environment from the effects of climate change (Cao and Zeng, 2016). Islam and Winkel (2017) however argue that while adaptation policies are very important for easing the impacts of climate change, they can often exacerbate existing inequalities between the rich and the poor. The design and implementation of these policies are frequently influenced by political forces, which may unintentionally benefit the richer and more powerful groups. These are groups that have a stronger voice in decision-making processes. This leaves the poorer communities, who are already more vulnerable to climate shocks such as droughts and floods (Dornan et al, 2014) struggling to access necessary resources and support.

While climate change and the disproportionate effect it has on the poor has greatly been discussed, the discourse has mainly focused on inequality across countries, mostly ignoring in country inequality (Islam and Winkel, 2017). This view is also held by Hendricks and Van Zandt (2021) who hiterate that research on climate change and social vulnerability neglects to examine spatial aspects, rather focusing on higher levels of study such as country level. Azzarri and Signorelli (2019) also share this opinion, as they cite that studies on international poverty have been constrained to country level comparisons ignoring sub-regional heterogeneity that is significant in the study of spatial clustering of welfare.

South Africa has increasingly felt the impacts of climate change. The urgency to address the climate change impact concern continues to escalate in importance (Chersich and Wright, 2019; Ziervogel

et al, 2014). This is due to the country being extremely susceptible to effects of climate change due as it highly depends on rain fed agriculture. The country also exhibits a high level of poverty and a very low adaptive capacity (World Bank, 2021). There, however, does not seem to be literature that delves into the effect of climate change on the on the poverty rates of all South African municipalities, differentiating the effects between the rich and poor municipalities.

There have been many studies on the impact of climate change in South Africa, such as Mthembu and Hlophe (2020) who evaluate the implications of climate change in the uMkhanyakude District Municipality, the poorest municipality in the KwaZulu-Natal province. They find that climate change mainly affects water resources in the district, as the changes in climate have led to a growth of invasive alien species, compromising water security and ecosystem services and thus impacting food security. Hosu et al (2016) also studied climate change at municipal level, assessing the vulnerability of small-scale crop producers in the Eastern Cape province. Following a comprehensive assessment of exposure, adaptive capacity, and vulnerability indices, their study found that small farms within the Karoo zone of the Eastern Cape are particularly susceptible to the adverse impacts of climate variability, especially agricultural production. Okolie et al (2023) perform a similar study in the Free State province. The results of their analysis, which focused on North, Central, and Southern regions of Thaba Nchu indicated that farming households in these regions exhibit heightened risks in terms of factors such as water access and health risks. This region also demonstrated higher vulnerability in relation to food security, due to climate change.A comparable study by Maponya and Mpandeli (2012) focuses on the Limpopo province. Their research underscored the escalating intensity and frequency of extreme weather events globally as a direct consequence of climate variability and change. The Limpopo province serves as one such example, having endured devastating floods in 2000 and 2012. These events resulted in substantial crop losses, infrastructure damage, and significant disruptions to agricultural cycles, exemplifying the province's vulnerability to the intensifying impacts of climate change.

This research report therefore seeks to address this gap. It explores climate change in the South African context, investigating the problem at municipal level and asking the question: Climate Change in South Africa - Is there a disproportionate effect on poorer municipalities?

South Africa remains one of the most unequal countries in the world (Mtapuri and Tinarwo, 2021) and its economy persistently exhibits spatial inequality in economic activities. For example, only three municipalities, namely Gauteng, Ethekwini and Cape Town contributed 35% to the South African economy in 2011 (David et al, 2018). In 2011, the country's municipal boundaries were changed, dividing it into 234 local municipalities (Statistics South Africa, 2022). These municipalities are tasked with ensuring the welfare of their citizens. The municipalities ae charged with delivery of basic municipal services such as water, sanitation, roads and electricity, which are needed to ensure that the residents have a decent quality of life (Shongwe and Meyer, 2015). Failing to provide these services endangers the health, safety and the environment of the inhabitants (Statistics South Africa, 2017). According to Sartorius and Sartorius (2016), however, service delivery patterns in South Africa continue to be unequal between municipalities. The problem persists as some local municipalities faced with high unemployment, poverty, lack of services and lack of resources required for development (Mashamaite and Lethoko, 2018). Municipalities in economically disadvantaged provinces such as the Eastern Cape and Limpopo struggle with significantly low service delivery, while their richer and more developed counterparts such as those in the Western Cape and Gauteng enjoy better service delivery. They elaborate the common challenges faced by the authorities in these provinces, such as lack of resources, poor infrastructure and lack of skilled personnel are a major hinderance to the efforts of delivering services. Using the 2011 municipal boundaries, this research report interrogates if the effect of climate change on poverty rates is different between municipalities, and if so, whether it disproportionately affects the poorest ones. While the effects of climate change in Africa, especially Sub-Saharan and South Africa have been studied extensively (Azzari & S Signorelli, 2019; Khine & Langkulsen 2022; Masipa 2017; Manderson & Levine 2022), and there is general consensus that the effects are unduly felt by the poor, the effects of climate change on poverty rates have not been studied for all municipalities at a spatial levels, comparing the effects on poorer municipalities to the one on rich municipalities.

In order to interrogate the relationship between climate change and poverty-rates in South African municipalities, the report establishes a balanced panel data fixed effects model, using climate data and municipal data from household surveys. Climate data for this study were sourced from the University of Delaware Climate Archives, a comprehensive repository of global climate records (http://climate.geog.udel.edu). Municipal data for this study was obtained from two primary sources: EasyData by Quantec (https://www.easydata.co.za/dataset/RIES/), a comprehensive database offering South African macroeconomic, industry, and regional indicators; and Statistics South Africa (https://www.statssa.gov.za/), the national statistical service responsible for generating official demographic, economic, and social data through censuses and surveys. A relationship between climate shocks, which are a result of the climate change phenomenon, and poverty rates in the period following the occurrence of a climate shock, is established. The relationships between climate shock and poverty rates are observed for all municipalities, and then they are analysed separately for the poorest municipalities, the less poor municipalities in the middle and the rich municipalities. This is to establish if indeed, the poorest municipalities are most affected by climate change.

Aims and Objectives

The research report explores the effects of climate change on poverty in South Africa and looks at whether it has a disproportionate effect on poorer municipalities. It looks at how the poverty rates of poor municipalities change after having experienced climate shocks, in comparison to the richer ones. It will look at whether after experiencing climate shocks, the poorer municipalities' poverty rates increase at a rate that is higher that of the richer municipalities. The report hypothesizes that the poverty rates for poorer municipalities increase at a higher rate than that of richer municipalities, after having experienced a climate shock, thus affecting them disproportionately.

The nexus between climate change and poverty in South African municipalities is investigated by first conducting a comparative analysis, examining how this relationship has been studied across various regions and countries. It then goes on to explore how the relationship has been studied in South Africa. Using a panel data with fixed-effects model, the report establishes that there is a

relationship between climate change and poverty rates within South African municipalities. The analysis delves deeper by stratifying municipalities by poverty rates (poorest, less poor, and rich). The results of these of the strata are presented and compared, revealing a clear trend: poorer municipalities bear a disproportionate burden from climate change. The report concludes by proposing policy recommendations, including spatially differentiated adaptation strategies implemented by the government, to enhance the resilience of poor communities.

2. Literature Review

The relationship between climate change and poverty has been studied extensively, and there is a consensus that there is a disproportionate effect on the poor. In their study of climate change and its effects, Hope Sr (2009) reflects that climate change will exacerbate the challenges faced by the poor and vulnerable in Africa, and governments will find it more and more difficult to cope with and adapt to its impacts. They indicate that several areas in Africa are particularly vulnerable to the impacts of climate due to their geography, patterns of settlements, and low adaptation capacity. Leinchenko and Silva (2014) analyse climate change literature in order to examine the intersection of poverty, vulnerability, and climate impacts in Southern Africa. They find that the connections between climate change and poverty are intricate, multifaceted, and vary depending on the context. Their research concludes that people who are already living in poverty are disproportionately exposed to the immediate and long-term impacts of climate change. They further elaborate that those already living in poverty have fewer resources to adapt, which can make it difficult for them to escape poverty. As a result of this they are more likely to be pushed further into poverty and struggle to escape it. Chen, Yan and Yang (2022) also share this view. In their study of the impact of extreme weather on the vulnerability of farming households to poverty, the authors look at six counties in Hubei and Yunnan provinces of China. To complete the study, they use three different models: a baseline regression model, a quantile regression model, and a mediating effect model to empirically test the impact of extreme weather on farmers' poverty vulnerability. Their results reveal that climate extremes can cause damage to the physical, the natural, and the environmental capital of farmers, as well as the environments that they live in. These climate extremes can also harm the health of farmers' families and damage their human capital, leading them into poverty and further entrapping those who are already poor.

Barbier and Hochard (2018) use infant mortality rate as a proxy for poverty to build on previous studies on the impact of climate change on the poor. They come up with a new global dataset using a variety of spatially referenced datasets to assess and estimate the rural population living in Less Favored Agricultural Areas (LFAA), and the different rates of infant mortality among these populations in 2000 and 2010. Their study finds that poor populations living coastal zones that have low elevation, and less favoured agricultural areas face greater risks of environmentally induced poverty - this makes them further vulnerable to climate change impacts. This view aligns with that of Mendelsohn et al (2006), who studied uneven distribution of climate change consequences across rich and poor nations countries using experimental and cross-sectional studies. In their work, they found that poor countries are more disproportionately on the devastating end of climate change, as they tend to be situated in lower latitude regions which are warmer and more prone to temperature shocks and flooding. The richer more developed countries that are on the higher latitudes that are cooler, making them less susceptible to the effects of climate change. Magiri et al (2020) study 5 districts in the river basin of Kenya and found that in the country is vulnerable to the impacts of climate variability and change. The vulnerability varies across the country, depending on the exposure, sensitivity, and adaptive capacity of different systems. Floods and droughts have had the most significant impacts, resulting in substantial economic losses, property damage, loss of life, and livelihood disruption.

In their analysis of how extreme weather events affect impoverished communities, Atanga and Tankpa (2021) found that changes in precipitation due to climate change can result in either an excess or lack of water, subjecting regions to floods and droughts and threatening especially the agricultural sector. This can lead to compromised food production and threaten overall food security, as the sector plays very important role in sustaining livelihoods and safeguarding food security. These findings are supported by Egbe et al (2014), who in their study of the perception of climate change among the people of Nigeria, found that extreme temperature and precipitation changes brought long-term negative consequences for sustainability and output of agricultural systems, especially in rural areas. The research of Lankes et al (2022) aligns with these findings and further add to them, as they found that climate change threatens the livelihoods of poor

communities by impacting the quality of their soil. This therefore diminishes crop production and quality, weakens soil structure and reduces the region's resilience to flooding and droughts. Flooding also increases the risks of illnesses for these low-income households as it is frequently followed by a lack of access to clean drinking water and water that is used for household needs. It is through its influence on temperatures and water scarcity that climate change intensifies the occurrence of waterborne diseases, including diarrhea, a leading cause of death among children under five years. South Africa is one of the five sub-Saharan countries facing the most critical water shortages (World Bank Group, 2021). The country has not been spared from the effects of climate change: they are in fact being felt at an increasing rate (Chersich and Wright, 2019) due to increased rainfall and temperature variability (National Climate Change Adaptation Strategy, 2019). While climate change is a global phenomenon that affects everybody, the effects throughout the world and in South Africa are being felt unduly by the poor.

3. Theoretical Considerations

The relationship between climate change and poverty is multifaceted, deeply rooted in the complex interplay of social, economic, and environmental factors. The theoretical underpinnings of this study draw from multiple frameworks that highlight how climate change disproportionately impacts poorer communities, and how these impacts are shaped by existing vulnerabilities and limited adaptive capacities. As such, it not only guides the empirical analysis but also underscores the importance of developing targeted adaptation strategies that address the unique vulnerabilities of poorer municipalities.

The Sustainable Livelihoods Framework (SLF) serves as a foundational model for understanding how climate change impacts poorer municipalities. Livelihoods are defined by the assets - natural, financial, human, social, and physical capital - that individuals and communities rely upon for survival and development (Parsons et al, 2024). In vulnerable communities, these assets are often limited, making it difficult for individuals to cope with or recover from climate shocks (Hope, 2019). The SLF suggests that communities with diverse and robust livelihood assets are better equipped to withstand environmental changes. Conversely, communities with limited assets, particularly those dependent on natural resources, are more susceptible to the adverse effects of

climate change, such as extreme weather events, which can destroy crops, reduce income, and increase poverty (Fadairo et al 2020).

Environmental justice theory emphasizes the uneven distribution of environmental risks and benefits across different social groups, often aligning with existing socio-economic inequalities (Scott, 2024). Climate change exemplifies this disparity, as the poorest populations, who have contributed least to greenhouse gas emissions, suffer the most from its consequences (Schlosberg and Collins, 2014). In the context of South African municipalities, this framework highlights how historical inequalities, including those related to race, land distribution, and economic marginalization, exacerbate the vulnerability of poorer municipalities to climate shocks. These areas are often under-resourced and lack the necessary infrastructure and institutional support to effectively adapt to climate change, leading to a cycle of increasing poverty and environmental degradation (Mani and Cleaver, 2021).

Political ecology provides a critical lens through which to examine the power dynamics that influence environmental governance and the distribution of resources. This perspective critiques the dominance of certain scientific paradigms in shaping climate policy, which often overlooks or marginalizes indigenous knowledge systems and local practices (Svarstad et al 2018, Escobar, 1998). In South Africa, where historical legacies of apartheid have created deep socio-economic divisions, political ecology underscores the importance of understanding how these power structures continue to shape the ability of poorer municipalities to respond to climate change. The unequal distribution of resources, coupled with inadequate political representation, limits the capacity of these communities to advocate for and implement effective adaptation strategies (Leck and Simon, 2018.

Adaptive capacity refers to the ability of a system, community, or individual to adjust to climate change, to moderate potential damages, and to take advantage of opportunities or cope with the consequences (Smith et al 2003). In poorer communities, adaptive capacity is often constrained by factors such as low income, limited access to education, inadequate infrastructure, and weak governance shocks (Pickson and He, 2021). Resilience, which is closely related to adaptive capacity, involves the ability to recover from or adjust to climate. The resilience of a community is enhanced by strong social networks, effective governance, and access to resources (Carmen et al,

2022). In the poorer South African municipalities, these elements are often lacking (Munzhedzi and Makwembere, 2019), making it difficult for communities to build resilience against the increasing frequency and severity of climate shocks.

The theoretical frameworks discussed above lead to several empirical predictions about the impact of climate change on poverty in South African municipalities. Based on the SLF and environmental justice theory, we can predict that poorer municipalities, characterized by limited livelihood assets and greater exposure to environmental risks, will experience more significant increases in poverty following climate shocks compared to wealthier municipalities. This prediction is grounded in the understanding that poorer communities have fewer resources to mitigate the effects of climate shocks and are more reliant on climate-sensitive sectors such as agriculture.

Political ecology further supports this prediction by highlighting the role of unequal power dynamics and resource distribution in shaping climate vulnerability. Municipalities with less political influence and fewer resources are less likely to receive adequate support for climate adaptation, leading to greater and more persistent poverty in these areas after climate shocks.

The concept of adaptive capacity suggests that municipalities with higher levels of education, better infrastructure, and stronger governance will be more resilient to climate shocks. Therefore, we would expect to see a smaller increase in poverty rates in wealthier municipalities with higher adaptive capacity compared to poorer ones.

These theoretical insights inform the empirical analysis of this study, which utilizes a fixed-effects model to examine the relationship between climate shocks and poverty rates across different municipalities. The empirical analysis aims to validate the hypothesis that climate change disproportionately affects poorer municipalities, resulting in a more significant increase in poverty rates in these areas following climate shocks. By stratifying municipalities based on their baseline poverty rates, the study further explores how the impact of climate shocks varies across different levels of wealth, providing a nuanced understanding of the socio-economic impacts of climate change in South Africa.

4. Methodology

This section outlines the hypothesis of the research report. It outlines the data, model and the approach that is to analyse the data. It highlights the decision to use the fixed effects model and its importance in accounting for heterogeneity across municipalities.

This research report seeks to establish whether climate change disproportionately affects the poorer municipalities in South Africa. It uses a panel data with fixed effect model. This model has been used extensively in climate economics research (Goodman et al, 2018, Obradovich et al, 2018, Chen and Qing 2022) and has the advantage of eliminating endogeneity that can stem from time invariant variables (Chen and Qing 2022). The data in the report is analysed using STATA SE 17.

Hypothesis

H_0: Poorer municipalities' poverty rates do not increase at a higher rate than richer municipalities, following a climate shock.

H_a: Poorer municipalities' poverty rates increase at a higher rate than richer municipalities, following a climate shock.

Data

The research report uses a panel data set that comprises of all the 234 South African municipalities (within the 2011 municipal boundaries) for the years 1996, 2001 and 2011. The report seeks to establish whether there is a positive relationship between climate shocks and poverty rates. Once a positive relationship is established, the report interrogates whether the increase in municipalities that have higher baseline poverty rates exceed that of municipalities with lower baseline poverty rates; it evaluates whether the poorer municipalities are disproportionately affected by climate change. The climate and municipal data are comprehensive, covering all the municipalities for the years in question. The municipal climate data in this report is sourced from the University of Delaware Climate Data archives, who collect their data collect their data from several weather stations throughout the world (http://climate.geog.udel.edu) in order to measure and predict climate risk. The municipal data is sourced from EasyData by Quantec

(https://www.easydata.co.za/dataset/RIES/), who compile a diverse set of indicators that encompass South Africa's macroeconomic performance, industry trade, and regional trends. It is also sourced from Statistics South Africa (https://www.statssa.gov.za/), the government statistics service which generates the country's official statistics through demographic, economic and social censuses, and surveys.

Model Specification

Based on the panel data of the municipal climate data and municipal data collected, the following regression formula is set up:

$$\text{povrate1} = \alpha + \beta_1 \text{ClimateShock} + \beta_2 \text{tress22} + \beta_3 \text{urbanisation} + \beta_4 \text{Black} + \beta_5 HDI + \varepsilon,$$

where povrate1, the dependent variable, represents poverty rates within municipalities for the period subsequent to the occurrence of a climate shock. $\beta_1 Climshk$ serves as a binary indicator of a municipality's experience with a climate shock, specifically precipitation shock and/or temperature shock, in the period prior: 1 indicates that a climate shock has occurred, while 0 shows that there hasn't been a shock. This variable controls for the influence of climate shocks while holding all other variables constant. *Tress22, Urbanisation, Black and HDI* are the control variables.

When using panel data, either the random effects model or the fixed effects model can be used. The fixed effects model seeks to address bias that may arise from time-invariant characteristics which can influence the outcome variable. The characteristics are presumed to be different amongst the individual observations, and uncorrelated with other individual observations. If, however, there may exist between-entity differences that influence the dependent variable in the regression, a random-effects model is considered to be more appropriate.

Variable Description

Poverty Rate (povrate1): The dependent variable in this report is the poverty rate in the period following the occurrence of a climate shock, measured as the percentage of the municipality that lives below the upper bound poverty line, which is part of the national poverty lines constructed

by Statistics South Africa. To construct the national poverty lines, the cost of basic needs approach is used, incorporating the consumption of essential goods and services to provide an inclusive assessment of poverty. The upper bound poverty line is R1335 per person per month, using 2021 prices (Statistics South Africa, 2022). As there is no specific measure to quantify how much people spend other basic necessities besides, the upper bound poverty limit is computed by collecting non-food expenditure data from distinct household groups and subsequently adding these figures established food poverty line food. The poverty measure therefore includes food and non-food items. h links welfare to the consumption of goods and services. This framework correlates levels with the consumption of goods and services. To differentiate between poor and non-poor municipalities, three subsamples have been constructed, identifying the poorest municipalities at 75% poverty rate and above. An extremely high level of poverty in a municipality may reflect severe economic hardship and the municipalities are likely to face acute problems such limited economic opportunities, inadequate infrastructure and high unemployment rates. According to Ngumbela et al (2020) high unemployment, poverty, and low income in many municipalities hinder their revenue collection and leads them to depend on government grants. This financial constraint exacerbates poverty and food insecurity due to inadequate service delivery. The next sample is the less poor municipalities, whose poverty rates fall between 50% and 74%. At a poverty rate above 50% (and below 75%) the residents of the municipality may face significant economic hardship, struggling to access basic necessities such as food, housing, and healthcare., and lastly the municipalities whose poverty rate is less than 50% are considered as the rich municipalities.

Climate Shock (clmshk): The main explanatory variable is climate shock. According to De la Fuente (2007), the definition of climate shocks encompasses events that have conventionally been defined as natural disasters. These are important when exploring the relationship between extreme weather events and societal vulnerability as these events pose a significant threat to society's wellbeing. They also inhibit it from maintaining its normal functioning. Fiordelisi et al. (2023) identify natural disasters and climate shocks as consequences of climate change, highlighting the link between rising global temperatures and increased extreme weather events. According to the Baptista et al (2023), climate change is understood to be increasing the frequency and severity of climate shocks, leading to enormous economic consequences. This research report measures

climate shocks using binary variables for the occurrence of precipitation shocks and temperature shocks in each municipality, where 0 identifies and instance where there has not been a climate shock, and 1 identifies a climate shock. Temperature and precipitation that deviate from averages affect economic activities in several ways, including the destruction of ecosystems, droughts, floods and even death, and poorer communities are likely to experience a much tougher time when it comes to the recovery of the effects of these shocks, due to limited resources (Odusola A and Abidoye B, 2015).

The report determines climate shocks by first establishing the standard precipitation index (SPI) to identify the precipitation shocks and the z score to identify the temperature shocks. An incidence of climate shock is perceived as either when a temperature shock, a precipitation shock or both occur.

Precipitation Shocks

To identify the shocks in precipitation, the report makes use of the Standardized Precipitation Index (SPI). Kamruzzaman et al (2019) describe the SPI as an index that is based on the average precipitation over a specified period of time. Initially developed by McKee at al (1993), it is the most common approach used to model deviations from normal temperatures (Zhang et al, 2011). It is calculated by taking the difference between the observed precipitation and the mean precipitation, which is then divided by the standard deviation of the precipitation.

$$\text{SPI} = \frac{x_i - x_m}{\sigma}$$

x_i = annual average rainfall recorded,

x_m = Average of the rainfall recorded

σ = Standard Deviation

To identify precipitation shocks, the report uses the SPI classification as identified by Malakiya and Suryanarayana (2016, who describe an SPI of 2.0 as extremely wet, 1.50 to 1.99 as very wet,

1.00 to 1.49 as moderately wet and 0 to 0.99 as near normal. They further go on to define SPIs 0 to -0.99 as describing a mild drought, -1 to -1.49 as moderate drought and -1.50 to -1.99 as severe drought. SPI above 1.5 and SPI below -0.99 are identified as precipitation shocks.

Temperature Shocks

To measure temperature shocks, this paper follows the work of Chen and Qing (2022) who measure how the health status of the elderly in China is affected by extreme temperature shocks. In their study they calculate the average monthly temperature of the selected regions and compare it to the local historical monthly average temperature. The z-score is calculated by dividing this comparison with the standard deviation of the average monthly temperature, measuring how many standard deviations the temperature of that day deviates from the monthly average. This report calculates the z-score by comparing the annual average temperatures of the municipalities for the years in study and finding their deviations average temperature of the municipality over the municipality's past average, 1996 to 2011. In line with the study on how droughts, floods, and temperature extremes impact rural Ethiopian children's education by Randell (2016), this report defines temperature shocks as z-scores above +1.5 and below -0.99.

$$\text{Z-Score} = \frac{Temp_{md} - Average_m}{\sigma_m}$$

$Temp_{md}$: Annual average temperature

$Average_m$: Average temperature

σ_m: Standard deviation of annual average temperature

Control Variables

Control variables are included in this report, to help to uncover the true effects of the explanatory variable on the dependent variable. Control variables help to limit the influence of confounding factors (Nielsen and Raswalt, 2018). The control variables employed in this model, tress22 (variable description), urbanization (variable description), black (variable description), and the Human Development Index (HDI), were obtained from the EasyData database by Quantec

(https://www.easydata.co.za/, dataset: RIES/0). Data for all relevant years under investigation were included.

Tress22

According to the Development Bank of Southern Africa (2001) the tress index measures the diversification of the economy of a region. A tress index of 0 shows a completely diversified economy, while a higher index indicates a more concentrated economy. A high tress index in a region indicates the dependence on a few economic activities. This can leave a region vulnerable to exogenous variables such as climate shocks and fluctuations in the price of commodities, due to lack of diversification. According to He et al (2022), diversification of economic industries significantly provides economic resilience for regions. As such, municipalities with lower a lower tress index will exhibit resilience to external challenges more effectively. This report therefore can posit that municipalities with lower tress index values exhibit greater resilience against climate shocks due to the buffering effect of economic diversification. The report therefore posits a positive relationship between tress22 index and poverty rates.

Urbanization:

Urbanization is defined as the wave of movement of people from rural to urban settings (Kuddus et al, 2020). This phenomenon has resulted in changes in the dynamic of urban areas. While South Africa undergoes increasing urbanization rates, 40% of its population remains in rural areas with limited economic opportunities, experiencing persistent poverty (Turok, 2021). However, research suggests urbanization can improve lives of the people who move to urban areas, with studies linking it to increased income, expenditure, and poverty reduction for rural households (Arouri et al, 2017). It is he expectation in this report, that urbanization has a negative relationship with poverty rates This study defines urbanization as the percentage of a municipality's population residing in urban areas.

Black:

According to Gardin (2012) South Africa has big racial disparities in poverty and deprivation, with the black population being the most affected. They elaborate that the higher rates of financial poverty and material deprivation among black South Africans stem from historical and current factors and there isn't a single factor that can be solely attributed to poverty, the accumulation of pre-labor market disadvantages, including overrepresentation of the black population in rural areas with limited access to basic services and persistent spatial inequalities, plays a significant role. In this research paper, black defines the percentage of the black population in a municipality. This research report proposes that there is potential association between a higher percentage of Black population within a municipality and its vulnerability to climate shocks, which also affects their poverty rates. Limited access to resources and historical disadvantages faced by these populations, may act as vulnerability factors amplifying the negative impacts of climate change on average poverty rates. The research report therefore posits a positive relationship between the percentage of the black population within a municipality and poverty rates.

Human Development Index (HDI):

There needs to be good governance for better economic growth and for human development to flourish – this is especially true in developing countries as good governance is fundamental to achieving positive outcomes in critical areas such as environmental protection, health, education (Ahmad and Saleem, 2014). Good governance is also important for the development of infrastructure, which is essential for climate change adaptation as it protects critical services and communities from climate risks (Adshead et al, 2021). Infrastructure, along with its operations and dependent communities, are considered resilient if they can withstand and quickly recover from infrequent, high-impact events that disrupt their capacity, functionality, and operability (Argyroudis et al, 2023).

The Human Development Index (HDI) offers a composite measure of a country's advancement in human development. It centers on three fundamental dimensions: longevity and health, educational opportunity, and access to resources necessary for a decent standard of living (Stanton, 2007) and serves as a gauge of governance success, encompassing both economic growth and human development outcomes (Muluk and Wahyudi, 2022). In their study of the relationship between

good governance indicators and the Human Development Index (HDI) in Africa, Tsegaw and Drive (2020) found that there is a clear correlation between clear governance and HDI, where strong governance is linked with higher HDI score. According to the UNDP (2020), the Human Development Index (HDI) is categorized as Very high (0.800 and above), High (0.700 to 0.799), Medium (0.550 to 0.699), and Low (below 0.550). Building upon this framework, we can posit a positive correlation between a municipality's Human Development Index (HDI) and its resilience to climate shocks. A high HDI, indicative of strong educational attainment, health outcomes, and access to basic necessities, is likely to equip a municipality with a greater capacity to absorb and adapt to the negative consequences of climate change. Furthermore, a robust HDI may act as a buffer, mitigating the potential for climate shocks to exacerbate poverty rates within a municipality.

5. Results and discussion

Model Specification Test

In order to establish whether the random effects model or the fixed effects model is more suited in this, case the Hausman test was run. The test establishes whether the unique errors of the observations are correlated with the regressors. The null hypothesis of the test is that the random effect model is the better model over the fixed effect model. In the results of the test, the p-value is 0, therefore the null hypothesis can be rejected. The fixed effect model is therefore the better model to use.

When using fixed effects models the problem of heteroscedasticity may be encountered, where the variance of the error terms is not equal, therefore introducing unreliable standard errors and may lead to incorrect conclusions, when assessing the significance of coefficients. When the regression model for this report was tested, heteroscedasticity was found, therefore the robust fixed effect robust model is used.

Hausman test

Hausman (1978) specification test

	Coef.
Chi-square test value	35.024
P-value	0

After determining the relationship between poverty and climate shock, the report seeks to establish whether there is a difference in the way poverty rate changes for poor municipalities and richer municipalities after they have experienced climate shocks. The municipalities are stratified into three subsamples: poorest (poverty rate > 75%), less poor (poverty rate between 50% and 75%) and wealthy municipalities (poverty rate < 50%). These subsamples are then regressed, and the relationship results between the increase poverty rates of each sub samples, in the period following climate shocks, are compared in order to interrogate whether the poverty rates of the poorer municipalities increase at a higher rate. The comparison establishes if the poorer municipalities are disproportionately affected by climate change.

Descriptive Statistics

Table 1 reports the descriptive statistics of the data used in this report. According to these results, the average poverty rate of municipalities, which is the population in municipalities that lives below the upper bound poverty line (UBPL), as defined by Statistics South Africa, is 68.2%. 95.3% of the population in the poorest municipality lives below this bound, while 23.2% of the population in the richest municipalities live below it.

The average poverty rates for the 234 municipalities is 68.2%, indicating that more than two thirds of the population in South African municipalities lives below the upper bound poverty line. On average, the tress22 index, which shows the diversification of economic activity is 78.70, showing a lack of diversification of economic industries in South African municipalities, as a lower score. On average, 47.8% of in South African municipalities were urban in the timeframe under consideration, with the lowest level of urbanization at 0% and the highest at 99.6%. The average percentage of the black population was 74.11%. The municipality with the lowest black population

was 22.5% and highest was 100%. The average human development index is 0.496, which is falls in the low level, indicating that on average, there is low human development in South African municipalities. The report therefore expects that there will be a negative relationship between poverty rates and the human development index.

Table 1

Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Poverty	702	.682	.162	.232	.953
Climshk	702	.349	.477	0	1
tress22	702	78.703	6.499	62	97.5
urbanisation	702	.478	.345	0	.996
Black	702	74.112	32.27	.225	100
HDI	702	.496	.092	.258	.719

A regression was run in order to establish if there is a relationship between poverty rates and climate shocks in all 234 municipalities. It uses a panel data with fixed effects model and the results are reported below in Table 2. The results show that when municipalities experienced climate shocks, there is an average increase of 0.086% in poverty rates in the period that follows, ceteris paribus. These results are statistically significant at a p-value of 0.00 and thus confirm a that there is a relationship between climate shocks and poverty rates. Tress22 shows a 0.001 percentage point increase in poverty rates, if a tress22 index increases by 1%nt. 1% increase in urbanization leads to, 0.194 percentage points in poverty rates. The results, however, are not statistically significant. An increase in the black population by 1% leads to a 0.011 percentage point increase in poverty rates. Unsurprisingly, a one unit increase in the human development index leads to a 0.16% decrease in poverty rates. In light of these findings, the report can conclude that a positive relationship between climate shocks and poverty rates exists.

Table 2

Regression results

povrate1	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Climshk	.086	.009	9.68	0	.069	.104	***
tress22	.001	.003	0.23	.82	-.006	.008	
Urbanization	.194	.064	3.04	.003	.068	.32	***
Black	.011	.002	6.01	0	.008	.015	***
HDI	-.16	.109	-1.47	.143	-.374	.054	
Constant	-.277	.338	-0.82	.413	-.943	.389	

Mean dependent var	0.661	SD dependent var	0.133
R-squared	0.240	Number of obs	702
F-test	22.571	Prob > F	0.000
Akaike crit. (AIC)	-1570.381	Bayesian crit. (BIC)	-1547.611

*** p<.01, ** p<.05, * p<.1

To interrogate whether the effects of climate change are more pronounced in the poorer municipalities, disproportionately affecting them, the report stratifies the municipalities based on their poverty rates: the municipalities whose poverty rates are above 75% are considered poorest municipalities, those whose poverty rates are between 50% and 75% are considered the less poor municipalities and the ones whose poverty rates are below 50% are considered the rich municipalities. Regressions on these subsamples are then run, with the results below:

Poorest municipalities (Municipalities with poverty rate above 75%)

Table 3 reports on the subsample of municipalities whose baseline poverty rates are above 75% which are the poorest municipalities in South Africa. The impact of climate shocks in this subsample is unambiguous. The results show that where a municipality has experienced climate shock, poverty rates increase by 10.3%. This is a statistically significant result at a p-value < 0.01, and therefore a positive relationship between climate shocks and poverty rates is clearly established. This result underscores the vulnerability of municipalities that are already impoverished to climate change – climate change behaves as a stress multiplier in these

municipalities, exacerbating challenges that already exist. As agriculture is the main economic industry in many of these economies, climate shocks in these areas can disrupt livelihoods. For example, floods and droughts can lead to the devastation of crops, leading to food insecurity and disrupting income generation in a municipality where the population is already grappling with poverty.

A one unit increase in the tress22 index leads to a 2% increase in the poverty rate, and this result is also statistically significant. A 1% increase in urbanization results in a 7.8 percentage point increase in poverty rates, while surprisingly a 1% increase in the black population within a municipality leads to a reduction in poverty by 1.4 percentage points. Both these results, however are not statistically significant, and therefore the effect of urbanization and that of an increase in black population on poverty rates is not conclusive. As expected, a 1 unit increase in the human development index in these municipalities has a negative relationship with poverty rates, where a 1 unit increase in the index leads to a 0.864% decrease in poverty rates, ceteris paribus. The results of this regression prove that for the poorest municipalities, climate shocks do increase poverty rates.

Table 3

Regression results

povrate1	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Climshk	.103	.014	7.52	0	.076	.13	***
tress22	.02	.008	2.56	.012	.005	.036	**
urbanisation	.078	.21	0.37	.712	-.339	.494	
Black	-.014	.018	-0.81	.418	-.049	.021	
HDI	-.864	.12	-7.19	0	-1.102	-.626	***
Constant	.736	1.89	0.39	.698	-3.006	4.478	

Mean dependent var	0.764	SD dependent var	0.097
R-squared	0.656	Number of obs	280
F-test	48.867	Prob > F	0.000
Akaike crit. (AIC)	-873.178	Bayesian crit. (BIC)	-855.004

*** p<.01, ** p<.05, * p<.1

Less Poor municipalities (Municipalities with poverty rate between 50% and 75%)

Table 4 reports on the subsample of municipalities whose baseline poverty rates lie between 50% and 75%. These are the municipalities that lie between the extremes of the poorest and richest municipalities - the less poor municipalities. The results show that there is a positive relationship between poverty and climate shocks – when there has been an incidence of climate shocks in these municipalities, average poverty rates increase by 6%. As hypothesized by this report, the impact of climate shocks on the less poor municipalities is weaker than that of the poorest municipalities. This can be due to various reasons. For example these municipalities may have economies that are more diversified than the poorest municipalities and they may have better social safety nets, which could provide much needed support in the aftermath of climate shocks. Having better access to resources also allows municipalities to recover quicker when they have experienced climate shocks.

A 1 unit increase in the tress22 index leads to a 0.5% average increase in poverty rates, while a 1% increase in the urbanization of municipalities leads to an average reduction of poverty by 1.5 percentage points. The results for the relationship between tress22 and poverty rates, and that for urbanization and poverty rates are not statistically significant, and therefore cannot be said to be conclusive. Surprisingly, there is an average decrease of 0.7 percentage points in poverty rates when there is a 1% increase in the size of the black population. Another unexpected result is the positive relationship between the human development index and the poverty rate, where a 1 unit increase in the HDI results in an increase of 1.162%.

Table 4

Regression results

povrate1	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Climshk	.061	.012	5.06	0	.037	.084	***
tress22	.005	.006	0.75	.452	-.007	.017	
urbanisation	-.015	.059	-0.26	.795	-.131	.101	
Black	-.007	.002	-3.41	.001	-.011	-.003	***
HDI	1.162	.141	8.25	0	.884	1.44	***
Constant	.1	.561	0.18	.858	-1.007	1.208	
Mean dependent var		0.602	SD dependent var			0.099	

R-squared	0.436	Number of obs	306
F-test	54.378	Prob > F	0.000
Akaike crit. (AIC)	-999.998	Bayesian crit. (BIC)	-981.380

*** p<.01, ** p<.05, * p<.1

Rich municipalities (Municipalities with poverty rates below 50%)

Table 5 reports on the subsample of municipalities whose baseline poverty rates lie below 50%. These are the richest municipalities in South Africa, and they primarily lie in the Gauteng and Western Cape provinces. There is a positive relationship between climate shocks and poverty rates. The average poverty rate increases by 5.9%when the municipalities have experienced a climate shock in the preceding period. This is a statistically significant result at a p-value < 0.01. A clear and confident positive relationship can therefore be deduced. These results demonstrate that the rich municipalities are more resilient to climate shocks than their poorer counterparts. This could be due to various reasons, including the types of climate shocks that the municipalities face and their resilience to them. Rich municipalities also benefit from access to larger financial resources and higher education and awareness, which can lead to better preparedness and responses to climate shocks. They may also have a diverse economy which promotes resilience, as disruption in one sector can be mitigated by the strength of another.

Expectedly, when the tress22 index increases by one unit, there is a reduction in average poverty rates, of 0.3 percentage points and a 10.4 percentage point increase average poverty rates when urbanization increases by 1% - these results are however not statistically significant and can therefore not be used to confidently infer a relationship between the variables and the average poverty rates. In line with expectations, there's an increase in average poverty rates of 1.4 percentage points, when the black population in the municipality increases by 1%. Surprisingly, when the human development index in these municipalities increases by 1 unit, there is an average increase of 3.081% in poverty rates. This counterintuitive result can be as a result of various factors, including failure of the index to capture factors that afford rich municipalities resilience when they have experienced climate shocks The results for the relationship between the poverty rates and increase in the black population within a municipality, and that of the relationship between poverty

rates and the human development index are statistically significant at a p-value <0.01 and can therefore the effects these variables on average poverty rates in these municipalities are conclusive.

Table 5

Regression results

povrate1 Climshk	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
	.059	.015	3.99	0	.029	.088	***
tress22	-.003	.003	-0.88	.379	-.01	.004	
Urbanization	.104	.114	0.92	.363	-.123	.332	
Black	.014	.003	5.50	0	.009	.019	***
HDI	3.081	.229	13.48	0	2.625	3.537	***
Constant	-1.847	.315	-5.87	0	-2.474	-1.22	***

Mean dependent var	0.568	SD dependent var	0.123
R-squared	0.867	Number of obs	116
F-test	111.743	Prob > F	0.000
Akaike crit. (AIC)	-442.576	Bayesian crit. (BIC)	-428.808

*** *p<.01, ** p<.05, * p<.1*

Discussion

This research report has sought to answer the following question - Climate Change in South Africa: Is there a disproportionate effect on poorer municipalities. The report sought to establish whether there is a positive relationship between average climate change and poverty rate. Once a positive result has been established, it delved deeper to r investigate whether the effect is more burdensome on poorer municipalities. The results confirm that climate change disproportionately poverty rates affect poorer municipalities, as the poverty rates in the poorest municipalities increase more than those in the less poor municipalities and the rich municipalities when they experience climate shocks.

Climate shocks occur as a result of climate change. In the overall analysis of all South African municipalities, climate shocks were reported to be positively related to poverty rates. An incidence of climate shocks resulted in an 8.6% average increase in poverty rates. Once this relationship was confidently established, the municipalities were stratified into three different subsamples based on

their poverty rates. The strata were analyzed in order to establish whether there is a difference in the effect of climate shocks on the poverty rates for the poorest, less poor and rich municipalities. The results show that the poorest municipalities, whose baseline poverty rates are above 75%, experience a 10.3% average increase in poverty rates when they had experienced a climate shock. The less poor municipalities, whose baseline poverty rates lie between the poorest and the wealthy municipalities, and range between 50% and 75%, experienced a 6.1% average increase in poverty rates in the period after they experienced a climate shock. The richest municipalities experienced the lowest increase in average poverty rates at 5.9%, in the period following a climate shock. The average increases in poverty rates for these samples of municipalities are all statistically significant, with p-values < 0.01. This therefore means that there can be a confident conclusion that for all municipality sub samples, climate shocks increase poverty rates. The poorest municipalities are the most affected, followed by the less poor, and the rich are the least affected. The results are in line with the hypothesis that climate change disproportionately affects poorer municipalities in South Africa.

These results of this research report mirror that the findings of Leinchenko and Silva (2014), who elaborate that the poorest communities are most susceptible to the effects of climate change. They explain that this can happen through direct and indirect channels. They elaborate that the direct channels assume there exists a direct relationship between environmental changes resulting from climate change and economic consequences that follow and ultimately poverty. Food prices and channels of agricultural production stand out as the direct channels through which climate change affects poverty. Baptista et al (2023) reiterate this, citing that climate shocks have contributed to continuing water and food insecurity. This finding is echoed by that of Leornard (2022), who found that in the Somkhele municipality in KwaZulu Natal climate change had impacted water security, ultimately caused droughts and compromised soil conditions, leading to residents not being able to grow their own food. This also corresponds with a study by Enwereji (2021) on South Africa's food security and water supply; they interviewed sixty-five municipal workers revealed that climate change poses a significant risk to food security by disrupting access to food, reducing food availability, hindering proper food utilization, and diminishing food quality.

Poor municipalities are more susceptible to the effects of climate change through direct channels, than rich municipalities. In their study of the effects of extreme temperature shocks on the health of the elderly in China, Chen and Qin (2022) found that residents of urban areas tend to fare better in adapting to local extreme temperatures in comparison to their poorer rural counterparts. This is due to the differences in infrastructure and economic activity. The sub-par economic standing of the poorer, rural areas puts them in a position where they lack the ability to recover from climate shocks. This finding is corroborated by Gentle and Maraseni (2012), who find that Climate change intensifies vulnerabilities in regions that are heavily reliant on rain-fed agriculture, especially in resource-constrained rural mountain communities. These areas are often already grappling with limited livelihood options, inadequate information, and insufficient access to essential services and productive assets, hindering their adaptive capacity. They further elaborate that for impoverished, marginalized communities that are already facing significant challenges, climate change presents an additional and substantial burden and that the projected intensification of climate-related risks poses a severe threat to livelihoods and is likely to deepen existing inequalities.

Leinchenko and Silva (2014) go on to explain that indirect channels on the other hand, have complexities and multiple factors that that link climate change and poverty. They propose that the way individuals and households are situated play a significant and critical role in indirect channels. Factors such as access to resources and existing vulnerabilities influencing how individuals and households adapt to climate shocks. Broader socio-economic conditions, such as income levels, access to education, and social safety nets also greatly impact a population's ability to cope with climate change. Additionally, the quality of institutions and governance plays a critical role. Strong institutions can provide vital support in the face of climate challenges, while weak governance can exacerbate existing vulnerabilities. Chen and Qin (2022) agree with this postulation, citing that over and above climate shocks being an environmental concern, they have an impact on healthcare, agriculture and fiscal policy.

In South Africa, a study by Lethoko (2016) on the inclusion of climate change the integrated development plans of municipalities found that these poor municipalities are plagued by weak governance. Along with local capacity for such planning being low, there's a lack of climate change awareness at grassroot levels. Financial constraints and competing priorities in these municipalities often push aside medium to long-term planning and projects that are misaligned with the brief tenure of political leaders fail to see implementation and thus convincing policymakers of the necessity for a climate strategy is challenging when climate forecasts extend beyond the shortterm political and developmental plans of municipalities. This weak governance in poor municipalities exacerbates the effects of climate change, negatively impacting their ability to recover from shocks when they occur.

The higher effect of climate shocks on the poverty rates of poorer municipalities in South Africa, verifying a disproportionate effect of climate change in poorer municipalities, suggests that these municipalities are more prone to experiencing increased poverty rates through these channels both direct and indirect channels. Cherisch and Wright (2019) explain that if the socio-economic standing of an individual or household is good, they will be more able to withstand the shocks experiences due to climate change. They however reveal that in South Africa, more than half of the population lives below the poverty line, making a large part of the population susceptible to climate change.

Limitations

While this research report has shed some insight on the disproportionate effect of climate change on poorer municipalities, illustrating that for the poorest municipalities, the effect of climate shocks is higher than the effect on the less poor municipalities, there were some limitations. The research used data from 1996 to 2011, as the results of the 2022 census were not available when the research commenced, making it impossible to establish whether the poorest municipalities are still disproportionately affected by climate change, beyond the years in the study.

Further the report looks at only whether a climate shock was experienced and does not distinguish between temperature shocks and precipitation shocks. Distinguishing between the shocks is important as it will assist in identifying the help that the different municipalities require. Temperature and precipitation shocks have varying effects on humans and the environment – temperature shocks can cause illness and death, while precipitation shocks can affect water available for drinking, farming and industrial use (United States Environmental Protection Agency, nd). As the different municipalities have different economic industries, they would require different adaptation measures to deal with the shocks that affect them the most.

While the report confirms that climate shocks occurred in the municipalities, it does not provide data on their frequency. Understanding which municipalities face frequent shocks, and if poverty rates correlate with shock intensity, type, or frequency, would be crucial. This knowledge would guide targeted adaptation plans to be most appropriate for the municipalities in question, maximizing the effectiveness of decision-maker efforts.

Further studies can therefore include the results from the 2022 census, and they may also enrich the results of the research by distinguishing between the types of climate shocks that municipalities experience, helping to enhance the effects to the adaptation measures that are put in place.

Conclusion

This research report addressed the question: Climate Change in South Africa: Is there a disproportionate effect on poorer municipalities? Using municipal climate data and municipal household data. A panel data with fixed effects model was utilized to interrogate whether climate change has a disproportionate effect on the poor. The results have shown that there is a positive relationship between climate shocks and poverty rates overall, in South African municipalities. The poorest municipalities, whose baseline poverty rates are above 75%, saw the highest increase in poverty rates after experiencing climate shocks. They were followed by the less poor municipalities, whose poverty rates are between 50% and 75%. The impact of climate shocks on the rich municipalities was the lowest. These results do show that indeed, climate change has a disproportionate effect on the poorer municipalities.

By demonstrating that poorer municipalities in South Africa are more vulnerable to the effects of climate change, this research provides valuable information for policy makers focused on climate change. The report shows a quantifiable impact of climate shocks on poverty rates in different municipalities, providing a strong basis for policy interventions. As municipalities may differ in terms demographics, economic industries, topography and the climate shocks they experience, their challenges are different. The research report therefore recommends spatially focused adaptation policies to address the effects of climate change, especially on the poorest municipalities. These policies assist in the efficient allocation of adaptation resources, ensuring that scarce resources are used where they are most required.

In urban areas, effects of climate change are exacerbated by concentration of infrastructure and population density (IPCC, 2022). Climate policy that is spatially focused on urbanized areas can focus on building climate resilient infrastructure. According to Sadawa et al (2011), infrastructure plays an important role in the reduction of poverty as it can improve income opportunities and encourage sustainable welfare. A study by Timilsina et al (2020) echoes this, citing that studies that examined the effect of physical infrastructure on inequality and poverty show that infrastructure does contribute to the reduction on poverty. Corroborating this, Ali and Pernia (2003) cite higher productivity, increased opportunities and better availability of basic goods and services as direct results of infrastructure investments. They argue that these can reduce poverty by improving income distribution.

Nucifera et al (2020), cite adjustment to technology as an adaptation strategy that may benefit the agricultural sector. They elaborate those strategies such as adjustment to the farming calendar, modified cultivation methods and monitoring seasonal forecast are adaptation strategies that may be used by the agricultural sector. Municipalities whose main industries are agriculture, which tend to be the poorer and more vulnerable ones, can benefit from this adaptation strategy. Municipalities that exhibit low employment and income levels should consider adopting adaptation strategies that improve income, as populations that have better incomes are more resilient to climate shocks. Ogolla et al (2022) cite that improving education, income, and job opportunities would empower residents to participate in local climate adaptation efforts and natural resource management, ultimately reducing their vulnerability.

It suggests that climate adaptation and resilience strategies should be targeted towards the most vulnerable communities, guiding allocation of resources. These findings are important for longterm planning and investment in infrastructure, education, and economic development to build resilience against future climate shocks.

While the report focuses on South Africa, its findings have a broader relevance. The findings contribute to the broader understanding of how climate change disproportionately affects the poor. It can therefore inform international efforts to combat the challenges brough about b by the spatially unequal effects of climate change. By demonstrating that poorer municipalities in South Africa are more vulnerable to the effects of climate change, this research provides valuable information for policy makers focused on climate change, and by showing a quantifiable impact of climate shocks on poverty, the research provides a strong basis for policy interventions. It suggests that climate adaptation and resilience strategies should be targeted towards the most vulnerable communities, guiding allocation of resources to address climate change effects, especially for the poorest municipalities. These findings are important for long-term planning and investment in infrastructure, education, and economic development to build resilience against future climate shocks.

In order to create a more resilient and equitable society, where the impacts of climate change do not disproportionately affect the poor, climate change policy needs to be designed to specifically target the spatial vulnerabilities of the poor municipalities, focusing on their needs and creating solutions that address the unique challenges of the municipalities. There should be an equitable distribution of resources for climate adaptation and resilience-building, ensuring that the most vulnerable populations receive the support they need. Most importantly, these policies should involve active participation from local communities, ensuring that their voices are heard, and their needs are met in the adaptation process.

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