Climate Change and Sectoral Labor Reallocation

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Abstract

This is paper investigates whether and how climate change affects structural transformation in Africa, with particular attention to gendered impacts and heterogeneities across population groups. Combining census data from 12 African countries spanning four decades (1974–2014) with gridded temperature and precipitation data, we find that a 1°C increase in decadal temperature leads to approximately a 6 percentage point increase in employment in agriculture and a comparable decline in non-agricultural sectors. Climate change causes a gendered delay in structural transformation, disproportionately affecting women and less-educated individuals. These findings suggest that climate change exacerbates existing societal inequities. The impacts are mediated through reduced agricultural productivity and increased labor force participation, particularly among women, as rising temperatures simultaneously suppress farm income and pull additional workers especially women into agriculture.

1. Introduction

Climate change presents one of the most profound socioeconomic challenges of our time, with consequences that extend far beyond environmental disruption (Carleton & Hsiang, 2016). In sub-Saharan Africa, where economies remain heavily dependent on rain-fed agriculture, the effects are particularly severe. Rising temperatures and shifting precipitation patterns reduce crop yields, erode agricultural productivity, and put immense pressure on rural livelihoods (Schlenker & Lobell, 2010; Knox et al., 2012; Lobell et al., 2011).

Structural transformation - the reallocation of labor from less productive agricultural activities toward more productive manufacturing and service sectors is a cornerstone of economic growth and poverty reduction in developing countries (Herrendorf et al., 2014; Duarte & Restuccia, 2010; Rodrik, 2010). Much of the historical poverty reduction in East Asia, for instance, was driven by this process. Yet in Africa, structural transformation has proceeded unevenly and slowly, leaving large shares of the labor force in low-productivity agriculture (McMillan & Headey, 2014; McMillan et al., 2014; Vries et al., 2015).

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Against this backdrop, a critical and underexplored question arises: does climate change hinder or accelerate structural transformation? Reduced agricultural productivity could, in theory, push labor out of farming and into other sectors. Alternatively, the collapse of farm incomes could depress demand for non-agricultural goods and services, pulling labor back into subsistence farming rather than releasing it to more productive sectors.

This paper addresses these questions empirically and goes further to explore whether climate change compounds existing inequalities particularly across gender lines and educational attainment. Women in sub-Saharan Africa bear a disproportionate share of agricultural labor while facing greater barriers to entry in non-agricultural sectors (Dinkelman & Ngai, 2022; Afridi et al., 2022). If climate shocks reinforce this pattern, they risk locking women into low-productivity work and widening structural inequalities (Diffenbaugh & Burke, 2019; Sitko et al., 2024).

We make three main contributions. First, we provide systematic empirical evidence on the relationship between climate change and structural transformation in Africa. Second, we document significant gendered and education-based heterogeneities in this relationship. Third, we examine the mechanisms through which climate change operates, including agricultural productivity, labor force participation, and migration.

2. Data

2.1 Census Data

We draw on the Integrated Public Use Microdata Series (IPUMS) database, which harmonizes census microdata across countries (Ruggles et al., 2024). Our sample comprises 30 national censuses from 12 African countries collected between 1974 and 2014. The countries included are Botswana, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Malawi, Morocco, Rwanda, South Africa, Tanzania, and Uganda. The census data provides individual-level information on age, gender, urban or rural residence, educational attainment, and employment sector, which we classify into agriculture, manufacturing, and services.

We aggregate individual observations to the district level, the finest geographic unit consistently available across censuses, yielding a panel dataset of district-level employment shares across census years. This design allows us to exploit variation within districts over time, controlling for time-invariant local characteristics.

2.2 Climate Data

Temperature and precipitation data come from the gridded monthly dataset of Willmott and Matsuura (2001), which covers the period 1900–2017 at a spatial resolution of $0.5° \times 0.5°$. We compute decadal averages of temperature and precipitation for each district by overlaying the climate grid with district boundaries, then match these averages to the census years to construct a climate panel aligned with our labor market data.

2.3 Agricultural Productivity Data

As a proxy for agricultural productivity and vegetation cover, we use the Normalized Difference Vegetation Index (NDVI) from the National Oceanic and Atmospheric Administration (NOAA), available from 1981 to 2014. NDVI captures the greenness and density of vegetation and has been widely used as a proxy for agricultural output in settings where crop-level productivity data are unavailable (Burke & Lobell, 2017).

3. Empirical strategy

3.1 Empirical specification

Our baseline specification is a two-way fixed-effects model estimated at the district level:

$$Y_{dt} = \beta_1 \, Temp_{dt} + \beta_2 \, Precip_{dt} + \alpha_d + \gamma_{ct} + \varepsilon_{dt}$$

where Y_{dt} is the employment share in a given sector (agriculture, manufacturing, or services) in district d at census year t. $Temp_{dt}$ and $Precip_{dt}$ are the decadal averages of temperature and precipitation for that district-year. αd are district fixed effects, which absorb all time-invariant local characteristics such as geography, soil quality, and baseline economic structure. γ_{ct} are country-year fixed effects, which control for country-level shocks common across all districts within a country at a given time — including macroeconomic conditions, national policy changes, and aggregate climate trends. Standard errors are clustered at the district level to account for serial correlation.

3.2 Long difference specification

To capture medium- to long-run effects, we also estimate a first-difference (long-difference) model that compares the first and last available census observations for each district:

$$\Delta_{Yd} = \beta_1 \, \Delta Temp_d + \beta_2 \, \Delta Precip_d + \Delta X_d + \Delta \varepsilon_d$$

This specification differences out all time-invariant confounders, focusing on how changes in climate over the full sample period correspond to changes in employment structure.

3.3 Heterogeneity Analysis

We disaggregate the main specification by gender (men vs. women), age group (youth aged 15–34 vs. adults aged 35–64), and educational attainment (less than primary vs. primary and above) to identify differential exposure and vulnerability to climate shocks. These subgroup analyses allow us to determine whether climate change compounds existing structural disadvantages.

4. Results and discussion

4.1 Main results

Table 1 presents our baseline results. A 1°C increase in decadal temperature is associated with approximately a 6 percentage point increase in the share of labor employed in agriculture. Correspondingly, manufacturing employment declines by about 3 percentage points and service sector employment by approximately 4 percentage points. These results are precisely estimated and robust across specifications.

Table 1: Effect of Climate on Employment Sectors

Variable	Agriculture (1)	Agriculture (2)	Manufacturing (3)	Manufacturing (4)	Services (5)	Services (6)
Temperature	0.064*	0.063*	-0.025*	-0.025*	-0.039*	-0.038*
	(0.014)	(0.014)	(0.012)	(0.008)	(0.008)	(0.012)
Precipitation	-0.029*	-0.016*	0.006**	0.023*	0.013*	0.013*
	(0.007)	(0.006)	(0.003)	(0.005)	(0.005)	(0.005)
Observations	1,927	1,927	1,927	1,927	1,927	1,927
Districts	819	819	819	819	819	819
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes

Higher precipitation exhibits the opposite pattern: it is associated with a decline in agricultural employment and increases in manufacturing and service employment, suggesting that more favorable rainfall conditions facilitate movement out of agriculture. Together, these findings indicate that rising temperatures delay structural transformation by retaining — or pulling — labor into agriculture, while adequate precipitation supports the transition to more productive sectors.

The magnitude of these effects is economically significant. A 6 percentage point increase in agricultural employment share represents a substantial reversal of structural transformation progress, particularly given that several African countries have achieved only modest declines in their agricultural labor shares over recent decades.

4.2 Long term impacts

The long-difference estimates corroborate the main findings (Table 2). When comparing the earliest and latest census observations for each district, cumulative warming over the sample period is associated with a comparable increase in agricultural employment and decline in non-agricultural employment, confirming that the effects are not artifacts of short-term fluctuations.

Table 2: Effect of Climate on Employment Sectors — Long-Difference Specification

Variable	Agriculture (1)	Agriculture (2)	Manufacturing (3)	Manufacturing (4)	Services (5)	Services (6)
ΔTemperature	0.074*	0.073*	-0.029**	-0.028**	-0.045**	-0.045*
	(0.023)	(0.020)	(0.012)	(0.011)	(0.019)	(0.016)
ΔPrecipitation	-0.031*	-0.015*	0.007	0.004	0.024*	0.011*
	(0.009)	(0.008)	(0.004)	(0.004)	(0.007)	(0.006)
Observations	819	819	819	819	819	819
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

4.3 Heterogeneity by gender

The gendered dimension of climate impacts is among the most striking findings of this paper (Table 3). A 1°C temperature increase raises women's agricultural employment share by approximately 8.7 percentage points, compared to only 3.9 percentage points for men. Women's service sector employment declines by roughly 7 percentage points, whereas men's declines by only about 1.5 percentage points. The gender differences are statistically significant (p-value for equality: 0.022 for agriculture, 0.003 for services).

Table 3: Impacts of Climate Change by Gender

Panel A: Male

Variable	Agriculture (1)	Agriculture (2)	Manufacturing (3)	Manufacturing (4)	Services (5)	Services (6)
Temperature	0.039*	0.038*	-0.023**	-0.023*	-0.016	-0.015
	(0.014)	(0.013)	(0.009)	(0.009)	(0.012)	(0.011)
Precipitation	-0.029*	-0.015*	0.009*	0.003	0.020*	0.012*
	(0.005)	(0.005)	(0.003)	(0.003)	(0.004)	(0.003)

Panel B: Female

Variable	Agriculture (1)	Agriculture (2)	Manufacturing (3)	Manufacturing (4)	Services (5)	Services (6)

Temperature	0.087*	0.087*	-0.018**	-0.017**	-0.069*	-0.070*
	(0.019)	(0.017)	(0.008)	(0.008)	(0.017)	(0.015)
Precipitation	-0.045*	-0.028*	0.005	0.006	0.040*	0.022*
	(0.010)	(0.008)	(0.004)	(0.004)	(0.008)	(0.007)
p-value {Male=Female }	0.039	0.022	0.697	0.591	0.009	0.003
Observations	1,927	1,927	1,927	1,927	1,927	1,927
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

These results reveal a pronounced gendered delay in structural transformation. Women are pulled more strongly into agriculture as temperatures rise, while losing ground more sharply in services — reflecting their greater dependence on agriculture and heightened vulnerability to climate shocks that depress opportunities outside the farm sector.

4.4 Heterogeneity by Age

Table 4 shows that youth (aged 15–34) experience a 7.3 percentage point increase in agricultural employment per 1°C, somewhat larger than the 4.9 percentage points for adults (aged 35+), but the differences across age groups are not statistically significant (p-value: 0.182). Age per se is therefore not a major source of differential vulnerability in the way that gender and education are.

Table 4: Impacts of Climate Change by Age

Variable	**Agriculture — Youth (1)**	**Agriculture — Youth (2)**	**Agriculture — Adults (3)**	**Agriculture — Adults (4)**
Temperature	0.073*	0.073*	0.050*	0.049*
	(0.016)	(0.014)	(0.014)	(0.012)
Precipitation	-0.032*	-0.019*	-0.025*	-0.013**
	(0.006)	(0.006)	(0.006)	(0.005)
p-value {Youth=Adult}	—	0.182	—	—
Observations	1,927	1,927	1,927	1,927

Country-Year FE	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes

4.5 Heterogeneity by Education

Table 5 shows that educational attainment strongly moderates climate vulnerability. Individuals with less than a primary education experience a 7.5 percentage point increase in agricultural employment per 1°C warming, while those with primary education and above experience only a 2.2 percentage point increase (statistically insignificant). The gap is statistically significant (p-value: 0.013) and similarly pronounced for non-agricultural employment losses.

Table 5: Impacts of Climate Change by Education Level

Panel A: Less than Primary

Variable	**Agriculture (1)**	**Agriculture (2)**	**Manufacturing (3)**	**Manufacturing (4)**	**Services (5)**	**Services (6)**
Temperature	0.077*	0.075*	-0.027*	-0.027*	-0.050*	-0.048*
	(0.015)	(0.015)	(0.009)	(0.009)	(0.015)	(0.015)
Precipitation	-0.020*	-0.016*	0.004	0.003	0.016*	0.013*
	(0.006)	(0.006)	(0.003)	(0.003)	(0.005)	(0.005)

Panel B: Primary and Above

Variable	**Agriculture (1)**	**Agriculture (2)**	**Manufacturing (3)**	**Manufacturing (4)**	**Services (5)**	**Services (6)**
Temperature	0.022	0.022	-0.006	-0.005	-0.016	-0.017
(0.015)	(0.015)	(0.009)	(0.009)	(0.014)	(0.014)	
Precipitation	-0.018**	-0.017**	0.005	0.004*	0.013*	0.012*
(0.008)	(0.008)	(0.005)	(0.005)	(0.007)	(0.007)	
p-value {Less=Above}	0.010	0.013	0.106	0.098	0.099	0.120
Observations	1,927	1,927	1,927	1,927	1,927	1,927
Country-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
District FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes	No	Yes

This pattern reflects the well-documented relationship between education and labor market flexibility. More educated individuals possess the skills and networks needed to transition into non-agricultural employment even under adverse conditions. Less educated individuals face narrower options and are more easily trapped in agriculture when climate shocks reduce opportunities elsewhere. Since women in the sample also tend to have lower educational attainment on average, these education effects partially compound the gender effects described above.

4.6 Robustness checks

We conduct a series of robustness checks to validate our main findings. First, we use alternative climate measurements, including higher-order temperature terms and growing-season-specific climate averages, and find broadly consistent results. Second, we experiment with different aggregation periods (5-year vs. 10-year averages) and find that the effects are robust to this choice. Third, we apply alternative clustering strategies — including clustering at the country-region level — and find that our standard errors remain similar. Fourth, we conduct subsample analyses, removing countries with fewer than three census waves or those with unusual climate trajectories, and the main findings hold. Finally, we test for pre-trends to assess whether treated and control districts followed similar trajectories before the climate changes in question, and find no evidence of differential pre-trends, supporting the validity of our identification strategy.

5. Mechanisms

We examine three potential mechanisms through which climate change may delay structural transformation: agricultural productivity, labor force participation, and migration.

5.1 Agricultural Productivity

Using NDVI as a proxy for agricultural productivity, we find that rising temperatures significantly reduce vegetation density and agricultural output (Ortiz-Bobea et al., 2021; Schlenker & Lobell, 2010). This productivity decline operates through two channels. First, lower farm income reduces households' purchasing power, depressing demand for manufactured goods and services, which in turn reduces labor demand in those sectors (Hertel et al., 2010; Barrett et al., 2023). Second, as farms become less productive, more labor is needed to produce the same level of output - a labor-intensification effect that retains workers in agriculture even as farm incomes fall (Emerick, 2018).

5.2 Labor Force Participation

Rising temperatures are associated with a significant increase in women's labor force participation - approximately 5 percentage points for a 1°C warming. This finding is consistent with an income effect: as agricultural earnings fall, households draw additional members — primarily women into the labor force to compensate for lost income (Afridi et al., 2022; Graff Zivin & Neidell, 2014). Because the non-agricultural labor market offers limited opportunities for women with low education and skills, this increased participation is channeled predominantly into agriculture, reinforcing the pattern observed in the main results.

This mechanism highlights a crucial dynamic: climate shocks do not simply reduce incomes but actively reshape labor supply, pushing previously non-working women into the labor force under adverse conditions. Rather than facilitating a transition to more productive work, this increased participation leads to an expansion of agricultural employment, further delaying structural transformation.

5.3 Migration and Urbanization

We find generally negligible impacts of climate change on rural-urban migration and urbanization rates in our sample. This is somewhat surprising given the theoretical expectation that climate-induced agricultural distress might push rural populations toward cities (Barrios et al., 2006; Cattaneo & Peri, 2016). One possible explanation is that climate shocks reduce not only the returns to farming but also the resources available for migration, effectively trapping households in rural areas (Henderson et al., 2017; Mueller et al., 2014). Another is that urban labor markets themselves constrained cannot absorb large inflows of rural migrants, reducing the migration incentive. We also find no significant effect of climate change on the probability of self-employment, suggesting that informal entrepreneurship does not serve as a significant buffer against agricultural shocks.

6. Discussion

Our results carry several important implications. The finding that climate change delays structural transformation by pulling labor into agriculture rather than pushing it out - challenges the simple narrative that environmental degradation necessarily accelerates rural-urban migration and urbanization (Barrett et al., 2023). In the African context, the more common outcome appears to be agricultural labor intensification: as farms become less productive, households invest more labor to maintain output, and additional family members (especially women) enter the agricultural labor force (Colmer, 2021; Liu et al., 2023).

The gendered dimension of these findings deserves particular emphasis. Women's disproportionate vulnerability reflects the intersection of climate exposure with pre-existing structural inequalities (Diffenbaugh & Burke, 2019). In sub-Saharan Africa, women face higher barriers to non-agricultural employment, including legal restrictions, social norms, lower educational attainment, and limited access to productive assets and finance (Dinkelman & Ngai, 2022). When climate shocks compress economic opportunities, these barriers become binding constraints, effectively trapping women in low-productivity agriculture while men retain greater flexibility to move into other sectors (Afridi et al., 2022; Sitko et al., 2024). These dynamic risks widening gender gaps in income, productivity, and economic empowerment precisely when the development imperative calls for their reduction.

Similarly, the education gradient in climate vulnerability underscores how human capital functions as a form of adaptive capacity (Porzio et al., 2022; Herrendorf & Schoellman, 2018). Investments in education particularly for women and girls may therefore serve double duty: directly facilitating structural transformation under normal conditions and building resilience to climate shocks that would otherwise delay or reverse that transformation.

The mechanisms we identify reduced agricultural productivity and increased female labor force participation also point toward targeted policy responses. Interventions that raise agricultural productivity under heat stress, such as drought-resistant crop varieties, irrigation, and climate-smart farming practices, could reduce both the income shock and the labor-intensification dynamic (Asmare & Tabe-Ojong, 2025; Aragón et al., 2021). Programs that expand women's access to non-agricultural employment, including vocational training, credit, and childcare, could help redirect increased female labor supply toward more productive sectors (Feriga et al., 2025; Tabe-Ojong et al., 2025).

7. Conclusion

This paper provides systematic evidence that climate change significantly delays structural transformation in Africa. A 1°C increase in decadal temperature increases the agricultural labor share by approximately 6 percentage points while reducing manufacturing and service employment by comparable magnitudes. These effects are robust across specifications and persist over medium- to long-term horizons.

Critically, the impacts are not evenly distributed. Women bear a substantially larger burden than men, with their agricultural employment rising more sharply and their service-sector employment declining more steeply in response to warming. Individuals with lower educational attainment are similarly more vulnerable, experiencing larger shifts into agriculture and greater losses in non-agricultural sectors. These heterogeneities reveal that climate change does not merely slow economic development, it actively compounds existing inequalities, threatening to leave behind the most disadvantaged members of African societies.

The mechanisms driving these outcomes operate through two main channels: the suppression of agricultural productivity, which reduces demand for non-agricultural goods and labor; and the increase in women's labor force participation, which channels additional labor into agriculture rather than into more productive sectors. Migration and self-employment do not appear to serve as significant adjustment mechanisms.

These findings carry urgent policy implications. Adaptation strategies must go beyond generic agricultural support and address the specific vulnerabilities of women and less-educated populations. This includes targeted investments in agricultural productivity under climate stress, expanded access to non-agricultural employment for women, and sustained commitment to girls' education as a long-run adaptive asset. Failure to act risks not only slowing Africa's structural transformation but entrenching and deepening the inequalities that already hold back the continent's development potential.

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