Diallo, Sadou, and Henri Atangana Ondoa. 2025. "Climate Shocks and the Labour Market in Sub-Saharan Africa: Effects on Youth Employment and the Reallocation of Labour Supply". *International Labour Review* 164 (2): 1–20. https://doi.org/10.16995/ilr.18840.

# Climate shocks and the labour market in sub-Saharan Africa: Effects on youth employment and the reallocation of labour supply

**Sadou Diallo**, Université Général Lansana Conté at Sonfonia-Conakry (UGLC-S), Guinea; Institute for Governance, Humanities and Social Sciences (PAUGHSS), Pan African University, Yaoundé, Cameroon (April to July 2022), donsadou1@gmail.com (corresponding author)

**Henri Atangana Ondoa**, Department of Economics, University of Yaoundé II, Cameroon, atanganaondoa@yahoo.fr

***Abstract.*** *Faced with major socio-economic challenges, high unemployment and poverty levels and slow economic growth, sub-Saharan Africa is vulnerable to climate change. We examine the effects of climate shocks on youth employment and employment in agriculture, manufacturing and services. We apply the difference-in-differences method to panel data and find that rising temperatures cause job losses among young people and in the agricultural sector. We also find that high temperatures drive the reallocation of labour from agriculture towards manufacturing and services.*

***Keywords:*** *climate change, climate shock, youth employment, employment in agriculture, reallocation of labour, occupational change, difference-in-differences, labour market.*

## 1. Introduction

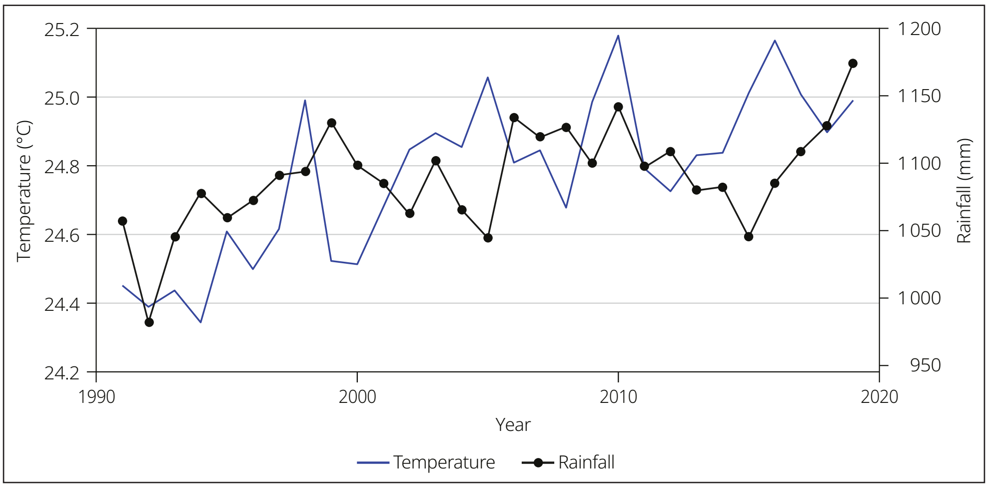
Jobs provide the cornerstone of economic and social development by improving social well-being and by helping to boost productivity, decrease poverty and strengthen social cohesion (World Bank 2012). However, these social objectives are threatened by the increasing frequency and intensity of climate shocks (IPCC 2014). This threat has attracted increasing attention from policymakers, entrepreneurs and the scientific and international communities. Climate change is a change in the statistical average and variability of temperature, wind, humidity, cloudiness, precipitation and other quantities over a long period of time (Nordhaus 2013). It can cause climate variability, which consists of variations in climate averages and other statistics (standard deviations, extremes, etc.) across temporal and spatial scales, beyond those of individual weather events (IPCC 2014). This climate variability can lead to climate shocks, which are unpredictable weather events that result in environmental degradation.

By reducing productivity, climate shocks can affect employment (Kjellstrom, Holmer and Lemke 2009; Sudarshan et al. 2015; Zhang et al. 2018; Diallo and Atangana Ondoa 2024). Their effects can be felt in workers' health (Kjellstrom et al. 2015; Kjellstrom et al. 2016; ILO 2019), the destruction of physical and human capital (Mueller and Quisumbing 2011) and reduced production and incomes (Dell, Jones and Olken 2012; Emran and Shilpi 2018; Adhvaryu, Kala and Nyshadham 2019; Desbureaux and Rodella 2019). The negative repercussions of these shocks on agricultural income and productivity can lead to a strategic reallocation of labour supply (Branco and Féres 2021; Colmer 2021; Josephson and Shively 2021). This reallocation may consist of an increase in working hours, the substitution of agricultural activities with non-agricultural ones, taking up a second job or migration (Rose 2001; Emran and Shilpi 2018; Minale 2018; Branco and Féres 2021). However, this depends on the capacity of workers to move between sectors and of other sectors to absorb them (Colmer 2021).

Aside from these effects on the labour market, by encouraging job creation linked to climate policies, by replacing jobs related to fossil fuels with jobs related to renewable energies and by transforming existing jobs, climate shocks can also act as a springboard for the world's economies, particularly in Africa (ILO 2010). Countries in sub-Saharan Africa are recording a rise in natural disasters (IPCC 2014). For example, between 2000 and 2017, more than 15 per cent of natural disasters worldwide were reported in sub-Saharan Africa. For the whole African continent, climate-induced losses account for 10 to 15 per cent of gross domestic product (GDP) per capita growth for the period 1986–2015 (Baarsch et al. 2020), with recurring droughts, flooding and heatwaves (IPCC 2022). Over the past decade, the climate in Africa has been marked by extreme weather and climate events. For example, 2010 was one of the hottest years on record on the continent for the 2010–19 period. Furthermore, certain regions have experienced prolonged droughts over this period (WMO 2020a). This trend is confirmed by our data (see figure 1). The temperature spike in 2010 and the drought in 2011 were exacerbated by La Niña (WMO 2020b). This meteorological phenomenon, which results in sharp variations in temperature and more frequent droughts, began in 2010 and lasted for two years. The negative effects of these shocks could stand in the way of achieving various key Sustainable Development Goals, particularly those relating to food security and health.

Given the high vulnerability of jobs and low productivity and incomes in sub-Saharan Africa (Szirmai et al. 2013; ILO 2020), the negative effects of climate shocks on employment are likely to have considerable economic and social costs. Vulnerable groups such as young people will be the hardest hit by forecast job and productivity losses. Young people account for over half the population of Africa and it is estimated that they will reach 295 million by 2035 (Filmer and Fox 2014). This demographic trend implies an increase in the number of young people entering the labour force. Young people make up 23.5 per cent of the working poor, who constitute 38.1 per cent of the labour force in sub-Saharan Africa (Yeboah and Flynn 2021).

**Figure 1. Temperature and rainfall, 1991–2020**




Source: Our own calculations based on CRU data (2021).

In sub-Saharan Africa, the labour force is highly exposed to unemployment, particularly young people. In 2003, the average unemployment rate was estimated at 5.8 per cent compared with 8.9 per cent among young people (ILO 2024). Youth unemployment can be a serious problem, as it weakens human capital and prevents the accumulation of professional experience, with negative effects on future income and career opportunities (Marelli and Signorelli 2016). From a social and psychological perspective, long-term unemployment among young people can also exclude them from society, resulting in discouragement and frustration (Seghiar 2014) and giving rise to social unrest and instability. For example, unemployed young people might be ripe for recruitment by armed groups, thus aggravating the fragile state of countries already facing security crises. Accordingly, as a catalyst for economic growth, poverty reduction and peace, youth employment is at the centre of the new vision of development defined in the African Union's Agenda 2063 and in the United Nations' (UN) 2030 Agenda for Sustainable Development.

Our study aims to estimate the effects of climate shocks on jobs in sub-Saharan Africa. In particular, we consider the effects of the temperature peak in 2010 and the drought of 2011 on youth employment and employment in agriculture, manufacturing and services.

The existing literature has mainly concentrated on the effects of climate change on the allocation of labour by agricultural households in developing and developed countries. Among many others, contributions include Josephson and Shively (2021) on Zimbabwe; Brookes Gray, Taraz and Halliday (2023) on South Africa; Liu, Shamdasani and Taraz (2023) on India; Desbureaux and Rodella (2019) on Latin America; Branco and Féres (2021) on Brazil; and Graff Zivin and Neidell (2014) on the United States. According to this literature, labour reallocation is a coping strategy against unexpected events related to a climate shock (Rose 2001; Emran and Shilpi 2018; Minale 2018; Colmer 2021). Households generally reallocate their labour when their income and means of subsistence are affected by meteorological shocks such as rainfall anomalies (Desbureaux and Rodella 2019; Branco and Féres 2021; Josephson and Shively 2021; Brookes Gray, Taraz and Halliday 2023), temperature spikes (Graff Zivin and Neidell 2014; Colmer 2021; Liu, Shamdasani and Taraz 2023) and floods (Mueller and Quisumbing 2011). Studies also document a fall in agricultural wages due to reduced demand for labour during climate shocks (Jayachandran 2006; Emran and Shilpi 2018).

Despite this rich literature, we know very little about the effects of climate shocks on youth employment in sub-Saharan Africa. Moreover, existing studies have explored the effects of specific climate shocks, whereas transmission mechanisms differ depending on the nature of the shock. Unlike studies that consider employment at the sectoral level,[1] our study provides estimations of the effects of climate change on youth employment in general. We also examine the effects on employment of two phenomena: temperature variation and drought. This allows us to identify the operative transmission mechanisms and make targeted recommendations. Lastly, we consider the process of labour reallocation from agriculture to manufacturing and services. On this basis, we formulate the following question: what are the effects of temperature shocks and drought on employment in the countries of sub-Saharan Africa?

In order to answer this question, we combined temperature and rainfall data with data on employment for 42 countries in sub-Saharan Africa for the period 1991–2020. The results from the difference-in-differences approach indicate that temperature variation has a negative effect on youth and agricultural employment but a positive effect on employment in manufacturing and services.

The remainder of the article is organized as follows. In the second section, we discuss the mechanisms through which climate change can affect employment. The third section presents our data and descriptive statistics. The fourth section describes our econometric model. We analyse our results in the fifth section and in the sixth, we conclude and discuss some public policy implications.

## 2. Literature review

The effects of climate shocks on employment can be reflected in labour productivity, in investment and in sectoral reallocation.

### 2.1. Labour productivity

The literature shows that exposure to high temperatures can cause heat stress, which has a negative impact on working conditions and causes fatigue, reduced performance and clinical diseases (Kjellstrom, Holmer and Lemke 2009; Graff Zivin and Neidell 2014). These physiological effects increase the risk of accidents (Ramsey et al. 1983) and decrease workers' physical and mental capacities (Ramsey 1995; Kjellstrom et al. 2016), reducing labour productivity (Seppänen, Fisk and Lei 2006; Kjellstrom et al. 2015; ILO 2019).

Heat stress theories explain losses in productivity by a psychological mechanism: the exhaustion of attentional resources[2] linked to exposure to excessive heat leads to a loss of the individual's cognitive performance and productivity (Duffy 1957; Provins 1966; Hancock and Warm 1989; Hocking et al. 2001; Vasmatzidis, Schlegel and Hancock 2002). This exhaustion is caused by a rise in body temperature above the thermal comfort zone, which is the range within which performance is highest because cognitive adjustments can be made easily (Hancock and Warm 1989).

Aside from a loss in productivity at the workplace, high temperatures can also lower productivity by increasing worker absenteeism (Somanathan et al. 2021). For example, trouble sleeping through hot nights may reduce workers' willingness and capacity to go into work. A fall in worker productivity can lead to a reduction in production and profit for the enterprise (Deschênes and Greenstone 2007; Somanathan et al. 2021).

Climate shocks can disrupt enterprises' supply chains and logistics (Sabbag 2013), which leads to a loss in production, global productivity and revenue, since companies are not able

1 For the agricultural sector, see Emran and Shilpi (2018). For non-agricultural sectors, see Branco and Féres (2021); Colmer (2021); Brookes Gray, Taraz and Halliday (2023); and Liu, Shamdasani and Taraz (2023).

2 Attentional resources include concentration, memory, retention, information processing and task performance (Blanchet 2015).

to use their workforce and other production factors to their full capacity (Allcott, Collard-Wexler and O'Connell 2016; Desbureaux and Rodella 2019).

### 2.2. Investment

The increasing uncertainty and risks introduced by climate shocks can discourage enterprises from investing, which affects production capacity and labour demand (Stern 2007; Dell, Jones and Olken 2008; Sabbag 2013; Hsiang and Burke 2014; Desbureaux and Rodella 2019) and results in two dynamic effects: the accumulation of capital and of savings (Fankhauser and Tol 2005). Lower production decreases the amount of money feeding the accumulation of capital and therefore leads to reduced investment, economic growth and revenue (Horowitz 2009; Burke, Hsiang and Miguel 2015). This effect on capital accumulation can be exacerbated if the fall in investment also slows down technical progress and improvements in labour productivity or the accumulation of human capital (Fankhauser and Tol 2005).

As regards savings, climate shocks make rational agents more likely to change their savings behaviour to anticipate them. They may either increase their savings to compensate for a shortfall in their future income, or the low rate of return on capital caused by falling capital productivity may encourage them to invest less and consume more in the present (Paxson 1992; Fankhauser and Tol 2005). This change in behaviour will also affect the accumulation of capital and future production. Moreover, these effects may be amplified by the reallocation of labour and capital due to unfavourable weather conditions. Migrant flow and a lack of investment opportunities in the areas affected by these shocks generate labour and capital movements to other sectors, enterprises and regions (Albert, Bustos and Ponticelli 2021).

### 2.3. Sectoral reallocation

Meteorological phenomena can bring about changes in the conditions of production and competitiveness in the various sectors of an economy (Stern 2007). Employment will fall in certain sectors such as agriculture, while it expands in more resilient sectors such as renewable energies and services (Jessoe, Manning and Taylor 2018; Emerick 2018). This structural change implies high adjustment costs for workers, who are forced to retrain or change sector.

## 3. Data and descriptive statistics

### 3.1. Data

In this study, we use secondary data from the databases of the World Bank's World Development Indicators (WDIs)[3] and Worldwide Governance Indicators (WGIs),[4] the Climate Research Unit of the University of East Anglia (CRU)[5] and the Fraser Institute.[6] These databases cover the majority of (if not all) African countries in a number of areas, whereas others only include some countries (e.g. the International Country Risk Guide) or focus on specific areas (e.g. Transparency International's Corruption Perceptions Index). Despite these advantages, Williams and Siddique (2008) have highlighted some limits to governance indicators. They argue that the period covered is not long enough, reducing the scope for time series studies and obtaining a sufficient quantity of information. Nevertheless, this does not detract from the quality of our data.

---

3 World Bank, "World Development Indicators". DataBank. https://datatopics.worldbank.org/world-development-indicators/.
4 World Bank, "Worldwide Governance Indicators". DataBank. www.govindicators.org.
5 https://www.uea.ac.uk/groups-and-centres/climatic-research-unit/data.
6 Fraser Institute, "Economic Freedom Rankings". https://efotw.org/economic-freedom/dataset?geozone=world&year=2022&min-year=2&max-year=0&filter=0&page=dataset.

The indicators for employment, foreign direct investment (FDI), educational attainment level, GDP per capita, total population and urbanization are drawn from the World Bank's WDIs. The indicators on employment provide data on youth employment and employment in agriculture, manufacturing and services. They are widely used in the literature as they provide information about the number of people employed in the production of goods and services, and on variations over time (Phélinas 2014). They enable the identification of the most vulnerable groups and sectors, and of potential levers for increasing resilience.

The climate variables are drawn from the University of East Anglia's CRU. This unit provides climate data collected by more than 4,000 meteorological stations with a 0.5° latitude by 0.5° longitude resolution from 1900 to the present day and is considered to be a reliable source of climate information for sub-Saharan Africa (Zhang, Körnich and Holmgren 2013). These data are collected at the national level; we chose them in the absence of georeferenced data, which offer specific climate information for precise geographical locations. Using data on temperature and rainfall, we calculated the standard deviation scores (z-scores) for each country[7] to identify the countries affected by the 2010 temperature peak and the 2011 drought. The first treatment variable is *Temperature in 2010*, equal to 1 if the deviation in temperature from the mean is greater or equal to 1.282 in a country in 2010. All the countries whose z-score is equal to or exceeds this limit are considered to have been affected by the climate shock and are included in the treatment group. The second treatment variable is *Drought in 2011*, equal to 1 if the deviation in rainfall from the mean is lower than 1.282 in a country in 2011. Following the same logic as above, the control group is made up of the countries whose z-score is below this limit. This value is the standard threshold used to define a hot season or a drought (Gebrehiwot, van der Veen and Maathuis 2011; Jain et al. 2015).

Data on the rule of law and labour market regulation are drawn from the World Bank's WGI database and from the Fraser Institute indicators. The rule of law indicator is the country score for the aggregated indicator, expressed in units of a standard normal distribution, in other words, ranging from approximately –2.5 to 2.5. High values indicate good governance, while low values indicate a poor quality of governance. The labour market regulation indicator relates to regulation of employment, dismissals, minimum wages, bargaining and working hours. On the basis of this variable, we have divided the countries into two categories: countries with weak regulation (scores between 1 and 5) and those with stringent regulation (scores between 6 and 10). Institutional variables reflect the adaptation measures employed to mitigate the negative effects of climate change. Our sample is made up of 42 countries in sub-Saharan Africa (see the list of countries in table A.1 in the supplementary online appendix) and covers the period 1991–2020. These choices are due to data availability. A description of the variables is presented in table A.2 in the supplementary online appendix.

## 3.2. Descriptive statistics

The descriptive statistics presented in table 1 show that the mean z-score for the temperature in sub-Saharan Africa is of –2.23e–09 with a minimum of –2.6148 and a maximum of 3.1749. The mean z-score for rainfall stands at 3.96e–10 with a minimum of –2.9950 and a maximum of 4.1583, which reflects wide variations in rainfall patterns in sub-Saharan Africa. This is a plausible observation since the countries in this region have suffered from episodes of both drought and flooding over the 1991–2020 period. These temperature and rainfall trends are in line with the IPCC (2014) climate projections. For 2010, the treatment group represents 10.57 per cent of our sample, compared with 89.43 per cent in the control group. In 2011, 8.29 per cent of countries were affected by drought and 91.71 per cent were not.

[7] We calculated the z-score for each country using a standard approach to obtain the z-scores for temperature and rainfall.

**Table 1. Descriptive statistics**

| Variable | N | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Youth employment | 1 230 | 41.8356 | 17.1589 | 2.81 | 77.204 |
| Employment in agriculture | 1 230 | 53.6027 | 22.1845 | 1.2036 | 92.5917 |
| Employment in manufacturing | 1 230 | 11.6749 | 7.31754 | 1.0679 | 40.0362 |
| Employment in services | 1 230 | 34.7223 | 17.6835 | 5.2047 | 93.1843 |
| Z-score temperature | 1 230 | −2.23e−09 | 0.9836 | −2.6148 | 3.1749 |
| Z-score rainfall | 1 230 | 3.96e−10 | 0.9836 | −2.9950 | 4.1583 |
| Rule of law | 902 | −0.6770 | 0.6283 | −1.9260 | 1.0442 |
| Educational attainment | 1 027 | 91.9597 | 26.9636 | 22.0793 | 151.5778 |
| FDI | 1 017 | 1.15e+08 | 6.20e+08 | −3.51e+09 | 7.69e+09 |
| GDP per capita | 1 220 | 1410.976 | 1829.506 | 99.7573 | 11643.46 |
| Total population | 1 230 | 1.89e+07 | 2.75e+07 | 372 721 | 2.08e+08 |
| Treatment 2010 | 1 230 | 0.1057 | 0.3076 | 0 | 1 |
| Treatment 2011 | 1 230 | 0.0829 | 0.2759 | 0 | 1 |
| Post-treatment 2010 | 1 230 | 0.36667 | 0.4821 | 0 | 1 |
| Post-treatment 2011 | 1 230 | 0.3333 | 0.4716 | 0 | 1 |

Sources: Our own calculations based on World Bank (WDI and WGI), Fraser Institute and CRU (2021) data.

## 4. Model specification and estimation method

In order to illustrate the means by which climate shocks can affect productive jobs, we consider a Cobb-Douglas production function, presented as follows:

$$Y_{it} = A_{it} K_{it}^{\beta} L_{it}^{1-\beta} \tag{1}$$

where $Y_{it}$ is the quantity produced in country $i$ at time $t$, $K_{it}$ is the stock of capital, $L_{it}$ is employment, $A_{it}$ is the total productivity of the factors; $\beta$ and $1-\beta$ are, respectively, the elasticities of capital and labour in relation to production.

By dividing equation (1) by $L_{it}$, we obtain:

$$y_{it} = A_{it} k_{it}^{\beta} \tag{2}$$

where $y_{it} = \frac{Y_{it}}{L_{it}}$ is the productivity of labour and $k_{it}$ is capital intensity. A climate shock can reduce production by affecting the productivity of the factors (Zhang et al. 2018; Huang et al. 2020). High temperatures impact labour productivity by causing physical discomfort, fatigue and lower cognitive functioning in workers (Hancock, Ross and Szalma 2007).

$$A_{it} = A_0 e^{\mu T_{it}} \tag{3}$$

In equation (3), $\mu$ is a group of parameters to estimate and $T_{it}$ represents the climate variables. By replacing (3) in (2) and using the logarithm, we obtain the following relationship:

$$y_{it} = a_0 + \mu T_{it} + \beta k_{it} \tag{4}$$

Our aim is to identify the causal effect of climate shocks on jobs, estimating the effect of the treatment on the treated. More specifically, it involves comparing the jobs affected by climate shocks with the counterfactual, that is, jobs in the absence of such shocks. Since the counterfactual is not observed, it needs to be estimated by means of a comparison group. The countries affected are in the treatment group and the unaffected countries in the control group. This distinction is based on the value for temperature in 2010 or for rainfall in 2011. According to the World Meteorological Organization (WMO 2020a), the year 2010 was one of the three hottest years ever recorded on the continent. Similarly, rainfall in 2011 displayed sharp geographical contrasts. Drought affected various parts of Africa between 2010 and 2016.

The literature offers a number of tools for estimating the counterfactual, namely random assignment. This is an excellent method of evaluating the impact of a policy or programme because it generates a solid counterfactual, which is taken as the gold standard for impact evaluation (Gertler et al. 2016). This method is applicable when: (i) the number of population units eligible for a programme exceeds the number of places available in that programme; (ii) the programme has to be progressively extended to cover the eligible population. As these criteria are not met in our case, random assignment is not applicable. Contrary to this method, the difference-in-differences approach does not require precise programme assignment rules. It is applicable when information is available on the treatment and control groups both before and after the implementation of the programme (Gertler et al. 2016). In our case, we have data on both of these groups for both before and after the implementation of the treatment variable (climate shocks). We therefore use the difference-in-differences approach to estimate the effect of climate shocks on jobs. Unlike the matching and before-and-after comparison methods, this approach considers the time-invariant differences between the treatment group and the control group (Gertler et al. 2016; Glewwe and Todd 2022). However, it does not remove the time-variant differences between the two groups (Gertler et al. 2016), which can bias the estimation of the counterfactual. As a result, to provide a robust counterfactual, it must be assumed that there is no time-variant difference between the treatment and control groups. This constitutes the parallel trends hypothesis, which assumes that in the absence of treatment, the mean change in the outcome variable for the treatment countries is equal to the mean change in the outcome variable observed for controls (Mora and Reggio 2019). This implies that results reflect equivalent trends in the absence of treatment (Gertler et al. 2016).

The difference-in-differences method is widely used to evaluate the impact of public policy interventions or specific treatments on outcomes of interest (Duflo 2001; Galiani, Gertler and Schargrodsky 2005; Imbens and Wooldridge 2009; Joshi 2019; Chávez and Rodríguez-Puello 2022). It compares the treatment group (jobs affected by the climate shock) and the control group (unaffected jobs) to identify the climate shock effect. The conventional difference-in-differences estimator is obtained using standard linear regression techniques. In the simplest case, with only two periods ($t \geq 2$), the treatment effect can be estimated with the parallel trend hypothesis based on a regression with one constant, the treatment indicator $D_{it}$, a mute variable for the post-treatment period ($C_{it}$), and the interaction term $D_{it} \times C_{it}$. In this configuration, the treatment effect is identified by the parameter associated with the interaction term ($\delta$) (see table 2). Formally, the standard difference-in-differences model can be specified as follows:

$$Y_{it} = \alpha + \beta C_{it} + \gamma T_i + \delta C_{it} T_i + \theta X_{it} + \eta_i + \psi_t + e_{it} \tag{5}$$

where $Y_{it}$ is the indicator for jobs in country $i$, in period $t$; $C_{it}$ is a binary variable taking the value of 1 if $t$ is the post-treatment period; $T_i$ is also a binary variable taking the value of 1 if country $i$ belongs to the treatment group; $\delta$ represents the mean estimated effect of the climate shock on jobs; $X_{it}$ represents all the control variables that vary both between country and over time; $\eta_i$ controls for the country fixed effects; $\psi_t$ represents the time shocks common to all the countries; $e_{it}$ is the error term – the error terms are grouped at the country level; and $\alpha$ is the constant.

**Table 2. Difference-in-differences approach**

| | Before shock | After shock | Before – after |
|---|---|---|---|
| Treatment group (1) | $\alpha + \beta + \gamma + \delta$ | $\alpha + \gamma$ | $\beta + \delta$ |
| Control group (2) | $\alpha + \beta$ | $\alpha$ | $\beta$ |
| (1) – (2) | $\gamma + \delta$ | $\gamma$ | $\delta$ |

Source: Our own compilation.

We assume that the temperature and rainfall shocks took place at the end of 2010 and 2011, respectively. Accordingly, the estimation equation is the following:

$$Y_{it} = \alpha + \sum_{t=1991}^{2020} \beta_t C_{it} + \gamma T_{it} + \sum_{t=1991}^{2020} \delta_t C_{it} T_{it} + \epsilon_{it} \tag{6}$$

# 5. Presentation and analysis of results

## 5.1. Parallel trend test for the treatment and control groups

The essential identification hypothesis for interpreting the estimated effect of the shock is that the variation in employment in the control group countries provides an unbiased estimation of the counterfactual. It requires that, in the absence of treatment, the difference between the treatment and control groups is constant over time. Although we cannot test this hypothesis directly, we can check whether the time trends in the countries in the two groups are identical for the period prior to the shock (from 1991 to 2010 and from 1991 to 2011, respectively). If the time trends are the same for this period, they are likely to also be the same over the period following the shock if the treatment group has not been affected. In this case, the identification strategy using the difference-in-differences approach is valid. Statistical tests are used to check for pre-treatment differences in trends (pre-trend) (Rambachan and Roth 2023).

We formally check that the time pre-trends for the control and treatment groups are not different by estimating a slightly modified version of equation (5), which describes the situation for more than two periods. To that end, we use only observations for the countries in the control and treatment groups relating to the pre-treatment period, that is, for both groups, the observations for the periods 1991–2010 and 1991–2011. The pre-trends are identical when the estimated treatment effect is null during the period under consideration, that is when the coefficients $\delta_{1991}$ to $\delta_{2010}$ and $\delta_{1991}$ to $\delta_{2011}$ are equal to zero. However, some recent studies have shown that the pre-trend tests may suffer from low power (Bilinski and Hatfield 2020; Kahn-Lang and Lang 2020; Roth 2022). Their authors estimate that making the validity of the difference-in-differences method conditional on the success of pre-trend tests introduces statistical problems associated with these tests (Roth 2022).

In this study, we nevertheless choose to use the pre-trend test. It indicates that the treatment group trend is identical to the control group trend prior to the 2010 and 2011 climate shocks (see table A.3 in the supplementary online appendix). As the probabilities are greater than 5 per cent, the null hypothesis is not rejected. The treatment effect coefficient is therefore null before the shock. That means that the two groups follow similar trends in the absence of treatment, which validates the use of the difference-in-differences method.

In order to reinforce the credibility of the parallel trends hypothesis, we introduced additional control variables in the model. These variables allow us to isolate the specific treatment effect, which improves the precision of the estimations of this effect (Joshi 2019).

## 5.2. Results and interpretation

### 5.2.1. Effects of the temperature shocks on employment

The estimations of the effects of the temperature shock on youth employment and employment in agriculture, manufacturing and services are presented in table 3. The main analysis variable is represented by the Post × Temperature 2010 interaction term. This coefficient measures the effect of the climate shock on employment and is estimated according to the degree of labour market regulation in each country. The results show that most of the coefficients for our variables have the expected sign according to the theory.

After regression, we find that the temperature shock has negative effects on youth employment and employment in agriculture. These effects vary according to the degree of labour market regulation. For example, we observe a 3.35 unit fall in youth employment in countries with weak labour market regulation compared with a 3.99 unit fall in countries with stringent labour market regulation (see columns (1) and (2)). The economic impacts of climate shocks can create instability, reducing investment and thus affecting youth employment opportunities. Similarly, young people are more likely to migrate to areas less impacted by extreme weather events. This can put pressure on the local labour market. Aside from the effects of economic instability and migration, the disruption of access to education and training caused by temperature shocks, especially in rural areas, can limit young people's skills and employment opportunities. This finding is in line with Choudhry, Marelli and Signorelli (2012) and Liotti (2020). These authors observe that the contraction in demand caused by economic and financial crises negatively affects youth employment.

Columns (3) and (4) show a negative and significant relationship between the temperature shock and employment in agriculture. Employment losses stand at 5.94 and 8.51 for countries with weak and stringent labour market regulation, respectively. These considerable losses indicate that agriculture is the most affected sector and is highly dependent on temperatures. Increased atmospheric temperatures can lengthen growing seasons and cause a decline in yields, farmers' incomes and the viability of farms, reducing employment in this sector. Moreover, climate disruption can put rainy seasons and growing seasons out of sync, making farming less predictable and less productive. Rising temperatures exacerbate pressure on water resources, affecting irrigation and the accessibility of farmland.

In contrast, we find a significant expansion in employment in the manufacturing and service sectors of the countries most exposed to high temperatures (see columns (5) and (7)). In countries with weak labour market regulation, employment increases by 2.88 in manufacturing and by 3.07 in services. Employment also increases in countries with stringent regulation, by 3.36 and 5.15 in the manufacturing and services sectors, respectively. These effects are the result of changes in the structure of the local economy, employment increasing in manufacturing and services while it contracts in agriculture. Indeed, a decline in agricultural productivity leads to a fall in demand for agricultural labour, which in turn leads to a reallocation of the workforce from this (most affected) sector towards manufacturing and services. Growing urbanization may also lead to an expansion of infrastructure and activities related to construction, energy and services. However, this reallocation depends on a number of factors, including the capacity of the workforce to move between sectors and of its absorption by other sectors. This finding is in line with the effect observed by Albert, Bustos and Ponticelli (2021). These authors observe an expansion of employment in manufacturing and a contraction of employment in services following loss of agricultural productivity due to a climate shock.

### 5.2.2. Effects of drought on employment

The estimated effects of drought on youth employment and employment in agriculture, manufacturing and services are presented in table 4. The effect is measured by the Post × Drought 2011 interaction term. We find that drought has a significant effect on youth employment and employment in manufacturing (see columns (1) and (6)). This result is

**Table 3. Effects of temperature on employment**

| Variables | Youth | | Agriculture | | Manufacturing | | Services | |
|---|---|---|---|---|---|---|---|---|
| | Weak regulation | Stringent regulation | Weak regulation | Stringent regulation | Weak regulation | Stringent regulation | Weak regulation | Stringent regulation |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Temperature 2010 | 2.326 | 2.382 | −0.00240 | 4.766 | −1.160 | −3.771*** | 1.162 | −0.995 |
| | (8.819) | (3.664) | (7.392) | (3.332) | (2.633) | (1.005) | (4.837) | (2.763) |
| Post 2010 | −0.440 | −1.850 | 2.124 | 1.184 | −0.357 | −2.098*** | −1.767 | 0.914 |
| | (2.719) | (1.290) | (2.377) | (1.318) | (0.964) | (0.696) | (1.600) | (0.883) |
| Post × Temperature 2010 | −3.353** | −3.987* | −5.944*** | −8.514** | 2.875*** | 3.363** | 3.069 | 5.151 |
| | (9.660) | (4.229) | (8.153) | (4.033) | (2.997) | (1.303) | (5.310) | (3.230) |
| Rule of law | 7.125*** | 3.151** | −1.905 | −5.882*** | 1.466* | 1.887*** | 0.439 | 3.995*** |
| | (2.224) | (1.247) | (1.935) | (1.405) | (0.778) | (0.681) | (1.363) | (0.946) |
| Educational attainment | −0.0816 | −0.101*** | −0.0174 | −0.102*** | 0.0333* | 0.0504*** | −0.0158 | 0.0515** |
| | (0.0561) | (0.0342) | (0.0447) | (0.0327) | (0.0182) | (0.0145) | (0.0309) | (0.0217) |
| FDI | 7.65e−09** | 3.99e−10 | 4.27e−09 | 1.05e−09** | −1.66e−09 | 0 | −2.61e−09 | −1.07e−09*** |
| | (3.81e−09) | (3.00e−10) | (3.64e−09) | (4.26e−10) | (1.16e−09) | (2.33e−10) | (2.56e−09) | (3.07e−10) |
| GDP per capita | −0.00580*** | −0.00369*** | −0.00881*** | −0.00497*** | 0.00259*** | 0.00133*** | 0.00622*** | 0.00365*** |
| | (0.00162) | (0.000475) | (0.00149) | (0.000500) | (0.000464) | (0.000198) | (0.00108) | (0.000342) |
| Population | 5.65e−07*** | −4.33e−08*** | 7.50e−07*** | −5.53e−08*** | −1.87e−07*** | −1.09e−08** | − 5.63e−07*** | 6.62e−08*** |
| | (1.77e−07) | (1.38e−08) | (1.60e−07) | (1.07e−08) | (5.31e−08) | (4.97e−09) | (1.11e−07) | (8.07e−09) |
| Urbanization | −0.145 | −0.306*** | −0.328*** | −0.464*** | −0.0993*** | 0.120*** | 0.428*** | 0.345*** |
| | (0.104) | (0.0439) | (0.0943) | (0.0527) | (0.0368) | (0.0238) | (0.0688) | (0.0355) |
| Constant | 58.79*** | 73.86*** | 64.39*** | 85.61*** | 13.44*** | 3.590* | 22.17*** | 10.80*** |
| | (6.384) | (3.911) | (5.453) | (4.385) | (1.803) | (1.890) | (3.959) | (2.901) |
| Observations | 162 | 404 | 162 | 404 | 162 | 404 | 162 | 404 |
| $R^2$ | 0.320 | 0.497 | 0.632 | 0.712 | 0.393 | 0.462 | 0.701 | 0.735 |

*, ** and *** indicate statistical significance at the 10, 5 and 1 per cent levels, respectively.

Note: The robust standard errors of the estimated coefficients appear in parentheses.

Sources: Our own calculations based on World Bank (WDI and WGI), Fraser Institute and CRU (2021) data.

**Table 4. Effects of drought on employment**

| Variables | Youth | | Agriculture | | Manufacturing | | Services | |
|---|---|---|---|---|---|---|---|---|
| | Weak regulation | Stringent regulation | Weak regulation | Stringent regulation | Weak regulation | Stringent regulation | Weak regulation | Stringent regulation |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Drought 2011 | −11.09* | 2.573 | −4.716 | 3.779 | 3.215 | −1.930 | 1.501 | 1.848 |
| | (6.117) | (3.834) | (8.434) | (3.387) | (1.962) | (1.315) | (6.531) | (1.854) |
| Post 2011 | −1.552 | −2.184* | −0.787 | 0.241 | 0.604 | −2.010*** | 0.183 | 1.769** |
| | (2.507) | (1.228) | (2.234) | (1.266) | (0.919) | (0.646) | (1.483) | (0.871) |
| Post × Drought 2011 | 37.53*** | 0.394 | 12.44 | −5.364 | −3.392 | 2.828* | −9.044 | 2.536 |
| | (7.311) | (4.900) | (8.815) | (4.151) | (2.212) | (1.695) | (6.765) | (2.855) |
| Rule of law | 6.612*** | 3.297*** | −1.875 | −5.815*** | 1.462* | 1.867*** | 0.413 | 3.948*** |
| | (2.219) | (1.255) | (1.919) | (1.415) | (0.770) | (0.683) | (1.351) | (0.965) |
| Educational attainment | −0.123** | −0.0996*** | −0.0245 | −0.0947*** | 0.0347* | 0.0443*** | −0.0102 | 0.0504** |
| | (0.0562) | (0.0348) | (0.0463) | (0.0327) | (0.0193) | (0.0143) | (0.0313) | (0.0218) |
| FDI | 7.51e−09* | 4.05e−10 | 4.34e−09 | 1.00e−09** | −1.60e−09 | 0 | −2.74e−09 | −1.04e−09*** |
| | (3.82e−09) | (3.05e−10) | (3.73e−09) | (4.38e−10) | (1.15e−09) | (2.31e−10) | (2.65e−09) | (3.05e−10) |
| GDP per capita | −0.00557*** | −0.00371*** | −0.00843*** | −0.00498*** | 0.00250*** | 0.00131*** | 0.00593*** | 0.00367*** |
| | (0.00160) | (0.000476) | (0.00154) | (0.000498) | (0.000472) | (0.000197) | (0.00112) | (0.000342) |
| Population | 5.17e−07*** | −4.32e−08*** | 7.64e−07*** | −5.03e−08*** | −1.94e−07*** | −1.36e−08*** | −5.70e−07*** | 6.38e−08*** |
| | (1.74e−07) | (1.42e−08) | (1.64e−07) | (1.13e−08) | (5.48e−08) | (5.17e−09) | (1.13e−07) | (8.46e−09) |
| Urbanization | −0.130 | −0.308*** | −0.325*** | −0.466*** | −0.100*** | 0.121*** | 0.426*** | 0.345*** |
| | (0.102) | (0.0437) | (0.0978) | (0.0523) | (0.0381) | (0.0237) | (0.0709) | (0.0355) |
| Constant | 62.80*** | 73.71*** | 65.15*** | 85.01*** | 13.15*** | 4.034** | 21.69*** | 10.95*** |
| | (6.230) | (4.062) | (5.579) | (4.497) | (1.867) | (1.933) | (3.999) | (2.994) |
| Observations | 162 | 404 | 162 | 404 | 162 | 404 | 162 | 404 |
| $R^2$ | 0.359 | 0.497 | 0.628 | 0.709 | 0.395 | 0.458 | 0.697 | 0.730 |

*, ** and *** indicate statistical significance at the 10, 5 and 1 per cent levels, respectively.

Note: The robust standard errors of the estimated coefficients appear in parentheses.

Sources: Our own calculations based on World Bank (WDI and WGI), Fraser Institute and CRU (2021) data.

surprising since drought contributes to the expansion of these categories of employment. In contrast, Brookes Gray, Taraz and Halliday (2023) find that the negative effects of drought are mainly concentrated in the tertiary sector and in informal economy jobs. Columns (4) and (7) show that drought reduces employment in agriculture and services. Countries with stringent labour market regulation record a loss of employment in agriculture of 5.36. Employment in services decreases by 9.04 in counties with weak labour market regulation. In line with the theoretical predictions, the reduction of employment in agriculture is largely due to the fall in productivity in this sector, which depends on the supply of raw materials, water and energy. In addition, the shortage of agricultural products caused by a decrease in rainfall affects production, which can lead to the suspension of activities and job destruction. Moreover, insufficient water can reduce the generation of electricity and cause income and employment losses for enterprises and workers. In this same vein, Desbureaux and Rodella (2019) show that prolonged episodes of drought decrease the probability of being employed, hourly wages, hours worked and labour income. Afridi, Mahajan and Sangwan (2022) also find that drought has a negative and significant effect on both agricultural and non-agricultural employment.

#### 5.2.3. Robustness test

We test the robustness of our results using alternative employment variables, grouping the countries together by climate zones and studying the non-linear effects of climate shocks.

(i) Alternative employment variables

Informal employment and self-employment are used as alternative measures of employment. These results indicate that the temperature shock contributes to the contraction of informal employment and self-employment (see columns (1), (2) and (3) in table A.4 in the supplementary online appendix). This reflects the vulnerability of these jobs to climate risk. We observe these effects both in countries with weak labour market regulation and in those with stringent regulation. The similarity of these results with our main results confirms the robustness of our findings on temperature effects. We also find that drought has no significant effect on informal employment (see columns (1) and (2) in table A.5 in the supplementary online appendix). However, in column (4) of table A.5 in the supplementary online appendix, we observe that drought causes a significant expansion of self-employment. These results are similar to those obtained for youth employment and employment in agriculture, manufacturing and services, confirming the robustness of our results.

(ii) Classification of countries by climate zone

Grouping countries together by climate zone,[8] we find that the effect of climate shocks on employment is stronger in desert countries than in tropical countries. The level of employment destruction in agriculture is 26.43 in desert countries compared to 2.5 in tropical countries (see columns (3) and (4) in table A.6 in the supplementary online appendix). Extreme temperatures have a greater effect on desert countries. However, the results indicate that drought has a positive effect on employment in desert countries and a negative effect in tropical countries (see table A.7 in the supplementary online appendix). This indicates that desert countries are more resilient to drought than tropical countries. This can be explained by investment in adaptation measures and the internalization of extreme weather events. Faced with frequent climate shocks, desert countries internalize these events, adopting different kinds of adaptation measures, such as heat-resistant crops and appropriate agricultural methods, among others.

[8] We grouped countries together into two climate zones based on temperature levels: desert countries and tropical countries. Tropical countries are those with average temperatures of 0 to 23.5° C and desert countries are those where average temperatures vary between 23.5 and 40° C.

(iii) Non-linear effects of climate shocks

The variability of temperature and rainfall caused by climate change can be measured through the estimation of non-linear effects. The results show that temperature contributes to job destruction in agriculture and the creation of jobs in manufacturing and services (see table A.8 in the supplementary online appendix). However, drought has no significant effect on employment (see table A.9 in the supplementary online appendix). These non-linear effects are therefore similar to the linear effects obtained in the previous section.

## 6. Conclusions

The increasing frequency and intensity of extreme weather events leads to a loss of labour and agricultural productivity, which could have negative effects on jobs and workers' income. Studies on sub-Saharan Africa have shown that the reallocation of labour supply is one of the main responses to climate shocks (Josephson and Shively 2021; Brookes Gray, Taraz and Halliday 2023).

By exploring the effects of climate shocks on youth employment, our study contributes to a limited literature on sub-Saharan Africa, while also strengthening our understanding of the factors that influence youth employment dynamics in particular and adult employment dynamics in general. We have shown that extreme temperatures lead to a loss of employment among young people and in agriculture. Our results indicate that the increase in temperature brings about a reallocation of labour away from agriculture and into the manufacturing and services sectors. Furthermore, we have found that drought has a positive effect on employment in desert countries, whereas the effect is negative in tropical countries.

These results enable us to make a number of recommendations for governments, enterprises and households. Governments should promote measures to strengthen resilience, such as developing infrastructure and technology, capacity-building and regulation. Investment in infrastructure and technology could promote energy transition and support structural transformation. This would be an ideal option for countries in sub-Saharan Africa, as it would enable workers who are vulnerable to high temperatures to leave the agricultural sector for more productive sectors. Capacity-building, especially among young people, could narrow the skills gap in the labour market. It could also stimulate structural change in economies and facilitate the development of new heat-resistant crops. This would contribute to improving agricultural production and reducing the risks of job loss and food insecurity.

The improvement of governance and the adoption of labour standards and rules can guarantee decent working conditions for workers and in enterprises, which could mitigate the negative effects of climate shocks. Moreover, the adoption of flexible labour market measures offers enterprises the possibility of adapting to changing economic conditions and managing their activities efficiently, which can protect jobs, especially for young people.

Enterprises and households need to adjust their practices and behaviours in order to promote the creation of new jobs and the protection of old ones. For example, investment will enable enterprises to reuse, recycle and reduce their consumption of fossil fuels, which, thanks to resultant efficiencies and productivity, can protect existing jobs and create new ones. Likewise, households could rationalize their use of resources and consumption and adopt altruistic behaviour in terms of reforestation.

We have conducted our analysis at the national level and have therefore not taken into consideration the heterogeneity among regions, which are at different stages of development. This limitation could be addressed in future research through the use of georeferenced data, which provide information at the infranational level, improving their precision and quality. Future research could also examine households' employment decisions in the event of climate shocks, which would provide a broader understanding of the problems surrounding employment in crisis situations.

## Acknowledgements

We would like to thank the African Union for its financial support for our research. We are also grateful to all those who have contributed by reading and improving the quality of this article, in particular François Nkoa.

## Competing interests

The authors declare that they have no competing interests.

## References

Adhvaryu, Achyuta, Namrata Kala, and Anant Nyshadham. 2019. "Management and Shocks to Worker Productivity". NBER Working Paper No. 25865. Cambridge, MA: National Bureau of Economic Research.

Afridi, Farzana, Kanika Mahajan, and Nikita Sangwan. 2022. "The Gendered Effects of Droughts: Production Shocks and Labor Response in Agriculture". *Labour Economics* 78 (October): 102227. https://doi.org/10.1016/j.labeco.2022.102227.

Albert, Christoph, Paula Bustos, and Jacopo Ponticelli. 2021. "The Effects of Climate Change on Labor and Capital Reallocation". NBER Working Paper No. 28995. Cambridge, MA: National Bureau of Economic Research.

Allcott, Hunt, Allan Collard-Wexler, and Stephen D. O'Connell. 2016. "How Do Electricity Shortages Affect Industry? Evidence from India". *American Economic Review* 106 (3): 587–624. https://doi.org/10.1257/aer.20140389.

Baarsch, Florent, Jessie R. Granadillos, William Hare, Maria Knaus, Mario Krapp, Michiel Schaeffer, and Hermann Lotze-Campen. 2020. "The Impact of Climate Change on Incomes and Convergence in Africa". *World Development* 126 (February): Article No. 104699. https://doi.org/10.1016/j.worlddev.2019.104699.

Bilinski, Alyssa, and Laura A. Hatfield. 2020. "Nothing to See Here? Non-inferiority Approaches to Parallel Trends and Other Model Assumptions", arXiv:1805.03273. https://doi.org/10.48550/arXiv.1805.03273.

Blanchet, Sophie. 2015. "Attentional Resources Theory". In *The Encyclopedia of Adulthood and Aging*, edited by Susan Krauss Whitbourne. Hoboken, NJ: John Wiley & Sons.

Branco, Danyelle, and José Féres. 2021. "Weather Shocks and Labor Allocation: Evidence from Rural Brazil". *American Journal of Agricultural Economics* 103 (4): 1359–1377. https://doi.org/10.1111/ajae.12171.

Brookes Gray, Harriet, Vis Taraz, and Simon D. Halliday. 2023. "The Impact of Weather Shocks on Employment Outcomes: Evidence from South Africa". *Environment and Development Economics* 28 (3): 285–305. https://doi.org/10.1017/S1355770X22000237.

Burke, Marshall, Solomon M. Hsiang, and Edward Miguel. 2015. "Global Non-Linear Effect of Temperature on Economic Production". *Nature* 527 (7577): 235–239. https://doi.org/10.1038/nature15725.

Chávez, Alicia, and Gabriel Rodríguez-Puello. 2022. "Commodity Price Shocks and the Gender Wage Gap: Evidence from the Metal Mining Prices Super-Cycle in Chile". *Resources Policy* 76 (June): 102497. https://doi.org/10.1016/j.resourpol.2021.102497.

Choudhry, Misbah Tanveer, Enrico Marelli, and Marcello Signorelli. 2012. "Youth Unemployment Rate and Impact of Financial Crises". *International Journal of Manpower* 33 (1): 76–95. https://doi.org/10.1108/01437721211212538.

Colmer, Jonathan. 2021. “Temperature, Labor Reallocation, and Industrial Production: Evidence from India”. *American Economic Journal: Applied Economics* 13 (4): 101–124. https://doi.org/10.1257/app.20190249.

Dell, Melissa, Benjamin F. Jones, and Benjamin A. Olken. 2008. “Climate Change and Economic Growth: Evidence from the Last Half Century”. NBER Working Paper No. 14132. Cambridge, MA: National Bureau of Economic Research.

———. 2012. “Temperature Shocks and Economic Growth: Evidence from the Last Half Century”. *American Economic Journal: Macroeconomics* 4 (3): 66–95. https://doi.org/10.1257/mac.4.3.66.

Desbureaux, Sébastien, and Aude-Sophie Rodella. 2019. “Drought in the City: The Economic Impact of Water Scarcity in Latin American Metropolitan Areas”. *World Development* 114 (February): 13–27. https://doi.org/10.1016/j.worlddev.2018.09.026.

Deschênes, Olivier, and Michael Greenstone. 2007. “The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather”. *American Economic Review* 97 (1): 354–385. https://doi.org/10.1257/aer.97.1.354.

Diallo, Sadou, and Henri Atangana Ondoa. 2024. “Climate Shocks and Labor Market in Sub-Saharan Africa: Effects on Gender Disparities in Urban and Rural Areas”. *Journal of Social and Economic Development*, published online 26 March 2024. https://doi.org/10.1007/s40847-024-00331-x.

Duffy, Elizabeth. 1957. “The Psychological Significance of the Concept of ‘Arousal’ or ‘Activation’”. *Psychological Review* 64 (5): 265–275. https://doi.org/10.1037/h0048837.

Duflo, Esther. 2001. “Schooling and Labor Market Consequences of School Construction in Indonesia: Evidence from an Unusual Policy Experiment”. *American Economic Review* 91 (4): 795–813. https://doi.org/10.1257/aer.91.4.795.

Emerick, Kyle. 2018. “Agricultural Productivity and the Sectoral Reallocation of Labor in Rural India”. *Journal of Development Economics* 135 (November): 488–503. https://doi.org/10.1016/j.jdeveco.2018.08.013.

Emran, Shahe, and Forhad Shilpi. 2018. “Agricultural Productivity, Hired Labor, Wages, and Poverty: Evidence from Bangladesh”. *World Development* 109 (September): 470–482. https://doi.org/10.1016/j.worlddev.2016.12.009.

Fankhauser, Samuel, and Richard S.J. Tol. 2005. “On Climate Change and Economic Growth”. *Resource and Energy Economics* 27 (1): 1–17. https://doi.org/10.1016/j.reseneeco.2004.03.003.

Filmer, Deon, and Louise Fox. 2014. “Youth Employment in Sub-Saharan Africa”. Africa Development Series. Washington, DC: World Bank.

Galiani, Sebastian, Paul Gertler, and Ernesto Schargrodsky. 2005. “Water for Life: The Impact of the Privatization of Water Services on Child Mortality”. *Journal of Political Economy* 113 (1): 83–120. https://doi.org/10.1086/426041.

Gebrehiwot, Tagel, Anne van der Veen, and Ben Maathuis. 2011. “Spatial and Temporal Assessment of Drought in the Northern Highlands of Ethiopia”. *International Journal of Applied Earth Observation and Geoinformation* 13 (3): 309–321. https://doi.org/10.1016/j.jag.2010.12.002.

Gertler, Paul J., Sebastian Martinez, Patrick Premand, Laura B. Rawlings, and Christel M.J. Vermeersch. 2016. *Impact Evaluation in Practice*. 2nd ed. Washington, DC: World Bank.

Glewwe, Paul, and Petra Todd. 2022. *Impact Evaluation in International Development: Theory, Methods and Practice*. Washington, DC: World Bank.

Graff Zivin, Joshua, and Matthew Neidell. 2014. "Temperature and the Allocation of Time: Implications for Climate Change". *Journal of Labor Economics* 32 (1): 1–26. https://doi.org/10.1086/671766.

Hancock, P.A., Jennifer M. Ross, and James L. Szalma. 2007. "A Meta-Analysis of Performance Response Under Thermal Stressors". *Human Factors: The Journal of the Human Factors and Ergonomics Society* 49 (5): 851–877. https://doi.org/10.1518/001872007X230226.

Hancock, P.A., and Joel S. Warm. 1989. "A Dynamic Model of Stress and Sustained Attention". *Human Factors: The Journal of the Human Factors and Ergonomics Society* 31 (5): 519 –537. https://doi.org/10.1177/001872088903100503.

Hocking, Chris, Richard B. Silberstein, Wai Man Lau, Con Stough, and Warren Roberts. 2001. "Evaluation of Cognitive Performance in the Heat by Functional Brain Imaging and Psychometric Testing". *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 128 (4): 719–734. https://doi.org/10.1016/S1095-6433(01)00278-1.

Horowitz, John K. 2009. "The Income–Temperature Relationship in a Cross-Section of Countries and Its Implications for Predicting the Effects of Global Warming". *Environmental and Resource Economics* 44 (4): 475–493. https://doi.org/10.1007/s10640-009-9296-2.

Hsiang, Solomon M., and Marshall Burke. 2014. "Climate, Conflict, and Social Stability: What Does the Evidence Say?" *Climatic Change* 123 (1): 39–55. https://link.springer.com/article/10.1007/s10584-013-0868-3.

Huang, Kaixing, Hong Zhao, Jikun Huang, Jinxia Wang, and Christopher Findlay. 2020. "The Impact of Climate Change on the Labor Allocation: Empirical Evidence from China". *Journal of Environmental Economics and Management* 104 (November): Article No. 102376. https://doi.org/10.1016/j.jeem.2020.102376.

ILO. 2010. "Climate Change and Labour: The Need for a 'Just Transition'". *International Journal of Labour Research* 2 (2).

———. 2019. *Working on a Warmer Planet: The Impact of Heat Stress on Labour Productivity and Decent Work*. Geneva.

———. 2020. *Report on Employment in Africa (Re-Africa): Tackling the Youth Employment Challenge*. Geneva.

———. 2024. *World Employment and Social Outlook: Trends 2024*. Geneva.

Imbens, Guido W., and Jeffrey M. Wooldridge. 2009. "Recent Developments in the Econometrics of Program Evaluation". *Journal of Economic Literature* 47 (1): 5–86. https://doi.org/10.1257/jel.47.1.5.

IPCC (Intergovernmental Panel on Climate Change). 2014. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects – Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. New York, NY: Cambridge University Press.

———. 2022. *Climate Change 2022: Impacts, Adaptation and Vulnerability – Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge and New York, NY: Cambridge University Press.

Jain, Vinit K., Rajendra P. Pandey, Manoj K. Jain, and Hi-Ryong Byun. 2015. "Comparison of Drought Indices for Appraisal of Drought Characteristics in the Ken River Basin". *Weather and Climate Extremes* 8 (June): 1–11. https://doi.org/10.1016/j.wace.2015.05.002.

Jayachandran, Seema. 2006. "Selling Labor Low: Wage Responses to Productivity Shocks in Developing Countries". *Journal of Political Economy* 114 (3): 538–575. https://doi.org/10.1086/503579.

Jessoe, Katrina, Dale T. Manning, and J. Edward Taylor. 2018. "Climate Change and Labour Allocation in Rural Mexico: Evidence from Annual Fluctuations in Weather". *Economic Journal* 128 (608): 230 – 261. https://doi.org/10.1111/ecoj.12448.

Josephson, Anna, and Gerald E. Shively. 2021. "Unanticipated Events, Perceptions, and Household Labor Allocation in Zimbabwe". *World Development* 141 (May): Article No. 105377. https://doi.org/10.1016/j.worlddev.2020.105377.

Joshi, Kuhu. 2019. "The Impact of Drought on Human Capital in Rural India". *Environment and Development Economics* 24 (4): 413–436. https://doi.org/10.1017/S1355770X19000123.

Kahn-Lang, Ariella, and Kevin Lang. 2020. "The Promise and Pitfalls of Differences-in-Differences: Reflections on *16 and Pregnant* and Other Applications". *Journal of Business & Economic Statistics* 38 (3): 613–620. https://doi.org/10.1080/07350015.2018.1546591.

Kjellstrom, Tord, David Briggs, Chris Freyberg, Bruno Lemke, Matthias Otto, and Olivia Hyatt. 2016. "Heat, Human Performance, and Occupational Health: A Key Issue for the Assessment of Global Climate Change Impacts". *Annual Review of Public Health* 37: 97–112. https://doi.org/10.1146/annurev-publhealth-032315-021740.

Kjellstrom, Tord, Ingvar Holmer, and Bruno Lemke. 2009. "Workplace Heat Stress, Health and Productivity – an Increasing Challenge for Low and Middle-Income Countries during Climate Change". *Global Health Action* 2 (1): Article No. 2047. https://doi.org/10.3402/gha.v2i0.2047.

Kjellstrom, Tord, Bruno Lemke, P. Matthias Otto, Olivia M. Hyatt, David J. Briggs, and Chris A. Freyberg. 2015. "Heat Impacts on Work, Human Performance, and Daily Life". In *Climate Change and Public Health*, edited by Barry S. Levy and Jonathan A. Patz, 73–86. New York, NY: Oxford University Press.

Liotti, Giorgio. 2020. "Labour Market Flexibility, Economic Crisis and Youth Unemployment in Italy". *Structural Change and Economic Dynamics* 54 (September): 150–162. https://doi.org/10.1016/j.strueco.2020.04.011.

Liu, Maggie, Yogita Shamdasani, and Vis Taraz. 2023. "Climate Change and Labor Reallocation: Evidence from Six Decades of the Indian Census". *American Economic Journal: Economic Policy* 15 (2): 395–423. https://doi.org/10.1257/pol.20210129.

Marelli, Enrico, and Marcello Signorelli. 2016. "Youth Unemployment and the Disadvantages of the Young in the Labour Market". In *Varieties of Economic Inequality*, edited by Sebastiano Fadda and Pasquale Tridico, 197–216. Abingdon: Routledge.

Minale, Luigi. 2018. "Agricultural Productivity Shocks, Labour Reallocation and Rural–Urban Migration in China". *Journal of Economic Geography* 18 (4): 795–821. https://doi.org/10.1093/jeg/lby013.

Mora, Ricardo, and Iliana Reggio. 2019. "Alternative Diff-in-Diffs Estimators with Several Pretreatment Periods". *Econometric Reviews* 38 (5): 465–486. https://doi.org/10.1080/07474938.2017.1348683.

Mueller, Valerie, and Agnes Quisumbing. 2011. "How Resilient are Labour Markets to Natural Disasters? The Case of the 1998 Bangladesh Flood". *Journal of Development Studies* 47 (12): 1954–1971. https://doi.org/10.1080/00220388.2011.579113.

Nordhaus, William. 2013. *The Climate Casino: Risk, Uncertainty, and Economics for a Warming World*. New Haven, CT: Yale University Press.

Paxson, Christina H. 1992. "Using Weather Variability to Estimate the Response of Savings to Transitory Income in Thailand". *American Economic Review* 82 (1): 15–33. https://www.jstor.org/stable/2117600.

Phélinas, Pascale. 2014. "Comment mesurer l'emploi dans les pays en développement?" *Revue Tiers Monde* 218 (2): 15–33. https://doi.org/10.3917/rtm.218.0015.

Provins, K.A. 1966. “Environmental Heat, Body Temperature and Behaviour: An Hypothesis”. *Australian Journal of Psychology* 18 (2): 118–129. https://doi.org/10.1080/00049536608255722.

Rambachan, Ashesh, and Jonathan Roth. 2023. “A More Credible Approach to Parallel Trends”. *Review of Economic Studies* 90 (5): 2555–2591. https://doi.org/10.1093/restud/rdad018.

Ramsey, Jerry D. 1995. “Task Performance in Heat: A Review”. *Ergonomics* 38 (1): 154–165. https://doi.org/10.1080/00140139508925092.

Ramsey, Jerry D., Charles L. Burford, Mohamed Youssef Beshir, and Roger C. Jensen. 1983. “Effects of Workplace Thermal Conditions on Safe Work Behavior”. *Journal of Safety Research* 14 (3): 105–114. https://doi.org/10.1016/0022-4375(83)90021-X.

Rose, Elaina. 2001. “Ex Ante and Ex Post Labor Supply Response to Risk in a Low-Income Area”. *Journal of Development Economics* 64 (2): 371–388. https://doi.org/10.1016/S0304-3878(00)00142-5.

Roth, Jonathan. 2022. “Pretest with Caution: Event-Study Estimates after Testing for Parallel Trends”. *American Economic Review: Insights* 4 (3): 305–322. https://doi.org/10.1257/aeri.20210236.

Sabbag, Lea. 2013. “Temperature Impacts on Health, Productivity, and Infrastructure in the Urban Setting, and Options for Adaptation”. Sheltering from a Gathering Storm Working Paper No. 4. Boulder, CO: Institute for Social and Environmental Transition-International.

Seghiar, Saliha. 2014. “Les jeunes, le chômage et la valeur du travail”. *Spécificités* 6 (1): 256–265. https://doi.org/10.3917/spec.006.0256.

Seppänen, Olli, William J. Fisk, and QH Lei. 2006. “Effect of Temperature on Task Performance in Office Environment”. LBNL Working Paper No. 60946. Berkeley, CA: Lawrence Berkeley National Laboratory.

Somanathan, E., Rohini Somanathan, Anant Sudarshan, and Meenu Tewari. 2021. “The Impact of Temperature on Productivity and Labor Supply: Evidence from Indian Manufacturing”. *Journal of Political Economy* 129 (6): 1797–1827. https://doi.org/10.1086/713733.

Stern, Nicholas. 2007. *The Economics of Climate Change: The Stern Review*. Cambridge: Cambridge University Press.

Sudarshan, Anant, E. Somanathan, Rohini Somanathan, and Meenu Tewari. 2015. “The Impact of Temperature on Productivity and Labor Supply: Evidence from Indian Manufacturing”. CDE Working Paper No. 244. Delhi: Centre for Development Economics.

Szirmai, Adam, Mulu Gebreeyesus, Francesca Guadagno, and Bart Verspagen. 2013. “Promoting Productive Employment in Sub-Saharan Africa: A Review of the Literature”. UNU-MERIT Working Papers No. 2013-062. Maastricht: Maastricht Economic and Social Research Institute on Innovation and Technology.

Vasmatzidis, Ioannis, Robert E. Schlegel, and Peter A. Hancock. 2002. “An Investigation of Heat Stress Effects on Time-Sharing Performance”. *Ergonomics* 45 (3): 218–239. https://doi.org/10.1080/00140130210121941.

Williams, Andrew, and Abu Siddique. 2008. “The Use (and Abuse) of Governance Indicators in Economics: A Review”. *Economics of Governance* 9 (2): 131–175. https://doi.org/10.1007/s10101-006-0025-9.

WMO (World Meteorological Organization). 2020a. “State of the Climate in Africa 2019”. WMO-Nº 1253. Geneva.

———. 2020b. "La Niña Has Developed". 29 October 2020. https://wmo.int/media/news/la-nina-has-developed.

World Bank. 2012. *World Development Report 2013: Jobs*. Washington, DC.

Yeboah, Thomas, and Justin Flynn. 2021. "Rural Youth Employment in Africa: An Evidence Review". Evidence Synthesis Paper 10/2021. Leiden: INCLUDE Knowledge Platform.

Zhang, Peng, Olivier Deschenes, Kyle Meng, and Junjie Zhang. 2018. "Temperature Effects on Productivity and Factor Reallocation: Evidence from a Half Million Chinese Manufacturing Plants". *Journal of Environmental Economics and Management* 88 (March): 1–17. https://doi.org/10.1016/j.jeem.2017.11.001.

Zhang, Qiong, Heiner Körnich, and Karin Holmgren. 2013. "How Well Do Reanalyses Represent the Southern African Precipitation?" *Climate Dynamics* 40 (3–4): 951–962. https://doi.org/10.1007/s00382-012-1423-z.