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# Climate Change and Long-term Structural Change: Evidence from Towns and Districts in India

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**Abstract**

Climate change poses a fundamental challenge to structural transformation in developing economies. I show that rising temperatures lead to reallocation within towns and districts in India, in larger magnitudes than rainfall. A 1°C increase in agricultural season degree days (DDS) leads to a significant increase in the share of agricultural labor in towns, with a decrease in the non-agricultural labor share, strongest in rural regions. Towns also show a significant increase in seasonal labor share, coupled with an increase in population but a decrease in population density, suggesting urban sprawl and opportunities for seasonal employment. I find stronger effects of rising temperatures on increase in agricultural and seasonal workers during the kharif/monsoon season and within towns that have rivers. A increase in rainfall of 1 mm. averaged over the same period has strongest effects in the decrease of non-agricultural labor sharein rural regions. These findings indicate that while climate change may impede rural structural transformation, towns serve as crucial adaptation nodes by facilitating sectoral mobility.

# 1 Introduction

Extreme weather brings significant challenges to developing economies, particularly for agriculture reliant populations. This research studies the historical pattern of structural transformation in India and builds upon prior work by Liu et al. (2023), Somanathan et al. (2021), Jessoe et al. (2017) and Dell et al. (2012). According to the 2011 Census, agriculture is a significant share (54.6%) of employment in India. Studying the effects of climate change on structural transformation is crucial to understanding economic growth and designing urban policy in this context. Jessoe et al. (2017) find that temperature shocks led to a reduction in non-agricultural employment through agricultural channels. The authors estimate extreme temperatures may decrease employment by upto 1.4 p.p. and increase migration by a similar magnitude in rural Mexico. Dell et al. (2014) study the effects of temperature shocks in poor countries, and find a significant reduction in economic growth in both level and growth effects. While existing research documents the immediate impacts of temperature on agricultural productivity, we know less about how climate shocks affect the longer-term process of labor reallocation across sectors and space. These long run effects on structural transformation remain understudied with low availability of granular historical data in developing countries. The focus on urban development complements Liu et al. (2023), who find that temperature increases lead to lower shares of workers in non-agriculture at the district level in India. I decouple the rural and urban impacts by observing town level shifts in the share of workers in 4 occupations: cultivation, agricultural labor, non-agricultural work, and seasonal employment.

I examine how temperature increases influence structural transformation and urbanization patterns in India between 1981 and 2011. Using an empirical strategy that compares the reallocation of labor within districts and within towns, I dcoument how labor adapts to climate stress across space. I show that rising temperatures have heterogeneous effects by region: while urban areas show resilience and adaptive capacity through increased seasonal employment, rural areas experience significant declines in non-agricultural employment. This pattern suggests challenges faced by the rural economy in moving from climate-vulnerable agricultural livelihoods. These findings also suggest that temperature increases may reinforce spatial inequality, particularly by reducing local demand for non-agricultural goods and services in rural areas as documented under Liu et al. (2023). Rising temperatures appear to be creating ”development traps” that limit the traditional pathways of structural transformation. Gollin and Rogerson (2014) present a model of productivity, transport costs and subsistence agriculture that serves as a theoretical framework to uncover the general equilibrium effects of climate induced labor reallocation. Additionally, Bustos et al. (2016) provide a theoretical framework under which structural transformation depends on the factor bias of change in technology across agriculture and industry. This divergence in comparison with urban regions has important implications for development policy, in rethinking traditional approaches to rural development and labor mobility.

# 2 Theoretical Framework

This model builds upon prior models of structural transformation from Liu et al. (2023) and Gollin and Rogerson (2014).

## 2.1 Model Environment

Consider an economy with two regions, rural $(R)$ and urban $(U)$ having two primary sectors: agriculture $(a)$ and non-agriculture $(n)$. Workers can engage in either regular employment $(l_a, l_n)$ or in seasonal work $(l_s)$ within the region's primary sector. Drawing on efficiency wage theory in Shapiro and Stiglitz (1984), workers receive higher wage under regular employment in both non-agriculture, and in agriculture as documented in Moretti and Perloff (2002).

### 2.1.1 Household Consumption

Household preferences follow the Stone-Geary utility functional form, where the elasticity of the agricultural good is less than one, i.e. the subsistence requirement is $c_a \geq \bar{a}$. Agricultural goods face an iceberg transport cost $\tau$, such that only $(1-\tau)$ share of quantity arrives in transit, reflected in the rural-urban price ratio $p_a^R / p_a^U$ - This captures the priority of agricultural consumption in developing economies from Gollin and Rogerson (2014).

$$U = \ln(c_a - \bar{a}) + \ln(c_n) \tag{1}$$

$$\frac{p_a^R}{p_a^U} = \frac{1}{1-\tau} \tag{2}$$

### 2.1.2 Agricultural Production

Agricultural output $(Y_a)$ assumes a CES production function with given agricultural productivity $(A_a)$, seasonal productivity $(A_s)$¡ and imperfect substitution $(\rho < 1)$ between regular labor $(l_a)$ and seasonal labor $(l_s)$. Output uses $(\theta_a)$ share of regular labor and $(1-\theta_a)$ share of seasonal labor.

$$Y_a = A_a[\theta_a l_a^\rho + (1-\theta) l_s^\rho]^{1/\rho} \tag{3}$$

Workers receive regular agricultural wage $(w_a)$ and seasonal wage $(w_s)$, with a regular wage premium $\bar{w}_a$ to ensure consistent labor supply during critical agricultural periods. Assuming perfect competition, the marginal product of labor is equal to the wage for regular and seasonal work.

$$\text{Agricultural labor: } \frac{\partial Y_a}{\partial l_a} = A_a \theta_a l_a^{\rho-1} [l_a^\rho + l_s^\rho]^{(1-\rho)/\rho}$$

$$\text{Seasonal labor: } \frac{\partial Y_a}{\partial l_s} = A_s (1-\theta_a) l_s^{\rho-1} [l_a^\rho + l_s^\rho]^{(1-\rho)/\rho} \tag{4}$$

$$\text{Equilibirum wage ratio: } \frac{w_a}{w_s} = \frac{A_a}{A_s} \left(\frac{\theta_a}{1-\theta_a}\right) \left(\frac{l_s}{l_n}\right)^{1-\rho}$$

Agricultural productivity $A_a(T, R)$ is dependent on temperature and rainfall, declining beyond a threshold temperature $T_a^*$. This specification captures the non-linear effects of temperature on productivity in agriculture, with $\phi_2 = 0$ if $T < T_a^*$. Temperature thresholds dominate productivity losses over rainfall, as under Schlenker and Roberts (2009).

$$A_a(T, R) = \phi_1 T - \phi_2 (T - T_a^*)^2 + \phi_3 R \tag{5}$$

### 2.1.3 Non-Agricultural Production

Non-agricultural output $(Y_n)$ combines regular $(l_n)$ and seasonal/marginal $(l_s)$ workers, such that -

$$Y_n = A_n \left[\theta_n \ln(l_n) + (1-\theta) \ln(l_s)\right] \tag{6}$$

where non-agricultural productivity $(A_n)$ is more resilient to temperature, i.e. $T_n^* > T_a$. This incorporates the empirical observation that temperature thresholds in manufacturing (around 35 °C) are higher than agricultural thresholds (around 32 °C).

$$A_n(T, R) = \psi_1 T - \psi_2 (T - T_n^*)^2 + \psi_3 R \tag{7}$$

Workers receive regular non-agricultural wage $(w_n)$ and seasonal wage $(w_s)$

$$\text{Non-agricultural labor: } \frac{\partial Y_n}{\partial l_n} = A_n \theta_n l_n^{-1}$$

$$\text{Seasonal labor: } \frac{\partial Y_n}{\partial l_s} = A_s (1-\theta_n) l_s^{-1} \tag{8}$$

$$\text{Equilibirum wage ratio: } \frac{w_n}{w_s} = \frac{A_n}{A_s} \left(\frac{\theta_n}{1-\theta_n}\right) \left(\frac{l_s}{l_n}\right)$$

#### 2.1.4 Social Planner's Problem

The planner maximizes aggregate utility:

$$\max_{\{c_a^R, c_a^U, c_n^R, c_n^U, l_a^R, l_s^R, l_n^U, l_s^U\}} [\ln(c_a^R - \bar{a}) + \ln(c_n^R) + \ln(c_a^U - \bar{a}) + \ln(c_n^U)] \tag{9}$$

subject to the feasibility constraints:

$$c_a^R + \frac{c_a^U}{1-\tau} = A_a \cdot [\theta_a (l_a^R)^\rho + (1-\theta_a)(l_s^R)^\rho]^{1/\rho} \tag{10}$$

$$c_n^R + c_n^U = A_n \cdot [\theta l_n^U + (1-\theta) l_s^U] \tag{11}$$

$$l_a^R + l_s^R = 1 \quad \text{(Rural)} \tag{12}$$

$$l_n^U + l_s^U = 1 \quad \text{(Urban)} \tag{13}$$

$$\frac{w_a}{w_s} = \frac{A_a}{A_s}\left(\frac{\theta_a}{1-\theta_a}\right)\left(\frac{l_s}{l_n}\right)^{1-\rho} \tag{14}$$

$$\frac{w_n}{w_s} = \frac{A_n}{A_s}\left(\frac{\theta_n}{1-\theta_n}\right)\left(\frac{l_s}{l_n}\right) \tag{15}$$

Assuming $\theta_a = \theta_n = \theta$, i.e. the returns to seasonal labor are equal across sectors.

Lagrangian -

$$\begin{aligned}
\mathcal{L} = & \ln(c_a^R - \bar{a}) + \ln(c_n^R) + \ln(c_a^U - \bar{a}) + \ln(c_n^U) \\
& + \lambda_1 \left[ A_a [\theta_a (l_a^R)^\rho + (1-\theta_a)(l_s^R)^\rho]^{1/\rho} - c_a^R - \frac{c_a^U}{1-\tau} \right] \\
& + \lambda_2 \left[ A_n [\theta_n l_n^U + (1-\theta_n) l_s^U] - c_n^R - c_n^U \right] \\
& + \mu^R (1 - l_a^R - l_s^R) + \mu^U (1 - l_n^U - l_s^U) \\
& + \nu_a \left[ \left( \frac{l_a^R}{l_s^R} \right)^{\rho-1} \right] \\
& + \nu_n \left[ \frac{\theta_n}{1-\theta_n} \right]
\end{aligned} \tag{16}$$

# 3 Data

This study combines rich data on demography and occupation from the Census of India with high-resolution weather data from the Indian Meteorological Department to examine climate impacts on structural transformation between 1961-2011.

## 3.1 Census of India

The main source of data is the Primary Census Abstract (PCA) from the Census of India published under 'District Census Handbooks', with population, literacy and occupation totals at the town and district level. The dataset constructs a panel of 640 districts and 7,715 towns spanning six decades from 1961 to 2011, with separate aggregation for rural and urban areas within districts.

Worker classifications in the census distinguish between main workers, who are employed for more than 183 days annually, and marginal or seasonal workers employed for less than 183 days. Workers are further categorized into agricultural laborers, cultivators, and non-agricultural workers. While these definitions have remained consistent from 1981 onwards, there were slight variations in the 1961 and 1971 rounds, as detailed in the Appendix.

The town panel reflects the evolution of India's urban landscape through multiple entry and exit of Census towns. A Census town is defined as an area meeting 3 criteria– A minimum population of 4,000, at least 75% of male working population in non agricultural activity, and a population density of over 400 persons per sq. km. Larger sets of Census towns consitute urban agglomerations. Of the total 8,794 unique towns that appear in the data the final analysis focuses on a sample of 2,655 towns with consistent data between 1981-2011, ensuring comparability in worker definitions and measurement.

## 3.2 Climate Data

Weather data comes from the Indian Meteorological Department's (IMD) gridded dataset, which provides daily temperature and precipitation measures from 1951-2023. The growing season occurs between June through February, with March-May being the hot pre-monsoon agricultural lean season. The temperature data is available at 1-degree spatial resolution, recording daily minimum and maximum temperatures in degrees Celsius. Rainfall data offers a higher resolution picture at 0.25 degrees, with precipitation measured in 10 mm.

**Seasonal degree days** Heat exposure is measured through Seasonal Degree Days (DDS), which has been used in prior empirical studies on the weather and agriculture relationship, by Blakeslee and Fishman (2015) in India and Schlenker et al. (2006) in the U.S. I construct the DDS measure by summing the daily degree day measure over the months occurring in each season to calculate seasonal measure of weather. DDS is calculated at the grid-point level for all days $d$ in a calendar year. Daily observations on minimum ($T_{min}$) and maximum ($T_{max}$) temperature are averaged to calculate the mean temperature (T), using the function described in equation (18). Finally, I aggregate the mean DDS for the past 10 years.

$$DDS = \sum_{d} D(T_d) \text{ ; where } T_d = \frac{T_{min,d} + T_{max,d}}{2} \tag{17}$$

$$D(T) = \begin{cases} 0, & \text{if } T \leq 8°C \\ T - 8, & \text{if } 8°C < T \leq 32°C \\ 24, & \text{if } T > 32°C \end{cases} \tag{18}$$

# 4 Empirical Specification

The empirical strategy employs the following fixed-effects regression approach:

$$Y_{irt} = \beta_{irt}\mathrm{T}_{irt} + \beta_2\mathrm{P}_{irt} + \alpha_i + \lambda_t + \delta_{rt} + \epsilon_{irt} \tag{19}$$

The main specification examines the effects of climate shocks on seasonal & main worker share of population, and non-agricultural & agricultural labor share of workers. $Y_{irt}$ is the outcome variable for town or district $i$ located in region $r$ in year $t$. $\mathrm{T}_{irt}$ is the temperature measured in Celsius as the degree days over the growing season (June-February) for the past 10 years. Temperature is measured around the centroid of town or district $i$ using daily weather grid observations within (25 km if town, or within 100 km if district, weighted by inverse squared distance. Both temperature measures are averaged over 10 years prior to $t$. $\mathrm{P}_{irt}$ is the daily precipitation (10 mm.) averaged over 10 years preceding $t$. $\alpha_i$ is a vector of town/district fixed effects, controlling for any time invariant factors in $i$ that may be correlated with climate or economic outcomes. $\lambda_t$ controls for year fixed effects, i.e. changes over time. $\delta_{irt}$ accounts for region-year fixed effects to control for region-specific confounders over time. $\epsilon_{irt}$ is an idiosyncratic shock to $i$ observed in each $t$. Standard errors are clustered at the town/district level to account for autocorrelation within $i$. This approach controls for time-invariant town/district characteristics, common time trends and region-specific heterogeneity varying over time.

The identification relies on the assumption that any variation in climate is plausibly exogenous to the outcome variable, conditional on town/district, year and region-year fixed effects. The key independent variables capture past decadal exposure to climate variation. Temperature exposure, measured through seasonal degree days (DDS), focuses on the growing season to capture agricultural relevance. The 10-year averaging period serves two purposes: first, it reduces measurement noise in annual weather fluctuations, and second, it allows examination of adaptation responses to persistent changes in climate. Similarly, precipitation is averaged over the same period to maintain consistency in measuring climate exposure. Primary outcomes include the logarithm of population shares in different employment categories: (1) seasonal workers as a share of total population; (2) agricultural laborers and cultivators as shares of total workers; and (3) non-agricultural workers as a share of total workers. These log transformations allow interpretation of the coefficients as percentage changes in response to climate shocks.

# 5 Results

## 5.1 Intra-town effects and rural/urban divide

Table 1: Town level estimates of an increase in growing season temperature and rainfall

| | Log | | Log share of population | | Log share of workers | | |
|---|---|---|---|---|---|---|---|
| | Population | Density | Regular | Seasonal | Non-Ag. | Ag. Labor | Cultivation |
| DDS (1 °C) | 0.095*** | -0.347*** | 0.152*** | 0.495*** | -0.042** | 0.244*** | 0.015 |
| | (0.028) | (0.092) | (0.023) | (0.117) | (0.018) | (0.081) | (0.062) |
| Precipitation (1 mm.) | -0.011 | -0.024 | 0.026*** | -0.070** | -0.019*** | -0.064** | -0.052** |
| | (0.010) | (0.019) | (0.005) | (0.030) | (0.005) | (0.025) | (0.021) |
| # Towns | 2657 | 2652 | 2593 | 2655 | 2582 | 2488 | 2526 |
| Mean | 10.01 | 7.97 | -1.27 | -4.19 | -0.27 | -3.01 | -3.02 |
| N | 10628 | 7732 | 10198 | 10231 | 10132 | 9425 | 9580 |

Standard errors in parentheses

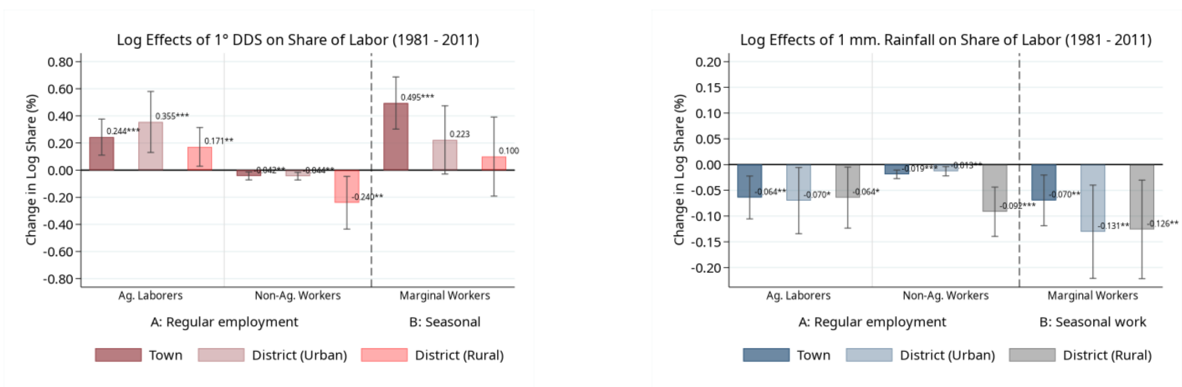
* p¡0.10, ** p¡0.05, *** p¡0.01

Additional controls for town, year and region-year fixed effects included. Standard errors clustered at the town level. Population density measured as total population per sq.km, not available for 2011. Seasonal workers are marginal workers employed for less than 183 calendar days in the past year.

Figure 1: Intra-town and district effects of rising DDS over growing seasons in the past decade

Panel A: Temperature

Panel B: Precipitation




The graph above plots estimates of the log share of each category of workers with 90% C.I of a unit increase in past decadal seasonal degree days (DDS). $*p < 0.1, **p < 0.05, ***p < 0.001$. Daily observations of degree days (DDS) averaged for agricultural months (June-February) over growing seasons in the preceding decade. Seasonal workers measured as share of population; other shares as proportion of total workers.

Table 1 shows the impact of an increase in growing season temperatures and rainfall on town demographics and occupation. Rising DDS leads to a 9.5% increase in overall population town population, but a 34.7% decrease in population density per sq. km. This implies that the total area within towns increases with degree days, which may be linked with urban sprawl and employment opportunities around towns. Within towns, increasing DDS leads to a 49.5% increase in the share of seasonal labor, a 24.4% increase in the agricultural labor share and and decrease of 4.2% in non-agricultural worker share, which are statistically significant. Further, there is a null and non-significant effect on the share of cultivators.

Figure 1 shows the spatial divide of the effects of increasing temperature and rainfall within towns and districts. A degree-day increase leads to a significant increase in the worker share of agricultural labor by 35.5% in urban areas within-districts, higher than rural areas (17.1%) and towns (24.4%). In contrast, the significant decrease in non-agricultural labor share is higher in rural areas (24%) than within urban areas and towns (3-4%). The marginal or seasonal labor share significantly increase in towns by 49.5%, with no significant effects in intra-district rural and urban totals. This asymmetric impact could suggest that urban areas may absorb displaced agricultural workers through seasonal and non-agricultural employment opportunities.

Simultaneously, figure 1 also presents a complementary story with the effects of an increase in precipitation, averaged by over the agricultural seasons in the preceding decade. A 1 mm. increase in precipitation significantly decreases agricultural labor share by 6-7% within towns and districts. However, the non-agricultural share is sigificantly impacted more in rural areas with a 9.2% decrease compared with a 1-2% decrease in the urban context. Additionally the negative estimates on seasonal labor share are statistically significant and more pronounced intra-district (12-13%) compared with the 5.2% decrease in towns. This pattern points towards greater urban resilience to higher rainfall. suggesting that rainfall-induced changes in labor demand are more effectively absorbed by labor markets in towns.

## 5.2 Long-term labor reallocation in districts

Table 2: District level estimates of an increase in rainfall and growing season temperature

| | Log | Log share of population | | Log share of workers | |
|---|---|---|---|---|---|
| | Population | Regular Work | Seasonal Work | Ag. Labor | Non-Ag. Labor |
| Degree days (1° DDS) | 0.342*** | 0.032** | -0.011 | 0.041*** | -0.073* |
| | (0.122) | (0.013) | (0.010) | (0.015) | (0.038) |
| Rainfall (1 mm.) | -0.017 | 0.001 | -0.005** | 0.001 | -0.008 |
| | (0.027) | (0.003) | (0.002) | (0.005) | (0.007) |
| # Districts | 283 | 283 | 283 | 283 | 283 |
| # Years | 4 | 4 | 4 | 4 | 4 |
| N | 1132 | 1132 | 1132 | 1132 | 1132 |

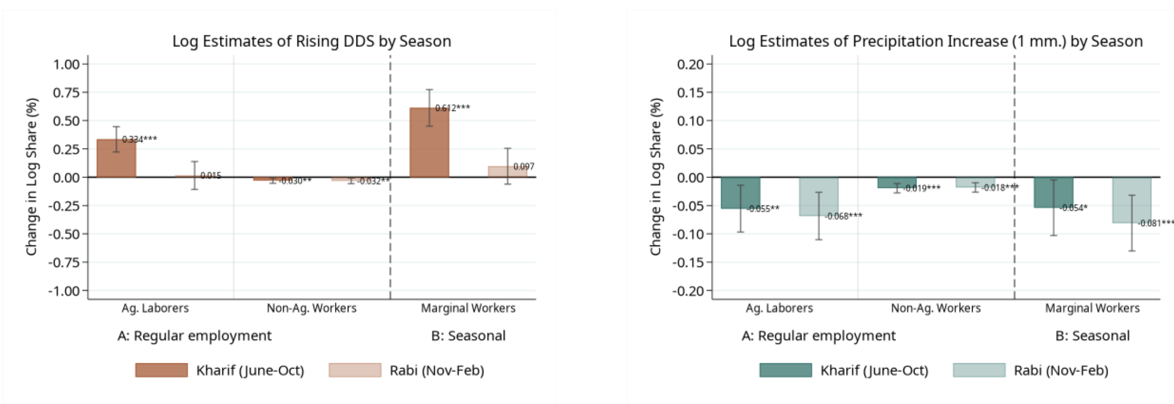
Standard errors in parentheses
Panel at district year level between 1981-2011.
Additional controls for district, year and region-year fixed effects included.
* p¡0.10, ** p¡0.05, *** p¡0.01

Additional controls for district, year and region-year fixed effects included. Standard errors clustered at the district level. Degree days (DDS) calculated over daily average temperatures during the growing seasons (June-February) in the preceding decade. Seasonal workers are employed for less than 183 calendar days in the year preceding the Census.

In Table 2, the estimates show that rising temperatures generate significant labor market reallocation within districts, with a 18.5% increase in agricultural labor share and a 29.9% decrease in the share of non-agricultural workers. The positive but non-significant effect on cultivator share of 14.7% may suggest that temperature shocks primarily affect agricultural wage labor rather than land-holding farmers. These estimates are in line with the literature documenting an increase of 18.1% in agricultural labor from Liu et al. (2023), with supporting evidence from Burgess et al. (2017) of the larger impacts that temperature has than rainfall on agricultural productivity.

Figure 2: Seasonal effects of rising temperatures and rainfall within districts between 1981-2011

Panel A: Temperature                Panel B: Precipitation




The figure plots coefficients with 95% C.I. of a unit increase in 10-year seasonal degree days on log shares of workers. Additional controls for district, year and region-year fixed effects included. Estimates plot separate panels for each base year, i.e. 2001-2011, 1991-2011, . . .

Figure 2 plots estimates at the district level separately for a increase in degree days across the kharif (monsoon), and rabi (winter) seasons. The effects of temperature are significantly higher in the kharif season with an increase of 33.4% in agricultural labor and 61.2% in seasonal workers. However, the effect in non-agricultural share of workers is dampened with a decrease of 3% in both seasons. This gap suggests that rising temperatures impact agriculture most during the monsoon season, while the effect on non-agricultural labor is seasonally constant.

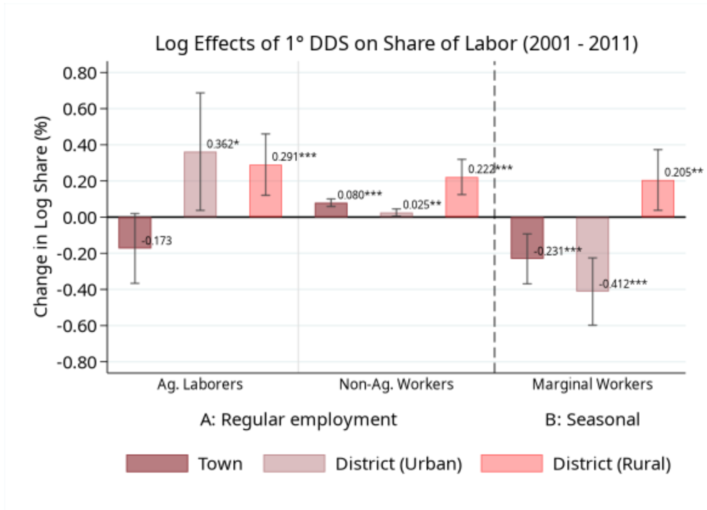
## 5.3 Effects post 2001

## 5.4 Robustness checks

### 5.4.1 Year-wise estimates

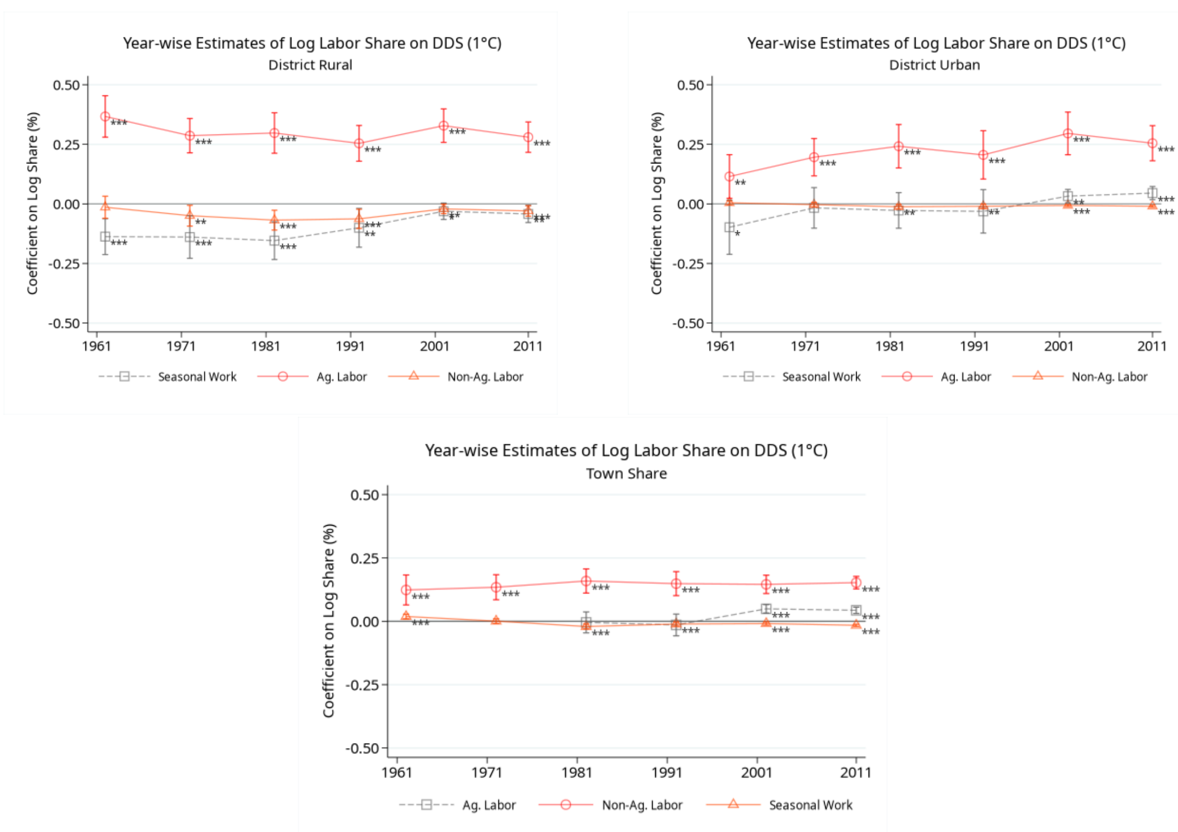
Figure 4 plots the cross-sectional estimates of rising DDS and rainfall. There magnitude of the effects is consistently greater in rural areas with an increase in the share of agricultural labor and decrease in non agricultural and seasonal labor share over time.

Figure 3: Effects of rising degree days (DDS) during kharif/monsoon on log share of workers



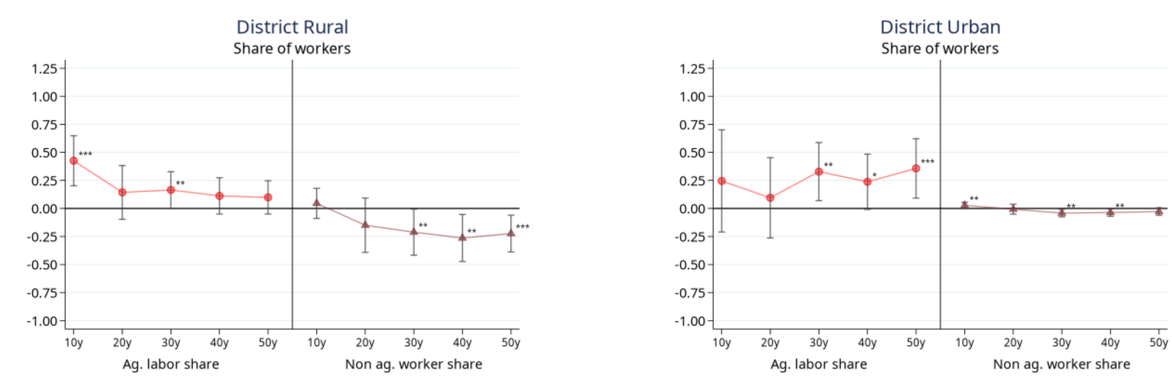

The graph above plots estimates of the log share of each category of workers with 90% C.I of a unit increase in past decadal seasonal degree days (DDS). $*p < 0.1, **p < 0.05, ***p < 0.001$. Seasonal workers measured as share of population; other shares as proportion of total workers.

Figure 4: Intra-town and district effects of rising temperatures between 1981-2011




The figure plots coefficients with 95% C.I. of a unit increase in 10-year seasonal degree days on log shares of workers. Additional controls for district, year and region-year fixed effects included. Estimates plot separate panels for each base year, i.e. 2001-2011, 1991-2011, . . .

Figure 5: Intra-district effects of rising temperatures by panel duration




The figure plots coefficients with 95% C.I. of a unit increase in 10-year seasonal degree days on log shares of workers. Additional controls for district, year and region-year fixed effects included. Estimates plot separate panels for each base year, i.e. 2001-2011, 1991-2011, . . .

### 5.4.2 Alternate panel time periods

Figure 5 shows the long-term impacts of an increase in DDS on the share of agricultural labor and non-agricultural workers within district, for rural and urban areas separately. The trend lines plot the 10, 20, 30, 40, and 50 year panel coefficients of rising temperatures on worker shares. I find the point estimates are consistent in direction but vary in magnitude, with non-linear effects across different time periods. At the district level, the effect on agricultural labor is positive and significant in rural areas over a time period of 10-30 years, and in urban areas over 30+ years. On the other hand, the effect on non-agricultural labor share is negative and significant for all time periods in rural areas. Additionally, the magnitude is closer to zero in urban areas, changing from positive between 10-20 years to negative past 20+ years.

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# 6 Appendix

## 6.1 Summary Statistics

Table 3: Share of town population in each sector by Census year

| | (1)<br>1961 | (2)<br>1971 | (3)<br>1981 | (4)<br>1991 | (5)<br>2001 | (6)<br>2011 |
|---|---|---|---|---|---|---|
| Total log. population | 9.409 | 9.532 | 9.607 | 9.807 | 9.909 | 9.741 |
| Total % of population: main workers | 0.349 | 0.295 | 0.298 | 0.296 | 0.290 | 0.300 |
| Total share of workers: non-agricultural | 0.778 | 0.822 | 0.750 | 0.744 | 0.837 | 0.842 |
| Total share of workers: agricultural | 0.207 | 0.272 | 0.251 | 0.245 | 0.148 | 0.151 |
| Total share of workers: cultivators | 0.139 | 0.131 | 0.124 | 0.110 | 0.069 | 0.057 |
| Total share of workers: agricultural laborers | 0.060 | 0.134 | 0.122 | 0.130 | 0.082 | 0.093 |
| Total share of workers: marginal/seasonal workers | . | . | 0.044 | 0.039 | 0.162 | 0.213 |
| Observations | 2393 | 2781 | 3557 | 4214 | 4646 | 7250 |

Each observation is a town in the panel. * Marginal workers not reported in 1961 and 1971. In the rounds of 1981-2011, marginal workers are defined as seasonal workers, employed for less than 183 days in the past calendar year.

Figure 6: Annual temperature and worker shares in districts (1971-2011)

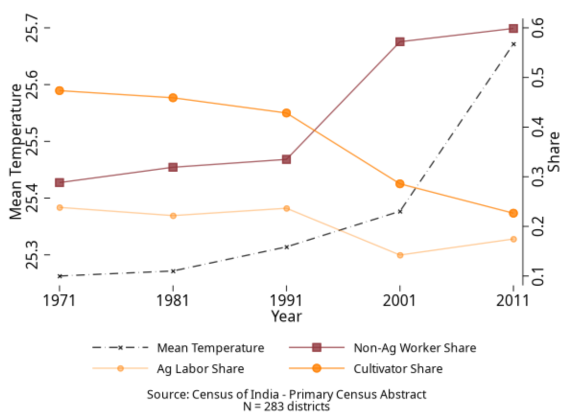
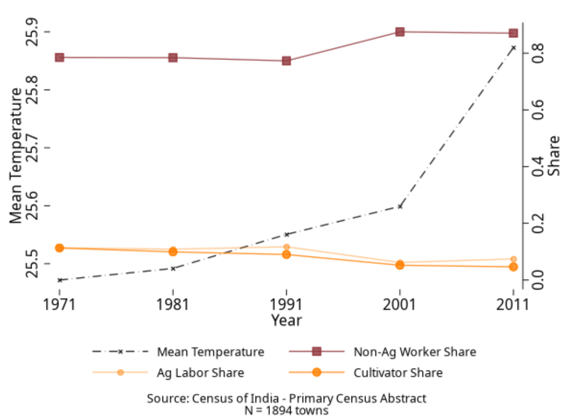



Figure 7: Annual temperature and worker shares in towns (1971-2011)



## 6.2 Regression estimates

### 6.2.1 Level effects

Table 4: District estimates of rising temperatures on share of population and workers

| | Log share of population | | Log share of main workers | | |
|---|---|---|---|---|---|
| | Main | Marginal | Non-Ag. | Ag. Labor | Cultivation |
| DDS (1 °C) | 0.032** | -0.011 | -0.073* | 0.041*** | 0.032 |
| | (0.013) | (0.010) | (0.038) | (0.015) | (0.031) |
| Precipitation (1 mm.) | 0.001 | -0.005** | -0.008 | 0.001 | 0.007 |
| | (0.003) | (0.002) | (0.007) | (0.005) | (0.007) |
| Mean | 0.380 | 0.071 | 0.456 | 0.194 | 0.350 |
| N | 1132 | 1132 | 1132 | 1132 | 1132 |

Standard errors in parentheses
Panel at district year level between 1981-2011.
Additional controls for district, year and region-year fixed effects included.
* p¡0.10, ** p¡0.05, *** p¡0.01

### 6.2.2 Log effects

Table 5: District total estimates of climate shocks

| | Log | Log share of population | | Log share of workers | |
|---|---|---|---|---|---|
| | Population | Regular Work | Seasonal Work | Ag. Labor | Non-Ag. Labor |
| Degree days (1° DDS) | 0.342*** | 0.032** | -0.011 | 0.041*** | -0.073* |
| | (0.122) | (0.013) | (0.010) | (0.015) | (0.038) |
| Rainfall (1 mm.) | -0.017 | 0.001 | -0.005** | 0.001 | -0.008 |
| | (0.027) | (0.003) | (0.002) | (0.005) | (0.007) |
| # Districts | 283 | 283 | 283 | 283 | 283 |
| # Years | 4 | 4 | 4 | 4 | 4 |
| N | 1132 | 1132 | 1132 | 1132 | 1132 |

Standard errors in parentheses
Panel at district year level between 1981-2011.
Additional controls for district, year and region-year fixed effects included.
* p¡0.10, ** p¡0.05, *** p¡0.01

Table 6: District rural estimates of climate shocks

| | Log. | Log share of population | | Log share of main workers | | |
|---|---|---|---|---|---|---|
| | Population | Main | Marginal | Non-Ag. | Ag. Labor | Cultivation |
| DDS (1 °C) | 0.337*** | 0.126*** | 0.100 | -0.240** | 0.171** | 0.123 |
| | (0.115) | (0.036) | (0.177) | (0.118) | (0.087) | (0.091) |
| Precipitation (1 mm.) | -0.022 | 0.003 | -0.126** | -0.092*** | -0.064* | -0.020 |
| | (0.029) | (0.008) | (0.058) | (0.029) | (0.036) | (0.020) |
| # Districts | 281 | 281 | 281 | 281 | 280 | 280 |
| # Years | 4 | 4 | 4 | 4 | 4 | 4 |
| N | 1124 | 1124 | 1124 | 1124 | 1120 | 1120 |

Standard errors in parentheses

* p¡0.10, ** p¡0.05, *** p¡0.01

Table 7: District urban estimates of climate shocks

| | Log. | Log share of population | | Log share of main workers | | |
|---|---|---|---|---|---|---|
| | Population | Main | Marginal | Non-Ag. | Ag. Labor | Cultivation |
| DDS (1 °C) | 0.232 | 0.061** | 0.223 | -0.044** | 0.355*** | 0.233 |
| | (0.248) | (0.025) | (0.153) | (0.017) | (0.137) | (0.210) |
| Precipitation (1 mm.) | -0.016 | -0.005 | -0.131** | -0.013** | -0.070* | -0.010 |
| | (0.040) | (0.005) | (0.055) | (0.005) | (0.039) | (0.039) |
| # Districts | 281 | 281 | 281 | 281 | 280 | 280 |
| # Years | 4 | 4 | 4 | 4 | 4 | 4 |
| N | 1121 | 1121 | 1120 | 1121 | 1117 | 1117 |

Standard errors in parentheses

* p¡0.10, ** p¡0.05, *** p¡0.01

Table 8: Town estimates of climate shocks

| | Log | | Log share of population | | Log share of workers | | |
|---|---|---|---|---|---|---|---|
| | Population | Density | Regular | Seasonal | Non-Ag. | Ag. Labor | Cultivation |
| DDS (1 °C) | 0.095*** | -0.347*** | 0.152*** | 0.495*** | -0.042** | 0.244*** | 0.015 |
| | (0.028) | (0.092) | (0.023) | (0.117) | (0.018) | (0.081) | (0.062) |
| Precipitation (1 mm.) | -0.011 | -0.024 | 0.026*** | -0.070** | -0.019*** | -0.064** | -0.052** |
| | (0.010) | (0.019) | (0.005) | (0.030) | (0.005) | (0.025) | (0.021) |
| # Towns | 2657 | 2652 | 2593 | 2655 | 2582 | 2488 | 2526 |
| Mean | 10.01 | 7.97 | -1.27 | -4.19 | -0.27 | -3.01 | -3.02 |
| N | 10628 | 7732 | 10198 | 10231 | 10132 | 9425 | 9580 |

Standard errors in parentheses

* p¡0.10, ** p¡0.05, *** p¡0.01

### 6.2.3 NSS Estimates

Table 9: IPUMS/NSS estimates of climate shocks

| | Log share | |
|---|---|---|
| | Non Agriculture | Ag. Labor |
| T (ddslst) | 0.178 | -0.554* |
| | (0.117) | (0.315) |
| Precipitation (10 mm.) | -0.040 | -0.002 |
| | (0.039) | (0.082) |
| # Districts | 261 | 261 |
| Mean | -1.04 | -1.92 |
| N | 1044 | 1029 |

Standard errors in parentheses

* p¡0.10, ** p¡0.05, *** p¡0.01

### 6.2.4 Heterogeneity checks

Table 10: Town estimates: heterogeneity

| | Log | | Log share of population | | Log share of workers | | |
|---|---|---|---|---|---|---|---|
| | Population | Density | Regular | Seasonal | Ag. Labor | Cultivation | Non-Ag. |
| River ¡ 500 m.=0 × T (ddslst) | 0.091*** | -0.338*** | 0.154*** | 0.408*** | 0.197** | -0.009 | -0.040** |
| | (0.028) | (0.093) | (0.024) | (0.116) | (0.083) | (0.063) | (0.018) |
| River ¡ 500 m.=1 × T (ddslst) | 0.118* | -0.387** | 0.141*** | 1.084*** | 0.548*** | 0.171 | -0.057** |
| | (0.068) | (0.193) | (0.035) | (0.197) | (0.140) | (0.127) | (0.027) |
| River ¡ 500 m.=0 × Precipitation (10 mm.) | -0.014 | -0.031 | 0.024*** | -0.092*** | -0.056** | -0.044** | -0.016*** |
| | (0.010) | (0.019) | (0.005) | (0.031) | (0.026) | (0.022) | (0.005) |
| River ¡ 500 m.=1 × Precipitation (10 mm.) | 0.017 | 0.024 | 0.043*** | 0.127 | -0.104 | -0.099 | -0.043*** |
| | (0.033) | (0.062) | (0.013) | (0.103) | (0.078) | (0.063) | (0.014) |
| # Towns | 2657 | 2652 | 2593 | 2655 | 2488 | 2526 | 2582 |
| Mean | 10.01 | 7.97 | -1.27 | -4.19 | -3.01 | -3.02 | -0.27 |
| N | 10628 | 7732 | 10198 | 10231 | 9425 | 9580 | 10132 |

Standard errors in parentheses

* p¡0.10, ** p¡0.05, *** p¡0.01

## 6.3 Notes

**Worker definitions** In 1961, a person qualified as a worker if they had worked regularly during the last season or if they had worked at least for a day in regular (non-seasonal) work during the preceding fortnight. At the 1971 census, a person was treated as a worker only if they spent their time mainly in work or if they worked at least for a day in regular (non-seasonal) work during the preceding week. The dichotomy of worker/ non-worker of 1961 and 1971 censuses was discarded at the 1981 Census and instead a trichotomy of main workers, marginal workers and non-workers was adopted. For main worker, the time criterion of engage- ment in work for the major part of the year, i.e., at least 183 days was adopted. Those who worked for some time during the last year but not for the major part were treated as marginal workers. Those who had never worked during the last year were non-workers. This trichotomy partially permits comparabi- lity of 1981 census economic data with that of 1971 as well as 1961. The main workers of 1981 census can be expected to correspond to the workers of 1971 and the main workers and marginal workers of 1981 together to correspond to the workers of 1961.

Note: The definition of workers is consistent with the above 1991 onwards.

**Definition of urban areas** Urban areas or Census towns are defined as all statutory places with a municipality, corporation, cantonment board or notified town area committee, etc. These towns satisfy the following three criteria simultaneously:

1. A minimum population of 4,000 (1991) and 5,000 (in 2001)
2. At least 75 per cent of male working population engaged in non-agricultural activity
3. A population density of 400 persons per sq. km.

The proportion of male working population in (2) above is calculated in reference to regular or main workers.

**Urban agglomerations** An Urban Agglomeration is a continuous urban spread constituting a town and its adjoining urban outgrowths (OGs) or two or more physically contiguous towns together and any adjoining urban outgrowths of such towns. Examples of OGs are railway colonies, university campuses, port areas, etc., that may come up near a city or statutory town outside its statutory limits but within the revenue limits of a village or villages contiguous to the town or city. Each such individual area by itself may not satisfy the minimum population limit to qualify it to be treated as an independent urban unit but may deserve to be clubbed with the town as a continuous urban spread.

For the purpose of delineation of Urban Agglomerations during Census of India 2001, following criteria are taken as pre-requisites:

1. The core town or at least one of the constituent towns of an urban agglomeration should necessarily be a statutory town; and
2. The total population of all the constituents (i.e. towns and outgrowths) of an Urban Agglomeration should not be less than 20,000 (as per the 1991 Census).

With these two basic criteria having been met, the following are the possible different situations in which Urban Agglomerations would be constituted:

1. A city or town with one or more contiguous outgrowths;
2. Two or more adjoining towns with their outgrowths; and
3. A city and one or more adjoining towns with their outgrowths all of which form a continuous spread.