Agricultural Mechanization and Gendered Structural Transformation in India

Koustuv Saha[a], Kajal Gulati[b], and Samuel S. Bird[c]

[a]Postdoctoral Researcher, American University of Sharjah, Sharjah, UAE
[b]Assistant Professor, Michigan State University, East Lansing, MI, USA
[a]Assistant Professor, Bates College, Lewiston, ME, USA

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Abstract

Adoption of modern methods of mechanized tilling in India caused a dearth in women's job opportunities in agriculture. While men were reabsorbed into the restructured agricultural sector or into non-agricultural jobs, women's labor force participation in rural India fell. Using the staggered roll out of the national rural employment guarantee scheme (NREGS) we examine if the creation of jobs under the scheme mitigated the fall in women's labor force outcomes due to the adoption of labor saving technology in agriculture. Instrumenting mechanization by the exogenous variation in the share of in the share of loamy soil and clayey soil across districts, we show that while the NREGS did slow down the fall in women's weekly work days it was not sufficient to offset the effect of mechanization. At the extensive margin, NREGS was not successful at reducing the number of women exiting the labor force, though it had a positive effect on the intensive margin, number of days of work in a week. We surmise that if the NREGS was targeted to districts especially affected by gendered structural transformation, it could be more effective in stemming the fall in female labor outcomes in rural India.

Keywords: Structural transformation, agricultural mechanization, labor, gender, public policy, workfare programs, India

JEL Codes: J16, J21, J45, O13

1 Introduction

The Lewis (1954) dual sector model describes development as a process by which excess labor moves from a labor-intensive "subsistence" sector with lower wages to a modern "capitalist" sector (Gollin, 2014). However, the process of transformation is slow-moving and market imperfections can prevent its effects from reaching all sections of society. Following the liberalization in the Indian tractor industry in 1992, the agricultural sector saw a rapid increase in the level of mechanization in its production processes (Bhattarai et al., 2016). The expansion of mechanized tilling during this period has been shown to be directly responsible for the fall in female labor force participation (Afridi et al., 2023). This reflects the gendered nature of India's rural labor market, where men and women are imperfect substitutes and exhibit differing degrees of complementarity with mechanized agricultural equipment. Men, being the primary labor type used in land preparation, were displaced by the new capital but they were largely reabsorbed into new jobs in the modernized agricultural sector. In contrast, women — who are primarily employed in downstream tasks such as weeding and transplanting — were displaced by the introduction of mechanized tilling which reduced the need for these secondary tasks, but they were not sufficiently reabsorbed into the modern agricultural sector.

Agricultural growth is widely recognized as more effective at reducing poverty than growth in other sectors (Ligon and Sadoulet, 2018; Ivanic and Martin, 2018; Dorosh and Thurlow, 2018; Christiaensen and Martin, 2018). Productivity gains in agriculture can benefit rural households by lowering production costs, reducing food prices, and increasing labor demand and wages (Emran and Shilpi, 2018; Christiaensen and Martin, 2018). The labor channel is especially important in labor-abundant countries like India, but its effectiveness depends on the nature of technological change — whether it is labor or land-saving — and the availability of alternative non-agricultural employment opportunities.

This paper investigates whether the expansion of alternative female-friendly jobs opportunities mitigated the fall in rural female labor force participation following the introduction of mechanized tilling. The roll-out of the National Rural Employment Guarantee Scheme between 2006 and 2008 is used a case study to investigate the validity of this hypothesis.

The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) was passed by the Indian Parliament and notified in 2005. The act led to the creation of state level public employment schemes which were collectively called the National Rural Employment Guarantee Schemes (NREGS) and which comprise the largest workfare program in the world (Sukhtankar et al., 2017). Under the schemes every adult member of a rural household is guaranteed 100 days of work every financial year. The act lays special emphasis on women's employment. One-third of all jobs created under the act are reserved for women. The

schemes became operational in 200 of the poorest[1] districts during Phase 1 in February 2006. An additional 130 districts were included as part of Phase 2 in April and May 2007 and the remaining districts were added in April 2008.

We exploit the staggered roll-out of the NREGS to test whether the program being operational in a district reduced female job loss due to mechanization. Put another way, our objective is to examine if and to what extent the female labor displacing effects of agricultural mechanization would have been worse in a district in the absence of NREGS. Although there is some evidence showing that NREGS was effective in increasing overall rural female employment (Azam, 2012; Imbert and Papp, 2015), there is also evidence that NREGS by raising rural wages increased the adoption of labor-saving technologies in India (Bhargava, 2023). A key challenge in estimating a causal relationship between agricultural mechanization and female employment outcomes is accounting for unobserved heterogeneity that affects both. We exploit the exogenous variation in soil texture in a district to instrument for the level of mechanization in tilling. Mechanized tilling by tractors is used for deep tilling which is possible in loamy but not clayey soil (Afridi et al., 2023; Carranza, 2014). Instrumenting the area of district land under mechanized tilling by the difference in the share of loamy and clayey soil in the district we investigate the heterogenous effect of tractor adoption across NREGS and non-NREGS districts.

Our results indicate that a 10% increase in the area of land in a district operated on by tractors leads to a 5.3 percentage point reduction in the likelihood of a woman participating in the rural labor force and a 4.5 point reduction in the percentage of weekly days spent in private sector agricultural work. We do not find any evidence of NREGS increasing women's labor force participation. However, women in NREGS districts were found to spend an additional 1.1 percentage point of weekly days on work in public sector sector such as those provided under the scheme. This result is robust to controlling for unobserved invariant heterogeneity between NREGS and non-NREGS districts and a rich set of individual and district level controls. The increase in women's days worked due to NREGS is not sufficient to offset the fall in women's agricultural work days due to mechanization. We also fail to find evidence that women in NREGS districts spend more days on public sector work with increasing level of mechanization. This may be because NREGS was not designed to target mechanization induced job loss in agriculture. While the NREGS promises 100 days of work to every rural household, it's effectiveness is constrained by capacity constraints in creating jobs (Sukhtankar et al., 2017). Our findings still suggest that creating female friendly job opportunities can increase women's participation in the work force. If workfare programmes like the NREGS can be targeted to districts experiencing faster adoption of labor saving technologies it can help alleviate women's job loss and improve the benefits to cost of expensive programmes like the NREGS.

[1]The Planning Commission ranked all 447 districts from poorest to richest (Bhargava, 2023) and based the order of assignment to phases based on this. However, there were at least two known exceptions: areas facing Naxalite pressures were prioritized and each state had to have at least two districts in Phase I (Sukhtankar et al., 2017)

This paper contributes to the literature on the gendered effects of agricultural mechanization and to the empirical literature on the effects of NREGS on rural employment. Recent work by Caunedo and Kala (2021) and Afridi et al. (2023) has shown that tractor adoption in India caused a decline in the demand for female labor in agriculture. Additionally, Afridi et al. (2023) find no evidence of women's labor shifting toward the non-farm sector. We exploit the staggered rollout of NREGS to examine heterogeneous effects of mechanization across districts with and without the programme. We find that in districts where NREGS provided additional jobs through public works projects, women shifted some of their workdays from agriculture into these new jobs. This suggests that the insufficient supply of non-agricultural jobs for women contributed to the overall decline in female labor force participation.

Early studies by Imbert and Papp (2015) and Azam (2012) showed that NREGS increased women's participation in public works projects. Imbert and Papp (2015) demonstrated that the introduction of NREGS led women to substitute private-sector work with public jobs. By studying the effects of mechanization and NREGS in a common framework, we show that NREGS on its own did not cause women to exit private-sector employment. Instead, the ongoing process of mechanization pushed women out of private-sector jobs in both types of districts; when the workfare programme was operational, women substituted some of their lost private-sector workdays with NREGS jobs.

2 Context and Data

Figure 1 describes the timeline of the NREGS roll-out. NREGS was rolled out in the first 200 districts as part of Phase I in February 2006, in the next 130 districts as part of Phase II in May 2007 and in the remaining districts as part of Phase III in May 2008. For the present study, July 1999 to June 2000 is taken as the pre-intervention period and the post-intervention period is July 2007-June 2008. In the post-intervention period, the NREGS was operational in both Phase I and II districts but was yet to be adopted in Phase III districts. Phase I and II districts constitute the *treatment* group and phase III districts the *control* group. Mechanization in agriculture was in its nascent stage in the baseline, and adoption took off during the first decade of the twenty-first century (Afridi et al., 2023). Thus, the period of study is well-suited to both interventions, in that the baseline provides a snapshot when NREGS was not operational and mechanized tilling was minimal and the endline had both treatments operation to some degree in the sample.

For ease of exposition, we will refer to phase I and II as NREGS districts and phase III districts as non-NREGS districts henceforth.

2.1 Employment Measures

Data on employment is available from the nationally representative employment and unemployment surveys conducted by the National Sample Survey Organisation (NSSO). The employment rounds of the National Sample Survey (NSS) are conducted irregularly, with thick (larger sample) rounds and thin (smaller sample) rounds (Imbert and Papp, 2015). We use the 55^{th} (July 1999 - June 2000) and 64^{th} (July 2007 - June 2008) rounds becuase they offer a representative sample and aligns with our period of study.

Using the data in the NSS, we create two measures of employment–at the extensive and at the intensive margins based on how the NSS measures employment. The extensive margin is measured based on the primary and subsidiary occupation of a person in the preceding year. The *primary occupation* is the economic activity a person spent the majority of the preceding year in. If there are multiple activities, the second-most performed activity is recorded as the *subsidiary occupation*. For an activity to qualify as a subsidiary occupation, a persons needs to be engaged in it for a minimum of 30 days but less than 6 months (Afridi et al., 2023). A person may be engaged in an economic activity as an employer or own-account worker in the family enterprise/farm (*Self-employed*); as an unpaid worker on the family enterprise/farm without autonomy on operations or management (*Unpaid family worker*); as a worker in private sector enterprises either as a casual wage worker or regular salaried worker (*Wage work*); or as a worker in government or public projects such as those created under NREGS (*Public work*). The sector of employment is adjudged to be agriculture or non-agriculture based on two-digit National Industry Classification (NIC) number for 2004 or 1998 depending on the year of the survey. A person engaged in an economic activity or seeking employment is considered as being in the labor force.

The intensive margin is measured using time-use data on the economic activities a person performed in the week preceding the survey. We measure the number of days a person spent on economic activities, and non-economic activities such as domestic work. Days spent on work is further classified into agricultural and non-agricultural sector work as well as the type of occupation (*Self-employed*, *Unpaid family labor*, *Wage work*, or *Public work*).

We only use observations from working age men and women, those aged 15-65, from the rural sector in our analysis.

2.2 Mechanization

District-level data on agricultural mechanization is obtained from the Input Census which is conducted every five years by the Indian Ministry of Agriculture [2]. There have been four rounds of the survey so far: 1996-97, 2001-02, 2006-07, 2011-12 and 2016-17. The Input Census rounds that align with the pre- and post-intervention periods the closest are the 1996-97, the 2001-02 and the 2006-07 rounds. However, the 2001-02 round has several missing observations and inconsistencies. Due to delays, the 1996-97 round was actually conducted over 1997-99. This round is used as the pre-intervention period before NREGS was rolled-out in any of the districts. The 2006-07 round is used to construct the post-intervention sample. The Input Survey reports the number of landholdings which use different farming implements–hand-driven, animal-driven, and power-operated implements. Following Afridi et al. (2023) we identify tractor drawn mouldboard ploughs, rotavators, and cultivators as power-operated primary tilling implements; and tractor drawn disc harrows, tractor drawn levellers and cagewheels are identified as secondary tilling implements. We calculate the percentage of total district land holdings under primary tilling and the percentage of total land holdings under secondary tilling. The mechanization variable is calculated as the sum of these two variables and thus takes values in the interval $[0, 200]$.

2.3 Soil Texture

Data on soil texture was obtained from the ISRIC World Soil Information Service (WoSIS) which hosts spatial maps of soil properties like texture for the entire globe. Specifically we use the SoilGrids 2.0 dataset which contains the fraction of sand, silt, and clay content in every 250mx250m cell at different soil depth (Poggio et al., 2021). We used the `gDalUtilities` library on R to download the spatial datasets hosted on ISRIC. Based on the mean fraction of sand, silt, and clay in soil at a depth of 0-5 cm we use the `TT.points.in.classes` function in the R `soiltexture` library to classify each grid cell it into the 12 group classification for soil texture type available from the United States Department of Agriculture (USDA). These groups were further consolidated into either clayey, loamy and sandy soil

[2]This data was downloaded from https://inputsurvey.dacnet.nic.in/. The website has migrated to a new address: https://inputsurvey.da.gov.in/, though the district tables are not visible yet.

classes [3]. We use GIS (Geographic Information System) boundary files for India obtained from IPUMS website to convert the spatial data into district-level observations suitable for our purposes [4]. The instrument variable used to predict the degree of mechanized tilling by tractors in a district is the difference between the fraction of loamy soil and the fraction of clayey soil in a district.

2.4 Controls

2.4.1 Individual-level controls

Individual-level controls for a person's age, caste, religion, marital status, monthly per capita consumption expenditure, and land owned were obtained from the NSS survey rounds.

2.4.2 District-level controls

District-level controls used include controls for cropping patterns in a district, fertilizer (NPK) consumption, fraction of irrigated land, average landholding size, fraction of urban population, night lights intensity, rural female and male labor force participation rates in 1991, total monthly rainfall averaged on each quarter, maximum and minimum temperature in a quarter, proportion of district area under different soil depth classes, proportion of district area under different terrain slope classes and the mean pH level of district soil. A number of the district-level controls; namely cropping patterns, fertilizer consumption, fraction of irrigated land, night light intensity, and male and female labor force particpation rates; were downloaded from the Tata Cornell ICRISAT (International Crops Research Institute for the Semi-arid Tropics) website wich hosts datasets from various sources [5].

District-level cropping patterns were captured using the fractions of the gross cropped area in a district used for cultivating different major crops (Rice, wheat, oil seeds, sugarcane, cotton, fruits and vegetables, coarse cereals, and pulses). This information is available from the Ministry of Agriculture's Annual District-wise Crop Production Statistics which also contains information about the fraction of irrigated land. Fertilizer consumption in a district is measured as the units (kg) of nitrogen, phosphate and potash fertilizers applied per hectare of land. This data which is originally collected by the Fertilizer Association of India. The labor force participation rates were calculated from the 1991 Indian Census. The night lights luminosity data are from the DMSP-OLS Nighttime Lights Time Series from the NOAA.

[3]Following Afridi et al. (2023) we classify clay loam, silty clay loam, silty clay, sandy clay and clay as clayey soil. Silt, loam, silty loam, sandy clay loam, sandy loam and clay loam are classified into loamy soil. Sand and loamy sand compose sandy soil. We diverge from Afridi et al. (2023) in one respect, while the cited paper distinguishes between coarse and fine clay loam, taking fine clay loam as clayey and coarse clay loam as loamy, we classify all clay loam soil as belonging to the clayey category of soils.

[4]The shapefile can be accessed at this link: https://international.ipums.org/international/gis_yrspecific_2nd.shtml.

[5]The data is available here: http://data.icrisat.org/dld/src/crops.html.

The data on the rainfall and temperature were downloaded as spatial rasters from GAEZ (Global Agro Ecological Zones) data portal maintained by the FAO (Food and Agriculture Organization) [6]. The fraction of each district area under various slope classes were also obtained as spatial rasters from *Bhuvan* which is the geo-portal of ISRO (Indian Space Research Organisation) [7]. The data on the soil pH level and terrain slope were obtained as spatial rasters from the ISRIC WoSIS portal which is described above. All spatial data were converted to district-level observations using the GIS boundary file already described.

2.5 A Note about Data Availability

The Input Survey rounds in 1996-1997 and 2006-07 were not conducted for the states of Bihar, Jharkhand and Maharshtra. Therefore these districts were exclude from the analysis, leading to us dropping 81 of the 511 districts for which the 55^{th} round of the NSS has data. Additionally, we exclude eight districts which were completely urban and so not eligible for NREGS, these are Hyderabad, Delhi, Mumbai, Suburban Mumbai, Mahe, Yanam, Chennai and Kolkata. Additionally, eight districts had missing mechanization data and due to certain issues with the GIS boundary file another nine districts were dropped. In total we had 404 districts in the baseline which were used for the analysis. Certain control variables were not available for all the districts, when these are added to the specifications it leads to further loss of sample. We will presents the results using both the whole sample and the restrcited sample with additional controls added.

2.6 Descriptive Statistics

Table 1 presents the trends in the main employment and mechanization variables between 1999/00 and 2007/08. The percentage change between the two rounds were computed using district fixed effects OLS regressions. We have data from 404 districts out of which 124 are from the first phase of NREGS roll-out, 92 are from the second phase, and 194 are from the third phase. In 1999/00 NREGS was yet to be rolled out to any of the districts in India. In 2007/08, NREGS had become operational in first and second phase districts and these are the "NREGS Districts" while the third phase districts are the "Non-NREGS Districts". A person is considered to be "In labor force" if they reported as being engaged in an economic activity as either their primary or subsidiary occupation in the preceding year. A person is an "Ag. worker" if they were engaged in an agricultural activity as either their primary or subsidiary occupation. "Non-ag. worker" status is defined in an analogous manner. The jobs created under NREGS were typical of public employment schemes, including jobs in construction of public goods like roads and irrigation projects and jobs clearing land for cultivation (Sukhtankar et al., 2017). Thus, people engaged in these public sector jobs could either be "Ag. workers" or "Non-ag. worker". To better pick out the independent effect of NREGS we create the additional category "Public worker". A "Public worker" is a person who engaged in a government sponsored project such as those created under NREGS either as their primary or subsidiary occupation. "District area under mechanized primary tilling"

[6]Data is available here: https://gaez.fao.org/.

[7]The dataset used is the NRSC Soil dataset. It is avialable here: https://bhuvan-app3.nrsc.gov.in/data/download/index.php?c=p&s=NI&g=all.

and "District area under mechanized secondary tilling" are constructed as defined above. The total of these two numbers is the measure of *Mechanization* we use for the present analysis.

Usage of mechanized implements for tilling was minimal in the baseline. However, the Non-NREGS districts had a higher degree of mechanization than the NREGS districts. This discrepancy is explained by the targeted roll out of NREGS to less developed states first and more developed states in later phases. Tilling by mechanized means rose by a large degree between the baseline and endline. The increase was greater in the NREGS districts, perhaps due to purely mechanical reasons as there was more potential capacity to be added in these districts than the more affluent districts which already had a higher degree of mechanization. Another potential reason maybe that NREGS which led to rise in private sector wages also accelerated adoption of labor-saving capital goods. Bhargava (2023) shows that this phenomenon did take place, however it was mainly limited to the adoption of animal-operated technology groups rather than power-operated ones which is the main focus of this study.

Women saw a fall in labor force participation in the whole sample, though the male labor force participation rate remained largely unchanged. In fact, men in NREGS districts experienced a moderate increase in labor force participation rates. Both men and women saw a considerable rise in participation rates in the non-agricultural sector. However, for women since non-agricultural jobs were quite rare in the baseline this increase though large in percentage terms was insufficient to counter the fall in agricultural jobs. Men saw a rise in agricultural job participation rates as well as non-agricultural job participation rates. Women as a whole also experienced a fall in public sector jobs which includes jobs created under NREGS. Strangely, even in the NREGS districts there was fall in the number of women who were public workers though the fall is smaller than in the Non-NREGS districts. There was a large rise in the male participation in public jobs in the NREGS districts though in the Non-NREGS districts there was a fall.

However, upon examining the intensive margin of employment there is evidence that NREGS led to large increases in the number of days spent on public sector work in the districts where it was operating. The increase was larger for women than men, though both sexes spent a very small fraction of weekly working days on public sector work. Both men and women experienced declines in the share of weekly days spent on agricultural or non-agricultural work whereas the share of domestic work increased for women in both NREGS and Non-NREGS districts and for men in the Non-NREGS districts.

These figures suggest that while agriculture saw a rise in the adoption of improved tilling technology there was an overall fall in rural female labor force participation rates even though male labor force participation remained unchanged or even rose in certain areas. The districts with NREGS saw a rise in male public workers though women public workers fell. However, NREGS seems to have had some effect for women as well since the fall in public workers in NREGS districts was smaller than in the Non-NREGS districts. In terms of days worked,

NREGS districts saw large increases in the category of public work while private sector work hours fell for both men and women. Overall it appears that while NREGS did increase female days worked, it may not been sufficient to offset the fall due to mechanized tilling.

3 Methodology

Mechanization in agriculture, specifically mechanization in tilling is a continuous process that has been shown to reduce female labor force participation over time (Afridi et al., 2023). Conversely, the NREGS is the world's largest workfare workfare programme which led to increased female non-farm employment opportunities through its guarantee of 100 days of work at minimum wages for every adult in a rural household (Imbert and Papp, 2015; Azam, 2012; Sukhtankar et al., 2017). We will use individual-level data on employment statistics to examine if NREGS mediated the labor-displacing effect of mechanized tilling by offering alternative forms of employment for women pushed out of the agricultural private sector. To that end we will estimate the following specification using repeated cross-sections from a period before NREGS implementation (1999/00) and from a period when NREGS had been implemented in a subset of districts (2007/08):

$$Y_{idt} = \beta_1 M_{dt} + \beta_2 \mathbb{1}_{NREGS\ Active} + \beta_3 M_{dt} \times \mathbb{1}_{NREGS\ Active} + X'_{idt}\beta_4 + \theta_d + \mathbb{1}_t + \epsilon_{idt} \quad (1)$$

where Y_{idt} is the relevant dependent variable which includes extensive measures of employment which are labor force participation status (0/1), agricultural worker status (0/1), and non-agricultural worker status of individual (0/1); and intensive measures of employment which are percentage of days worked in a week, percentage of days in a week spent on private sector agricultural work, and percentage of days in a week spent on public sector work (like those provided under NREGS) for individual i in district d at time t; M_{dt} is the mechanization level in district d at time t; $\mathbb{1}_{NREGS\ Active}$ is an indicator variable for wether NREGS is operational in district d at time t; X_{idt} is a vector of both individual and district level controls; θ_d are the district fixed effects; $\mathbb{1}_t$ is an indicator variable for the endline and ϵ_{idt} is the random error. To account for correlated errors within districts, standard errors are clustered at the district level. We include individual level controls for age, education, marital status, religion, caste, owned land and monthly consumption expenditure. District level controls include controls for soil characteristics like pH level, slope of the terrain, depth; controls for average fertilizer usage, irrigation, and types of crops cultivated.

In equation 1, the coefficient β_1 measures the effect on employment of an additional percentage of district land under either primary or secondary tilling equipment. We expect $\beta_1 < 0$ when the dependent variable is labor force participation, agricultural worker status, days worked in a week, or days in agricultural private sector work. β_2 measures the independent effect of NREGS operating in a district on the employment measures. It is expected that $\beta_2 > 0$ for the dependent variable days of public sector work, and for female labor force participation status if NREGS is successful in increasing overall labor force participation for women. β_3 tells us of the additional effect of the availability of NREGS jobs with a percentage point increase in the level of agricultural mechanization in a district. If women are more likely to accept NREGS jobs as agricultural mechanization increases we would expect $\beta_3 > 0$. Whether NREGS was successful in offsetting job loss due to mechanized tilling can

be judged by the relative magnitudes of β_1, β_2, and β_3.

NREGS was rolled out in a staggered manner across districts, providing us with a counterfactual in late phase districts which were yet to receive NREGS in the endline. However, the roll out across districts was not randomized. To account for this, we include district level fixed effects in the above specification which control for unobserved differences between early and late adopters of NREGS. However, in order to estimate the mediating effect of the NREGS on the fall in female employment opportunities due to agricultural mechanization one also must take into account of the possibility of reverse causality affecting the relationship between the mechanization and female employment. Additionally, the two treatment variables could have affected each other. Specifically, NREGS which created jobs in the public sector which offered a fixed and competitive wage to workers, this could have in turn accelerated the adoption of labor-saving technology if private sector wages were pushed up supply side factors.

One way of measuring the heterogeneous effects of mechanization on women's labor outcomes based on NREGS status, is to predict mechanization level using the exogenous variations in a variable which is arguably not linked directly to either female labor market outcomes or the order in which NREGS was rolled out across districts. We propose that a district's distribution of soil texture fulfills both these requirements. Namely, the share of district soil that is loamy and the share that is clayey affects the soil's suitability to tilling by tractors. Mechanized tilling by tractors is used for primary or deep tilling which is possible in loamy but not clayey soil (Afridi et al., 2023; Carranza, 2014). Crucially, the soil texture only determines the depth of tillage and does not affect the quality or crop suitability of a soil (Carranza, 2014). Soil texture is therefore arguably exogenous to female labor outcomes. We also add controls for crop choice at the district level as well as other inputs into agricultural production like fertilizer use and irrigation, which might be linked to soil texture.

Since both mechanization level and NREGS are right hand side variables, robustness to endogeneity concerns does not require independence between the two treatments. In fact, we expect there to be some relationship between the two thereby making it crucial to account for both these economic forces. However, if the two treatments are highly correlated it can lead to multicollinearity concerns which can make getting precise estimates of either of the two treatment variables difficult. NREGS rollout was based on a ranking of the 447 poorest districts by the Indian Planning Commission (IPC) using mid-1990s data on wages, productivity, and fraction of scheduled castes and tribes. Given that the soil texture in a district does not directly affect agricultural productivity, it is unlikely to be directly linked with any of the deciding factors for NREGS rollout. This helps ensure that the variation in mechanization used in our regression represents the variation due a mechanical quality of the soil which is exogenous to any factor which may have affected NREGS roll out as well as being exogenous to general equilibrium effects on wages arising due to NREGS adoption.

Thus we adopt an instrumental variable strategy in our estimation exercise, using the exogenous variation in soil texture across districts to predict adoption of mechanized tilling

in a regression of male and female labor outcomes on predicted mechanization and NREGS status.

We estimate the following specification using repeated cross-sections for the years 1999/00 and 2007/08:

$$Y_{idt} = \beta_1^1 M_{dt} + \beta_2^1 \mathbb{1}_{NREGS\ Active} + \beta_3^1 M_{dt} \times \mathbb{1}_{NREGS\ Active} + X'_{idt}\beta_4^1 + \theta_{NREGS} + \theta_s + \mathbb{1}_t + \epsilon_{idt} \quad (2)$$

where M_{dt} is now predicted using S_{dt} which is the difference between the share of district soil which is loamy and the share which is clayey. The instrument S_{dt} varies spatially across districts but is constant over time. As a result we are unable to use district level fixed effects since these would absorb the instrument. However, in order to account for the fact that NREGS roll out was non-random, we include fixed effects at the NREGS group level, θ_{NREGS}, which is a dummy variable equal to unity for phase I and phase II NREGS districts irrespective of the year. We also include state level fixed effects θ_s to account for unobserved time-invariant confounders at the state level.

The first stage regressions are given by:

$$M_{dt} = \beta_1^2 S_d + \beta_2^2 \mathbb{1}_{NREGS\ Active} + \beta_3^2 S_d \times \mathbb{1}_{NREGS\ Active} + X'_{idt}\beta_4^2 + \theta_{NREGS} + \theta_s + \mathbb{1}_t + \epsilon_{idt}$$

and,

$$M_{dt} \times \mathbb{1}_{NREGS\ Active} = \beta_1^3 S_d + \beta_2^3 \mathbb{1}_{NREGS\ Active} + \beta_3^3 S_d \times \mathbb{1}_{NREGS\ Active} + X'_{idt}\beta_4^3 + \theta_{NREGS} + \theta_s + \mathbb{1}_t + \epsilon_{idt}$$

While we account for both time variant heterogeneities at the NREGS district group level and state level, our estimated effects should be interpreted as the heterogenous effects of mechanization under NREGS non-operational and NREGS operational conditions. Through our present exercise we aim to observe the effects of agricultural mechanization in the presence and absence of rural workfare programmes rather than identify the causal effect of NREGS on employment which has been studied previously (Imbert and Papp, 2015; Azam, 2012; Sukhtankar et al., 2017).

4 Results

Table 2 shows the first stage results from the IV regression of mechanization and NREGS on female employment outcomes. Columns (2) and (4) have smaller samples as compared to those in columns (1) and (3) due to data on district level controls for fertilizer consumption, nightlight luminosity, cropping patterns, irrigation patterns, and labor force participation rates in 1991 not being available for all districts in the sample. The instruments are statistically significant and the first-stage F statistic for the specifications with all the control variables are either very close to (Column 2) or grater than (Column 4) than the cutoff of ten. Further diagnostic tests should be conducted to judge the quality of the instruments. A similar table for the regressions for male labor outcomes is presented in the appendix (Table A1).

The results from the second-stage regression of labor force participation status on mechanization and NREGS status are presented in Table 3. The dependent variable is an indicator function for whether an individual is in the labor force. This variable was multiplied by a factor of 100 in order to able to interpret the estimates as percentage points. These results suggest that a one percent incraese in district land area under either primary or secondary tilling by machines led to a 0.5 percentage point fall in female labor force participation rates. This very stark result for women is contrasted by the absence of any detectable of mechanization on men's participation rates. However, as suggested by the descriptive statistics there is no detectable effect of NREGS either independently (NREGS Act.) or as a mediating force for mechanization (Mech.*NREGS Act.) at the extensive margin for women's labor force participation. There is no evidence of mechanization affecting men's labor force participation rates. Tables 5 and 7 present the results from the IV regression of agricultural worker status and non-agricultural worker status on NREGS and mechanization respectively. Mechanized tilling significantly reduces the likelihood of a woman working as an agricultural worker but understandably does not affect the likelihood of a woman being a non-agricultural worker.

While NREGS does not appear to have any effect on extensive margin of women's employment, we find evidence to suggest that it increased days of public work for women. Table 9 presents the results from the regression of percentage of weekly days spent on private agricultural work and on public sector work for women on mechanization. We find that a 10% rise in the area of district land under mechanized tilling is associated with a 4.5 percentage point reduction in the percentage of work days in private agricultural work. Column (3) presents the results for the regression on percentage days spent on public work. The results from this specification indicate that women in districts where NREGS was operational, spent 1.1 percentage point more days on public sector. This indicates that while NREGS was successful in increasing women's employment at the intensive margin, it may not have been sufficient to offset the loss of days worked due to mechanization. Interestingly, the coefficient for mechanization is weakly significant and positive, indicating that increasing mechanization pushed women into public sector jobs. The interaction between NREGS and mechanization is however not statistically significant. This indicates that the effectiveness of NREGS did

not increase in districts with increasing mechanization. This could be because of either demand or supply side factors. Though given that we find strong evidence that mechanization pushed women out of the agricultural labor force, it seems unlikely that women displaced from agricultural jobs would not be more likely to move into the public sector than women who were not displaced. What seems more likely is that since the NREGS was not directly targeted to alleviate mechanization led job loss, the supply of NREGS jobs did not vary by the level of mechanization in different districts.

Furthermore, unlike Imbert and Papp (2015), we do not find any evidence to suggest that the NREGS operation on its own caused a fall in women's participation in the private sector. Rather, the fall in women's private sector jobs appears to largely originate from the effect of the ongoing process of mechanization.

Column (4) includes additional controls for crop choice, fertilizer application, irrigation, and other inputs into agricultural production. These controls are necessary to estimate the relationship between mechanization and agricultural labor outcomes, however they are not direct inputs into the relationship between public sector employment. Because of data availability issues, adding these controls reduces our sample size to a large degree. This may be a reason why we are unable to identify the effect of NREGS on women's public sector employment in column (4). We are exploring alternative data sources for these controls which are more complete.

Table 11 shows that mechanization did not reduce men's private sector employment even at the intensive margin. Additionally, men in NREGS districts spent around 2.3 percentage point more days on publis sector jobs (Column 3). There is also some weak evidence again that mechanization pushed people into public sector jobs. The interaction term between mechanization and NREGS is statistically significant and negative. This indicates that higher mechnization in a district reduces the number of work days men allocate to public sector jobs such as those created under NREGS. This is possible given that men did not lose agricultural jobs due to mechanization. In fact men's jobs in agriculture were in a sense complementary to tractors, as they were more likely than women to be hired to operate the new tractors (Afridi et al., 2023).

5 Conclusion

This paper examines whether the insufficient supply of female labor opportunities in the non-agricultural sector contributed to the fall in women's labor force participation due to mechanization in the agricultural production process in India. Using the roll out of the NREGS as a case study, we show that districts which had the workfare programme saw a substitution in female work days from agriculture to public work projects. We used the exogenous variation in soil textures across districts to instrument for mechanization in a fixed effects regression of NREGS status on labor outcomes. While we find that NREGS increased female employment at the intensive margin, it was not able to reduce the number of women exiting the labor force. Men were unaffected by the introduction of the new agricultural technology, and also saw a rise in public work days due to NREGS. Overall, there appears to have been a substitution of male labor for female labor in rural India during the period of this study.

While the NREGS is intended to provide 100 days of work to ever rural household in India, it is widely accepted that job supply constraints have affected its efficacy (Sukhtankar et al., 2017). This may be the reason that we don't find that women's employment in public sector jobs do not go up with increasing levels of mechanization across districts. Our results suggest that female friendly labor opportunities can reduce the fall in female labor and if programmes like the NREGS can be targeted to districts with greater adoption of labor saving technologies it can better reduce the fall in women's labor outcomes and improve the benefit-cost of public outlay into similar programmes.

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6 Tables

Table 1: Trends in employment and mechanized tilling between baseline (1999/00) and endline (2007/08).

	Whole sample		NREGS Districts		Non-NREGS Districts	
	1999/00 Mean (SE)	2007/08 Change (%)	1999/00 Mean (SE)	2007/08 Change (%)	1999/00 Mean (SE)	2007/08 Change (%)
District area under mechanized:						
Primary tilling (%)	6.206 (0.793)	201.03***	3.592 (0.923)	282.57***	8.704 (1.283)	175.54***
Secondary tilling (%)	10.956 (0.986)	87.22***	5.152 (0.757)	163.42***	16.770 (1.840)	65.91***
Mechanization	17.162 (1.648)	128.38***	8.744 (1.564)	212.36***	25.475 (2.911)	103.37***
Women:						
In labor force (%)	44.645 (0.421)	-3.87**	45.875 (0.563)	-3.62	43.335 (0.598)	-4.57
Ag. worker (%)	36.784 (0.398)	-5.27**	37.744 (0.516)	-3.13	35.802 (0.590)	-8.53**
Non-ag. worker (%)	7.152 (0.143)	26.46***	7.469 (0.197)	25.80***	6.762 (0.194)	27.06***
Public worker (%)	1.348 (0.065)	-68.85***	1.390 (0.090)	-53.06***	1.273 (0.084)	-90.61***
Days in week spent on:						
Pvt. ag. work (%)	26.772 (0.322)	-12.01***	28.544 (0.410)	-14.38***	24.770 (0.487)	-8.95**
Pvt. non-ag. work (%)	22.442 (0.284)	-7.61***	22.580 (0.351)	-9.44***	22.483 (0.447)	-5.75
Public work (%)	0.104 (0.037)	323.76***	0.117 (0.064)	474.92***	0.083 (0.017)	71.52*
Domestic work (%)	56.864 (0.368)	4.68***	55.682 (0.475)	5.63***	58.121 (0.541)	3.77**
Men:						
In labor force (%)	85.879 (0.135)	0.46	86.235 (0.187)	1.32***	85.306 (0.177)	-0.59
Ag. worker (%)	56.662 (0.298)	2.71***	58.493 (0.419)	5.52***	54.152 (0.379)	-0.89
Non-ag. worker (%)	27.552 (0.281)	33.17***	26.014 (0.400)	39.81***	29.470 (0.352)	25.62***
Public worker (%)	0.482 (0.061)	92.57***	0.446 (0.101)	196.55***	0.496 (0.045)	-15.99***
Days in week spent on:						
Pvt. ag. work (%)	61.382 (0.275)	-8.55***	63.106 (0.386)	-9.27***	59.207 (0.361)	-7.65***
Pvt. non-ag. work (%)	61.842 (0.239)	-1.71**	60.923 (0.319)	-1.64	63.119 (0.340)	-1.95*
Public work (%)	0.315 (0.049)	158.65***	0.318 (0.080)	271.06***	0.286 (0.030)	15.08
Domestic work (%)	1.300 (0.058)	30.96***	1.465 (0.083)	18.89*	1.076 (0.074)	52.08***
	1999/00	2007/08	1999/00	2007/08	1999/00	2007/08
Number of districts	404		210		194	
Number of women	90424	95558	51717	54648	42356	40910
Number of men	92261	94459	52531	54416	43248	40043

Notes: All estimates are from district fixed effects regression models. Percentage changes are calculated as 100 * coefficient on year dummy/constant. Standard errors were clustered at district level. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

Table 2: Results from first stage of IV regressions for women.

	Mechanization		Mech.*NREGS Act.	
	(1)	(2)	(3)	(4)
Soil texture	9.217**	12.193**	-2.126	-5.836**
	(3.706)	(5.004)	(1.582)	(2.371)
Soil texture*NREGS Act.	1.286	2.666	19.021***	18.700***
	(4.052)	(4.662)	(5.229)	(5.580)
Constant	-96.951*	58.648	-56.730	-36.258
	(50.976)	(100.289)	(43.695)	(48.950)
Year FEs	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes
NREGS Group FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
First stage F stat.	3.615	8.078	6.075	24.253
R^2	0.635	0.715	0.390	0.527
Districts	397	226	397	226
Individuals	183433	98113	183433	98113

Notes: Individual level controls for age, education, marital status, caste, religion, size of land owned by household, and monthly per capital consumption expenditure were included in each specification. District level controls for minimum temperature, maximum temperature, and average rainfall in a quarter; fraction of urban population; and average land holdings size were included in each specification. Additional district level controls for per hectare application of nitrogen, phosphate, and potash fertilizers; nightlight intensity; cropping patterns; fraction of irrigated district land; male and female labor force participation rates in 1991 were added where indicated. Standard errors clustered at district-level reported in parentheses. * p<0.1, ** p<0.05, and *** p<0.01.

Table 3: Results from second stage of IV regressions of labor force participation status on mechanization and NREGS.

	Women		Men	
	(1)	(2)	(3)	(4)
Mechanization	-0.525*	-0.543**	0.029	0.045
	(0.289)	(0.239)	(0.066)	(0.065)
NREGS Act.	2.836	1.758	1.363	-0.440
	(5.958)	(6.724)	(1.149)	(1.465)
Mech.*NREGS Act.	-0.167	-0.074	0.001	0.055
	(0.172)	(0.193)	(0.033)	(0.046)
Constant	81.168	76.120	52.884***	71.148***
	(55.249)	(76.047)	(12.709)	(15.381)
Year FEs	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes
NREGS Group FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
Kleinbergen-Paap F Stat.	3.548	3.780	2.895	3.467
R^2	0.041	0.066	0.188	0.185
Districts	397	226	397	226
Individuals	183433	98113	183932	98154

Notes: The dependent variable is an indicator variable for whether an individual is in the labor force. This variable was multiplied by 100, so that the estimates could be interpreted as percentage points. Individual level controls for age, education, marital status, caste, religion, size of land owned by household, and monthly per capital consumption expenditure were included in each specification. District level controls for minimum temperature, maximum temperature, and average rainfall in a quarter; fraction of urban population; and average land holdings size were included in each specification. Additional district level controls for per hectare application of nitrogen, phosphate, and potash fertilizers; nightlight intensity; cropping patterns; fraction of irrigated district land; male and female labor force participation rates in 1991 were added where indicated. Standard errors clustered at district-level reported in parentheses. * p<0.1, ** p<0.05, and *** p<0.01.

Table 4: Results from TWFE regressions of labor force participation status on mechanization and NREGS.

	Women		Men	
	(1)	(2)	(3)	(4)
Mechanization	0.025	0.022	-0.003	0.016**
	(0.022)	(0.030)	(0.005)	(0.007)
NREGS Act.	0.688	-0.762	1.712***	1.594**
	(1.923)	(2.887)	(0.630)	(0.718)
Mech.*NREGS Act.	-0.048	0.028	-0.018**	-0.010
	(0.035)	(0.046)	(0.008)	(0.009)
Constant	37.467***	52.955***	70.486***	64.899***
	(4.795)	(12.557)	(2.794)	(4.807)
Year FEs	Yes	Yes	Yes	Yes
Dist. FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
R^2	0.203	0.200	0.197	0.194
F stat.: Mech. + Mech.*NREGS = 0	0.612	1.104	7.374***	0.447
Districts	397	226	397	226
Individuals	183433	98113	183932	98154

Table 5: Results from second stage of IV regressions of agricultural worker status on mechanization and NREGS.

	Women		Men	
	(1)	(2)	(3)	(4)
Mechanization	-0.497*	-0.484**	0.146	-0.038
	(0.272)	(0.222)	(0.173)	(0.116)
NREGS Act.	4.837	5.372	3.691	4.702
	(5.680)	(6.343)	(2.852)	(2.967)
Mech.*NREGS Act.	-0.181	-0.091	-0.002	0.015
	(0.164)	(0.179)	(0.083)	(0.087)
Constant	55.004	67.130	84.977***	74.061**
	(51.269)	(68.948)	(26.726)	(32.412)
Year FEs	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes
NREGS FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
Kleinbergen-Paap F Stat.	3.548	3.780	2.895	3.467
R^2	0.090	0.118	0.243	0.257
Districts	397	226	397	226
Individuals	183433	98113	183932	98154

Notes: The dependent variable is an indicator variable for whether an individual worked as an agricultural worker in the reference year. This variable was multiplied by 100, so that the estimates could be interpreted as percentage points. Individual level controls for age, education, marital status, caste, religion, size of land owned by household, and monthly per capital consumption expenditure were included in each specification. District level controls for minimum temperature, maximum temperature, and average rainfall in a quarter; fraction of urban population; and average land holdings size were included in each specification. Additional district level controls for per hectare application of nitrogen, phosphate, and potash fertilizers; nightlight intensity; cropping patterns; fraction of irrigated district land; male and female labor force participation rates in 1991 were added where indicated. Standard errors clustered at district-level reported in parentheses. * $p<0.1$, ** $p<0.05$, and *** $p<0.01$.

Table 6: Results from TWFE regressions of agricultural worker status on mechanization and NREGS.

	Women		Men	
	(1)	(2)	(3)	(4)
Mechanization	0.025	0.024	0.001	0.020
	(0.023)	(0.031)	(0.010)	(0.016)
NREGS Act.	2.140	1.576	4.163***	6.121***
	(1.843)	(2.834)	(1.214)	(1.636)
Mech.*NREGS Act.	-0.055	0.018	-0.063***	-0.061***
	(0.036)	(0.044)	(0.016)	(0.019)
Constant	21.658***	28.655**	26.333***	-4.299
	(4.675)	(12.036)	(3.019)	(9.392)
Year FEs	Yes	Yes	Yes	Yes
Dist. FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
R^2	0.252	0.238	0.268	0.270
F stat.: Mech. + Mech.*NREGS = 0	0.945	0.791	18.024***	4.271**
Districts	397	226	397	226
Individuals	183433	98113	183932	98154

Table 7: Results from second stage of IV regressions of non-agricultural worker status on mechanization and NREGS.

	Women		Men	
	(1)	(2)	(3)	(4)
Mechanization	0.034	0.006	-0.273	0.039
	(0.086)	(0.091)	(0.204)	(0.153)
NREGS Act.	1.110	0.280	-3.460	-5.327
	(1.344)	(1.975)	(3.014)	(4.069)
Mech.*NREGS Act.	-0.041	-0.056	0.194**	0.230*
	(0.040)	(0.060)	(0.088)	(0.135)
Constant	42.128	12.650	-22.824	27.112
	(28.634)	(28.860)	(30.807)	(44.475)
Year FEs	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
Kleinbergen-Paap F Stat.	3.548	3.780	2.895	3.467
R^2	0.050	0.057	0.140	0.154
Districts	397	226	397	226
Individuals	183433	98113	183932	98154

Notes: The dependent variable is an indicator variable for whether an individual worked as a non-agricultural worker in the reference year. This variable was multiplied by 100, so that the estimates could be interpreted as percentage points. Individual level controls for age, education, marital status, caste, religion, size of land owned by household, and monthly per capital consumption expenditure were included in each specification. District level controls for minimum temperature, maximum temperature, and average rainfall in a quarter; fraction of urban population; and average land holdings size were included in each specification. Additional district level controls for per hectare application of nitrogen, phosphate, and potash fertilizers; nightlight intensity; cropping patterns; fraction of irrigated district land; male and female labor force participation rates in 1991 were added where indicated. Standard errors clustered at district-level reported in parentheses. * p<0.1, ** p<0.05, and *** p<0.01.

Table 8: Results from TWFE regressions of non-agricultural worker status on mechanization and NREGS.

	Women		Men	
	(1)	(2)	(3)	(4)
Mechanization	0.005	-0.005	-0.002	0.003
	(0.005)	(0.008)	(0.010)	(0.014)
NREGS Act.	-0.231	-0.528	2.964**	3.045*
	(0.649)	(0.910)	(1.162)	(1.619)
Mech.*NREGS Act.	0.012	0.015	0.013	0.009
	(0.008)	(0.013)	(0.015)	(0.024)
Constant	11.477***	15.914***	34.113***	41.403***
	(1.600)	(5.238)	(2.455)	(9.055)
Year FEs	Yes	Yes	Yes	Yes
Dist. FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
R^2	0.078	0.085	0.182	0.178
F stat.: Mech. + Mech.*NREGS = 0	5.021**	0.530	0.659	0.233
Districts	397	226	397	226
Individuals	183433	98113	183932	98154

Table 9: Results from second stage of IV regressions of percentage of weekly days spent on private agricultural work and public work by women on mechanization and NREGS.

	Private Ag.		Public	
	(1)	(2)	(3)	(4)
Mechanization	-0.464**	-0.437**	0.022*	0.020
	(0.231)	(0.199)	(0.013)	(0.014)
NREGS Act.	0.072	1.446	1.097**	0.857
	(5.133)	(6.169)	(0.448)	(0.603)
Mech.*NREGS Act.	-0.126	-0.115	-0.021	-0.019
	(0.149)	(0.179)	(0.014)	(0.017)
Constant	28.674	-25.359	7.559	-0.128
	(48.017)	(57.872)	(5.597)	(4.262)
Year & Quarter FEs	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes
NREGS Group FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
Kleinbergen-Paap F Stat.	3.392	3.659	3.392	3.659
R^2	0.009	0.036	-0.005	0.002
Districts	397	226	397	226
Individuals	183433	98113	183433	98113

Notes: The dependent variables are percentage of days in reference spent on private agricultural work and on public sector work. Individual level controls for age, education, marital status, caste, religion, size of land owned by household, and monthly per capital consumption expenditure were included in each specification. District level controls for minimum temperature, maximum temperature, and average rainfall in a quarter; fraction of urban population; and average land holdings size were included in each specification. Additional district level controls for per hectare application of nitrogen, phosphate, and potash fertilizers; nightlight intensity; cropping patterns; fraction of irrigated district land; male and female labor force participation rates in 1991 were added where indicated. Standard errors clustered at district-level reported in parentheses. * p<0.1, ** p<0.05, and *** p<0.01.

Table 10: Results from TWFE regressions of percentage of weekly days spent on private agricultural and public work by women on mechanization and NREGS.

	Private		Public	
	(1)	(2)	(3)	(4)
Mechanization	0.029*	0.035*	0.002***	-0.001
	(0.016)	(0.021)	(0.001)	(0.002)
NREGS Act.	-1.772	-3.475*	0.517***	0.414*
	(1.469)	(2.051)	(0.133)	(0.224)
Mech.*NREGS Act.	-0.025	0.036	-0.001	0.001
	(0.024)	(0.029)	(0.002)	(0.004)
Constant	22.887***	33.653***	0.203	-0.254
	(4.225)	(11.737)	(0.374)	(1.274)
Year & Quarter FEs	Yes	Yes	Yes	Yes
Dist. FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
R^2	0.190	0.176	0.030	0.038
F stat.: Mech. + Mech.*NREGS = 0	0.030	4.782**	0.263	0.024
Districts	397	226	397	226
Individuals	183433	98113	183433	98113

Table 11: Results from second stage of IV regressions of percentage of weekly days spent on private agricultural and public work by men on mechanization and NREGS.

	Private Ag.		Public	
	(1)	(2)	(3)	(4)
Mechanization	-0.050	-0.085	0.036*	0.006
	(0.129)	(0.116)	(0.022)	(0.020)
NREGS Act.	-2.281	-4.287	2.249***	2.463***
	(2.335)	(3.083)	(0.611)	(0.909)
Mech.*NREGS Act.	0.028	0.116	-0.050***	-0.063**
	(0.066)	(0.089)	(0.018)	(0.027)
Constant	10.724	1.693	9.107	1.644
	(28.148)	(33.255)	(6.588)	(5.954)
Year & Quarter FEs	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes
NREGS Group FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
Kleinbergen-Paap F Stat.	2.771	3.344	2.771	3.344
R^2	0.191	0.194	-0.009	-0.008
Districts	397	226	397	226
Individuals	183932	98154	183932	98154

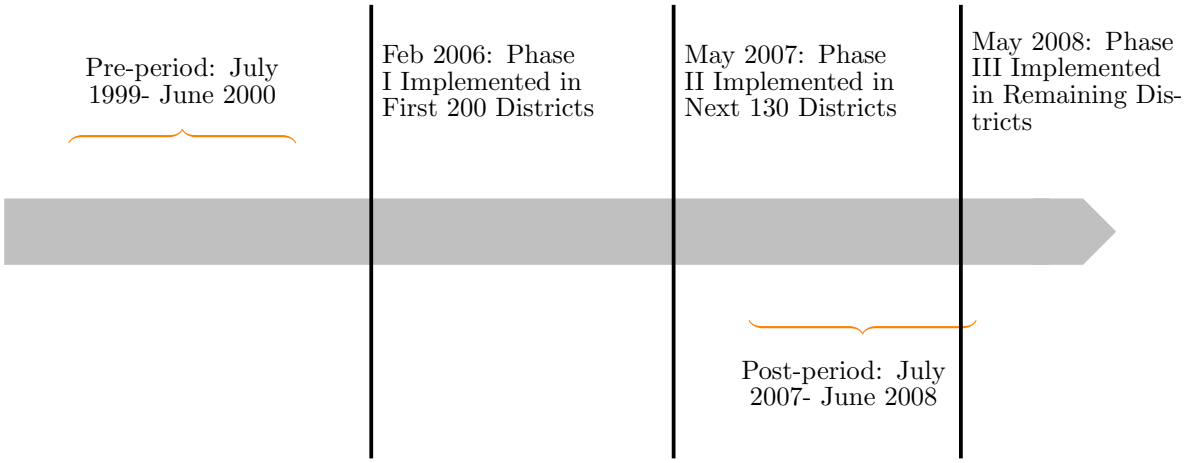
Notes: The dependent variables are percentage of days in reference spent on private agricultural work and on public sector work. Individual level controls for age, education, marital status, caste, religion, size of land owned by household, and monthly per capital consumption expenditure were included in each specification. District level controls for minimum temperature, maximum temperature, and average rainfall in a quarter; fraction of urban population; and average land holdings size were included in each specification. Additional district level controls for per hectare application of nitrogen, phosphate, and potash fertilizers; nightlight intensity; cropping patterns; fraction of irrigated district land; male and female labor force participation rates in 1991 were added where indicated. Standard errors clustered at district-level reported in parentheses. * $p<0.1$, ** $p<0.05$, and *** $p<0.01$.

Table 12: Results from TWFE regressions of percentage of weekly days spent on private agricultural and public work by men on mechanization and NREGS.

	Private		Public	
	(1)	(2)	(3)	(4)
Mechanization	-0.009	0.021	0.002**	0.002
	(0.010)	(0.017)	(0.001)	(0.003)
NREGS Act.	-1.144	-1.016	0.926***	0.801***
	(1.148)	(1.597)	(0.194)	(0.307)
Mech.*NREGS Act.	-0.035**	-0.028	-0.005*	-0.003
	(0.015)	(0.023)	(0.003)	(0.005)
Constant	34.486***	11.766	0.833	-2.037
	(3.918)	(10.312)	(0.547)	(1.984)
Year & Quarter FEs	Yes	Yes	Yes	Yes
Dist. FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
R^2	0.207	0.209	0.031	0.035
F stat.: Mech. + Mech.*NREGS = 0	12.957***	0.112	0.932	0.058
Districts	397	226	397	226
Individuals	183932	98154	183932	98154

7 Figures

Figure 1: Timeline of the NREGS



8 Appendix

Table A1: Results from first stage of IV regressions for men.

	Mechanization		Mech.*NREGS Act.	
	(1)	(2)	(3)	(4)
Soil texture	8.091**	10.878**	-2.238	-5.760**
	(3.686)	(4.887)	(1.509)	(2.251)
Soil texture*NREGS Act.	2.423	3.551	19.162***	18.324***
	(3.879)	(4.501)	(4.916)	(5.250)
Constant	-85.625*	74.643	-52.622	-30.639
	(49.215)	(99.655)	(40.940)	(46.936)
Year FEs	Yes	Yes	Yes	Yes
State FEs	Yes	Yes	Yes	Yes
NREGS Group FEs	Yes	Yes	Yes	Yes
Ind. and dist. controls	Yes	Yes	Yes	Yes
Add. dist. controls	No	Yes	No	Yes
First stage F stat.	3.457	7.532	6.281	23.074
R^2	0.633	0.716	0.391	0.529
Districts	397	226	397	226
Individuals	183932	98154	183932	98154

Notes: Individual level controls for age, education, marital status, caste, religion, size of land owned by household, and monthly per capital consumption expenditure were included in each specification. District level controls for minimum temperature, maximum temperature, and average rainfall in a quarter; fraction of urban population; and average land holdings size were included in each specification. Additional district level controls for per hectare application of nitrogen, phosphate, and potash fertilizers; nightlight intensity; cropping patterns; fraction of irrigated district land; male and female labor force participation rates in 1991 were added where indicated. Standard errors clustered at district-level reported in parentheses. * p<0.1, ** p<0.05, and *** p<0.01.