Gender and Mechanization: Evidence from Indian Agriculture

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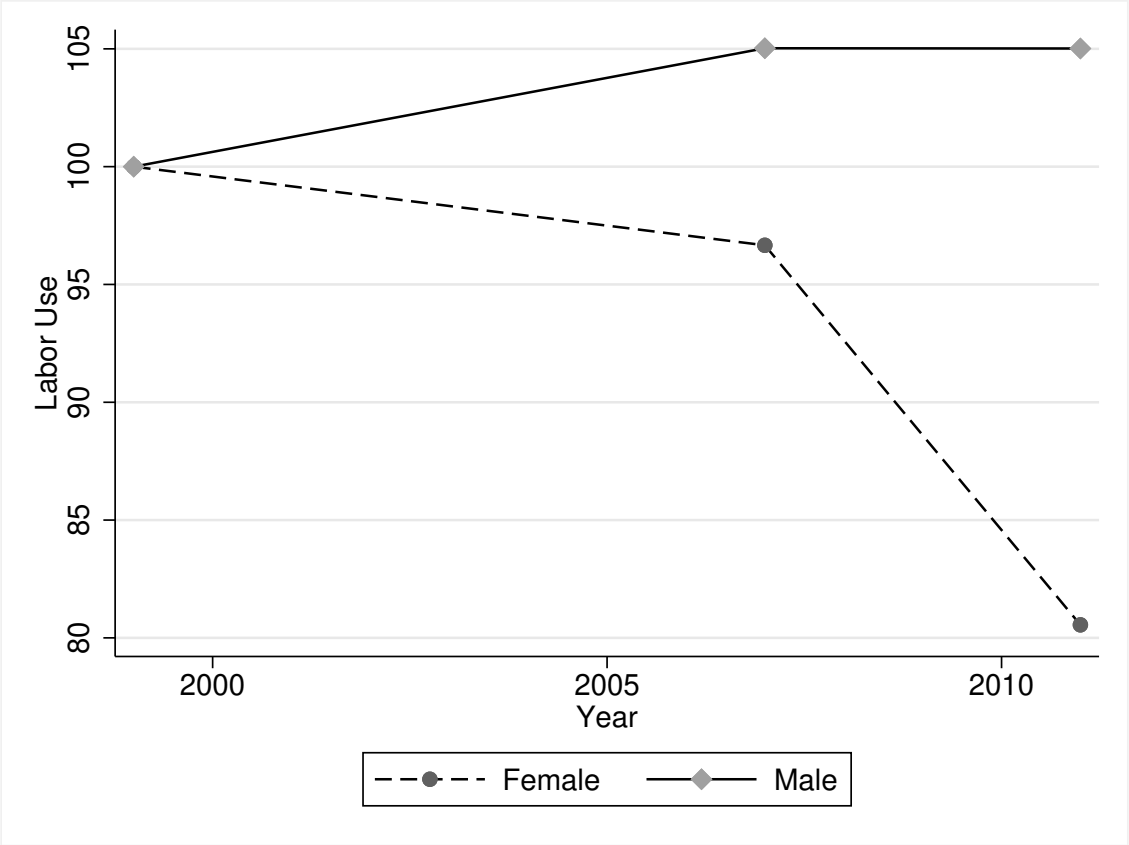
- Falling role of farm sector in employment over time in India (55% to 44% during 1999-2011)
  - Women in agri LF: 39% in 1999 and 27% in 2011
- Increasing agricultural mechanization in India
  - Tractor penetration in India: 1 million in 1990, doubled to 2 million in 2000 and tripled to 6 million in 2011
  - Subsidies on machinery and agri credit

Motivation

Trends in Labour Use in Agriculture

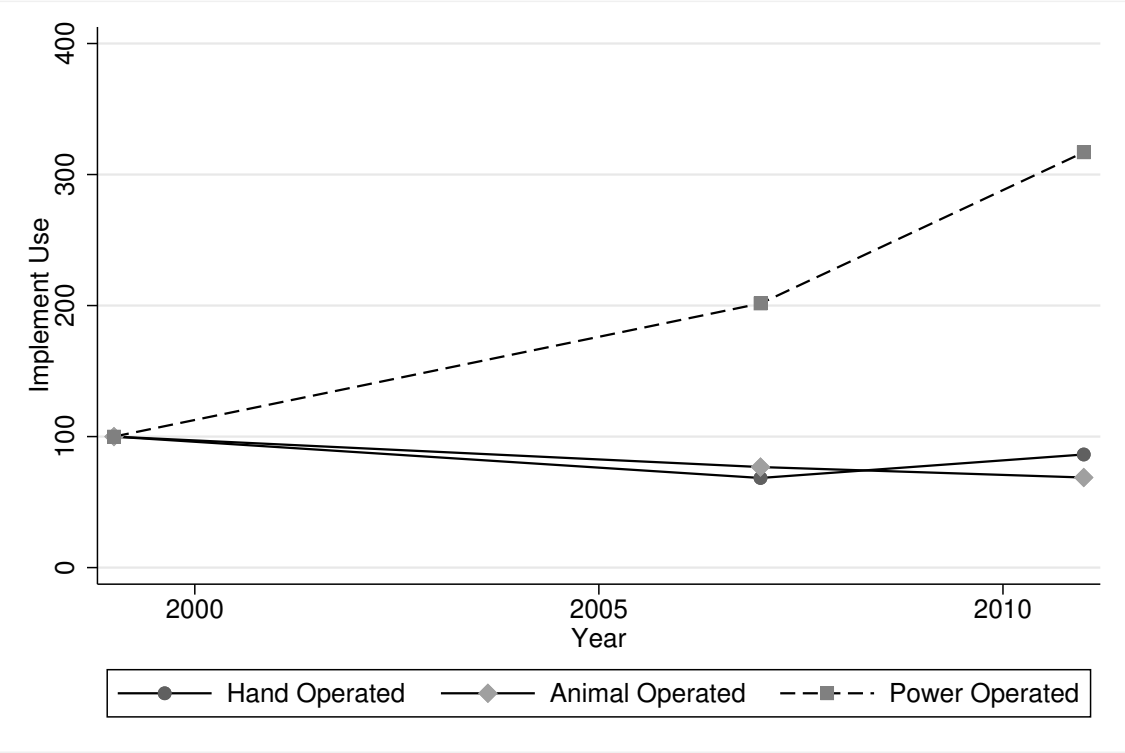


Agriculture Production Process

- Stages of agricultural operations:
  - Stage 1 - land preparation (primary and secondary tilling)
  - Stage 2 - sowing and intercultural operations like weeding
  - Stage 3 - harvesting and threshing
- Agricultural implements can be classified into:
  - Hand operated
  - Animal operated
  - **Power operated** (diesel, electric etc)
    - Tractor ot PT driven
    - Self-propelled

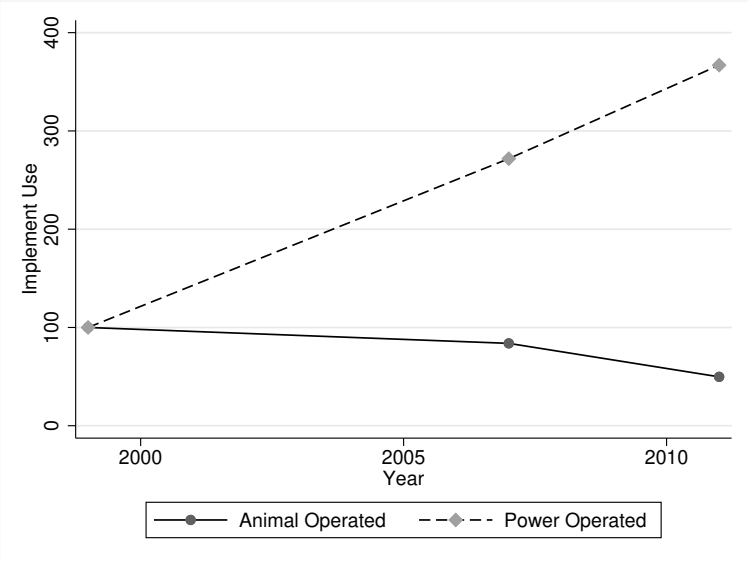
Motivation

Increasing Agriculture Mechanization

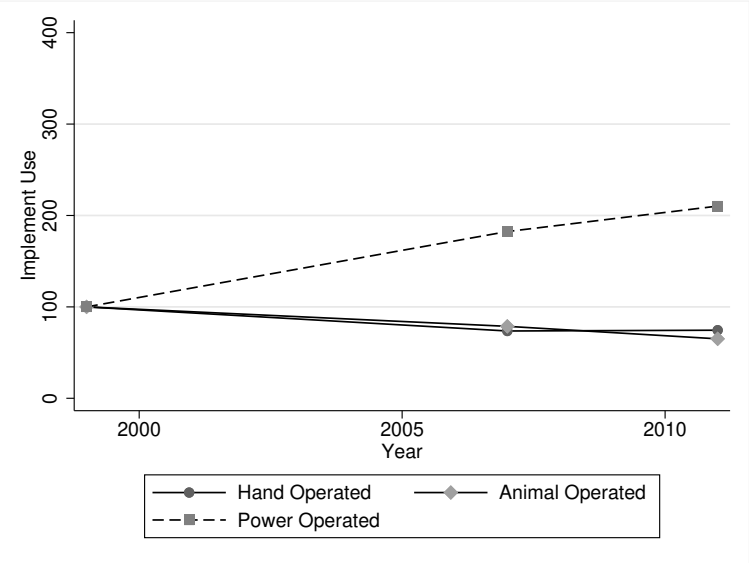


Machine Use in Indian Agriculture

By operation: Stage 1



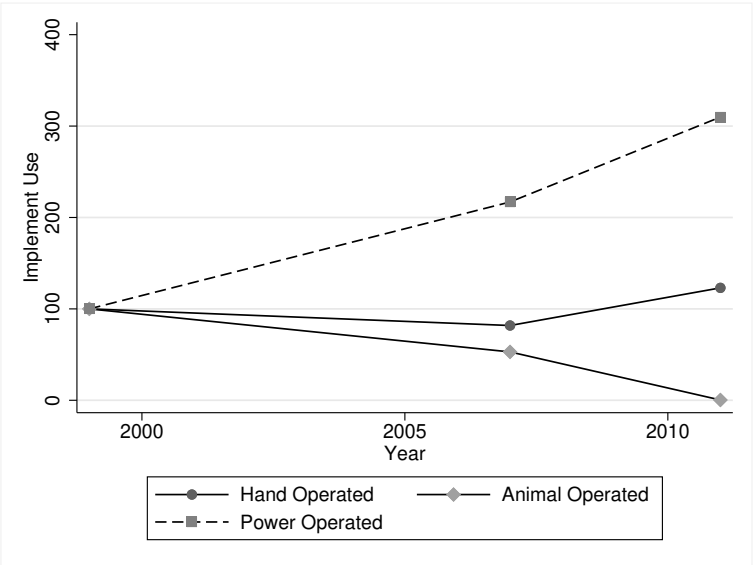
Stage 1: Primary Tilling



Stage 1: Secondary Tilling

Machine Use in Indian Agriculture

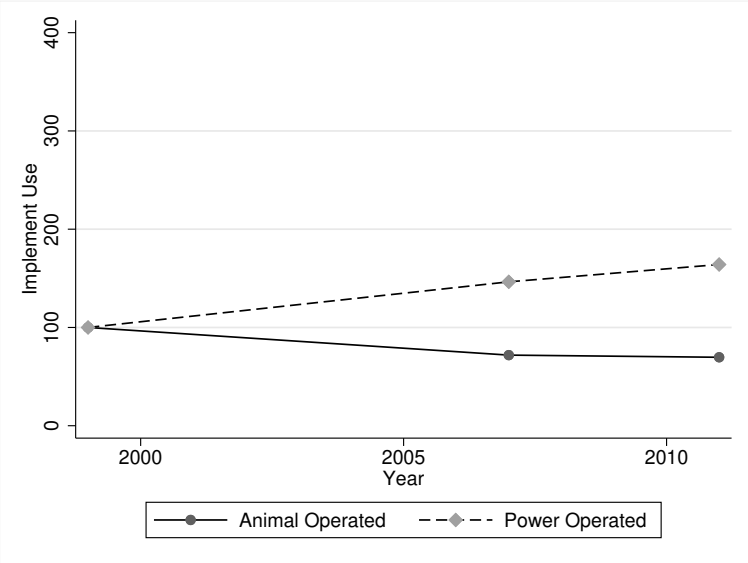
By operation: Stage 3



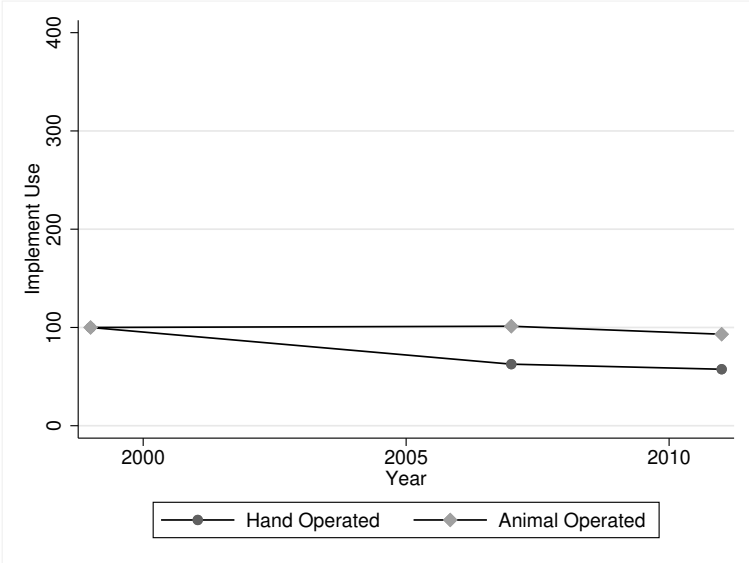
Stage 3: Harvesting

Machine Use in Indian Agriculture

By operation: Stage 2



Stage 2: Sowing



Stage 2: Weeding

What we do in this paper

- Examine the effect of mechanization in land-preparation stage on labor use
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- Examine the effect of mechanization in land-preparation stage on labor use
  - Specifically, gender differentiated impacts
- Use an instrumental variable strategy to deal with endogeneity in adoption of machines for land preparation
  - Link between soil texture and deep tillage requirements
- Findings:
  - Overall - significant reduction in women labor employed in cultivation per hectare, driven by weeding
  - Male labor employed also falls - but only family male - compensated by increase in hired labor use

Literature: Labor Impacts of Mechanization of Land Preparation

- Gender differentiated impacts have been ignored in the literature
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- Gender differentiated impacts: How?
  - Land preparation, Direct substitution: men involved relatively more but men are also more likely to be operators of these implements
  - Land preparation with machines, deeper tillage of better quality can reduce weed growth, lower weeding labor (more women here)

Table: Gender composition across tasks

Proportion of Females	Tilling	Sowing	Weeding	Harvesting
All Years	0.095	0.328	0.379	0.299

Data

- Compile district level data using a variety of sources
  - Soil characteristics: digitize soil maps of India to get information on soil texture, Ph, Depth, Slope
  - Mechanization: Agricultural Input Censuses (1997-99, 2006-07 and 2011-12)
  - Employment: National Sample Survey (1999, 2007, 2011)
  - Other agri controls: Crop composition, rainfall, temperature, irrigation, landholding size, urban population (land use, APY statistics, census of India)
  - Demographic controls, input controls, development controls (NSS, census of India, input census, fertilizer association of India, DMSP)

Soil (surface texture): District level variation

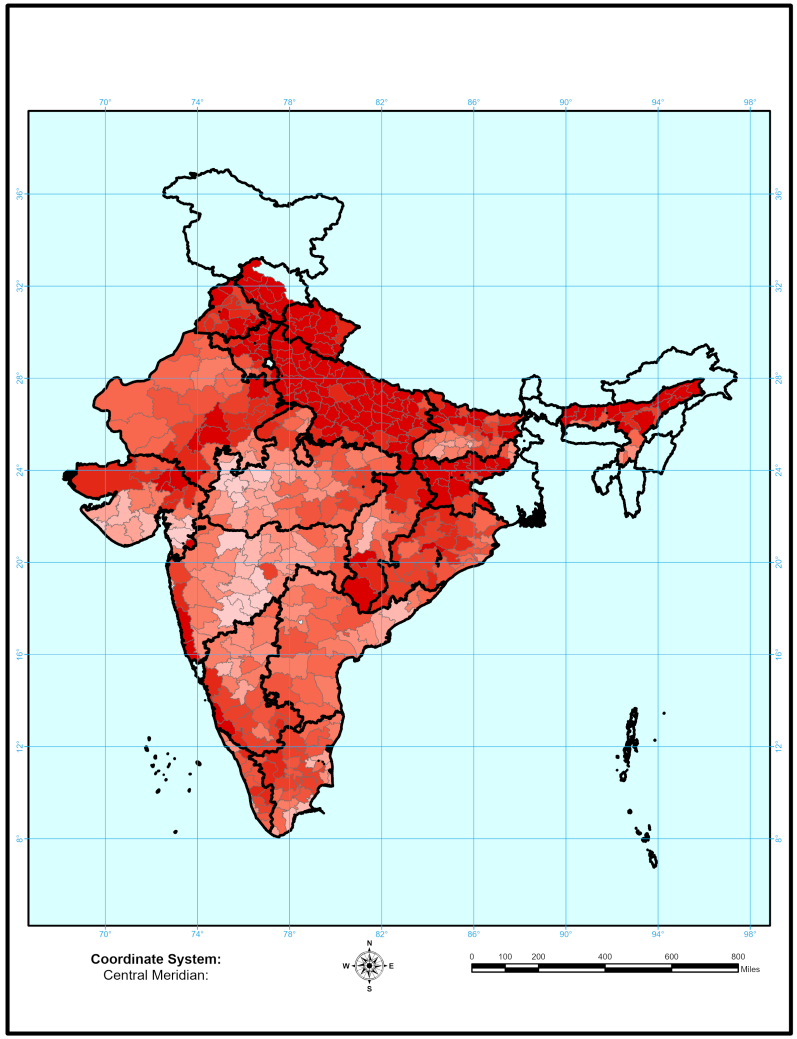

Figure: (%Loamy-%Clayey)

Source: Digitized by authors from National Bureau of Soil Survey (1995-98) Maps

Empirical Strategy: IV Estimation

$$L^F_{dst} = \beta_0 + \beta_1 MC_{dst} + X_{dst}\beta_2 + D_s + D_t + \epsilon_{dst}$$
$$L^M_{dst} = \beta_0 + \beta_1 MC_{dst} + X_{dst}\beta_2 + D_s + D_t + \epsilon_{dst}$$

- Here, d refers to district, in state s at time t and the superscript refers to male employment (M) and female employment (F).
- The dependent variable is Inverse Hyperbolic Sine Transformation of labor employment per unit of cultivated land (L).
- The variables MC captures mechanization in Stage 1: *Tillage & Sowing*.
- D_s are state fixed effects and D_t are time fixed effects.
- Since MC is likely to be endogenous, we instrument for it using the difference in loamy and clayey composition of the soil.
- X_{dst} are other district level controls

Data: Other Controls

- *Initial Employment*: Labor use by gender in 1993
- *Agriculture*: Crop composition, rainfall, temperature, % urban, average land size, %Irrigated area
- *Lagged Input*: Fertilizer
- *Development*: Approach road and nightlights

Empirical Strategy: IV Estimation (First Stage)

$$MC_{dst} = \pi_0 + \pi_1(Loamy - Clayey)_{ds} + X_{dst}\pi_2 + D_s + D_t + \epsilon_{dst}$$

Here, *Soil Texture* is defined as the difference in the proportion of loamy and clayey soils in district d, in state s. Since this is an initially given endowment, it does not vary over time.

Instrumental Variable: Mechanization in Stage 1

- Extent of machine uptake in tilling: depth of required tillage
  - Primary or Deep tilling (at least 45 cm of soil turned over): most power intensive
  - Followed by secondary tillage or sowing
- Primary tilling: more amenable in loamy than clayey content of soil (Muller and Schindler (1999); Wildman (1981); Basant (1987))
- Higher loamy soil content, more likely to use deep tilling/ploughing implements
- Once tractors adopted for primary tillage, shallow tilling can be mechanized too (tractor driven implements)

IV: Exogeneity

- Soil texture may have direct effects on employment, especially by women
  - soil texture affects soil fertility - concern alleviated in results for yields/wages/expenditure above
  - historically women are more disadvantaged in areas requiring more primary tilling (Carranza 2014) - check for rice/wheat ratio (Alesina, Giuliano and Nunn 2013) and also control for it; check for labor use in 1993 and also control for it
  - norms around women's labor - check for it but still control labor use in 1993

Agricultural Yields, Wages, Labor Use, Cropping Patterns and Loaminess: Pre-mechanization period

(1)	(2) Loaminess	(3) Observations	(4) R-Squared
Panel A: Labor use			
Female labor per hectare	-.084 (.11)	385	.62
Male labor per hectare	.014 (.088)	385	.77
Panel B: Wage rate and income			
Wage Rate - Female	-.012 (.043)	342	.63
Wage Rate - Male	-.042 (.031)	371	.72
MPCE	.018 (.027)	385	.66
Panel C: Cropping pattern and yields			
Ratio of cropped area: Wheat by Rice	219 (142)	370	.35
Wheat Yield	.025 (.071)	332	.72
Rice Yield	-.062 (.062)	366	.77

Effect of Soil Texture on Tilling Mechanization: First Stage

	(1)	(2)	(3)
	Primary Tilling	Secondary Tilling	Mechanization Tilling
Loaminess	6.337***	5.540***	11.878***
	(1.903)	(1.760)	(3.335)
Constant	29.864	–34.959	–5.095
	(48.337)	(42.922)	(84.507)
Observations	1077	1077	1077
FS F Stat	11.09	9.90	12.68

Note: All specification have State and Year Fixed Effects and Initial Values of employment; Controls for agriculture, demographic, agricultural inputs and development. Robust standard errors clustered at the district level in parentheses

The measure of mechanization: power operated implements adoption in Primary tillage and Secondary tillage

Effect of Mechanization on Farm Labor Use: IV Estimates

	(1)	(2)	(3)	(4)	(5)
	Panel A: Female labor per hectare				
Mechanization	–0.034	–0.040*	–0.030**	–0.028**	–0.024**
	(0.024)	(0.024)	(0.014)	(0.014)	(0.011)
Constant	5.098	5.998*	4.444	6.022*	7.420**
	(3.273)	(3.547)	(3.427)	(3.452)	(3.084)
Observations	1077	1077	1077	1077	1077
FS F Stat	3.62	4.55	9.73	9.47	12.68
	Panel B: Male labor per hectare				
Mechanization	0.018	0.006	0.001	0.000	0.001
	(0.013)	(0.008)	(0.004)	(0.004)	(0.003)
Constant	3.819**	5.591***	5.480***	5.558***	5.529***
	(1.677)	(1.130)	(1.260)	(1.263)	(1.137)
Observations	1077	1077	1077	1077	1077
FS F Stat	3.46	4.20	9.49	9.26	12.49
Test of Equality [*p-value*]					
Female=Male	0.100	0.075	0.034	0.043	0.036
Controls					
Agriculture-Demographic	✓	✓	✓	✓	✓
Land-size		✓	✓	✓	✓
Crop composition			✓	✓	✓
Development				✓	✓
Fertilizer input					✓

Effect of Mechanization on Female Farm Labor Use: By operation

	(1)	(2)	(3)	(4)	(5)
	Tilling	Sowing	Weeding	Harvesting	Total
Panel A: Female labor per hectare					
Mechanization	0.004	–0.007	–0.056**	–0.004	–0.021
	(0.011)	(0.015)	(0.024)	(0.016)	(0.015)
Constant	4.874	–0.438	1.524	10.040**	14.583***
	(3.105)	(3.722)	(7.063)	(4.913)	(3.479)
Observations	1077	1077	1077	1077	1077
Test of Equality [*p-value*] Col(3)=Col(1)/(2)/(4)	0.021	0.047	–	0.029	–
Agriculture-Demographic	✓	✓	✓	✓	✓
Land-size	✓	✓	✓	✓	✓
Crop composition	✓	✓	✓	✓	✓
Development	✓	✓	✓	✓	✓
Fertilizer	✓	✓	✓	✓	✓

Effect of Mechanization on Male Farm Labor Use: By operation

	(1)	(2)	(3)	(4)	(5)
	Tilling	Sowing	Weeding	Harvesting	Total
	Panel B: Male labor per hectare				
Mechanization	–0.002	0.029*	–0.019	–0.004	0.005
	(0.017)	(0.017)	(0.021)	(0.012)	(0.006)
Constant	8.233*	3.365	3.089	6.824*	6.9698***
	(4.719)	(4.799)	(5.239)	(3.861)	(2.812)
Observations	1077	1077	1077	1077	1077
Test of Equality [*p-value*] Col(3)=Col(1)/(2)/(4)	0.434	0.099	–	0.538	–
Agriculture-Demographic	✓	✓	✓	✓	✓
Land-size	✓	✓	✓	✓	✓
Crop composition	✓	✓	✓	✓	✓
Development	✓	✓	✓	✓	✓
Fertilizer	✓	✓	✓	✓	✓

Ruling out other channels

- Rise in incomes
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- Structural transformation
  - No change in non-farm employment for men or women
- Instrument does not effect take up of harvesters

Conclusion

- Increased mechanization in tilling leads to reduction in women's labor use in agriculture: we find that a one percentage point increase in mechanization decreases female labor use per hectare by 2.4%
- Technological change can reduce labor use, but that it can have a differential impact by gender when men and women are imperfect substitutes
- Lack of alternative job opportunities for women - skills and mobility