# Misallocation in Indian Agriculture

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# Introduction

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- Agriculture important for income differences between rich and poor countries (Gollin et al. 2002, Restuccia et al. 2008)
- Agriculture in poor countries feature
  - low relative labor productivity
  - high share of employment
  - **lower allocative efficiency** across productive units
- Sources of this misallocation are less well understood

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This Paper:

- Frictions in the rental market for land as a source of misallocation
- Study this question in the context of Indian agriculture Why India?
- Comparison of states within India allows focus on land institutions while keeping national institutions constant

## What we do and find

1. Land market institutions and misallocation
2. Model of heterogeneous farms
3. Distortions have substantial negative impact on agricultural TFP

# What we do and find

1. Land market institutions and misallocation
   - **Within states:** rentals facilitate better resource allocation
   - **Across states:** rentals associated with less misallocation
   - **Over time:** rentals associated with efficient land reallocations
2. Model of heterogeneous farms
3. Distortions have substantial negative impact on agricultural TFP

# What we do and find

1. Land market institutions and misallocation

2. Model of heterogeneous farms
   - Endogenous rental market activity in both intensive and extensive margins
   - State-level and Idiosyncratic farm-level distortions to access rental markets
   - Estimate distortions using micro data on farms and their rental activity

3. Distortions have substantial negative impact on agricultural TFP

# What we do and find

1. Land market institutions and misallocation

2. Model of heterogeneous farms

3. Distortions have substantial negative impact on agricultural TFP
    - Eliminating distortions increases productivity by 38% on average, more than 50% in states with highly distorted land markets
    - State level distortions contribute to 2/3 of re-allocation gains

# Institutional context

Substantial variation in agricultural activity across states Details

- Tenancy reforms Variation
- Poorly defined property rights Variation

$\Longrightarrow$ variation in ability and willingness to lease land Land Rentals
$\Longrightarrow$ variation in farm operational scales across states Farm Scales

# Institutional context

Substantial variation in agricultural activity across states Details

- Tenancy reforms Variation
  - Legislation and implementation differed substantially by state
  - Number: 0 (Rajasthan, Haryana) to 9 (West Bengal)
  - Stringency: Minimum lease, Right to aquire ownership, Prohibition
  - (Potentially) due to differences in colonial land administrative systems
- Poorly defined property rights Variation

$\Longrightarrow$ variation in ability and willingness to lease land Land Rentals
$\Longrightarrow$ variation in farm operational scales across states Farm Scales

# Institutional context

Substantial variation in agricultural activity across states Details

- Tenancy reforms Variation
- Poorly defined property rights Variation
  - Quality of land records and titles vary across regions
  - Due to differences in colonial land administrative systems
  - Deeds registration v/s title registration

$\Longrightarrow$ variation in ability and willingness to lease land Land Rentals

$\Longrightarrow$ variation in farm operational scales across states Farm Scales

# Institutional context

Substantial variation in agricultural activity across states Details

- Tenancy reforms Variation
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# Literature

- Economic institutions in India
  - Agriculture: Besley and Burgess (2000); Banerjee et al. (2002); Banerjee and Iyer (2005); Besley et al. (2016)
  - Non-agriculture, inter-sectoral: Besley and Burgess (2004); Lahiri and Yi (2009); Boehm and Oberfield (2020)
- Resource allocation and aggregate productivity
  - Heterogeneous production units: Restuccia and Rogerson (2008); Hsieh and Klenow (2009)
  - Extensive/intensive margins: Distortions in occupational choice, Guner et al. (2008); Buera et al. (2011); Midrigan and Xu (2014)
- Land markets and agricultural productivity
  - Resource misallocation: Adamopoulos and Restuccia (2014); Chen (2017)
  - Rental markets: Holden et al. (2011); Chen et al. (2017); Chari et al. (2017); Beg (2019)

# Rentals & Productivity

# Data

- India Human Development Survey (IHDS) Data Cleaning
  - HH-level panel data: 2004-2005 and 2011-2012
  - Focus on farm HHs that cultivate a positive amount of land
  - Keep states with more than 20 mill population: 15 states, 8642 HHs
  - 97% of India's population and 92% of value added in agriculture

- Detailed information on farm outputs and inputs
  - **outputs**: quantity units and farm-specific prices
  - **labor**: family and hired labor in agriculture, in days and hours
  - **capital**: large machinery, small tools, draft animals, rented capital
  - **intermediate inputs**: expenditure on seeds, fertilizers, etc.
  - **land**: cultivated, owned, rented in and rented out

# Measuring farm-level TFP

- Measure farm-level TFP $z_{it}$ as residual from production function
- Farm-level production function, farm $i$ in state $s$ at date $t$:

$$y_{ist} = z_{it}[(k_{ist}^{\alpha} l_{ist}^{\beta} n_{ist}^{1-\alpha-\beta})^{1-\theta} m_{ist}^{\theta}]^{\gamma}$$

  where $y_{ist}$ is gross output, $k_{ist}$ capital, $l_{ist}$ operated land, $n_{ist}$ labor hours, $m_{ist}$ intermediate inputs

- Cost shares: $\alpha = 0.09$, $\beta = 0.36$, $\theta = 0.35$, and $\gamma = 0.54$

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- Cost shares: $\alpha = 0.09$, $\beta = 0.36$, $\theta = 0.35$, and $\gamma = 0.54$
- Permanent $\text{TFP}_i$ estimated after controlling for district and time FEs:

$$\ln z_{ist} = \ln z_t + \ln z_i + \nu_{ist}$$
$$\ln z_i = \ln z_d + \ln \text{TFP}_i$$

- 3 facts linking rental markets and productivity that motivate our model

# Within States: Farms renting in are more productive

| | Dependent variable is whether a farm rents in land or not | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| | Probit | Probit | Probit | Probit | Probit |
| TFP (log) | 0.188*** | 0.199*** | 0.294*** | 0.305*** | 0.295*** |
| | (0.0355) | (0.0394) | (0.0512) | (0.0528) | (0.0556) |
| Own land (log) | | | -0.181*** | -0.170*** | -0.168*** |
| | | | (0.0396) | (0.0405) | (0.0394) |
| State FE | N | Y | Y | Y | Y |
| Demographic controls | N | N | N | Y | Y |
| Land quality controls | N | N | N | N | Y |
| Observations | 8359 | 8359 | 8359 | 8359 | 8359 |
| $R^2$ | 0.0192 | 0.1019 | 0.1148 | 0.1213 | 0.1220 |

- Rentals facilitate a more efficient allocation of land
- Farms renting out are less productive, endowed with more land Details

## Across States: Active rental markets feature lower misallocation

Measure **misallocation** as the dispersion in marginal product of land

| | Dependent variable is absolute deviation of (log) marginal product of land from state mean | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| | OLS | OLS | OLS | OLS | OLS |
| Share hh renting | -1.439*** | -1.439*** | -1.441*** | -1.216*** | -1.092*** |
| | (0.362) | (0.362) | (0.360) | (0.351) | (0.324) |
| TFP (log) | | -0.0155* | -0.0165* | -0.0103 | -0.0134 |
| | | (0.00800) | (0.00900) | (0.00819) | (0.00822) |
| Demographic controls | N | N | Y | Y | Y |
| Land quality controls | N | N | N | Y | Y |
| State-level controls | N | N | N | N | Y |
| Observations | 8617 | 8617 | 8617 | 8617 | 8617 |
| $R^2$ | 0.028 | 0.029 | 0.029 | 0.038 | 0.051 |

# Over Time: Active rental markets feature more efficient reallocation

Measure **reallocation potential** as ratio between efficient and actual land size in farm $i$ state $s$

| Dependent variable is change in (log) cultivated land between waves I and II | (1) OLS | (2) OLS | (3) OLS | (4) OLS | (5) OLS |
|---|---|---|---|---|---|
| Reallocation potential wave I | 0.272*** | 0.231*** | 0.175*** | 0.177*** | 0.161*** |
| | (0.0272) | (0.0498) | (0.0323) | (0.0327) | (0.0344) |
| Reallocation potential wave I x Share hh renting | | 0.473 | 1.042*** | 1.039*** | 1.079*** |
| | | (0.389) | (0.255) | (0.249) | (0.246) |
| State FE | N | N | Y | Y | Y |
| Demographic controls | N | N | N | Y | Y |
| Land quality controls | N | N | N | N | Y |
| Observations | 8617 | 8617 | 8617 | 8617 | 8617 |
| $R^2$ | 0.151 | 0.152 | 0.217 | 0.220 | 0.228 |

# Model & Estimation

# Model

- State $s$ with $L_s$ land endowment and $F_s$ number of farm HH
- Farm HH $i$ with productivity $z_{is}$ and $\bar{l}_{is}$ land endowment
- All farms produce a homogeneous output
- Land cannot be sold, land reallocation occurs through rentals
- Farms choose amount of land to rent in $l_{is}^{in}$ and rent out $l_{is}^{out}$
- Farms face idiosyncratic rental costs, we model these costs as taxes on state-level rental market prices $q_s$

$$
\begin{aligned}
q_{is}^{in} &= q_s(1+\tau_{is}^{in}) \\
q_{is}^{out} &= q_s(1+\tau_{is}^{out})
\end{aligned}
$$

# Decentralized allocation

$$\max_{\{l_{is}, l_{is}^{out}, l_{is}^{in}\} \geq 0} \pi_{is} = z_{is} l_{is}^{\gamma} - q_s [(1 + \tau_{is}^{in}) l_{is}^{in} + (1 + \tau_{is}^{out})(\bar{l}_{is} - l_{is}^{out})$$

$$\text{s.t.} \quad l_{is} = \bar{l}_{is} + l_{is}^{in} - l_{is}^{out}$$

❶ $q_s(1 + \tau_{is}^{in}) \geq MPL_{is} = q_s(1 + \tau_{is}^{out})$ if $l_{is}^{in} = 0$ and $l_{is}^{out} > 0$

❷ $q_s(1 + \tau_{is}^{in}) = MPL_{is} \geq q_s(1 + \tau_{is}^{out})$ if $l_{is}^{in} > 0$ and $l_{is}^{out} = 0$

❸ $q_s(1 + \tau_{is}^{in}) \geq MPL_{is} \geq q_s(1 + \tau_{is}^{out})$ if $l_{is}^{in} = 0$ and $l_{is}^{out} = 0$

Equilibrium Comparison with standard model

# Estimating land-market distortions

Impose the following restrictions on distortions:

$$(1+\tau_{is}^{in}) = (1+\tau_{is}^{l})$$
$$(1+\tau_{is}^{out}) = (1+\tau_{is}^{l})(1+\tau_s)^{-1}$$
$$\ln(1+\tau_{is}^{l}) = \kappa_s + \theta_s \ln z_{is} + \epsilon_{is}, \quad \epsilon_{is} \sim \text{i.i.d. } N(0, \sigma_{\epsilon,s}^2)$$

- $(1+\tau_{is}^{l})$ farm-specific wedge, corr with TFP (Restuccia and Rogerson, 2017)
- $(1+\tau_s)$ state-specific distortion,

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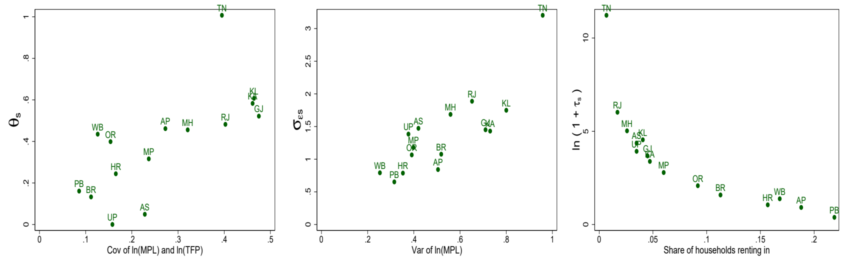
- $(1+\tau_{is}^{l})$ farm-specific wedge, corr with TFP (Restuccia and Rogerson, 2017)
- $(1+\tau_s)$ state-specific distortion,

Calibration by matching to corresponding moments in data:

1. Normalize $\kappa_s = 0$, cannot separate from $\tau_s$
2. $cov(\ln MPL_{is}, \ln z_{is}) \rightarrow \theta_s$
3. $var(\ln MPL_{is}) \rightarrow \sigma_{\epsilon,s}^2$
4. Share households renting in $\rightarrow \tau_s$

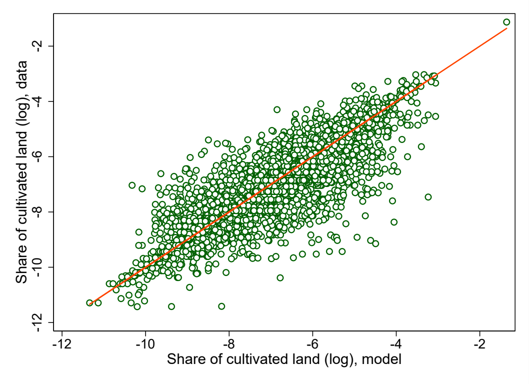
Solving the Model Parameter Estimation

# Identification of land-market distortions




- Moments informative about distortion parameters Details

# Model fit—land allocations




- Cultivated land in farms relative to total cultivated land in each state
- Unweighted average of 100 simulations
- The red line represents the 45 degree line
- Good fit despite parsimonious parameterization: Details

# Experiments

# Quantitative Experiments

Quantify aggregate consequences of land market distortions

1. Efficient: Eliminate all land-market distortions
   - $\theta_s = \sigma^2_{\epsilon,s} = \tau_s = 0$
2. No Idiosyncratic: Eliminate individual distortions keeping average distortions
   - $\theta_s = \sigma^2_{\epsilon,s} = 0$ and $\kappa_s = \bar{\tau}^l_{is}$
3. Residual: Difference between 1 and 2
   - Contribution of state-level wedge $\tau_s$

Counterfactual Agricultural TFP relative to Baseline Model

# Agricultural productivity gains relative to Baseline

| | Efficient | No idiosyncratic | Residual |
|---|---|---|---|
| India: | 1.38 | 1.15 | 1.20 |
| State: | | | |
| Andhra Pradesh (AP) | 1.50 | 1.27 | 1.18 |
| Assam (AS) | 1.51 | 1.06 | 1.43 |
| Bihar (BR) | 1.31 | 1.23 | 1.06 |
| Gujarat (GJ) | 1.49 | 1.18 | 1.26 |
| Haryana (HR) | 1.32 | 1.15 | 1.14 |
| Karnataka (KA) | 1.48 | 1.21 | 1.22 |
| Kerala (KL) | 1.63 | 1.15 | 1.42 |
| Maharashtra (MH) | 1.46 | 1.16 | 1.26 |
| Madhya Pradesh (MP) | 1.37 | 1.12 | 1.23 |
| Orissa (OR) | 1.26 | 1.16 | 1.09 |
| Punjab (PB) | 1.21 | 1.18 | 1.02 |
| Rajasthan (RJ) | 1.40 | 1.13 | 1.24 |
| Tamil Nadu (TN) | 1.67 | 1.22 | 1.43 |
| Uttar Pradesh (UP) | 1.28 | 1.10 | 1.24 |
| West Bengal (WB) | 1.26 | 1.12 | 1.37 |

- TFP increases by 38% in efficient allocation
  - Gains are largest in states with least active rental markets Details
  - Potentially more gains if we allowed reallocation of labor out of agriculture and endogeneous productivity investments
- Idiosyncratic distortion contribute to one third of productivity gains
- State-specific land distortions contribute to remaining two third

# Channels of Productivity Gains

| Change in share of: | farms renting | land operated by 10% most productive farms |
|---|---|---|
| India: | 0.22 | 0.34 |
| State: | | |
| Andhra Pradesh (AP) | 0.07 | 0.37 |
| Assam (AS) | 0.28 | 0.37 |
| Bihar (BR) | 0.34 | 0.18 |
| Gujarat (GJ) | 0.18 | 0.27 |
| Haryana (HR) | 0.15 | 0.21 |
| Karnataka (KA) | 0.13 | 0.48 |
| Kerala (KL) | 0.25 | 0.47 |
| Maharashtra (MH) | 0.20 | 0.44 |
| Madhya Pradesh (MP) | 0.21 | 0.28 |
| Orissa (OR) | 0.25 | 0.31 |
| Punjab (PB) | 0.14 | 0.10 |
| Rajasthan (RJ) | 0.21 | 0.44 |
| Tamil Nadu (TN) | 0.43 | 0.54 |
| Uttar Pradesh (UP) | 0.32 | 0.23 |
| West Bengal (WB) | 0.18 | 0.23 |

1. Extensive Margin: Share of farms renting triples (from 10%)
2. Intensive Margin: Share of land operated by the best farms doubles (from 30%)

# Conclusions

# Conclusions

What we do:

- Examine the large productivity differences across Indian states
- Establish barriers to renting land can be a source of land misallocation
- Counterfactuals suggest huge potential for TFP gains from removing distortions

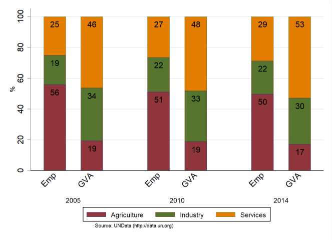
Food for thought:

- Substantial differences in agricultural TFP across states that remain unexplained
  - Absorbed by the district-level FEs when measuring farm TFP
  - Interesting to explore other differences across regions
- Land distortions can interact with other farmer behaviour
  - Barriers to adopt modern technology (seed varieties, mechanization etc.)
  - Selection into and out of agriculture

# Appendix

# Why India?

1. India is unproductive in agriculture




- RVA per worker only 5 % of that in the US, whereas 32% in in non-agri in 2010

2. Detailed micro data, representative at state level

3. Most agricultural land is inherited (95% of Farm HHs), very few HHs bought land (3%)

4. Substantial variation in agricultural activity and outcomes across states in India, resembling cross-country variations Details

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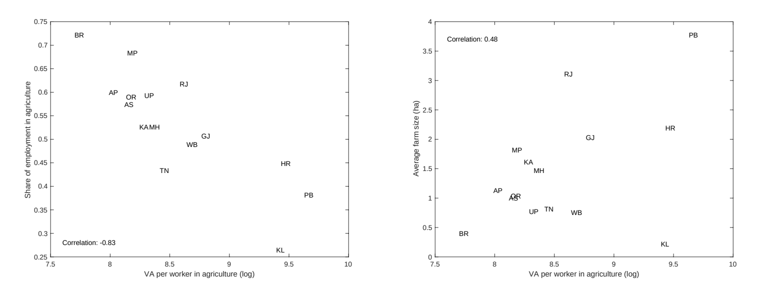
# Agriculture Outcomes across Indian states

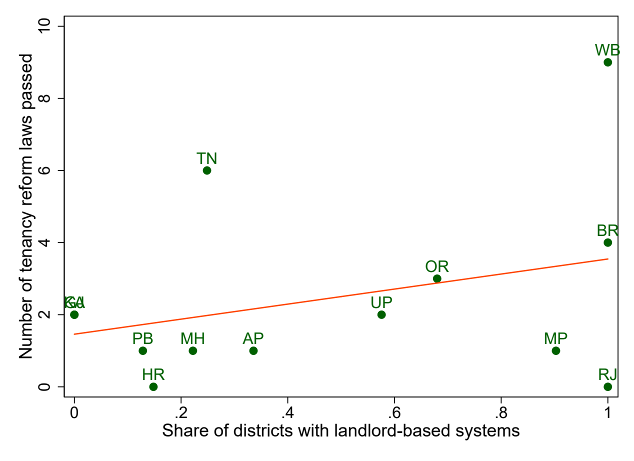



Substantial differences across states in terms of:

- Agricultural productivity
- Employment shares in agriculture
- Farm operational scales

Back to Why India   Back to Institutional Context

# Institutional context: British land administration and Tenancy

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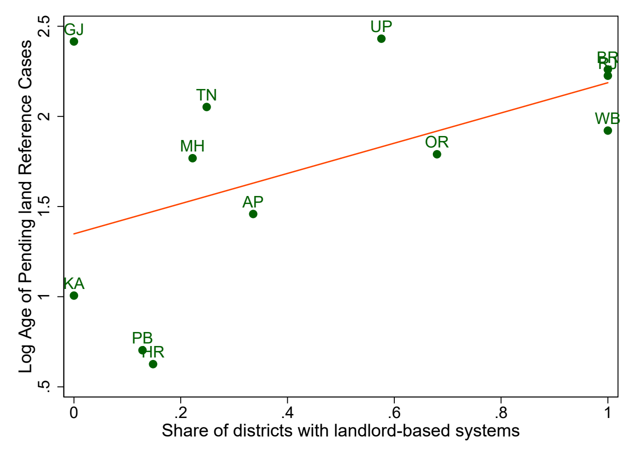
# Institutional context: British land administration and Court Quality

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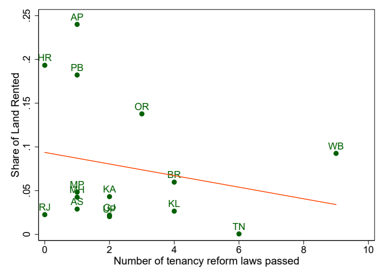
# Institutional context: Share of Land Rented





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# Farm Scales and Distribution

| | Land Operational Scale of Farms | | | | | |
|---|---|---|---|---|---|---|
| | Ag. Census (2010-11) | | | IHDS-II (2011-12) | | |
| | Average Farm Size | % of Farms $\leq$ 2 Ha | % of Farms $\geq$ 20 | Average Farm Size | % of Farms $\leq$ 2 Ha | % of Farms $\geq$ 20 |
| India | 1.15 | 85 | 0.1 | 2.12 | 71 | 1.0 |
| State: | | | | | | |
| Andhra Pradesh (AP) | 1.08 | 86 | 0.03 | 2.41 | 60 | 0.7 |
| Assam (AS) | 1.10 | 86 | 0.1 | 1.15 | 88 | 0.0 |
| Bihar (BR) | 0.39 | 97 | 0.003 | 1.63 | 81 | 0.5 |
| Gujarat (GJ) | 2.03 | 66 | 0.1 | 3.64 | 50 | 1.4 |
| Haryana (HR) | 2.25 | 68 | 0.5 | 3.50 | 47 | 1.4 |
| Karnataka (KA) | 1.55 | 76 | 0.1 | 2.40 | 64 | 1.0 |
| Kerala (KL) | 0.22 | 99 | 0.01 | 1.61 | 75 | 0.0 |
| Madhya Pradesh (MP) | 1.78 | 71 | 0.1 | 3.68 | 50 | 1.7 |
| Maharashtra (MH) | 1.44 | 79 | 0.1 | 2.88 | 55 | 0.9 |
| Orissa (OR) | 1.04 | 92 | 0.03 | 1.16 | 85 | 0.0 |
| Punjab (PB) | 3.77 | 34 | 1.0 | 5.67 | 36 | 3.4 |
| Rajasthan (RJ) | 3.07 | 58 | 1.3 | 1.71 | 76 | 0.2 |
| Tamil Nadu (TN) | 0.80 | 92 | 0.04 | 2.84 | 82 | 1.9 |
| Uttar Pradesh (UP) | 0.76 | 92 | 0.01 | 1.57 | 77 | 0.2 |
| West Bengal (WB) | 0.77 | 96 | 0.01 | 1.03 | 89 | 0.0 |

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# Data Cleaning

- From 13,971 farm households in IHDS-I, 17% leave farming, 4% split up, 7% lost to recontact = 10,077 in both waves
- Trimming: Drop 2% of households with largest absolute changes in output-land ratios
- Keeping states with more than 20 mill population, final sample comprises 8,642 farm households in 15 states
- Andhra Pradesh (AP), Assam (AS), Bihar (BR), Gujarat (GJ), Haryana (HR), Karnataka (KA), Kerala (KL), Madhya Pradesh (MP), Maharashtra (MH), Orissa (OR), Punjab (PB), Rajasthan (RJ), Tamil Nadu (TN), Uttar Pradesh (UP), and West Bengal (WB)
- These states account for 97% of India's population and 92% of value added in agriculture
- Final sample represents well full sample on the distribution of cultivated land

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# Fact I: Within States farms renting out are less productive

| | Dependent variable is whether a farm rents out land or not | | | | |
|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) |
| | Probit | Probit | Probit | Probit | Probit |
| TFP (log) | 0.0590** | 0.0633** | -0.150*** | -0.159*** | -0.189*** |
| | (0.0272) | (0.0261) | (0.0416) | (0.0374) | (0.0361) |
| Own land (log) | | | 0.415*** | 0.411*** | 0.428*** |
| | | | (0.0570) | (0.0584) | (0.0614) |
| State FE | N | Y | Y | Y | Y |
| Demographic controls | N | N | N | Y | Y |
| Land quality controls | N | N | N | N | Y |
| Observations | 8359 | 8359 | 8359 | 8359 | 8359 |
| $R^2$ | 0.0019 | 0.0457 | 0.1065 | 0.1196 | 0.1262 |

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# Efficient allocation

## Social Planner's Problem

$$\max_{\{k_{is}, l_{is}, n_{is}, m_{is} \geq 0\}_{i=1}^{F_s}} \sum_{i=1}^{F_s} z_{is} [(k_{is}^{\alpha} l_{is}^{\beta} n_{is}^{1-\alpha-\beta})^{1-\theta} m_{is}^{\theta}]^{\gamma},$$

$$\text{s.t.} \quad \sum_{i=1}^{F_s} x_{is} = X_s, \quad \text{for} \quad X \in \{K, L, N, M\}$$

## Efficient Allocation

$$x_{is}^{e} = \frac{s_{is}}{\sum_{i=1}^{F_s} s_{is}} X_s, \quad \text{where} \quad s_{is} \equiv z_{is}^{1/(1-\gamma)}$$

## Aggregate Output

$$Y_s^e = A_s^e (F_s)^{1-\gamma} [(K_s^{\alpha} L_s^{\beta} N_s^{1-\alpha-\beta})^{1-\theta} M_s^{\theta}]^{\gamma}, \quad \text{where} \quad A_s^e = \left[ \frac{1}{F_s} \sum_{i=1}^{F_s} s_{is} \right]^{1-\gamma}.$$

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# Equilibrium

For each state and given aggregate resources, a *competitive equilibrium* is a set of prices/wedges $\{q_s, \tau_{is}^{in}, \tau_{is}^{out}\}$ and allocations $\{l_{is}, l_{is}^{in}, l_{is}^{out}\}$ such that:

$(i)$ Given prices, farmers' allocations maximize profits

$(ii)$ Land market clears

$$\sum_i l_{is} = \sum_i \bar{l}_{is} = L_s$$

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# Comparison with standard model

- Standard model (e.g. Adamopoulos et al., 2017), farms face specific wedge:

$$q_{is} = q_s(1 + \tau_{is})$$

- In our model, this price is the weighted average of renting in/out:

$$q_{is} = q_{is}^{out} \frac{\bar{l}_{is} - l_{is}^{out}}{l_{is}} + q_{is}^{in} \frac{l_{is}^{in}}{l_{is}}$$

- The distortion in the standard model is a weighted average as well:

$$(1 + \tau_{is}) = (1 + \tau_{is}^{out}) \frac{\bar{l}_{is} - l_{is}^{out}}{l_{is}} + (1 + \tau_{is}^{in}) \frac{l_{is}^{in}}{l_{is}}$$

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# Solving for decentralized equilibrium

Given each state distortions $\theta_s$, $\tau_s$, and $\sigma_{\epsilon,s}$, perform the following steps:

1. For each farmer, draw $\epsilon_{is} \sim N(0, \sigma^2_{\epsilon,s})$.
2. Compute $MPL_{l_{it}=\bar{l}_{is}} = \gamma z_{is}(\bar{l}_{is})^{\gamma-1}$.
3. Guess land price $q_s$ (the initial guess could be the land price associated with the efficient allocation of resources) and compute:
   - $q^{in}_{is} = \ln q_s + \theta \ln z_{is} + \epsilon_{is}$,
   - $q^{out}_{is} = \ln q_s + \theta \ln z_{is} - \ln(1+\tau_s) + \epsilon_{is}$.
4. Partition farmers into three sets and compute demand for land $l^D_{is}$ for each farmer:
   - $l^D_{is} = (\frac{\gamma z_{is}}{q^{in}_{is}})^{\frac{1}{1-\gamma}}$ if $\ln MPL_{l_{it}=\bar{l}_{is}} > q^{in}_{is}$,
   - $l^D_{is} = (\frac{\gamma z_{is}}{q^{out}_{is}})^{\frac{1}{1-\gamma}}$ if $\ln MPL_{l_{it}=\bar{l}_{is}} < q^{out}_{is}$,
   - $l^D_{is} = \bar{l}_{is}$ if $q^{in}_{is} \geq \ln MPL_{l_{it}=\bar{l}_{is}} \geq q^{out}_{is}$.
5. Compute total demand $L^D_s$ and total supply $L^S_s$ of land:
   - $L^D_s = \sum_{i=1}^{F_s} l^D_{is}$,
   - $L^S_s = \sum_{i=1}^{F_s} \bar{l}_{is}$.
6. Check $f = L^D_s - L^S_s$. If not converged, i.e., $f$ not close to 0, update guess of $q_s$ and iterate on (3)-(6) until convergence.

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# Estimation of parameters

We follow these steps to find parameter values for distortions:

1. Guess initial parameters $(\tilde{\theta}_s)_1$, $(\tilde{\sigma}^2_{\epsilon,s})_1$, $(\tilde{\tau}_s)_1$.
2. For each of X different sets of draws $\{\epsilon^x_{is}\}_{i=1}^{F_s}$, solve the decentralized equilibrium.
3. Compute implied moments by averaging over X equilibria:
   - $[(\tilde{M}^1)]$ $c\tilde{o}v(\ln MPL_{is}, \ln z_{is})$,
   - $[(\tilde{M}^2)]$ $v\tilde{a}r(\ln MPL_{is})$,
   - $[(\tilde{M}^3_1)]$ $1 - \sum_{i=1}^{F_s} 1(l^{in}_{is} > 0)$.
4. Compute distance $D_t$ between actual moments $(M^x)$ and implied moments $(\tilde{M}^x_t)$.
5. If not converged, construct new implied moments using adjusted parameter guesses. Separately identify $q_s$ and $\tau_s$ using:

$$\mathbb{E}(\ln MPL_{is}) = \ln q_s + \theta_s \mathbb{E}(\ln z_{is}) - (\ln(1+\tau_s))\mathbb{E}(l^{out}_{is} > 0).$$

6. Iterate (2)-(4) until distance is less than tolerance.

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# Identification of land-market distortions

In the model:

- If $\tau_s = 0$, most farmers participate in the rental market, share of farmers renting in gives variation to identify $\tau_s$
- If $\tau_s = 0$ and $\theta_s = 0$, the covariance between $\ln MPL_{is}$ and $\ln z_{is}$ equals zero, this covariance gives variation to identify $\theta_s$, conditional on $\tau_s$
- If $\tau_s = 0$, $\theta_s = 0$ and $\sigma^2_{\epsilon,s} = 0$, the variance of $\ln MPL_{is}$ equals zero, this variance gives variation to identify $\sigma^2_{\epsilon,s}$, conditional on $\tau_s$ and $\theta_s$

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# Model fit—land allocations, rented land

| | Correlation of Land Allocations Model and Data | Share of Land 10% Most Productive | |
|---|---|---|---|
| | | Data | Model |
| India: | 0.88 | 0.27 | 0.30 |
| State: | | | |
| Andhra Pradesh (AP) | 0.64 | 0.30 | 0.32 |
| Assam (AS) | 0.84 | 0.19 | 0.22 |
| Bihar (BR) | 0.71 | 0.26 | 0.41 |
| Gujarat (GJ) | 0.88 | 0.24 | 0.26 |
| Haryana (HR) | 0.79 | 0.27 | 0.39 |
| Karnataka (KA) | 0.85 | 0.26 | 0.27 |
| Kerala (KL) | 0.84 | 0.21 | 0.20 |
| Maharashtra (MH) | 0.88 | 0.27 | 0.27 |
| Madhya Pradesh (MP) | 0.88 | 0.37 | 0.37 |
| Orissa (OR) | 0.76 | 0.23 | 0.29 |
| Punjab (PB) | 0.75 | 0.33 | 0.39 |
| Rajasthan (RJ) | 0.87 | 0.27 | 0.29 |
| Tamil Nadu (TN) | 0.89 | 0.11 | 0.11 |
| Uttar Pradesh (UP) | 0.86 | 0.24 | 0.32 |
| West Bengal (WB) | 0.83 | 0.25 | 0.26 |

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# Agricultural productivity gains relative to Baseline


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