# Agricultural Productivity and Structural Transformation
## Evidence from Brazil

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# Introduction

Economic development is accompanied by structural transformation

- Reallocation of employment from agriculture to manufacturing [Clark (1940), Kuznets (1957)]

Theoretical mechanisms

- Supply-side: faster productivity growth in agriculture
- Demand-side: income growth + non-homotetic preferences
- Predictions are reversed in an open economy [Matsuyama (1992)]

Scarce direct empirical evidence testing theoretical mechanisms

# Introduction

We study the effect of the adoption of new agricultural technologies on industrial development in Brazil

Introduction of genetically engineered (GE) soy seeds

- gene that makes them herbicide-tolerant
- reduced need to plow
- land-biased technical change

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Introduction of second-harvest maize

- effectively increases land endowment
- labor-biased technical change

▸ Soy Productivity ▸ Maize Productivity

# Introduction

## Empirical strategy

To establish causality, we exploit the timing of adoption and its differential impact on potential yields across geographical areas

- GE soy seeds were commercially introduced in the U.S. in 1996 and legalized in Brazil in 2003
- Their impact on potential yields depends on local weather and soil characteristics

# Introduction

## Theory

To guide empirical work, we build a simple model

- small open economy
- two sectors: agriculture and industry
- two factors: land and labor
- technical change can be factor-biased

Effects of increase in agricultural productivity

- Hicks-neutral: labor reallocates towards Agriculture
- Labor-biased: idem
- Land-biased: labor reallocates towards Manufacturing

# Preview of empirical findings

Main findings on the effects of the adoption of GE soy in Brazil

- Agriculture
  - increase in productivity
  - reduction in labor intensity
  - reduction in employment share
- Manufacturing
  - reduction in wages
  - increase in employment

Opposite effects for second-harvest maize

Findings suggest that effects of agricultural productivity on industrialization depend on the factor bias of technical change

# Related Literature

Origins of Industrialization

- Rosenstein-Rodan (1943), Nurkse (1958), Rostow (1960), Mokyr (1976)

Structural Transformation, Theory:

- Baumol (1967), Murphy Shleifer Vishny (1989), Matsuyama (1992), Kongsamut, Rebelo and Xie (2001), Gollin, Parente and Rogerson (2002), Ngai and Pissarides (2007), Caselli and Coleman (2001), Acemoglu and Guerrieri (2008)

Structural Transformation, Empirics:

- Foster and Rosenzweig (2004), (2008): rural industries grow faster in areas with lower yield growth during the Green Revolution in India.

- Buera and Kaboski (2008),Desmet and Rossi-Hansberg (2009), Nunn and Qian (2011), Michaels, Rauch and Redding (2012), Hornbeck (2012)

# Structure of Talk

Data and Background

Basic correlations in the data

- Did areas where soy (maize) expanded experience faster (slower) structural transformation?

Causality

- Did areas where the new technology had a higher impact on *potential* yields experience faster structural transformation?

# Data

Agricultural Census 1995-6 and 2006. IBGE

- municipality-level data: employment, output and area

Population Census 2000 and 2010. IBGE

- individual-level data: employment and wages

Yearly Industry Survey 1996-2007 IBGE

- firm-level data: revenues, employment, wages, investment

Potential yield of soy and other crops from FAO-GAEZ

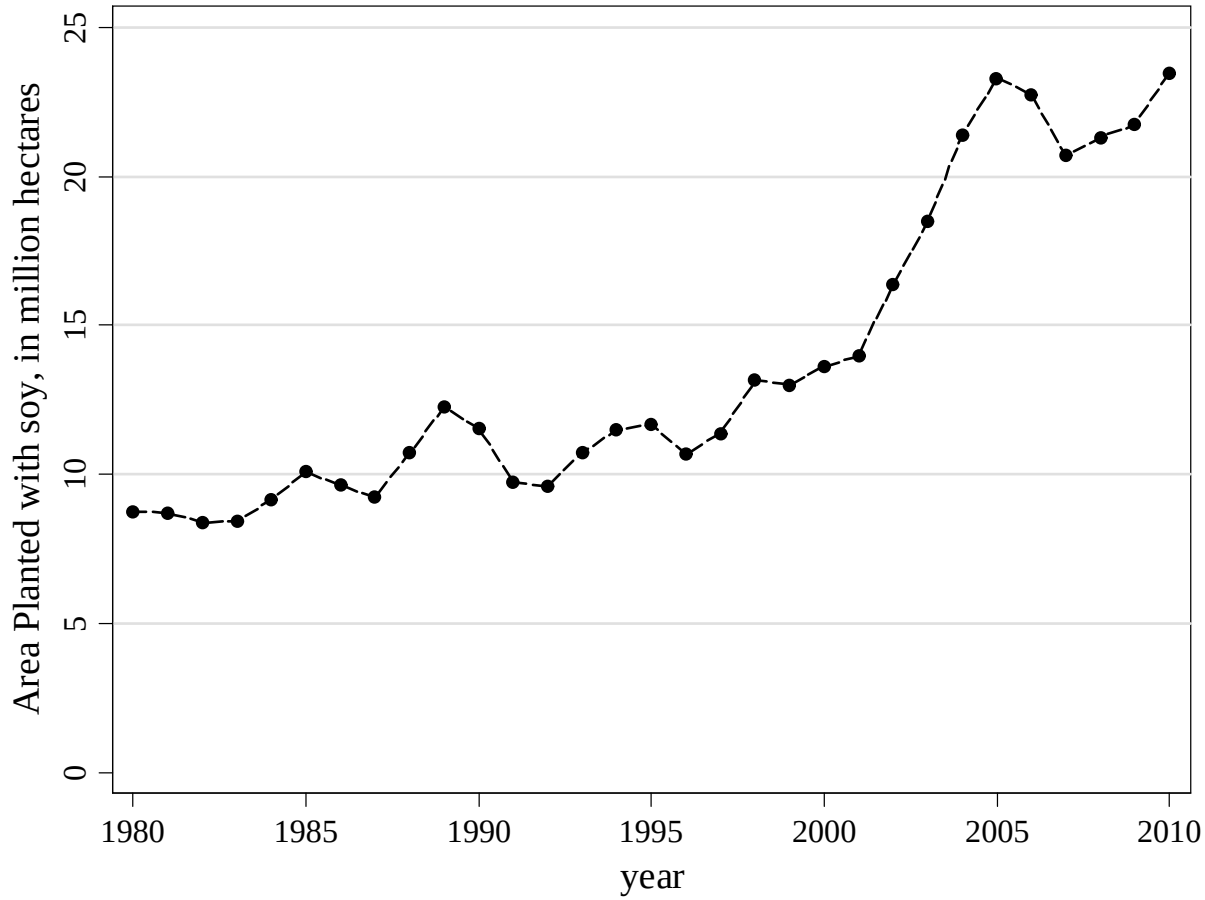
- geo-referenced grid of 9.25 x 9.25 km

National Household Survey 2002 to 2011 (PNAD, IBGE) and Crop Surveys 1980 to 2010 (CONAB)

- aggregate data: employment and area by crop

# Background

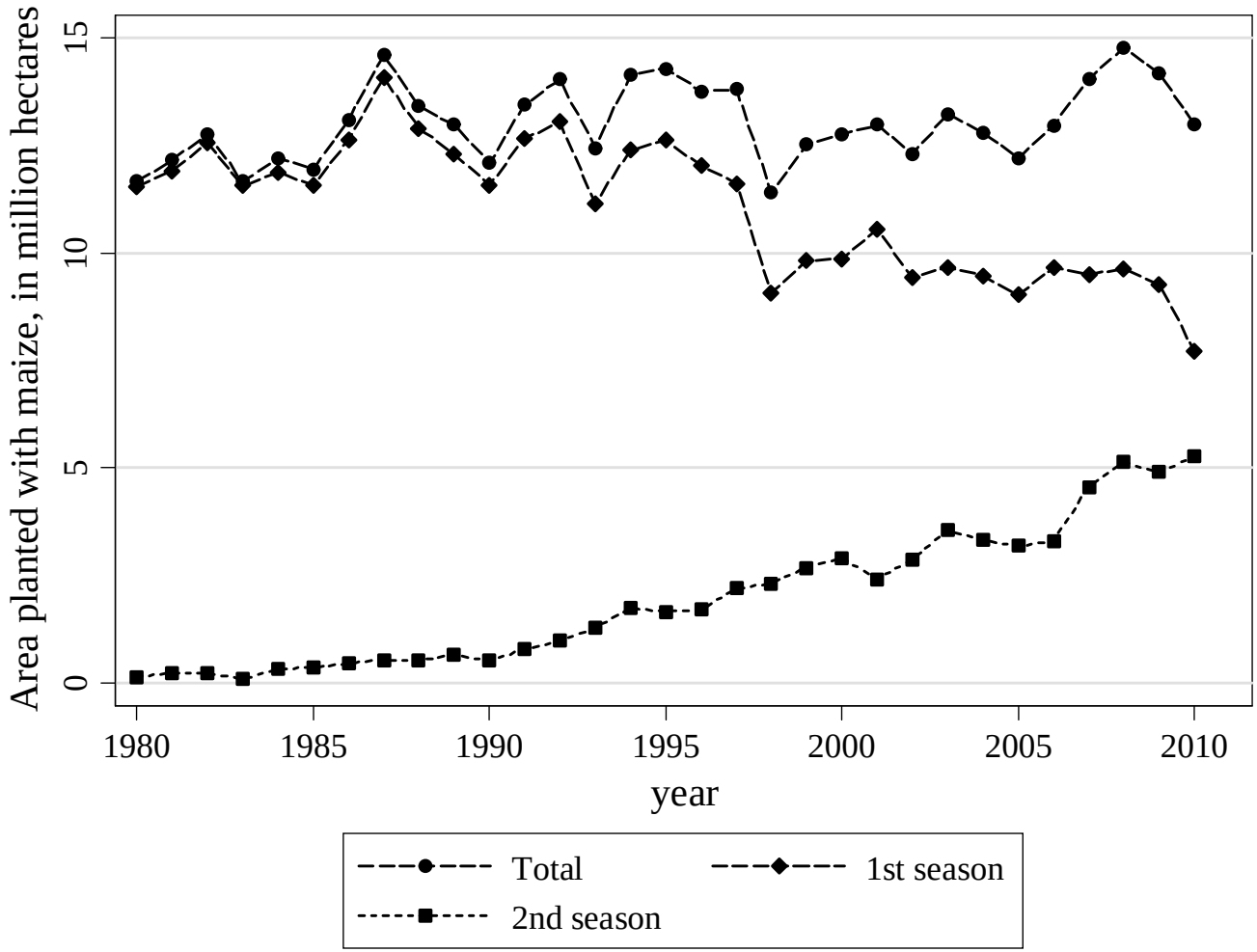
## Expansion of area planted with soy: 1980-2010




Source: CONAB

# Background

## Area planted with maize in Brazil




Source: CONAB

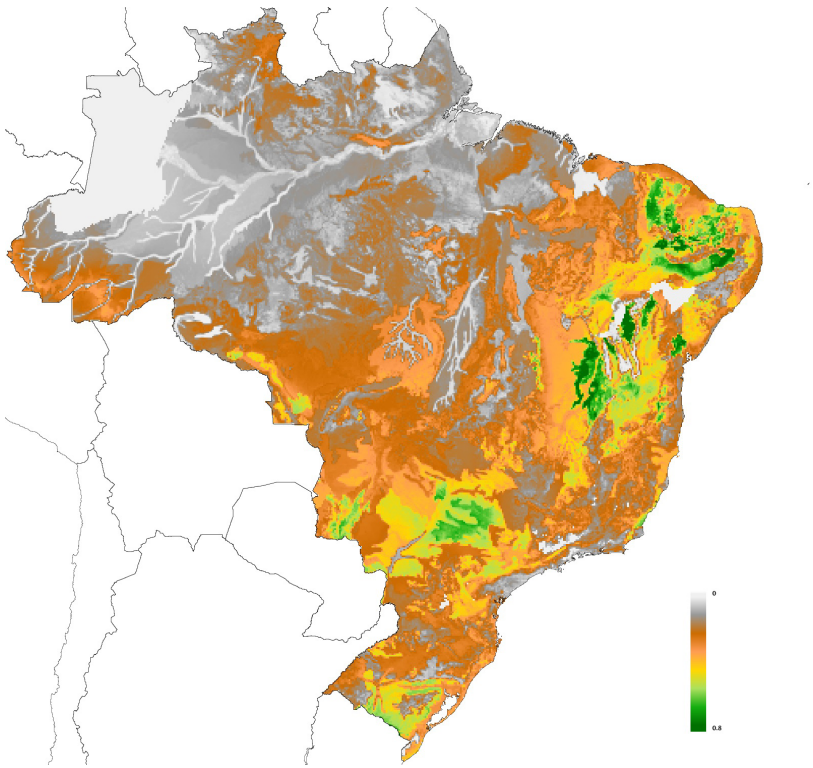
# Empirics

- We find that areas where soy expanded experienced a reduction in labor intensity in agriculture while industrial employment increased.
- This could be caused by labor saving technological change in agriculture
- Alternatively, it could be due to other shocks to local labor markets
  - For example: an increase in industrial productivity could increase wages, inducing agricultural firms to switch to less labor intensive crops, like soy.
- To establish the direction of causality we need an exogenous measure of technological change in agriculture

# A Measure of Technological Change

## FAO-GAEZ Potential Yield for Soy

*Low* inputs: $A_j^{\text{soy, low}}$



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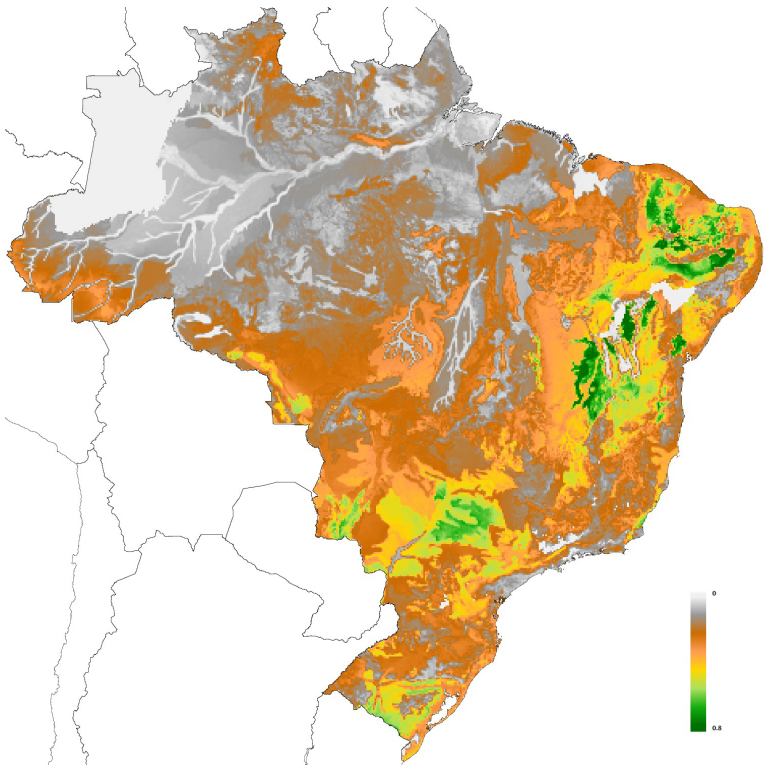
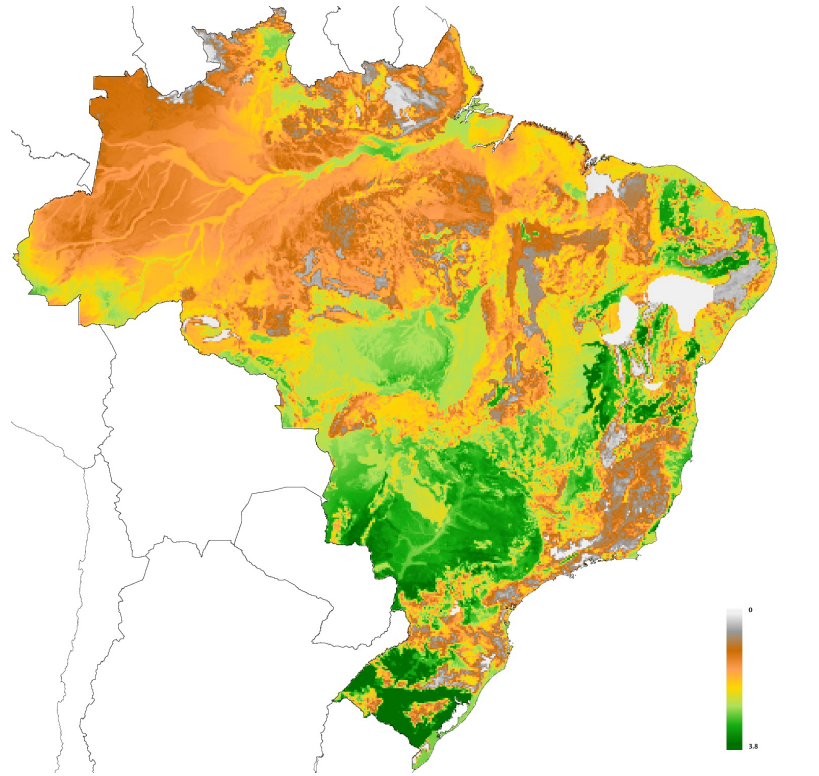


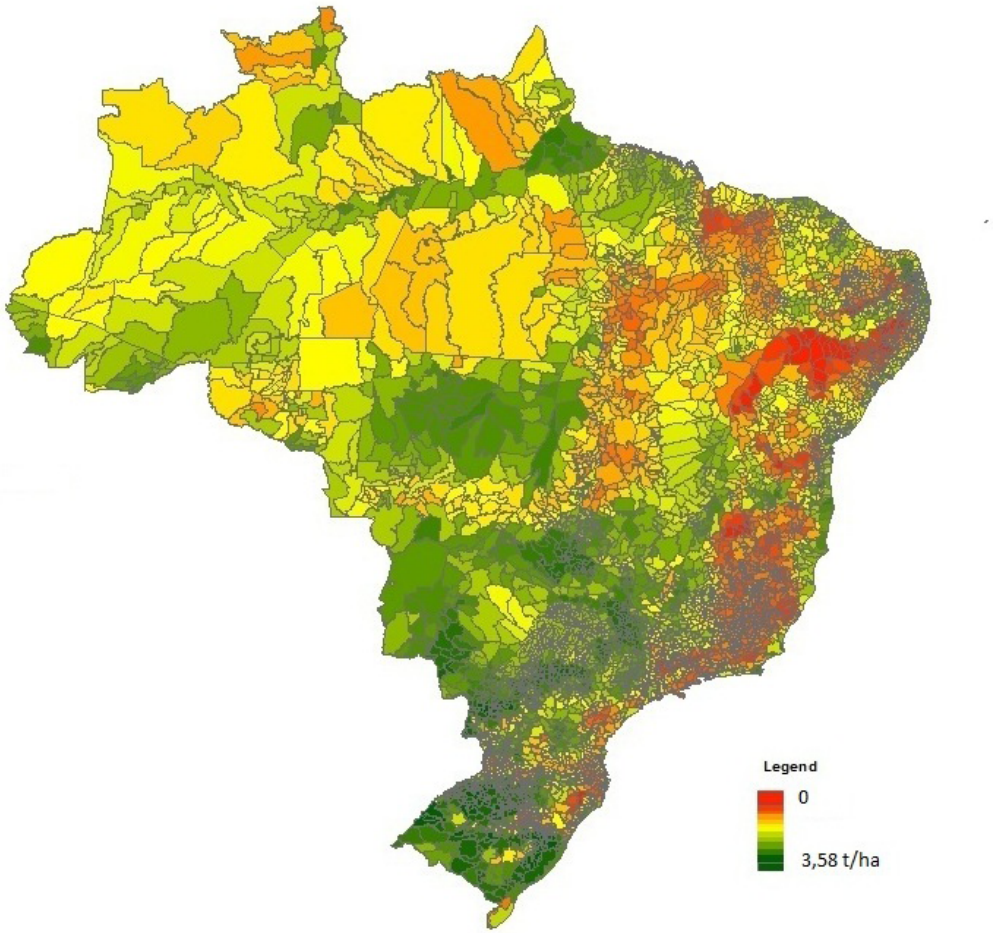
*High* inputs: $A_j^{\text{soy, high}}$



# A Measure of Technological Change

## FAO-GAEZ Potential Yield for Soy

$$\Delta A_j^{soy} = A_j^{soy,\ high} - A_j^{soy,\ low}$$




▶ Technology change at microregion level

# Empirical Strategy

Effect of technological change in agriculture ($\Delta A_j^{soy}$) on two sets of outcomes:

- Agriculture
- Industry

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In first differences:

$$\Delta y_j = \Delta\alpha + \beta \Delta A_j^{soy} + \Delta\varepsilon_j$$

where $\Delta A_j^{soy} = A_J^{soy,\ high} - A_J^{soy,\ low}$

# Empirical Strategy

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controlling for maize:

$$\Delta y_j = \Delta\alpha + \beta \Delta A_j^{soy} + \gamma \Delta A_j^{maize} + \Delta\varepsilon_j$$

# Agricultural Outcomes

## Soy and maize area expansion

| | $\Delta \frac{\text{Soy area}}{\text{agricultural area}}$ | | $\Delta \frac{\text{Maize area}}{\text{agricultural area}}$ | |
|---|---|---|---|---|
| $\Delta A^{soy}$ | 0.012*** | 0.014*** | | -0.006*** |
| | (0.001) | (0.002) | | (0.002) |
| $\Delta A^{maize}$ | | -0.002** | 0.003*** | 0.005*** |
| | | (0.001) | (0.001) | (0.001) |
| Municipalities | 3,920 | 3,920 | 4,111 | 4,111 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Agricultural Outcomes

## Quantification

The estimated coefficients imply that municipalities with a one standard deviation above the mean increase in potential yields of

- soy increased the share of soy in planted land area by 28% of a standard deviation
- maize increased the share of maize in planted land area by 14% of a standard deviation

# Agricultural Outcomes

## GE soy adoption

| | $\Delta \frac{\text{GE soy area}}{\text{agricultural area}}$ | $\Delta \frac{\text{non-GE soy area}}{\text{agricultural area}}$ |
|---|---|---|
| $\Delta A^{soy}$ | 0.017*** | -0.007*** |
| | (0.002) | (0.002) |
| Municipalities | 3,769 | 3,769 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Agricultural Outcomes

## Productivity, labor intensity and employment share

| | Δ Value per worker | Δ Labor intensity | Δ Employment share |
|---|---|---|---|
| $\Delta A^{soy}$ | 0.090*** | -0.034** | -0.024*** |
| | (0.031) | (0.016) | (0.003) |
| $\Delta A^{maize}$ | -0.017 | 0.024*** | 0.010*** |
| | (0.015) | (0.008) | (0.002) |
| Municipalities | 4,149 | 4,231 | 4,254 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

# Agricultural Outcomes

## Summary of findings

Municipalities with faster increase in potential soy yields

- reduced the number of workers per unit of land
- experienced reductions in the agriculture share of total employment

# Manufacturing Outcomes

## Employment share, employment and wage

| | Δ Manufacturing employment share | Δ Manufacturing workers | Δ Wage |
|---|---|---|---|
| Δ $A^{soy}$ | 0.018*** | 0.241*** | -0.044*** |
| | (0.002) | (0.016) | (0.013) |
| Δ $A^{maize}$ | -0.003*** | -0.062*** | 0.027*** |
| | (0.001) | (0.008) | (0.006) |
| Municipalities | 4,255 | 4,249 | 4,249 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

▸ Results at microregion level

# Manufacturing Outcomes

## Quantification

The estimated coefficients imply that municipalities with a 1 s.d. above the mean increase

- in potential soy yields
  - increased manufacturing employment by 34% of a standard deviation faster
  - reduced wages in manufacturing by 8.7% of a standard deviation faster

# Manufacturing Outcomes

## Quantification

The estimated coefficients imply that municipalities with a 1 s.d. above the mean increase

- in potential soy yields
  - increased manufacturing employment by 34% of a standard deviation faster
  - reduced wages in manufacturing by 8.7% of a standard deviation faster
- in potential maize yields
  - increased wages in manufacturing by 11.5% of a standard deviation faster

# Summary of findings

- Areas with higher increases in potential soy yields experienced a
  - reduction in the labor intensity of agricultural production
  - reduction in agriculture's employment share
  - reduction in wages and increase in employment in manufacturing
- The opposite is true for areas with higher increases in potential maize yields
- Findings suggest that the effect of agricultural productivity on the industrial sector depend on the factor-bias of technical change
- Ongoing work to understand effects on industrial composition and income distribution

# Extensions

Exploit differences across industries to identify channel

$$y_{ijts} = \alpha_j + \alpha_t + \alpha_s + \beta_1 A_{jt}^{soy} + \beta_2 A_{jt}^{soy} \times \sigma_s + \varepsilon_{ijts}$$

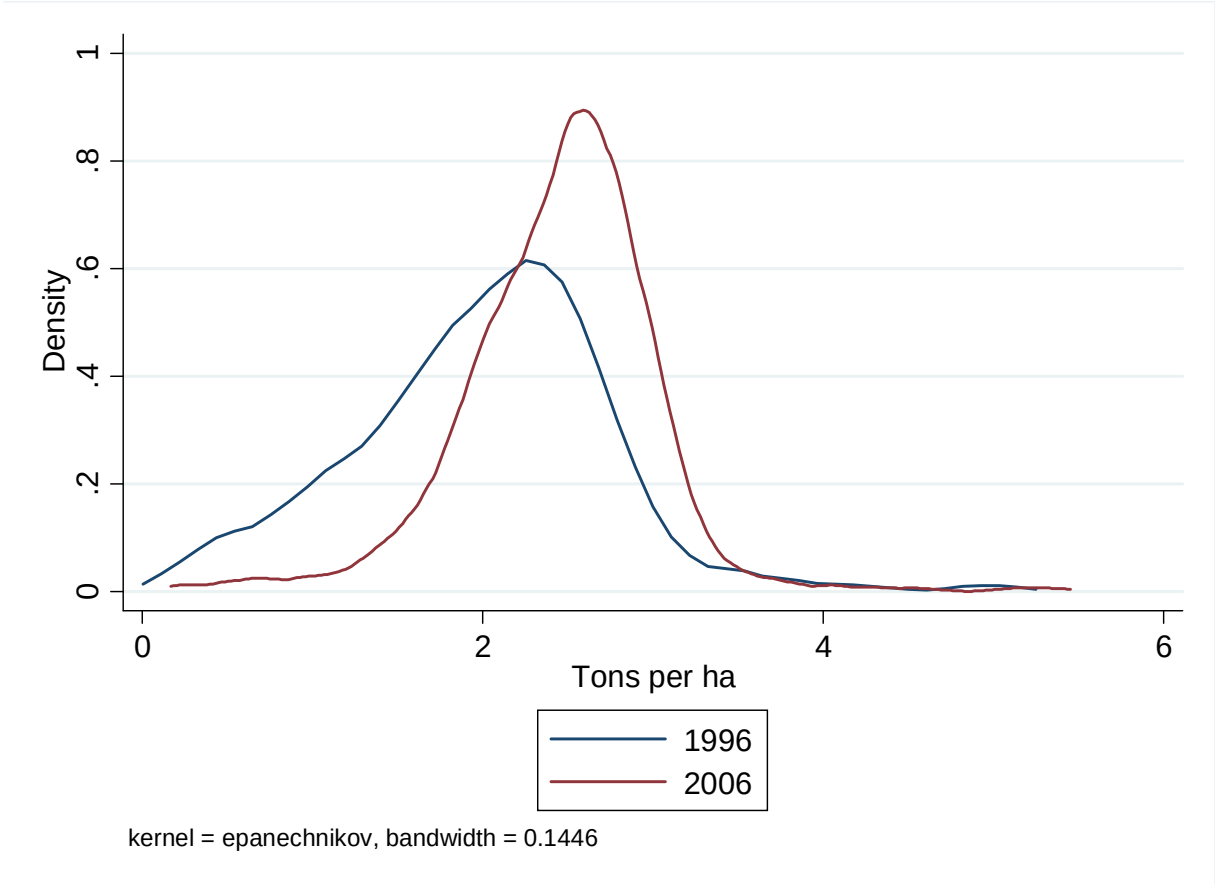
where $\sigma_s$ is a characteristic of industry $s$

- labor and skill intensity
- income elasticity of demand
- backward and forward linkages

# Background

## Agricultural Productivity

Average soy yield across municipalities

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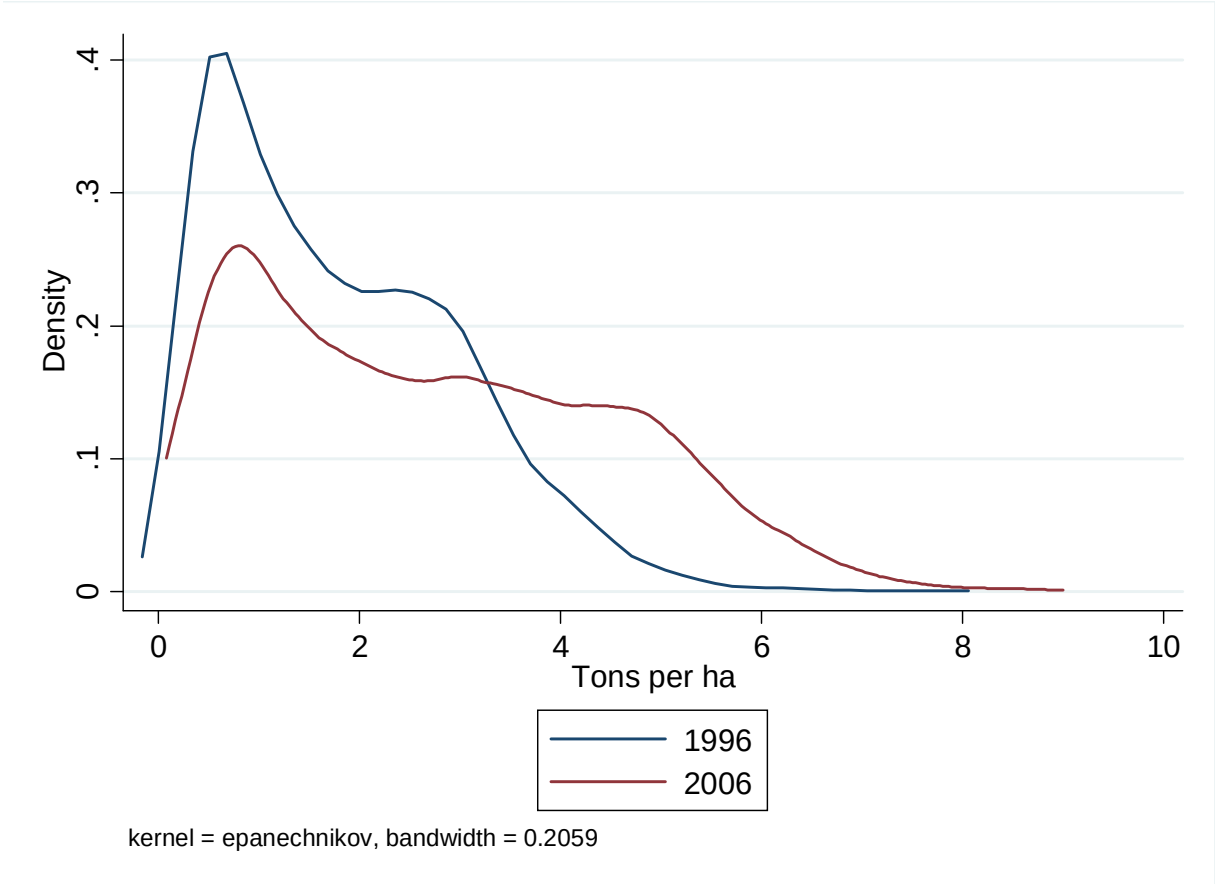
## Agricultural Productivity

Average maize yield across municipalities

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# Theoretical Predictions

## Production Function in Agriculture

$$Y_A = \left[\gamma \left(A_L L\right)^{\frac{\sigma-1}{\sigma}} + (1-\gamma)\left(A_T T\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

$$\frac{MP_T}{MP_L} = \gamma \left(\frac{A_T}{A_L}\right)^{\frac{\sigma-1}{\sigma}} \left(\frac{T}{L}\right)^{-\frac{1}{\sigma}}$$

Assume $\sigma < 1$ ( L and T are complements):

Soy technical change: L-augmenting technical change is T-biased

Maize technical change: T-augmenting technical change is L-biased

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# Basic Correlations: Manufacturing

## Data at the Microregion Level

| | Δ Employment share | Δ Employment | Δ Wage |
|---|---|---|---|
| Δ Soy area share | 0.091** | 0.819** | -0.378 |
| | (0.045) | (0.381) | (0.316) |
| Δ Maize area share | 0.037 | 0.107 | 0.641*** |
| | (0.032) | (0.467) | (0.225) |
| Microregions | 557 | 557 | 557 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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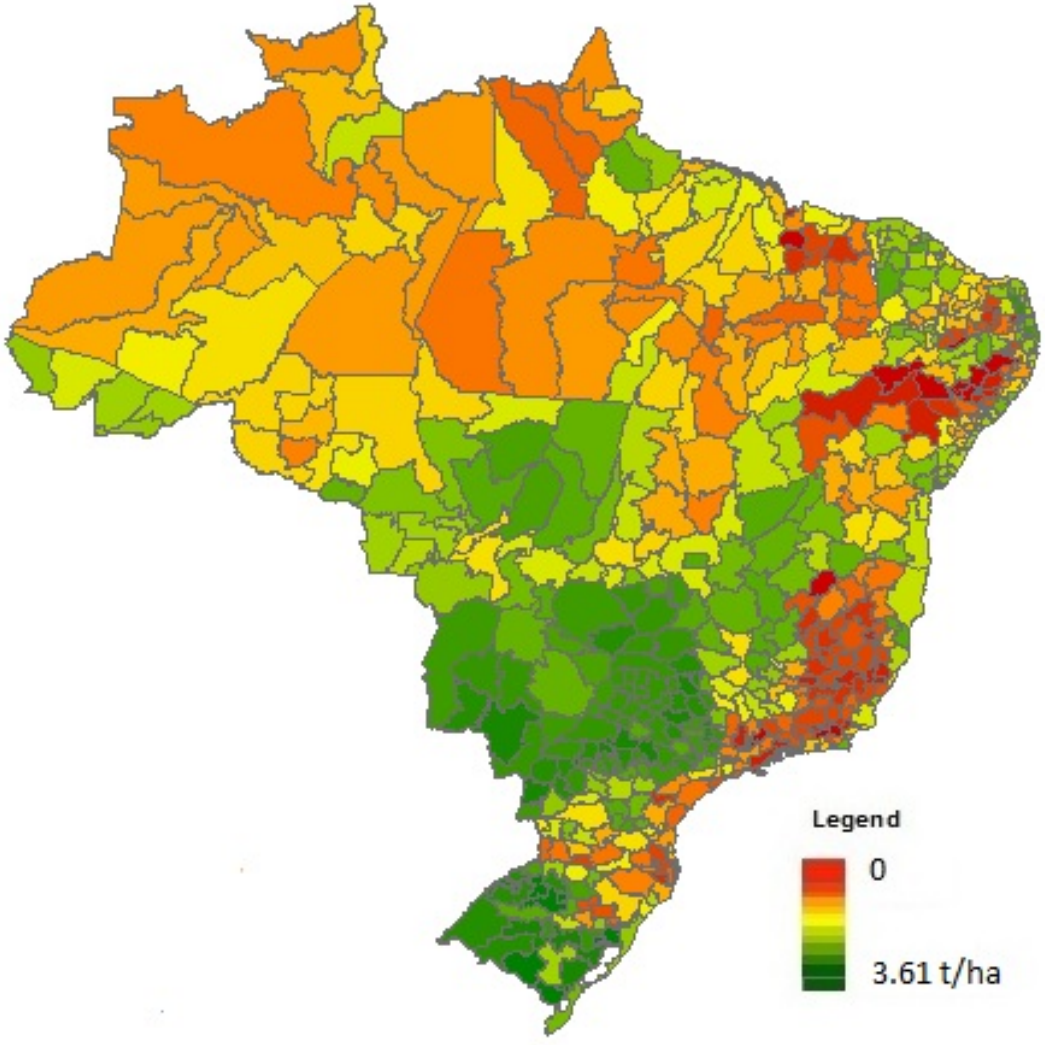
# A Measure of Technological Change

## Microregions

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# Manufacturing Outcomes

## Data at the Microregion level

| | Δ Manufacturing Employment Share | Δ Manufacturing Workers | Δ Wage |
|---|---|---|---|
| Δ $A^{soy}$ | 0.009*** | 0.171*** | -0.087*** |
| | (0.003) | (0.024) | (0.019) |
| Δ $A^{maize}$ | -0.000 | -0.048*** | 0.041*** |
| | (0.001) | (0.011) | (0.009) |
| Microregions | 557 | 557 | 557 |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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# Basic Correlations in the Data

## Did areas where soy expanded experience faster structural transformation?

We start by reporting the "effect" of the expansion in the area planted with soy and maize within each municipality on

- Agricultural outcomes
  - Value of output per worker
  - Labor intensity
  - Employment share
- Manufacturing outcomes
  - Employment share
  - Level of employment
  - Wages

# Basic Correlations in the Data

## Did areas where soy expanded experience faster structural transformation?

In levels:

$$y_{jt} = \alpha_j + \alpha_t + \beta_1 \left( \frac{Soy\ Area}{Agric.\ Area} \right)_{jt} + \beta_2 \left( \frac{Maize\ Area}{Agric.\ Area} \right)_{jt} + \varepsilon_{jt}$$

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In first differences:

$$\Delta y_j = \Delta\alpha + \beta_1\ \Delta \left( \frac{Soy\ Area}{Agric.\ Area} \right)_j + \beta_2\ \Delta \left( \frac{Maize\ Area}{Agric.\ Area} \right)_j + \Delta\varepsilon_j$$

# Basic Correlations: Agriculture

## Did areas where soy expanded experience faster structural transformation?

| | Δ Value per worker | Δ Labor intensity | Δ Employment share |
|---|---|---|---|
| Δ Soy area share | 2.405*** | -0.475*** | -0.098*** |
| | (0.301) | (0.153) | (0.036) |
| Δ Maize area share | 2.405*** | 0.746*** | 0.033 |
| | (0.229) | (0.119) | (0.026) |
| Municipalities | 3,754 | 3,806 | 3,804 |

Source: Agricultural Census 1996, 2006

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

# Basic Correlations in the Data

## Quantification

Change in agricultural employment (1996-2006): - 1.3 million workers

- increase in soy area "explains" - 177.420 workers (13% of total)
- increase in maize area "explains" + 79.886 workers (- 6% of total)

# Basic Correlations: Manufacturing

## Did areas where soy expanded experience faster structural transformation?

| | Δ Employment share | Δ Employment | Δ Wage |
|---|---|---|---|
| Δ Soy Area share | 0.084*** | 0.982*** | -0.198 |
| | (0.020) | (0.224) | (0.177) |
| Δ Maize Area share | 0.005 | -0.004 | -0.090 |
| | (0.011) | (0.142) | (0.113) |
| Municipalities | 3,805 | 3,799 | 3,799 |

Source: Agricultural Census (1996, 2006) and Population Census (2000, 2010)
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

▸ Results at microregion level

# Basic Correlations in the Data

## Quantification

The estimated coefficients imply that the average change in soy area "explains"

- 10% of the aggregate increase in manufacturing employment (+ 179.013 workers)