Agricultural Productivity and Industrial Growth Evidence from Brazil

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Introduction

We study the effects of agricultural productivity on the industrial sector.

- Classic view that increases in agricultural productivity are a precondition for industrial growth.
  [Rostow, 1960]
  - increasing income per capita $\longrightarrow$ demand for manufacturing goods
- However, this effect can be reversed in an open economy
  [Matsuyama, 1992]
  - Comparative advantage in agriculture $\longrightarrow$ reallocation of labor towards agriculture and smaller industrial sector.

Introduction

- We study the effect of the adoption of a new agricultural technology (GE soybean seeds) on Brazilian manufacturing firms
- 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.

Preview of preliminary findings

Main findings on the effects of the soy productivity shock

- Agriculture
  - reduction in labor intensity
- Local Labor Market
  - reduction in employment share of agriculture
- Industry
  - reduction in wages
  - increase in employment, revenues and investment

Structure of Talk

- Data
- Empirical Strategy
- Preliminary Findings

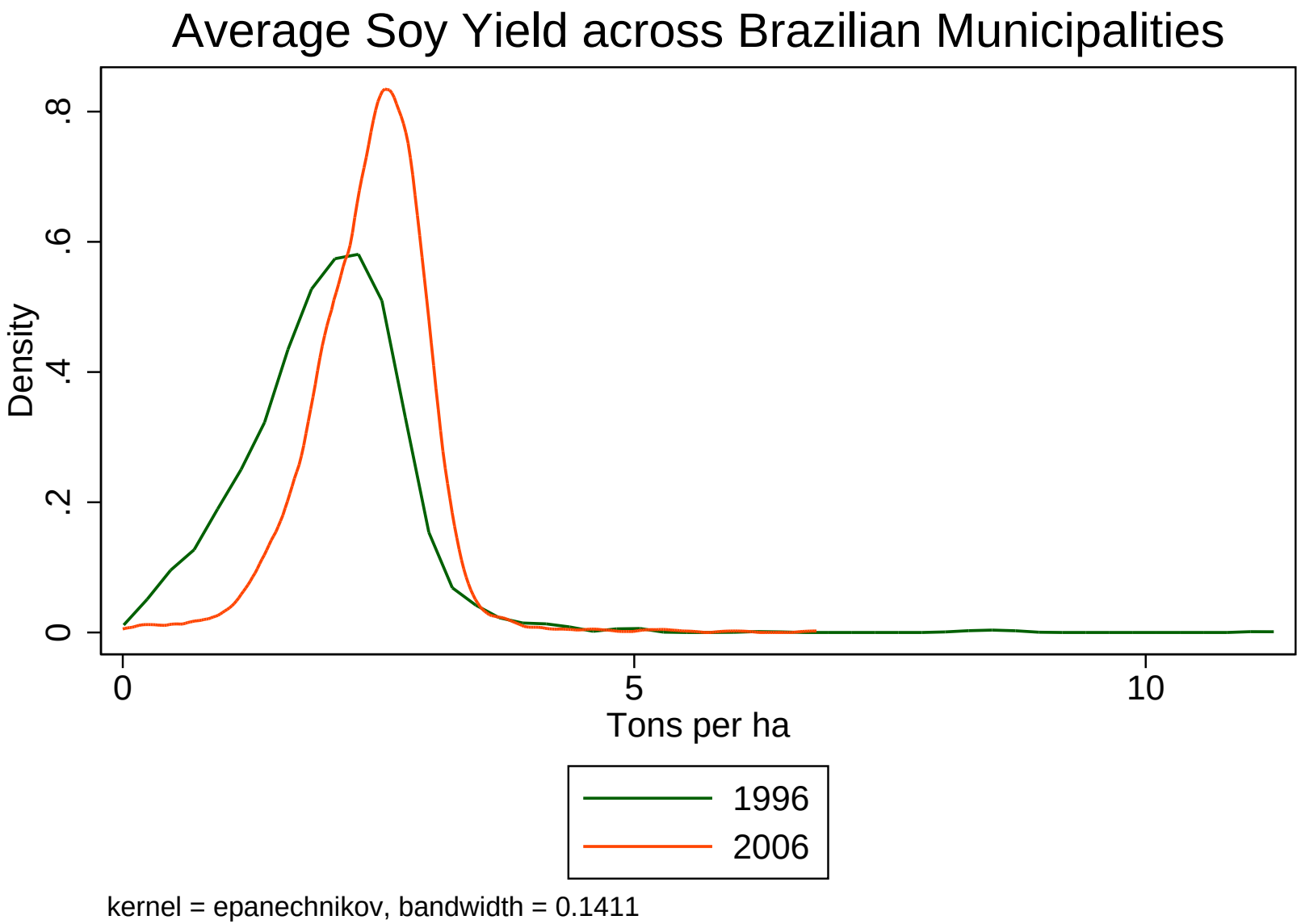
Data

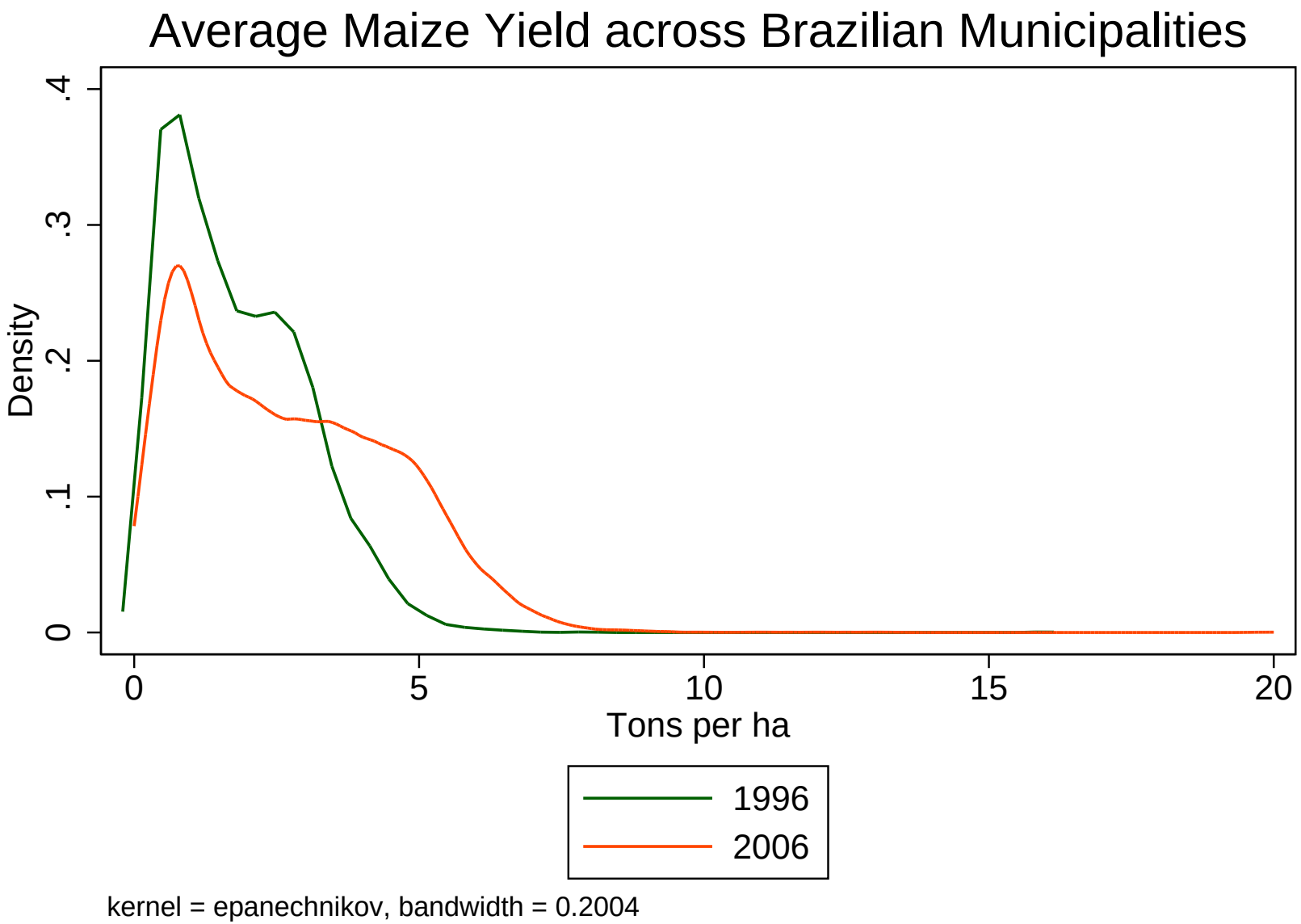
- Agricultural Census 1995-6 and 2006. IBGE
  - municipality-level data on quantity, value and area by crop
- Yearly Industry Survey 1996-2007 IBGE
  - firm-level data on revenues, employment by skill, investment
- Potential yield of soy and other crops from FAO-GAEZ
  - geo-referenced grid of 9.25 x 9.25 km

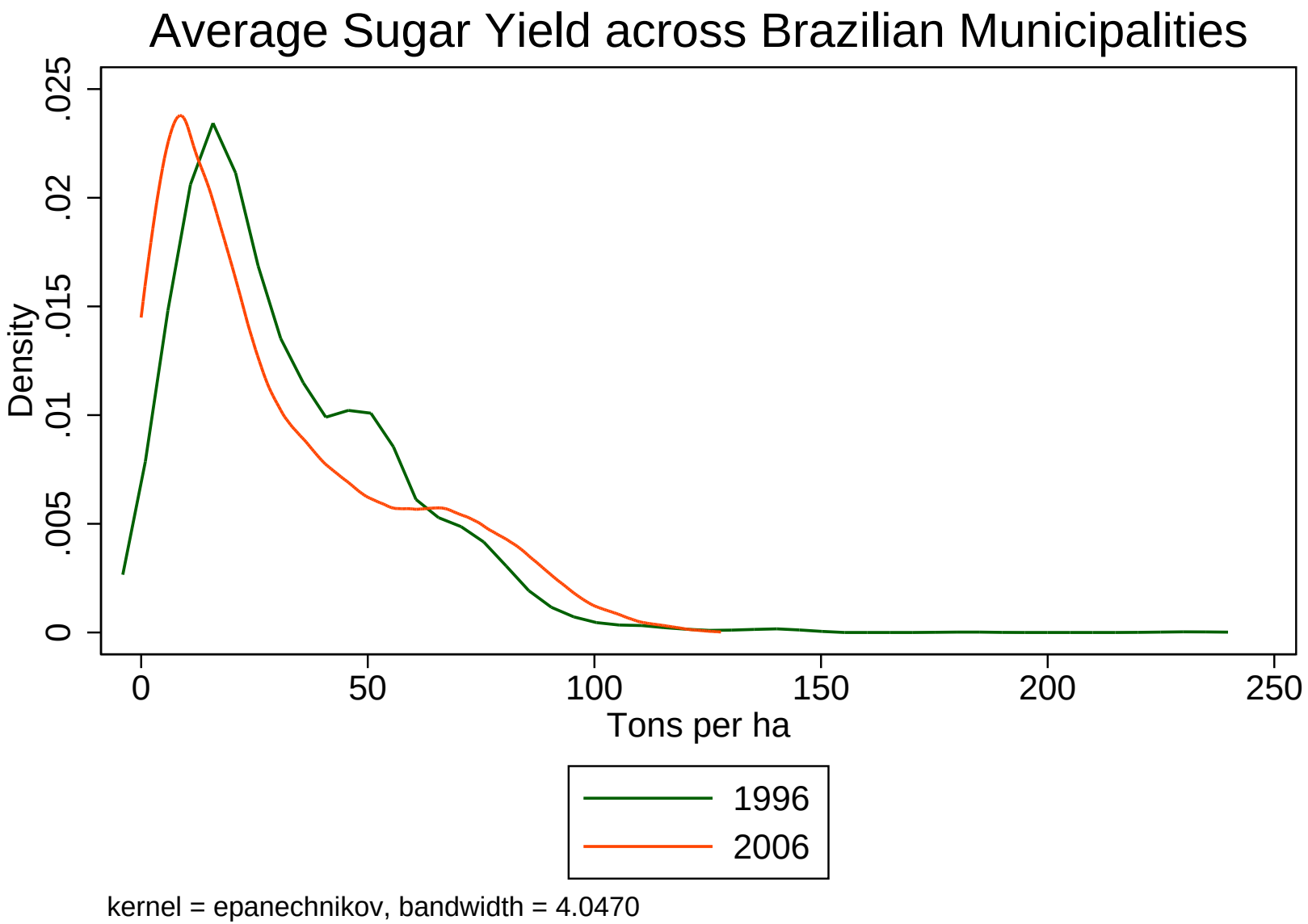
Agricultural Census Summary Statistics

	1996	2006	change
Area Reaped (million ha)			
Soy	9.2	15.7	6.4
Maize	10.5	11.7	1.3
Sugar	4.2	5.6	1.4
All seasonal crops	36.8	48.2	11.4
Employment (million workers)			
Seasonal crops	6.8	6.4	-0.4
Agriculture	17.9	16.6	-1.3

Note: in 1996 soy production employs 42 workers per 1000 ha, while maize employs 106 and sugar 138.


Average Soy Yield across Brazilian Municipalities
Density
0
.2
.4
.6
.8
0
5
10
Tons per ha
1996
2006
kernel = epanechnikov, bandwidth = 0.1411


Average Maize Yield across Brazilian Municipalities
Density
0
.1
.2
.3
.4
0
5
10
15
20
Tons per ha
1996
2006
kernel = epanechnikov, bandwidth = 0.2004


Average Sugar Yield across Brazilian Municipalities
Density
0
.005
.01
.015
.02
.025
0
50
100
150
200
250
Tons per ha
1996
2006
kernel = epanechnikov, bandwidth = 4.0470

Basic Correlations in the Data

We start by reporting the correlation between the expansion in area planted with soy within each municipality and:

- Value of output per worker (seasonal crops)
- Labor intensity (seasonal crops)
- Agriculture's employment share

Basic Correlations in the Data

In levels:

$$y_{jt} = \alpha_j + \alpha_t + \beta \left(\frac{Soy\ Area}{Agricultural\ Area} \right)_{jt} + \varepsilon_{jt}$$

In first differences:

$$\Delta y_j = \Delta\alpha + \beta\ \Delta \left(\frac{Soy\ Area}{Agricultural\ Area} \right)_j + \Delta\varepsilon_j$$

Agricultural outcomes: OLS results

	Δ Value per Worker	Δ Labor Intensity	Δ % Agri Workers
Panel A			
Δ % Soy Area	3.303***	-0.630***	-0.0734**
	(0.281)	(0.210)	(0.0358)
N	3,841	3,838	3,921
Panel B			
Δ % Maize Area	2.907***	0.679***	0.0204
	(0.209)	(0.160)	(0.0252)
N	4,062	4,053	4,112

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

Basic Correlations in the Data

Quantification

The average change in soy area "explains":

- a 1.8 workers per 1000 ha reduction in labor intensity
- 1/3 of the reduction in seasonal crop employment

Causality

The basic correlation: areas where soy expanded reduced labor intensity in agriculture

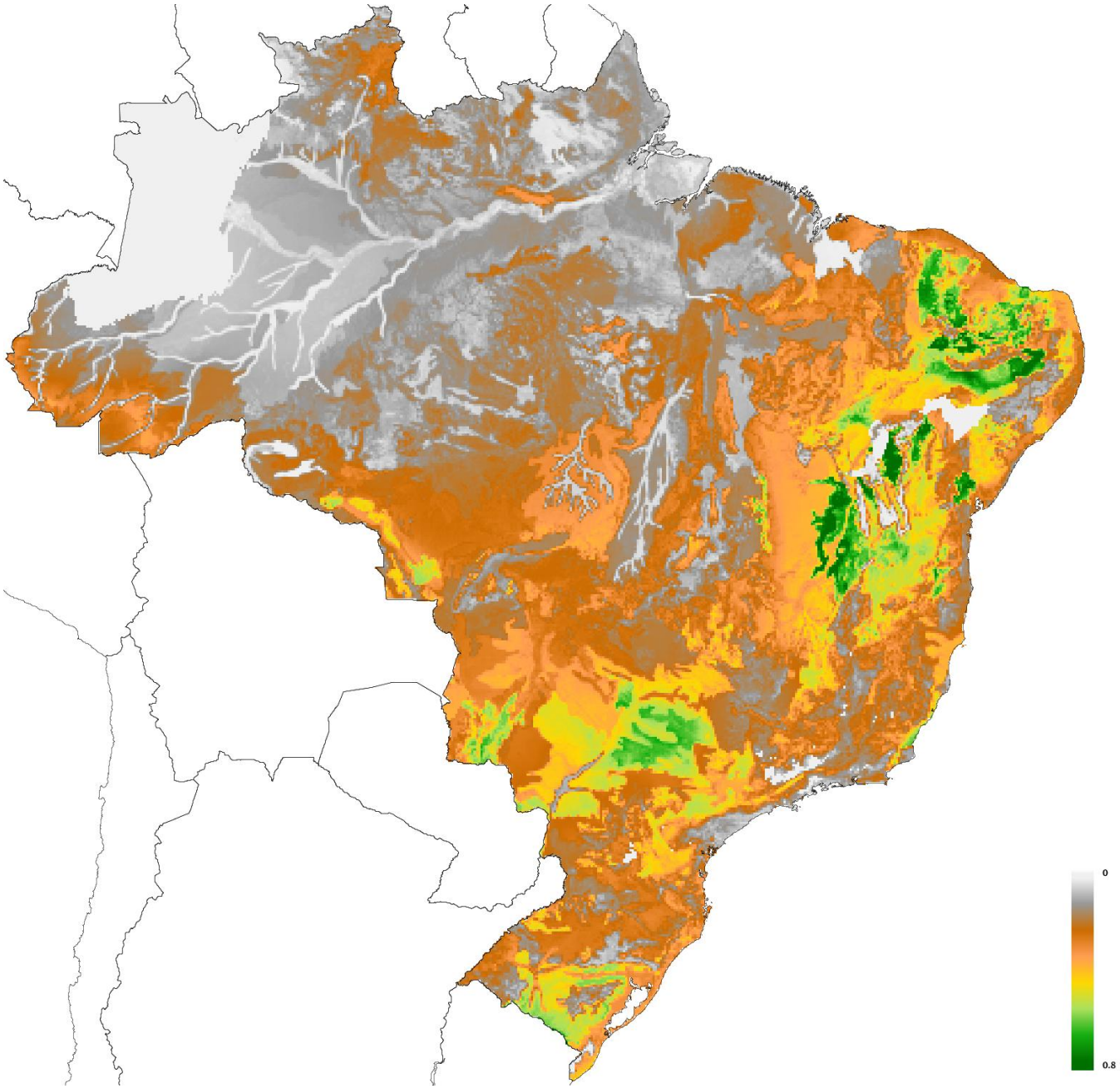
- This could be caused by labor saving technological change in agriculture
- Alternatively it could be due to other shocks to local labor markets
  - For example: an increase in labor demand in other sectors could increase wages, inducing agricultural firms to switch to less labor intensive crops, like soy.
- To establish the direction of causality we need an exogenous measure of technological change in agriculture

A Measure of Technological Change in Agriculture

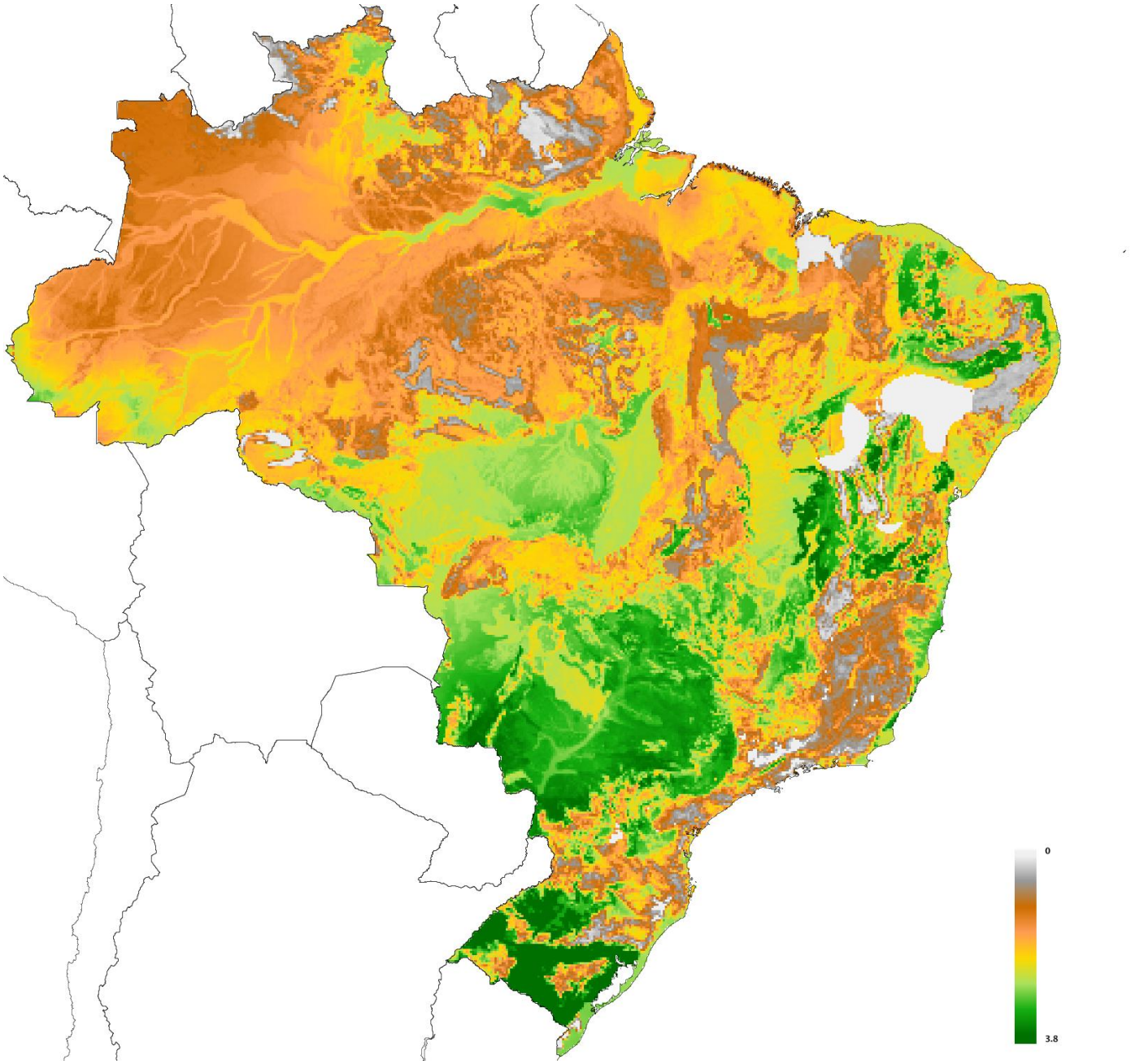
Potential yield of soy and other crops from FAO-GAEZ

- agricultural model prediction based on soil and weather characteristics
  - weather data from East Anglia CRU
  - soil map of the world
  - agronomic model linking weather and soil characteristics to yields for each crop
- worldwide grid of 9.25 x 9.25 km
- reports potential yields under low and high level of inputs

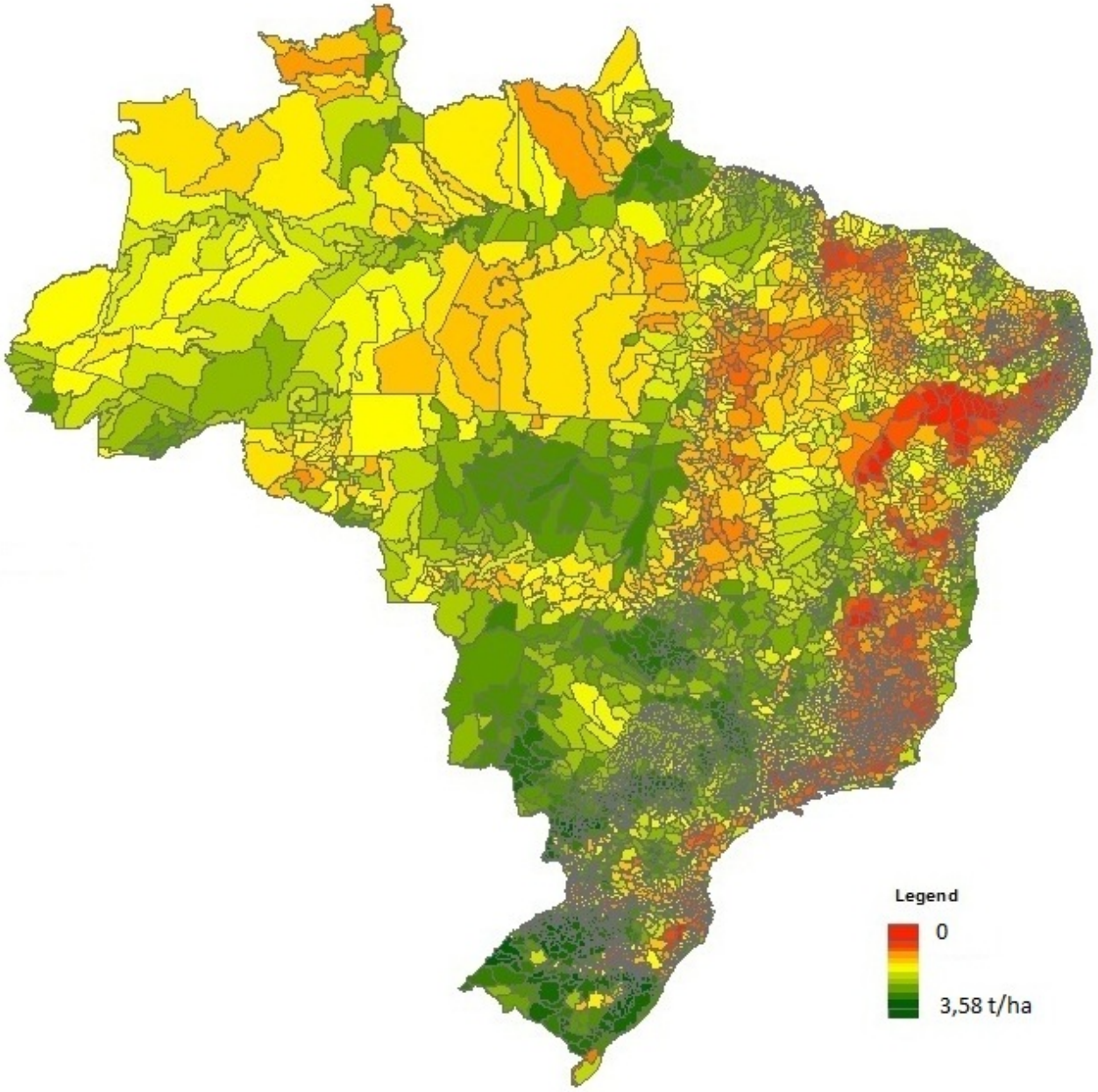
Potential Soy Yields under Low Inputs



Potential Soy Yields under High Inputs



Potential Soy Tech Shock = $\text{Yield}^{\text{high inputs}}$ - $\text{Yield}^{\text{low inputs}}$



Empirical Strategy

Effect of agricultural technology shock on two sets of outcomes

- Agriculture
- Industry

Agricultural Outcomes: Empirical Strategy

In first differences:

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

where:

$$\Delta A_j^{soy} = A_j^{soy,\text{HIGH inputs}} - A_j^{soy,\text{LOW inputs}}$$

Agricultural Outcomes: Empirical Strategy

In first differences:

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

where:

$$\Delta A_j^{soy} = A_j^{soy,\text{HIGH inputs}} - A_j^{soy,\text{LOW inputs}}$$

with controls:

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

Agricultural Outcomes: First Stage

	Δ % Soy Area	Δ % Soy Area	Δ % Maize Area	Δ % Maize Area
ΔA^{soy}	0.012***	0.025***		0.002
	(0.001)	(0.002)		(0.003)
ΔA^{maize}		-0.003***	0.003***	0.004***
		(0.001)	(0.001)	(0.001)
A^{sugar}		-0.007***		-0.006***
		(0.001)		(0.001)
N	3,921	3,921	4,112	4,112
R-squared	0.054	0.074	0.006	0.013

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

Agricultural Outcomes: Quantification

The estimated coefficient implies that municipalities with a one standard deviation above the mean increase in potential soy yields

- increased the share of soy in planted land area by 36% of a standard deviation.

Agricultural Outcomes: Reduced Form

	Δ Value per Worker	Δ Labor Intensity	Δ % Agri Workers
ΔA^{soy}	0.143***	-0.088**	-0.027***
	(0.044)	(0.035)	(0.005)
ΔA^{maize}	-0.025	0.049***	0.010***
	(0.016)	(0.013)	(0.002)
A^{sugar}	-0.036*	-0.027	0.002
	(0.021)	(0.017)	(0.002)
N	4,150	4,146	4,254
R-squared	0.003	0.007	0.013

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

Industrial Outcomes

- firm-level data from IBGE
  - employment and wages by skill
  - revenues
  - investment

Industrial Outcomes: Empirical Strategy

$$y_{jt} = \alpha_j + \alpha_t + \beta A_{jt}^{soy} + \varepsilon_{jt}$$

$$A_{jt}^{soy} = \begin{cases} \text{potential yield of soy under high inputs if } t \geqslant 2003 \\ \text{potential yield of soy under low inputs if } t < 2003 \end{cases}$$

Industrial Outcomes: Empirical Strategy

$$y_{jt} = \alpha_j + \alpha_t + \beta A_{jt}^{soy} + \varepsilon_{jt}$$

$$A_{jt}^{soy} = \begin{cases} \text{potential yield of soy under high inputs if } t \geqslant 2003 \\ \text{potential yield of soy under low inputs if } t < 2003 \end{cases}$$

with controls:

$$y_{jt} = \alpha_j + \alpha_t + \beta A_{jt}^{soy} + \gamma A_{jt}^{maize} + \sum_z \theta_z p_t^z A_{j0}^z + \varepsilon_{jt}$$

z= soy, maize and sugar

Industrial Outcomes: Reduced Form

plant-level data

	Employment	Wages	Revenues	Investment
A^{soy}	0.008**	-0.051***	0.030***	0.051***
	(1.98)	(-16.96)	(5.31)	(2.86)
A^{maize}	-0.005***	0.024***	-0.016***	-0.018**
	(-2.64)	(17.42)	(-6.04)	(-2.3)
$P^z A^z$ controls	Yes	Yes	Yes	Yes
Plant fixed effects	Yes	Yes	Yes	Yes
Observations	550260	549896	546942	241501

Robust t statistics in parentheses. ** significant at 5%; *** significant at 1%

Industrial Outcomes: Reduced Form

firm-level data

	production / non-production workers	production workers
A^{soy}	0.005***	0.008*
	(4.47)	(1.78)
A^{maize}	-0.003***	-0.008***
	(-6.38)	(-3.84)
$P^z A^z$ controls	Yes	Yes
Firm fixed effects	Yes	Yes
Observations	430783	426136

Robust t statistics in parentheses. ** significant at 5%; *** significant at 1%

Summary of preliminary findings

- Areas with higher increases in potential soy yields experienced a (relative)
  - reduction in the labor intensity of agricultural production
  - reduction in agriculture's employment share
  - reduction in wages and increase in employment in manufacturing
- These findings suggest that the effects of changes in agricultural productivity on the industrial sector depend not only on openness but also on factor bias of technological change