GM technology over the agricultural productivity in Brazilian Cerrado

Prof. Dr. Pablo Miranda Guimarães
Prof. Dr. Marcelo José Braga

Abril 2023

Universidade Federal Rural do Rio de Janeiro - Instituto Três Rios
Universidade Federal de Viçosa/MG

IAAE INTERCONFERENCE SYMPOSIUM
CONGRESO REGIONAL DE ECONOMÍA AGRARIA
1st Latin-American Workshop on Productivity and Efficiency

GM technology over the agricultural productivity in Brazilian Cerrado

GM technology over the agricultural productivity in Brazilian Cerrado

Introduction

- Advances in agricultural investments R&D in new technologies can drive the sector's productivity
    - Agricultural Biotechnology $\rightarrow$ Increase productivity and diminish environmental footprint
- Relevance of Brazil in the agricultural production context $\rightarrow$ Maize and Soybeans
    - Cerrado region of Brazil and its waves of occupation

- Brazilian Biosafety Law (2005)
- Fast spread of GM seeds in Brazilian Crops
  - 94% of cotton Crops (2018)
  - 92.3% of soybeans Crops (2018)
  - 86.7% of maize winter Crops (2018)
  - 74.7% of maize summer Crops (2018)
- Advances over the Last Brazilian Agricultural Frontier - MATOPIBA
- Study aims to explore and measure the effects on agricultural productivity of GM technology in the Cerrado
- Examines elements that impact the technical efficiency of agricultural production in the biome
- Paper's Contribution:
  - Offer empirical analysis of the productivity impact of GM technology
  - Verify the results of productivity on MATOPIBA region

GM technology over the agricultural productivity in Brazilian Cerrado

Theoretical Model

- Stochastic Frontier Model with Technical Inefficiency Specification

$$y_{it} = f(X_{it}\beta)e^{v_{it}-u_{it}}$$

where X_{it} is the input of locality i at time t; v_{it} is the random error term; u_{it} is a non-negative random term associated with the effects related to technical inefficiency of production.

- Technical Efficiency ($0 < TE < 1$):

$$\begin{aligned} TE_{it} = & \quad \frac{y_{it}}{y_{it}^*} \\ = & \quad E[e^{(-u_{it})}|\epsilon] \end{aligned}$$

- Marginal effect of the exogenous variable on efficiency:

$$\frac{\partial TE_{it}}{\partial z_{kit}}$$

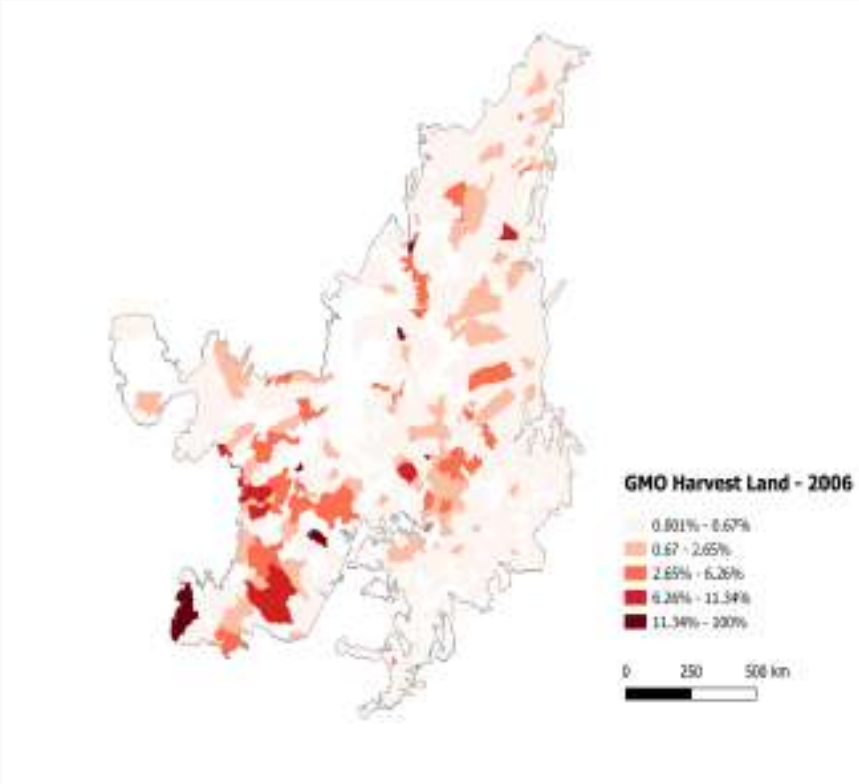
GM technology over the agricultural productivity in Brazilian Cerrado

Empirical Model anda Data

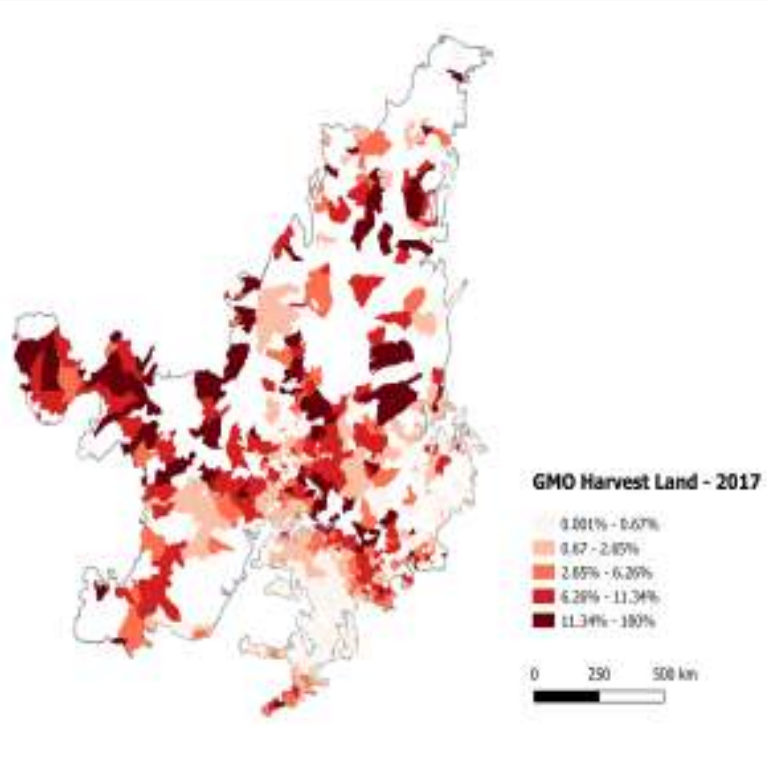
Data

- Agricultural Censuses 2006 and 2017: Pooled estimated via MLE (KUMBHAKAR; WANG; HORNCASTLE, 2015)
- 1390 municipalities from 10 states - At least 50
    - 322 of the 337 MATOPIBA municipalities are in the Cerrado biome
- Output: Gross Value of Agricultural Production - Sum of all agricultural production in the municipality, at 2017 prices (2006 was deflated by IGP-DI)
- Stochastic Frontier:
    1. Labor: Number of rural workers
    2. Land: Agricultural area (Ha)
    3. Capital: Number of tractors
    4. GMO: $\frac{GMHarvestedArea}{TotalHarvestedAreainTemporary\ \ Crops}$

Evolution of the Percentage of Harvested Area of GM Plants



(1.1) 2006



(1.2) 2017

Data

- Inefficiency Control:
  1. *Schooling* is the percentage of properties in the municipality whose manager has at least a bachelor's degree;
  2. *Social Capital* is the percentage of agricultural land in the municipality that is associated with a Cooperative or class entity;
  3. $AI = \frac{AnnualAveragePrecipitation}{AnnualAveragePotentialEvapotranspiration}$ (Davis, 2014) Proxy for agricultural potential: High values of the index identify more humid areas;
  4. *Size*1: is the % of agricultural land in properties from 0 to 5 ha;
  5. *Size*2: is the % of agricultural land in properties from 5 to 20 ha;
  6. *Size*4: is the % of agricultural land in properties from 100 to 500 ha;
  7. *Size* 5: is the % of agricultural land in properties with more than 500 ha.

Empirical Model

$$ln\ Y_{i,t} = \beta_0 + \sum_{k=1}^{4} \beta_k X_{i,k} + 0.5 \sum_{k=1}^{4} \sum_{j=1}^{4} \beta_{kj} X_{i,k} X_{i,j} + \alpha_0 t + \sum_{k=1}^{4}$$

$$+ \mu_i\ M_i + \sum_{h=1}^{9} \gamma_i\ FS_i + v_i - u_i$$

where $Y_{i,t}$ is the Gross Agricultural Production Value; $X_k and X_j$ represent: (ln *Land*, ln *Labor*, ln *Capital* and *GMO*); M_i is the MATOPIBA Dummy; and FS_i represents the State dummies

- Half-normal distribution of the inefficiency term: $[u \sim i.i.d\ N^{+}(0, \sigma_u)]$:
- The parameterization of the inefficiency term is based on its variance:

$$u_{it} = f(Schooling_{i,t}; TA_{i,t}; Coop_{i,t}; IA_{i,t}; Size\ 1_{i,t}; Size\ 2_{i,t}; Size\ 4_{i,t}; Size\ 5_{i,t})$$

where $u_{i,t}$ is the inefficiency term; *Schooling* is schooling level; *Coop* is social capital; *TA* is technical assistance; *IA* is the Local Aridity Index; $Size_1$, $Size_2$, $Size_4$, and $Size_5$ are the property size characteristics according to Helfand and Taylor (2020).

Table 1: Descriptive Statistics for agricultural inputs and output in Brazilian Cerrado - 2006 and 2017

		2006				2017			
	Unit	Mean	DP	Min	Max	Mean	DP	Min	Max
Output	*R*$ 1000.00	87172.1	150804.2	233.8	1725491	156517.4	287622.9	286	3248127
Capital	of Tractors	208.3	269.9	0	2424	302	384.2	0	3777
Land	Ha	112630.1	208973.2	351	5000952	119298.5	215239.8	31	5000982
Labor	of Workers	3500.8	3732.8	59	33284	2514.0	2372.3	0	21812
GMO	%	0.0185	0.0604	0	1	0.1940	0.2593	0	.9530
Schooling	%	0.0734	0.0763	0	0.6190	0.1313	0.0957	0	.5000
Social Capital	%	0.3927	0.2396	0	0.9987	0.1389	0.1667	0	0.7987
Farm Size 1	%	0.0061	0.0121	0	0.1129	0.0099	0.0494	0	0.9934
Farm Size 2	%	0.0376	0.0427	0	0.3384	0.0381	0.0439	0	0.3864
Farm Size 3	%	0.1738	0.1252	0	0.8766	0.1665	0.1208	0	0.7098
Farm Size 4	%	0.2833	0.1450	0	0.8822	0.2494	0.1380	0	0.8499
Farm Size 5	%	0.3942	0.3036	0	0.9971	0.3345	0.2846	0	0.9949
Precipitation	mm	122.6	23.8	0	200	120.8	22.9	200.8	0
Evapotranspiration	mm	4.4	0.2	5.1	3.9	3.8	0.3	5.3	2.9

GM technology over the agricultural productivity in Brazilian Cerrado

Results

Table 2: Estimated Production Elasticities/Semi-Elasticity at the mean level for Cerrado

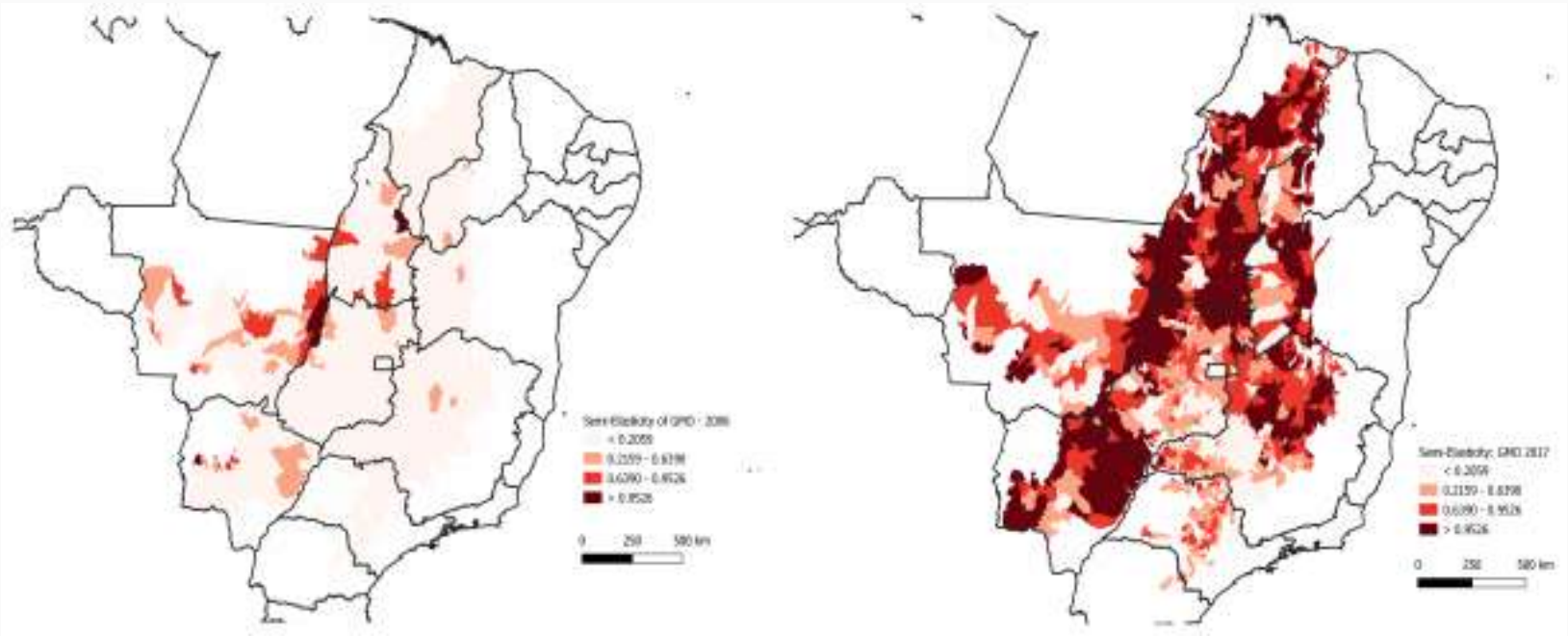
	Model I	Model II	Model III	Model IV
s_{Land}	0.073***	0.117***	0.119***	0.174***
	(0.0146)	(0.0173)	(0.0187)	(0.0214)
$s_{Capital}$	0.917***	0.804***	0.855***	0.774***
	(0.0151)	(0.0180)	(0.0194)	(0.0210)
s_{Labor}	0.060***	0.128***	0.065***	0.091***
	(0.0170)	(0.0202)	(0.0196)	(0.0217)
s_{GMO}	0.157	0.2513	0.300*	0.349**
	(0.1862)	(0.1783)	(0.1840)	(0.1760)
TC	0.161**	0.191***	0.151***	0.170***
	(0.0355)	(0.040)	(0.035)	(0.041)
FS	No	Yes	No	Yes
Inefficiency Control	No	No	Yes	Yes

$^{***}p < 0.01;^{**}p < 0.05;^{*}p < 0.1$

Source: Research Results

- Relevance and impact of mechanization on Cerrado's agricultural production;
    - Fit well with the kind of crops $\rightarrow$ 74.49% of total planted area in 2017 was devoted to cotton, soybean ($\uparrow$ 228%) and maize ($\uparrow$ 101%)
    - Labor decreased, between 2006 and 2017, by almost 28.18%, while Land increased 6%;
- Mechanical technologies + GMO technology = $\downarrow$ the demand for labor in the agricultural sector, as described in Bustos (2006);
- TC: Annual average productivity gains of 1.014%
- A one percentage point increase in the planting of GMO seeds increases the output by 0.364%
- MATOPIBA: 17.6% higher than the other parts of Cerrado

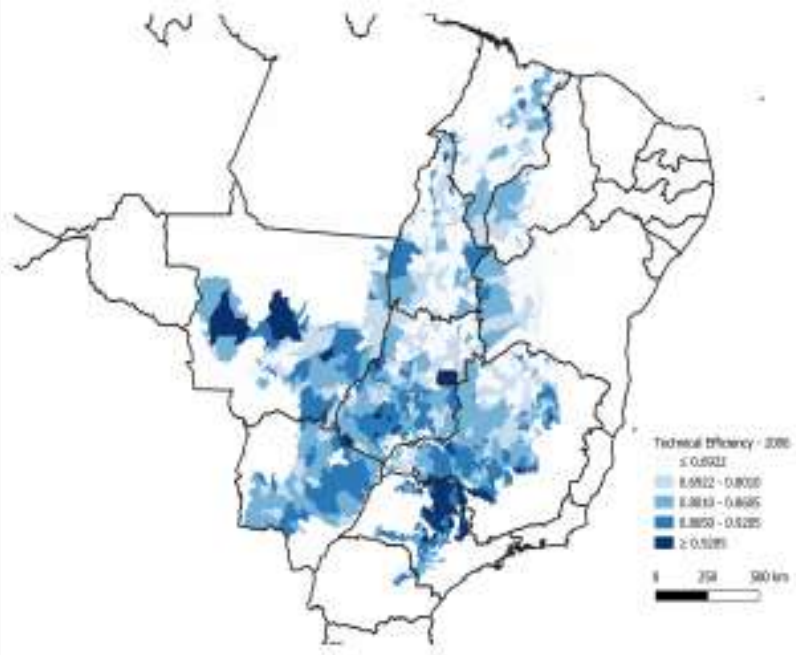
GM Semi Elasticity, per municipality



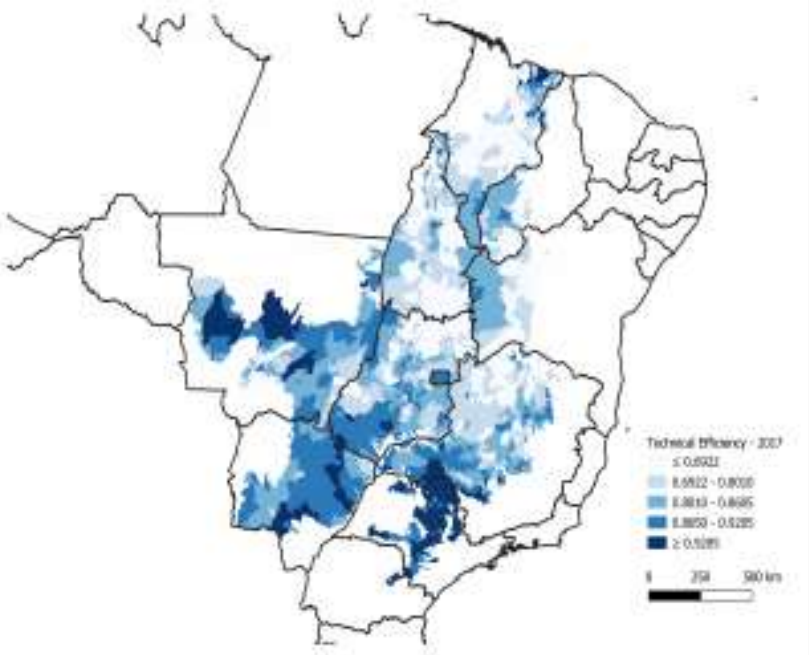
(1.3) 2006

(1.4) 2017

Technical Efficiency rate, per municipality



(1.5) 2006



(1.6) 2017

Table 3: Technical Efficiency Exogenous Control

Size 1 (0 - 5 ha)	-1.073
	(5.153)
Size 2 (5 - 20 ha)	-4.626
	(3.487)
Size 4 (100 - 500 ha)	5.713***
	(0.922)
Size 5 (+ 500 ha)	1.694***
	(0.604)
Schooling	-7.408*
	(2.307)
Social Capital	-1.573***
	(0.426)
Aridity Index	-0.110***
	(0.0178)
Constant	-0.194
	(0.637)

Source: Research Results

GM technology over the agricultural productivity in Brazilian Cerrado

Conclusion

- Genetic technology applied in agriculture is a relevant factor to support the comprehension of the technological change of the activity
- The advance of 1 percentage point of harvested land planted with GMO seed increases, on average, the production by 0.364%
- Some regions, such as the North of MS, and especially agricultural areas from Tocantins and Maranhão showed the highest results of the technological implementation.

Thanks

pablomguima@ufrrj.br