Unlocking agricultural potential: an opportunity cost analysis in Brazil

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Impact of agricultural practices on Brazilian agriculture productivity evolution

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Introduction

- Agricultural activities promote changes in the biological, physical, and chemical processes of the environment.
- Implementing conservation practices such as crop rotation, green manure, and the no-till system, can help reduce or mitigate the negative effects of agricultural production.
- The adoption of these practices has the potential to improve both crop productivity and the efficient use of resources.

Objective

- I analyze the impact of adopting agricultural practices on the evolution of productivity of Brazilian agriculture accounting for GHG emissions from agricultural and livestock activities.

Methods

- I use the Data Envelopment Analysis (DEA) and output-oriented Malmquist–Luenberger (ML) productivity index based on the Output Directional Distance Function (ODDF).
- Regional models.
- ML productivity index can be decomposed into two components: environmental efficiency and technical changes between two periods.
- The directional vector is defined as the observed values for desirable and undesirable outputs.
- A second-stage analysis involves running a fractional probit regression to analyze the impact of the adoption of agricultural practices on the evolution of productivity and its components.

Data

- Panel of 588 microregional data from the 2006 and 2017 Agricultural Censuses and the Greenhouse Gas Emission Estimation System (SEEG).
- For the second stage, I selected two groups of variables. In the first group, I use the area utilized with irrigation, no-tillage, planting in contour lines, crop rotation, fallow soil, and slope protection/conservation as a proportion of the area available for agricultural and livestock activities.
- In the second group, we use internet access, higher education, energy access, storage capacity, technical assistance, credit access, pesticides, and conditions with respect to the land and association.
- Inspection and outliers: 112 DMUs were removed due to their atypical influence.

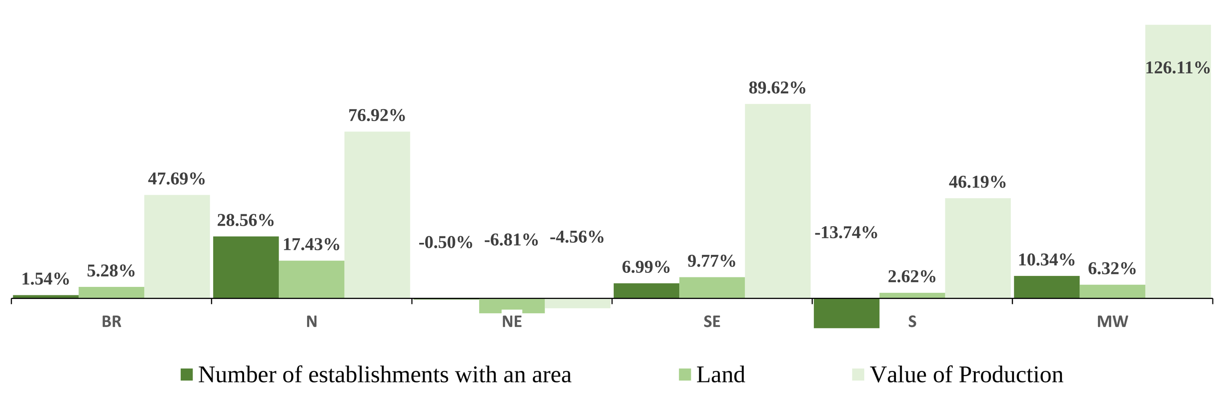
Table 1. Summary statistics of the variable for microregions in 2006 and 2017

	2006				2017			
	Mean	Std. Dev	Min.	Max	Mean	Std. Dev	Min.	Max
Output								
Livestock's VP (Mi US$)*	50.13	64.41	0.04	560.81	85.27	102.06	0.04	754.09
Agriculture's VP (Mi US$)*	119.25	155.58	0.19	1252.85	165.07	294.23	0.26	3138.18
GHG Emission (Mi ton CO2e)	0.89	1.17	0.00	8.17	0.97	1.32	0.00	8.04
Input								
Land (1,000 hectare)	418.79	518.99	0.08	4730.40	440.03	570.60	0.02	4225.81
Capital (1,000 units)	1.47	1.86	0.00	12.00	2.20	2.71	0.00	16.01
Labor (1,000 people)	29.69	25.14	0.07	162.95	27.07	21.83	0.03	140.21
Expenditure (Mi US$)*	72.72	138.33	0.07	1416.53	115.13	182.82	0.06	1885.33

Notes: * Monetary values were converted from Real (R$) of 2017 to US Dollars (US$) considering an exchange rate of 3.31 *R$*/US$.

Results

Figure 1. Evolution of Value of Production, Number of establishments with area, and Area of establishments (Land) in Brazil and Regions



- The value of Production (VP) in 2006 was US$95.14 billion, while in 2017, it was US$140.52 billion, showing a growth of 47 .69%. The variation of the VP does not follow a pattern.
- Variations in the number and area of establishments can provide us some initial insights into the possible causes and magnitudes of variations in the VP.
- The growth in VP in Brazil (+47.69%) is not fully explained by the increases in the number of establishments with an area (+1.54%) and in the total area of establishments (+5.28%). The result suggests that this increase may be linked to the productivity gains of agricultural activities and the improvement in the prices of agribusiness products.
- Recent works point to an increase in the productivity of Brazilian agriculture.
- Despite their productivity gains in the period and their importance to the economy in general, whether through income and employment generation, agricultural and livestock activities are subject to negative externalities, such as the emission of GHGs.
- In 2017, emissions from the agriculture sector totaled 561.76 million tons of CO_2 equivalent, an increase of 8.54% compared to 2006.

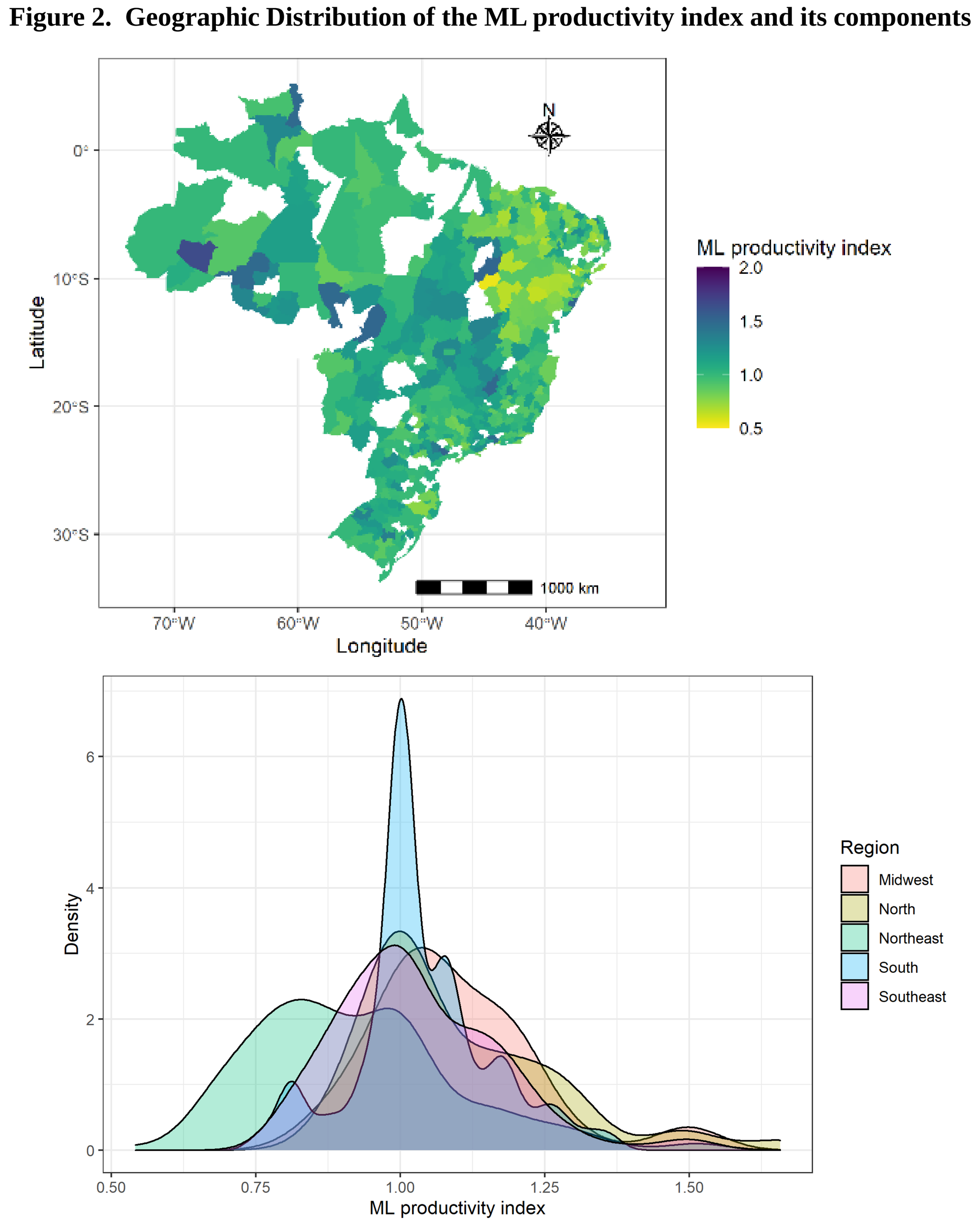
Productivity analysis

- Based on the ODFF, the average productivity in agriculture and livestock remains almost unchanged over 2006-2017 (1.006), mainly influenced by the opposite results presented by its components.
- The decomposition results show that although average environmental efficiency (MLEEC) increased (3.4%) over the period, technical changes (MLTC) fell (1.8%).
- The values of the productivity indexes by regions indicate that all Brazilian regions, on average, presented TFP expansion, except for the Northeast region. For the North and Mid-West regions, the engine of growth was the technological progress since that was a regress in environmental efficiency. On the other hand, for the Southeast and South regions, the growth driver was the expansion of environmental efficiency since, on average, a technical regress was observed.

Table 2. The ML productivity index and its components by Regions and Federal units

Region	Federation Unity	ML index			Envir. Eff. Change			Tech. Change		
		Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
North		**0.893**	**1.100**	**1.657**	**0.674**	**0.994**	**1.522**	**0.939**	**1.112**	**1.388**
	Acre	1.00	1.01	1.06	1.00	1.03	1.13	0.94	0.99	1.00
	Amapá	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Amazonas	0.90	1.11	1.66	0.81	1.02	1.52	1.00	1.09	1.18
	Pará	0.90	0.98	1.04	0.67	0.95	1.09	0.96	1.05	1.39
	Rondônia	0.96	1.24	1.49	0.92	1.04	1.32	1.04	1.19	1.26
	Roraima	0.89	1.16	1.49	0.68	1.00	1.28	1.09	1.17	1.31
	Tocantins	1.02	1.17	1.27	0.82	0.95	1.00	1.14	1.24	1.35
Northeast		**0.541**	**0.920**	**1.513**	**0.549**	**1.041**	**1.720**	**0.662**	**0.895**	**1.250**
	Alagoas	0.66	0.83	1.16	0.64	0.90	1.36	0.77	0.95	1.25
	Bahia	0.64	0.88	1.51	0.66	1.03	1.52	0.67	0.88	1.20
	Ceará	0.67	0.90	1.21	0.74	1.04	1.46	0.72	0.87	1.03
	Maranhão	0.69	0.94	1.28	0.84	1.11	1.64	0.70	0.85	1.00
	Paraíba	0.70	0.93	1.26	0.68	0.98	1.37	0.76	0.95	1.18
	Pernambuco	0.75	0.94	1.12	0.82	1.00	1.29	0.74	0.95	1.10
	Piauí	0.54	0.93	1.51	0.55	1.15	1.72	0.67	0.81	0.99
	Rio Grande do Norte	0.73	1.01	1.30	0.77	1.08	1.37	0.73	0.94	1.09
	Sergipe	0.73	0.93	1.18	0.75	1.06	1.60	0.66	0.90	1.13
Southeast		**0.794**	**1.030**	**1.516**	**0.719**	**1.045**	**1.593**	**0.617**	**0.993**	**1.254**
	Espírito Santo	0.83	0.99	1.20	0.87	1.12	1.56	0.62	0.90	1.10
	Minas Gerais	0.87	1.07	1.50	0.83	1.07	1.59	0.80	1.01	1.25
	Rio de Janeiro	0.79	1.01	1.47	0.74	1.02	1.37	0.84	0.99	1.23
	São Paulo	0.79	1.00	1.52	0.72	1.01	1.44	0.71	1.00	1.25
South		**0.759**	**1.035**	**1.360**	**0.759**	**1.045**	**1.362**	**0.855**	**0.993**	**1.157**
	Paraná	0.81	1.05	1.28	0.87	1.07	1.36	0.85	0.99	1.08
	Rio Grande do Sul	0.88	1.07	1.36	0.90	1.08	1.29	0.88	0.99	1.09
	Santa Catarina	0.76	0.95	1.12	0.76	0.94	1.19	0.93	1.01	1.16
Midwest		**0.843**	**1.092**	**1.509**	**0.711**	**0.986**	**1.343**	**0.986**	**1.111**	**1.392**
	Distrito Federal	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Goiás	0.95	1.09	1.30	0.81	1.00	1.18	0.99	1.09	1.31
	Mato Grosso	0.84	1.12	1.51	0.71	1.01	1.34	1.00	1.11	1.20
	Mato Grosso do Sul	0.89	1.07	1.19	0.77	0.91	1.00	1.00	1.18	1.39
	Brazil	**0.541**	**1.006**	**1.657**	**0.549**	**1.034**	**1.720**	**0.617**	**0.982**	**1.392**

Figure 2. Geographic Distribution of the ML productivity index and its components



The impact of the adoption of agricultural practices

- Among the evaluated practices, only irrigation and no-till showed positive and significant effects when considering the level of adoption in 2017. However, they influence only the productivity index and the change component of environmental efficiency.
- In relation to no-tillage, in 2017, 553,382 producers declared that they proceeded with no-till, with a total of 33,052,969 hectares. Compared to 2006, this modality had an increase of 9% in the number of establishments and an increase of 85% in the area with no-tillage.
- Regarding irrigation, in 2017, 10% of establishments used irrigation techniques (flood, infiltration, sprinkler, or similar). The irrigated area comprised 6.7 million hectares or 10% of the total area with temporary and permanent crops, corresponding to an increase of 48% compared to 2006.
- When considering the speed of change in adoption, irrigation had a negative effect on the productivity index and on the environmental efficiency change component.
- The effect was positive for no-tillage.
- The speed of change in the adoption of the counter lines practice had a positive impact on the productivity index and the technological change.

Table 3. Margins effects of agricultural practices' adoption

Variable	ML index	Env. Eff. Change	Tech. Change
Irrigation	0.0718	0.0926	
No-tillage	0.1126	0.101	
Δ Irrigation	-0.0156	-0.0126	
Δ No-tillage	0.0054	0.0177	
Δ Contour lines	0.1236		0.069

Conclusion

- The present study found that agricultural productivity showed modest growth between 2006 and 2017, reflecting the behavior of its components—environmental efficiency and technological changes. In essence, most of the analyzed micro-regions showed advances in environmental efficiency, while most showed technological regression.
- When evaluating the impact of adopting agricultural practices, in general, there were positive impacts of adopting irrigation, no-tillage, and Contour lines practices. Only the speed of adoption of the agricultural practice evidenced a negative impact on the productivity index and on the component of technological change.

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