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Assessing the Gap between GHG Emissions and Productivity in Brazilian Agriculture

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Abstract: Brazil's agricultural sector has seen significant economic growth due to increased productivity, yet its greenhouse gas (GHG) emissions have risen by about 2.5% annually. This study examines Total Factor Productivity (TFP) and GHG emissions in Brazilian municipalities from 2006 to 2017. It compares standard TFP measures with those considering GHG emissions, finding lower growth and efficiency in the latter. TFP growth didn't lead to emissions reduction; 65% of municipalities didn't control emissions while improving productivity. The study also highlights the need to monitor environmental efficiency in Brazilian agriculture, a topic overlooked in existing literature.

Keywords: GHG emissions, Total Factor Productivity, Green productivity

JEL Classification Number:Q10, Q53, O44

1. Introduction

The Brazilian agriculture sector was responsible for a substantial economic growth, much of which was owing to the stable Total Factor Productivity (TFP) growth in the last decades (Bragagnolo et al., 2010; Gasques et al., 2014; Pereira et al., 2012). Bragagnolo et al. (2010) pointed that, from 1975 to 2005, while the output increased 2.4% per year, the TFP raised 3.1% per year. Most recently (1995-2017), the TFP remained stable, with approximate 3.0% growth per year (Bragagnolo et al., 2021), which illustrates its importance bound to the economic performance of the agriculture sector.

Considering the substantial impact of the agriculture sector in Brazil's GHG emissions, we ask how much of the sector's thriving economic performance was based upon the generation of environmentally undesirable by-products. The practical importance to consider the harmful environmental impacts in agriculture's productivity analysis is to shed a light on which interventions and public policies would enable a better

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environmental performance to Brazilian's agriculture sector, as well as to measure their results. As far as we know, this is the first study to assess the variation in GHG emissions related to the changes in Brazilian's agricultural TFP.

Our main objective is to assess and compare the Brazilian's TFP growth in the agriculture sector by considering undesirable by-products (i.e., GHG) with measurements that do not.

2. Methodology and data

We will employ the Malmquist – *M* – (Färe et al., 1994b) and the Generalized Malmquist – *GM* – (Pastor and Lovell, 2005) methods to calculate the standard measurement of the productivity; while the environmentally sensitive measurement of productivity (i.e., considering the GHG emissions) is assessed by the Malmquist-Lundemberg – *ML* – (Chung et al., 1997) and the Generalized Malmquist-Lundemberg – *GML* – (Oh, 2010a, 2010b) methods.

Oh (2010b) categorizes the sample's outcomes using color codes: i) green indicates countries where environmentally sensitive productivity measures (*GML* or *ML*) surpass standard measures (*GM* or *M*) correspondingly; ii) yellow denotes countries where environmentally sensitive productivity is lower than the standard, suggesting TFP growth prioritizes economic activity over the environment. This study adopts Oh (2010b) categorization, classifying municipalities as green if $GML>GM$ or $ML>M$, and yellow if $GML<GM$ or $ML< M$.

As for the data, we employed data of 2006 and 2017, from the Brazilian Census of Agriculture (2006, 2017) and Municipality Agricultural Production (PAM), which were retrieved from the Brazilian Institute of Geography and Statistics (IBGE). Concerning GHG emissions, we consulted the Greenhouse Gas Emission and Removal Estimating System (SEEG) database. We employed municipality data level of aggregation, from which we excluded from the sample the observations whose information was lacking for at least one variable and for both 2006 and 2017. The final sample consisted in 3,959 municipalities for the years of 2006 and 2017, which consists of 7,918 observations.

3. Empirical Results and Discussion

Table 1 shows the weighted average (by the GPV) of productivity growth, the technical efficiency change, and the technological change for Brazilian states. The productivity indexes displayed are the GML (Oh, 2010a, 2010b), ML(Chung et al., 1997), GM (Pastor and Lovell, 2005) and M (Färe et al., 1994b), for the period between 2006 and 2017.On the one hand, since the indexes returned values higher than one for most of the states, the results indicated a positive TFP growth (Table 1). The state of Amapá was the only one that presented values for the GM and M productivity indexes below one, which would indicate a decrease in the TFP. All other states presented values for the GM and M indexes higher than one, which indicates growth in TFP. On the other hand, for the environmentally sensitive measurement methods (*GML* and *ML*), not only there was a strong indication of lower TFP growth, compared to the standard methods, but also eight states presented productivity indexes below one, indicating TFP decrease. The greatest productivity gain was from Amazonas state in all indexes. The slightest environmentally sensitive TFP change was of Espírito Santo. As for the standard TFP, Amapá state presented the slightest change in TFP.

The results concerning technical efficiency change (*EC*) were substantially distinct when GHG emissions were considered (*GML* and *ML*), compared to the standard TFP measures (*GM* and *M*) (Table 1). Meanwhile results for most Brazilian states and the whole country indicated a decrease in *EC* (lower than one), according to the *GML* and *ML* methods, the *GM* and *M* reported increasing values for *EC.*

Table 1: Productivity growth indexes (*GML, ML, GM* and *M*), technical efficiency change (*EC*) and technological change (*BPC* and *TC*) in the agriculture sector for Brazilian states (2006-2017)

State	*GML*			*ML*			*GM*			*M*		
	Prod.	*EC*	*BPC*	Prod.	*EC*	*BPC*	Prod.	*EC*	*TC*	Prod.	*EC*	*TC*
AC	1.0009	0.9979	1.0030	1.0012	0.9979	1.0033	1.2258	1.0903	1.1181	1.2859	1.0903	1.1698
AL	1.0104	1.0529	0.9875	1.0427	1.0529	1.0051	1.7052	1.7547	0.9632	1.6958	1.7547	0.9486
AP	1.0044	0.9745	1.0361	0.9945	0.9745	1.0235	0.7830	0.6983	1.1934	0.7476	0.6983	1.1275
AM	1.3861	1.3540	1.0248	1.5024	1.3540	1.0874	4.8099	4.4017	1.1076	4.7530	4.4017	1.1190
BA	1.1118	0.9594	1.1819	1.1535	0.9594	1.2116	1.6879	1.7753	0.9921	1.6808	1.7753	0.9937
CE	1.0294	0.9847	1.0511	1.0553	0.9847	1.0717	1.6785	1.6858	1.0451	1.6590	1.6858	1.0269
ES	0.9644	0.9014	1.0784	0.9590	0.9014	1.0667	1.2135	1.0498	1.1651	1.2385	1.0498	1.1967
GO	1.0522	0.9987	1.0544	1.0924	0.9987	1.0955	2.0521	1.8171	1.1413	2.0638	1.8171	1.1505
MA	1.1805	1.1037	1.0544	1.2199	1.1037	1.0984	2.5851	2.8649	0.9418	2.4946	2.8649	0.9050
MG	1.0008	0.9554	1.0501	1.0173	0.9554	1.0670	1.4725	1.0996	1.3375	1.4850	1.0996	1.3430
MS	1.0456	1.0024	1.0440	1.0967	1.0024	1.0953	2.3018	2.3001	1.0073	2.2833	2.3001	1.0046
MT	1.1593	1.0876	1.0684	1.1683	1.0876	1.0794	2.1524	2.4109	0.9002	2.1079	2.4109	0.8836
PA	1.0750	1.0482	1.0255	1.1398	1.0482	1.0723	2.0778	1.8723	1.0958	2.1027	1.8723	1.1023
PB	0.9973	0.9711	1.0496	0.9794	0.9711	1.0063	1.2288	1.1861	1.0323	1.1976	1.1861	0.9868
PE	1.0691	0.9987	1.0668	1.0799	0.9987	1.0770	1.2055	1.0711	1.1568	1.2060	1.0711	1.1398
PI	1.2272	1.1823	1.0369	1.3094	1.1823	1.1049	3.0651	3.7639	0.8315	3.0334	3.7639	0.8215
PR	1.0077	0.9689	1.0427	1.0509	0.9689	1.0872	1.7255	1.4014	1.2471	1.7628	1.4014	1.2773
RJ	1.1611	1.0990	1.0531	1.2181	1.0990	1.0890	1.9322	1.6070	1.2140	1.9787	1.6070	1.2390
RN	1.0184	0.9842	1.0372	1.0197	0.9842	1.0370	2.1349	2.0869	0.9884	2.1937	2.0869	1.0106
RO	1.0077	1.0039	1.0038	1.0195	1.0039	1.0155	2.5132	2.3083	1.1068	2.5683	2.3083	1.1240
RR	0.9870	0.9767	1.0102	1.0010	0.9767	1.0243	1.3054	1.1773	1.1182	1.3515	1.1773	1.1325
RS	1.0000	0.9686	1.0388	1.0233	0.9686	1.0594	1.7825	1.3877	1.2987	1.8176	1.3877	1.3215
SC	1.0058	0.9796	1.0269	1.0117	0.9796	1.0296	1.5994	1.2355	1.3024	1.6207	1.2355	1.3124
SE	0.9969	0.9758	1.0222	0.9966	0.9758	1.0214	2.2376	2.0154	1.1101	2.2323	2.0154	1.1249
SP	1.0063	0.9092	1.1209	1.0457	0.9092	1.1593	1.3908	1.0716	1.3247	1.4123	1.0716	1.3393
TO	1.0168	0.9931	1.0251	1.0211	0.9931	1.0288	2.3317	2.1378	1.0795	2.4137	2.1378	1.1251
BR	1.0490	0.9895	1.0662	1.0786	0.9895	1.0940	1.8159	1.6526	1.1639	1.8237	1.6526	1.1723

By and large, there was a positive technological change in Brazilian agriculture sector during the period from 2006 to 2017 (Table 1). Regarding technological changes (*BPC*), for models *GML* and *ML*, the environmentally sensitive TFP measure indicated an increase in the growth rate, except for Alagoas, by the *GML* method, and an increase in the growth rate for all other states and Brazil by the *ML* method (Table 1). Concerning technological changes (*TC*), for models *GM* and *M*, results indicated an increasing growth in the indexes for most of the states, except for Alagoas, Bahia and Maranhão, in the Northeast of Brazil, as well as for Piauí and Rondônia, in the North of Brazil, and for Mato Grosso, located in the Midwest.

Figure 1 illustrates the quintile spatial distribution of productivity growth for sample's municipalities for contemporaneous TFP methods: *M* and *ML* from 2006 and 2017. Like Figure 1, Figure 2 displays the quintile spatial distribution of productivity growth for global TFP methods: *M* and *ML* from 2006 and 2017. Once again, in general, as we can see in the maps presented in Figures 1 and 2, the growth of TFP is lower for municipalities in environmentally sensitive models when compared to standard models.

Figure 1: Spatial distribution of *M* and *ML* productivity growth measures for Brazilian municipalities (2006 to 2017)

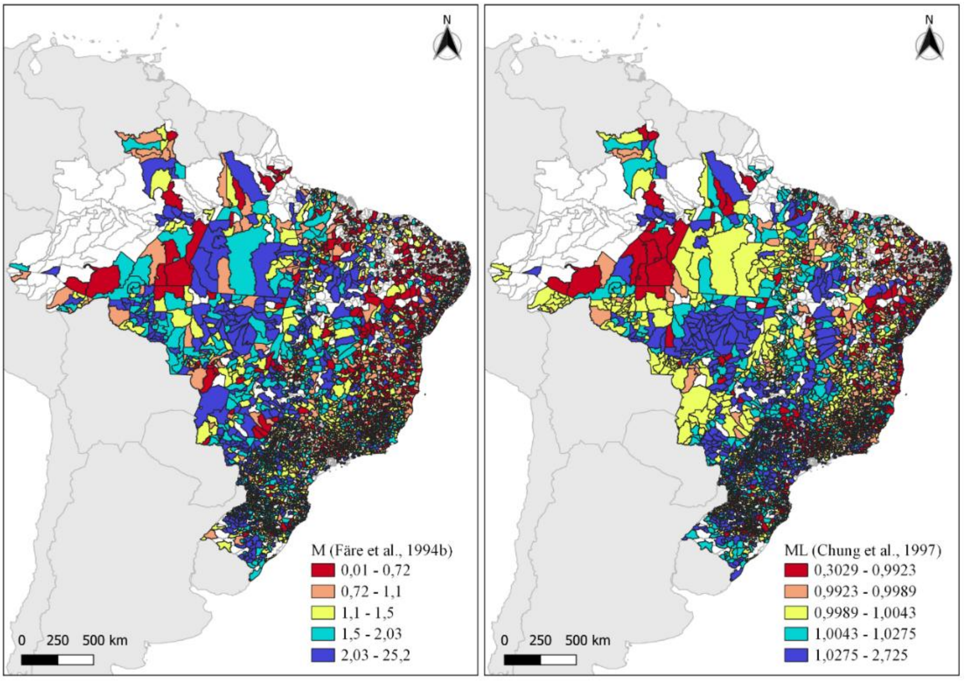


Figure 2: Spatial distribution of *GM* and *GML* productivity growth measures for Brazilian municipalities (2006 to 2017)

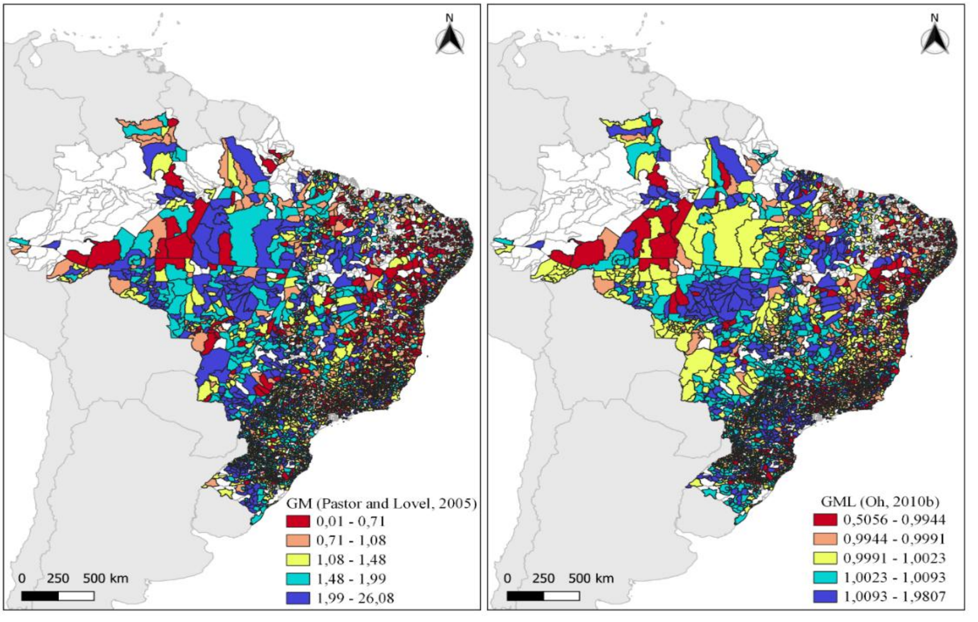


Table 2 shows the simple and the GPV weighted averages of the annual growth rates of the output, technical efficiency change (*EC*)and technological change (*TC*)for Brazilian municipalities in the sample of the study, from 2006 to 2017.

Table 2: Simple and GPV weighted averages of annual growth rates of productivity, technical efficiency change, and technological change, Brazil (from 2006 to 2017)

Method	Variable	Annual growth rate
GML	Productivity	0.40%
	Technical efficiency	-0.09%
	Technological change	0.54%
ML	Productivity	0.63%
	Technical efficiency	-0.09%
	Technological change	0.75%
GM	Productivity	5.10%
	Technical efficiency	4.28%
	Technological change	1.27%
M	Productivity	5.13%
	Technical efficiency	4.28%
	Technological change	1.33%

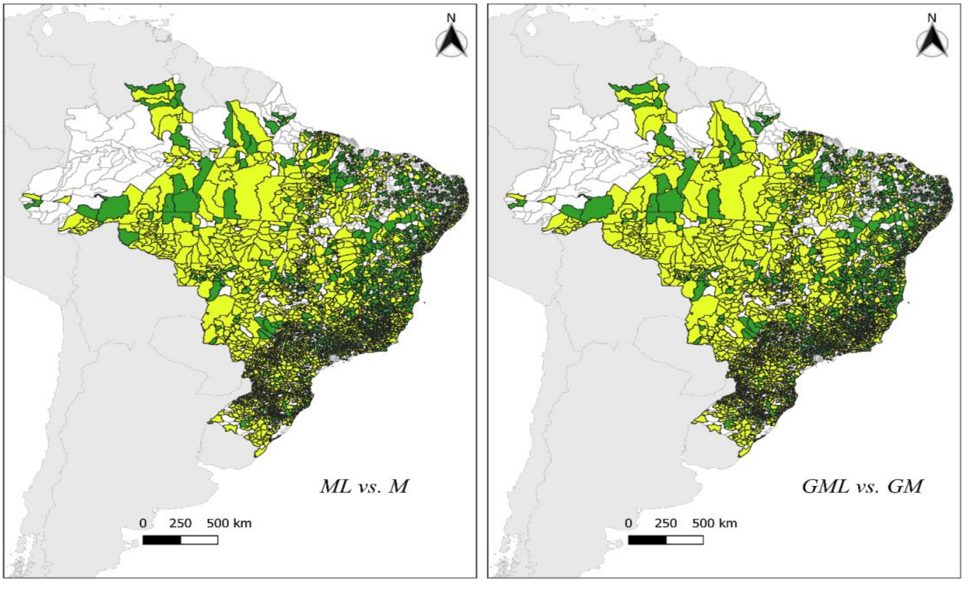
The quantity (number) and the corresponding proportion (%) of green (i.e., *GML* > *GM* and *ML* > *M*) and yellow municipalities are displayed in Table 3, for Brazil and by Brazilian states.

Table 3: Quantity and proportion of municipalities within Brazilian states classified as green by the comparison between *GML* against GM and ML against *M*

State	Number of municipalities	*GML* vs. *GM*		*ML* vs. *M*	
		Number of green municipalities	Percentage of green municipalities	Number of green municipalities	Percentage of green municipalities
AC	12	2	16.7%	2	16.7%
AL	60	26	43.3%	26	43.3%
AP	4	3	75.0%	3	75.0%
AM	21	6	28.6%	6	28.6%
BA	316	204	64.6%	206	65.2%
CE	100	52	52.0%	50	50.0%
ES	72	24	33.3%	24	33.3%
GO	192	50	26.0%	51	26.6%
MA	132	62	47.0%	66	50.0%
MG	682	362	53.1%	353	51.8%
MS	75	10	13.3%	10	13.3%
MT	130	22	16.9%	22	16.9%
PA	105	24	22.9%	24	22.9%
PB	78	55	70.5%	55	70.5%
PE	102	63	61.8%	63	61.8%
PI	92	37	40.2%	34	37.0%
PR	360	51	14.2%	41	11.4%
RJ	66	19	28.8%	16	24.2%
RN	64	37	57.8%	37	57.8%
RO	52	2	3.8%	2	3.8%
RR	14	4	28.6%	5	35.7%
RS	400	67	16.8%	62	15.5%
SC	232	44	19.0%	43	18.5%
SE	51	22	43.1%	22	43.1%
SP	445	142	31.9%	140	31.5%
TO	102	20	19.6%	22	21.6%
BR	3959	1410	35.6%	1385	35.0%

The classification of sample's municipalities by color (i.e., green for environmentally sensitive or green TFP greater than standard TFP, and yellow stands for the opposite) is displayed in Figure 3. From left to right, the first map shows the results of contemporaneous technology TFP productivity measure: the *ML*, which is the environmentally sensitive TFP, against *M*, which is the standard TFP. The second map illustrates the comparison for global indexes that are: the *GML* – environmentally sensitive, against *GM* – standard.

Figure 3: Spatial distribution of green and yellow Brazilian municipalities in the sample, classified by *GML* against *GM* and *ML* against *M*



4. Summary and Conclusions

To our sample of 3,959 municipalities, 35% of them were classified as in green, which indicates that the growth of the environmentally sensitive TFP was higher than the standard TFP's. The green classification indicates that the economic growth occurred simultaneously to an emissions reduction. Conversely, as for most municipalities (65%), the yellow color classification indicated that the pursue of economic growth was not followed by a steady control of GHG emissions. This proportion is even higher in traditional agricultural production states.

Our results indicated that public policies that target exclusively at TFP growth can be lacking considerable environmental concern, as our green, or environmentally sensitive, productivity measures showed that the emission increase that occur with these productivity gains are substantial and that, when these emissions are accounted for, the TFP growth is significantly reduced. In addition, we can also see a considerable reduction in efficiency change in green productivity models compared to standard productivity models. Thus, it can be inferred that the standard TFP measures mask the productive inefficiencies resulting from the emission of GHG in Brazilian agricultural production and, consequently, overestimate productivity growth measurement.

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