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Socioeconomic efficiency of the Araguaia River Valley – Goiás: a deterministic frontier and Malmquist index approach

The present study aimed to evaluate socioeconomic efficiency in 41 Brazilian municipalities in the years 2014 and 2016 in the area comprised by the Araguaia River Valley, in the Central-West, Goiás state, Brazil. We used the data envelopment analysis and Malmquist index methods to estimate municipality efficiency and its intertemporal variation. In the frontier model, average income, per capita GDP, and average agricultural income were used as input, and for outputs, the following Municipality Performance Indexes: MPI-Work, MPI-Formal Work, MPI-per capita GDP, and MPI-Agriculture. Results obtained showed a desirable socioeconomic efficiency advance in municipalities, related to a period when agriculture impacted positively on indexes of productivity, per capita GDP, population's average gains, and municipal development index (MPI), with average efficiency in 2014 at 0.92 and 0.93 in 2016. The number of municipalities for each sample that obtained Malmquist index with M_o> 1 progress was higher than that with regression (M_o <1). Results are relevant considering the novelty in the analysis and show, in the period studied, the productivity and efficiency dynamics in municipalities as for inclusive and sustainable economic and social growth of a region so important in Brazil's Central-West context, and can aid effectively public policies for the Araguaia River Valley, in the state of Goiás, Brazil.

Keywords: Efficiency; Productivity; Performance; Agriculture; Index.

Eficiência socioeconômica do Vale do Rio Araguaia – Goiás: uma fronteira determinística e abordagem do índice de Malmquist

O presente estudo teve como objetivo avaliar a eficiência socioeconômica em 41 municípios brasileiros nos anos de 2014 e 2016 na área compreendida pelo Vale do Rio Araguaia, no Centro-Oeste, estado de Goiás, Brasil. Utilizamos os métodos de análise envoltória de dados e índice de Malmquist para estimar a eficiência do município e sua variação intertemporal. No modelo de fronteira, foram utilizados como insumos a renda média, o PIB per capita e a renda agrícola média e, para os produtos, os seguintes Índices de Desempenho dos Municípios: IPM-Trabalho, IPM-Trabalho Formal, IPM-PIB per capita e IPM-Agricultura. Os resultados obtidos mostraram um avanço desejável na eficiência socioeconômica dos municípios, relacionado a um período em que a agropecuária impactou positivamente nos índices de produtividade, PIB per capita, ganhos médios da população e índice de desenvolvimento municipal (IPM), com eficiência média em 2014 em 0,92 e 0,93 em 2016. O número de municípios para cada amostra que obteve índice de Malmquist com M_o> 1 progresso foi maior do que com regressão (M_o <1). Os resultados são relevantes considerando a novidade na análise e mostram, no período estudado, a dinâmica de produtividade e eficiência nos municípios quanto ao crescimento econômico e social inclusivo e sustentável de uma região tão importante no contexto Centro-Oeste brasileiro, podendo auxiliar efetivamente políticas para o Vale do Rio Araguaia, no estado de Goiás, Brasil

Palavras-chave: Eficiência; Produtividade; Atuação; Agricultura; Índice.

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INTRODUCTION

Production and economy are determining factors for a sustainable and efficient development, growth and job generation, contributing for reducing social inequalities. Economic efficiency can be verified through the data envelopment analysis (DEA) by using empirical data to model the production function in several situations (BLUM et al., 2018). Among the most recent studies, we highlight that of Wang et al. (2019), who used this technology to estimate economic efficiency at provinces and cities of China in the period 2000 to 2016. In this same line, also in China, the study of Liu et al. (2020) evaluated economic efficiency and the regional innovation development of five municipalities of production zones in Sichuan Province.

Studies with this approach are important, especially for municipalities in development phase necessitating to plan growth in more sustainable medium- and long-term perspectives (CHARNES et al., 1989; ÜNSAL et al., 2018). The studies have helped planning toward sustainability in countries around the world. In this line, are the publications of Stuart et al. (2016) for municipalities of Canada; Gnangoin et al. (2019), evaluating public expenditures, income inequality and economic growth in Asian countries; Trang (2020), which verified whether economic growth and income inequality were intimately related, and Woo (2020), proving that there has been meaningful income inequality increase in recent decades, a fact that has been a focus of attention in several regions of the world.

The Sustainable Development Goals (SDGs-8) can help promote growth and full employment (RAMOS, 2016; OECD/UNDP, 2019; OECD, 2019; HEIMBERGER, 2020). In this context, data showed that in the first trimester of 2019, unemployment in the interior of Brazil was lower than in metropolitan regions at 18 states, except for Alagoas, Rio Grande do Norte, Goiás and Mato Grosso do Sul (IBGE, 2019). In the face of this scenario and looking at Goiás state, it is possible to see less employment in the capital in this period. It is worth noting that southwest municipalities from Goiás stood out in generating jobs driven by agriculture and industry in this period. Beyond the industrial sector increase, however, agriculture continues being an important economic activity in Goiás as the meat and grains production drives exports (IMB, 2020).

The southwest of Goiás has a total area of approximately 2.47 million hectares, which is 16% of the state's total area. Among its municipalities, Rio Verde and Jataí concentrate more than 50% of the micro-regional population; further, it is important to mention the Mineiros municipality, where the headwaters of an important water resource of Goiás state is located, the Araguaia River (PINTO et al., 2016; IMB, 2020).

Another region prominent for Goiás state is the northwest. Driven by the tourism in the Araguaia River valley, with a predominant cerrado vegetation and peculiar characteristics as to its hydrography, this region has become one of the country's best centers of ecotourism, leisure, sport fishing and camping (GOIÁS, 2015; IMB, 2020).

In this context, the present study aimed to estimate socioeconomic efficiency in 41 municipalities in the years 2014 and 2016, which were located adjacent to the headwaters (southwest of Goiás) and circumscribed regions (northwest of Goiás) of the Araguaia River Valley, considered one of Brazil's most important natural resources, belonging to the Legal Amazon and delimited by the Mato Grosso, Pará and

Tocantins states. The Data Envelopment Analysis (DEA) method was used and Malmquist Index.

MATERIALS AND METHODS

We used social and economic data from the years 2014 and 2016 of each municipality evaluated. They comprehended 41 municipalities located in the Araguaia river valley, close to the heads and at the borders of the river basin, and comprising the southwest and northwest regions of Goiás state (Figure 1).

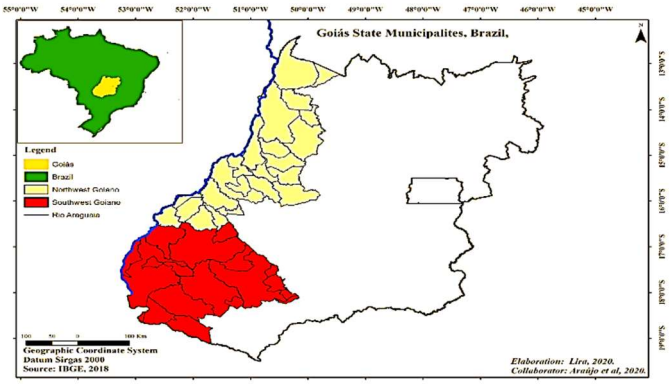

Figure 1: Cartographic map of the location of municipalities, Araguaia Valley, Goiás state, Brazil.

Variables of study and processing of data

Data corresponding to municipalities were collected in the Mauro Borges Institute of Statistics and Socioeconomic Studies (IMB, 2019) website. Firstly, 17 variables were selected to comprise the model. However, to follow the technique proposed by Banker et al. (1989) and Cooper et al. (2000) as to maximum variable quantity and minimum number of DMUs (decision-making units), for selecting inputs and outputs the Pearson linear correlation coefficient was estimated; further, we followed the classification proposed by Hopkins (2006). This methodology was employed by Cunha et al. (2013), Wang et al. (2016) and Razmi et al. (2014).

After Pearson correlation application, variables classified as moderate to almost perfect were selected. Afterwards, the technique recommended by Banker et al. (1989) and Cooper et al. (2000) was used for defining the total number of DMUs, considering *p* the number of inputs and *q* the number of outputs used in the analysis. So, sample size (n) must satisfy n>= Max {p x q, 3 (p + q)}. For this study, we have 41> = Max {3 x 4, 3 (3 + 4)} =21, hence the minimum number of DMUs will be 21 municipalities. For our work 41 DMUs were used.

Variables used as input in the model according with the Mauro Borges Institute (IMB, 2020) available data were the following: a) **Average Income (US$):** determined by the division of salary mass by number of jobs contained in the Ministry of Work and Employment (MTE) and in the Annual Social Information Report (RAIS); b) **per capita GDP (US$)**: corresponds to the global GDP divided by the absolute number of inhabitants of a country, region, state or municipality; and c) **Average Income - Agriculture, Vegetal Extraction, Hunting and Fishing (US$)**: it is determined by the division of salary mass by the number of jobs in the activity.

The variables selected used as outputs in the model were the following: a) **Municipality Performance**

Index (MPI-Work): formal jobs characterized between the 18 - to 64-year old population (working age population's labor market formalization level), workers' average wage (level of average wage of formal labor market), formal market workers' education level (secondary or higher education level workers) and variation in the number of formal jobs (formal jobs evolution in the last two years); **b) Munipality Performance Index (MPI-Formal Work):** based on the Annual Social Information Report (RAIS), which is a yearly administrative record; c) **Municipality Performance Index (MPI-per capita GDP)**: total wealth (goods and services) generated for a period of time (generally one year) at a geographic space (country, region, state or municipality) divided by total of inhabitants; and d) **Municipality Performance Index (MPI-Agriculture)**: development index determined by the municipalities' agriculture variable. Table 1 contains authors and their studies which in diverse contexts, used variables considered in the present study.

Table 1: References of authors that worked with the variables used in this research.

Variable	Type	References
Employment and Income (Formal), Average Yield Agriculture	Input or output	Morais et al. (2013), Costa et al. (2015), Silva et al. (2019), Skica et al. (2019).
Per capita GDP	Input or output	Abreu et al. (2012), Silva et al. (2019)
Agricultural index, MPI-Work, MPI-Formal Work, MPI-per capita GDP and MPI-Agriculture.	Input or output	Abreu et al. (2012), Carvalho et al. (2017)

The data envelopment analysis (DEA) methodology

The data envelopment analysis model began with Debreau (1951), Koopmans (1951) and Farrell (1957), and was subsequently perfected by Charnes et al. (1978), and Banker et al. (1984), initiating the current DEA. There are two main models, as follows: the first, called CRS - constant returns to scale - and the second model, VRS - variable returns to scale. Moreover, they can follow two orientation types as to modifications in variables, namely, input orientation or output orientation. Thus, there are four types of basic models: CRS/Input, CRS/Output, VRS/Input and VRS/Output (BANKER et al., 1984). The BCC model, also called VRS (variable returns to scale), considers situations of production efficiency with scale variation and does not assume proportionality between inputs and outputs. For the proposed study we used the output-oriented variable return to scale (VRS) model deduced by Banker et al. (1984) and used in the study of Staníčková et al. (2012). Its primal formulation, defined as Multipliers Model, is determined by equation 1.

$$MIN\ Eff_0 = \sum_{j=1}^{N} v_j X_{jo} + v_*$$

$$subject\ to\ \textbf{(1)}$$

$$\sum_{i=1}^{m} u_i y_{io} = 1$$

$$\sum_{i=1}^{m} u_i\, y_{ik} - \sum_{j=1}^{n} v_j x_{jk} + v \leq 0, \forall\ k\ for\ k = 1,2, \dots z$$

$$u_i and\ v_j \geq 0, u_i and\ v_j\ \geq 0 i = 1 \dots m, j = 1.., n$$

Where:
u_i - weight calculated for the product i; v_j - weight calculated for the input j; x_{jk} - quantity of input j for unit k; y_{ik} - quantity of product i for unit k; X_{jo} - quantity of input j for unit under analysis; y_{io} - quantity of product i for unit under analysis; z- quantity of DMUs analyzed; m - number of product types; n - number of inputs type, and u and v - scale return coefficient.

We opted to use the output-oriented VRS model seeking to consider the size disparity existing between municipalities in Goiás, as recommended by Souza Júnior et al. (2006).

Malmquist Index

The Malmquist Index (MI) was developed by Caves et al. (1982) on the basis of Sten Malmquist's (1953) work. The index is calculated considering quotient between distance function in the period t and in t+1. It is possible to choose the type of orientation (input/output) to be given to distance functions. In the present study we used the output-oriented VRS DEA analysis. The Malmquist Index approach used was that of Ray et al. (1997), suggested as an alternative modality to the formulation of Färe et al. (1994). In this methodology, the MI production function is produced by decision unit distance in relation to the efficiency frontier, as inputs remain constant (RAY et al., 1997). The index proposed by Ray et al. (1997) stems from equation 2:

$$MI = TC \cdot PEC \cdot SEC \quad \textbf{(2)}$$

The productivity index can be decomposed into two factors, as follows: technological change index (TC), equation 3, and technical efficiency change index (catching up). This second index is decomposed into two terms, the pure efficiency change index (PEC), equation 4, and scale change index (SEC), equation 5 (RAY et al., 1997; CHENG et al., 2015).

$$(TC) = \left[\frac{D_0(x_0,y_0)}{D_1(x_0,y_0)} . \frac{D_0(x_1,y_1)}{D_0(x_1,y_1)}\right]^{\frac{1}{2}} \quad \textbf{(3)}$$

$$(\mathrm{PEC}) = \frac{D_1(x_1,y_1)}{D_0(x_0,y_0)} \quad \textbf{(4)}$$

$$(SEC) = \left[\frac{D_0(x_1,y_1)}{D_0(x_0,y_0)} . \frac{D_1(x_1,y_1)}{D_0(x_0,y_0)}\right]^{\frac{1}{2}} \quad \textbf{(5)}$$

The model of Ray et al. (1997) calculates the Malmquist index on the basis of the DEA methodology with VRS. This model inverts the way of analyzing results. A result <1 means that there was regress, result =1, that there was no change, and result >1, that there was progress in the indicator between the periods (SOUZA, 2012). The Malmquist extension allows assessing efficiency dynamics in more than one period. It enabled identifying the Araguaia river valley municipalities that improved, remained the same or worsened in optimizing resource applications. The Malmquist technique was used by Abreu et al. (2012), who worked the data envelopment analysis (DEA) and Malmquist index to evaluate efficiency in 11 cattle farms in the Pantanal region. Results showed that five properties exhibited technical efficiency lower than 1, while from the technological progress viewpoint the result was higher than 1.

For data processing we used the software R with the benchmarking package, ISYDS (Integrated System For Decision Support) and SAS (Statistical Analysis System). Efficiency intervals were determined with adaptations from the Municipal Development Index established by the Industry Federation of the State of Rio de Janeiro (FIRJAN, 2020) (Table 2).

Table 2: Efficiency intervals of municipalities.

Classification	**Intervals**
Low	0.0<DI ≤ 0.60
Medium	0.60<DI ≤0.80
High	0.80<DI ≤0.99
Efficiency	DI=1.00

These intervals were created to determine classification level in the municipalities' efficiency indexes. The closer to 1, the more efficient and developed the municipality.

RESULTS AND DISCUSSION

Efficiency indexes years 2014 and 2016

Efficient and inefficient municipalities in the years 2014 and 2016 in the output-oriented VRS model are presented in figures 2 and 3.

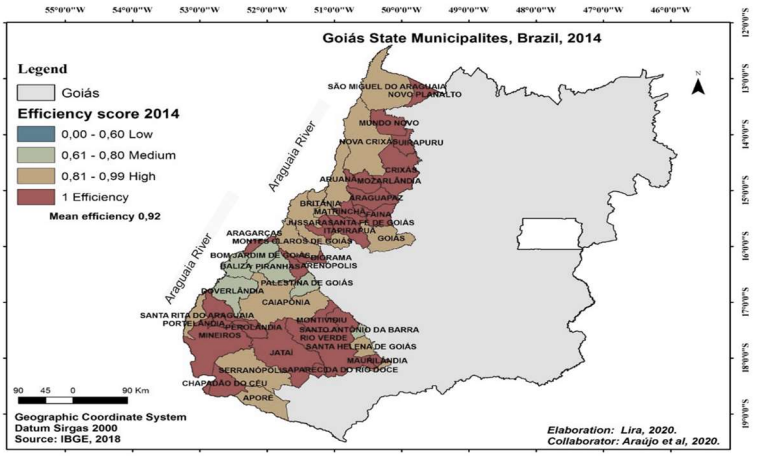

Figure 2: Efficiency scores for each DMU in the year 2014 – Output-oriented VRS model.

According with results of the DEA model (Figure 2), 22 municipalities obtained maximum efficiency in 2014. Nine were located adjacent to the Araguaia river headwaters, in the southwest region of Goiás. Among them, the city of Mineiros, where the fountainhead is located, stood out and also Rio Verde, the region's most populous municipality. The other thirteen were in the river basin, northwest region of the state, among which the tourist city of Aragarças stood out.

In 2016 this number decreased to 20 municipalities, seven in the southwest region and 13 in the northwest of the state (Figure 3).

These results show that the two regions are in wide socioeconomic development. The southwest region stands out. According to IMB (2020), its per capita GDP reached US$ 7,80 in 2018. It concentrates activities in the agricultural sector and holds four of the ten greatest municipalities as for agriculture added

value: Rio Verde, Jataí, Mineiros and Chapadão do Céu.

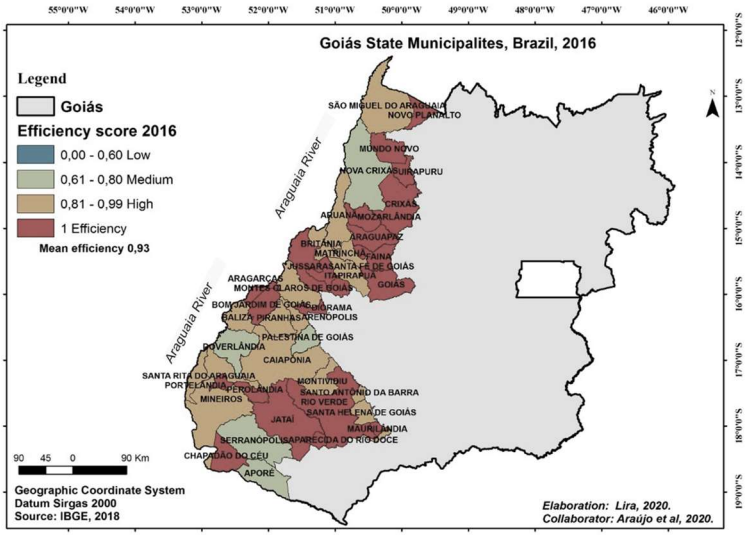

Figure 3: Efficiency scores for each DMU in the year 2016 – Output-oriented VRS model.

According with the values presented in figures 2 and 3, results show mean efficiency and socioeconomic development at 0.92 in the 41 Araguaia River valley municipalities in 2014 and 0.93 in 2016. They are classified in the high efficiency and development interval as per classification established by the Industry Federation of the State of Rio de Janeiro (FIRJAN), as previously presented in Table 2. However, it is found that agriculture, salary average income and per capita GDP drive these development indexes in addition to the municipality performance index (MPI) included as output in the DEA model, which is close to the ideal of maximum efficiency expected.

The high socioeconomic efficiency average of these municipalities in 2014 and 2016 can be explained as well by data reported by the Mauro Borges Institute of Statistics and Socioeconomic Studies of Goiás (IMB, 2016). They show that in 2014, the Goiás Gross Domestic Product (GDP) grew 1.9%, a rate higher than the national mean, which was 0.5%. In this same year, the state moved US$ 73.700 billion, involving resources applied in agriculture, in the industry and in services, and corroborating municipal socioeconomic efficiencies.

As for 2016, Goiás' per capita GDP reached US$ 7.798,98, the Rio Verde municipality kept the largest share in the state's total agricultural production, with soy and swine standing out, followed by Jataí, with prominence in soy and sugar cane production, cultivation of cereal, and breeding of swine and bovine (IMB, 2020).

Nonetheless, it is worth highlighting that Perolândia, located in the southwest of the state, obtained maximum efficiency level in the two periods analyzed and presented the highest per capita GDP among DMUs. In this regard, what most impacted these values was the agricultural production of alcohol.

The efficiency indexes of these municipalities were driven, too, by formal jobs fostered by the labor market, income and human capital productivity (IMB, 2020).

Technological change index (TC), pure efficiency change index (pec) and scale change index (SEC)

Table 3 presents results from Malmquist index values of the Araguaia River Valley municipalities for

the period 2014 and 2016.

Table 3: Intertemporal efficiency variation of municipalities using Malmquist index.

Municipalities	DMUs	TC	SEC	PEC	TFPG (Malmquist Index)
Aparecida do Rio Doce	DMU 1	1	1	1	1
Aporé	DMU 2	0.94	0.93	0.8	0.7
Aragarças	DMU 3	1	1.33	1	1.33
Araguapaz	DMU 4	1	1.01	1	1.01
Arenópolis	DMU 5	1.06	0.98	0.89	0.93
Aruanã	DMU 6	0.99	1.01	0.92	0.92
Baliza	DMU 7	0.92	1.16	1.18	1.26
Bom Jardim de Goiás	DMU 8	0.86	1.17	1.36	1.36
Britânia	DMU 9	0.93	1.04	1.08	1.05
Caiapônia	DMU 10	1.08	1.01	1.07	1.17
Castelândia	DMU 11	1.08	1.06	0.95	1.09
Chapadão do Céu	DMU 12	1	1	1	1
Crixas	DMU 13	1	1	1	1
Diorama	DMU 14	1	1	1	1
Doverlândia	DMU 15	0.94	1.13	1.02	1.08
Faina	DMU 16	0.94	1	1	0.94
Goiás	DMU 17	0.97	0.93	1.05	0.96
Itapirapuã	DMU 18	0.98	1.13	0.99	1.1
Jataí	DMU 19	1	0.99	1	0.99
Jussara	DMU 20	0.91	1.13	1.21	1.24
Matrinchã	DMU 21	1.01	0.96	0.86	0.84
Maurilândia	DMU 22	1.11	1.02	1	1.13
Mineiros	DMU 23	1.02	0.98	0.99	0.99
Montes Claros de Goiás	DMU 24	1.04	1.01	0.9	0.94
Montividiu	DMU 25	1.03	0.98	0.99	1
Mozarlândia	DMU 26	1	0.98	1	0.98
Mundo Novo	DMU 27	0.99	1	1	0.99
Nova Crixas	DMU 28	1.07	1	0.86	0.92
Novo Planalto	DMU 29	1	1	1	1
Palestina de Goiás	DMU 30	0.93	1.07	0.94	0.94
Perolândia	DMU 31	1	1	1	1
Piranhas	DMU 32	1	1.02	1.07	1.1
Portelândia	DMU 33	1	1.03	1	1.03
Rio Verde	DMU 34	1	1	1	1
Santa Fé de Goiás	DMU 35	1	1	1	1
Santa Helena de Goiás	DMU 36	1.07	0.99	0.91	0.97
Santa Rita do Araguaia	DMU 37	1.02	0.96	1.03	1.01
Santo Antônio da Barra	DMU 38	1.01	1.1	1.22	1.37
São Miguel do Araguaia	DMU 39	0.99	1.02	1.02	1.03
Serranópolis	DMU 40	0.96	1.02	0.9	0.88
Uirapuru	DMU 41	1	1.05	1	1.05
Mean		1	1.02	1.01	1.03

When decomposing the Araguaia River valley municipalities' productivity index, the scale efficiency (SEC) had a 2% mean variation, indicating that there was scale growth for the Araguaia River valley municipalities. The result reveals how much the frontier is corrected by the scale variable inclusion, that is, measures the difference observed in relation to scale gains in the DMU over time. Therefore, it identifies returns to scale effect in time (PAL et al., 2018), and shows that the relation between products (outputs) and consumed production factors (inputs) can define an organization's productivity (MARQUES et al., 2006).

The Aragarças municipality obtained the highest scale efficiency index (33%), which indicates efficiency gain for 2016 in relation to 2014. The DMUs with the lowest variation were Aporé and Goiás, which means 7% regress from 2014 to 2016. Santos et al. (2014), by applying the same methodology to analyze municipalities of Brazil's southwest region as to expenses with primary care, found results similar to the

present study.

The technological change index (TC - frontier shift) had a value equal to one and did not interfere with productivity change. This suggests that for those years, the municipalities of Aparecida do Rio Doce, Chapadão do Céu, Crixas, Diorama, Montividiu, Novo Planalto, Perolândia, Rio Verde and Santa Fé de Goiás did not obtain gains in technical efficiency (pairing).

In relation to technological change (TC), the municipality of Maurilândia had the greatest variation, 11% increase, and Bom Jardim de Goiás had a 14% regress. This technology verifies if the unit's production is approaching or moving away from the frontier. As regards the regions regress, Marques et al. (2006) obtained similar results when they studied the water sector in Portugal. They found a negative variation (regress) justified by the technological change in productivity in the period 1994-2001, and to a lesser extent, by the scale efficiency variation.

Pure efficiency change (PEC) is the ratio from each DMU's distance to its respective frontier at the same instant of time. In regard to this index, municipalities had a mean variation of 1%, confirming progress towards the best practices frontier between 2014 and 2016. In the pure efficiency change (PEC), Bom Jardim de Goiás reached the greatest variation, at 36%. Improvements in the municipality performance efficiency indexes in the period analyzed explain this increase, while MPI-Work, MPI-Formal Work, MPI-per capita GDP and MPI-Agriculture are variables that show to be relevant to this municipality's development.

The average Malmquist index (M_o) was 1.03, due especially to the scale efficiency (SEC) index progress that reached mean variation of 2% and the change in pure efficiency (PEC), of 1% mean variation, as previously indicated.

Total factor productivity growth (TFPG)

In relation to total factor productivity growth (TFPG), results showed that in the periods 2014 and 2016 the number of DMUs for each one of the samples that obtained Malmquist index (M_o) with progress, that is, DMUs with $M_o > 1$, was greater than that for those obtaining M_o index with regress, $M_o < 1$. In Figure 4, we observe this situation with municipalities that reached progress, regress or remained constant in the total factor productivity change index (TFPG).

It was found that there was progress for seventeen municipalities. They were Araguapaz, Santa Rita do Araguaia, Portelândia, São Miguel do Araguaia, Britânia, Uirapuru, Doverlândia, Castelândia, Itapirapuã, Piranhas, Maurilândia, Caiapônia, Jussara, Baliza, Aragarças, Bom Jardim de Goiás and with the highest index Santo Antônio da Barra, which reached a 37% progress from 2014 to 2016. This municipality with highest productivity level is located in the southwest of Goiás and is an economic highlight in agricultural production and beef and dairy cattle breeding, contributing to municipal development rates (MPI). In this same vein, Maciel et al. (2009) worked with Malmquist index and its decompositions to study the human development index (HDI) and well-being of Brazilian individuals, arriving at results similar to the present study.

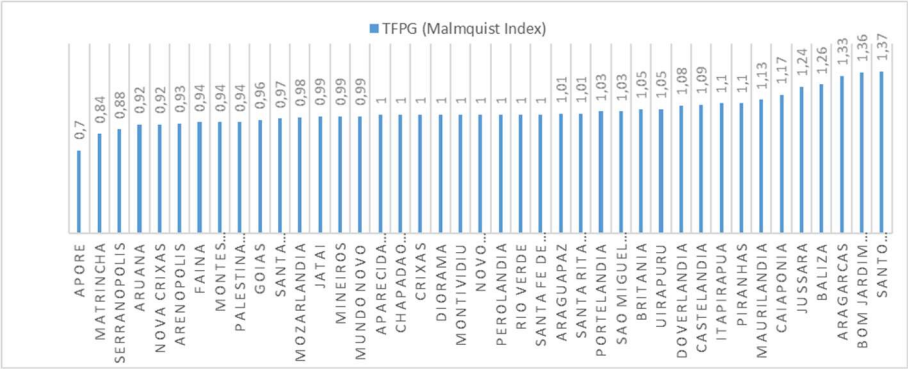

Figure 4: Total factor productivity growth (TFPG)

In relation to the productivity of municipalities that remained constant in the period t+1 in relation to t, nine DMUs stood out, namely, Aparecida do Rio Doce, Chapadão do Céu, Crixas, Diorama, Montividiu, Novo Planalto, Perolândia, Rio Verde and Santa Fé de Goiás (Figure 4). There was no change in their M_o indexes, and efficiency was maintained over time.

Among DMUs whose productivity decreased in the period t+1 in relation to t, the following municipalities stood out: Aporé, Matrinchã, Serranópolis, Aruanã, Nova Crixas, Arenópolis, Faina, Montes Claros de Goiás, Palestina de Goiás, Goiás, Santa Helena de Goiás, Mozarlândia, Jataí, Mineiros and Mundo Novo. Similar results were reported in the study of Ferreira et al. (2013) in relation to the total productivity factor growth (Malmquist productivity index), with negative average annual growth in two corporate governance segments, objects of the study.

On the other hand, two important municipalities in the socioeconomic development of the state's southwest region regressed as to their productivity. They were Jataí, driven by a decrease of scale efficiency (SEC), and Mineiros in the scale efficiency and pure efficiency change (PEC).

We note that, by and large, most municipalities of the Araguaia River Valley obtained productivity gains with regard to Malmquist index. Other studies using the index have demonstrated that the productivity growth is the actuator for the sustainable economic growth of municipalities (KANEKO et al., 2004).

Targets

The targets values (λ'k) are goals that inefficient DMUs have in order to achieve efficiency, that is, they are calculated aiming to project inefficient municipalities into the efficiency frontier in reference to their benchmarks. To examine targets and slacks, municipalities with low performance in the years 2014 and 2016 were included as examples.

In 2014, the Bom Jardim de Goiás municipality ranked last in the efficiency ranking, with 0.73 index. The data envelopment analysis (DEA) proposes a radial projection of inefficient DMUs. Table 4 shows which adjustments should be performed in every input or output for them to become efficient as per each DMU's need (BORGES, 2006).

According with results in Table 4, Output 2 (Municipality Performance Index in formal work), for example, needs to achieve a 111.51% improvement. This variable is that which needs the greatest variation

among outputs. In the Data Envelopment Analysis, whenever there are inputs or product slack, production is being inefficient (FERREIRA et al., 2009).

Table 4: Targets Bom Jardim de Goiás Municipality – 2014.

Variable	Current Value	Targets	Gains (%)
Input 1	524.51	524.51	0
Input 2	5 972.22	5 972.22	0
Input 3	481.26	481.26	0
Output 1	1.87	2.540111	35.83
Output 2	0.56	0.760675	111.51
Output 3	0.36	0.489005	35.83
Output 4	0.32	0.434671	35.83

Input 1: average income -US$; Input 2: per capita GDP -US$; Input 3: average yield (agriculture, vegetal extraction, hunting and fishing -US$); Output 1: Municipality Performance Index - MPI-Work; Output 2: Municipality Performance Index - MPI-Formal Work; Output 3: Municipality Performance Index - MPI-per capita GDP; Output 4: Municipality Performance Index - MPI-Agriculture.

Table 5 shows how much the Aporé municipality, with 0.69 efficiency rate, could increase production in 2016 by using the inputs 1, 2 and 3 (input quantity) in relation to frontier values (targets) for each input and for each output.

Table 5: Targets of the Aporé municipality - 2016.

Variable	Current Value	Targets	Gains (%)
Input 1	606.02	606.02	0
Input 2	21 374.57	21 374.57	0
Input 3	480.21	480.21	0
Output 1	2.6	3.76	44.63
Output 2	3.19	4.61	44.63
Output 3	2.47	4.16	68.36
Output 4	0.55	0.89	61.35

Input 1: average income -US$; Input 2: per capita GDP -US$; Input 3: average yield (agriculture, vegetal extraction, hunting and fishing -US$); Output 1: Municipality Performance Index - MPI-Work; Output 2: Municipality Performance Index - MPI-Formal Work; Output 3: Municipality Performance Index - MPI-per capita GDP; Output 4: Municipality Performance Index - MPI-Agriculture.

According with Table 5, Output 3, for example, requires greater adjustment, and the DEA model suggests an increase of 68.36% in the Municipality Performance Index MPI - per capita GDP.

CONCLUSIONS

In the period considered in this study there was an advance in the socioeconomic efficiency of municipalities located in the Araguaia river valley, in the state of Goiás. This development occurred over a period marked by the region's strong agricultural production impacting directly productivity indexes, per capita GDP, population average income and the municipal performance index (MPI). In this context, the Rio Verde municipality stood out in 2016, when it had the greatest share in the state's total agricultural production, with soy and swine production predominating, as well as Jataí, which had prominence in the soy and sugarcane production, cereal cultivation and breeding of swine and bovine. These municipalities belong to the southwest region, where the Araguaia River headwaters are.

Results for the VRS model showed high efficiency and socioeconomic development average (0.92) in 2014, with 22 municipalities reaching maximum efficiency. Nine were in the southwest region of Goiás,

located adjacent to the Araguaia river headwaters, including the city of Mineiros, where the fountainhead is, and thirteen in the river basin of the state's northwest region, with prominence for the tourist city of Aragarças.

In 2016 socioeconomic efficiency reached the average rate of 0.93 and the total of 20 municipalities with maximum efficiency, seven in the southwest region and thirteen in the northwest. However, the region that showed more efficient municipalities was the northwest for both periods analyzed.

In regard to the total factor productivity growth (TFPG), results showed that in the periods 2014 and 2016 the Malmquist index (M_o) with progress was higher than with regress. In this interval, two important municipalities in the socioeconomic development of the southwest region regressed as to their productivity. They were Jataí, driven by a decrease of scale efficiency (SEC), and Mineiros in the scale efficiency and pure efficiency change (PEC).

The analysis of Malmquist index demonstrated that progress in scale efficiency (SEC) and pure efficiency change were the main responsible for the development of productivity in the southwest and northwest regions of Goiás state. Moreover, technical change (TC) had a value equal to one, not interfering with productivity change. The use of Malmquist index demonstrated to be adequate in cases in which one desires to analyze the dynamics of efficiency over time.

The evaluation with DEA and Malmquist was important to measure and assess which municipalities were in socioeconomic development, and can be an information source for decision-making as to the inclusive and sustainable economic growth of the analyzed regions, which allows meeting public policies' needs. It can also aid in the reformulation of municipal master plans and sustainable development goals.

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