# Uma análise do crescimento da PTF agrícola em municípios brasileiros

## *An Agricultural TFP growth analysis of Brazilian municipalities*

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**Resumo**: Este estudo analisa o crescimento da produtividade total dos fatores (PTF) na agricultura brasileira em nível municipal, utilizando uma abordagem de fronteira estocástica com variáveis climáticas. O objetivo é identificar padrões espaciais de produtividade, incluindo quais estados ganharam e perderam produção e a presença de polos de progresso tecnológico. Os resultados mostram que cerca de 42% dos municípios apresentaram PTF negativa, enquanto os polos de alto crescimento estão concentrados em regiões de fronteira agrícola, como Matopiba e o norte do Mato Grosso. A região Centro-Oeste apresenta o maior progresso tecnológico, enquanto alguns estados do Nordeste apresentam efeitos negativos. A eficiência técnica média é de cerca de 82%, com baixa dispersão regional. O crescimento geral da PTF é estimado em 2,12% ao ano, consistente com a literatura anterior. Os resultados destacam a forte heterogeneidade espacial e a importância do progresso tecnológico para impulsionar a produtividade agrícola no Brasil.
**Palavras-chave:** Produtividade Total dos Fatores, Agricultura Brasileira, Fronteira Estocástica.

**Abstract**: This study analyzes total factor productivity growth (TFPI) in Brazilian agriculture at the municipal level using a stochastic frontier approach with climatic variables. The objective is to identify spatial patterns of productivity, including which states gained and lost production and the presence of clusters of technological progress. Results show that around 42% of municipalities experienced negative TFPI, while high-growth clusters are concentrated in agricultural frontier regions such as MATOPIBA and northern Mato Grosso. The Central-West region shows the highest technological progress, whereas some Northeast states present negative effects. Average technical efficiency is about 82%, with low regional dispersion. Overall TFPI growth is estimated at 2.12% per year, consistent with previous literature. The findings highlight strong spatial heterogeneity and the importance of technological progress in driving agricultural productivity in Brazil
**Keywords:** Total Factor Productivity, Brazilian Agriculture, Stochastic Frontier.

## 1. Introduction

According to a 2025 report by OECD (Organization for Economic Co-operation and Development), Brazil remains one of the world's major agricultural producers and exporters: agriculture's share of Brazil's GDP rose from about 5.5% in 2000 to 6.2% in 2023, and agro-food exports made up 44.1% of all Brazilian exports in 2023.

According to Spolador and Danelon (2024), the TFP analysis of Agriculture it's essential to understanding economic development, the author argues that the decomposition of TFP and our determinants are relatively large in literature, some results that the Agricultural sector in Brazil is the most the greatest growth in production, moreover that sector explain the most of Brazilian TFP growth.

Climate change can impact the TFP negatively, because the farming activity was too sensible to climate volatility, mostly in increase of average temperature (Lachaud et al., 2022)

show a 10% loss of TFP of LAC (Latin American Countries) countries moreover monetary injuries of US$ 14.7 to 31.4 billion dollars. In general, the average TFP studies of Brazilian agriculture's can lead to weak or contradictory conclusions.

## 2. Literature Review

Lachaud et al. (2022) & Lachaud and Bravo-Ureta (2021) demonstrate that the omission of important climatic variables tends to overestimate the TFPI. Both Lachaud et al. (2022) and Njuki et al. (2019) use stochastic frontier estimation with random parameters using O'Donnell's TFPI (Total Factor Productivity Index). Njuki et al. (2019) estimates the time-invariant effect of the 48 US states and analyzed TFPI decomposition to assess the impact for each state.

O'Donnell's TFPI indicator is used in several recent studies (Njuki et al., 2019; Lachaud and Bravo-Ureta, 2021; Lachaud et al., 2022). It is based on index theory. Its main advantage over the Tornqvist-Thiel index is the non-use of input cost tables and the use of elasticities and semi-elasticities of the explanatory variables.

Ferreira and Vieira Filho (2020) in their SFA implementation argues that spatial heterogeneity can be viewed by heat maps of the Efficient Technique and TFP variation by the regions, the author highlights too about the efficiency belts in their results.

This study aims to show TFPI growth at the municipal level, identify which states gained and lost total production, and detect spatial clusters of technological and productive progress.

## 3. Methodology

Average annual rainfall in mm/day per municipality and the average temperature are obtained from Saldanha et al., (2024). This work used tables 1113, 3355, 820, 836, 860, and 3372 from the 2006 Agricultural Census and tables 6872, 6883, 6885, 6897, 6899 and 6908 from the 2017 Agricultural Census, totaling 5567 municipalities. The SFA model is given by equation (1)

$$y_i = \alpha_i + \sum_{k=1}^{K} \beta_k \, ln(x_k) + \sum_{j=1}^{J} \eta_j(z_j) + \sum_{l=1}^{L} \gamma_l(d_l) + v_{it} - u_{it} \quad (1)$$

The variable response it's production, $x_k$ values are expenses, labor, cattle, machines, area crop and pasture, $z_j$ it's environmental variables (with climate anomalies and their quadratics terms), $d_l$ are dummies time-variant states. Equation (2) shows the calculation of

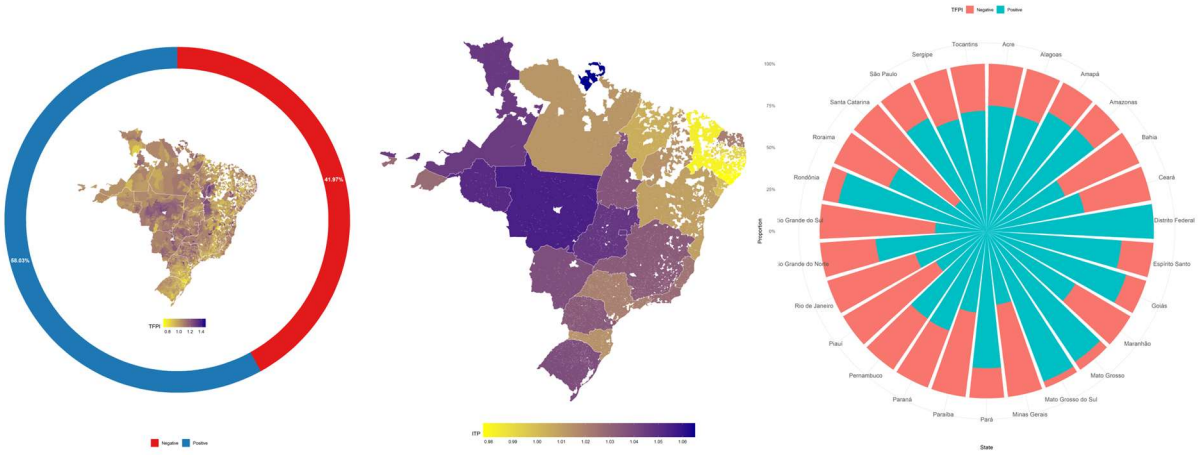
TFPI as a function of its components. The $\epsilon_{it} = v_{it} - u_{it}$ composed error is left Skewed distribution.

$$TFPI_{msit} = \exp\left[(\alpha_i - \alpha_m) + \sum_{k=1}^{K}(\beta_k - b_k)\ln\left(\frac{x_{kit}}{x_{kms}}\right) + \sum_{j=1}^{J}\eta_j(z_{jit} - z_{jms}) + \sum_{l=1}^{L}\gamma_l(d_{lit} - d_{lms}) - (u_{it} - u_{ms}) + (v_{it} - v_{ms})\right] \quad (2)$$

First Component is the fixed effect that captures unobserved heterogeneity across municipalities. Second is the Observed scale efficiency index, the third represents the Climate Effect Index, the fourth represents the Technological Progress Index, the fifth represents the and sixth represents the technical efficiency and Statistical Noise.

## 4. Results

Figure 1 - Growth of TFPI by municipality in Brazil (2006–2017)



Source: The authors

According to figure 1, almost 42% of municipalities lost TFP, and some municipalities experienced exceptionally high, double-digit TFP growth during periods of rapid technological adoption and land-use transformation forming the high efficiencies clusters. The Index of technological Progress of Dummies time-variant states indicate high values of annualized progress (5% to 6%) for middle-west region, the state dummies with negative effects are Ceará, Paraíba, Pernambuco, Alagoas and. Sergipe. At the state level, MT, MS, and GO boosted the Central-West region, with most cities showing positive TFPI. BA, MG, PI, RS, and SC showed the lowest proportion of positive progress. Firm efficiency was around 82%, with a large left skewing, and overall, it was quite homogeneous across the national territory on heat map. A general TFPI for Brazil of around 2.12% was obtained; the growth rate estimated for Brazil by

Gasques et al. (2020) is 2.21% per year. The author argues that this is lower than those reported in other studies by the same authors using alternative data sources and methodologies.

## 5. Final considerations

This work contributes to knowledge by showing that the leading municipal clusters in TFPI are located on the agricultural frontier (Matopiba, Mato Grosso North), which states gained and lost TFPI in proportion to leadership in the Midwest, and identifying the same axis between the Midwest and Southeast regions of high technological progress.

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