

## EFFECTS OF AGRICULTURAL INSURANCE ON THE PRODUCTION OF INSURED RURAL PRODUCERS IN BRAZIL

**Grupo de Trabalho (GT):** GT01. Mercados agrícolas e comércio exterior

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### Abstract

The objective of this paper was to assess the impact of the Brazilian Rural Insurance Premium Subsidy Program (*Programa de Subvenção ao Prêmio do Seguro Rural - PSR*) on the production of insured rural producers across different regions of Brazil. Utilizing data from the 2017 Agricultural Census, this research compared results with the 2006 Census and employed impact evaluation techniques of entropy balancing. The findings from entropy balancing suggest that the insurance variable positively affects the Gross Production Value (GPV) per establishment in municipalities where producers participated in the PSR program. This underscores the significance of the program for enhancing Brazilian agribusiness.

**Keywords:** Rural Insurance; PSR; Entropy Balancing; Brazil.

### 1. Introduction

Brazilian agribusiness has experienced significant growth in recent decades. In 2019, the total value of goods and services generated by the agribusiness sector reached R\$ 1.55 trillion, accounting for 21.4% of Brazil's GDP. Within this sector, agriculture alone contributed R\$ 1.06 trillion, representing 68% of the total agribusiness value (CNA, 2020). Brazil's agricultural achievements have earned the country the title of the world's largest producer of coffee, sugar, and orange juice; the second-largest producer of soybeans; the largest global exporter of coffee, sugar, soybeans, and orange juice; and the third-largest exporter of corn (CNA, 2020; World Bank, 2015).

Despite the clear positive impact of the agricultural sector on the Brazilian economy, it is also the most economically volatile (Gouveia, 2016; Medeiros, 2013; Silva et al., 2014; Ozaki, 2010; Tabosa and Vieira Filho, 2018). This volatility is driven by various types of risks, which can lead to extreme economic losses.

The dependence on climatic conditions and high price volatility creates uncertainties in the agricultural production process (Ozaki, 2007, 2010; World Bank, 2015). Among the primary risk factors are climatic factors, pest incidence, fires, and price volatility, which is

linked to market failures such as imperfect competition, credit scarcity, demand fluctuations, and technological aspects (Ozaki, 2010; Tabosa and Vieira Filho, 2018).

These factors can reduce investments in the sector, causing financial resources to be redirected to other lower-risk activities. In the Northeast, for example, climate-related adversities such as drought in the semi-arid region can lead to losses of up to 90% of agricultural production (World Bank, 2015).

As a result, agricultural insurance becomes a public policy tool capable of creating stability in the business environment, thereby reducing the risk of adverse events and preventing fluctuations in productive investment (Ozaki, 2008). Amid these adversities and the resulting economic and financial losses, producers seek financial intermediaries to provide minimum guarantees for their production. In some cases, the financial system itself adjusts, offering different types of insurance. However, given the unique characteristics of agricultural production, it is necessary to create incentives that link producers to financial institutions.

To make insurance protection more accessible to rural producers in Brazil, the Rural Insurance Premium Subsidy Program (*Programa de Subvenção ao Prêmio do Seguro Rural - PSR*) was established in 2004 (Decree n. 5,121), with its implementation beginning the following year. This public policy was designed to subsidize part of the cost of agricultural insurance for producers, thereby bringing insured producers and financial agents closer together. In some cases, the subsidy granted for acquiring agricultural insurance can vary from 30% to 40%<sup>1</sup> of the premium value, depending on the type of crop, insurance product, and activity, with different levels of coverage.

Although the subsidy is intended for rural producers, its application process is handled by the insurance company, which submits the contracted policies for review to the Ministry of Agriculture, Livestock, and Supply (Ministério da Agricultura, Pecuária e Abastecimento - MAPA). After the producer's registration is evaluated without restrictions and with availability of budget resources, ministry technicians grant the subsidy to settle part of the premium specified in the contracts.

Indeed, specific policies aimed at increasing rural producer production aim to minimize risks and their negative effects. For example, the primary goal of agricultural insurance is to maintain investment stability on one hand and sector competitiveness on the other, even in conditions of capital loss or crop failure (Adami and Ozaki, 2012; Macedo et al., 2013; Hess and Hazell, 2016; Iturrioz, 2009; Loyola et al., 2016; Tabosa and Vieira Filho, 2018).

Therefore, the objective of this paper is to assess whether the PSR impacts the production of insured rural producers across different regions of Brazil. To achieve this, the 2017 Agricultural Census database was utilized, which underscores the uniqueness and relevance of this study. Additionally, comparing the results obtained in the 2017 and 2006 Censuses will be possible.

Furthermore, this analysis also innovates by making use of impact evaluation techniques for public policies, specifically entropy balancing, which has been previously applied to agricultural insurance studies in Brazil.

After this introduction, a theoretical framework is featured in the following section, discussing the evolution of insurance in agriculture in Brazil. Then, methodological aspects are discussed, and the data is presented and analyzed. In the fourth section, the results are discussed. Lastly, the concluding remarks.

## **2. Theoretical Framework**

### **2.1 A Brief Discussion on the Evolution of Agricultural Insurance in Brazil**

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<sup>1</sup> These values have been in effect since the implementation of the Triennial Rural Insurance Plan (*Plano Trienal do Seguro Rural - PTSR*) for 2019-2021.

Rural insurance began in Brazil in the late 1930s when the state of São Paulo instituted mandatory hail insurance for cotton crops through Decree No. 10,554 (Ozaki, 2010). Based on the satisfactory results obtained, the São Paulo State Department of Agriculture subsequently established the Hail Insurance Fund for Viticulture (Law No. 11) and the Frost Insurance Fund for Horticulture (Law n. 8,375).

In 1954, Law No. 2,168 established agricultural insurance aimed at preserving crops and livestock against specific risks, and the Agricultural Insurance Stability Fund (Fundo de Estabilidade do Seguro Agrário - FESA) to ensure the stability of agricultural insurance and provide supplementary coverage for catastrophic risks. Additionally, the National Agricultural Insurance Company (Companhia Nacional de Seguro Agrícola - CNSA) was created. However, none of these instruments became operational or met the objectives for which they were created. In 1966, Decree n. 73 abolished FESA and established the Rural Insurance Stability Fund (Fundo de Estabilidade do Seguro Rural - FESR). This new fund had different sources of resources, a different operational structure, and was launched as the solution to the problems that limited the implementation of rural insurance contracts (Almeida, 2011, p.12).

Nevertheless, in 1973, the federal government instituted the Agricultural Activity Guarantee Program (Programa de Garantia da Atividade Agropecuária - PROAGRO) through Law No. 5,969/73. The purpose of PROAGRO was to relieve rural producers, as established by the National Monetary Council, of financial obligations related to credit operations whose repayment was hindered by the occurrence of natural phenomena, pests, and diseases affecting goods, livestock, and crops (Gouveia, 2016).

Until 1985, the Brazilian financial system was characterized by strong speculative demand due to the financial gains from the negative interest rates then in practice. In fact, there was a significant implicit subsidy for borrowers, who could invest rural credit resources directly in the financial market at much higher rates, thereby realizing substantial financial gains.

The purpose of the program was to cover the financial charges of rural credit operations in the event of losses, funded by a 1% levy on rural credit operations, thus representing a significant cost to the public sector. Macedo et al. (2013) emphasize the virtues of PROAGRO in linking agricultural credit operations, effectively ushering in a new era for agricultural insurance in Brazil.

According to Almeida (2011), PROAGRO played a crucial role, particularly in the development of rural credit from the 1970s to the 1990s, by providing the necessary guarantees for the implementation of rural credit operations.

Law No. 8,171 of 1991 recognized agricultural insurance as both an action and an instrument of rural policy, where the insurance policy would serve as collateral in rural credit operations. The legislation also expanded PROAGRO to compensate farmers for their own resources used in rural financing, in case of crop failure due to climatic events, whether related to rural financing or not.

According to Ozaki (2008), in 2002, Law No. 10,420 created the Harvest Insurance Fund (Fundo Seguro-Safra), to provide resources for the payment of the harvest insurance benefit. This initiative aimed to ensure a minimum income for family farmers in the Northeast region, the semi-arid region of the state of Minas Gerais, and the northern region of Espírito Santo, due to droughts.

Buaianin (2014) pointed out that the Brazilian federal government recognized the unique characteristics of the rural insurance market when it instituted the PSR program through Decree No. 5,121 on June 29, 2004. The program aimed to enhance access to agricultural insurance, thereby providing greater income stability for producers, encouraging the adoption of new technologies in production, and modernizing agricultural management. The subsidy was

authorized to reduce the premium paid by the producer and thus promote the development and widespread adoption of agricultural insurance across the country.

Tabosa and Vieira Filho (2018) sought to evaluate the impact of the PSR program on the planted area and productivity of insured producers in Brazil. The results indicated that in the analyzed program, the number of insured producers and the insured amount had a positive short-term impact on productivity, which persisted for an average of six years. However, the number of insurance policies had a negative impact on both the planted area and the productivity of those insured.

## 2.2. Agricultural Insurance

Agricultural insurance enhances agricultural stability and security by mitigating production uncertainties for farmers, thereby reducing reliance on individual savings accounts or funds for cash reserves (Raulston et al., 2010). In agriculture, several market failures hinder the establishment of more secure systems. These include asymmetric information between policyholders and insurers, adverse selection driven by averaging prices across diverse risks, and moral hazard; where economic agents modify their behavior due to inadequate monitoring, thus increasing the risk of accidents or losses. (Loyola et al., 2016; Stiglitz and Walsh, 2003).

Risk management practices have demonstrated notable effectiveness even in regions prone to drought (Walker and Jodha, 1986; Bhattamishra and Barrett, 2010). Nevertheless, these studies come with associated costs and limitations. For instance, in drought-prone areas of India and Burkina Faso, farmers are advised to allocate 12% to 15% of their average income towards risk reduction efforts (Sakurai and Reardon, 1997).

Petrovic et al. (2013) emphasized the significance of agricultural insurance and explored its varying effectiveness across Serbia and other former Yugoslavian countries. Their study aimed to identify challenges and propose solutions, revealing that insurance mitigated agricultural production risks including crop damage from hail or fire, theft of agricultural property, and health or mortality risks among agricultural producers.

Ferreira and Ferreira (2009) evaluated key international experiences in rural insurance, focusing particularly on the United States and Canada. The findings identified the significant role of government in facilitating insurance against losses, thereby enhancing the sustainability of the production process. This contributes to greater income stability economically and promotes job creation for farmers and their families socially.

Fornazier et al. (2012) analyzed the influence of rural insurance on risk reduction in agriculture compared to other international experiences. The authors highlight the need for a more efficient insurance structure, emphasizing greater cooperation among markets, government, producers, cooperatives, universities, and research centers. The institutional framework accelerates the development of the rural insurance market in both the public and private sectors.

Rosenzweig and Binswanger (1993) found that smaller and poorer farmers in a semi-arid region of India sacrificed 27% of their expected income to mitigate risk. Farmers are less inclined to invest in more profitable technologies and land improvements in riskier environments, leading to additional reductions in average income.

Siddiqui and Das (2017) emphasize that in India, 70% of the population lived in rural areas, engaging in agriculture and related activities. A crop failure would directly or indirectly impact farmers' lives, leading to widespread financial crisis. Climatic conditions (or pests) are the primary reasons for crop failures. The authors suggest that 39% of the variation in expected crop failure rates could be attributed to soil and climate factors. Therefore, insurance provided

a means to reduce losses and enhance economic security, contingent upon access being dependent on literacy levels, awareness, and guaranteed income.

Furthermore, the authors concluded that even in the case of accidents, a rural insurance policy would provide farmers with support to feed their families. The insurance sector has implemented various policies across different fields in rural areas. Thus, insurance is beneficial not only for the urban population, but also for rural communities. However, only a very small percentage of people are aware of this. It is up to the government to take the initiative to raise awareness among the rural population

Risks also pose challenges for financial institutions and input suppliers, as these entities face loan defaults and unpaid bills. Agricultural traders suffer from shortages of raw materials, while rural retailers and small businesses experience declining local incomes and reduced demand for their services. More dramatic evidence comes from research on severe drought, where income losses exceed production declines in percentage terms due to productivity collapse, resulting in reduced employment, wages, non-agricultural incomes, and asset prices (Webb and von Braun, 1994; Hazell and Ramasamy, 1991).

In Brazil, the importance of agricultural insurance as income assurance for rural workers becomes evident. Adami and Ozaki (2012) analyzed the behavior of direct premiums of the PSR program for the year 2011. The results indicated that the allocated funds were insufficient to sustain the growth trend of insurance, potentially leading to market regression to prevent market stagnation and the vulnerability of many producers exposed to issues arising from climatic conditions.

Loyola et al. (2016), for example, assessed the recent evolution of the Rural Insurance Premium (PSR) and its main variables: insured area, policies, average area, producers, total premiums involved, and total subsidies. An exploratory and descriptive analysis was conducted to evaluate the outcomes of this agricultural policy program. The study focused on examining the development of rural insurance within the PSR framework, utilizing data sourced from the Ministry of Agriculture, Livestock, and Supply (Ministério da Agricultura, Pecuária e Abastecimento - MAPA), considering the period of 2005 to 2013, while also using general data of the program from 2014.

The results suggest an increase in supply and demand for rural insurance in the South, particularly in agricultural sectors for grains and fruits, with potential for growth in other sectors and regions across the country. The PSR program, as a public policy, has been instrumental in expanding the rural insurance market, encouraging and facilitating producers' access to agricultural insurance through premium subsidies. Although this expansion has been gradual, by 2013, approximately 13.8% of Brazil's agricultural area was covered by rural insurance. This underscores the need to expand the program further to popularize this important tool for mitigating risks inherent in agricultural production.

Gouveia (2016) examined the factors contributing to the limited uptake of rural insurance in Brazil. The study revealed that the market was underdeveloped and still in its early stages, with fewer than 10% of the national crop insured. This low adoption rate was attributed to the inherent riskiness of agricultural operations and the absence of government policies subsidizing the insurance market, contrasting unfavorably with higher adoption rates observed in countries like the United States.

Tabosa and Vieira Filho (2018) assessed the impact of the PSR program on planted area and the productivity of insured producers in Brazil. The authors utilized state-level data of insured producers from 2006 to 2017. The methodological approach relied on panel Vector Autoregression (VAR) analysis. The findings indicated a significant concentration of producers and insurance policies in the South, Southeast, and Center-west regions of Brazil, particularly

in states such as Paraná, Santa Catarina, Rio Grande do Sul, São Paulo, Minas Gerais, Goiás, and Mato Grosso.

Furthermore, according to the authors, the number of insured producers and the insured amount had a short-term positive impact on insured productivity, with this effect extending up to an average of six years. Regarding the planted area, only the insured amount had a positive effect. However, the number of policies had a negative impact on both the planted area and insured productivity.

Tabosa and Vieira Filho (2021) revisit this analysis and examined the relationship between the number of insured producers, policies contracted under the PSR program, and the productivity of insured producers. Using the Panel Vector Autoregression (PVAR) method, the authors find a positive relationship among these variables. Similarly, employing the same methodology, Tabosa et al. (2021) assessed the impact of the PSR program on the productivity of insured producers in the MATOPIBA region, highlighting its influence on both planted area and productivity in the area. The MATOPIBA region refers to a major agricultural frontier in Brazil, which is an acronym derived from the initials of the states it encompasses: Maranhão (MA), Tocantins (TO), Piauí (PI) and Bahia (BA).

Lastly, Ferreira (2024) analyzed the impact of the PSR program on soybean production in the MATOPIBA region using the Difference-in-Differences and entropy balancing methods. The results suggest that the PSR effectively increased both the planted area and the quantity produced.

### **3. Methodology**

#### **3.1. Data**

The data used in this paper was obtained from the Brazilian Agricultural Censuses for the years 2006 and 2017, conducted by the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística- IBGE) through the IBGE Automatic Recovery System (Sistema IBGE de Recuperação Automática - SIDRA). This database contains microdata, allowing for the identification, at the individual level, of the characteristics of rural producers and agricultural establishments, as well as the technologies and agricultural practices adopted. Information on financing and its sources is also available, which facilitates the estimation of the effect of rural insurance. However, this microdata is not easily accessible due to the confidential nature of the information; therefore, this work uses aggregated municipal-level data, which is publicly available.

The use of aggregated data can present a limitation as it overlooks the heterogeneity within a municipality; that is, there can be really different farms, and aggregation would not allow for the exploration of this variation among the units of analysis. In this work, however, the concept of representative farms is adopted, following previous literature (Freitas et al., 2020; Helfand et al., 2015). Each unit of analysis, therefore, is a 'representative' rural property within the municipality, where the variables are averaged. These representative units are obtained by dividing all municipal-level variables by the total number of rural establishments.

Regarding the variables Rainfall Index and Temperature, these were collected from the National Institute of Meteorology (Instituto Nacional de Meteorologia - INMET). An important detail is that 2006 was the first year following the implementation of the PSR, while 2017 represents the most recent agricultural census.

To consistently estimate the impacts of the agricultural insurance provided by the PSR program, used entropy balancing, are widely recognized in the literature on estimating the causal effects of a treatment and are described in some detail further on. The impacts are evaluated using the Gross Production Value (GPV) per establishment as the outcome variable.

The variables in the entropy balancing, are those that influence the rural producer's decision to obtain a PSR policy, as outlined in Chart 1 below.

**Chart 1-** Description of the Variables

Variable	Description
Gross Production Value per establishment	Gross Value of Total Production from temporary and/or permanent crops per establishment in the municipality
Insurance	Dummy variable, where 1 means that the municipality has at least one producer acquired a PSR policy or otherwise
Harvested/planted área	In hectares
Technical assistance	Percentage of producers with technical assistance in the municipality
Male	Percentage of male rural producers in the municipality.
Region	Dummy variables referring to the regions of Brazil (North, Northeast, Central West, Southeast and South)
Rainfall Index *	Rainfall index value
Temperature*	Average annual temperature

Source: Prepared by the authors. \*Data collected from INMET.<sup>2</sup>

The next section will cover Entropy balancing.

### 3.2. Entropy balancing

The entropy balancing method is a weighting scheme that adjusts weights to satisfy a potentially large set of moment constraints. This method allows researchers to specify a desired level of balance for covariates by using a set of conditions associated with the moments of the distribution (COSTA et al., 2016).

This procedure was developed by Hainmueller (2012), who asserts several advantages in the data preprocessing steps for subsequent estimation of treatment effects compared to propensity score-based impact evaluation methods.

Considering a sample with  $n_1$  observations belonging to the treated group and  $n_0$  control units, which were randomly selected from a population of size  $N_1$  and  $N_0$ , respectively ( $n_1 \leq N_1$  and  $n_0 \leq N_0$ ). Let  $D_i \in \{1,0\}$  be a binary treatment variable, which takes the value 1 if unit  $i$  belongs to the treatment group, and 0 if it belongs to the control group. Let  $X$  be a matrix containing observations of  $J$  pre-treatment exogenous variables;  $X_{ij}$  corresponds to the value of the  $j$ -th covariate for unit  $i$ , such that  $X_i = [X_{i1}, X_{i2}, \dots, X_{iJ}]$  refers to the vector of characteristics for unit  $i$ , and  $X_j$  to the column vector of the  $j$ -th covariate. The density of the covariates in the treatment and control populations is given by  $f_{X|D=1}$  and  $f_{X|D=0}$ , respectively. The potential outcome  $Y_i(D_i)$  corresponds to the pair of outcomes for unit  $i$  under the treatment and control conditions. Thus, the observed outcome is given by  $Y = Y(1)D + (1 - D)Y(0)$ .

The Average Treatment Effect on the Treated (ATT) is given by:  $\tau = E[Y(1)|D = 1] - E[Y(0)|D = 1]$  (1)

The first expectation can be directly identified from the treated group, but the second corresponds to the counterfactual, which is not observed. Rosenbaum and Rubin (1983) show that, assuming selection on observables,  $Y(0) \perp D|X$ , and overlap,  $\Pr(D = 1|X = x) < 1$  for all  $x$  in the support of  $f_{X|D=1}$ , the ATT is identified as:

$$\tau = E[Y|D = 1] - \int E[Y|X = x, D = 0] f_{X|D=1}(x) dx \quad (2)$$

To estimate the last term in Equation (8), the distribution of the covariate in the control group needs to be adjusted to make it like the distribution in the treated group, such that the treatment indicator  $D$  becomes closer to being orthogonal to the covariates.

<sup>2</sup> <https://portal.inmet.gov.br/>. Accessed on August 31<sup>st</sup>, 2024.

Various data preprocessing methods, such as nearest neighbor matching and propensity score matching, have been proposed to reduce the imbalance in the distribution of independent variables. Once the distributions of independent variables are adjusted, standard analysis methods, such as regression, can subsequently be used to estimate the treatment effect with reduced error and model dependency (IMBENS, 2004; RUBIN, 2006; HO et al., 2007; IACUS et al., 2011; SEKHON, 2009).

Consider the simplest case where the treatment effect on pre-processed data is estimated using the difference in mean outcomes between the adjusted treated and control groups. A popular preprocessing method is to use propensity score weighting (HIRANO; IMBENS, 2001; HIRANO et al., 2003), in which the counterfactual mean is estimated as:

$$E[Y(0)|\widehat{D} = 1] = \frac{\sum_{\{i|D=0\}} Y_i d_i}{\sum_{\{i|D=0\}} d_i} \quad (3)$$

The control units receive a weight given by  $d_i = \frac{\hat{p}(x_i)}{1-\hat{p}(x_i)}$ .  $\hat{p}(x_i)$  in equation (3) represent the propensity score, commonly estimated through a probit or logit regression. If this model is correctly specified, then the estimated weight  $d_i$  will ensure that the distribution of covariates among the reweighted control units matches the distribution in the treatment group. However, in practice, this approach often fails to balance all covariates simultaneously.

Entropy balancing generalizes the propensity score weighting approach by estimating weights directly from a set of balance constraints, which leverage the researcher's knowledge about the moments from the sample.

Consider  $w_i$  to be the weight chosen by entropy balancing for each control unit, which is determined by the following reweighting scheme that minimizes the entropy distance metric:

$$\min_{w_i} H(w) = \sum_{\{i|D=0\}} w_i \log(w_i/q_i) \quad (4)$$

Subject to balance constraints and normalization

$$\sum_{\{i|D=0\}} w_i c_{ri}(X_i) = m_r \quad (5)$$

with  $r \in 1, \dots, R$

$$\sum_{\{i|D=0\}} w_i = 1 \quad (6)$$

and  $w_i \geq 0$  for all  $i$ , such that

$$D = 0 \quad (7)$$

Given that  $q_i = 1/n_0$  is a base weight and  $c_{ri}(X_i) = m_r$  describes a set of  $R$  constraints imposed on the moments of covariates in the reweighted control group. Initially, the covariate to be included in the reweighting is chosen. For each covariate, a set of balancing constraints is specified to equalize the moments of covariate distributions between the treatment and reweighted control groups. Moment constraints may include the mean (first moment), variance (second moment), and skewness (third moment). A typical balancing constraint is formulated such that  $m_r$  contains the moment of a specific covariate  $X_j$  for the treatment group, and the moment function for the control group is specified as:  $c_{ri}(X_{ij}) = X_{ij}^r$  ou  $c_{ri}(X_{ij}) = (X_{ij} - \mu_j)^r$  with mean  $\mu_j$ .

Thus, entropy balancing seeks weights  $W = [w_i, \dots, w_{n_0}]'$  for a set of units that minimize the entropy distance between  $W$  and the base weight vector  $Q = [q_i, \dots, q_{n_0}]'$ , subject to balancing constraints in Equation (5), normalization constraint in Equation (6), and non-negativity constraint in Equation (7).

#### 4. Results

In this section, the results of the entropy balancing test are presented and analyzed to assess the impact of the PSR program on agricultural production among rural producers in the regions of Brazil during the years 2006 and 2017.

It's worth noting that the analysis excludes the capitals of the Brazilian states and the Federal District. Additionally, the North region is excluded due to minimal insurance policy contracts in 2006 and 2017, which would not guarantee a robust analysis.

Tables 1 and 2 present the descriptive statistics of the variables used in the analyses for the years 2006 and 2017, respectively.

In 2006 (Table 1), it was observed that the Northeast region of Brazil showed lower results compared to the other regions. Only 0.45% of municipalities in the Northeast had contracted PSR policies, while the South region had 36.95%. Regarding the Gross Value of Agricultural Production (GPV) per establishment, the Northeast had an average value of R\$11,336.07, whereas the Center-west region achieved R\$36,731.22. Another relevant point is the percentage of Northeastern municipalities with technical assistance (11.55%), contrasting with 58.32% in the South region. These disparities are attributed to the strong presence of small-scale and subsistence agriculture in the Northeast. PSR contracts were concentrated in the MATOPIBA region, particularly in southeastern Bahia.

In contrast, in the South region, 36.95% of municipalities had at least one PSR policy contracted. This high percentage is expected due to the strong concentration of PSR resources in the region, driven by the production of soybeans, corn, and wheat, which are the main products covered by the PSR (Tabosa and Vieira Filho, 2021). Additionally, the South region had a high percentage of municipalities with technical assistance (58.32%) and an average Gross Value of Agricultural Production (GPV) per establishment of R\$22,183.56. The Center-West region had the highest Gross Value of Agricultural Production (GPV) per establishment (R\$36,721.22), with 25.11% of municipalities served by PSR. This is attributed to the region's strong production of soybeans and corn (in states like Mato Grosso and Goiás) and livestock (in Mato Grosso do Sul).

On the other hand, the Southeast region had 14.57% of municipalities assisted by the PSR program, with 40.81% receiving technical assistance. The GPV per establishment was the second highest among the regions (R\$20,778.07), second only to the Center-West region.

**Table 1 - Descriptive Statistics of Variables - 2006**

<b>NORTHEAST REGION</b>					
Variables	Obs.	Mean	Std. Dev.	Min	Max
PSR insurance	1,784	0.0045	0.0668	0	1
GPV per establishment	1,784	11,336.07	36,154.57	0	790,259.8
Assistance	1,784	0.1155	0.1306	0	0.9545
Male	1,784	0.8747	0.0505	0.5828	0.9782
Temperature	1,784	25.9	1.3414	22.33	28.29
Precipitation	1,784	1,163.72	437.81	319.35	2,608
<b>SOUTHEAST REGION</b>					
Variables	Obs.	Mean	Std. Dev.	Min	Max
PSR insurance	1,664	0.1457	0.3529	0	1
GPV per establishment	1,664	20,778.07	39,563.87	0	521,479.7
Assistance	1,664	0.4081	0.2383	0	0.7173

Male	1,664	0.9152	0.0364	0.70	0.9951
Temperature	1,664	22.77	1.62	18.05	26.44
Precipitation	1,664	1.460,2	180.56	780.97	2,294.55
<b>CENTER-WEST REGION</b>					
Variables	Obs.	Mean	Std. Dev.	Min	Max
PSR insurance	463	0.2511	0.4341	0	1
GPV per establishment	463	36,731.22	85,013.87	0	597.129,8
Assistance	463	0.3477	0.2148	0.2331	0.4134
Male	463	0.9163	2.8042	0.8076	0.9922
Temperature	463	25.74	1.0577	22.36	27.97
Precipitation	463	1,681.22	210.89	1,164.6	2,320.64
<b>SOUTH REGION</b>					
Variables	Obs.	Mean	Std. Dev.	Min	Max
PSR insurance	1,188	0.3695	0.4829	0	1
GPV per establishment	1,188	22,183.56	28,580.95	0	271,419.1
Assistance	1,188	0.5832	0.2601	0.0275	0.6573
Male	1,188	0.9216	0.0319	0.7151	0.9907
Temperature	1,188	20.14	1.22	16.09	23.3
Precipitation	1,188	1,330.97	101.69	1,076.48	1,598.3

Source: Prepared by the authors using data from the Agricultural Census.

Table 2 presents the descriptive statistics of the variables for the year 2017. The Northeast region showed that 5.49% of its municipalities were served by the PSR. This increase compared to 2006 was mainly due to the expansion of MATOPIBA, with soybean and corn production. The Gross Value of Agricultural Production (GPV) per establishment was R\$16,113.61, with 9.92% of municipalities receiving technical assistance. Compared to 2006, GPV increased; however, the percentage of municipalities receiving technical assistance decreased.

Regarding the Southeast region, 45.69% of municipalities were served by the PSR program, with approximately 10% of municipalities receiving technical assistance. The Gross Value of Agricultural Production (GPV) in the region averaged R\$45,910.95, significantly higher than in 2006 (R\$20,778.07), due to the expansion of soybeans, corn, and fruits, which experienced a strong increase in commodity prices starting in 2007/2008.

In the Center-West region, there was also an expansion in the number of municipalities served by the PSR program (66.74%), resulting in an increase in the Gross Value of Agricultural Production (GPV) to R\$177,885.50, driven by soybeans<sup>3</sup> and corn. Meanwhile, in the Southern region, 75.84% of municipalities were assisted by the PSR, with a GPV of R\$63,018.61.

When comparing the two analyzed periods, there was an increase in the number of municipalities assisted by the PSR. In 2006, as previously mentioned, it was the first year of program implementation. By 2017, the program's allocated resources were significantly higher (R\$3.54 billion in 2006 compared to R\$12.85 billion in 2017<sup>4</sup>), along with the number of producers (16.46 thousand in 2006 to 47.48 thousand in 2017). Due to this expansion of the program, there was an observed increase in the number of municipalities with producers benefiting from the PSR.

The Gross Value of Agricultural Production (GPV) per establishment increased in all analyzed regions. The expansions in cultivated areas, as well as the rise in agricultural commodity prices, were significant factors contributing to this outcome (FREITAS, 2022; IBGE, 2022).

<sup>3</sup> The states of Mato Grosso (MT) and Goiás (GO) are indeed the largest producers of soybeans in Brazil.

<sup>4</sup> For more details, see <https://mapa-indicadores.agricultura.gov.br/publico/extensions/SISSER/SISSER.html>. Accessed on August 31<sup>st</sup>, 2024

However, the percentage of municipalities receiving technical assistance decreased (PEREIRA and CASTRO, 2021).<sup>5</sup>

**Table 2 - Descriptive Statistics of Variables - 2017**

<b>NORTHEAST REGION</b>					
Variables	Obs.	Mean	Std. Dev.	Min	Max
PSR insurance	1,784	0.0549	0.2278	0	1
GPV per establishment	1,784	16,113.61	93,513.93	0	2,377.157
Assistance	1,784	0.0992	0.1064	0.1299	0.8028
Male	1,784	0.7884	0.0822	0.4431	0.9750
Temperature	1,784	25.71	1.8540	21.21	29.26
Precipitation	1,784	922.02	428.34	159.4	2067.8
<b>SOUTHEAST REGION</b>					
Variables	Obs.	Mean	Std. Dev.	Min	Max
PSR insurance	1,664	0.4569	0.4982	0	1
GPV per establishment	1,664	45.910,95	83.807,87	0	955.291
Assistance	1,664	0.3495	20.1318	0.3032	0.9932
Male	1,664	0.8695	5.9237	0.4729	0.9903
Temperature	1,664	22.09	2.2714	16.71	0.2740
Precipitation	1,664	1,132.15	240.29	574,4	2,247.15
<b>CENTER-WEST REGION</b>					
Variables	Obs.	Mean	Std. Dev.	Min	Max
PSR insurance	463	0.6674	0.4716	0	1
GPV per establishment	463	177,885.5	360,407.7	0	2,993,145
Assistance	463	0.2547	0.1760	0.1918	0.9378
Male	463	0.8461	0.0478	0.6842	0.9784
Temperature	463	26.16	1.58857	22.76	30.28
Precipitation	463	1.492,70	269,58	908,9	2.222,38
<b>SOUTH REGION</b>					
Variables	Obs.	Mean	Std. Dev.	Min	Max
PSR insurance	1,188	0.7584	0.4282	0	1
GPV per establishment	1,188	63,018.61	82,983.62	0	617.013
Assistance	1,188	0.5124	0.2097	0.2539	0.9798
Male	1,188	0.8819	0.0484	0.6667	0.9856
Temperature	1,188	20.15	1.76	15.78	24.5
Precipitation	1,188	1,996.02	370.89	1,153.5	2,694

Source: Prepared by the authors using data from the Agricultural Census.

In the next section we will analyze Entropy balancing.

#### 4.1. Entropy Balancing

Thus, entropy balancing was performed, a methodology proposed by Hainmueller (2012), aimed at obtaining weights that minimize the disparities between municipalities served by the PSR and the control group, making them more homogeneous. This approach allows for the isolation of the effects of observable characteristics used in the impact evaluation model.

Tables 3 to 6 show the mean, variance and asymmetry regarding the behavior of the first, second and third moments of the distribution of the covariates of the treatment and control groups, before and after balancing, in the regions analyzed. It was found that, after the

<sup>5</sup> Pereira and Castro (2021) found that other sources of technical guidance, such as self-guidance and cooperatives, have been showing significant growth.

procedure, there was an adjustment of the three moments in all the variables considered. Therefore, the groups are balanced regarding the covariates analyzed.

**Table 3** - Statistical distribution of covariates before and after entropy balancing – Northeast region of Brazil

2006	Treatment - Before 2006			Treatment - After 2006		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	16.67	284,2	1.665	16.67	284.2	1.665
Percentage of males	88.68	7,75	1.689	88.86	7,65	1.689
Temperature	25.25	0.44	-0.5106	25,25	0.44	-0.5106
Precipitation	1,286	89.661	0.218	1.286	89.661	0.218
	Control - Before 2006			Control - After 2006		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	11.38	163	2.303	16.67	270.8	1.609
Percentage of males	87.45	25.67	-1.117	88.86	18.07	-0.7054
Temperature	25.91	1.811	-1.1737	25.25	1.66	0.2231
Precipitation	1,161	191.533	0.7312	1,286	179.219	0.4345
2017	Treatment - Before 2017			Treatment - After 2017		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	11.1	88,14	1.533	11,1	88,14	1,533
Percentage of males	80.39	45.19	-0.5534	80.39	45.19	-0.5534
Temperature	25.82	2.646	-0.3424	25.82	2.646	-0.3424
Precipitation	1,084	104.723	-0.0562	1,084	104,723	0.0562
	Control - Before 2017			Control - After 2017		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	9.83	114.7	2.521	11.1	173.5	2.274
Percentage of males	78,77	68,66	-0.71	80,39	61,23	-0,6946
Temperature	25.71	3.492	-0.0365	25.82	3.43	-0.0771
Precipitation	912.3	186,983	0.7087	1,084	247,972	0.3455

Source: Prepared by the authors using data from the Agricultural Census.

**Table 4** - Statistical distribution of covariates before and after entropy balancing – Southeast region of Brazil

2006	Treatment - Before 2006			Treatment - After 2006		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	52.84	442.3	0.2942	52.84	442.3	0.2942
Percentage of males	92.11	9.969	-2.118	92.11	9.969	-2.118
Temperature	22.98	2.653	-0.1933	22.98	2.653	-0.1933
Precipitation	1,462	24.988	0.1143	1,462	24.988	0.1143
	Control - Before 2006			Control - After 2006		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	38.68	549.5	0.4978	52.82	642.9	0.1836
Percentage of males	91.44	13.46	-1.104	92.1	11.93	-1.175
Temperature	22.8	2.602	-0.2717	22.98	2.472	-0.3158
Precipitation	1,454	33,998	3.445	1,462	29,724	-0.6304
2017	Treatment - Before 2017			Treatment - After 2017		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	41.58	368.4	0.238	41.58	368.4	0.238
Percentage of males	88.27	25.98	-1.873	88.27	25.98	-1.873

Temperature	22.22	5.709	0.2116	22.22	5.709	0.2116
Precipitation	1,236	38,549	-0.0492	1,236	38,549	-0.0492
<b>Control - Before 2017</b>			<b>Control - After 2017</b>			
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	29.02	358.3	0.7917	41.57	461.6	0.3105
Percentage of males	85.89	38.93	-0.9839	88.27	26.02	-1.156
Temperature	22	4.674	0.8699	22.22	5.19	0.6454
Precipitation	1,036	54,679	0.8699	1,236	79.775	3,336

Source: Prepared by the authors using data from the Agricultural Census.

**Table 5** - Statistical distribution of covariates Before and after entropy balancing – South region of Brazil

2006	<b>Treatment - Before 2006</b>			<b>Treatment - After 2006</b>		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	58.65	668	0.2832	58.65	668	0.2832
Percentage of males	92.14	7.96	-0.6305	92.14	7.96	-0.6305
Temperature	20.61	2.065	-0.4258	20.61	2.065	-0.4258
Precipitation	1,315	9913	-0.1365	1,315	9913	-0.1365
<b>Control - Before 2006</b>			<b>Control - After 2006</b>			
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	58.18	682.4	0.326	58.65	650.8	0.4454
Percentage of males	92.2	10.96	-1.426	92.14	10.1	-1.44
Temperature	19.87	0.9716	0.0362	20.61	1.425	0.395
Precipitation	1,342	10280	-0.222	1,315	10371	0.2044
2017	<b>Treatment - Before 2017</b>			<b>Treatment - After 2017</b>		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	52.05	446.2	0.0309	52.05	446.2	0.0309
Percentage of males	88.33	21.71	-0.8096	88.33	21.71	-0.8096
Temperature	20.15	3.502	-0.0443	20.15	3.502	-0.0443
Precipitation	2,007	129518	0.1455	2,007	129518	0.1455
<b>Control - Before 2017</b>			<b>Control - After 2017</b>			
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	48.55	416	-0.0709	52.05	409.4	-0.213
Percentage of males	87.76	28.85	-0.7739	88.33	26.94	-0.8335
Temperature	20.16	1.963	-0.0692	20.15	1.841	-0.139
Precipitation	1,967	163911	0.5557	2,007	169988	0.3951

Source: Prepared by the authors using data from the Agricultural Census.

**Table 6** - Statistical distribution of covariates Before and after entropy balancing – Center-West region of Brazil

2006	<b>Treatment - Before 2006</b>			<b>Treatment - After 2006</b>		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	49.3	509	0.4147	49.3	509	0.4147
Percentage of males	91.84	7.479	-0.2177	91.84	7.479	-0.2177
Temperature	25.45	1.1	-0.7602	25.45	1.1	-0.7602
Precipitation	1,684	40490	0.5508	1,684	40490	0.5508
<b>Control - Before 2006</b>			<b>Control - After 2006</b>			
	Mean	Variance	Skewness	Mean	Variance	Skewness

Percentage of technical assistance	29.78	351	1	49.3	782.7	0.3192
Percentage of males	91.6	7.67	-0.5544	91.84	7.794	-0.2499
Temperature	25.84	1.091	-0.7918	25.45	1.911	-0.8627
Precipitation	1,682	46298	0.5113	1,684	67409	0.8385
	<b>Treatment - Before 2017</b>			<b>Treatment - After 2017</b>		
<b>2017</b>	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	28.65	335.6	0.9895	28.65	335.6	0.9895
Percentage of males	84.57	23.17	-0.6095	84.57	23.17	-0.6095
Temperature	26.08	2.761	0.0623	26.08	2.761	0.0623
Precipitation	1,535	76240	0.5829	1,535	76240	0.5829
	<b>Control - Before 2017</b>			<b>Control - After 2017</b>		
	Mean	Variance	Skewness	Mean	Variance	Skewness
Percentage of technical assistance	19.01	199.8	1.407	28.65	317.9	0.624
Percentage of males	84.71	22.46	-0.6281	84.57	18.57	-0.4997
Temperature	26.36	1.973	-0.1191	26.08	1.61	-0.5392
Precipitation	1,140	55607	0.8759	1,535	66869	2.01

Source: Prepared by the authors using data from the Agricultural Census.

Table 7 presents the result of the entropy balancing for the Northeast region of Brazil. In both periods, the coefficient related to the Insurance variable was statistically significant at 10%, and with a positive sign. This indicates that the municipalities benefiting from the PSR program had a higher GPV per establishment than the other municipalities in the region, and that this difference was R\$15,852.5 in 2006 and R\$19,524.4 in 2017.

These results corroborate those obtained in the Propensity Score Matching, except for 2006. Agricultural expansion in the region, mainly in the MATOPIBA, as well as the increase in policies contracted in the region are important points to explain these results. Similar results were found by Ferreira (2024), Teixeira et al (2023) and Tabosa et al (2021).

**Table 7- Result of entropy balancing – Northeast region**

<b>GPV per establishment 2006</b>	Coefficient	Std. Dev	T	P> t
Insurance Policy	15,852,5	9219.25	1.72	0.08
<b>GPV per establishment 2017</b>	Coefficient	Std. Dev	T	P> t
Insurance Policy	19,524,4	34383.26	2.31	0.01

Source: Prepared by the authors using data from the Agricultural Census.

In relation to the Southeast region, as with the Propensity Score Matching, the results suggest that the PSR program was efficient in increasing the GPV per establishment in the region, when comparing the municipalities served by the program, against the others.

For 2006, the estimated coefficient was R\$16,263.52. In other words, the difference between the GPV per establishment in the municipalities served by the PSR and the GPV of the other municipalities was R\$16,263.52. For 2017, this difference was R\$17,887.71. The results are shown in Table 9.

The Southeast region, between 2006 and 2018, concentrated around 10% of the policies contracted by the PSR, which provided producers in the region with a greater opportunity to expand their production, associated with improvements in management, machinery, equipment; in addition to the increase in the prices of agricultural commodities (MACEDO et al, 2013).

**Table 8- Result of entropy balancing – Southeast region**

<b>GPV per establishment 2006</b>	Coefficient	Std. Dev	T	P> t
Insurance Policy	15,263.52	3894.69	3.92	0.00
<b>GPV per establishment 2017</b>	Coefficient	Std. Dev	T	P> t
Insurance Policy	17,887.71	5904.57	3.03	0.00

Source: Prepared by the authors using data from the Agricultural Census.

Table 9 presents the balancing result for the South region of Brazil. According to Tabosa and Vieira Filho (2021), this region concentrates the largest share of insurance policies contracted by the PSR. It was found that the PSR was efficient in the GPV per establishments in the municipalities that were served by the program, since the coefficient related to the Insurance variable was positive and statistically significant, with values equal to R\$10,577.29 in 2006 and R\$32,613.48 for 2017. The production of soybeans, wheat, and corn were of utmost importance for these results.

**Table 9- Result of balancing by entropy – South region**

<b>GPV per hectare 2006</b>	Coefficient	Std. Dev	T	P> t
Insurance Policy	10.577,29	2723,35	3.88	0.00
<b>GPV per hectare 2017</b>	Coefficient	Std. Dev.	T	P> t
Insurance Policy	32.613,48	5062,96	6,44	0.00

Source: Prepared by the authors using data from the Agricultural Census.

Finally, the results of the entropy balancing in the Center-West region were significant for 2006. The value of R\$59,839.77 in the GPV differential per establishment between the municipalities served and not served by the PSR highlights the efficiency of the program for that year. However, for 2017, this result did not occur, because the factors already mentioned, such as technological expansion and corn and soybean production, occurred throughout the region (VIEIRA FILHO, 2016). These results are shown in table 10 below.

**Table 10- Result of entropy balancing - Center-West region**

<b>GPV per hectare 2006</b>	Coeficiente	Std. Err	T	P> t
Insurance Policy	59.839,77	30430,08	2.62	0.00
<b>GPV per hectare 2017</b>	Coeficiente	Std. Err	T	P> t
Insurance Policy	45.572,4	96116,39	0,79	0.35

Source: Prepared by the authors using data from the Agricultural Census.

## 5. Concluding Remarks

The objective of this work was to analyze the impact of agricultural insurance on production of insured rural producers in different regions of Brazil through the Premium Subsidy Program for Rural Insurance (PSR), using data from the 2006 and 2017 Agricultural Censuses.

Upon examining the descriptive statistics, it was observed that PSR policies are significantly prevalent in the Southern and Central-Western regions. In contrast, the Northeast region shows low adoption of the PSR program, with only the MATOPIBA region having contracted policies. The predominance of males being the head of the household persists across all regions.

Moreover, Gross Value of Agricultural Production (GPV) per establishment showed a considerable increase in all regions from 2006 to 2017. This indicates strong growth in Brazilian agriculture driven by technological modernization, agricultural expansion, particularly in the MATOPIBA region, and increased value of agricultural commodities in the international market.

Results from entropy balancing suggest that the insurance variable positively impacts GPV per establishment in municipalities where producers have purchased PSR policies. This underscores the program's importance to Brazilian agribusiness. According to Tabosa and Vieira Filho (2021), producers who acquire these policies can farm with reduced risk, encouraging expansion of cultivated areas and consequently increasing production.

As for suggestions, further studies are needed to assess the impact of the PSR program, particularly using primary data to directly assess its impact on each agricultural establishment in Brazil. Additionally, efforts should focus on diversifying PSR investments away from regions like the South and toward addressing the needs of the North and Northeast regions to reduce regional disparities in agribusiness.

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