Heterogeneous regional effects of rural credit on agricultural production in Brazil

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RESUMO

O acesso ao crédito rural tem sido persistentemente heterogêneo entre as regiões brasileiras ao longo do tempo. Este estudo teve como objetivo estimar os efeitos regionais do crédito rural sobre a produção agropecuária devido à heterogeneidade observada no acesso ao crédito. Com base em dados do Censo Agropecuário 2017 e variáveis climáticas, o efeito do crédito rural foi estimado por meio de regressões padrão, combinadas com a técnica de balanceamento de entropia. Os resultados mostram efeitos positivos e significativos do crédito rural na produção agrícola brasileira, mesmo após o controle das covariáveis observadas. Esse resultado foi consistente mesmo após o balanceamento das covariáveis em relação à entropia. O efeito do crédito rural mostrou-se heterogêneo entre as regiões brasileiras, sendo positivo e significativo para as regiões com maior acesso ao crédito rural e estatisticamente nulo nas regiões menos intensivas em crédito. Além disso, as estimativas mostram que a assistência técnica é um importante mecanismo de transmissão do efeito do crédito rural. **Palavras-chave**: crédito rural; assistência técnica; produção agropecuária; Brasil.

ABSTRACT

Access to rural credit has been persistently heterogeneous across Brazilian regions over time. This study aimed to estimate the regional effects of rural credit on agricultural production due to the heterogeneity observed in access to credit. Based on data from the 2017 Agricultural Census and climate variables, the effect of rural credit was estimated by standard regressions, combined with the entropy balancing technique. The results show positive and significant effects of rural credit on Brazilian agricultural production, even after controlling for observed covariates. This result was consistent even after balancing the covariates with regard to entropy. The effect of rural credit proved to be heterogeneous across Brazilian regions, being positive and significant for regions with greater access to rural credit and statistically null in less credit-intensive regions. Furthermore, estimates show that technical assistance is an important transmission mechanism of the rural credit effect. **Keywords**: rural credit; technical assistance; agricultural production; Brazil.

JEL Classification: Q14; Q18

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1 INTRODUÇÃO

Productivity increases and agricultural production growth have placed Brazil in a prominent position in the international scenario in recent decades with agricultural production value reaching around 4.5% of GDP between 1996 and 2020, on average (CEPEA, 2022).[1] This may be the result of various public policies and technological advances that have contributed to maintaining the competitiveness of this sector. In Brazil, several rural credit policies have been implemented[2] which have allowed small producers in regions with less modernized production systems, low technical efficiency, and which are more susceptible to climatic variations to have access to financial support, thus reducing market failures. However, the last Agricultural Census, conducted in 2017, revealed a subtle reduction in the share of agricultural establishments that had access to rural credit.[3] Furthermore, access to credit has been persistently lower in the North and Northeast regions over time.

The effect of rural credit has been widely discussed in important previous studies, especially in developing economies. These studies detected that rural credit had positive effects on different economic and environmental variables in the agricultural sector.[4] Regarding agricultural production and/or productivity in Brazil, these results have not been different (ARAUJO; Vieira Filho, 2018; ASSUNÇÃO; SOUZA, 2019; COSTA; FREITAS, 2018; FREITAS; SILVA; TEIXEIRA, 2020; GASQUES; BACCHI; BASTOS, 2017). However, these studies assumed homogeneous effects of rural credit.

In addition to the extensive Brazilian territorial expanse, and the different natural, climatic and cultural conditions and particularities of rural producers in each Brazilian region, access to rural credit tends to be more restricted in some regions. These differences allow us to expect that rural credit produces heterogeneous effects on agricultural production across regions. However, there is little evidence in this regard, e.g., (EUSÉBIO; MAIA; SILVEIRA, 2020; GARCIAS; KASSOUF, 2016; MAIA; EUSÉBIO; SILVEIRA, 2020).

This paper aimed to estimate the regional effects of rural credit on agricultural production due to observed heterogeneous access to credit. Based on data from the Agricultural Census (2017) and climate variables, the effect of rural credit was estimated using standard regressions, combined with entropy balancing. By expanding the debate on the causal effects of rural credit across Brazilian regions, we provide at least two contributions to the literature. First, in contrast to studies based on propensity scores, our estimates take into account an exact balance of covariates between the treated and control groups, without loss of valuable information in the preprocessed data. Second, we provide evidence on potential transmission mechanisms through which rural credit can influence agricultural production.

In order to estimate the effect of rural credit, data were needed regarding characteristics of rural producers and agricultural activity which allowed identifying those with and without access to rural credit. The only database that met these conditions was the Agricultural Census. However, two important limitations should be mentioned. First, it was not possible to obtain a data panel of rural producers which limited the use of more robust techniques to estimate the

[1] In 2020, agricultural production accounted for 7% of Brazilian GDP, which is the largest share recorded between 1996 and 2020.

[2] For example, the National Support Program for Medium Rural Producers (PRONAMP) and the Program for the Strengthening of Family Farming (PRONAF), among others.

[3] The proportion of rural establishments that received some funding decreased from 17.76% in 2006 to 15.46% in 2017 (IBGE, 2022).

[4] For example, positive effects on agricultural income and participation in agricultural activities (ELY et al., 2019; KHANDKER; KOOLWAL, 2016; LUAN; BAUER, 2016; NEVES et al., 2020; SI et al., 2021); on farmland rental market participation of rural households (LI et al., 2020); on GDP (BORGES; PARRÉ, 2022); on land use, agricultural practices and deforestation (ASSUNÇÃO; SOUZA, 2019; ASSUNÇÃO et al., 2019; CARRER et al., 2020; PORGO et al., 2018).

treatment effect. Furthermore, since access to microdata requires authorization from IBGE for restricted use in a confidential room in Rio de Janeiro, we used the census data which is publicly available at the municipal level. Thus, we adopted the concept of representative farms, used in previous studies (FREITAS; SILVA; TEIXEIRA, 2020; HELFAND; MAGALHÃES; RADA, 2015). As for the treatment variable, we created a dummy variable that received the value of 1 if the municipality had a proportion of rural establishments that obtained funding in 2017 above the average plus one standard deviation in each region. Thus, the treatment condition in this study indicated greater intensity in rural credit access.

The results suggest that treated representative farms, i.e., those which are more intensive in rural credit, are associated with greater agricultural production in Brazil, when compared to less intensive representative farms. Our estimates also support the hypothesis of heterogeneous regional effects of rural credit, so that the effect of rural credit remains positive and significant in regions where access to financial support is less restrictive. Furthermore, the results indicate that technical assistance is an important transmission mechanism through which rural credit affects the performance of agriculture in Brazil and regions. In other words, rural credit has a direct effect on agricultural production and an indirect effect through technical assistance.

In addition to this introduction, our article is structured as follows. Section 2 discusses recent literature regarding the role of rural credit in the Brazilian agricultural sector. Section 3 presents the empirical strategy. Section 4 discusses the dataset used in this study and the descriptive statistics, and Section 5 presents the findings and discussion of our analysis. In Section 6 we present our concluding remarks.

2 RURAL CREDIT AND AGRICULTURAL PERFORMANCE

The Brazil has become one of the largest producers and exporters of agricultural products in the world in recent decades, as a result of technological advances, the expansion of the agricultural frontier, greater productivity, and competitiveness. In addition to advances in research developed by Embrapa, Araújo et al. (2020) emphasize that rural credit has been fundamental in achieving these positive results, even in light of a series of difficulties, such as infrastructure deficiencies, high interest rates, and a devalued currency. According to these authors, rural credit has remained the main instrument to support rural producers, since the enactment of the National Rural Credit System (SNCR) by Law nº 4,829 of 1965. Also in this regard, Servo (2019) highlighted the existence of a historical dependence of the agricultural sector in Brazil on rural credit, making this instrument of support for rural producers one of the main determinants of Brazilian agricultural GDP.

Impacts of rural credit have been widely investigated in the literature, in which the effects are measured on different outcome variables of the agricultural sector (economic and environmental) through different methodological approaches. In the Brazilian case, for example, evidence can be found on the effect of rural credit on agricultural or agribusiness GDP (ARAÚJO; HECK; CARRARA, 2021; BORGES; PARRÉ, 2022; GASQUES; BACCHI; BASTOS, 2017); on Total Factor Productivity (TFP), land or labor productivity and/or technical efficiency (ARAUJO; Vieira Filho, 2018; COSTA; FREITAS, 2018; FIGUEIRA, 2020; FREITAS; SILVA; TEIXEIRA, 2020; GARCIAS; KASSOUF, 2016; GASQUES; BACCHI; BASTOS, 2017); on the quantity produced (COSTA; Vieira Filho, 2018; FIGUEIRA, 2020; SOUZA; MOURÃO; ASSUNÇÃO, 2021); and on the income of rural producers (ARAUJO; ALENCAR; Vieira Filho, 2020). Furthermore, recent studies have investigated the effects of rural credit on environmental aspects such as land use, and planted and harvested areas (ARAUJO; Vieira Filho, 2018; ASSUNÇÃO et al., 2019; COSTA; Vieira Filho, 2018; FIGUEIRA, 2020; SOUZA; MOURÃO; ASSUNÇÃO, 2021).

The evidence also highlights the positive and significant effects of rural credit on the gross value of production, which is the variable of interest in this study (ARAUJO; ALENCAR; Vieira Filho, 2020; ARAUJO; Vieira Filho, 2018; ASSUNÇÃO; SOUZA, 2019; COSTA; Vieira Filho, 2018; EUSÉBIO; MAIA; SILVEIRA, 2020; FIGUEIRA, 2020; FREITAS; SILVA; TEIXEIRA, 2020; GARCIAS; KASSOUF, 2016; GASQUES; BACCHI; BASTOS, 2017; MAGALHÃES et al., 2006; MAIA; EUSÉBIO; SILVEIRA, 2020; SOUZA; MOURÃO; ASSUNÇÃO, 2021). Using different methodological approaches, most of these studies assumed that rural credit has homogeneous impacts on Brazilian agricultural production. However, studies that have focused on the heterogeneity of the effects of rural credit on Brazilian agricultural production are still scarce. Among those who aimed to estimate causal relationships, Eusébio, Maia e Silveira (2020), Garcias e Kassouf (2016) and Maia, Eusébio e Silveira (2020) found evidence of the heterogeneous effects of rural credit across Brazilian regions. Using data from the 2006 Agricultural Census, the last two studies used approaches based on propensity scores to estimate the effects of rural credit.

In this context, this study contributes by providing new evidence of heterogeneous regional effects, considering the intensity of access to rural credit as treatment, by using an alternative empirical strategy to models based on propensity scores with advantageous statistical properties, and by exploring potential mechanisms of rural credit transmission neglected in previous studies.

3 EMPIRICAL STRATEGY

We are interested in measuring the effect of the intensity of access to rural credit (where the treatment dummy is an indicator variable for municipalities with greater access to rural credit) on agricultural production (gross production value) in Brazil and regions. To estimate the true effect of this treatment it would be necessary to compare the potential outcome of the treated municipalities against the potential outcome of the treated municipalities if these municipalities had not received the treatment (counterfactual group). However, only the potential outcomes of rural credit-intensive municipalities (treated group) and non-intensive municipalities (control group) can be observed. This issue is a problem in the evaluation literature. Since the potential results of the counterfactual group were not observed, the alternative found in the literature was to use information from the control group to derive the counterfactuals.

Specifically, we are interested in estimating the parameter that measures the effect of the intensity of access to credit in municipalities that were indeed treated, i.e., the average effect of treatment on the treated (ATT), making it possible to guide policy makers whether being intensive in rural credit has any impact. A simple way to measure ATT using cross-section data is to estimate a standard linear regression by Ordinary Least Squares (OLS) controlling for treated observations and for observed characteristics, according to equation 1 below:

$$Y_i = \alpha_i + \beta_i T_i + \gamma' X_i + \epsilon_i \tag{1}$$

where, Y_i is the gross value of agricultural production in the i-th municipality; X_i is a vector of observable characteristics; T_i is a treatment indicator variable that assumes the value 1 if the municipality is intensive in accessing rural credit, and 0 otherwise; β is the parameter of interest to be estimated, equivalent to the ATT. However, given the non-randomized nature of treatment assignment, it is likely that the ATT estimated in equation (1) is biased by omitting unobserved characteristics which may be correlated with treatment. It is possible that in certain municipalities rural producers are risk lovers and are more willing to make investments via financing, while in other municipalities risk-averse rural producers may predominate, and therefore would avoid financing. This self-selection could overestimate the effect of rural credit by capturing part of the effect of these unobserved characteristics.

Instrumental variable estimators are suitable options for estimating the ATT. However, the use of this approach is limited to the availability of good instruments. Another alternative would be the use of approaches based on propensity scores, as in Rosenbaum e Rubin (1983). This approach assumes that selection by unobservable variables would not affect the outcome variable in the absence of treatment. Under this hypothesis, known as the conditional independence hypothesis, comparisons between the potential outcomes of the treated group and the control group, provided that groups are similar in observable characteristics (i.e., groups balanced in observable characteristics), would provide unbiased estimates of the ATT. The propensity score matching (PSM) technique has been widely used in the literature in this regard, allowing to improve the distribution of observable characteristics, making them independent of the treatment. These techniques, however, can result in low levels of balance.

Thus, Hainmueller (2012) proposed the Entropy Balancing approach, which involves a weighting scheme of the units of analysis for later estimation of the treatment effect. The propensity score-based scheme requires large samples and an estimated propensity score close to the actual one, which is often unknown. Thus, poorly specified propensity scores can increase bias in subsequent estimates of the treatment effect by failing to balance the covariates. Furthermore, they achieve balance only asymptotically. In this sense, the Entropy Balancing method appears as a more accurate alternative to find the balance of covariates.

We adopted the following empirical strategy. Initially, the balancing of the covariates was performed using the Entropy Balancing technique proposed by Hainmueller (2012) and the conditional independence hypothesis was tested by reporting the differences in the means of the observable characteristics. Then, to determine the effect of rural credit on the value of production in Brazil and in the different regions, our ATT estimates were estimated by standard OLS regressions after weighting the data by the entropy weight.

In practice, we assumed that the treatment corresponds to the intensity of access to rural credit, considering representative farms, which are described in the next section, as the unit of analysis. Therefore, representative farms with greater intensity in access to rural credit belonged to the treatment group and representative farms with less intensity belonged to the control group. Thus, the effect of the average treatment on the treated (ATT) is given by the difference in the expected results of the treated rural establishments, $E\Big[Y(1) \mid T = 1\Big]$, and the counterfactuals $E\Big[Y(0) \mid T = 1\Big]$:

$$\tau_{ATT} = E\Big[Y(1) \mid T = 1\Big] - E\Big[Y(0) \mid T = 1\Big] \tag{2}$$

where Y is the result of interest (value of agricultural production), and T is an indicator of treatment (T=1, treated; T=0, control). The second term on the right side of equation (2) cannot be observed. Entropy Balancing, however, gets around this situation by rebalancing the control units, i.e., the sample units of the control group were weighted by a weight w_i, such that the estimate of $E\Big[Y(0) \mid T = 1\Big]$ can be determined, as in equation (3):

$$E\Big[Y(0) \hat{\mid} T = 1\Big] = \frac{\Sigma_{(i|T=0)} Y_i w_i}{\Sigma_{(i|T=0)} w_i} \tag{3}$$

The weights w_i were assigned to each control unit and were obtained through an optimization problem subject to equilibrium and normality constraints. Balancing constraints were imposed to equalize the average of the covariates between the two groups, ensuring that the control group contained, on average, units of analysis that are as similar as possible to the treated units.[5]. The weights w_i were used to weight the units of analysis in subsequent regressions, con-

[5] For details on obtaining the weights, see Hainmueller (2012)

taining the treatment indicator variable (T) as an explanatory variable, according to equation (1). This way, the estimated coefficient β was the unbiased ATT measure. To verify the sensitivity of the estimated coefficient, equation (1) was estimated before and after weighting the data by the entropy weight. Furthermore, the ATT was estimated for Brazil and regions, making it possible to verify whether the effect of rural credit was heterogeneous between regions.

4 DATA

Data from the 2017 Agricultural Census were used, which are available at the Brazilian Institute of Geography and Statistics (IBGE) website, through the IBGE Automatic Recovery System (SIDRA). This database contains microdata, making it possible to identify, at the individual level, the characteristics of rural producers and rural establishments, in addition to the technologies and agricultural practices adopted. Information on financing and its sources is also available, which facilitated the identification of treated and control groups in order to estimate the effect of rural credit. However, these microdata are not readily accessible, given the confidential nature of the information and, therefore this study made use of aggregate data at the municipal level, which are publicly available.[6]

The use of aggregate data may represent a limitation as they disregard all heterogeneity within the municipality. Thus, if farms are very different, aggregation would not allow exploring this variation between the units of analysis. We therefore adopted the concept of representative farms, following previous literature (FREITAS; SILVA; TEIXEIRA, 2020; HELFAND; MAGALHÃES; RADA, 2015). Each unit of analysis thus symbolizes a 'representative' rural property within the municipality, where the variables correspond to the average. These representative units were thus obtained by dividing all the municipal level variables by the total number of rural establishments. For example, the area of a representative establishment is given by the sum of the areas of all rural establishments divided by the total number of rural establishments in municipality i.

Data at the municipal level did not allow us to identify whether the establishment had access to rural credit, which was another limitation of the data. Therefore, we created a dummy variable that indicated the treatment condition of the representative farms. Thus, representative farms whose proportion of establishments that obtained some financing greater than the mean, added by a standard deviation, assumed a value of 1, and 0 otherwise.[7] This was a proxy for the treatment variable that indicated the intensity of access to rural credit.

The sample size varied depending on the region analyzed and the missing values of the variables. Of the 5563 municipalities registered in the Agricultural Census, 127 were excluded from the sample.[8] Table 1 below shows some statistics of the variable proportion of rural establishments that received some type of funding, and the number of representative farms treated and controls according to the regions of interest. The data revealed a certain heterogeneity regarding access to rural credit among the regions considered, which could suggest different regional effects of rural credit on agricultural performance. The North and Northeast regions, respectively, had lower averages, especially in comparison with the South region. Garcias e

[6] Microdata can be accessed upon approval of a research project. However, these data can only be accessed in a confidential room located in Rio de Janeiro, substantially increasing research costs.

[7] This criterion was adopted in Freitas, Silva e Teixeira (2020) for rural credit, and by Costa, Vizcaino e Costa (2020) for the case of cooperativism. Garcias e Kassouf (2016), on the other hand, defined the treatment if most establishments faced credit restrictions in the municipality.

[8] Six municipalities were excluded due to the absence of gross agricultural production values, 42 due to lack of information on the number of establishments that obtained financing, and an additional 79 for lacking information on the number of establishments with irrigation. Missing values were considered the following: absolute zero, not resulting from a rounded value; values omitted so as to not identify the informant; when not applicable; or when value was not available.

Kassouf (2016) showed that in 2006 the North and Northeast regions predominated as the areas of greater credit restriction in Brazil.[9]

Tabela 1 – Descriptive statistics - Rural establishments with financing – 2017

Regions	Mean	S.D.	Min.	Max.	Treated	Control	N
Brazil	0.17	0.122	0.002	0.754	753	4683	5436
North	0.107	0.077	0.002	0.382	73	349	422
Northeast	0.127	0.076	0.003	0.495	251	1506	1757
Southeast	0.145	0.086	0.004	0.591	255	1364	1619
South	0.29	0.157	0.005	0.752	202	977	1179
Midwest	0.17	0.098	0.009	0.754	68	391	459

Source: 2017 Agricultural Census.

The natural logarithm of the gross value of agricultural production (animal and plant) was used as the outcome variable. Statistics on the value of agricultural production, according to the region of interest and treatment condition, are shown in Table 2. In addition, tests of mean differences between the treated and control groups were performed. Statistics show regional heterogeneity in terms of agricultural production. The Midwest region, due to the comparative advantages in the production of temporary crops, stood out as the one with the highest average agricultural production. On the other hand, the Northeast and North regions respectively have lower levels of agricultural production. Table 2 also shows positive and significant differences in agricultural production regarding treated representative farms, meaning that municipalities that received intensive rural credit performed better in terms of agricultural production in relation to less intensive municipalities (considered here as controls). These results are valid for both Brazil and for the regions, except for the Northeast, where the control group presented better performance in relation to the treated group. However, these differences may not reflect the true effect of rural credit, since access to rural credit among rural establishments may not occur randomly. Thus, potential differences in observable and unobservable characteristics between the two groups may explain part or a large part of these differences, and not necessarily the treatment effect. In this sense, it was necessary to use methods capable of attenuating these problems.

Estimates of the rural credit effect were controlled by a set of variables, which were incorporated in the modeling. We selected four vectors of observed characteristics. The first vector is composed of dummies of mesoregions which were identified based on the municipal codes, and subsequently associated with the codes of the mesoregions provided by IBGE.[10] The second vector contains climatic variables obtained from the Terrestrial Hydrology Research Group (THRG), according to the procedures of Sheffield, Goteti e Wood (2006). Towards this end, monthly average temperature (°C) and monthly accumulated precipitation (mm) data were used between 1980 and 2006, and then averages were calculated for the summer (December to February) and winter (June to August) for this period. We chose to transform these data into natural logarithms. The strategy based on climatic seasons, used in previous studies on

[9] According to Garcias e Kassouf (2016), the concept of credit restriction must take into account whether the rural establishment applied for credit, but had its request denied, since producers who did not demand credit cannot be considered restricted. Unfortunately, data from the 2017 Agricultural Census do not allow the identification of establishments that had their request denied and, therefore, the variable of proportion of establishments that obtained credit, used in this study, does not strictly represent the concept of restriction.

[10] These codes were generated from the combination of the two-digit codes of the Units of the Federation (UF) and the two-digit codes of the 2017 mesoregions, provided by the IBGE: <https://www.ibge.gov.br/geociencias/organizacao-do-territorio/estrutura-territorial/23701-divisao-territorial-brasileira.html?=&t=o-que-e.>

agriculture (CUNHA; COELHO; FÉRES, 2015; PEREDA, 2012; REYNA; BRAGA; MORAIS, 2020), is justified by the significant change in climate between the two seasons.

Tabela 2 – Differences in the means of the gross value of agricultural production - Brazil and Regions - 2017

Region	**Obs**	**Mean**	**S. E.**	**S. D.**
Brazil	5463	4.035	0.02	1.466
Control	4683	3.895	0.021	1.447
Treated	780	4.911	0.046	1.264
Difference		-1.016***	0.056	
North	422	3.801	0.046	0.943
Control	349	3.699	0.05	0.936
Treated	73	4.288	0.096	0.821
Difference		-0.589***	0.118	
Northeast	1757	2.675	0.026	1.086
Control	1506	2.695	0.029	1.113
Treated	251	2.553	0.057	0.902
Difference		0.142+	0.074	
Southeast	1619	4.637	0.031	1.235
Control	1364	4.546	0.032	1.179
Treated	255	5.122	0.088	1.41
Difference		-0.576***	0.083	
South	1179	4.783	0.023	0.789
Control	977	4.703	0.026	0.799
Treated	202	5.172	0.042	0.601
Difference		-0.468***	0.059	
Midwest	459	5.415	0.055	1.18
Control	391	5.178	0.048	0.954
Treated	68	6.78	0.172	1.415
Difference		-1.603***	0.136	

Source: 2017 Agricultural Census. Notes: + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

The third vector is comprised of individual characteristics of the managers of rural establishments, namely the number of male managers; the number of managers aged 65 or over, and the level of education of the managers (never attended school; know how to read and write; attended adult education classes; attended primary school). The fourth and final vector is formed by variables that reflect the characteristics of the property and/or practices adopted by the manager, which were the size of the area of the rural establishment (in hectares), the number of producers who owned the land, the number of producers residing on the establishment, the number of people employed at agricultural establishment, the number of producers who do not belong to the family farming category, and the number of producers associated to cooperatives and/or class entities. Two other variables were also included in our model: the number of establishments using some type of irrigation method, and the number of establishments that received some type of technical assistance. All variables extracted from the 2017 Agricultural Census were divided by the total number of rural establishments in the municipalities, following the strategy of representative rural establishments. The area and employed persons variables were transformed into natural logarithms, given the different scale of the other variables.

The entropy weight was calculated using the third and fourth covariate vectors, as they are variables related to both treatment and agricultural production, based on previous literature on determinants of access to rural credit and agricultural production functions (DIAS et al., 2021; FREITAS; SILVA; TEIXEIRA, 2020). However, only the dummies of mesoregions and climatic variables were included in the regression, acting exclusively as a control of the estimates. The irrigation and technical assistance variables, which also determine agricultural production, were incorporated in the model to test potential transmission mechanisms of effects of rural credit on agricultural production.

Table 3, below, provides the means of the covariates according to the treatment condition, in addition to the mean difference tests between the groups. Significant differences violate the covariate balancing hypothesis and therefore, for the third and fourth vector variables, these statistics are expressed before (panel A) and after (panel B) entropy weighting to test this hypothesis. For simplicity, only the statistics of the variables at the Brazil level are presented. The first column contains the mean values of the treated, the second column contains the mean values of the control observations, the third column expresses the difference between the groups, and the fourth column provides the p-value, whose null hypothesis is the non-existence of significant differences. Descriptive statistics by region are available in the Appendix (see Table 6-A).

Tabela 3 – Differences in observable characteristics before and after entropy balancing - Brazil - 2017

Variables	Before entropy weighting (A)				After entropy weighting (B)			
	T	C	Diff	p-value	T	C	diff	p-value
Ln (Precipitation [summer])	5.108	5.048	0.060***	0.000				
Ln (Precipitation [winter])	4.256	3.429	0.828***	0.000				
Ln (Temperature [summer])	3.214	3.245	-0.031***	0.000				
Ln (Temperature [winter])	2.891	3.098	-0.207***	0.000				
Male’	0.888	0.825	0.063***	0.000	0.888	0.888	0.000	0.999
Age $\geq$ 65 years’	0.231	0.253	-0.022***	0.000	0.231	0.231	0.000	1.000
Low education level’	0.438	0.487	-0.049***	0.000	0.438	0.438	0.000	1.000
Ln (area)’	3.871	3.807	0.064	0.124	3.871	3.871	0.000	1.000
Establishment owner’	0.867	0.806	0.061***	0.000	0.867	0.867	0.000	1.000
Resides on the establishment’	0.730	0.666	0.064***	0.000	0.730	0.730	0.000	1.000
Ln (workers)’	1.125	1.109	0.016	0.310	1.125	1.125	0.000	1.000
Non-family farming’	0.236	0.279	-0.043***	0.000	0.236	0.236	0.000	1.000
Association’	0.600	0.349	0.251***	0.000	0.600	0.600	0.000	1.000
Irrigation	0.084	0.11	-0.026***	0.000				
Assistance	0.575	0.234	0.341***	0.000				

Source: 2017 Agricultural Census. Notes: + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. ’Variables used in the entropy weight calculation.

Before weighting the data, it was possible to identify significant differences in the covariates between the groups. The treated group is characterized by a higher incidence of male managers, a lower proportion of managers over the age of 65, and a lower proportion of managers with low education in relation to farms that are less intensive in rural credit. Furthermore, representative farms with intensive access to rural credit had a higher proportion of owners and producers residing on the establishment, a greater proportion of associated producers, and family farmers. These differences could confound the treatment effect. Rural credit-intensive units may, for example, present higher levels of production simply because they have more educated producers than less rural credit-intensive units. This bias could be reduced if the observable characteristics were orthogonal to the treatment. In Table 3, all covariates were accurately balanced after entropy balancing, eliminating the differences previously observed for the variables that jointly determine the variable of interest and the treatment, thus fully meeting the balancing hypothesis.

Significant differences in covariates were also found for Brazilian regions. Although few of the differences observed did not reveal statistical significance and/or maintained the same direction, the South and Midwest regions were the most similar in relation to the national context. However, these results also show relative heterogeneity between regions, especially regarding treatment status. For example, while the representative untreated farms in the South and Midwest regions showed a higher proportion of less educated managers, managers over the age of 65, and fewer people employed, the farms in the North and Northeast regions moved in the opposite direction (see Appendix A, Table 6-A).

5 RESULTS AND DISCUSSION

The following analysis will essentially determine whether there was an effect, whose treatment is given by the intensity farms have access to rural credit, of rural credit on Brazilian agricultural production, and whether these effects are heterogeneous between regions. Furthermore, we explored potential transmission mechanisms of this treatment.

The main results of this study are shown in Table 4, where the ATT of rural credit on agricultural production is presented after weighting the data by the entropy weight. Seven different specifications were estimated to verify the sensitivity of the ATT to the inclusion of covariates. In column [1], in addition to the treatment dummy variable, only dummies from mesoregions were included in the regression. In the second specification [2], temperature and precipitation variables were added. In column [3], producer characteristics were incorporated in the model. In specification [4], the variables of the establishment were added. In the fifth model [5], the irrigation variable was added to verify whether part of the ATT was capturing the irrigation effect. In the same way, in the sixth specification, column [6], the irrigation variable was removed and the technical assistance variable was added. Finally, in column [7], all covariates were included in the regression (full specification), which is the representation of the base specification of this study.

Table 4 is divided into six panels, where each panel provides the ATT for each region. The coefficients of the covariates and intercept, except for the coefficients of the variables irrigation (columns [5] and [7]) and technical assistance (columns [6] and [7]), were purposely omitted due to space limitations and to simplify the presentation of the ATT.[11] Each regional panel also contains the r-square statistic for each specification. The complete specification [7] presented r-squared that varied between 0.68 and 0.89 depending on the region, suggesting good explanatory power. As expected, the r-squared increased as new variables were added to the model.

The result in Table 4 shows that rural credit had positive and significant effects on the value of agricultural production in Brazil. In other words, representative farms with intensive access to rural credit were positively associated with better agricultural production results. This result corroborates previous and recent findings on the effect of rural credit in Brazil (EUSÉBIO; MAIA; SILVEIRA, 2020; FREITAS; SILVA; TEIXEIRA, 2020). However, the results found for Brazil are not necessarily the same when analyzed by individual region. The estimated effect were positive and significant for those regions where rural credit was more accessible, i.e., in regions with a greater proportion of rural establishments that obtained some financing, such as the South and Midwest regions. On the other hand, in regions where access was more restricted, such as in the North, Northeast, and Southeast regions, the effect of rural credit was statistically

[11] Complete estimates can be provided upon request.

null. Therefore, our estimates indicate the existence of heterogeneous regional effects of rural credit on agricultural production in Brazil.

This regional heterogeneity of the effects of rural credit may be strictly associated with imbalances between supply and demand for rural credit. Although our treatment measure compared municipalities with greater and lesser rural credit access coverage, it is noteworthy that the intensity of treatment was different between regions. While in the South and Midwest regions the maximum coverage of rural establishments that received rural credit reached 75.4% of establishments, in the North and Northeast regions this percentage did not exceed 50% (see Table 1). Furthermore, the volume of rural credit from Pronaf was proportionally more significant in the North and Northeast regions. However, this line of credit generally extends small amounts per individual.

Our results are supported by findings of previous studies. Assunção, Souza e Figueiredo (2018), for example, showed that imbalances between supply and demand for credit had important consequences for producers and for the regions in which they live. Thus, the credit available to producers is generally not the most appropriate for their respective circumstances and needs. Furthermore, Freitas, Silva e Teixeira (2020) emphasized that a lower financial constraint provided by the amount of credit available to the municipality would allow producers to acquire modern inputs more easily, adopt more productive technologies and services, and thus have greater productive performance.

Although the mesoregion dummies controlled part of the regional heterogeneity, some issues should be mentioned. The effect of rural credit may vary depending on the particularities of the type of financial support considered and between regions. The variable used to measure the intensity of access to rural credit in municipalities did not consider the differences in the various types of rural credit, such as the source of funding (public/private), the type of funding (to cover initial costs, capital investments, commerialization, etc.) or differences in the volume of credit obtained by the establishments. Freitas, Silva e Teixeira (2020) found positive and significant effects of rural credit, regardless of the source of funding. However, the effect of rural credit from other sources was higher in comparison with credit from Pronaf. In addition, our model did not consider efficiency regarding the source of funding, meaning that producers may be technically more efficient regarding the source of funding in one region than in others.

The estimates without data weighting are presented in Table 7-A in the Appendix. Before weighting the covariates in the entropy sense, the estimates were relatively superior to the estimates after weighting the data. The observed variation, however, did not seem to be important when marginally overestimating the ATT in the case of Brazil. On the other hand, the effect estimated before weighting the data for the South region significantly underestimated the effect of rural credit, going from 8.4% before weighting to 16.1% after weighting. The bias on observed characteristics thus underestimated the ATT estimate, and may be considered as a lower limit of the rural credit effect in the unweighted model. This result however shows the importance of balancing the covariates in the entropy sense.

Furthermore, the estimated effect was sensitive to the model specification, when significant. There was a significant reduction in the estimated effect after the inclusion of the characteristics of the rural establishment. Another significant reduction was observed after the inclusion of the technical assistance variable, but this does not happen after the inclusion of the irrigation variable. In other words, for both models [5] and [7], the estimated effect did not change after the inclusion of the irrigation variable in relation to the previous models [4] and [6], respectively. On the other hand, the variation observed in the ATT, after the inclusion of the technical assistance variable (specification [6] and [7]), suggests an overestimation of the rural credit effect in light of the absence of this variable.

The behavior of the ATT remained for all regions. For regions where the estimated effect of rural credit was significant, when the technical assistance variable was inserted (models [6]

Tabela 4 – The effect of rural credit in Brazil and regions – 2017

Regions	Gross Production Value	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Brazil	ATT	0.378***	0.391***	0.377***	0.177***	0.167***	0.095**	0.089*
		[0.049]	[0.047]	[0.049]	[0.031]	[0.031]	[0.036]	[0.036]
	Irrigation	No	No	No	No	0.585***	No	0.479**
						[0.160]		[0.153]
	Technical assistance	No	No	No	No	No	0.843***	0.816***
							[0.117]	[0.120]
	R^2	0.704	0.708	0.722	0.869	0.871	0.877	0.879
North	ATT	0.083	0.026	0.005	0.057	0.058	0.034	0.035
		[0.130]	[0.128]	[0.122]	[0.083]	[0.083]	[0.084]	[0.084]
	Irrigation	No	No	No	No	0.52	No	0.316
						[0.449]		[0.422]
	Technical assistance	No	No	No	No	No	1.235**	1.206**
							[0.449]	[0.445]
	R^2	0.275	0.319	0.377	0.665	0.666	0.679	0.68
Northeast	ATT	0.02	0.052	0.047	0.014	0.006	0.001	-0.004
		[0.062]	[0.058]	[0.054]	[0.043]	[0.042]	[0.042]	[0.041]
	Irrigation	No	No	No	No	1.365***	No	1.285***
						[0.198]		[0.195]
	Technical assistance	No	No	No	No	No	0.786***	0.632**
							[0.227]	[0.215]
	R^2	0.43	0.466	0.514	0.678	0.693	0.684	0.697
Southeast	ATT	0.003	0.056	0.027	0.104*	0.105*	0.06	0.067
		[0.066]	[0.063]	[0.060]	[0.047]	[0.046]	[0.046]	[0.045]
	Irrigation	No	No	No	No	1.094***	No	0.993***
						[0.219]		[0.209]
	Technical assistance	No	No	No	No	No	0.675***	0.575***
							[0.157]	[0.148]
	R^2	0.746	0.761	0.788	0.874	0.881	0.879	0.884
South	ATT	0.322***	0.277***	0.280***	0.208***	0.209***	0.159***	0.161***
		[0.054]	[0.050]	[0.050]	[0.031]	[0.031]	[0.032]	[0.033]
	Irrigation	No	No	No	No	0.294*	No	0.273+
						[0.139]		[0.162]
	Technical assistance	No	No	No	No	No	0.391***	0.385***
							[0.095]	[0.092]
	R^2	0.41	0.454	0.462	0.819	0.821	0.826	0.827
Midwest	ATT	0.738***	0.693***	0.601***	0.391***	0.394***	0.258**	0.258**
		[0.159]	[0.160]	[0.151]	[0.083]	[0.083]	[0.083]	[0.083]
	Irrigation	No	No	No	No	-0.241	No	-1.142
						[1.025]		[1.002]
	Technical assistance	No	No	No	No	No	1.312***	1.456***
							[0.352]	[0.353]
	R^2	0.517	0.533	0.601	0.878	0.878	0.889	0.89
X	Mesoregion Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Temperature and precipitation	No	Yes	Yes	Yes	Yes	Yes	Yes
	Producer characteristics	No	No	Yes	Yes	Yes	Yes	Yes
	Establishment characteristics	No	No	No	Yes	Yes	Yes	Yes

Source: 2017 Agricultural Census. Notes: + p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001. Robust standard errors in brackets. Entropy-balance weighted regression estimates.

and [7]), the ATT coefficient and its significance changed in relation to models that did not contain this variable. In the case of the Southeast region, in addition to the variation in the ATT, all the statistical significance found in specifications [4] and [5] was lost after the inclusion of the assistance variable.

Although the irrigation and technical assistance variables were positively and significantly associated with agricultural production, except for the North and Midwest regions where irrigation was not statistically significant, these results may indicate that technical assistance is an important transmission channel of rural credit. Thus, part of the effect of rural credit on the value of production may be explained by the indirect effect of rural credit on technical assistance, which in turn is also positively and significantly associated with the value of agricultural production.

To test this hypothesis, complementary regressions were designed to verify the influence of rural credit on technical assistance (see Table 5) in Brazil and regions.[12] Regressions without and with data weighting in the entropy sense were also estimated, represented by the upper and lower panels of Table 5, respectively. Our estimates show that rural credit was positively and significantly associated with technical assistance. As observed in the previous analysis, the effect of rural credit on the proportion of rural establishments that received technical assistance was also relevant for Brazil and for regions with greater intensity in rural credit access, such as the Southeast, the Midwest, and to a greater extent, the South region of the country.

Tabela 5 – Effect of rural credit on technical assistance - Brazil and regions - 2017

	Dependent variable: Technical assistance	Brazil	North	Northeast	Southeast	South	Midwest
Before weighting	ATT: Rural credit	0.127***	0.017	0.018*	0.075***	0.115***	0.079***
		[0.008]	[0.015]	[0.007]	[0.012]	[0.013]	[0.018]
	Mesoregion Dummies	Yes	Yes	Yes	Yes	Yes	Yes
	Producer characteristics	Yes	Yes	Yes	Yes	Yes	Yes
	Establishment characteristics	Yes	Yes	Yes	Yes	Yes	Yes
	Intercept	0.005	0.186+	-0.005	0.217+	-0.395**	0.280*
		[0.063]	[0.097]	[0.031]	[0.124]	[0.132]	[0.132]
	R^2	0.716	0.33	0.414	0.504	0.553	0.635
	Number of observations	5436	422	1757	1619	1179	459
After weighting	ATT: Rural credit	0.100***	0.021	0.015+	0.058***	0.138***	0.109***
		[0.014]	[0.015]	[0.008]	[0.014]	[0.022]	[0.017]
	Mesoregion Dummies	Yes	Yes	Yes	Yes	Yes	Yes
	Producer characteristics	Yes	Yes	Yes	Yes	Yes	Yes
	Establishment characteristics	Yes	Yes	Yes	Yes	Yes	Yes
	Intercept	-0.498***	0.630**	-0.022	0.169	-0.02	0.157
		[0.138]	[0.209]	[0.062]	[0.182]	[0.428]	[0.236]
	R^2	0.707	0.438	0.454	0.589	0.365	0.748
	Number of observations	5436	422	1757	1619	1179	459

Source: 2017 Agricultural Census. Notes: + p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001.

Thus, our estimates suggest that technical assistance may be an important transmission mechanism through which rural credit influences agricultural production. Agricultural production, therefore, is positively and directly affected by rural credit, and indirectly through technical assistance. In other words, producers in municipalities with greater access to rural credit may be seeking more information and knowledge regarding the activity and/or the best choice and use of inputs, machinery, equipment and agricultural implements through technical assistance, which in turn promotes more efficient agricultural production. Freitas, Silva e Teixeira (2020), for example, show that municipalities with greater access to rural credit were more efficient in

[12] We chose variables that determine access to technical assistance. Therefore, climate and irrigation variables were not considered in this analysis. The estimated coefficients of the other covariates were purposely omitted to simplify the presentation of the results and can be provided upon request.

agricultural production and emphasize that technical assistance was associated with a reduction in inefficiency of representative establishments. Furthermore, Costa e Freitas (2018) suggested that the combination of technical assistance and rural credit was more beneficial to producers, since technical assistance allowed the efficient use of financed resources, indirectly increasing the return of the rural credit.

6 CONCLUSION

Rural credit in Brazil has become the main instrument to support rural producers, including family farmers. This financial support, among other factors, has contributed to Brazilian rural development, allowing the agricultural sector to maintain its relative importance in the Brazilian economy and in the international scenario. However, access to rural credit in Brazil has been persistently more restrictive in certain regions. This study, therefore, sought to explore issues related to the intensity of access to rural credit and the heterogeneous effects of rural credit on agricultural production across Brazilian regions. Furthermore, this study also investigated potential channels through which rural credit influenced agricultural performance.

The regional effects of rural credit on agricultural production, whose treatment was defined by the intensity of access to credit, were calculated by estimating the Average Treatment Effects on Treated (ATT), using data from the Brazilian Agricultural Census of 2017 and climate variables. To reduce bias, estimates were obtained using standard regressions weighted by entropy balancing, taking into account robust standard errors. Entropy balancing provides significant advantages over propensity score models by allowing an exact balance of observed characteristics between treated and control groups regarding known sample moments. Thus, the significant differences in observed characteristics between treated and control groups found in this study were removed after weighting the data by entropy balancing, making the observed characteristics independent of the treatment.

On the one hand, the results show that greater access to rural credit increased the gross value of agricultural production in Brazil. Thus, municipalities that are more intensive in accessing rural credit produce more when compared to less intensive municipalities. In general, the results of this study support the hypothesis that rural credit contributes to rural development and the maintenance of competitiveness in the agricultural sector. Therefore, it is sensible to stimulate the provision of rural credit in order to promote agricultural production.

On the other hand, the results also show that the effect of rural credit was heterogeneous across Brazilian regions. This result is important for those regions that have greater access to rural credit, namely the South and Midwest regions. However, for Brazilian regions characterized by greater restrictions in access to credit, the results do not seem to be so encouraging. Greater availability of credit promotes the implementation of new production technologies, and thus the effect of rural credit is stronger in regions with greater mechanization. Furthermore, technical assistance proved to be an important mechanism for transmitting the effect of rural credit in Brazil and regions, whose effect was significant. Rural credit thus directly improves agricultural production of the treated establishments, and indirectly through technical assistance, since greater access to technical assistance makes it possible to reduce technical production inefficiencies.

Our results suggest that greater intensity in the access to rural credit is fundamental for Brazilian rural development. Although the results are not encouraging for all Brazilian regions, it is important to emphasize that imbalances between supply and demand for credit, as well as other factors between regions, such as access to technical assistance, can limit the effects of rural credit in regions with higher levels of restriction. Reducing these imbalances in these regions can allow their producers to acquire adequate and modern inputs for production, more sophisticated machinery and equipment which, combined with technical assistance, may promote more efficient use of production inputs.

The results found in this study may be subject to self-selection problems in unobserved variables. This problem may be reduced in the presence of panel data, which would allow the removal of the effects of unobserved variables that are constant over time. Furthermore, some issues were not explored in this research and could be investigated in future studies. For example, a future study could consider variations in the types of financing. Credit destined for capital investments generally mobilizes a considerable volume of resources for the acquisition of agricultural implements that improve land and labor productivity. Therefore, it would be reasonable to expect that the effect of this modality will be different in relation to the others.

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ACKNOWLEDGEMENTS

The authors wish to thank the Carlos Charris (Getulio Vargas Foundation) for his comments that helped us to improve the article. We also thank to Marcelo Braga for kindly sharing data on the climate variables used in this study.

APÊNDICE A –

Tabela 6 – A Differences in observable characteristics before and after entropy balancing – Regions - 2017

Region	Variables	Before entropy weighting (A)				After entropy weighting (B)			
		T	C	diff	p-value	T	C	diff	p-value
North	Ln (Precipitation [summer])	5.567	5.534	0.033*	0.037				
	Ln (Precipitation [winter])	2.33	3.598	-1.268***	0.000				
	Ln (Temperature [summer])	3.286	3.293	-0.007**	0.001				
	Ln (Temperature [winter])	3.288	3.312	-0.024***	0.000				
	Male’	0.845	0.806	0.039***	0.000	0.845	0.845	0.000	0.974
	Age $\geq$ 65 years’	0.209	0.177	0.031***	0.000	0.209	0.208	0.000	0.993
	Low education level’	0.502	0.465	0.038*	0.013	0.502	0.502	0.000	0.992
	Ln (area)’	4.949	4.329	0.620***	0.000	4.949	4.945	0.004	0.972
	Establishment owner’	0.886	0.819	0.067***	0.000	0.886	0.886	0.000	0.985
	Lives on the establishment’	0.782	0.756	0.026*	0.038	0.782	0.781	0.000	0.997
	Ln (workers)’	1.175	1.241	-0.066*	0.020	1.175	1.175	0.000	0.993
	Non-family farming’	0.248	0.200	0.047**	0.005	0.248	0.248	0.000	0.990
	Association’	0.289	0.256	0.033	0.137	0.289	0.289	0.000	1.000
	Irrigation	0.061	0.067	-0.006	0.604				
	Assistance	0.195	0.12	0.074***	0.000				
Northeast	Ln (Precipitation [summer])	4.404	4.497	-0.093**	0.004				
	Ln (Precipitation [winter])	3.116	3.531	-0.414***	0.000				
	Ln (Temperature [summer])	3.297	3.293	0.004	0.144				
	Ln (Temperature [winter])	3.221	3.218	0.003	0.535				
	Male’	0.813	0.782	0.031***	0.000	0.813	0.813	0.000	1.000
	Age $\geq$ 65 years’	0.253	0.236	0.017***	0.000	0.253	0.253	0.000	1.000
	Low education level’	0.626	0.608	0.018*	0.011	0.626	0.626	0.000	1.000
	Ln (area)’	3.369	3.127	0.242***	0.000	3.369	3.369	0.000	1.000
	Establishment owner’	0.770	0.757	0.013	0.210	0.770	0.770	0.000	1.000
	Resides on the establishment’	0.757	0.683	0.074***	0.000	0.757	0.757	0.000	0.999
	Ln (workers)’	1.000	1.032	-0.032+	0.069	1.000	1.000	0.000	1.000
	Non-family farming’	0.210	0.22	-0.010	0.111	0.210	0.210	0.000	1.000
	Association’	0.444	0.365	0.079***	0.000	0.444	0.444	0.000	1.000
	Irrigation	0.114	0.105	0.010	0.200				
	Assistance	0.154	0.096	0.059***	0.000				
Southeast	Ln (Precipitation [summer])	5.335	5.368	-0.033*	0.037				
	Ln (Precipitation [winter])	2.759	3.09	-0.331***	0.000				
	Ln (Temperature [summer])	3.218	3.199	0.019***	0.000				
	Ln (Temperature [winter])	3.054	3.002	0.052***	0.000				
	Male’	0.864	0.857	-0.009	0.123	0.864	0.864	0.000	1.000
	Age $\geq$ 65 years’	0.280	0.288	0.143+	0.095	0.280	0.280	0.000	1.000
	Low education level’	0.388	0.403	-0.015	0.185	0.388	0.388	0.000	1.000
	Ln (area)’	4.385	3.991	0.394***	0.000	4.385	4.385	0.000	0.999
	Establishment owner’	0.830	0.823	0.007	0.337	0.830	0.830	0.000	1.000
	Resides on the establishment’	0.546	0.587	-0.041**	0.001	0.546	0.546	0.000	1.000
	Ln (workers)’	1.419	1.174	0.245***	0.000	1.419	1.419	0.000	1.000
	Non-family farming’	0.357	0.337	0.020*	0.028	0.357	0.357	0.000	1.000
	Association’	0.518	0.332	0.186***	0.000	0.518	0.518	0.000	0.999
	Irrigation	0.145	0.154	-0.009	0.432				
	Assistance	0.471	0.328	0.143***	0.000				

Continue...

Region	Variables	Before entropy weighting (A)				After entropy weighting (B)			
		T	C	diff	p-value	T	C	diff	p-value
South	Ln (Precipitation [summer])	5.117	5.121	-0.004	0.440				
	Ln (Precipitation [winter])	4.903	4.744	0.159***	0.000				
	Ln (Temperature [summer])	3.202	3.184	0.019***	0.000				
	Ln (Temperature [winter])	2.789	2.791	-0.002	0.674				
	Male’	0.917	0.867	0.050***	0.000	0.917	0.917	0.000	0.995
	Age $\geq$ 65 years’	0.223	0.243	-0.020***	0.000	0.223	0.223	0.000	1.000
	Low education level’	0.411	0.447	-0.036**	0.001	0.411	0.411	0.000	0.999
	Ln (area)’	3.573	3.625	-0.052	0.272	3.573	3.573	0.000	0.999
	Establishment owner’	0.913	0.861	0.052***	0.000	0.913	0.913	0.000	0.994
	Resides on the establishment’	0.763	0.756	0.007	0.536	0.763	0.763	0.000	0.999
	Ln (workers)’	1.036	1.000	0.036*	0.013	1.036	1.036	0.000	1.000
	Non-family farming’	0.173	0.256	-0.083***	0.000	0.173	0.173	0.000	0.998
	Association’	0.728	0.474	0.255***	0.000	0.728	0.728	0.000	0.994
	Irrigation	0.052	0.084	-0.032***	0.000				
	Assistance	0.743	0.464	0.279***	0.000				
Midwest	Ln (Precipitation [summer])	5.567	5.553	0.014	0.570				
	Ln (Precipitation [winter])	2.816	2.558	0.258**	0.004				
	Ln (Temperature [summer])	3.274	3.265	0.010**	0.007				
	Ln (Temperature [winter])	3.204	3.207	-0.003	0.785				
	Male’	0.851	0.838	0.013*	0.018	0.851	0.851	0.000	0.999
	Age $\geq$ 65 years’	0.238	0.259	-0.020*	0.018	0.238	0.238	0.000	0.999
	Low education level’	0.317	0.383	-0.066***	0.000	0.317	0.318	0.000	0.998
	Ln (area)’	6.207	5.292	0.915***	0.000	6.207	6.207	0.000	0.997
	Establishment owner’	0.808	0.833	-0.026	0.150	0.808	0.808	0.000	0.999
	Resides on the establishment’	0.574	0.658	-0.084***	0.000	0.574	0.574	0.000	0.998
	Ln (workers)’	1.639	1.165	0.474***	0.000	1.639	1.638	0.001	0.997
	Non-family farming’	0.497	0.368	0.128***	0.000	0.497	0.496	0.000	0.998
	Association’	0.371	0.242	0.129***	0.000	0.371	0.371	0.000	0.996
	Irrigation	0.058	0.051	0.007	0.425				
	Assistance	0.448	0.224	0.224***	0.000				

Source: 2017 Agricultural Census. Notes: + p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001.

Tabela 7 – A - Rural credit effect in Brazil and regions - before entropy weighting–2017

Regions	Gross Production Value	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Brazil	ATT	0.459*** [0.041]	0.467*** [0.041]	0.403*** [0.039]	0.208*** [0.028]	0.202*** [0.028]	0.100*** [0.028]	0.106*** [0.027]
	Irrigation	No	No	No	No	1.057*** [0.086]	No	0.955*** [0.084]
	Technical assistance	No	No	No	No	No	0.851*** [0.064]	0.761*** [0.063]
	R^2	0.731	0.734	0.757	0.855	0.86	0.86	0.864
North	ATT	0.105 [0.123]	0.072 [0.120]	0.035 [0.119]	-0.009 [0.089]	-0.003 [0.088]	-0.027 [0.090]	-0.018 [0.089]
	Irrigation	No	No	No	No	1.854*** [0.401]	No	1.565*** [0.388]
	Technical assistance	No	No	No	No	No	1.474*** [0.404]	1.181** [0.396]
	R^2	0.399	0.414	0.437	0.627	0.649	0.645	0.66
Northeast	ATT	-0.013 [0.058]	0.007 [0.056]	-0.009 [0.052]	0.016 [0.042]	0.009 [0.041]	-0.004 [0.041]	-0.005 [0.041]
	Irrigation	No	No	No	No	1.495*** [0.176]	No	1.416*** [0.175]
	Technical assistance	No	No	No	No	No	0.983*** [0.200]	0.733*** [0.190]
	R^2	0.442	0.457	0.517	0.684	0.704	0.689	0.707
Southeast	ATT	0.283*** [0.057]	0.264*** [0.056]	0.205*** [0.053]	0.068 [0.042]	0.065 [0.041]	0.025 [0.042]	0.026 [0.041]
	Irrigation	No	No	No	No	0.737*** [0.122]	No	0.678*** [0.120]
	Technical assistance	No	No	No	No	No	0.553*** [0.100]	0.494*** [0.098]
	R^2	0.661	0.681	0.713	0.822	0.827	0.826	0.83
South	ATT	0.447*** [0.048]	0.462*** [0.048]	0.412*** [0.048]	0.172*** [0.033]	0.176*** [0.033]	0.080* [0.034]	0.084* [0.035]
	Irrigation	No	No	No	No	0.414** [0.152]	No	0.238 [0.154]
	Technical assistance	No	No	No	No	No	0.855*** [0.096]	0.836*** [0.097]
	R^2	0.3	0.343	0.375	0.692	0.694	0.715	0.716
Midwest	ATT	1.324*** [0.151]	1.299*** [0.149]	1.161*** [0.134]	0.358*** [0.076]	0.356*** [0.075]	0.279*** [0.076]	0.282*** [0.076]
	Irrigation	No	No	No	No	0.896 [0.646]	No	0.508 [0.625]
	Technical assistance	No	No	No	No	No	1.005*** [0.269]	0.948*** [0.275]
	R^2	0.446	0.459	0.529	0.821	0.823	0.829	0.83
X	Mesoregion Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Temperature and precipitation	No	Yes	Yes	Yes	Yes	Yes	Yes
	Producer characteristics	No	No	Yes	Yes	Yes	Yes	Yes
	Establishment characteristics	No	No	No	Yes	Yes	Yes	Yes

Source: 2017 Agricultural Census. Notes: + p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001. Robust standard errors in brackets.