IMPACT OF MICROCREDIT ON SMALL-FARM AGRICULTURAL PRODUCTION: EVIDENCE FROM BRAZIL

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ABSTRACT

The purpose of this study is to analyze the impact of PRONAF credit program on small-farm agricultural production in Brazil. The study compares farmers' production value considering the obtainment of PRONAF credit, controlling for farm, farms and production system characteristics. The data set consists of the 2006 Agricultural Census, which considers 5.2 million of small farmers in Brazil. In addition to using multiple linear regression model to estimate the net impact of PRONAF on total production value, we applied a propensity score matching method in order to identify pairs of family farms relatively homogeneous, one that accessed the credit and other that did not, estimating the average difference between their production values. Regression analysis showed that the access to PRONAF had a positive and significant net effect on production value of around 18%. In addition, propensity score matching results seemed to exhibit similar evidence to those obtained by regression model. Farmers that obtained PRONAF microcredit presented a production value higher than others, with the difference ranging from 6% to 20%. The impact is lower in the less developed regions, which is characterized by forestry, subsistence agriculture and low technology adoption. For more developed regions, where farmers are more specialized and integrated in the market, the PRONAF has shown relevant net impacts on the production value.

Keywords: agricultural production; agricultural microcredit; small farmers; propensity score.

INTRODUCTION

Over the last decades, Brazil has experienced a strong agricultural production growth, which has occurred especially in the center-west area of the country. Major reason for the fast expansion of Brazilian agricultural production is explained by modern technology adoption that has improved the crop yield, along with the cropped area growth. Despite this scenario, small family farmers still play an important socioeconomic role in this country. According to the Brazilian Institute of Geography and Statistics (IBGE), there were more than 4 million small family farmers in Brazil in 2006 (84% of the total number of farmers), most of them living in vulnerable regions. In spite of the substantial number of small family farmers, their production represents a minor share of the Brazilian total agricultural harvest, due to the huge inequality in distribution of land and productivity (Buainain et al., 2014).

Several policies have been targeted to small farmers in Brazil. In order to offer microcredit to small farmers at low interest rates, the Brazilian government created an important program in 1995, known as PRONAF (National Program for Strengthening Family Farming) (Kumar, 2005). In 2015, more than 1.8 million credit agreements were conceived by PRONAF. The program's volume of lending reached BRL 28.9 billion in 2015/2016 crop year, with maximum loan amount of BRL 100,000 credit for working capital and BRL 150,000 for investment with at an annual interest rate between 2% and 5.5% (MDA, 2015). Despite advances in PRONAF financial resource distribution, farming dynamism has accentuated the differences between the most and least productive areas of the territory, promoting intense farmer selectivity and deepening the social differentiation in the countryside.

In order to understand this socioeconomic dynamics, it is important to consider the high concentration of land in Brazil, identified as one of the main determinants of income inequality in the countryside. Ney and Hoffmann (2003) showed that physical capital, represented by the area of agricultural business, is one of the most important variables for the composition of agricultural income. Despite the great importance of government policies in reducing land ownership inequality, there are other relevant factors that influence rural poverty. Stiglitz (2000) pointed that the efficiency of a land reform program depends on the access to land, credit, agricultural extension and other services.

Recent studies analyzed the impact of microfinance credit on social welfare and economic improvement in different rural areas across the world (Khandker and Faruqee, 2003; Li, Gan, and Hu, 2011; Tu, Ha, and Yen, 2015). However, despite the magnitude of Brazilian agricultural market and the relevant extension of government credit programs, no study has comprehensively explored the impact of PRONAF on agricultural value production of small farmers using microdata. The objective of this paper is to analyze the impact of PRONAF program on small-farm agricultural production in Brazil, examining the differences across Brazilian regions. The study compares the production value of farmers that received and did not receive PRONAF microcredit, controlling for farmers, farms, and production system characteristics. The analysis is based on information from the 2006 Agricultural Census microdata[1]. We hypothesize that the access of PRONAF microcredit has a positive net impact on agricultural production, especially in those more developed regions, where production can be more easily commercialized and investments are more related to the adoption of new technologies.

PRONAF PROGRAM AND MICROCREDIT IMPACT ON RURAL AREAS

Credit is an important tool for the agricultural sector development. It enables, for example, investment in basic petrochemical activity, enabling the production process and industry innovation. In addition, credit brings benefits not directly associated with production, such as allowing the regularization of farmer's consumption expenditure through compatibility of their income.

However, difficulties to access agricultural credit are presented since the sector has a number of characteristics that make it riskier from lenders' point of view. Yaron et al. (1997) and Spolador (2001) evaluated that there are several aspects that explain why financial systems, in general, have problems to adequately reach smallholder farmers, such as rural income, which tends to be lower compared to urban income; small-scale operations; low population density; lack of collateral for the loan; fragmented markets and isolation, which creates barriers to information and limits the risk diversification; seasonality; and high income fluctuation over time due to climate changes and price risks; and asymmetric information.

[1] The authors would like to thank IBGE for providing the data.

Given the importance of credit to agricultural farmers and the difficulty of reaching rural areas, many governments have created programs for rural funding, especially for small farms. In Brazil, until 1993, there were no financial resources to finance family farms (Pereira et al., 2006). Small farms had to dispute rural credit with more capitalized farmers in the market.

PRONAF was launched in 1995 in order to provide credit to small family farms (Mattei, 2005). According to the Agrarian Studies and Rural Development report, we can define four main lines of PRONAF action: i) production financing; ii) infrastructure and municipal services financing; iii) training and professionalization; iv) research and extension funding to develop and transfer technology to farmers (PRONAF, 2005). The program has changed over the years. We highlight the inclusion of many family farmer groups as beneficiaries of the program and the diversification of credit lines (Pronaf Woman, Pronaf Young, Pronaf Agroecology, Pronaf Forest etc). Despite advances, previous studies pointed to a number of problems with the program, such as concentration of resources in some areas, inequality of transfers between the beneficiary groups, and also the need for more adequate credit to the family farm reality (Costa, 2000; Feijó, 2005; Mattei, 2006; Aquino and Schneider, 2010; Altieri et al., 2012; Feijó, 2013).

The heterogeneous structure of family farmer groups and the diversity of agricultural activities highlight the importance of regional studies that evaluate the program achievements. Several studies have explored the socioeconomic impacts of PRONAF in different regions of Brazil using municipal aggregated data (Magalhães et al., 2006; Feijó, 2001; Gazolla and Scheneider, 2005; Martins et al., 2006; Assunção and Chein, 2007). However, only the use of the Agricultural Census microdata allows a more comprehensive and precise analysis of the impact of PRONAF on the production value of different types of farmers' groups.

Previous work also explored microfinance impact on rural areas in different countries of the world. Khandker and Faruqee (2003), for example, examined the impact of farm credit in Pakistan, applying a two stage method of estimation to control for endogeneity in these variables. The authors found evidence that the credit contributed to increase social welfare, especially for smallholders. Li et al. (2011), using the difference-in-difference estimation approach, showed that the microcredit programs improved income and consumption in Chinese rural areas. Tu et al. (2015) explored this issue in Vietnam. Using regression analysis, they found a significant and positive economic and social impact of rural credit on Vietnamese rural population. Conversely, focusing on Thailand, Coleman (2006) evaluated the impact of two microfinance programs, extending a previous research conducted by him (Coleman, 1999). Based on econometric models, results suggested that these programs failed to reach the poorest. In addition, Rooyen et al. (2012) reviewed evidences of microcredit impacts in sub-Saharan Africa, finding mixed evidence about the impacts of microfinance on the poorest.

Overall, previous studies have found evidence that microfinance programs have a positive impact in rural areas. However, to our knowledge, there is no study in the literature that investigated the effect of microcredit in Brazil rural areas using microdata. In the next section it will be discussed how the present study will evaluate the impact of the PRONAF program on small-farm agricultural production in Brazil.

DATA

Analyses are based on microdata of the 2006 Agricultural Census, provided by IBGE, filtered by the 5.2 million of small farms located in five Brazilian regions (Northern-NO, North-eastern-NE, South-eastern-SE, Southern-SU and Center-West-CW). We first identified three groups of small farmers – the ones that accessed PRONAF microcredit in 2006 (Group 1), the ones that accessed other governmental credit programs (Group 2) and the ones that did not participate in any program (Group 3). The Agricultural Census provides no accurate information about the types of governmental funds in the Group 2, but they are probably linked to programs managed by the Federal Savings Bank and the National Bank of Social Development, such as the National Program for Land Credit (PNCF) and the National Support Program for Medium Rural Farmers (PRONAMP). We also examined several characteristics of farmers, farms and production system. Appendixes A and B present the list of these variables.

Table 1 presents the average values of the variables associated with farmer and farm characteristics by region. Differences between regions are substantial. The levels of socioeconomic development are remarkably higher in the Southern, South-eastern and Center-West regions. The Northern and North-eastern regions are the less developed, characterized by the subsistence agriculture and low technology adoption.

The Southern region presents the largest number of small farms that accessed PRONAF (Group 1) in 2006 (260,002 observations), followed by North-eastern (180,171 observations). In addition, for Group 1, the Center-West farmers present the highest education level (*EL*), while Southern (Northern) has the greatest percentage of farmers that participate as a member of a cooperative - *COOP* – or a farming association (entity class - *ENT*).

In relation to farms' characteristics, for Groups 1, 2 and 3, the Center-West and Northern regions show the highest average farm size (*FAS*) and the greatest percentage of pasture area (*PAP*). Conversely, the Southern and North-eastern regions are characterized by percentage of crops area (*CAP*) higher than the percentage of pastures.

The Group 1 farmers, located in South-eastern, Center-West, and Southern regions, also present average production values substantially higher than other regions (Northern and North-eastern). In addition, the average production values of the Groups 1 and 2 are greater compared to Group 3 value. Analyzing the average productivity per hectare (BRL/ha) of Group 1, South-eastern region shows the highest value

(BRL1,618.1/ha), followed by South-eastern (BRL1,476.6/ha) and Center-West (BRL479.39/ha).

Table 2 shows the average value of the variables associated with production system, exploring the use of technology and technical orientation, along with specialization degree, and market integration degree. The proxy for technology adoption is given by the use of mechanical traction (*TRAMEC*). For Groups 1 and 2, the Southern region presents the highest percentage of mechanical traction (70.2% and 80.4%, respectively), while the Northern shows the lowest percentage (16.0% and 12.2%, respectively). Discrepancy across regions is verified in relation to access of technical assistance (*TECH*) and adoption of fertilization and soil treatment (*SOILTR*). For Group 1, for example, 66.4% (94.3%) of Southern family farmers have technical assistance (land treatment), while only 13.2% (25.4%) of the farmers in the North-eastern region receive technical assistance (land treatment).

The specialization degree (*SPEC*) is measured by the ratio between the value of production of the main agricultural product and the total value of production. This variable is analyzed by four categories: highly specialized, with specialization degree equal to 1; specialized, with specialization degree lower than 1 and greater than 0.65; diversified, with specialization degree between 0.65 and 0.35, and highly diversified, with specialization degree lower than 0.35. In turn, the market integration degree (*INT*) is measured by the ratio between the total revenue from agricultural activity and the total value of agricultural production, using three categories: highly integrated, with integration degree higher than 0.9; integrated, with integration degree between 0.5 and 0.9; poorly integrated, with integration degree between zero and 0.5. Results highlight that the Center-West presents more specialized establishments, while the North-eastern and Southern farms are more diversified. Finally, North-eastern region presents the lowest average percentage of market integration.

Table 1 - Average values of farmers and farms characteristics.

Variable	Northern (NO)			North-eastern (NE)			South-eastern (SE)			Southern (SU)			Center-West (CW)		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
Number of farmers - *n*	20,945	8,565	353,021	180,171	48,981	1785,289	69,358	15,63	596,729	260,002	28,273	543,336	18,016	5,39	190,489
Gender (%) - *GE* (a)	8.0	11.7	10.9	10.1	18.9	16.8	6.6	10.8	12.0	4.70	5.3	11.7	8.6	8.5	11.7
Age - *AGE*	46.7	52.4	46.6	46.9	55.1	50.5	49.9	53.3	52.9	47.7	49.5	51.7	49.2	51.7	50.2
Education level 1 (%) - *EL*1 (b)	10.1	10.8	9.5	13.5	13.2	12.9	9.2	7.5	8.2	3.2	3.0	4.4	6.5	7.2	7.2
Education level 2 (%) - *EL*2 (b)	9.3	8.6	10.5	5.0	5.0	5.5	5.2	5.2	5.6	2.0	2.2	3.3	8.0	5.5	7.0
Education level 3 (%) - *EL*3 (b)	51.7	45.6	47.7	35.1	26.2	29.2	55.3	45.2	48.9	74.2	60.5	63.3	55.4	49.4	50.2
Education level 4 (%) - *EL*4 (b)	8.1	6.3	7.2	5.0	3.9	4.9	10.6	11.6	11.4	11.2	15.3	11.5	11.5	11.7	11.7
Education level 5 (%) - *EL*5 (b)	5.3	4.9	4.2	3.4	3.0	3.9	7.2	10.7	9.5	6.3	13.0	8.7	9.1	11.7	10.3
Education level 6 (%) - *EL*6 (b)	0.5	0.8	0.7	0.2	0.4	0.6	1.1	4.8	3.8	0.5	3.3	2.3	1.2	3.7	3.0
Cooperative membership (%) - *COOP*	5.3	4.2	2.5	2.4	2.2	1.5	18.3	23.2	11.0	45.9	56.2	21.5	13.8	17.4	7.8
Class entity membership (%) - *ENT*	64.2	52.1	34.1	54.7	47.8	36.5	41.7	37.0	23.0	61.4	43.0	33.0	38.7	32.5	23.0
Crop area (in hectares, ha) - *CROP*	4.3	5.7	5.1	3.2	3.0	2.8	4.5	7.7	3.2	9.2	17.5	4.9	4.2	8.7	3.1
Pasture area (in hectares, ha) - *PAST*	27.6	22.1	18.3	6.9	6.4	6.1	11.6	12.6	11.0	4.5	4.3	5.2	30.3	34.4	28.7
Natural preserved forest area (in hectares, ha) - *NPA*	8.9	10.5	7.9	0.8	0.7	0.7	1.6	2.0	1.5	1.3	1.8	1.2	6.5	8.2	6.6
Exploited forest area (in hectares, ha) - *EFA*	7.6	9.0	8.6	3.0	2.7	2.4	1.2	1.0	1.0	1.3	1.1	1.1	2.1	2.0	2.8
Agroforestry system area (in hectares, ha) - *ASA*	1.4	1.8	1.2	1.1	0.9	0.9	0.4	0.4	0.4	0.2	0.2	0.2	0.5	0.4	0.5
Area with another use (in hectares, ha) - *AAU*	1.7	2.0	1.6	1.0	0.9	0.8	1.2	1.3	1.1	1.5	1.4	1.4	1.4	1.5	1.5
Farm size (in hectares, ha) - *FS*	51.4	51.1	42.8	16.0	14.8	13.8	20.6	25.1	18.3	18.0	26.4	14.0	45.1	55.3	43.2
Crop area percentage (%) - *CAP*	17.8	26.6	31.0	52.6	52.9	55.8	41.2	42.9	35.2	56.9	63.9	43.6	15.2	19.2	13.7
Pasture area percentage (%) - *PAP*	48.7	36.3	32.3	27.2	27.2	26.2	40.4	38.8	44.9	20.6	16.6	28.9	64.7	60.9	63.3
Forest area percentage (%) - *FAP*	29.8	32.5	32.1	14.2	13.0	12.1	11.7	11.1	11.4	15.6	13.0	17.3	16.0	15.6	16.8
Share of animal production value in the total production value (%) - *SAPV*	57.5	47.3	41.5	41.5	41.9	34.2	41.4	41.4	45.9	34.4	28.4	39.3	76.4	73.2	75.2
Share of crop production value in the total production value (%) - *SCPV*	41.6	51.5	56.8	57.5	57.2	64.6	58.0	58.2	53.7	65.5	71.5	60.5	23.4	26.5	24.6
Added value of the agricultural industry in total value of production (%) - *AVA*	0.8	1.2	1.7	1.0	0.8	1.1	0.5	0.3	0.4	0.2	0.1	0.1	0.2	0.2	0.2
Value of agricultural production (BRL) - *Y*	14,852	23,378	12,377	8,206	7,926	6,252	25,419	41,549	15,465	33,636	59,553	19,361	27,554	29,392	12,952

Source: 2006 Agricultural Census, IBGE.
(a) Percentage of women that direct the farm; (b) Maximum education level of the farmer (in percentage): (1) ability to only read and write (*EL*1), (2) adult literacy (*EL*2), incompleted elementary school (*EL*3), completed elementary school (*EL*4), completed high school (*EL*5), completed undergraduate course (*EL*6).

Table 2 - Average values of the production system characteristics.

Variable	Northern (NO)			North-eastern (NE)			South-eastern (SE)			Southern (SU)			Center-West (CW)		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
Animal traction force and/or mechanical (%) - *TR*	48.8	36.5	27.9	61.8	54.7	47.3	68.8	67.6	50.6	96.0	91.8	69.0	70.9	70.9	51.8
Animal traction force (%) – *TRAN*	38.7	28.7	22.9	47.3	41.2	35.3	41.8	33.2	30.0	57.2	25.6	39.4	52.3	46.3	38.0
Mechanical force (%) – *TRAMEC*	16.0	12.2	7.1	28.5	23.6	20.3	45.3	48.4	29.6	70.2	80.4	44.0	39.2	41.5	23.5
Technical orientation (%) – *TECH*	30.8	23.4	13.3	13.2	10.9	6.8	35.9	41.4	23.2	66.4	76.0	37.0	36.3	39.5	20.5
Fertilization and/or soil treatment (%) - *SOILTR*	18.4	17.0	10.4	25.4	25.2	19.7	67.5	65.9	50.3	94.3	89.9	65.8	42.9	43.6	25.1
Pesticides (%) - *PEST*	27.4	23.4	13.8	33.4	26.5	20.0	40.4	42.4	23.6	87.2	84.3	52.8	26.7	31.0	15.8
Super specialized (%) - *SPEC*1	17.2	17.2	25.0	11.4	14.3	19.0	19.1	24.3	28.3	6.2	13.4	18.2	18.5	20.6	25.0
Specialized (%) - *SPEC*2	46.9	46.5	36.5	36.7	37.0	33.1	47.5	44.6	34.0	41.1	40.9	37.1	51.8	51.5	37.6
Diversified establishment (%) - *SPEC*3	25.7	26.2	21.0	41.2	37.9	32.9	26.2	23.2	19.5	45.4	40.1	30.8	20.3	19.9	15.2
Very diversified establishment (%) - *SPEC*4	2.9	3.3	2.9	6.7	5.3	4.2	3.3	2.6	2.1	6.2	3.7	4.1	1.1	1.1	1.1
Very integrated establishment (%) - *INT*1	29.7	27.1	24.3	17.7	18.2	18.4	42.1	45.4	34.8	28.3	50.6	27.9	36.2	42.0	28.8
Integrated establishment (%) - INT2	33.8	32.0	26.7	27.9	24.7	19.9	24.9	20.5	16.9	48.1	27.6	25.6	32.0	28.9	21.5
Poorly integrated establishment (%) - INT3	29.1	34.0	34.5	50.5	51.6	50.9	29.0	28.7	32.2	22.8	19.9	36.6	23.5	22.2	28.7
Number of workers – *NWORK*	3.1	3.2	2.9	2.8	2.7	2.5	2.8	3.0	2.2	2.7	2.7	2.3	2.5	2.7	2.2

Source: 2006 Agricultural Census, IBGE.

RESEARCH METHOD

The empirical analysis of this study is conducted using two approaches. The first one is a multiple linear regression model that estimates the net impact of PRONAF on the total production value. The characteristics of the farmers, farms, and the production systems are used as control variables. Since the composition of the control group can deviate from the treatment group due to unobservable characteristics (related, for example, to agricultural performance - management abilities or agricultural entrepreneurship), this study also applies the method of propensity score matching. This technique identifies pairs of family farmers relatively homogeneous in each region, one that accessed PRONAF microcredit (Group 1) and other that did not (Group 3), estimating the average difference between their production values.

Multiple linear regression model

The multiple linear regression model is adjusted to evaluate the funding impact on the logarithm of agricultural production value (*Y*). The linear regression model consists of adjusting the average *Y* values as a linear function of independent variables, including $PRONAF_i$ variable that assumes 1 when the farm *i* accessed the PRONAF financial resources, and 0 otherwise. The multiple regression model is given by equation 1:

$$Y_i = \alpha + \delta PRONAF_i + \sum_{j=1}^{k} \beta_j X_{j_i} + e_i \qquad (1)$$

As determinants of Y_i, we use, in addition to funding source, several variables to control the farmer, farm, and production system characteristics. Binary variables are used to discriminate the three categories of funding source: Pronaf financial resources (*PRONAF*); financial resource from other government programs (*OGP*); and no government resources, which is the reference of the analysis.

Appendixes 1 and 2 present the description of the variables used in this study. The explanatory variables are derived from the characteristics presented in Tables 1 and 2. However, some characteristics are not considered in the model due to high multicollinearity with other regressors or for having low discriminatory power in explaining *Y* variability In addition, some categories are aggregated to facilitate and give greater significance in the analysis.

After the definition of the relationship between the variables (equation 1), the impact of PRONAF on the production value is measured by comparing the expected Y values of Groups 1 and 3. In other words, the PRONAF impact is given by equation 2:

$$E(Y \mid PRONAF_1 = 1) - E(Y \mid PRONAF_1 = 0) = \delta \qquad (2)$$

Where, the coefficient δ indicates the difference between the expected Y values of farms with access to PRONAF financial resources (*PRONAF*=1) and without access to PRONAF financial resources (*PRONAF*=0).

However, we must consider that the composition of the control group (Group 3) can deviate from the treatment group (Group 1) due to unobservable characteristics (management capacity or agricultural entrepreneurship, for example), which would also be related to the farm economic performance (Y). One of the assumptions of classical linear regression models is that the unobservable factors expressed in the model by error e are not related to regressors X (and *PRONAF*).

The relation between the unobservable factors and *PRONAF* variable would make the estimates of the coefficients model 1 biased and inconsistent. The ideal situation would be observing the results for farm i before accessing PRONAF credits (Y_{0i}) and after receiving PRONAF (Y_{1i}). In this situation, the average effect of PRONAF on Y would be given by (Heckman *et al.*, 1997):

$$E(Y_{1i} - Y_{0i} \mid PRONAF_i = 1) \qquad (3)$$

The problem is that in cross-sectional studies, once observed Y_{1i}, the possibility of observing Y_{0i} is excluded. In other words, at any given point of time, it is impossible to simultaneously observe Y of the same farm with and without PRONAF financial resources. A solution for this problem is given by the propensity score technique, which, briefly, consists in finding individuals with relatively equal characteristics (pairs); one of them belonging to the treatment group (Group 1) and another to the control group (Group 3).

Propensity Score

The bias caused by Equation (2) in estimating the impact of PRONAF on total production value is because it tries to represent the expected Y_0 value of Group 1 by the average values of Group 3. In other words, this *selection bias* would be expressed by:

$$E(Y_{0i} \mid PRONAF_i = 1) - E(Y_{0i} \mid PRONAF_i = 0) \qquad (4)$$

The matching techniques seek to represent the treated subjects (*PRONAF*=1) in the control group (*PRONAF*=0). Among the alternatives proposed, the propensity score matches individuals with similar probabilities of belonging to the treated group. These estimates are obtained by adjusting the probability of an individual (farm) *i* belong to the treated group (Group 1) due to a set of *X* variables that influence both the designation of the groups and the *Y* economic performance. In other words, we have:

$$p(X) = pr(PRONAF_i = 1 \mid X) \tag{5}$$

This adjustment can, for example, be obtained by a binary logistic regression model:

$$pr(PRONAF_i = 1 \mid X) = \frac{1}{1 + e^{-(\phi_0 + \sum_{j=1}^{k} \phi_j X_{ji})}} \tag{6}$$

Although certain farms have characteristics from the treated group and others farms do not have, its chance *p*(*X*) to participate in the treatment should be used as a matching criterion. Farms with similar chances of belonging to the treatment group, however in different situations, treated and untreated, should be paired. Those who do not present similar representations in the distinguished groups should be disregarded in the analysis.

The central idea is that once the pairs of treated and untreated are defined, it is possible to estimate the expected result of no exposure to the treatment (Y_0) among those who were actually exposed to the treatment –$E[Y_{0i}|p(X), PRONAF_i=1]$. Although this value is not observed, it can be estimated by $E[Y_{0i}|p(X), PRONAF_i=0]$, since conditioning on *p*(*X*) gives indifferent results to exposure to the treatment (*PRONAF*). In other words, we have:

$$E[Y_{0i} \mid p(X), PRONAF_i = 1] = E[Y_{0i} \mid p(X), PRONAF_i = 0] = E[Y_{0i} \mid p(X)] \tag{7}$$

Thus, we can obtain PRONAF impact on the farm economic performance, or average treatment effect, known in the literature as average treatment effect on treated (ATT):

$$E[Y_{1i} - Y_{0i} \mid PRONAF_i = 1, p(X)] = E[Y_{1i} \mid PRONAF_i = 1, p(X)] - E[Y_{0i} \mid PRONAF_i = 0, p(X)] \tag{8}$$

RESULTS

Regression Analysis

The estimates of the linear regression model are reported in Table 3. There are 3.618.198 valid observations, with 505.997 observations that were excluded due to the presence of null values for at least one of the variables under analysis. The model fitted well to the sample of observations, as shown by its goodness of fit statistics. The coefficient of determination (R^2) indicates that approximately 49% of Y (log of agricultural production value) variability can be explained by the explanatory variables.

Table 3 – Estimates of multiple regression model.

Variable	Coefficient	*t*	*p*-value	
PRONAF	0.170	73.820	<.0001	18,53%
OGP	0.174	37.970	<.0001	19,01%
AGE	0.021	68.960	<.0001	2,12%
AGE2	0.000	-67.660	<.0001	-0,01%
GEN	-0.358	-157.780	<.0001	-30,09%
EL1	0.071	25.580	<.0001	7,36%
EL2	0.059	16.500	<.0001	6,08%
EL3	0.178	85.740	<.0001	19,48%
EL4	0.306	92.270	<.0001	35,80%
EL5	0.340	88.820	<.0001	40,49%
EL6	0.397	54.410	<.0001	48,74%
COOP	0.299	106.650	<.0001	34,85%
ENT	0.001	0.980	0.3259	0,10%
CAP	0.005	168.520	<.0001	0,50%
PAP	0.001	57.950	<.0001	0,10%
FS	0.305	543.770	<0,001	35,66%
NO	0.683	235.120	<.0001	97,98%
SE	0.582	240.020	<.0001	78,96%
SU	0.653	256.300	<.0001	92,13%
CW	0.510	132.780	<.0001	66,53%
TRAN	0.117	72.470	<.0001	12,41%
TRAMEC	0.246	131.690	<.0001	27,89%
TECH	0.341	157.100	<.0001	40,64%
SOILTR	0.321	162.800	<.0001	37,85%

PEST	0.283	147.040	<.0001	32,71%
SPEC1	-0.937	-415.950	<.0001	-60,82%
SPEC2	0.156	88.530	<.0001	16,88%
INT1	1.260	608.170	<.0001	252,54%
INT2	0.658	343.950	<.0001	93,09%
WORK	0.253	188.260	<0,001	28,79%
c	4.886	591.770	<.0001	18,53%
R^2	0.490			
F	115,679		<0.001	

Source: 2006 Agricultural Census, IBGE.

Independent of the characteristics of farmers, farms, and production systems, a significant difference in agricultural production value is verified between family farmers with and without access to governmental credit programs. Results suggest that farmers that access PRONAF microcredit (Group 1) have a mean production value 18.53% ($e^{0.17}$ – 1) higher than that of the Group 3. In addition, the coefficient associated with the *OGP* variable indicates that farmers with other governmental credits have a mean production value 19% ($e^{0.174}$ – 1) higher.

With respect to the coefficients associated with farmer characteristics, results indicate a significant quadratic relationship between age (*AGE*) and agricultural production value (*Y*). The dependent variable grows up to 54 years old, when it starts to decrease with the farmer age[2]. In addition, results suggest that education level (*EL*) variables have a great influence on *Y*. For example, the farmers with an undergraduate degree have a production value 48.74% higher compared to the farmers without schooling.

The estimated parameter of the gender binary variable (*GEN*) is negative and statistically different from zero. The coefficient indicates that the production value of female-managed farms is 30.09% lower than male-managed farms. These findings can be explained by the fact that female-managed farms are more likely to be in vulnerable conditions than male-managed farms. Finally, there is statistical evidence that when a farmer is a member of a cooperative (*COOP*) his production value is 34.85% higher than the others.

[2] Supposing a quadratic relation given by $\beta_1 X + \beta_2 X^2$, the net effect of *X* on *Y* will be given by $\beta_1 + 2\beta_2 X$, and the value of *X* when the net impact is maximum will be given by $-\beta_1/2\beta_2$.

In relation to the farm characteristic variables, farm size coefficient (*FS*, in logarithmic form) is positive and statistically different from zero. Thus, *FS* has a positive impact on *Y*, with elasticity equal to 0.305%. Furthermore, the binary variables for regions (*NO*, *SE*, *SU*, and *CW*) are positive and statistically different from zero. Since the Northeast region is the reference of analysis, the positive estimates indicate that all other regions have production value higher than the Northeast region. In addition, for each percentage point increase in the crop areas (*CAP*), with consequent decrease of a percentage point in the forest areas (*FAP*), the mean production value increases by 0.5%. On the other hand, one percentage point increase in the pasture areas (*PAP*) increases the production value in a smaller proportion, 0.1%.

The coefficients associated with production system variables show that the use of mechanical traction (*TRAMEC)*, technical assistance (*TECH*), soil treatments (*SOILTR*), and pesticides (*PEST*) has a high positive impact on *Y*. Finally, the estimate for the market integration degree (*INT*) is positive and significant, while estimates for the degree of specialization (*SPEC*) shows that, if the farm is highly specialized, the mean production value is 60.82% lower than the diversified or much diversified farms.

Propensity Score Analysis

The second analysis strategy is based on the selection of homogeneous farmers of Groups 1 and 3 in order to compare their production values. As control group (Group 3), we consider only those farmers without access to government credit. In other words, the group of farmers with access to credit from other governmental programs (Group 2) was excluded from these analyzes.

The binary logistic regression model is used to identify the factors that contribute to access PRONAF microcredit. Results are reported in Table 4. Although it is not the main objective of the analysis, the estimates of the coefficients allow important insights about the determinants of PRONAF access. For example, farms managed by individuals who completed elementary school (*EL*4) and members of cooperatives are more likely to receive financial resource than others. The bureaucracy needed to meet the program requirements may be a major barrier for farmers without any source of knowledge. Focusing on production system variables, famers that use soil treatment (*SOILTR*), pesticides (*PEST*), mechanical traction (*TRAMEC)*, and technical assistance (*TECH*) are also more likely to receive financial resources from PRONAF than others. In other words, the farms with access to PRONAF are those with the better socioeconomic conditions and higher levels of technology.

Table 4 – Estimates of the binary logistic regression model.

Variable	Parameter estimates	Error standard	Wald Chi-Square	p-value
AGE	0.038	0.004	101.111	<0.001
AGE2	-0.0004	<0.0001	142.846	<0.001
GEN	-0.159	0.028	31.551	<0.001
EL1	0.192	0.031	38.279	<0.001
EL2	0.226	0.032	49.602	<0.001
EL3	0.228	0.023	97.297	<0.001
EL4	0.240	0.035	47.338	<0.001
EL5	0.191	0.042	21.13	<0.001
EL6	-0.310	0.110	8.008	0.0047
COOP	0.607	0.036	288.358	<0.001
ENT	0.932	0.016	3.241.375	<0.001
CAP	-0.002	0.0003	22.728	<0.001
PAP	0.007	0.0002	604.83	<0.001
FS	0.125	0.006	370.397	<0.001
TRAN	0.195	0.017	134.788	<0.001
TRAMEC	0.343	0.023	230.893	<0.001
TECH	0.471	0.018	698.925	<0.001
SOILTR	0.419	0.022	377.255	<0.001
PEST	0.285	0.018	236.606	<0.001
SPEC1	-0.278	0.024	135.273	<0.001
SPEC2	-0.035	0.018	3.573	0.059
INT1	0.109	0.021	27.841	<0.001
INT2	0.141	0.019	53.846	<0.001
WORK	0.027	0.013	414.81	0.042
c	-5.045	0.095	2.828.374	<0.001

Source: 2006 Agricultural Census, IBGE.

Table 5 shows the results of the propensity score method (Equation 8). The differences between the log production values, or log mean production differences, are significant in all regions (North, Northeast and Southeast), although some differences between the production values are not significant. For example, the ATT for the logarithm of the production value in the Northern region, the less developed in technological advances, indicates that the farmers of the Group 1 have an average log value that is 5.9% ($e^{0.0576}$–1) higher than that of farmers of the Group 3. Differences between average log values represent relative differences between geometric means Thus, the geometric mean in Group 1 is 5.9% higher than in Group 3 in the Northern region. This is the lower difference observed among the regions, although it is also significant at 0.01%.

For the Southern and Center-west regions, the most developed in technological advances, the ATT are significant for both the production value and its logarithm. For the Southern region, the average production value is R$ 1,640 higher in Group 1 than in Group 3, and the geometric mean of the production value is 14.7% higher. In addition, for the Center-west region, differences are also high: the average production value is R$ 8,853 higher in Group 1 and the geometric mean of the production value is 12.9% higher.

The total production value in the South-eastern region is the third highest in Brazil, and the relative difference between the geometric means of the Group 1 and 3 is also significant: 18.3% higher in the former group. With respect to the North-eastern region, the absolute difference between Group 1 and 3 is very low and insignificant, only R$ 102.3. However, the log mean production difference is significant at 0.01%, since small absolute changes make differences among very low mean values.

The positive impact of the PRONAF program on production value were expected in Southern, South-eastern and Center-west, since these farmers can transact in consolidated agri-food supply chains, such as tobacco, corn and soybeans. Conversely, results for the North-eastern area also suggest that PRONAF is contributing marginally to increase the small-farmers' production, although in lesser extent than in developed regions.

Table 5 – Tests for production value differences between Groups 1 and 3

Region	**Variable**	**Group 1**	**Group 3**	**ATT**	***t***	***p*-value**
Northern	*Y*	16,050.21	15,014.87	1,035.30	1.21	0.2266
	ln *Y*	8.499	8.441	0.0576	3.73	0.0002
North-eastern	*Y*	8,540.20	8,437.93	102.3	0.2	0.8378
	ln *Y*	7.43	7.249	0.1803	33.43	<.0001
South-eastern	*Y*	26,422.31	24,970.16	1,452.20	0.74	0.4587
	ln *Y*	8.835	8.666	0.1682	18.69	<0.001
Southern	*Y*	32,812.59	31,172.86	1,639.70	2.07	0.0381
	ln *Y*	9.499	9.362	0.1368	34.24	<0.001
Center-West	*Y*	30,122.64	21,269.76	8,852.90	2.51	0.012
	ln *Y*	8.853	8.732	0.1216	7.6	<0.001

Source: 2006 Agricultural Census, IBGE.

CONCLUSIONS

This study highlighted that PRONAF has positive and significant impact on the production values of family farming. More than 600,000 farms received financial support from PRONAF in 2006, which is the most import public microcredit program targeted to small family farms in Brazil. These families are mostly located in the Southern (46%) and North-eastern (33%) regions. The former region is historically characterized by family farms with high levels of socioeconomic development, while the second is characterized by the lowest levels. The farm areas are substantially higher in the North and Center-West regions, the new frontier of agricultural development. In turn, the productivity is higher in the South and Southeast regions, where the adoption of important technologies to increase agricultural production is also more common.

The total production value small farms that received PRONAF in 2006 was compared to that of two other groups: (i) small farms with other types of public credit programs; (ii) family farms with no access to public credit. Special emphasis was given to the differences between farms with PRONAF and those without access to any governmental credit. Two different strategies were used to analyze the consistency of estimates. First, we controlled the effect of factors that could also influence the production value through a multiple linear regression model. Results suggested that, holding constant other characteristics, the access to PRONAF credit caused a positive and significant net impact on the expected production value, when compared to farms deprived of any public credit.

Second, the difference between the total production values of the group with PRONAF and the group with no access to public credits was also compared by the propensity score technique. We defined a treatment and a counterfactual (control) group in each region: a group of farms receiving PRONAF (treatment) and a group of farms without any public funding (control). These groups of farms presented relatively similar characteristics, except for the access to PRONAF credits. This means that a direct comparison between their mean production values would be a good proxy for the impact of PRONAF on agricultural production. Results were very similar to those obtained by the multiple linear regression model, indicating positive and significant differences between the logarithm of the average production values.

The relative similarity of the results obtained by the two techniques suggested that the selectivity bias was not as severe as expected. Furthermore, it suggested the consistency of the estimators, indicating the existence of significant differences in the net effect of PRONAF on the total production value of small family farmers in different regions of the country. In other words, the access to public credit would imply significant differences between the total production values, even between small farms subjected to similar conditions of production in different regions. The impact was lower in the Northern and Northeastern regions, which are characterized by forestry, subsistence agriculture and low level of technology adoption. In the more developed regions, the PRONAF has shown relevant impacts on the production value, in spite of other characteristics that are also important to determine the production performance.

Finally, we must emphasize that these analyses only considered the net impact of PRONAF on the total production value. Farms receiving PRONAF also present better socioeconomic and productive characteristics than those with no access to public credit, which contributes to increase differences between their average production values. We did not consider, for example, the net impacts of this important microcredit program on the adoption of technologies or management systems that also influence the productive performance.

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Appendix 1 – List of farmer and farm characteristics variables.

Variable	Description
AGE	Age (in years) of the farmer
GEN	Binary variable which assumes 1 if a woman directs the establishment and 0 otherwise
EL1	Binary variable for educational level; 1 if maximum education level is can write and read and 0 otherwise
EL2	Binary variable for educational level; 1 if maximum education level is the adult literacy and 0 otherwise
EL3	Binary variable for educational level; 1 if maximum education level is incompleted elementary school and 0 otherwise
EL4	Binary variable for educational level; 1 if maximum education level is completed elementary school and 0 otherwise
EL5	Binary variable for educational level; 1 if maximum education level is completed high school and 0 otherwise
EL6	Binary variable for educational level; 1 if maximum education level is completed undergraduate and 0 otherwise
COOP	Binary variable which assumes 1 if the farmer is a member of a cooperative and 0 otherwise
ENT	Binary variable which assumes 1 if the farmer is a member of an entity class and 0 otherwise
CROP	Crop area (in hectares)
PAST	Pasture area (in hectares)
NPA	Natural forest preserved area (in hectares)
EFA	Natural forest exploited area (in hectares)
ASA	Agroforestry system area (in hectares)
AAU	Area with another use (in hectares) (planted forests, lakes, construction, etc.)
CAP	Crop area percentage
PAP	Pasture area percentage
FAP	Forest area percentage
SAPV	Share of animal production value in the total production value
SCPV	Share of crop production value in the total production value
AVA	Added value of the agricultural industry of the total value of production
FS	Farm size (in hectares)
Y	Value of agricultural production (BRL)
PRONAF	Binary variable which assumes 1 if the farmer access PRONAF credit and 0 otherwise
OGP	Binary variable which assumes 1 if the farmer access credit from other government program and 0 otherwise
NO	Binary variable which assumes 1 if the establishment is located in Northern area and 0 otherwise
NE	Binary variable which assumes 1 if the establishment is located in North-eastern area and 0 otherwise
SE	Binary variable which assumes 1 if the establishment is located in South-eastern area and 0 otherwise
SU	Binary variable which assumes 1 if the establishment is located in Southern area and 0 otherwise
CW	Binary variable which assumes 1 if the establishment is located in Center-West area and 0 otherwise

Appendix 2 – List of production system characteristics variables

Variable	Description
TR	Binary variable which assumes 1 if the farmer uses animal traction force and/or mechanical and 0 otherwise
TRAN	Binary variable which assumes 1 if the farmer uses animal traction force and 0 otherwise
TRAMEC	Binary variable which assumes 1 if the farmer uses mechanical force and 0 otherwise
TECH	Binary variable which assumes 1 if the farmer receives technical orientation and 0 otherwise
SOILTR	Binary variable which assumes 1 if the farmer uses fertilization and/or soil treatment
PEST	Binary variable which assumes 1 if the farmer uses pesticides to control pests and/or diseases and 0 otherwise
SPEC1	Binary variable which assumes 1 if establishment is super specialized and 0 otherwise
SPEC2	Binary variable which assumes 1 if establishment is specialized and 0 otherwise
*SPEC*3	Binary variable which assumes 1 if establishment is diversified and 0 otherwise
*SPEC*4	Binary variable which assumes 1 if establishment is very diversified and 0 otherwise
INT1	Binary variable which assumes 1 if establishment is very integrated and 0 otherwise
INT2	Binary variable which assumes 1 if establishment is integrated and 0 otherwise
INT3	Binary variable which assumes 1 if establishment is poorly integrated into and 0 otherwise
NWORK	Number of workers in the farm (contracted and family).