Italian Review of Agricultural Economics, Vol. 73, n. 2, 2018: 147-169

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Effects of pluriactivity of brazilian rural establishments on technical efficiency

This paper examines Brazilian rural establishments which carry out both agricultural and non-agricultural activities. The combination of these activities, in the same agricultural unit, characterizes and defines pluriactivity. The research aims to analyze the effect of pluriactivity on the technical efficiency of rural establishments. To do so, Propensity Score Matching (PSM), a Probit Model and the Stochastic Production Frontier were used. The data used refer to a special tabulation, based on the micro-data of the 2006 Agricultural Census. The results found that establishments which carry out exclusively agricultural activities make better use of available resources than those involved in pluriactivity, as they are technically more efficient.

Keywords: puriactivity, non-pluriactivity, technical efficiency, agriculture, stochastic production frontier
JEL codes: A23, I23

1. Introduction

Agricultural industrialization and urban overflow to space traditionally defined as rural have significantly transformed the Brazilian rural environment in recent decades (Silva, 1997), thereby challenging the concept that such space is solely characterized by the practice of activities related to agriculture and livestock.

Studies have highlighted increased non-agricultural activities in the countryside as a means towards supplementing people's income (Schneider , Fialho, 2000; Silva, 2001; Schneider, 2003). In the literature, the combination of rural agricultural and non-agricultural activities is called pluriactivity. This phenomenon is not new in the formation of agrarian economies. Both Chayanov (1974) and Kautsky (1980) refer to such income supplementary activities which also seek to boost the economic insertion of small landowners. Thus, it is understood that pluriactivity is characterized by the existence of a multidimensional productive unit, where agriculture and other activities are practiced, both on the farm and outside, from which different types of payment are received (Marofan, 2006).

These agricultural activities are associated with planting, harvesting, and preparation of the land etc., that is, activities relating to procedures and op-

DOI: 10.13128/REA-24080
ISSN (print): 0035-6190
ISSN (online): 2281-1559
Published by Firenze University Press
www.fupress.com/rea

erations which involve the cultivation of living organisms (animals and plants) and the management of biological processes (Schneider, 2009). Non-agricultural activities involve the provision of services, rural tourism, handicrafts, etc., that is, activities carried out in addition to agricultural activities. That said, pluriactivity is understood as a combination of two or more activities, one of which is essentially agricultural.

According to Reardon *et al.* (2001), the decision to undertake non-agricultural activities depends mainly on two factors: namely, the incentives found in non-agricultural activity, such as profitability and risk; and general abilities of those involved, such as their education, knowledge and skills, and access to credit.

Silva (2001) shows that in the 1990s involvement in these activities grew at a rate of 3.7% per year in Brazil. Based on data from the 2006 Agricultural Census, Escher *et al.* (2014) pointed out that 37% of all Brazilian agricultural establishments are pluriactive[1]. It has thus been observed that, in the space reserved for agriculture, a process of restructuring agricultural production involving pluriactivity has acquired significant importance.

Schneider (2003) believes that with the passage of time, rural families are reducing the time they spend in agricultural production, and this can lead to a decrease in agricultural income. Thus, nonfarm labor emerges as a valuable source of complementary income for such families. However, he states that pluriactivity is not necessarily detrimental to agricultural activities, as such activities, with the incorporation of new technologies, can demand less working time, for example, by developing new forms of organization.

A key issue emerges in this context. On the one hand, pluriactivities contribute to the diversification of income and consequent reduction in risks involved in rural activity. But on the other hand, there are reasons to believe that such practice could have adverse effects on efficiency. Lima and Piancenti (2009) observed that pluriactive families in southern Brazil are more economically efficient than those which are non-pluriactive.

On considering the evolution and significance of the non-agricultural activities of rural establishments (agricultural units) in Brazil, research on the subject is relevant and could study specifically the efficiency of establishments which carry out this activity. Literature on the efficiency of Brazilian rural establishments presents studies by authors, such as Imori (2011), Oliveira (2013) and Freitas *et al.* (2014), while studies on pluriactivity in the Brazilian countryside have been undertaken by Del Grossi and Silva (1998), Schneider and

[1] In this study, pluriactive establishments and establishments carrying out agricultural and livestock activities and non-agricultural activity will be treated as synonymous.

Fialho (2000), Schneider (2001, 2003), Ney and Hoffmann (2008), Lima and Pianceti (2009) and Escher *et al.* (2014). However, studies on efficiency have emphasized its relationship with the rural area, while those evaluating pluriactivity have addressed the effects of efficiency on levels of poverty and income inequality. We now wish to expand the scope of analysis and provide evidence of the efficiency of pluriactive when compared to non-pluriactive establishments. We analyze this issue in Brazil, a developing country which has experienced rapid change in farming and in the countryside. Thus, this study sets out to investigate if the fact that these establishments are pluriactive leads to a reduction in their productive performance in the main activity of the establishment. Our main goal is to evaluate the effect of pluriactivity on the technical efficiency of Brazilian rural establishments. A special tabulation of the micro-data of the 2006 Agricultural Census is used to reduce the bias caused by the aggregation of information at state or regional level.

2. Efficiency measures

Assumptions of neoclassical economic theory indicate that economic agents are rational and aim to optimize their behavior. In agriculture, for example, this behavior can be seen when producers seek to maximize production and/or minimize costs. Thus, maximum profit would be obtained when these two objectives are simultaneously reached. However, in practice, it can be seen that not all producers can optimize these objectives, that is, achieve economic efficiency in their activities (Almeida, 2012).

In the economic literature on productivity, the efficiency measure is defined as the comparison between the observed values of products, inputs, revenues, profits and costs and the values considered optimal. Thus, efficiency is related to the lowest cost or the highest production possible in a particular production system.

The first researches on efficient production levels were drafted by Debreu (1951), Koopmans (1951) and Shephard (1953). The definitions of Debreu (1951) and Shephard (1953) for technical efficiency incorporated the concept of distance functions, which consisted of modeling the production technology and measuring the distance from the producer to the frontier of production or optimal product. For Koopmans (1951), a producer would be technically efficient when he could not increase the production of a given product without reducing that of another, or when he could not reduce the use of any input and still keep production constant.

Using Koopmans (1951) concepts as a basis, Debreu (1951) and Farrell (1957) proposed two approaches or guidelines for the measurement of technical efficiency. One is input oriented, where the objective is to reduce inputs by keeping output fixed; while the other is product oriented, where the focus is on increasing production without changing the use of inputs. These two approaches to the identification of technical efficiency could be considered a special case of the Koopmans (1951) definition, as they allow only radial adjustments of inputs or products, that is, all products or inputs are modified proportionally.

Thus, technical efficiency can be understood as the way in which an optimal combination of inputs is used in the productive process in order to obtain the maximum product. This means that such efficiency deals with the relationship between inputs and final product, that is, the analysis is related to the physical factors of the production process. However, when input prices are taken into account, it is also possible to obtain the economic efficiency of the firm, which reflects the company's ability to use inputs at optimum proportions given their relative prices. Moreover, according to Reis *et al.* (2005), a combination of these two measures can be considered a measure of economic efficiency.

3. Empirical strategy

In methodological terms, two steps are necessary to analyze the effects of pluriactivity on efficiency. First, it must be emphasized that establishments which opt for pluriactivity should present characteristics different from those which only carry out rural farm activities. Thus, a simple comparison between the efficiency of one group and another could be erroneous due to the possibility of selection bias or rather, the observed difference in efficiency could be a result of the characteristics which lead to pluriactivity and not just of the activity itself. In this paper, to try to minimize this bias, we start with the assumption that the differences between establishments which engage in or do not engage in pluriactivity are based on observable characteristics. Once these characteristics are controlled, the establishments become statistically similar, and therefore comparable. Thus, the first methodological step refers to the identification of groups of non-pluriactive establishments which are more similar in observable terms, to the pluriactive group, through Propensity Score Matching (PSM).

The second step is to calculate technical efficiency in order to identify the effect of pluriactivity. To do so, the stochastic production frontier for each group was estimated considering the selection bias resulting from the decision to adopt non-pluriactivity, based on the Heckman (1979) approach. Using this approach, we expect to obtain technical efficiency scores free of bias caused by observable and unobservable factors for the two groups considered (pluriactive and non-pluriactive).

3.1 Propensity Score Matching (PSM)

With PSM, the characteristics of each unit are summarized in a single variable, the propensity score, which makes matching feasible (Becker and Ichino, 2002). According to the definition of Rosenbaum and Rubin (1983), the propensity score consists of the conditional probability of receiving treatment – or being pluriactive – given a vector of observable variables. According to Becker and Ichino (2002):

$$p(X) \equiv \Pr(D=1|X) = E(D|X) \tag{1}$$

where *D* a binary variable that assumes a value of 1 if the establishment is pluriactive and 0 if otherwise, and X refers to the vector of baseline observable characteristics which affect that decision.

Two assumptions must be satisfied for estimating impacts with propensity score matching. The first assumes balancing between the constituent variables of the vector, given the propensity score. This hypothesis ensures that units with identical values of the propensity score have the same distribution as the observable characteristics analyzed, whether treated or not (Becker, Ichino, 2002). Or:

$$\mathrm{D} \perp \mathrm{X} \big| \, \mathrm{p}(\mathrm{X}) \tag{2}$$

in which $\perp$ indicates independence.

The second assumption refers to the conditional independence of treatment: given the observable characteristics in the vector, the potential results should be independent of the participation status. Thus, according to Becker and Ichino (2003), if equation (3) is valid, then so is (4):

$$Y_1, Y_0 \perp D \big| \, \mathrm{X} \tag{3}$$

$$Y_1, Y_0 \perp D \big| \, \mathrm{p}(\mathrm{X}) \tag{4}$$

in which Y^1 and Y^2 denote the potential results of the pluriactive and non-pluriactive groups, respectively. In this context, once these observable characteristics are controlled, the existence of pluriactivity among the establishments becomes random, allowing one to compare the results between these groups with a view to identifying the impacts.

The matching should preferably be done on the basis of characteristics observed prior to the situation analyzed, in this case, before the decision on pluriactivity. In the absence of these data, we proceed to the so-called *ex-post-matching* (Gertler *et al.*, 2011). In this procedure, one must consider the choice of the constituent explanatory variables of the vector X, which by definition cannot themselves be results of the treatment. Thus, the variables selected for PSM estimation in this paper were those that could determine pluriactivity but are not the result of efficiency.

The *propensity score* is usually estimated using parametric models, such as the *logit* or *probit models* (Cameron and Trivedi, 2005). In addition, different matching criteria can be used to associate beneficiary sectors with non-participants. According to Becker and Ichino (2002), the techniques most frequently used for this purpose are: Nearest-Neighbor Matching; Radius Matching; Kernel pairing (Kernel Matching) and Stratified matching (Stratification Matching).

3.2 Sampling selection

In order to consider the possibility of the existence of selection bias, which can occur when the factors affecting the efficiency of the agricultural establishments are different from those affecting the probability of these establishments being pluriactive, we use the Heckman Sampling Selection model (1979).

The estimation procedure is performed in two stages. In the first, the selection equation (Binary Probit model) is estimated (probability of agricultural establishments exercising pluriactivity) while in the second, the equation of interest (the frontier production) is defined using estimated components (inverse Mills ratio[2]) of the previous stage.

3.2.1 Probit

According to Greene (2011), the Binary Probit model of choice is defined by:

$$y_i^* = x_n^{'}\beta + \varepsilon_i \text{ , } n=1,\ldots,N \tag{5}$$

[2] Variable generated from the Probit model and included in the stochastic production frontier to correct the selection bias. The existence of the selection bias is confirmed when the inverse Mills ratio is statistically significant (Greene, 2011).

where $y_i = \begin{cases} 1 \; if \;\; y_i^* > 0 \\ 0 \; otherwise \end{cases}$,

in which *Y*i* is a latent variable which indicates the non-observed probability of the agricultural establishment *i* to exercise pluriactivity; y_i is an observed binary variable which is equal to 1 if the latent variable is positive ; β the vector of estimated parameters; and ε_i the independent and identically distributed error term.

Thus, the estimated selection equation (Probit) is:

$$y_i^* = \beta_0 + \beta_1 \; gender + \beta_2 \; assistance + \beta_3 \; debt + \beta_4 \; financing + \beta_5 \; age + \beta_6 \; schooling + \beta_7 \; experience + \varepsilon_i \quad (6)$$

in which gender is a dummy variable which is given a value of 1 if it is male and 0 otherwise; assistance represents the number of properties which had access to technical assistance; debt represents the number of properties with some debt; financing represents the logarithm of the total financing made; age is a categorical variable divided into: up to 25 years, from 26 to 35 years, from 36 to 45 years, from 46 to 55 years, from 56 to 65 years and over 66 (the base); similarly, schooling is grouped into: literate; incomplete elementary schooling, complete elementary schooling and high school, the latter being the base category; experience is a variable which represents the number of establishments whose manager has agricultural experience expressed in years, categorized into: up to 1 year, 1 to 5 years, 5 to 10 years, over 10 years (base).

3.2.2 Stochastic Production Frontier

The second stage calculates the stochastic production frontier, whose objective is to estimate a production function, in which it is expected to obtain the maximum product from a combination of factors, at a certain technological level. However, there is no guarantee that an efficient combination of factors is being used, as there could be technical inefficiencies in the production process. This implies that the unit could be producing below the maximum production boundary (Marinho and Ataliba, 2001).

To apply the method empirically, one must first specify the functional form to be used to represent the production technology, as argued by Coelli and Battese (1996). In this research, we chose to use the Cobb-Douglas functional form, as the estimated coefficients are the elasticities. This is also true of papers by Almeida (2012), Freitas *et al.* (2014), Lima (2012) and others[3].

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[3] Chambers (1988) and Silva (1996) have identified some advantages of using Cobb-Douglas: 1) simplicity in estimating parameters, because in the logarithmic form the Cobb-Douglas

Instead of considering the agricultural establishments of individual municipalities (i), the present paper groups these establishments by area groups (j). Thus, we can specify the production frontier function in the following general form:

$$Y_{ij} = f\left(X_{ij}\beta\right)e^{\left(v_{ij}-u_{ij}\right)} \tag{7}$$

Incorporating dummy variables for State and total area group, the logarithmic form can be represented by:

$$lnY_{ij} = \sum_{i=1}^{n} ln\beta_{ij}X_{ij} + \sum_{h=1}^{26} E_h + \sum_{g=1}^{3} G_g + v_{ij} - u_{ij} \tag{8}$$

where Y_{ij} is the vector of the value of the quantities produced by municipality i referring to the area group j; X_{ij} is the input expenditure vector i used in group *j*; E_h are *dummies* to represent the Brazilian states; G_g are *dummies* to represent the area groups; and β_{ij} is a vector of the parameters to be estimated, which define the production technology. It should be noted here that *dummies* had to be included to capture the fixed characteristics of each area or state group, and also to try to control possible spatial autocorrelation, in order to obtain an estimate of efficiency, free of such effects.

The error terms v_{ij} and u_{ij} are vectors representing distinct components of the error. v_{ij} is the random error term, normal, independent and identically distributed (iid), zero-truncated with variance $\sigma_v^2[v \sim iid \quad N(0,\sigma_v)]$ and captures the stochastic effects outside the control of the productive unit, such as errors of measurement and climate, for example; and u_{ij} is responsible for capturing the technical inefficiency of the ith group, i.e. the part of the error that constitutes a downward deviation from the production frontier, and are non-negative random variables. This unilateral term can follow the normal, truncated, exponential and gamma normal distribution (Aigner, Lovell, Schmidt, 1977; Greene, 1980). In this study, and in those by Conceição (1998), and Tupy and Shirota (1999), the exponential distribution was considered.

function is linear in the parameters; 2) regression coefficients provide the elasticities of production, and can be compared to each other; 3) because it is a homogeneous function, the sum of the regression coefficients determines the returns to scale; and (4) if compared to the translogical transcendental functional form (translog), the Cobb-Douglas production function presents a small number of parameters to be estimated, and is thus less susceptible to the common problems of multicollinearity in estimating the production function.

The empirical measurement of the agricultural production function in Brazil is based on the estimation of the function by the maximum likelihood method. Thus, according to Greene (1993), Aigner *et al.* (1977) and Meeuser and Van Der Broeck (1977), when the exponential distribution for the error term related to inefficiency is considered, the logarithm of the maximum likelihood function is given by:

$$lnL=\sum_{i=1}^{n}\left[-ln\sigma_u+\frac{1}{2}\left(\frac{\sigma_v}{\sigma_u}\right)+ln\Phi\left(\frac{-(\varepsilon_{\mathrm{i}+\sigma_v^2/\sigma_u}}{\sigma_v}\right)+\frac{\varepsilon_{\mathrm{i}}}{\sigma_u}\right] \quad (9)$$

In estimating the parameters by the maximum likelihood method, the following reparametrization is used, which provides a relevant interpretation in the analysis:

$$\lambda=\frac{\sigma_u}{\sigma_v} \quad (10)$$

in which, according to Bagi (1982), the coefficient λ indicates the relative variation of the two sources of random errors which distinguish one productive unit from the other. When λ approaches zero, it indicates that the symmetric error v_{ij} the determination of the sum of the total ε_i, thereby indicating that the distance between the production observed and the estimated frontier from a certain combination of inputs is mainly a result of factors beyond the control of the firm. When λ becomes larger, it means that the unilateral error u_{ij} dominates the sources of the random variation of the model, that is, the difference between observed production and frontier production is mainly a result of technical inefficiency.

When the boundary function has been estimated, the Jondrow *et al.* (1982) procedure on the separation of boundary deviations into their random components and inefficiency is used to obtain the measure of technical efficiency. According to this procedure, technical efficiency can be defined as the ratio between the observed product and the potential product of the sample. Thus, the expression for the technical efficiency of a given observation can be defined as follows:

$$ET_{ij}=\frac{Y_{ij}}{Y_{ij}^{*}}=\frac{Y_{ij}}{f\left(X_{ij}\right)}=\frac{\exp\left(X_{ij}\beta+v_{ij}\right)\exp\left(-u_{ij}\right)}{\exp\left(X_{ij}\beta+v_{ij}\right)}=\exp\left(-u_{ij}\right) \quad (11)$$

in which the value ET_i will be in the interval [0; 1], where zero represents complete inefficiency and 1, full efficiency.

Thus, equation (12) presents the frontier function of stochastic production to be estimated in this research:

$$lnY_{ij} = \beta_0 + \beta_1 \ln(area_{ij}) + \beta_2 \ln(labor_{ij}) + \beta_3 \ln(inputs_{ij}) + \beta_4 \ln(capital_{ij}) + \sum_{h=1}^{26} E_h + \sum_{g=1}^{3} G_g + \varepsilon_i \quad (12)$$

where $\varepsilon_i = v_{ij} - u_{ij}$

in which Y_{ij} is the gross value of production of municipality i in area class j; area is the total area of the establishment, in hectares (*ha*); *labor* refers to the total number of family members and employees; *inputs* refers to total expenditure on fertilizer, pesticides, seeds, animal medicine, soil correctives, salt and feed, electricity and transport of production; *capital* refers to the total value of buildings, facilities and other improvements, land, vehicles, tractors, machinery and implements, in Reals E_h are *dummies* to represent the Brazilian states; G_g are *dummies* to represent the area groups; and ε_i the compound error term.

It is expected to find a positive relation between the explanatory variables and the Gross Value of Production (GVP), thus indicating a positive relation between the increase in the factors of production and the increase in the value of agricultural production.

3.3 Source and treatment of data

The data used to carry out this research were obtained from the 2006 Agricultural Census, made available by the Brazilian Institute of Geography and Statistics - IBGE. However, the database used refers to a special tabulation of the Census microdata, which involved organizing information from the Census according to different classes of sizes of Brazilian agricultural establishments[4].

It is noteworthy that, similar to studies by Helfand and Levine (2004), Freitas *et al.* (2014), Helfand *et al.* (2015) and others, representative units were created for each size of establishment in each municipality. After removing observations with missing values, Brazilian establishments were grouped into 13,169 representative units. These were obtained by dividing the total value of a given variable by the number of establishments in a specific area and mu-

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[4] This tabulation was coordinated by Professor Steven M. Helfand and made available by the Institute of Applied Economic Research (IPEA).

nicipality group. Thus, in each area group belonging to each municipality, a representative unit was constructed. It was necessary to use this procedure, as the information obtained does not represent the microdata of the Agricultural Census. It is also worth noting that four area groups: 0 to less than 10ha, 10 to less than 100ha, 100 to less than 500ha, and over 500ha were used.

It is important to highlight the procedure used to construct the dummy for pluriactivity[5]. As the data used were aggregated into representative productive units, there was an initial average rate of pluriactive producers for each unit considered. Thus, to transform this variable into a *dummy*, the following criterion was adopted: the representative productive units which presented values for the rate equal to the average plus a half standard deviation were classified as pluriactive (they received a value of 1 for pluriactivity in the *dummy*), while observations which presented values for the rate equal to the mean minus a half standard deviation were classified as non-pluriactive (they received a value of 0 for pluriactivity in the *dummy*). As a result of this procedure, it was seen that, of the 13,169 representative establishments considered, 46.2% were classified as pluriactive.

4. Results and discussion

First of all, in this section, after the sample balancing, a descriptive analysis of the main variables used will be made. Then the results of the Probit and the Stochastic Production Function will be presented. Finally, the technical efficiency scores of the representative units which carried out non-agricultural activities will be found.

4.1 Descriptive analysis of data

As described in Section 3.1, the first step in the empirical strategy adopted in this paper involved using the Propensity Score Matching procedure to identify, in the total sample, a control group as similar as possible to the treatment group, based on a set of observable characteristics. The results are shown in Table 1[6], where the means and standard deviations of the unmatched (original

[5] The concept of pluriactive establishments in this paper is based on the 2006 Agricultural Census, that is, those which indicated carrying out both agricultural and non-agricultural activities.

[6] The results of the estimation of the Probit model to obtain the propensity score were omitted due to the page limit, but they can be made available on request.

sample) and matched samples are subdivided into untreated (non-pluriactive) and treated (pluriactive). A total of 1,101 representative productive units were excluded after sample matching.

In the unmatched sample, the average values between the untreated and treated groups were all statistically different, except for *experience 1, experience 1 to 5 and experience 5 to 10*. After the matching procedure, all means of the variables were statistically equal between groups, as was expected.

Some variables presented interesting patterns. The gender variable indicates the presence of a male as head of the establishment (manager). In both matched and unmatched samples, this was the situation for more than 90% of establishments. The presence of properties with access to technical assistance, in average terms, is greater in the pluriactive establishment group. The existence of debts was higher in the non-pluriactive group, which could be related to the fact that such debts are exclusively from the agricultural establishments. As expected, the value of non-pluriactive establishment financing was about 61% higher than that of the pluriactive establishments, which suggests that establishments which do not exercise pluriactivity need more financial resources for agricultural activity. In the age variable categories, for both untreated and treated, the highest mean was for the 46 to 55 years of age category. In terms of schooling levels, the highest mean was Incomplete Elementary School, which indicated similar low levels of schooling for managers of the agricultural establishments, whether pluriactive or otherwise. Experience in agricultural activity, on average, is similar and high (over 10 years) between non-pluriactive and pluriactive establishments.

As for the variables used in the stochastic frontier, it was seen that the average GVP among the pluriactive groups is higher, which indicates that the diversification of economic activity does not decrease the production of rural establishments, in monetary terms. However, this result could be related to the fact that, on average, such establishments present larger total areas under use, greater use of labor and greater expenditure on inputs, as presented in Table 1.

4.2 Determinants of pluriactivity

As shown in the methodology, estimation of the selection equation using the Probit model is the first stage in correcting a possible selection bias in the research. These results are shown in Table 2.

It was seen that among the characteristics of rural establishment managers considered, only ages from 46 to 55, and from 56 to 65 were not statistically significant.

The gender variable indicated that the fact of the manager being male increases the probability of pluriactivity, which is similar to the findings of Cruz

Tab. 1. Descriptive statistics of the variables used in the selection equation and the Stochastic Production Frontier.

Variables	Unmatched sample				Matched sample			
	Untreated		Treated		Untreated		Treated	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Gender	0.907***	0.0962	0.918	0.0914	0.91ns	0.0952	0.918	0.0914
Assistance	0.154***	0.188	0.21	0.184	0.162 ns	0.193	0.21	0.184
Debt	0.203***	0.213	0.152	0.174	0.191 ns	0.205	0.152	0.174
Financing	8425***	93404	4888	22103	8031 ns	99042	4888	22103
Age 25	0.028***	0.0516	0.0166	0.0399	0.026 ns	0.0515	0.0166	0.0399
Age 26to35	0.126***	0.116	0.095	0.103	0.12 ns	0.118	0.095	0.103
Age 36to45	0.218***	0.144	0.204	0.138	0.216 ns	0.149	0.204	0.138
Age 46to55	0.237***	0.151	0.257	0.149	0.239 ns	0.156	0.257	0.149
Age 56to65	0.202***	0.14	0.22	0.14	0.204 ns	0.145	0.22	0.14
Age 65	0.189***	0.161	0.208	0.146	0.195 ns	0.168	0.208	0.146
Literate	0.136***	0.146	0.0957	0.122	0.128 ns	0.14	0.0957	0.122
IncompElementary	0.403***	0.234	0.372	0.211	0.398 ns	0.235	0.372	0.211
CompElementary	0.095***	0.121	0.122	0.117	0.099 ns	0.126	0.122	0.117
HighSchool	0.077***	0.122	0.138	0.137	0.081 ns	0.126	0.138	0.137
Experience 1	0.032 ns	0.0704	0.0326	0.0581	0.032 ns	0.0738	0.0326	0.0581
Experience 1to5	0.175 ns	0.156	0.179	0.146	0.176 ns	0.16	0.179	0.146
Experience 5to10	0.175 ns	0.147	0.174	0.134	0.174 ns	0.149	0.174	0.134
Experience 10	0.618***	0.222	0.615	0.208	0.618 ns	0.226	0.615	0.208
GVP	84065	417446	90291	478116	86124	431151	90291	478116
Total Area	176	418.2	267.3	454.2	181.7	425.6	267.3	454.2
Labor	2.684	11.18	3.564	9.39	2.711	12.05	3.564	9.39
Purchased Inputs	30245	297693	47096	1.34E+06	27579	176067	47096	1.34E+06
Capital	720938	2.53E+06	898795	2.08E+06	753001	2.62E+06	898795	2.08E+06
Nº Obs	7,090		6,079		5,989		6,079	

Source: Research Results
Note: *** Averages are statistically different from the 1% treated group; ns - means are not statistically different from 1%.

(2013) and Almeida (2016). This result can be justified by the socioeconomic characteristics of Brazil, where the figure of the male as head of the family predominates. The assistance variable showed a positive relationship with pluriactivity, which indicates the fact that when an agricultural establishment receives some type of assistance this makes it easier for the leader to work in a non-agricultural activity. This result could be related to the fact that the objectives of rural extension go beyond technical assistance and involve helping farmers with agricultural production itself. The objectives of the National Policy on Technical Assistance and Rural Extension (Pnater) include that of helping to implement strategies which would lead to the generation of new agricultural and non-agricultural jobs and would result in improvement in welfare in the countryside (MDA, 2007). In this sense, the extensionist, on verifying that the rural establishment has not been able to generate a minimum income level that can provide the necessary welfare, can suggest complementary activities (agricultural and non-agricultural) to complement income.

The existence of debt and financing presented a negative relation with pluriactivity, which indicates that debts generated by the establishment, and the fact that it has financing targeted to agricultural activities, reduce the probability of the manager branching out into non-agricultural activities.

The categories of the manager's age variable considered in the research showed a negative relationship with pluriactivity up to the 56 to 65 years, above which a positive relation was seen. Such a result suggests that greater experience, in terms of age, can provide greater security in activities outside of agriculture. In a similar way, the categories of the schooling variable used suggest that higher levels of schooling increase the probability of the agricultural manager being pluriative. These results are also found by Chayanov (1985) and Schneider (2003) who observe that as the age and schooling of family members increase, there is a greater probability that an agricultural family will diversify sources of work and income, that is, be pluriactive.

In terms of experience in agricultural activity, it was seen that producers with up to 10 years' experience as managers of establishments are more likely to carry out non-agricultural activities, when compared to those with more than 10 years' experience (base category). This result was expected because the broader experience of the latter allows them, even in adverse situations, to adapt and find alternatives so as to maintain the income from their agricultural activity at desired levels, without needing to put effort and resources into non-agricultural activities.

Tab. 2. Estimation of the selection equation (Probit) for participation in pluriactivity, considering the paired sample.

Pluriactivity	Coefficient	Default Error	Statistic Z	P-value
Gender	0.471	0.124	3.810	0.000***
Assistance	0.838	0.064	13.160	0.000***
Debt	-1.052	0.064	-16.410	0.000***
Financing	-0.000002	0.0000004	-3.660	0.000***
Age25	-3.395	0.295	-11.510	0.000***
Age26to35	-1.746	0.125	-13.970	0.000***
Age36to45	-0.675	0.098	-6.860	0.000***
Age46to55	-0.025	0.094	-0.270	0.791ns
Age56to65	0.033	0.101	0.320	0.746ns
Literate	-1.525	0.094	-16.220	0.000***
IncompElementary	-0.599	0.054	-11.030	0.000***
CompElementary	0.418	0.098	4.270	0.000***
Experience1	0.646	0.177	3.660	0.000***
Experience1to5	0.516	0.081	6.340	0.000***
Experience5to10	0.217	0.085	2.570	0.010***
Constant	0.140	0.130	1.070	0.282ns
Log Likelihood	-8311.706			
Chi2	1555.010	Prob>Chi2:	0.000	
Nº OBS	12,068			

Source: Research Results.
Note: Significance: *** significant at 1%; ns - not significant.

4.3 Stochastic Production Frontier

For the second stage of the Heckman approach, we estimated the stochastic production frontier function. As shown in Section 3.2, in addition to the factors of production, the inverse Mills ratio, calculated in the previous step, was added to the production function in order to take the selection bias caused by unobservable factors into account. It should once more be emphasized that the functional form used was the log-linear Cobb-Douglas, and the parameters were obtained using the Maximum Likelihood method. Thus, since the variables are transformed into their natural logarithm, each estimated coefficient refers to the elasticity of that factor of production, which must be interpreted in percentage terms. In addition, to allow for better visualization, the coefficients of fixed effects for Federative Units and area groups were omitted. The results are shown in Table 3.

In order to obtain more accurate coefficients, the model was estimated using the bootstrap method to obtain robust standard errors. It also solved a possible heteroskedasticity problem in the sample. In addition, the Wald statistic result presented in Table 3 indicates a good fit of the model, thereby rejecting the null hypothesis of joint insignificance of the variables for the three models estimated.

An important detail in the use of the Cobb-Douglas functional form is that it allows the return from the production function to be identified by the simple sum of the elasticities of the factors of production. In the models referring to the total sample, for both properties which did not and for properties which did carry out non-agricultural activities, the sum of the coefficients was 0.98, 0.93 and 1.03, respectively (Tab. 3). Such values indicate that the technology used in all three situations approximates constant returns to scale, which implies that an increase in the use of the productive factors would lead to a proportional increase in production value. Alves *et al.* (2012) and Helfand *et al.* (2015) also identified constant returns to scale when estimating production functions to represent rural Brazil.

The results presented in Table 3 show that there is a negative and significant impact of the total area on the formation of GVP in all three models analyzed. Although not expected, this result could be related to the fact that the variable used for this factor represents the total area of the establishment, and not just that destined to crops or pastures, which could limit the variable's capacity to correctly capture the contribution of the area of the establishment. In addition, part of this effect could also be explained by gains in land productivity, implying higher production from a smaller stretch of land. Almeida (2012) also found negative elasticity for this factor when analyzing the technical efficiency of Brazilian agricultural establishments.

The labor variable was statistically significant and, as expected, presented positive elasticity in all the models estimated. However, when comparing the results found for establishments not carrying out non-agricultural activities with those which do, it was seen that the impact of labor is relatively higher in the latter group of producers. This result is not surprising, as the fact that rural workers are simultaneously involved in both types of activity could provide an increase in their marginal contribution to agricultural production, and thus increase their participation in the formation of GVP. For this group of producers, a 10% increase in the total number of workers (family members or employees) would be associated with a 2.8% increase in GVP, on aver-

Tab. 3. Stochastic Production Frontier Function for the total sample, for non-pluriactive and for pluriactive establishments.

LnGVP	Total Sample (Pooled)		Non-Pluriactive		Pluriactive	
	Coefficient	Robust Standard Error (bootstrap)	Coefficient	Robust Standard Error (bootstrap)	Coefficient	Robust Standard Error (bootstrap)
Ln(Area)	-0.222***	0,007	-0.243***	0.014	-0.173***	0.013
Ln(Labor)	0.259***	0.018	0.206***	0.023	0.289***	0.018
Ln(PurchasedInputs)	0.243***	0.015	0.240***	0.019	0.256***	0.0087
Ln(Capital)	0.703***	0.010	0.725***	0.014	0.663***	0.011
Mills	-	-	-0.326***	0.124	-0.285***	-0.071
$Mills^2$	-	-	-0.159***	0.056	0.060***	0.018
Const.	0.085ns	0.095	0.154ns	0.246	3.888***	0.093
Usigma	-0.089*	0.046	0.339***	0.092	-0.122**	0.059
Vsigma	-0.4852***	0.032	-0.508***	0.036	-0.535***	0.050
Lambda	0.185	-	0.677	-	0.228	-
Wald Test	1.03e+06	Prob>chi2 0.00	575191.11	Prob>chi2 0.00	1.04e+06	Prob>chi2 0.00
LFMV	-20931.244	-	-9139.338	-	-9913.118	-
Nº Obs	13,169	-	5,989	-	6,079	-

Source: Research Results.
Note: Significance: *** significant at 1%; ** significant at 5%; ns - Not significant at 1%; LFMV = Logarithm of the maximum likelihood function.

age, while for non-pluriactive producers, it would be 2.1%. It should also be pointed out that, for exclusively agricultural establishments, this was the factor which made the lowest contribution to increasing the value of production.

As regards the coefficients estimated for the variable representing inputs (electricity, soil correctives, fertilizer, seed, feed and medicines, and transport of production), it was seen that the elasticity found for pluriactive establishments was higher than that estimated for the group of producers not carrying out non-agricultural activities, where both coefficients were positive and statistically significant. In addition, in the model for pluriactive establishments, this production factor presented higher elasticity than that found for the national average, which indicates that a 10% increase in input expenditure would be associated with about a 2.6% increase in production. Helfand *et al.* (2015) also identified a significant effect of input expenditure on GVP when estimating distinct production frontiers for each region in the country and considering different sizes of establishment, the production factor which most contributed to the formation of production value in most estimates. It should be mentioned that the greater values found for the pluriactive properties were expected, as some of the inputs included in this variable, such as electricity, for example, are also used intensively in non-agricultural activities.

The capital factor was statistically significant and positive and was also that which most contributed to the formation of GVP in the three models estimated. This result is corroborated by Alves *et al.* (2012), when analyzing the profitability of Brazilian agriculture based on the estimation of a production function. As they also found, more than half of the formation of production value was explained by the capital factor, and this effect was even greater for exclusively agricultural establishments. For them, a 10% increase in this variable would be associated with a 7.2% increase in the production value of the property.

The hypothesis of sampling selectivity bias in the adoption of pluriactivities was statistically confirmed by the significance of the coefficient estimated for the inverse Mills ratio, for both pluriactive and exclusively agricultural establishments. This result suggests that there are, in fact, unobservable factors which influence the producers' decisions to adopt non-agricultural activities in their establishments.

Another interesting result presented in Table 3 refers to the *Lambda* parameter, obtained by dividing the variance of the error term related to inefficiency (*Usigma)* by the variance of the random error term (*Vsigma)* $(\lambda = (\sigma_{\mu} / \sigma_{\upsilon}))$ which allows for testing the significant existence of technical inefficiency. The values obtained were all greater than zero (0.185, 0.677 and 0.228), which indicates that, in all three models estimated, part of the error term is due to inefficiency, that is, the difference between the observed product and the optimal production frontier is due to technical inefficiency in using production factors.

4.4 Technical efficiency scores of representative pluriactive and non-pluriactive establishments

After estimating stochastic production frontiers, the technical efficiency scores of representative pluriactive and non-pluriactive establishments were obtained as described in Section 3.1. In addition to average efficiency, the standard deviations are also shown in Table 4, in order to verify if the data is dispersed in relation to the mean.

According to the results presented in Table 4, it can be seen that the average efficiency of the representative productive units (total sample) analyzed was 53.1%, which indicates that it is possible to improve the productive performance of the establishments by 46.9%, without altering the quantity of factors of production used. However, when establishments not performing non-agricultural activities are considered separately from pluriactive establishments, there are significant discrepancies between the technical efficiency scores of the two groups, with the former being, on average, relatively more efficient than establishments with multiple activities in rural areas.

Tab. 4. Mean, standard deviation, minimum and maximum technical efficiency scores for each situation considered in relation to non-agricultural activity.

Technical Efficiency Scores	Nº Obs	Mean	Standard deviation	Minimum	Maximum
Total Sample (Unmatched)	13,169	0.531	0.167	0.000	0.9270
Matched Sample					
Non-pluriactive	5,989	0.545	0.169	0.000	0.9309
Pluriactive	6,079	0.519	0.169	0.000	0.9306

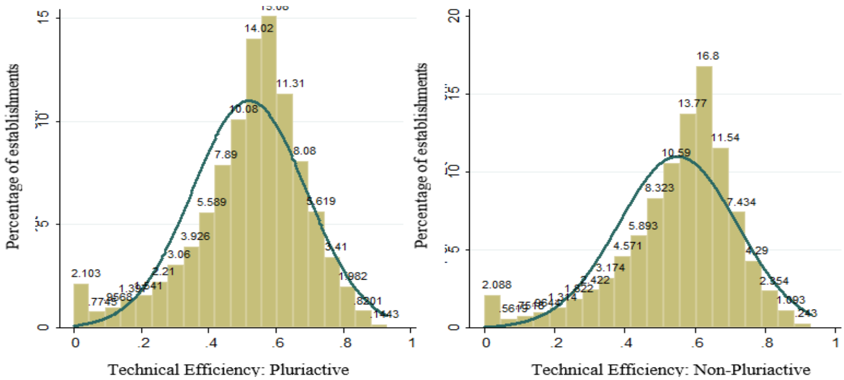
Source: Research Results.

The results indicate that the average technical efficiency of non-pluriactive establishments was 54.5%, which indicates that these producers can considerably increase their productive performance through a more efficient allocation of the factors of production. However, those properties which performed non-agricultural activities obtained an average technical efficiency of 51.9%. In addition, it was found that the highest technical efficiency score for establishments in both groups was similar, around 93%.

In relation to the values obtained for the standard deviations, the high value found indicates great heterogeneity in the sample, for both pluriactive and for establishments with exclusively agricultural activities. This is clearly presented in Figure 1 below.

Figure 1 shows the frequency distribution of the technical efficiency scores for the two cases analyzed, that is, in the presence or absence of non-agricultural activities in the agricultural establishment. As shown by the value of the standard deviation for both groups analyzed (0.169), in Figure 1, there is great dispersion of the data in relation to the mean, which reflects a rather heterogeneous sample in terms of technical efficiency. However, there is a greater

Fig. 1. Frequency distribution of the technical efficiency scores of pluriactive and non-pluriactive establishments.



Source: Research Results.

concentration of establishments at higher levels of efficiency in the non-pluriactive group. For example, it can be seen that approximately 40% of non-pluriactive producers are concentrated in the 60% to 80% technical efficiency range, whereas for the pluriactive establishments the concentration within this range is only 28%. These results show that, on average, establishments whose main activity is exclusively agricultural can more efficiently convert inputs into production value. Moreover, the lower technical efficiency score found for the pluriactive properties can be explained by the fact that these producers allocate part of the factors of production, such as labor and capital, to complementary activities, which would imply a lower conversion rate of agricultural products.

5. Final comments

In this paper, we analyzed the effects of pluriactivity on the technical efficiency of Brazilian agricultural establishments. To do so, a strategy was used that combined the use of the Propensity Score matching method with estimation of the Stochastic Production frontier while taking the sample selectivity bias into account, in order to obtain comparable technical efficiency scores between the groups, thereby reducing the possible bias caused by observable and unobservable factors.

Taken as a whole, our results suggest that schooling levels and technical assistance were key variables in explaining the decision of the property manager to carry out pluriactive activity. As regards the estimated production frontier, it was seen that capital was the factor which made the greatest contribution to the formation of production value in both the pluriactive and non-pluriactive representative productive units. In addition, labor and purchased inputs presented greater elasticity for the group of dual activity producers. With regard to the possible difference in efficiency between pluriactive and non-pluriactive units, our results suggest that establishments which carry out exclusively agricultural activities make better use of available resources when compared to the others, as they are technically more efficient.

In terms of the promotion of greater rural development in Brazil, the relevance of the adoption of non-agricultural activities is recognized, as they can make for a significant increase in family income. However, the higher technical efficiency obtained by establishments with agricultural activities suggests that policies which increase the availability of productive resources may have an even greater effect on the profitability of such producers, given their more efficient use. In this context, greater investment in policies such as the National Policy on Family Agriculture and Rural Family Enterprises (PRONAF) which provide credit for small farms, and the National Policy on Technical Assistance and Rural Extension (PNATER) which increase farmers' access to new technologies, knowledge and information, can be more successful in terms of increasing income and well-being for both non-pluriactive and pluriactive farms, as the secondary activities are carried out at a lower level of technical efficiency.

It is suggested that further research be undertaken to extend the analysis to take into account groups of different establishment sizes along with the farm productive scale. Such research is relevant as there is a greater incidence of small and poor producers carrying out multiple activities to guarantee higher levels of income and alleviate situations of poverty. Such an analysis would allow for a better understanding of the phenomenon of pluriactivity in rural Brazil. Using strategies which lead to indentify the efficiency determinants between the two groups of producers would also be relevant, as it would contribute towards understanding the main factors which explain the greater efficiency obtained by the exclusively agricultural establishments.

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