

CARLOS OTÁVIO DE FREITAS

**THREE ESSAYS ON THE EFFECT OF RURAL EXTENSION IN THE
BRAZILIAN AGRICULTURAL SECTOR**

Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Economia Aplicada, para obtenção do título de *Doctor Scientiae*.

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ABSTRACT

FREITAS, Carlos Otávio de, D.Sc., Universidade Federal de Viçosa, December, 2017.
Three essays on the effect of rural extension in the Brazilian agricultural sector.
Adviser: Marcelo José Braga.

The rural extension service is of great importance in the process of transferring technologies, information and new knowledge to rural producers. However, a significant part of Brazilian farms, especially small ones, has not obtained access to this service, which raises doubts about the effectiveness of the policy on the performance of producers and their ability to serve their target audience. In this sense, the present thesis sought to analyze the effect of rural extension in the Brazilian agricultural sector. To achieve this objective, three chapters were elaborated: Effects of rural extension on commodity supplies in Brazil; The effect of rural extension on farm technical efficiency in Brazil; Can rural extension reduce the income differential in rural Brazil?. In the first chapter, the effect of rural extension on product supply and input demand was analyzed by estimating a system of equations derived from a restricted quadratic profit function. The results pointed to a positive effect of rural extension on the supply of products, mainly related to private extension. In addition, the extension service contributed to a 4.1% increase in the average revenue generated by the products under consideration. In the second chapter, the effect of rural extension on the technical efficiency of Brazilian agricultural establishments was identified. For this, an approach that combines the stochastic production frontier structure, taking into account the selection bias in the adoption of extension services, was used. The results showed that the rural extension contributes, in fact, to the increase of the efficiency in the use of the productive factors, being this effect greater for the group of large producers. The third chapter analyzed the effect of rural extension on income levels and income inequality in rural Brazil, based on the unconditional quantile regression approach. Among the results, it was verified that, although rural extension contributes to raising the income of rural households, the service contributes to the aggravation of income inequality. It was also observed that educational levels and rural credit explain a significant part of the differences in incomes between adopters and non-adopters of rural extension.

RESUMO

FREITAS, Carlos Otávio de, D.Sc., Universidade Federal de Viçosa, dezembro de 2017. **Três ensaios sobre o efeito da extensão rural no setor agropecuário brasileiro.** Orientador: Marcelo José Braga.

O serviço da extensão rural tem grande importância no processo de transferência de tecnologias, informações e novos conhecimentos para os produtores rurais. No entanto, parte significativa das fazendas brasileiras, principalmente de pequeno porte, não tem obtido acesso a este serviço, o que levanta a dúvida sobre a efetividade da política sobre o desempenho dos produtores e sua capacidade de atender seu público alvo. Nesse sentido, a presente tese buscou analisar o efeito da extensão rural no setor agropecuário brasileiro. Para atingir tal objetivo, foram elaborados três capítulos: *Effects of rural extension on commodity supplies in Brazil*; *The effect of rural extension on farm technical efficiency in Brazil*; e *Can rural extension reduce the income differential in rural Brazil?*. No primeiro capítulo, analisou-se o efeito da extensão rural sobre a oferta de produtos e demanda de insumos, por meio da estimação de um sistema de equações derivado de uma função de lucro quadrática restrita. Os resultados apontaram para um efeito positivo da extensão rural sobre a oferta de produtos, principalmente relacionado à extensão privada. Além disso, o serviço extensionista contribuiu para um aumento de 4.1% na receita média gerada pelos produtos considerados. No segundo capítulo, foi identificado o efeito da extensão rural sobre a eficiência técnica dos estabelecimentos agropecuários brasileiros. Para tal, foi utilizada uma abordagem que combina a estrutura de fronteira de produção estocástica, levando em conta o viés de seleção na adoção da extensão rural (abordagem de Heckman), com a técnica de balanceamento por entropia. Os resultados mostraram que a extensão rural contribuiu, de fato, para o aumento da eficiência na utilização dos fatores produtivos, sendo este efeito maior para o grupo de grandes produtores. Já o terceiro capítulo analisou o efeito da extensão rural nos níveis de rendimentos e na desigualdade de renda no meio rural brasileiro, com base na abordagem da regressão quantílica incondicional. Entre os resultados, verificou-se que embora a extensão rural contribua para elevar a renda dos domicílios rurais, o serviço contribuiu para o agravamento da desigualdade de renda. Foi

observado ainda que os níveis de escolaridade e o crédito rural explicam parte significativa das diferenças de rendas entre produtores adotantes e não adotantes da extensão rural.

1. Introduction

Rural extension services seek to provide new technologies and knowledge to rural producers to assist them in the farm decision-making process (ANDERSON; FEDER, 2004). Its final goal is to increase farm's productive performance. Extension services also provide educational activities to develop producers' management skills seeking to increase production's efficiency even under a constrained access to resources (CHRISTOPOLOS, 2010). In Brazil, the National Policy on Technical Assistance and Rural Extension - Pnater is responsible for disseminating extension services throughout the country (Ministry of Agrarian - MDA, 2017). Rodrigues (1997) indicates that public policies towards rural extension have had different emphases throughout the history of Brazil although it focuses on the economic and social aspects of agricultural establishments. These public policies sought to increase agricultural production and productivity, and social well-being of rural families, through improvements in health conditions, food, education and organization of the activity¹ (Peixoto, 2014).

The creation of Pnater in 2003 brought new dimensions to the objectives of rural extension in Brazil. In addition to provide information and technologies to farms, Pnater also focuses on: developing the rural environment in a sustainable way, compatible with the proper use of natural resources and preservation of the environment; adoption of ecologically based agriculture; actions to ensure sustainable food and nutritional security; strategies for generating new agricultural and non-agricultural jobs, and others (MDA, 2017).

¹ For more details on the emerging and development of rural extension services in Brazil, see Pettan (2010).

Pnater also have led to an increase in the participation of nongovernmental entities in the provision of extension services (PETTAN, 2010). Before the Pnater, these services were provided almost exclusively by public and state institutions. This new policy has led to a higher participation of private companies, integrating companies, cooperatives, nongovernmental organizations - NGOs and other entities (RIVERA *et al.*, 2001). Peixoto (2009) characterizes this new policy as a "plurality of institutional form"². However, the public assistance still assists around 43% of the farms in Brazil in 2006.

This policy has also led to an increase of federal resources directed to rural extension services in the Brazil. In the 2001/2002 crop season, R\$ 3 million of government budget was destined to rural extension while in the 2006/2007 crop season R\$ 109 million was designated to these services. Even thou funding has increased, it is not enough to supply these services adequately. Although it is an important source of financing for rural extension, the share of federal resources in the total invested by the states and municipalities does not exceed 10% (SCHOLZ, 2014). Peixoto (2014) argues that these services face challenges related to low wages of the extension agents and the high cost to attend a larger number of farms in each municipality.

Despite the advantages offered by rural extension, as well as the growing support from non-state institutions, it is observed that in Brazil, only 22% of farms reached this policy, according to data from the Agricultural Census of 2006 (Brazilian Institute of Geography and Statistics - IBGE, 2017). In addition, the average size of the assisted

² The institutionalization of Laws 12,188 on Technical Assistance and Rural Extension - ATER (Law of ATER) in 2010, and No. 12.897 in 2013, contributed to a greater articulation between public and private agencies in the rural extension offer. Among the new dimensions and objectives for rural extension, defined by the new laws: accreditation and contracting of public and private entities providing the extension service; greater integration between the agricultural research system and rural extension; greater support for the use of social technologies and the traditional knowledge of rural producers; promote the qualification of rural extension professionals, and others (PEIXOTO, 2014).

properties was 228 ha, while the average of the ones that did not receive the extension service was 42 ha. This shows that most of the small producers, despite being the focus of the policy, did not receive any type of rural extension. We also observe that farms that have had access to these services also have a higher level of education. Plata and Fernandes (2011) argue that this may be occurring because of selection bias in the access to such services: because they have greater social mobility, greater resources and greater information in the decision-making process, such producers are more likely to access rural extension. This raises the question whether Pnater has achieved its goal of providing these services to farms with a constrained access to new technology and small producers.

One factor that may contribute to the lack of political and financial support for this type of policy is the fact that investments in rural extension services, public or private, do not always show visible results and returns (at least in the short term), if compared to investments in alternative areas such as transport, where costs can be reduced with the construction of better roads (FEDER *et al.*, 2001). Therefore, it is important to obtain a precise valuation of returns to the rural extension services. An increase on investments in rural extension services could improve agricultural productivity and enhance farmers socioeconomic conditions. Our results could be used to seek greater political and financial support.

1.2. Problem and importance

Rural extension services in Brazil, especially after the creation of Pnater, have received greater governmental attention as an instrument to support the rural environment, emphasizing their importance in promoting the economic and social development of

agricultural farms. Two factors contribute to a not accurate and under-evaluation of the effects of rural extension on the Brazilian agricultural performance: a small access to these services by smaller farms; and limited allocation and poor distribution of the resources. This uncertainty about the potential of extension, according to Anderson and Feder (2004), ends up contributing to the weakening of political support, thus aggravating problems related to budget allocation, concentration of beneficiaries, lack of incentive to the extension workers and others. Thus, a precise evaluation of the effect of the rural extension can lead us to better understanding of the real importance of this activity, which could justify an increase of the investment and governmental support for this policy aiming to generate economic growth and greater social welfare in the Brazilian rural environment.

In the literature on international agriculture in developing economies, several studies have sought to measure the benefits of rural extension over the rural sector as a whole (BIRKHAUSER; FENSER, 1991; AKER, 2011; VAN RIJN et al., 2015; and others). These studies usually estimate production and/or cost functions to obtain the marginal effect of rural extension on farm production/cost. Guantam (2000) identified a low performance of rural extension in Kenya, showing that this service was inefficient and had no impact on the efficiency of producers and crop yields. Oehmke et al. (1997) identified a high return to rural extension in sub-Saharan Africa countries. Jim and Huffman (2016) also identified a positive effect of rural extension on the total factor productivity of 48 American states between 1970 and 2004.

Some research has also verified the effect of rural extension on income levels and income inequality in agriculture. Deribew (2016) identified a positive effect of rural extension on the income of rural households in northern Ethiopia. However, when verifying the effect of the policy on income inequality, results suggested an increase in income

inequality from agricultural activity. Cungara and Moder (2011) have identified that rural extension increases agricultural income in Mozambique. These authors found, however, that the wealthier rural households were the ones most benefited by the policy, which may result in an increase in income inequality in the region. Landini (2016) also highlights the role of rural extension in promoting the increase of social capital in a given region, such as encouraging the formation of collective organizations by producers.

A few recent studies have directly measured the impact of extension on the economic and productive performance of rural establishments in Brazil. In general, the strategy adopted by the great majority of the research that indirectly analyzed the role of rural extension consists of incorporating the service as an explanatory variable into models that seek to explain levels of efficiency, productivity or agricultural production. However, the outcome of these studies have not been uniform, which suggests that there is no consensus in the literature about the effects of the extension service in rural Brazil.

Helfand and Levine (2004), Moura et al. (2000) and Gonçalves *et al.* (2008) identified a positive effect of rural extension on levels of technical efficiency in rural Brazil³. Campos (2011) found a negative effect of this policy in the milk activity in Minas Gerais. Pereira *et al.* (2010) also demonstrated the importance of the extension service by identifying a positive effect of the policy on the probability of adopting modern technologies in the coffee pulping process.

One of the main limitations of the approach adopted by the studies cited is that it does not take into account the endogenous character of the variable, since the adoption of rural extension is, at least, a producer's choice, which can be affected by observable factors (e.g., income, experience, farm characteristics and others) and unobservable factors (e.g.,

³ These and other researches are presented in more detail in the next chapters.

management capacity of the farmer). By ignoring these characteristics, the results obtained may be biased, which limits the analysis of the true importance of extension to the performance of rural properties. Thus, one of the contributions of this research is to identify the impact of rural extension, seeking to correct the limitations in literature. For this, an approach that combines the stochastic production frontier structure, taking into account the selection bias in the adoption of extension services, was used. It was also verified the way that rural extension affects the supply of products and the demand for inputs, as well as the measurement of the return of the policy, i.e., the return that the producer has, in fact, in terms of revenue obtained, with the adoption of such service. The use of the microdata of agricultural establishments in Brazil in these analyzes also contributes to obtaining estimates free from bias caused by the aggregation at the municipal or state level.

Helfand *et al.* (2015) highlight the important role that policies such as technical assistance and rural extension can play in reducing poverty in the countryside. Alex *et al.* (2002) and Christopolos (2010) argue about the relevance of rural extension in elevating the social welfare in rural areas. Thus, in order to obtain a more detailed evaluation of the extension service in Brazil, we also verify whether rural extension improve welfare, increase rural incomes and reduce inequality of families in rural areas.

A more robust evaluation of the effect of rural extension services can contribute to a greater understanding of the importance of this service for the Brazilian rural sector. The lack of a robust measure of the potential impact and return of this policy can reduce the incentive of rural extension workers and may even discourage such individuals from investing in greater knowledge and skills in the long run, which would imply less effectiveness of this policy. We also investigate whether the effect of rural extension varies by farm size. As argued above, there is evidence that most small farms do not have access

to the policy, which could limit the impact of these services in reducing inequality in Brazilian rural areas.

1.3. Hypotheses

- a) Rural extension contributes to improve both technical efficiency and commodities supplies.
- b) Rural extension contributes to the reduction of income inequality in the Brazilian rural environment.

1.4.Objectives

1.4.1. General Objective

Analyze the effect of rural extension on the Brazilian rural sector.

1.4.2. Specific Objectives

- a) Verify how rural extension affects the supply of commodities and demand for productive factors;
- b) Determine the return of the rural extension in terms of contribution in the generation of agricultural revenue;
- c) Estimate the unbiased technical efficiency of agricultural establishments;
- d) To identify the effect of rural extension on income levels and income inequality in rural areas;
- e) To identify the main factors that explain the income differentials between producers assisted by the extension service and the others;
- f) To identify the relationship between the effect of the rural extension and farm size;

This thesis is structured in three chapters. The first chapter seeks to verify the importance of rural extension services by identifying their effects on the supply of commodities and demand for inputs in Brazilian agriculture, and on the revenue obtained from these products, in line with the specific objectives "a" and "b". The second chapter seeks to identify the effect of rural extension on the technical efficiency of Brazilian agricultural farms, thus meeting the specific objective "c". Regarding the third chapter, we seek to identify the effect of rural extension on income and income inequality in the Brazilian rural environment, in order to meet the objectives "d" and "e". To meet the specific objective "f", we considered different farm size groups in the three chapters.

CHAPTER 1

EFFECTS OF RURAL EXTENSION ON COMMODITY SUPPLIES IN BRAZIL

1. Introduction

Rural extension, research, and credit availability have contributed to enhancing agricultural productivity in Brazil since the late 1970s (Buainain *et al.*, 2013). Rural extension has also been used as a welfare improvement tool (Anderson, 2007) in Brazil, which seeks to connect small farms to high-value domestic markets and export markets, to develop new environmentally sustainable production techniques, and to improve the health of rural families. Rodrigues (1997) and Peixoto (2014) highlight the effects of rural extension on Brazilian agriculture in addition to a few other articles that have investigated this topic qualitatively (Gasques *et al.*, 2004, Melo *et al.*, 2015). No analysis has been found in the literature that identifies, quantitatively, the effect of rural extension in the Brazilian agriculture using the methodology adopted in this paper.

Brazilian agricultural policy includes the National Policy on Technical Assistance and Rural Extension (PNATER), implemented in 2003, which has been used to spread technical support in Brazil. This policy also seeks to disseminate new technologies (Christoplos, 2010) and new agricultural techniques to farms and provide farm management consultancy. After more than a decade without government attention, PNATER represented the new centralized policy focused on rural extension, compared to the decentralized pre-

existent structure⁴. It also included new goals, such as the provision of managerial tools related to sustainable use of natural resources (Ministry of Agrarian Development – MDA, 2017). In 2006 around 20% of farms received rural extension, mostly medium and large farms (Brazilian Institute of Geography and Statistics – IBGE, 2017). An increase of non-governmental provision of rural extension was observed with the new policy directions (Pettan, 2010; Peixoto, 2014), where more than 40% was provided by these institutions in 2006 (IBGE, 2017).

A few papers have investigated indirectly the effect of rural extension in the Brazilian agricultural^{5,6} production and efficiency. Moura *et al.* (2000) finds that rural extension increases farm efficiency but has no effect on the use of inputs. Gonçalves *et al.* (2008), Helfand and Levine (2004) and Freitas *et al.* (2014) find that rural extension services increase the efficiency of farms. In this article, we focus on identifying the effect of rural extension on commodities supplies and input demands using more than 2 million farm observations from the Agricultural Census of 2006. We estimate the farm marginal effect and the market effect of rural extension on soy, corn, rice, coffee, sugarcane, milk, and cassava supplies and labor and fuel demands. We estimate seven output supplies and two input demands derived from a restricted quadratic normalized profit function.

Our analysis contributes to the literature by providing estimates of rural extension effects on Brazilian agriculture using a rich farm dataset that allows disaggregating this effect by farm size and institution provider of this service. This information is also important to evaluate the effectiveness of the PNATER. Our results indicate that public

⁴ Before 2003 rural extension provision was discussed in government policies differently in each state, by the State enterprises of technical assistance and rural extension - Ematers (Empresas Estaduais de Assistência Técnica e Extensao rural).

⁵ On an international perspective, several papers have analyzed technical assistance for different countries' use of production and cost functions (Birkhauser *et al.* 1991, Van Rijn *et al.* 2015 and others).

⁶ Campos (2011) has found a non-significant negative effect of technical assistance.

rural extension affects positively soybean and milk supply while private support drives up the supply of soybean, sugarcane, milk, and coffee. We also find that private support has a higher effect on commodities supply of larger farms. It also suggests an increase of 4.1% on the sector revenue due to rural extension services.

2. Background

In this article, we define rural extension as what the PNATER delineates as technical assistance and rural extension. These services have taken place in the Brazilian agricultural sector since the nineteenth century (Bergamasco, 1983), but mostly performed by non-governmental institutions that sought to assist with on-farm training (Pettan, 2010). In the late 1940s, a decentralized governmental policy introduced rural extension provision directions that were based mainly on public institutions, such as the state governmental institutions, but without federal guidance.

This scenario was to be changed only in the 1970s, with the creation of the Brazilian Company for Technical Assistance and Rural Extension - EMBRATER, which together with State Agencies for Technical Assistance and Rural Extension - EMATERs, configured the Brazilian System of Technical Assistance and Rural Extension – SIBRATER. This period marked the beginning of the public financing of rural extension, with a significant expansion in the quantity and quality of services provided in the following years, as well as in the number of signed agreements, especially in those states that did not yet have extension services (ROMANIELLO; PAULA ASSIS, 2015).

However, consecutive financial crises faced by Brazil, as well as the reduction of the participation of rural credit in the adoption of agricultural innovations from the second

half of the 1980s, provoked an intense crisis throughout the public system of rural extension, resulting in the extinction of EMBRATER in 1992 (Peixoto, 2014). It can be said that the extension to the producer was out of the main guidelines of the government from 1990 to 2002⁷, returning only in 2003 with the formulation of Pnater, developed by the MDA⁸.

Thus, after 2003, rural extension provision directions are defined within the Pnater guidelines, which in addition to provide information and technologies to farms, also focuses on: developing the rural environment in a sustainable way, compatible with the proper use of natural resources and preservation of the environment; adoption of ecologically based agriculture; actions to ensure sustainable food and nutritional security; strategies for generating new agricultural and non-agricultural jobs, and others (MDA, 2017). These new directions also aimed to build a new rural extension provision structure that includes both governmental and non-governmental institutions (Peixoto, 2014).

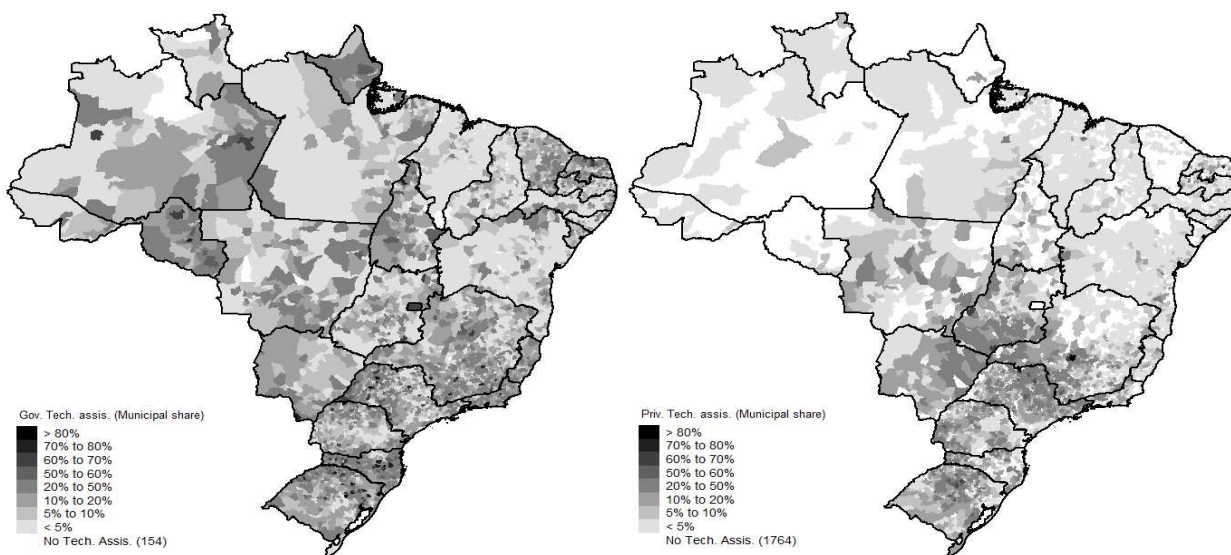
Despite the new policy directions on these services, larger farms and farms in more developed agricultural regions continue to obtain greater access to rural extension than smaller farms (Alves, 2013). Peixoto (2014) argues that the provision's structure of these services should be revised to include the socioeconomic features described in the PNATER lines, such as increasing the provision of these services to small and medium farms. Rivera and Alex (2004) believe these services would be more efficient within a broader rural development agenda and with a greater participation of non-governmental institutions within PNATER lines.

⁷ This period being considered a "lost decade" for extension professionals, given the lesser recognition of the importance of these services for rural development (Scaramelo et al., 2009).

⁸ Peixoto (2009) argues that the National Policy on Family-Owned Farm (PRONAF), established in 1996, was used as a seed to the PNATER development.

Rural extension has been poorly provided to farms in the North and Northeast regions and to family-owned farms (Kageyama, 1990). Regional disparity of the rural extension provision is illustrated in Figure 1.1, where a higher proportion of farms that have had access is observed in municipalities at the South and Southeast regions. On average, 49% of the farms in the South have had access to these services compared to only 15% in the North. Although family-owned farms have received more attention under this new policy and have experienced an increase of 35% on rural extension access during the period 2002-2007 (Peixoto, 2014), small farms still only represent 27.9% of the farms that have had access to this service. Regarding the type of rural extension, there is a concentration of private extension in the center-south region of the country, while the public extension is widespread throughout rural Brazil.

Figure 1. 1 - Share of farms that have received any rural extension support in 2006



Source: Own elaboration from 2006 Agricultural Census data.

On the other hand, PNATER implementation has led to an increase in resources used on rural extension, from R\$3 million on the 2001/02 crop season to R\$1.1 billion on the 2015/16 crop season (Sistema Integrado de Administração Financeira do Governo Federal – SIAFI, 2016), as well as in non-governmental provision (Pettan, 2010; Peixoto, 2014). However, this increase in the provision's resource is not enough to overcome PNATER's obstacles, and still represents a small share in total spending by states and municipalities in rural extension (Scholz, 2014). Peixoto (2014) describes a system with low remuneration for extension agents and with large costs to provide a rural extension to several farms within the municipality.

Effects of rural extension on agricultural income and on socioeconomic aspects of rural families have been investigated by several authors, such as Alex et al. (2002), Anderson and Feder (2004), Christoplos (2010), and Landini (2016). They argue that rural extension leads to information diffusion, farm productivity, income enhancement, and farmer's organization improvement. Empirical articles have not found a unique direction of rural extension effect on agriculture. Shakya and Flinn (1985) find that rural extension⁹ has increased the likelihood of adoption of new technology in rice farms in Nepal. Gautam (2000) finds a non-significant effect of rural extension on productivity¹⁰enhancement in Kenyan farms. Analyzing the effect of rural extension on small farms in Virginia, Akobundu *et al.* (2004) identified a significant effect on net income growth in addition to an aggregate benefit of approximately \$5 million per year. For 48 U.S. states during the

⁹ Rural extension service was measured as the yearly number of attending visits to the farm and new technology adoption as the use of fertilizer and new varieties in rice.

¹⁰ This article concludes that rural extension services has limited effect range on productivity given it has had a positive effect only on less productive farms.

period 1970-2004, Jim and Huffman (2016) find a positive and strong effect of rural extension on agricultural total factor productivity (TFP).

In Brazil, Pereira *et al.*(2010) also briefly discuss the effect of rural extension on post-harvest technology adoption in coffee production in the state of Minas Gerais. Their findings suggest that even though rural extension services increase the likelihood of adopting a new technology, economic returns to the technology adoption, farm's characteristics and cooperative's membership have had a greater effect on this likelihood.

Moura *et al.* (2000) investigate rural extension effects on farm efficiency and inputs use using a set of 68 small farms in the state of Ceará, Brazil. They find that rural extension increases efficiency but has no effect on inputs. A few studies have indirectly studied the link between rural extension and farm efficiency. Gonçalves *et al.* (2008) find a greater effect on larger farms and a non-significant effect on small farms. Helfand and Levine (2004) find that rural extension decreases farm inefficiency in the Brazilian Midwest region, and Freitas *et al.* (2014) identify a positive effect of rural extension only in the less efficient farms.

We propose to directly estimate the effect of rural extension in Brazilian agricultural outputs and inputs using more than 2 million farm observations. We also investigate whether farm size and provision type (public or private) play a role on this effect. This will allow us to identify the market effect of rural extension services in the Brazilian agriculture.

3. The model

We propose to identify the effect of rural extension on agricultural outputs and inputs using the derivative properties of the restricted profit function¹¹. It represents the profit function in the short run where some of the inputs have little or zero mobility during a brief period, implying time and cost to adjust the input quantity (Huffman and Evenson, 1989). These inputs are commonly known as quasi-fixed inputs.

The rural extension service can affect both outputs supplies and input demands by different ways. According to Biskhauser *et al.* (1991), rural extension can increase farm productivity by increasing the speed of technology transfer and improving farm management practices, resulting in increased production offered to the market. The information transfer process can also lead producers to know about the behavior of market prices as well as the availability of improved crops as a result of agricultural research. The extensionist can also assist the producer in the use of specific inputs, such as knowledge related to the ideal time and the intensity of fertilizer use, which may directly affect the inputs demand (Byerlee, 1998). Christopolos (2010) also argue that rural extension can also promote greater communication between the different links of the productive chain that the producer is inserted, which can create and / or raise the social capital of the farm, thus facilitating the flow of production to the market or the access to better inputs. Thus, in this paper we modeled rural extension (public and private) as a quasi-fixed input, since it affects commodity production as an input but it is not completely flexible.

¹¹ The restricted profit function and the duality theory are extensively discussed in Lau (1976).

Several articles have used this approach to evaluate public policies, research, and development effects on agricultural production, such as Shumway *et al.* (1988), Huffman and Evenson (1989), and Schuring *et al.* (2011). These papers assumed the quadratic normalized functional form to represent the restricted profit functions.

A multi-output and multi-input production can be represented considering y_i , $i = 0, 1, \dots, n + m$, as vector of inputs and outputs (Lau, 1976). A numeraire output is represented by y_0 , outputs by $y_i > 0$, $i = 0, 1, \dots, n$, where n represents outputs and m represents inputs $y_i < 0$, $i = n + 1, \dots, n + m$. The quasi-fixed factors are represented by z_k , where $z_k \geq 0$, $k = 1, \dots, K$. The restricted profit function is homogeneous of degree one with respect to prices, non-decreasing in output prices and non-increasing in input prices (monotonicity in inputs and outputs), second order derivatives is symmetric, and convex in prices.

Homogeneity of degree one in prices \mathbf{p} can be imposed by dividing both profit and output and input prices (P_i) by one chosen price (P_0), $\pi = F(\mathbf{p}, \mathbf{z})$, where π is the normalized restricted profit ($\pi = \pi' / P_0$ where π' is the nominal profit and P_0 represents the price of the numeraire output y_0), \mathbf{p} is a vector of $n + m$ normalized prices ($p_i = P_i / P_0$ where P_i is the nominal price of each input and output y_i , $i = 1, \dots, n + m$), and \mathbf{z} is a vector of K quasi-fixed inputs.

Output supplies and input demands can be obtained using the envelope theorem (Chambers, 1986), by taking the first derivative of the restricted profit function with respect to a price:

$$y_i^*(\mathbf{p}, \mathbf{z}) = \frac{\partial \pi}{\partial p_n} > 0, \quad m = 1, \dots, M \quad (1a)$$

$$y_i^*(\mathbf{p}, \mathbf{z}) = \frac{\partial \pi}{\partial p_m} < 0, \quad n = 1, \dots, N \quad (1b)$$

where equation (1a) represents output supplies and (1b) represents input demands, and the numeraire output supply or input demand, which depend on the price chosen to be used as normalizer (P_0), can be obtained using the homogeneity property. We obtain output and input own and cross elasticities using equations (1)

$$\frac{\partial^2 \pi}{\partial p_i \partial p_i} \frac{p_i}{\partial \pi / \partial p_i} = \frac{\partial y_i^*}{\partial p_i} \frac{p_i}{y_i^*} \quad (2)$$

where $\partial \pi / \partial p_i = y_i^*$ is positive for output and negative for inputs, which implies a negative own price elasticity for input demands and positive for output supplies. To estimate the effect of a quasi-fixed input on an output or variable input we obtain input and output elasticity with respect to the quasi-fixed input.

$$\frac{\partial^2 \pi}{\partial p_i \partial z_k} \frac{z_k}{\partial \pi / \partial p_i} = \frac{\partial y_i^*}{\partial z_k} \frac{z_k}{y_i^*} = \mu_{z_k}^{y_i} \begin{matrix} \leq 0 \\ \geq 0 \end{matrix} \quad (3)$$

where theory does not impose any sign on $\mu_{z_k}^{y_i}$; a positive (negative) sign suggest an increase (decrease) on output supply or input demand due to an increase on the quasi-fixed input. We have suppressed the subscript representing each farmer from equations (1) to (3).

To obtain how much rural extension ($z_{1,j}$) has affected each output revenue and total revenue, we multiply the farm marginal effect by the output price summed over producers

$$\lambda_{i,z_1} = p_i * \sum_{j=1}^J \left(\frac{\partial y_i^*}{\partial z_k} * z_{1,j} \right) = p_i * \frac{\partial y_i^*}{\partial z_k} * \sum_{j=1}^J z_{1,j} \quad (4)$$

where $j = 1, \dots, J$ represents each farm producing the output or input i and the second equality holds for a $y_i^*(\mathbf{p}, \mathbf{z})$ linear on \mathbf{p} and \mathbf{z} . To obtain a relative measure, we divide each

λ_{i,z_1} by total revenue observed in the market ($p_i * Y_i$ where $Y_i = \sum_{j=1}^J y_{ij}$ over all j

producers). A measure for the entire sector is estimated by first obtaining the revenue gain from extension in the entire market, then summing up the sector observed revenue, and finally by the ratio of these two measures.

3.1.Data and Estimation

In this article, we have used a rich farm level dataset only available at the secrecy room at the IBGE¹². We have used 2.03 million farms that have produced at least one of the outputs selected in this article: soy, corn, rice, coffee, sugarcane, milk, and cassava. Huffman and Evenson (1989) and Figueiredo and Teixeira (2002) have selected the outputs included in their estimation based on their relevance to the Brazilian total value of production. The seven outputs that we have chosen added up to 70% of the Brazilian value of production in 2006¹³. Soy, cassava and sugarcane outputs are clustered in a few regions of Brazil, while other outputs supplies are spread across the country. Cassava is mainly produced in the northern region while sugarcane in the southeast of Brazil. The states of Sao Paulo and Minas Gerais are the larger agricultural producers, responsible for 17.2% and 12.7% of the Brazilian value of production in 2006, respectively.

Rural extension is defined in this paper as the access to any service that have guided output production in the crop season of 2005/06. It consists of a yes-or-no question, which leads us to measure rural extension as a *dummy* variable. Out of the 2.03 million

¹²The access to farm level data is only possible with prior approval of a research project. In addition, a few conditions were imposed by the IBGE to access this data. We have had access to this dataset only for one year at the IBGE headquarters in Rio de Janeiro. Every estimation output had to be analyzed by an IBGE staff, and we could request only two estimation output.

¹³ For the value of production in this research, the sum of the production value of permanent, temporary and milk production was considered.

observations we selected, 30.6% of the farms have had access to rural extension. Farms producing soy and coffee have had higher access to these services with 77.5% and 35.6% of farms producing these outputs, respectively. The type of the institution provider of these services also plays an important role on its effect on output supplies and input demands. Public provision of rural extension represents 40.9% of the farms that have had access to rural extension while private provision represents 59.1% in 2006 (Table 1.1).

Alves *et al.* (2013) and Plata and Fernandes (2011) suggest that rural extension provision in Brazil has been associated with medium and large farms, rather than with smaller farms, clustered in agricultural developed areas. In this article, we include *dummies* representing four different farm sizes. To test their argument, we use the concept of fiscal module to capture the farm's size effect: very small (less than 1 fiscal module), small (between 1 and 4 fiscal module), medium (between 4 and 15 fiscal module) and large (more than 15 fiscal module). Fiscal module¹⁴ is defined as the minimum area required for rural properties to be considered economically viable, ranging in area from 5 to 110 hectares, depending on the municipality (Landau *et al.*, 2012). Table 1.1 displays the descriptive statistics of the variables used in the model (before price normalization), for the Brazil and farm size.

¹⁴ The Fiscal Module (MF) is an agrarian unit of measure expressed in hectares, fixed for each municipality, considering the type of predominant production in the municipality and the income obtained with the predominant production and other crops, if they represent significant portions of the municipality income or area used.

Table 1. 1 - Descriptive statistics of the raw variables obtained in the IBGE for Brazil and farm size

<i>Quantities</i> ¹	Brazil		Very Small		Small		Medium		Large	
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>
<i>Soybean (y₁)</i>	16581	299346	1290	51363	10116	99447	72527	516693	519066	1.903e+06
<i>Milk (y₃)</i>	8965	34244	4315	12122	16206	34491	31437	82557	38371	140218
<i>Sugarcane (y₄)</i>	47736	2.70E+06	4434	529170	33786	751782	190892	1.886e+06	1.470e+06	1.930e+07
<i>Corn (y₆)</i>	11551	344653	3215	242733	10871	486312	43680	209424	247559	1.152e+06
<i>Coffee (y₇)</i>	694.5	11373	325.5	3018	988.3	9296	2925	26211	4818	59756
<i>Rice (y₈)</i>	2664	96386	437.2	13788	2195	33916	10181	125744	72465	662310
<i>Cassava (y₉)</i>	2817	147919	2503	124348	2690	45836	6192	414492	5858	146745
<i>Labor (x₁)</i>	2.951	6.484	2.683	4.032	3.093	4.155	4.225	16.50	7.872	24.06
<i>Fuel (x₂)</i>	869.6	12203	334.3	3504	1029	20876	3240	12259	12708	45985
<i>Prices</i>²										
<i>Soybean (p₁)</i>	0.0409	0.141	0.0257	0.110	0.0730	0.184	0.0871	0.211	0.127	0.245
<i>Milk (p₃)</i>	0.288	0.288	0.269	0.297	0.342	0.256	0.335	0.255	0.292	0.268
<i>Sugarcane (p₄)</i>	0.0171	0.15	0.0164	0.143	0.0187	0.157	0.0190	0.190	0.0171	0.184
<i>Corn (p₆)</i>	0.19	0.302	0.203	0.265	0.166	0.369	0.134	0.339	0.124	0.530
<i>Coffee (p₇)</i>	0.241	2.721	0.247	2.419	0.232	3.611	0.219	2.833	0.163	1.535
<i>Rice (p₈)</i>	0.0432	0.169	0.0454	0.172	0.0385	0.160	0.0339	0.162	0.0368	0.170
<i>Cassava (p₉)</i>	0.113	0.315	0.128	0.329	0.0866	0.281	0.0489	0.233	0.0394	0.236
<i>Labor (p₅)</i>	0.795	1.152	0.728	1.092	1.005	1.323	0.842	1.137	0.901	1.137
<i>Fuel (p₂)</i>	736.6	127581	174.2	4519	816.3	18470	3128	89477	14498	934158
<i>Fixed Factors</i>										
<i>Public Rural Ext. (%) (z₁)</i>	0.125	0.331	0.115	0.318	0.164	0.370	0.126	0.332	0.102	0.303
<i>Private. Rural Ext. (%) (z₂)</i>	0.181	0.385	0.119	0.324	0.298	0.458	0.409	0.492	0.562	0.496
<i>Irrigated Area (ha.) (z₃)</i>	0.89	25.45	0.131	0.961	0.669	4.905	3.409	23.54	25.52	182.2
<i>N° Observations</i>	2033612		1457886		421052		118031		36643	

Note: ¹Quantities of soybean, sugarcane, corn, coffee, rice and cassava area defined in kilograms; milk and fuel are defined in liters; and labor is defined in number of workers, which are weighted by age and gender. ²prices are defined in Brazilian R\$ of 2006; ha – hectares. SD = standard deviation.

Medium and large farms have had a higher access to rural extension compared to small farms; 53.5% and 66.4% of medium and large farms have had access, respectively. Small¹⁵ farms have had a higher access to public provision of this service compared to medium and large farms, which have used more the private provision. Within small and very small farms that have had access, 27.9% used public rural extension to produce outputs compared to medium and large farms which have used 12.6% and 10.2%, respectively.

To build the prices used on the estimation we followed a three-step process. First, we selected the price made available by the IBGE, which is a mean output price. Given that the farmer might have sold the output at different times, IBGE calculated a mean price for the crop season investigated, 2005/06. Second, we took an average of these prices per municipality. IBGE does not report a mean output price for the farms that have not sold the output in that crop season. Although the farmer has not sold the output, she/he still faces the price in the market but opted for not producing it. Third, we substituted the prices equal to zero, for farms that have not produced the output, by a municipality level mean output price. This procedure assumes that farmers have full information about all seven output prices in the market and that a municipality level mean output price holds within the municipality boundaries for all municipalities.

We were able to obtain information on two inputs: labor and fuel. Labor input price was calculated as the ratio of labor expenses to its quantity and considered both hired and family labor. These prices do not reflect exactly the national minimum wage established by the government for two reasons: this price estimation is considering a wide range of

¹⁵ Small farms include the two bottom classifications: very small and small.

employees' qualification and both formal and informal employees. For these reasons, we believe this price is also a better estimative than using a national minimum wage rate. Fuel input price was calculated as the ratio of fuel expenses to its quantity and included gas, gasoline, charcoal, diesel, ethanol, kerosene and others. Burniaux and Truong (2002) and Pereda (2012) have suggested that fuel can be used to capture a measure of farm capital. These prices were also transformed by the three-step process described in the previous paragraph.

In addition to rural extension, we obtained information on two more quasi-fixed input: land irrigated, in hectares, and the farm size, represented by the dummies defined above. Both variables are assumed to be costly to adjust. Irrigation adoption is still in a seminal stage in Brazil; only 8.1% of the land planted is irrigated and 6.4% of the farms considered in this research have adopted it. It is mainly used among rice producers (24.2% of the rice producers use irrigation), sugarcane (11.8%), coffee (6.5%), and corn (5.0%).

3.2. Estimation

We assume that the restricted profit function is represented by a quadratic functional form¹⁶ to obtain the output supplies and input demands using the derivative property. Equations (1a) and (1b) are linear on normalized input prices (homogeneity property) and quasi-fixed inputs. We added an error term to each of these equations to obtain

$$\Gamma * \frac{\partial \pi}{\partial p_i} = \Gamma * y_i^* = \alpha_i + \sum_{j=1}^{n+m} \beta_{ij} p_j + \phi_{ik} z_k + \sum_{s=1}^4 \phi_{is} ds_s \quad (5)$$

¹⁶ Chambers *et al.* (2013) indicated that the quadratic normalized is superior to the other functional forms using a Monte Carlo simulation.

$$+ \sum_{r=1}^4 \phi_{ir} dr_r + \sum_{s=1}^4 \sum_{k=1}^2 \phi_{isk} ds_s z_k + \sum_{r=1}^4 \sum_{k=1}^2 \phi_{irk} dr_r z_k + \varepsilon_{y_i}$$

where $\Gamma = 1$ if y_i^* represents an output supply and $\Gamma = -1$ if y_i^* represents an input demand, ds_s is a *dummy* variable capturing farm size s (three *dummies* out of four), dr_r is a *dummy* variable capturing region r (four *dummies* out of five). We considered in this article seven output supplies and two input demands, symmetry property is imposed $\beta_{ij} = \beta_{ji}$ across equations, and ε_{y_i} represent random errors for these equations. They are soybean, milk, sugarcane, corn, coffee, rice, and cassava output supplies, and labor and fuel as variable input demands. One of the inputs was used as the numeraire (y_0^*), which was the price of fuel.

Output supply and input demand own and cross elasticities were obtained using equation (2) and the parameters estimated from equation (5)

$$\epsilon_{y_i p_j} = \frac{\partial \ln y_i}{\partial \ln p_j} = \frac{\partial y_i^*}{\partial p_j} \cdot \frac{p_j}{y_i^*} = \beta_{ij} \cdot \frac{p_j}{y_i^*} \quad (6)$$

Farm output supply and input demand elasticity with respect to rural extension ($\mu_{z_k}^{y_i}$) was obtained using equation (3) and the parameters estimated from equation (5) for each type of institution provider (public or private)

$$\mu_{z_k}^{y_i} = \left(\phi_{ik} + \sum_{s=1}^4 \phi_{isk} ds_s + \sum_{r=1}^4 \phi_{irk} dr_r \right) * z_k / y_i \quad (7)$$

where z_k is a *dummy* variable and disparities in the rural extension elasticities by farm size and region can be observed by analyzing the parameters ϕ_{isk} and ϕ_{irk} , respectively. To estimate the effects of rural extension on output revenue and industry revenue, we used equation (4) jointly with the parameters obtained from equations (5)

$$\lambda_{i,z_1} = \bar{p}_i * \left(\phi_{ik} + \sum_{s=1}^4 \phi_{isk} ds_s + \sum_{r=1}^4 \phi_{irk} dr_r \right) * O_{z_1,j} \quad (8)$$

where \bar{p}_i is the average output price and $O_{z_1,j} = \sum_{j=1}^J z_{1,j}$. λ_{i,z_1} is the market output revenue gain obtained from rural extension services. We also obtained the agricultural sector revenue gain from having access to rural extension by summing up all output revenue gains and dividing by the sector total observed revenue from all outputs.

Equation (5) was estimated using Seemingly Unrelated Regression (SUR). Eight equations were estimated: output supplies of soybean, milk, sugarcane, corn, coffee, rice, and cassava and labor demand¹⁷. Symmetry and homogeneity properties were imposed on the estimation but monotonicity on output and inputs was checked after the estimation. In addition, standard errors were corrected by *bootstrap* procedure.

4. Results and Discussion

The results of the system of equation estimated was presentd in Table A1 in the appendix. As mentioned in the previous section, fuel price was used as normalizer price and was estimated after imposing symmetry. Around 80% of the coefficients were statistically significant at 10%.

Most of the farm level output supplies and input demand elasticities have presented a correct theoretical sign, as shown in Table 1.2. The own-price elasticities and cross-price elasticities are displayed in the supplementary material. Own price elasticity for all output supplies and input demand of labor are statistically significant. Rice, soy, and coffee were

¹⁷ Codes *reg3* and *sureg* of Stata 14 are used. For the standard errors estimation of the farm marginal effect and market effect of rural extension we have used the delta method incorporated on the code *predictnl* and *nlcom* in Stata 14.

the outputs with larger price-effect compared to the other outputs – an increase of 10% on its price would lead to an increase on supply of these products by 14.3%, 9.9% and 3.3%, respectively. Castro (2008) finds a much smaller elasticity for rice (0.32) and slightly smaller for soybean (0.54) by estimating a profit function for Brazil at the state level. Our results suggest that soybean and corn supplies are complementary, sugarcane and corn are substitutes, and milk and soy are complementary (TABLE 1.2).

Table 1. 2 - Average Brazilian agricultural output supply and input demand elasticities

	Elasticity with Respect to the Price of								
	<i>Soybean</i>	<i>Milk</i>	<i>Sugarc.</i>	<i>Corn</i>	<i>Coffee</i>	<i>Rice</i>	<i>Cassava</i>	<i>Labor</i>	<i>Fuel</i>
<i>Soybean</i>	0.9995 (0.0117)	0.0285 (0.0007)	0.0002 ^{NS} (0.0002)	0.0116 (0.0006)	-0.0001 ^{NS} (0.0001)	-0.0010 (0.0001)	-0.0019 (0.0004)	0.0006 (0.0001)	-0.9805 (0.0117)
<i>Milk</i>	-0.0455 (0.0011)	0.0466 (0.0021)	-0.0002 ^{NS} (0.0002)	-0.0155 (0.0011)	-0.0028 (0.0001)	-0.0011 (0.0003)	-0.0024 (0.0003)	0.0007 (0.0001)	0.0202 (0.0030)
<i>Sugarc.</i>	0.0320 ^{NS} (0.0813)	-0.0017 ^{NS} (0.0015)	0.0320 (0.0813)	-0.0278 (0.0145)	-0.0018 (0.0003)	-0.0002 ^{NS} (0.0007)	0.0334 ^{NS} (0.0311)	0.0140 (0.0011)	-0.0482 ^{NS} (0.0974)
<i>Corn</i>	0.0182 (0.0009)	-0.0486 (0.0034)	-0.0092 (0.0048)	0.1320 (0.0402)	0.0009 ^{NS} (0.0004)	-0.0130 (0.0048)	-0.0229 ^{NS} (0.0159)	-0.0020 ^{NS} (0.0013)	-0.0554 ^{NS} (0.0459)
<i>Coffee</i>	-0.0035 ^{NS} (0.0037)	-0.1418 (0.0098)	-0.0273 (0.0143)	0.0172 (0.0524)	0.3252 (0.0070)	-0.0164 (0.0060)	0.0322 ^{NS} (0.0225)	-0.0101 (0.0064)	-0.2746 (0.0102)
<i>Rice</i>	-0.1198 (0.0089)	-0.0704 (0.0203)	-0.0012 ^{NS} (0.0042)	-0.1876 (0.0689)	-0.0004 ^{NS} (0.0014)	1.4603 (0.1190)	-0.0003 ^{NS} (0.0233)	0.0170 (0.0024)	-1.0975 (0.1304)
<i>Cassava</i>	-0.0005 (0.0001)	-0.0018 (0.0002)	0.0024 ^{NS} (0.0022)	-0.0035 ^{NS} (0.0024)	-0.0001 (0.0001)	0.0000 ^{NS} (0.0001)	0.1201 (0.0136)	-0.0005 (0.0002)	-0.1161 (0.0149)
<i>Labor</i>	-0.0005 (0.0001)	-0.0007 (0.0001)	-0.0010 (0.0001)	0.0005 ^{NS} (0.0003)	-0.0002 (0.0000)	-0.0005 (0.0001)	0.0005 (0.0002)	-0.0007 (0.0001)	0.0028 (0.0005)

Note: NS: non-significant. Parameters in bold are significant at 1%, 5% or 10%. Standard errors in parentheses. The elasticities of hired labor (numeraire) were obtained by the coefficients of numeraire demand equation (The estimates of hired labor input are not reported, but available upon request).

Source: Research results.

Our result on the own-elasticity of labor demand, -0.0007, suggests that labor is an inelastic input while Castro (2008) and Neves *et al.* (2017) have found an elasticity of -2.9 and -4.8, respectively. In these papers, they have considered only hired labor. We also included family labor, which leads to a smaller price effect given that family labor is expected to be less volatile to changes in their wages (labor prices). Our findings indicate that labor price has a small effect on outputs. Fuel price has an inverse effect on all outputs except milk; an increase on this price would lead to a decrease on supply. Rice and soy outputs have higher elasticities with respect to fuel, which was expected, since these outputs are capital intensive in the major producing states. We have found that fuel and labor are substitutes.

The effect of irrigation (land irrigated) on output supplies and input demands is statistically significant. A positive effect of the latter was found in the output supplies, with a larger effect on sugarcane, rice, and soybean given that rice and sugar are the crops with the largest share of irrigated land. We have found that output supplies and input demands are higher among medium and large farms, which also varied by regions. For instance, soybean output is clustered in the Midwest region, which is captured by a larger and significant regional dummy in its equation.

4.1. Rural extension policy implication

We estimated the supply and input elasticities with respect to the quasi-fixed inputs to evaluate the impact of rural extension on agriculture, reported in Table 1.3. Our results suggest that public rural extension access leads to a statistically significant increase on soybean and milk supply and labor demand of 11.4%, 6.1%, and 1.2% respectively.

On the other hand, it has an adverse effect on coffee and cassava supply. The negative result found for coffee should be analyzed carefully. Because it is a permanent crop, the result of the extension service may require more time to be observed, but the data used in the present research do not allow to make an inference to the effect of extension in the long term. Thus, the results of rural extension in the coffee supply may be underestimate. Regarding the results found for cassava, Neto and Marcolan (2010) argue is mainly a subsistence output, which is mostly produced in the north and northeast regions,. Therefore, although rural extension might increase the production of cassava, it would not imply an increase on cassava sold. In addition, these farms have shown a diversified production, which implies that rural extension could be redirecting farm assets to the production of different crops. Public rural extension has not affected sugarcane, corn, and rice output.

Table 1. 3 - Output and input elasticity with respect to rural extension (RE) by type of provision in Brazil, 2006.

Variable	Soybean	Milk	Sugarcane	Corn	Coffee	Rice	Cassava	Labor
<i>Pub.RE</i>	0.114	0.061	-0.027 ^{NS}	-0.179 ^{NS}	-0.217	-0.334 ^{NS}	-0.060	0.012
	(0.024)	(0.003)	(0.101)	(0.222)	(0.086)	(0.416)	(0.0358)	(0.002)
<i>Priv.RE</i>	0.276	0.086	0.153	0.024 ^{NS}	0.132	-0.026	-0.038 ^{NS}	0.024
	(0.027)	(0.003)	(0.013)	(0.040)	(0.007)	(0.013)	(0.022)	(0.002)

Note: NS means non-significant. Parameters in bold are significant at 1%, 5% or 10%. Standard errors in parentheses. Pub. RE: Public Rural Extension. Priv.RE: Private Rural extension.

Source: Research results.

Private rural extension support has impacted positively soybean, milk, sugarcane, and coffee supplies. Farm access to these services increases soybean and sugar supply, on average, 27.6% and 15.3% respectively. To evaluate the market effect of rural extension, we estimated market revenue change per output for all of them. We used the parameters estimated which are the average output price, total output supplied,

and number of farms that have had access to rural extension (Table A2 in the appendix). These results are displayed in table 1.4. They suggest an increase of 4.1% on outputs revenue due to rural extension access, split in 3.51% from access to private rural extension and 0.58% from public.

Gonçalves *et al.* (2016) argue that public rural extension seeks both farm economic development and technological development, in addition to providing educational tools to develop producers' management skills, to ensure sustainable food and nutritional security, and to enhance social development. On the other hand, private rural extension focuses on production and marketing tools, and these services are usually hired by integrated farms with high economic performance. These farms may have already overcome obstacles related to mediocre farm management and hire these services to update production technologies used.

Table 1. 4 - Average effects of the rural extension (RE) on the change in revenue for Brazil and selected outputs (%)

	Brazil	Soybean	Milk	Sugarcane	Corn	Coffee	Rice	Cassava
<i>Pub. RE</i>	0.58	0.09	3.79	-0.07	0.43	0.24	0.00	0.02
<i>Priv. RE</i>	3.51	6.40	9.84	0.79	2.57	2.17	-0.60	-0.28
<i>Total</i>	4.09	6.49	13.63	0.72	3.00	2.41	-0.60	-0.26

Source: Research results.

We observe an increase in milk revenue of 3.8% due to public rural extension and of 9.84% due to private rural extension. The greatest effect for dairy production is not surprising, since it is an activity to which the actions of the extension worker, such as changes in animal feeding, milking equipment, sanitary measures and other

management issues, can take effect in a few weeks, compared to the response time to changes in crops, generating a relatively larger aggregate effect at the end of the harvest.

Soybean market revenue has faced an increase of 6.4% due to private rural extension. These services also have led to an increase in corn and coffee revenues of 2.6% and 2.2%, respectively. These outcomes should not be attributed solely to the adoption of new technologies. Bonfada *et al.* (2014) highlight that in crops such as soybean and corn the rural extension agent also monitors the production seeking pest prevention, which also leads to greater efficiency on the use of chemical fertilizers. In addition, these agents provide support on determining the harvest period, which contributes to reduction of losses, to quality improvements, and to increases in productivity. As a result, they observe an increase in farm production which increases the farm profitability.

4.2. Rural extension support and farm size

Alves (2013) and Kageyama (1990) suggest that the higher access to rural extension by large farms might be associated with their larger access to rural credit. Plata and Fernandes (2011) indicate that farms that have accessed rural extension are, on average, 228 hectares and farms that have not accessed these services are, on average, 42 hectares. Therefore, it implies an unequal distribution of these services among farms in Brazil. In our sample, we observed an average farm size of 129 hectares for those that have had access to rural extension and of 45 hectares for those that have not. To evaluate whether rural extension affects supplies/demands unequally within the farm size spectrum, we estimate the elasticity of rural extension for four different farm sizes: very small, small, medium and large, displayed in table 1.5.

Table 1. 5 - Output and input elasticity with respect to rural extension by type of provision and by farm size in Brazil, 2006.

	Soy	Milk	Sugarc.	Corn	Coffee	Rice	Cassava	Labor
Public RE								
<i>Very Small</i>	0.005 ^{NS} (0.017)	0.068 (0.004)	-0.019 ^{NS} (0.099)	-0.243 (0.259)	-0.313 (0.111)	-0.477 ^{NS} (0.564)	-0.051 ^{NS} (0.032)	0.008 (0.002)
<i>Small</i>	0.149 (0.029)	0.053 (0.002)	-0.044 ^{NS} (0.153)	0.015 (0.126)	0.067 (0.0140)	0.019 ^{NS} (0.061)	-0.175 (0.081)	0.018 (0.002)
<i>Medium</i>	0.305 (0.039)	0.035 (0.001)	-0.014 ^{NS} (0.034)	0.092 (0.020)	0.085 (0.005)	0.051 (0.013)	0.016 ^{NS} (0.021)	0.030 (0.002)
<i>Large</i>	0.381 (0.020)	0.030 (0.002)	-0.100 (0.008)	0.099 (0.010)	0.082 (0.008)	0.023 (0.003)	0.020 ^{NS} (0.046)	0.038 (0.002)
Private RE								
<i>Very Small</i>	0.024 ^{NS} (0.030)	0.075 (0.003)	0.088 (0.011)	0.027 (0.008)	0.096 (0.007)	-0.026 (0.013)	-0.026 ^{NS} (0.018)	0.008 (0.001)
<i>Small</i>	0.421 (0.032)	0.101 (0.002)	0.254 (0.013)	-0.166 ^{NS} (0.186)	0.187 (0.010)	0.021 (0.007)	-0.096 (0.053)	0.033 (0.003)
<i>Medium</i>	0.740 (0.012)	0.117 (0.002)	0.332 (0.032)	0.527 (0.018)	0.424 (0.005)	-0.298 (0.048)	-0.399 (0.077)	0.110 (0.005)
<i>Large</i>	0.824 (0.004)	0.165 (0.004)	0.217 (0.012)	0.745 (0.009)	0.326 (0.006)	0.196 (0.007)	-0.089 ^{NS} (0.081)	0.268 (0.006)

Note: NS means non-significant. Parameters in bold are significant at 1%, 5% or 10%. Standard errors in parentheses.

Our results suggest that public rural extension has a smaller effect on output supplies compared to private services. It is important to highlight that a large part of the

private extension is carried out by integrating companies, input sales companies, and others, whose actions are more market-oriented than the public service, and can generate more significant results in terms of quantity sold and prices obtained. In addition, the profile of the farm served also differs as to the origin of the extension. That is, public extension focuses on small producers, which are often associated with a lower level of technology, limiting the role of rural extension in increasing production, if compared to farms with more advanced technologies and access to the private extension service.

The public extension has had an impact on very small farms only in milk and coffee supplies and labor demand. Very small and small farms that have had access to the public rural extension observed an increase in milk supply of 6.8% and 5.3%, respectively. Public rural extension has had a higher effect on soybean supply among small farms; on average, there has been an increase of 14.9%. Although this service has led to a decrease in coffee supply among very small farms, it leads to increases in larger farms supply. It also increases corn and rice supplies for medium and large farms.

Our findings suggest that public rural extension is having a stronger effect on medium and large farms rather than on smaller farms. The lack of rural credit available to very small and small farms might be playing a role in this result given its restriction on acquisition and implementation of new technologies. Although we observe a positive effect of rural extension on output supplies for small farms, these farms have had a restricted access to these services. Only 23% of the very small farms have had access to rural extension while more than 50% of the medium and large farms have had access. Gonçalves *et al.* (2016) argue that drawbacks on the PNATER structure have been affecting this policy efficacy, such as the reduced number of rural extension agents and the limited resources available to them.

The access to private rural extension has led to an increase in most of the output supplies within different farm size segments. Among the very small farms this service has led to an increase in milk, sugarcane, corn, and coffee supplies. Small farms that have had access to this service have observed a higher increase in output supply in comparison to those that have access to public rural extension, except cassava supply. As expected, the medium and large farms of soybean and corn were the most benefited by these services. Our results suggest that private rural extension services are more effective on increasing output supply, although Silva (2016) argues that the access to these services is limited to a specific group of farms. These are usually medium and large farms, associated with cooperatives and/or integrated to companies that provide technical assistance¹⁸.

Peixoto (2014) argues that the most effective policy structure is the pluralistic rural extension, composed of public and private organizations providing these services. Our findings indicate that the current structure has shown positive effects on the Brazilian agricultural sector. However, the greatest challenge of this national policy is determining and implementing the public policy target, rural extension to very small and small farms. Alves and Souza (2014) pointed out that public rural extension should focus on the least economic developed farms within the very small and small groups, given the ability of family own-farms within these groups and medium and large farms to integrate with other firms in the market and obtain access to private services.

5. Conclusions

In this paper, we aimed to evaluate rural extension effects on the Brazilian agricultural industry, which resonates in the National Policy on Technical Assistance

¹⁸ These companies provide technical assistance aiming to guarantee a standardized and high-quality output.

and Rural Extension (PNATER) analysis. To evaluate these effects, we estimated a system of agricultural supplies (soy, corn, sugarcane, milk, cassava, rice, coffee) and inputs (labor and fuel) at the farm level using the Agricultural Census of 2006, available at the IBGE. Our findings suggest a positive effect of rural extension on this sector, which could be used as guidance on policy restructure. For instance, the agricultural sector has observed an increased in total output revenue of 4.1% due to rural extension.

Our estimates of the rural extension effect indicate an increase in soybean and milk supplies due to public provision. It also shows an increase in soybean, sugarcane, milk and coffee supplies due to private provision of this service. Private provision of this service has had a higher effect on the large farms supplies such as soybeans and corn. On the other hand, public rural extension has not achieved its main objective, which is to give support to very small and small farms, except for milk supply.

Although our results indicate a higher effect of private provision on commodities supplies, public provision has also impacted farms of different sizes. However, around 11.5% of very small farms have had access to public rural extension while the overall average is 12.5%. This outcome shows a misdirection of PNATER resources. The restricted access to rural credit, to new technologies, and to private services make this type of provision essential to this group of farms. Therefore, this national policy should be restructured with the aim of installing a fully pluri-structure composed of both public and private institutions that also address the very small and small farms that are restricted by their socioeconomic conditions.

In this article, we disaggregate rural extension in private and public provision. These services are often provided by cooperatives, integrating companies and other private institutions. Our results do not allow to infer the disaggregate role of these types of extension on agriculture although they are being captured by our analysis. These

services are also frequently associated with fertilizer and seed use. However, the Agricultural Census of 2006 does not provide prices and quantities on these inputs. The relationship between rural extension and these inputs might be captured by the inputs fuel and area irrigated included in our model given that they are proxies to capital inputs.

CHAPTER 2

THE EFFECT OF RURAL EXTENSION ON FARM TECHNICAL EFFICIENCY IN BRAZIL

1. Introduction

Brazilian governmental agricultural policies have been incentivizing agricultural production throughout the generation of new economic conditions and instruments that enables the agricultural sector development. Teixeira *et al.* (2014) suggest that future performance of the Brazilian agriculture is directly related to the generation of these factors, which allows the modernization of the sector. One of these policies is the National Policy of Technical Assistance and Rural Extension (PNATER). Peixoto (2014) suggests that this policy's goal is to provide rural extension to farms seeking to achieve rural socioeconomic enhancement by increasing agricultural production and productivity. He also adds that it also leads to higher social welfare by improving rural family health conditions, access to more nutritive food and education, and to better farm organizational structure¹⁹.

Christoplos (2010) argues that the rural extension provision seeks to strengthen the link of new technologies discoveries with the adoption of technology in the agricultural production; i.e. it stimulates the diffusion of new technologies among farms. It also seeks to inform famers about agricultural practices and market price behavior, and provide farm management consultancy. This policy has changed over the decades. Formally implemented in 2003, PNATER was the first centralized policy focused on rural extension since the extinction of the Embrater, compared to the decentralized structure existing in previous years, which led to an increase on the

¹⁹For more details about the emergence and development of extension services in Brazil, see Pettan (2010).

provision of these service by non governmental entities (PETTAN, 2010). Swinner and Maertens (2007) indicate this evolution as a new direction in these service provision given that farm input suppliers are providing these services jointly with their products.

Although rural extension services have increase in the last decades, less than 30% of the 4.3 million farms analyzed in this research²⁰ have had access to rural extension services (Institute of Geography and Statistics – IBGE, 2017). It is also observed that medium and large farms have a greater access to these services. In 2006, the average farm size that have had access was 128.5 hectares (ha), while the average farm size of those farms that have not accessed them was 44.6 ha. Plata and Fernandes (2011) argue that this unequal outcome might occur because medium and large farms have greater volume of resources and access to information. It raises the question whether the rural extension policy has been achieving its main goal of serving the most technologically vulnerable groups of farmers and small producers, and whether it has stimulate the Brazilian agricultural sector.

A few papers have investigated indirectly the effect of rural extension in the Brazilian agricultural production and efficiency. Moura *et al.* (2000) finds that rural extension increases farm efficiency but has no effect on the use of inputs. Helfand and Levine (2004), Gonçalves *et al.* (2008) and Freitas *et al.* (2014) find that rural extension services increase farms efficiency. The latter studies focused on farm efficiency as a measure of productive performance. In this paper we seek to identify the effect of rural extension on farm technical efficiency in Brazil. Farm technical efficiency is a proxy for technical productive performance, which is a measure of how well the farm technically determine the input use to achieve the technical maximum output. In this article, we

²⁰The procedures used to treat the microdata in order to arrive at the final sample considered in the research are presented in detail in the section "Data and empirical application".

define rural extension as what the PNATER delineates as technical assistance and rural extension.

Helfand and Levine (2004), Gonçalves *et al.* (2008) and Freitas *et al.* (2014) do not consider rural extension as an endogenous decision; i.e. the choice of accessing extension services is made by the farmers. Birkheuser *et al.* (1987) indicate that results might be biased if the endogeneity issue is ignored. This choice depends on both observable factors such as experience and farm characteristics, and not observable factors such as farmer management capacity. Plata and Fernandes (2011) indicate these factors as some of the reasons why greater access to rural extension is observed among medium and large farms.

To incorporate these features we estimate a stochastic production frontier considering possible selection bias from access to rural extension in addition to using a sampling matching technique, *Entropy*. Our approach allows to estimate an unbiased effect of rural extension on farm technical efficiency. This approach also permits to identify which factors affect the choice of accessing the extension services and whether there are consistent differences in the input use among groups of farms. Although Plata and Fernandes (2011) indicate a greater access of medium and large farms to these services, the effect on farm efficiency might not be higher in these groups. We test the hypothesis that rural extension has a greater effect on medium and large farms.

Our analysis contributes in three fronts. First, it provides an unbiased estimate of the effect of rural extension on farm efficiency, which is essential for policy evaluation and future policy design. Second, to obtain these estimates we use a suitable methodology that allows to incorporate the endogenous decision on accessing rural extension. Third, we use more than 4 million farm-level observations from the Agricultural Census of 2006 (IBGE, 2017). It is a unique and confidential dataset

available only at the IBGE headquarters that allows us to access farm-decision level and obtain more powerful conclusions.

Results indicate that rural extension increase farm technical efficiency, it has a greater effect among large farms, and governmental provision of these services have a greater effect on technical farm efficiency opposed to nongovernmental provision. Although we do not find evidence that this policy is achieving its main goal of serving vulnerable and small farms our results suggest that, overall, farms have benefit from this policy. We do find evidence that corroborates the hypothesis derived from Plata and Fernandes (2011), which states that larger farms receive a greater benefit from this policy.

2. Background on rural extension

There are several studies that have investigate the effect of rural extension in rural family welfare. Most of these studies focus in developing economies, where great disparities on agricultural income and productivity are observed and can be ameliorate. Anderson and Feder (2004) argue that rural extension intensification can increase farm income in developing countries. The majority of the population in these countries lives in rural areas, which implies a greater impact of these policies on population welfare (Gautam, 2000). These changes are also originated from the access to more knowledge, information and technology (Christoplos, 2010).

Christoplos (2010) discusses the current rural extension policies across the world. He presents both the new opportunities and the challenges faced by policy makers related to implementation of these policies. This author suggests that rural extension translates into farmer and family access to research institutions and higher level of education, in addition to contribute to better managerial, technical, and

organizational skills. Christoplos (2010) also argues that although a more diverse set of provision entities is desirable a well-established governmental provision of this services is needed given that small farms are not able to afford nongovernmental services.

Anderson and Feder (2004) argue that expansion on rural extension provision can lead to higher farm productivity and income in developing countries because of the adoption of new technologies among small farms. They suggest that it would increase profitability because it allows farmers to better manage the agricultural production under risk, for example. As Christoplos (2010), they also argue that access to rural extension increases farmer's human capital, which has a direct impact on managerial skills.

Gautam (2000) investigates the effects of the National Extension Project (NEP) in Kenya, where 70% of the population lives in rural areas. Although he does not find an effective role of the NEP on agricultural income changes during the years investigated, he suggests that rural extension is essential to decrease disparities in agricultural productivity and income in Kenya. Landini (2016) investigate the quality of rural extension services in rural Argentina using an interview approach. He concludes that rural extension services must promote increases in social capital such as incentivizing farmers to take training courses and to better organize themselves. The latter social change can lead to higher farm income due to scale effects also by increasing farms bargaining power (Landini, 2016).

Van Der Ban (1999) highlights the role of rural extension on enhancing farmer's education level, which translates into being more resourceful and sharp when facing new market and environmental conditions. In addition to Christoplos (2010) and Anderson and Feder (2004), he argues that these services should also focus on inducing

farms competitiveness in the market and to assist farm interactions with the other nodes of the production chain such as the demand side.

2.1. Rural extension in Brazil

In Brazil, farms have been having access to rural services since the nineteenth century (Bergamasco, 1983). However, Pettan (2010) argues that, in this period, these services were mostly performed by non-governmental institutions that sought to assist with on-farm training. Government support for rural extension began with the creation of the Brazilian Company for Technical Assistance and Rural Extension – EMBRATER in the 70's, which together with state enterprises formed the Brazilian System of Technical Assistance and Rural Extension - SIBRATER. However, economic crises and financial constraints faced by the country led this system to decline in the late 1980s.

In 2003, rural extension provision directions were defined within the PNATER guidelines, developed by the MDA, which substituted the decentralized governmental policy prevailed with the extinction of Embrater in 1992²¹. Peixoto (2014) indicates that this policy sought to build a new rural extension provision structure incorporating both governmental and non-governmental institutions.

Alves (2013) suggests that large farms and farms in more developed agricultural regions continue to obtain greater access to rural extension than smaller farms. This contradicts the new policy directions, which indicates that more vulnerable groups should receive greater attention. Peixoto (2014) suggests a revision on the provision's structure of these services where it should incorporate the socioeconomic features described in the PNATER. Rivera and Alex (2004) agree with Christoplos (2010) and argue that a greater participation of non-governmental institutions within PNATER

²¹ After the extinction of the EMBRATER, the supply and financing of the public extension service was under the responsibility of the States themselves through the EMATERs (State Companies of Technical Assistance and Rural Extension).

lines and a broader rural development agenda would lead to a more efficient provision of these services.

Kageyama (1990) highlights the great disparity on these services provision, farms in the North and Northeast regions of Brazil have been poorly provided. A higher proportion of farms that have had access is observed in municipalities at the South and Southeast regions of Brazil. On average, 49% of the farms in the South have had access to these services compared to the North with only 15%. Although disparities on the provision are still observed the implementation of PNATER have led to an increase in resources used on rural extension, from R\$ 3 million on the 2001/02 crop season to R\$ 1.1 billion on the 2015/16 crop season (Sistema Integrado de Administração Financeira do Governo Federal – SIAFI, 2016). Pettan (2010) and Peixoto (2014) also indicate an increase in non-governmental provision during this period.

Despite the increase on resources designated to rural extension provision, several PNATER's obstacles have led to great disparities on regional provision and farm size access to this services. The PNATER system still has low remuneration for extension agents and large costs to provide a rural extension to several farms within the municipality (Peixoto, 2014).

2.2. Effect of rural extension on technical efficiency

Several studies have indirectly investigated the effect of rural extension on farm technical efficiency using the stochastic frontier approach. In this approach, the error term is composed by a random standard error and an error term that measures the distance from the frontier or the inefficiency. A few of these studies incorporate heterogeneity in the inefficiency term by including variables that might affect the efficiency level; i.e. a measure of rural extension. However, these studies do not

consider possible effects from selection bias and the endogenous nature of the choice to access rural extension.

Gonçalves *et al.* (2008) estimate technical efficiencies of 771 dairy farms in Minas Gerais. They divided the sample into three groups: farms with production smaller than 50 liters of milk per day; with production between 50 and 200 liters of milk per day; and with production with more than 200 liters of milk per day. To obtain the technical efficiency scores, they use a Data Envelopment Analysis (DEA) approach and then identify the efficiency determinants using a Tobit regression. They include a dummy to capture the effect of rural extension on farm technical efficiency. Results show a statistically significant effect of rural extension on farm technical efficiency but only for the farms with large production of milk (more than 200 liters per day). This conclusion adds up to the hypothesis we derived from Alves *et al.* (2013) and Plata and Fernandes (2011), which states that larger farms benefit more from rural extension.

Using a similar approach, Helfand and Levine (2004) investigate the determinants of the technical efficiency of agricultural farms in the Central West region using the 1995/96 Agricultural Census. Although their variable of interest is farm size, they include access to rural extension as a determinant of farm technical efficiency. They find a positive and significant effect of rural extension on farm technical efficiency.

Moura *et al.* (2000) investigate the effect of rural extension services on efficiency and input use of 68 small farms in the State of Ceará. They use a stochastic production function approach where the functional form is a Cobb-Douglas. They find a positive effect of rural extension on farm efficiency. Using a similar approach, Magalhães *et al.* (2011) investigate the determinants of technical and allocative inefficiency of establishments that participated in the agrarian reform program known as

“Cedula da terra”. This program incorporates establishments in five states of the Northeast region of Brazil. They include a dummy variable to capture the effect of rural extension in the efficiency error term and find no effect of this variable on farm technical efficiency.

Freitas *et al.* (2014) also identify the effect of rural extension on the agricultural production and technical efficiency of Brazilian agricultural farms, combining stochastic production frontier with quantile regression methods and using the Agricultural Census of 2006 as a database. They find a positive effect of the rural extension services on technical efficiency only in farms at the lower efficiency quantiles, while for the more efficient farms, this variable had a negative effect.

These studies highlight the relevance of rural extension in enabling farm development, productivity and socioeconomic welfare enhancements, and in increasing technical efficiency. However, it lacks in the literature a study that focus in this topic and uses a suitable methodology that incorporates specific features of this issue such as the endogenous nature of accessing rural extension. We seek to identify the effect of rural extension on farm technical efficiency and the determinants of choosing to access it using a unique dataset with more than 4 million farm-level observations.

3. Methodology

To identify the effect of rural extension on farm technical efficiency we use an approach that consists of two steps. We first deal with possible selection bias in the choice of accessing rural extension caused by the observable pre-choice characteristics. This possible selection bias does not allow the direct comparison between the technical efficiency of farms that have had access to it with farms that have not had access it. We use the *Entropy* methodology to eliminate the bias caused by the observable

characteristics. This method is used to obtain a control group as similar as possible to the group of farms that have had access to rural extension, which it allows us to compare the groups without any possible selection bias. In the second step we estimate a stochastic production frontier for each group, using the two-stage approach developed by Heckman (1979).

This approach allow us to obtain comparable and unbiased farm technical efficiency scores for both groups. A few papers have addressed this topic using a similar approach. Bravo-Ureta *et al.* (2012) use a propensity score matching to deal with the possible bias from observed variables and a selectivity correction model proposed by Greene (2010) to deal with possible self-selection arising from unobserved variables. They find evidence of selection bias. Duangbootsee and Myers (2014) uses the same procedure as Greene (2010) and the Heckman's two-step approach, although they did not correct the bias caused by observable characteristics, as Bravo-Ureta *et al.* (2012). The results show that there is no strong evidence to support the presence of selectivity bias in their analysis.

3.1. Entropy Balancing

We use the Entropy Balancing method proposed by Hainmuller (2012) to obtain a balanced "matching" sample. It allows to find a sample with the closest possible control units of the treatment units based on the vector of observable characteristics. This method consists of a non-parametric method that allows to weight a set of information (covariates) to reweight the observations in a manner that the distribution of the variables satisfy a set of special conditions of moments. The weighting scheme ensures balance and similarity between the control and treatment groups.

Following Hainmuller (2012), consider a random sample with n_1 observations from the treatment group and n_0 from the control group, selected from a total population $N = N_1 + N_2$, where $n_1 \leq N_1$ and $n_0 \leq N_0$. Let $D_i \in \{1,0\}$ be a binary treatment variable such as access to rural extension, which assume a value equal to 1 if unit i is exposed to the treatment, and 0 if not. Also consider \mathbf{X} an matrix containing observations of the J -th exogenous pre-treatment variables; X_{ij} correspond to the value of the j -th covariates of unit i , such that, $X_i = [X_{i1}, X_{i2}, \dots, X_{ij}]$ refers to the vector of observable characteristics of the unit i e X_j refers to the column vector with j -th covariates.

This method looks for a set of weights $\mathbf{W} = [w_1, \dots, w_{n_0}]'$ minimizing the entropy distance between \mathbf{W} and the weight vector $\mathbf{Q} = [q_1, \dots, q_{n_0}]'$, Equation (1), subject to the balancing constraint, Equation (2), the normalization constraint, Equation (3), and a non-negativity constraint, Equation (4).

$$\min_{w_i} H(w) = \sum_{\{i|D=0\}} w_i \log(w_i/q_i) \quad (1)$$

subject to the equilibrium and the normalization constraints

$$\sum_{\{i|D=0\}} w_i c_{ri}(X_i) = m_r, \quad r \in 1, \dots, R \quad (2)$$

$$\sum_{\{i|D=0\}} w_i = 1 \quad (3)$$

$$w_i \geq 0 \text{ for all } i, \text{ such that } D = 0 \quad (4)$$

where $q_i = 1/n_0$ is a basis weight and $c_{ri}(X_i) = m_r$ describes a set of R constraints imposed on the moments (m_r) of the covariates in the reweighted control group. First, we choose the covariates that will be included in the re-weighting scheme. For each covariate, a set of balancing restrictions (Equation (1)) is specified to match the moments of the covariates distribution between treatment groups and reweighted

controls. There are three possible moment constraints: mean (first moment), variance (second moment), and asymmetry (third moment). A typical balancing restriction is formulated such that m_r contains the moment of a specific covariate X_j for the treatment group. The moment function for the control group is then specified as: $c_{ri}(X_{ij}) = X_{ij}^r$ or $c_{ri}(X_{ij}) = (X_{ij} - \mu_j)^r$, where X_{ij}^r is the covariate vector and μ_j is the mean.

We set the moment restriction to the first moment of the covariates²². After selecting the covariates, the method calculates the means in the treatment group and searches for a set of entropy weights such that the weighted averages of the control group are similar. Such weights are used in the following steps in order to obtain unbiased estimates of selection bias caused by observable characteristics.

3.2. Sample Selection Model

We use the procedure proposed by Heckman (1979) to test for possible sample selection bias; i.e. factors that affect farm technical efficiency might be different from the factors that determine the likelihood of accessing rural extension services. First, we estimate a binary choice model (selection equation) to find out which factors increase the likelihood of accessing (choosing) rural extension, the treatment variable. Second, we estimate a stochastic production frontier (interest equation) for each group incorporating the Inverse Mills Ratio²³, obtained at the selection equation. We performed this two-step procedure to three different treatment variables: rural extension overall; public rural extension; and private rural extension.

3.2.1. Selection Equation

²² The covariates used in entropy balancing are presented in section 3.3.

²³ Variable generated from the Probit model and included in the stochastic production frontier to correct the sample selection bias. The existence of the selection bias is confirmed when the inverse mills ratio is statistically significant (GREENE, 2011).

First, as proposed by Heckman procedure (1979) we estimate the likelihood the treatment occur using a Probit model; i.e. the likelihood a farm have accessed rural extension. Assume that d_i^* is a binary variable that represents the (unobservable) selection criterion and that is a function of a vector of exogenous variables (z_i)

$$d_i^* = \alpha' z_i + w_i \quad (5)$$

where α is a vector of parameters to be estimated and w_i is the error term distributed as $N(0, \sigma_w^2)$. The latent variable d_i^* is observed and receives the value of 1 when $\alpha' z_i + w_i > 0$ and zero otherwise:

$$d_i^* = 1[\alpha' z_i + w_i > 0], \quad w_i \sim N[0,1] \quad (6)$$

3.2.2. Stochastic Production Frontier

Second, we estimate a stochastic production frontier model correcting for sample bias and the matching sample weighting scheme. It means that we include the inverse Mills ratio and estimate considering a weight vector obtained using the *Entropy* method. The Stochastic Frontier approach²⁴ has been widely used to obtain efficiency measures. It consists in estimating a production function that represents the relation between agricultural input and output (Helfand and Levine, 2004; Rada; Valdez, 2012; Helfand *et al.* 2015). Aigner, Lovell and Schmit (1977) and Coelli and Battese (1996) specify the model as follows:

$$Y_i = f(X_i, \beta) e^{(v_i - u_i)} \quad (7)$$

where Y_i is the value of production of *i-th* farm; X_i is the vector of expenses with inputs of the *i-th* farm ; and β is a vector of the parameters to be estimated, which define the

²⁴According to Agner *et al.* (1977) and Chambers (1988), the objective of the model is to estimate a production function in which it is expected to obtain the maximum product from the combination of inputs, considering a certain technological level. However, there is no guarantee that an efficient combination of inputs will be used to maximize production, since there may be technical inefficiencies in the use of these inputs. This implies that the unit may be producing below the maximum production frontier.

production technology. The error terms v_i and u_i are vector that represent distinct components of the error: v_i , the random error component, has a normal distribution, independent and identically distributed (*iid*), with variance $\sigma_v^2[v \sim iidN(0, \sigma_v)]$ and captures the stochastic effects beyond the control of the productive unit, such as measurement errors and climate, for example; and u_i is responsible for capturing the technical inefficiency of the i -th farm, that is, the distance from the production frontier, and are non-negative random variables. This unilateral (non-negative) term can follow half-normal, truncated normal, exponential or gamma distributions with mean $\mu > 0$ and variance σ_u^2 (Aigner *et al.*, 1977; Greene, 1980). We have assumed a exponential distribution to the inefficiency error term [$u \sim iidN^+(0, \sigma_u)$].

To obtain farm technical efficiency we follow Jondrow *et al.* (1982). Farm technical efficiency is defined as the ratio between the observed product and the potential product of the sample:

$$ET_{ij} = \frac{Y_{ij}}{Y_{ij}^*} = \frac{Y_{ij}}{f(X_{ij})} = \frac{\exp(X_{ij}\beta + v_{ij}) \exp(-u_{ij})}{\exp(X_{ij}\beta + v_{ij})} = \exp(-u_{ij}) \quad (8)$$

where the value of ET_{ij} will be in the range [0; 1], where zero represents complete inefficiency and 1, full efficiency.

3.3.Data and Empirical application

We use a rich farm level dataset only available at the secrecy room at the IBGE, the microdata of the 2006 Census of Agriculture. We first clean the dataset, excluding farms without area declaration (255,019 observations), farms located in the urban area (192,350 observations), farms in special sectors such as favelas, barracks, indigenous

villages, nursing homes, etc. (117,530 observations), and farms in settlements²⁵(139,496 observations). We also excluded observations in which the producer type was not identified (20,440 observations) and observations where the farm is not owned by an individual producer (190,838 observations)²⁶. Around 17% of the original data was dropped. We use a dataset composed by 4,259,963 farms. In the following section (Table 2.1) we present a descriptive statistics analysis of our sample.

The three treatment variables –rural extension, public rural extension and private rural extension –are binary variables. They are constructed based on the farmer’s answer to the following questions: "The establishment received technical guidance?" And "what is the origin of the guidance?". In our sample, 27.7% of the farmers have received technical guidance, 11.4% from public institutions and 16.3% from private institution. We also divided our sample in four size classes according to the IBGE classification. We categorized the farms in very small, small, medium and large based on the concept of fiscal module classes²⁷.

The Agricultural Census of 2006 also presents farm socioeconomic characteristic. In addition to economic variables, we use these characteristics in the selection equation and for the entropy balancing. We obtain information on farmer gender, age, schooling level and experience. The variable *gender* is a dummy variable equals 1 if it is male and 0 otherwise. Farmer’s age is the manager’s age. The variable schooling is a categorical variable for the farm manager’s education level (from 0 to 7) in the following order: do not read and write, read and write, literate, incomplete

²⁵Kageyama *et al.* (2013) suggest that the inclusion of these observations might lead to possible variable measurement error given that the agricultural production is performed collectively.

²⁶ We exclude farms categorized as condominium, consortium or partnership, cooperative, corporation or limited liability shares, public utility, government (Federal, state, or municipal) or other condition.

²⁷Fiscal module is defined as the minimum area required for rural properties to be considered economically viable, ranging in area from 5 to 110 hectares, depending on the municipality. Based on the concept of fiscal module, the agricultural farms can be classified into: very small (less than 1 fiscal module), small (between 1 and 4 fiscal module), medium (between 4 and 15 fiscal module) and large (more than 15 fiscal module) (Landau *et al.*, 2012).

elementary school, complete elementary school, agricultural technician, high school and higher education (base). We capture experience using a categorical variable of the years in which the farmer is in charge of the activity, being divided in: up to 1 year, between 1 and 5 years, between 5 and 10 years, over 10 years (base).

Farm ownership, the presence of skilled labor in the farm workforce, family farm classification and whether the farm's manager lives in urban area also play an important role on the likelihood of accessing rural extension. We capture farm ownership by including a categorical variable: Owner (base), tenant, partner and occupant. Skilled labor is capture with a dummy variable equals 1 if there is presence of skilled labor in the farm and zero otherwise. Family farm classification is capture in a similar manner. To capture whether the farm's manager lives in a urban area or not we construct a dummy variable that equals 1 if the head of the farm lived in the urban area and zero otherwise.

We use the gross value of production in 2006 (GVP) in R\$ as a proxy to the output variable, Y_i . We obtain information on 4 inputs. We use the sum of the farm area (in hectares) designated to agriculture, livestock and agroforestry to capture the land input. The total value in R\$ of the assets in the agricultural establishment is used as a proxy to capital. As a proxy to labor, we use the sum of the family member and hired labor. As in Helfand *et al.* (2015) we include a variable to capture purchased inputs (other): the sum of expenses with soil correctives, fertilizers, pesticides, animal medicines, seeds and seedlings, salt/feed, fuel and energy.

3.3.1. Estimation

After obtaining the weights for the control groups using the Entropy balancing method we estimate the selection equation using a *Probit* as in Equation (6):

$$d_i^* = \alpha_0 + \sum_{e=1}^7 \alpha_e Z_e + \sum_{o=1}^3 \alpha_o Exp_o + \sum_{k=1}^7 \alpha_k School_k + \sum_{r=1}^4 \alpha_r FarmStatus_r + \varepsilon_i \quad (9)$$

where Z_e is a vector of explanatory variables that includes gender, total farm area (*totalarea*), age, age square, skilled labor (*Qualif*) in the workforce, family farm classification (*Family*) and if the farm's manager lives in a urban area (*Urban*); *Exp* represents experience and it is divided into three categories (farmer in charge of the activity over 10 years as base category), *School* represents schooling and it is divided into 7 categories (higher education as base category), and farm ownership (*FarmStatus*) into 4 categories (owner as base category). We include the square of the variable farm manager's age seeking to capture a nonlinear effect. From this estimation we obtain the inverse mills ratio (*Mills*). Then, we include it in the stochastic production frontier.

We use a *Translog*²⁸ production function, weighted by the vector of weights obtained by *Entropy* method, to represent the technology given that it presents some desirable properties such as flexibility, linearity in parameters, regularity and parsimony (Mariano *et al.*, 2010). In addition to the inverse mills ratio we also include in the stochastic production dummy variables for each state and farm size group seeking to capture non-observable factors that are fixed across these groups. As in Battesi and Coelli (1992) the technology can be represented as

$$\ln y_i = \beta_0 + \sum_{k=1}^N \beta_k \ln x_{ki} + \frac{1}{2} \sum_{k=1}^N \sum_{h=1}^N \ln x_{ki} \ln x_{hi} + \rho Mills_i + \sum_{h=1}^{26} FS_h + \sum_{g=1}^4 G_g + v_i - u_i \quad (10)$$

where y_i represents the gross value of production of *i-th* farm; x_{ki} represents inputs *k*, which are: productive area, labor, capital stock and expenses with purchased inputs; FS_h represents dummies for federative states; and G_g represents dummies for the four farm

²⁸However, as Battesi and Coelli (1992) and Helfand *et al.* (2015), Log-likelihood Ratio(LR) tests were performed to identify the best production frontier specification (Cobb-Douglas versus Translog), which pointed to the Translog functional form.

sizes groups considered. We test whether we face selection bias by analyzing the statistical significance of the parameter ρ . We have assumed a exponential distribution to the inefficiency error term [$u \sim iid N^+(0, \sigma_u)$]. We use the STATA® 2014 software to estimate all steps of this approach.

4. Results

We first present the descriptive statistics of the variables used, displayed in Table 2.1. This table also shows the result of the Entropy method. On average, farms that have had access to rural extension have a greater agricultural area and a manager with higher levels of schooling (a higher *share*). They also have shown a greater gross value of the production in 2006, on average, R\$77.3 thousand opposed to farms that have not accessed these service, on average, R\$12.0 thousand. These farms have also a greater input expenditure (fertilizers, agrochemicals, electricity, transportation, and others). These disparity is not observed in the averages of age, experience and farm ownership status.

Table 2. 1 - Mean of the variables used in the selection equation and in the Stochastic Production Frontier

Variables	Non Balanced Sample				Balanced Sample					
	Without RE (Control)	RE	Public RE	Private RE	Without RE (Control)	RE	Control	Public RE	Control	Private RE
<i>Gender</i>	0.863	0.933***	0.921***	0.940***	0.933	0.933 ^{ns}	0.921	0.922 ^{ns}	0.940	0.940 ^{ns}
<i>Total Area</i>	44.56	128.5***	66.00***	172.5***	128.5	128.500 ^{ns}	65.99	66.000 ^{ns}	172.4	172.500 ^{ns}
<i>Age</i>	50.5	49.56***	50.61***	48.82***	49.56	49.560 ^{ns}	50.61	50.610 ^{ns}	48.82	48.820 ^{ns}
<i>Read and write</i>	0.108	0.0462***	0.0666***	0.0319***	-	-	-	-	-	-
<i>Do not read and write</i>	0.295	0.0685***	0.116***	0.0352***	0.069	0.068 ^{ns}	0.116	0.116 ^{ns}	0.036	0.035 ^{ns}
<i>Literate</i>	0.0577	0.0341***	0.0467***	0.0252***	0.034	0.034 ^{ns}	0.047	0.047 ^{ns}	0.025	0.025 ^{ns}
<i>Incomplete elementary</i>	0.404	0.506***	0.526***	0.491***	0.506	0.506 ^{ns}	0.526	0.526 ^{ns}	0.491	0.491 ^{ns}
<i>Complete elementary</i>	0.072	0.121***	0.113***	0.127***	0.121	0.121 ^{ns}	0.113	0.113 ^{ns}	0.127	0.127 ^{ns}
<i>Agricultural Technician</i>	0	0.0607 ^{ns}	0.0178***	0.0909***	0	0	0.018	0.018 ^{ns}	0.091	0.091 ^{ns}
<i>High School</i>	0.0482	0.0966***	0.0803***	0.108***	0.097	0.097 ^{ns}	0.080	0.080 ^{ns}	0.108	0.108 ^{ns}
<i>Higher Education</i>	0.0155	0.0669***	0.0339***	0.0900***	0.067	0.067 ^{ns}	0.034	0.034 ^{ns}	0.090	0.090 ^{ns}
<i>exp1</i>	0.0281	0.0190***	0.0168***	0.0205***	0.019	0.019 ^{ns}	0.017	0.017 ^{ns}	0.021	0.021 ^{ns}
<i>exp2</i>	0.169	0.152***	0.140***	0.161***	0.153	0.153 ^{ns}	0.140	0.140 ^{ns}	0.161	0.161 ^{ns}
<i>exp3</i>	0.168	0.173***	0.172***	0.174***	0.173	0.173 ^{ns}	0.172	0.172 ^{ns}	0.174	0.174 ^{ns}
<i>exp4</i>	0.635	0.656***	0.671***	0.645***	-	-	-	-	-	-
<i>Qualif</i>	0.0236	0.0964***	0.0621***	0.121***	0.096	0.096 ^{ns}	0.062	0.062 ^{ns}	0.121	0.121 ^{ns}
<i>Family</i>	0.876	0.745***	0.821***	0.692***	0.745	0.745 ^{ns}	0.821	0.821 ^{ns}	0.692	0.692 ^{ns}
<i>Urban</i>	0.118	0.194***	0.136***	0.234***	0.194	0.194 ^{ns}	0.136	0.136 ^{ns}	0.234	0.235 ^{ns}
<i>Owner</i>	0.824	0.894***	0.905***	0.887***	0.894	0.894 ^{ns}	0.905	0.905 ^{ns}	0.887	0.887 ^{ns}
<i>Tenant</i>	0.0451	0.0530***	0.0354***	0.0653***	0.053	0.053 ^{ns}	0.035	0.035 ^{ns}	0.065	0.065 ^{ns}
<i>Partner</i>	0.0316	0.0172***	0.0173***	0.0170***	0.017	0.017 ^{ns}	0.017	0.017 ^{ns}	0.017	0.017 ^{ns}
<i>Ocupant</i>	0.0997	0.0355***	0.0424***	0.0307***	-	-	-	-	-	-
<i>GVP</i>	12009	77292	35761	106488	-	-	-	-	-	-
<i>Labor</i>	2.559	3.272	2.953	3.497	-	-	-	-	-	-
<i>Area</i>	28.53	91.81	45.71	124.2	-	-	-	-	-	-
<i>Capital</i>	101960	524921	236827	727447	-	-	-	-	-	-
<i>Purchased Inputs</i>	1995	31938	9117	47981	-	-	-	-	-	-
Nº Obs.	3,336,328	923,228	381,104	542,124	3,336,328	923,228	381,104	542,124		

Source: Research results.

Note: RE = Rural extension; ***Means are statistically different from the control group (no extension) at 1%; NS – means are statistically the same as the control group at 1%.

The analysis of Table 2.1 corroborates Plata and Fernandes (2011) argument, that medium and large farms have greater volume of resources and access to information. Farms that have had access to private rural extension have a larger agricultural area, higher schooling and a higher share of the workforce with skilled labor opposed to farms that have not accessed these services. These farms also obtained, on average, a three times larger income in 2006, compared to the farms that have accessed public rural extension. The same behavior is observed in the value of land, buildings and other facilities.

The columns in the "Balanced sample" part of Table 2.1 show the result of the balancing method using the first moment of the sample (average of the variables). Before using this method, we observe statistically significant difference between the treatment and control groups. However, after using the entropy method, we did not find any statistically significant difference between these groups (test of equality of means). It implies that, we are able to obtain a very similar control for each treatment group, based on observable characteristics. The main difference between these two groups is the access to rural extension services.

4.1. Sample Selection

We present in Table 2.2 the determinants of the likelihood to access rural extension services using a *Probit* model. We rejected the null hypothesis of joint insignificance of the variables (χ^2) at 1% in all models considered. We found that larger farms face greater likelihood of accessing rural extension services. This confirms the hypothesis that larger farms have higher access to rural extension. Being male is associated with a greater probability of accessing these services, compared to being female. We find a nonlinear effect of age, which suggests that the probability would

increase up 56 years old, which is higher than the overall age average of 50 years old.

We also find that farm with managers that have more experience have higher probability to access these services.

Table 2. 2 - Estimation of the selection equation (Probit) for participation in rural extension services, after balancing the sample.

Variables	Rural Extension (1)	Public Rural Extension (2)	Private Rural Extension (3)
<i>Gender</i>	0.393*** (0.00258)	0.237*** (0.00302)	0.389*** (0.00322)
<i>Total Area</i>	7.68e-05*** (1.64e-06)	-3.96e-05*** (2.53e-06)	9.24e-05*** (1.59e-06)
<i>Age</i>	0.0340*** (0.000324)	0.0268*** (0.000388)	0.0257*** (0.000384)
<i>Age2</i>	-0.000302*** (3.08e-06)	-0.000229*** (3.67e-06)	-0.000239*** (3.68e-06)
<i>Read and write</i>	-1.115*** (0.00497)	-0.327*** (0.00621)	-1.231*** (0.00557)
<i>Do not read and write</i>	-1.386*** (0.00468)	-0.507*** (0.00587)	-1.574*** (0.00527)
<i>Literate</i>	-0.946*** (0.00535)	-0.206*** (0.00663)	-1.063*** (0.00604)
<i>Incomplete Elementary</i>	-0.515*** (0.00426)	-0.00855 (0.00546)	-0.570*** (0.00438)
<i>Complete Elementary</i>	-0.334*** (0.00463)	0.0842*** (0.00589)	-0.401*** (0.00480)
<i>Agricultural Technician</i>	-	0.0700*** (0.00853)	1.579*** (0.00799)
<i>High School</i>	-0.259*** (0.00473)	0.108*** (0.00603)	-0.325*** (0.00489)
<i>Exp1</i>	-0.344*** (0.00513)	-0.213*** (0.00636)	-0.305*** (0.00593)
<i>Exp2</i>	-0.162*** (0.00223)	-0.0808*** (0.00268)	-0.157*** (0.00258)
<i>Exp3</i>	-0.0919*** (0.00209)	-0.0128*** (0.00248)	-0.121*** (0.00244)
<i>Qualif.</i>	0.484*** (0.00346)	0.157*** (0.00410)	0.445*** (0.00357)
<i>Family</i>	-0.274*** (0.00201)	-0.0323*** (0.00251)	-0.336*** (0.00221)

<i>Urban</i>	-0.0575*** (0.00224)	-0.138*** (0.00275)	0.0264*** (0.00247)
<i>Tenant</i>	0.137*** (0.00348)	-0.135*** (0.00455)	0.282*** (0.00383)
<i>Partner</i>	-0.178*** (0.00500)	-0.194*** (0.00614)	-0.0998*** (0.00598)
<i>Ocupant</i>	-0.418*** (0.00330)	-0.298*** (0.00389)	-0.391*** (0.00417)
<i>Constant</i>	-1.086*** (0.00972)	-2.069*** (0.0119)	-1.159*** (0.0112)
<i>Log likelihood</i>	-1.894e+06	-1.238e+06	-1.330e+06
<i>chi2</i>	492307***	90057***	587009***

Source: Research results.

Note: ***significat at 1%; Standard erros in parentheses.

Our results suggested that farms with managers with a high level of education have greater probability to access rural extension services. Lapple and Hennessy (2014) investigate the participation of dairy farms in extension programs in the United States, and they also find that higher education increases the adoption of these services. These authors highlight the importance of investments in rural education to facilitate access to rural extension because: the farmer inherent motivation to obtain information and knowledge; and/or the extension services are often promoted by agricultural education. Farms classified as “family agriculture” and farm’s manager that lives in urban areas lead to lower probability of accessing rural extension services. Genius *et al.* (2006) also find similar results. We also find that hiring skilled labor increases the probability of accessing these services.

For the treatment variables private rural extension and public rural extension, also in Table 2.2, we did not observe any difference on the effects of gender, age, skilled labor and experience. However, we observed that a higher education of the farm’s manager have a stronger effect on the probability of accessing private extension compared to public services. Where farm’s manager lives also has a different impact, positive on the probability to access private rural extension and negative on accessing

public services. Swinnen and Maertens (2007) indicate that part of the private extension services is carried out by input suppliers and/or food processing and distribution companies. A higher interaction between farm managers and these companies is expected when farm managers live in urban areas.

4.2. Stochastic Production Frontier

We estimated the stochastic production frontier function for the entire sample and for each group of the rural extension services. In addition to the inputs, the Inverse Mills Ratio - IMR, estimated in the previous step, was included in the production function to correct for possible selection bias caused by unobservable factors. We estimated the *Translog* production function using the weighting scheme from the *Entropy* method. The Wald statistic indicates that the model has a good fit, rejecting at 1% the null hypothesis of joint insignificance of the variables. Results are shown in Table 2.3.

Table 2. 3 - Estimation of Stochastic Production Frontier for the total sample and for the different treatment groups considered.

Ly(GVP)	Total Sample (Pooled) (1)	Rural Extension (2)	Without Rural Extension (3)	Public Rural Extension (4)	Private Rural Extension (5)
<i>lx1 (Area)</i>	0.454*** (0.0029)	0.437*** (0.0076)	0.423*** (0.0033)	0.332*** (0.0108)	0.486*** (0.0103)
<i>lx2 (Labor)</i>	0.204*** (0.0078)	0.294*** (0.0175)	0.193*** (0.0095)	0.223*** (0.0268)	0.516*** (0.0238)
<i>lx3 (Purchased Inputs)</i>	-0.116*** (0.0019)	0.0859*** (0.0056)	-0.0953*** (0.0024)	-0.0547*** (0.0082)	0.161*** (0.0077)
<i>lx4 (Capital)</i>	-0.288*** (0.0029)	-0.233*** (0.0069)	-0.262*** (0.0036)	-0.221*** (0.0095)	-0.233*** (0.0098)
	-				
<i>lx12</i>	0.0031*** (0.0005)	0.0491*** (0.0013)	-0.0006 ^{NS} (0.0006)	0.00112 (0.0020)	0.0768*** (0.0017)
<i>lx22</i>	-0.0065** (0.0032)	0.103*** (0.0048)	0.0008 ^{NS} (0.0038)	0.0719*** (0.0091)	0.149*** (0.0056)

<i>lx32</i>	0.0978*** (0.0003)	0.0973*** (0.0005)	0.102*** (0.0003)	0.103*** (0.0008)	0.0916*** (0.0007)
<i>lx42</i>	0.0349*** (0.0004)	0.0508*** (0.0008)	0.0317*** (0.0004)	0.0363*** (0.0012)	0.0576*** (0.0011)
<i>lx1x2</i>	0.0243*** (0.0010)	-0.0281*** (0.0019)	-0.0234*** (0.0011)	-0.0105*** (0.0032)	0.0343*** (0.0023)
<i>lx1x3</i>	0.0174*** (0.0003)	-0.0275*** (0.0007)	-0.0209*** (0.0003)	-0.0195*** (0.0010)	0.0284*** (0.0009)
<i>lx1x4</i>	0.0097*** (0.0003)	-0.0196*** (0.0008)	-0.0046*** (0.0004)	-0.0043*** (0.0011)	0.0296*** (0.0010)
<i>lx2x3</i>	0.0608*** (0.0006)	-0.0492*** (0.0015)	-0.0694*** (0.0007)	-0.0504*** (0.0022)	0.0619*** (0.0019)
<i>lx2x4</i>	0.0514*** (0.0009)	0.0303*** (0.0020)	0.0567*** (0.0011)	0.0321*** (0.0030)	0.0224*** (0.0025)
<i>lx3x4</i>	0.0031*** (0.0002)	-0.0209*** (0.0007)	0.00125*** (0.0003)	-0.0092*** (0.00095)	0.0251*** (0.0008)
<i>Mills</i>	-	-0.0151*** (0.0020)	-0.0446*** (0.0011)	-	-
<i>Millspub</i>	-	-	-	-0.0119*** (0.0046)	-
<i>Millspriv</i>	-	-	-	-	0.0120*** (0.0033)
<i>Constant</i>	7.897*** (0.0186)	7.314*** (0.0434)	8.039*** (0.0214)	7.790*** (0.0632)	6.945*** (0.0637)
<i>Usigma</i>	1.571*** (0.00128)	1.101*** (0.00278)	1.822*** (0.0014)	1.165*** (0.0043)	1.194*** (0.0034)
<i>Vsigma</i>	0.0814*** (0.00134)	-0.385*** (0.00274)	0.0458*** (0.0016)	-0.224*** (0.0042)	-0.497*** (0.0036)
<i>Lambda</i>	19.299	2.859	39.782	5.201	2.402
<i>Wald-Test</i>	3.016e+06	738658	1.783e+06	229269	476631
<i>Prob>chi2</i>	0.000	0.000	0.000	0.000	0.000
<i>Observations</i>	4,259,963	867,145	3,336,328	381,104	542,124

Source: Research results.

Note: *** significant at 1%, ** significant at 5%, * significant at 10%; Standard errors (bootstrap) in parentheses.

Our results suggest that unobservable factors influence the producer's decision to access rural extension services. It confirms the hypothesis of sampling selection bias, demonstrated in the statistical significance of the coefficients for the IMR. The negative coefficient found in all three models suggests that these factors are associated

with the selection of producers at the lower level of gross value of production. Our results also suggest that most of the error is due to inefficiency, given that the value of the Lambda parameter found is above the unit in all the estimated models.

We estimated the production elasticities for *land, labor, capital and purchased inputs*, displayed in Table 2.4. The sum of these elasticities gives us a measure of returns to scale. We found it to be close to one in all models, which suggests that the technology used is under constant returns to scale. Alves *et al.* (2012) find a similar result using the same data. For the pooled model, we found that *purchased inputs* and *labor* were the inputs with the greatest production elasticities. An increase of 10% in these inputs would lead to an increase, on average, of 4.4% and 3.2% in the production, respectively. Helfand *et al.* (2015) also find that these inputs have the greatest elasticities for Brazilian agricultural²⁹.

Table 2. 4 - Elasticities of the inputs for the total sample and for the different treatment groups considered.

	Area	Labor	Purchased Inputs	Capital	Sum
<i>Total Sample (Pooled)</i>	0.2316 (0.0018)	0.3183 (0.0035)	0.4372 (0.0013)	0.1023 (0.0016)	1.0894
<i>Rural Extension</i>	0.1469 (0.0036)	0.3421 (0.0066)	0.3700 (0.0024)	0.1436 (0.0030)	1.0025
<i>Without Rural Extension</i>	0.2367 (0.0017)	0.3171 (0.0038)	0.4313 (0.0013)	0.0843 (0.0015)	1.0694
<i>Public Rural Extension</i>	0.1696 (0.0053)	0.2900 (0.0105)	0.3994 (0.0038)	0.1071 (0.0044)	0.9662
<i>Private Rural Extension</i>	0.1353 (0.0047)	0.4369 (0.0086)	0.3675 (0.0031)	0.1634 (0.0040)	1.1030

Source: Research results.

Note: All elasticities were statistically significant at 1%. Standard error in parentheses.

We found significant differences in the production elasticities in the models of the treatment and control groups. For both groups, *purchased inputs* still has the greatest production elasticity. For the treatment group, there is a greater contribution of *capital*

²⁹The elasticities found by Helfand *et al.* (2015) for purchased inputs and labor were, respectively, 0.62 and 0.21. Although they also use the 2006 Agricultural Census, the authors use a more aggregated database, with information grouped in representative farms.

and *labor* compared to the control group, as expected. One of the main goals of rural extension is to facilitate the access to new technologies and knowledge, which leads to greater investments and capital use generating higher agricultural income. *Land* production elasticity is greater for the control group. This group is composed mostly by small farmers that often increases production by expanding the productive area. This occurs because of lack of knowledge on more productive techniques or existence of constrained access to financial resources.

The production elasticities of *purchased inputs* and *labor* were the greatest in the two models related to the type of rural extension: public and private. The *capital* production elasticity is around 6 percentage points higher for farmers that have accessed private rural extension compared to farmers that have accessed public services. Farms that have access to private rural extension usually have greater financial resources available. It allows them to have greater investment in capital goods, which also facilitates the extension agent action.

4.3. Analysis of technical efficiency scores

We obtained unbiased farm technical efficiency scores for the five models estimated, and we present the mean and the standard deviation in Table 2.5³⁰. We observed that the average technical efficiency of the farms that have had access to rural extension was of 32.1% opposed to 31.4% from the farms that have not accessed. It suggests that farms that have had access to these services are technically more efficient than the others. The value of the estimated standard deviation for both groups (0.22 and 0.19, respectively) shows the dispersion of the data, which reflects the very heterogeneous sample we have.

³⁰It should be emphasized that, among the rules for the use of the secrecy room in the IBGE, it is not allowed to extract any maximum and minimum values, in order to prevent any producer from being identified through such information.

The use of a very heterogenous and large sample leads to low average technical efficiency. Alves *et al.* (2012) also use microdata from the 2006 Census of Agriculture and find that around 66% of the farms produces around 3% of the gross value of production. They also argue that around 64% of these farms were not been able to pay for their inputs. It is very likely that these farms are located in the lower part of the technical efficiency distribution, which pulls down the average efficiency, as can be seen in Figures A1 and A2, in the appendix.

Studies using more aggregate data usually find higher average technical efficiency because these farms are geographically dispersed. Magalhães *et al.* (2011) use a more homogenous sample and find an average technical efficiency of 47%. Almeida (2012) uses a more aggregate sample and finds an average technical efficiency of 92%. On the other hand, Freitas *et al.* (2014) uses the Agricultural Census of 2006 and finds an average technical efficiency of 62%. Although we are finding low averages, we are interested in the difference between groups. We believe that the magnitude of these differences is not affected by the level of the efficiency.

Table 2. 5 - Mean and standard deviation of the technical efficiency scores for rural extension group considered.

Balanced Sample	N° OBS	Mean	Standard Deviation
<i>Rural Extension</i>	923228	0.3209	0.2245
<i>Without Rural Extension</i>	3336328	0.3137	0.1998
Type of Extension			
<i>Public Rural Extension</i>	381104	0.3285	0.2178
<i>Private Rural Extension</i>	542124	0.3077	0.2274

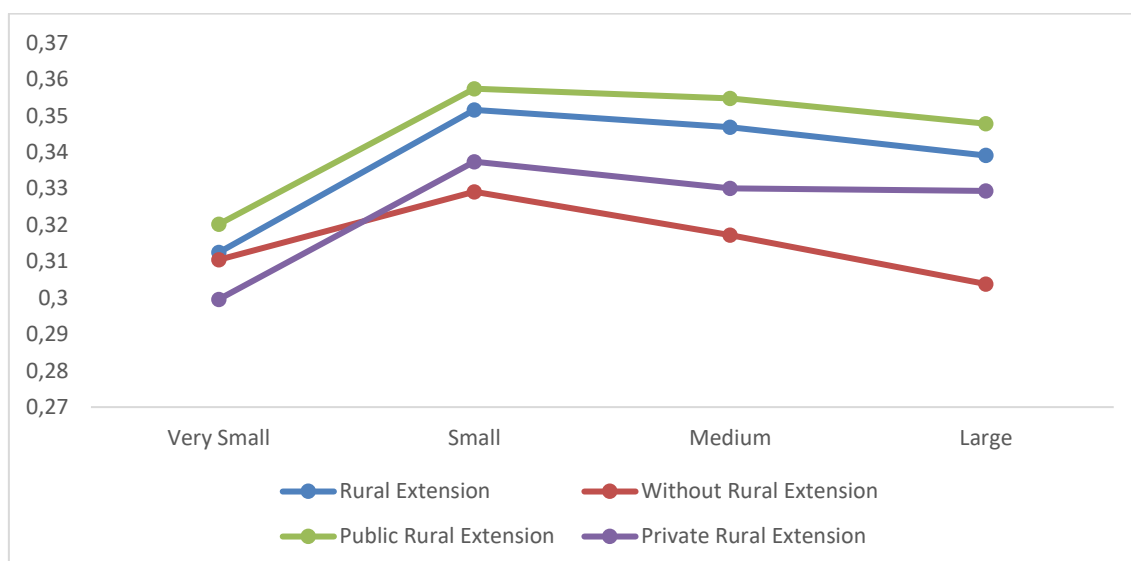
Source: Research results.

We find that farms that have accessed public rural extension have a technical efficiency average 2 p.p. higher than the technical efficiency average of farms that have accessed private rural extension. Despite farms that have accessed public rural extension

are associated with relatively low use of inputs (*land, labor, capital and purchased inputs*) if compared to those that adopt private extension, this result shows a good performance of public rural extension in the transfer of information, knowledge on alternative agricultural and management techniques and other actions in order to allow such producers to use scarce resources more efficiently. Such actions can offset some of the budget and credit constraints faced by these farms, which limit their acquisition of large input quantities and the adoption of more advanced technologies.

In Figure 2.1 we display technical efficiency averages per farm size and group considered in this paper. "Small" farms have shown the highest technical efficiency averages. As the farm size increases the average score decreases. Our results corroborate what have been found in the literature, that a U-inverted relation between farm size and technical efficiency exists in which small farms have the highest efficiency scores (Helfand and Levine, 2004; Freitas *et al.*, 2014, Helfand *et al.*, 2015). We found that access to rural extension has a stronger effect on technical efficiency in the medium and large farms. For large farms the difference in technical efficiency due to these service is approximately 4 p.p..

Figure 2. 1 - Averages of the technical efficiency scores by farm size.



Source: Research results.

5. Conclusions

In this paper we seek to estimate the unbiased effect of rural extension on the Brazilian farm technical efficiency using a stochastic frontier approach that considers sample selection bias and endogeneity of the treatment variable. To estimate this effect we have used more than 4 million observation at farm-level from the microdata of the 2006 Agricultural Census (Brazilian Institute of Geography and Statistics – IBGE).

We have found that a more educated farm manager, more skilled labor in the workforce and the farm ownership status increase the likelihood of accessing rural extension services. The production elasticities results indicated that farms that have not accessed rural extension services rely more on *land* input opposed to farms that have accessed these services. We also find that the private access to these services increase the *capital* production elasticity, which indicates that these services are *capital-intensive*. Our estimates of technical efficiency suggest a good performance of public provision of these services, being the type of extension with greater impact on the

efficiency of Brazilian farms. An even greater effect was observed among large farms, an increase of 4p.p..

Our findings suggest that an increase on public investments in rural extension would result in greater development of rural areas given its effect on agricultural technical efficiency. Although small farms are the main focus of these services, only a small part of these producers have benefited from the extension service, which may reduces overall policy effectiveness. As for the farms that adopted the policy, was observed a greater effect of rural extension on the larger farms, even considering only the public service. This result suggests that for rural extension to be more successful among small producers, it is necessary the joint action of other governmental mechanisms, such as greater access to rural credit policy, and others. This may facilitate the access of such producers to new knowledge research and new productive technologies, most of which are already used by larger farms.

CHAPTER 3

CAN RURAL EXTENSION REDUCE THE INCOME DIFFERENTIAL IN RURAL BRAZIL?

1. Introduction

In developing countries, economic policies mainly target reduction of poverty and income concentration (CHAKRAVARTY *et al.*, 2008). Food insecurity and poverty are the main obstacles to the economic growth and the development of rural areas. Three out of four people living in poverty reside in rural areas and depend directly or indirectly on agricultural activity in these countries (World Bank, 2007). Therefore, it is essential to identify the factors that lead to income enhancement and reduction of income inequality to better design and implement public policies toward the agricultural sector.

Brazilian agriculture has shown a great performance along domestic and international markets. However, this sector still faces a high income inequality. The Gini index of income distribution in rural areas decreased from 0.544 in 2000 to 0.483 in 2010 (Brazilian Institute of Geography and Statistics – IBGE, 2017), which shows a decrease on income inequality between 2000 and 2010. However, Alves *et al.* (2013) shows that 87% of the Brazilian agricultural gross income is generated by 11.4% of the farms in Brazil. The most desirable stage in income inequality, Gini index equal zero, is still a distant target.

Income transfer policies, pension, and other socioeconomic policies have contributed to a modest decrease on income inequality in rural areas. The labor-related

income (both agricultural and non-agricultural) still account for more than 70% of rural household income (HELFAND *et al.*, 2009). To reduce income inequality in these areas, public policies have to increase the agricultural competitiveness, which would lead to an increase in income. Public policies should affect areas beyond agricultural production itself (BARROS *et al.*, 2000).

The National Policy on Technical Assistance and Rural Extension (PNATER) is a public policy that supports this sector giving farmers access to rural extension. There were several public policies on rural extension since the 1950s but it was the creation of PNATER in 2003 and the institutionalization of Law No. 12,188 on Technical Assistance and Rural Extension - ATER³¹ in 2010 that defined socioeconomic guidelines to these policies (PEIXOTO, 2014). It also included new goals, such as provision of managerial tools related to sustainable use of natural resources (Ministry of Agrarian Development – MDA, 2017). PNATER structures the Brazilian rural extension as a "National Decentralized Public Extension System" and encourages the participation of nongovernmental institutions, private companies, unions and cooperatives in addition to public entities (PEIXOTO, 2009).

Access to rural extension can increase farmer's access to new technologies, knowledge and information (CHRISTOPOLOS, 2010). However, only 22% of farmers have had access to these services (IBGE, 2017) and most of the small-scale farmer shave not accessed these services (ALVES *et al.*, 2013; PATA; FERNANDES, 2011). This suggests that the current PNATER structure might not be achieving its goal of also reducing income inequality. To better tackle this problem, it is important to identify the effects of these services on income generation in the Brazilian agricultural sector. In this

³¹ According to Law No. 12,188, of January 11, 2010, technical assistance and rural extension is the informal education service, of a continuous nature, in the rural environment, which promotes processes of management, production, processing and marketing of activities and agricultural and non-agricultural services, including agroextractivist, forestry and artisanal activities (MDA, 2017).

paper we focus on identifying these effects. To estimate them we use an income decomposition proposed by Firpo *et al.* (2007) and the National Household Sample Survey (Pesquisa Nacional de Amostra em Domicílios - PNAD). This method consists in the estimation of income regressions for different unconditional quantiles of income distribution in a first stage. Then the income differential for the groups considered is decomposed to identify the main factors that explain the income gap across all quantiles analyzed.

Our analysis allows to conclude whether rural extension contribute to welfare enhancements of rural families, to increases in rural income and to reductions on rural inequality. Our study contributes to the literature on income inequality in rural areas by identifying the effect of rural extension and other income determinants such as schooling and access to rural credit on different income ranges. We find that although rural extension increases rural household income in the all income distribution quantiles, it also increases income inequality. In addition, we also find that the private rural extension service has a greater effect on rural income compared to public service provision. Regarding the income differential decomposition, the results show that the difference in individual characteristics, especially the schooling and access to rural credit, explains the majority of the income differential.

2. Related Literature

There are several studies that have investigate the effect of rural extension on rural income in developing economies, where great disparities on agricultural income are observed and can be ameliorate. Rural extension can increase farm income in developing countries (ANDERSON; FEDER, 2004), where the majority of the

population lives in rural areas and would observe a greater impact of these policies on population welfare (GAUTAM, 2000).

Rural extension services seek to facilitate producers' access to new technologies, knowledge and information. The extension agent also helps rural producers to develop their own management skills and technical practices aiming to increase agricultural productivity and income, and thus rural welfare (CHRISTOPOLOS, 2010). Alex et al. (2002) indicate several socioeconomic benefits from rural extension such as positive impacts on the environment and the rural families health as a result of the use of appropriate technology, reduction of poverty as a result of greater equity in access to information and greater economic development and food security generated by increases on productivity, competitiveness and sustainability of the agricultural activity.

2.1. Rural Extension in Brazil

Rural extension services have taken place in Brazil since the nineteenth century (BERGARMASCO, 1983). However, these services were mostly performed by non-governmental institutions that sought to assist with on-farm training (PETTAN, 2010). Although these services has always occurred in Brazil, the creation of PNATER established new dimensions (economic and socioeconomic) to the Brazilian rural extension services.

The PNATER also includes goals in developing the rural environment in a sustainable way, the adoption of ecologically based agriculture, ensuring sustainable food and nutritional security and the generation of new agricultural and non-agricultural job (MDA, 2017). However, large farms and farms in more developed agricultural regions continue to obtain greater access to rural extension than smaller farms (ALVES, 2013). It contradicts the new policy directions of focusing in vulnerable groups.

Farms in the North and Northeast regions of Brazil have been poorly provided with rural extension services compared to other regions (KAGEYAMA, 1990). Only 15% of the farms in the Northern region have had access to these services compared to farms in the South, which, on average, 49% of them have had access. However, the implementation of PNATER have led to an increase in resources used on rural extension, from R\$ 3 million on the 2001/02 crop season to R\$ 1.1 billion on the 2015/16 crop season (Sistema Integrado de Administração Financeira do Governo Federal – SIAFI, 2016).

Despite the increase on resources designated to rural extension provision, several PNATER's obstacles have led to great disparities on regional provision. The PNATER system still has low remuneration for extension agents and large costs to provide a rural extension to several farms within the municipality (PEIXOTO, 2014).

2.2. Income Inequality and Rural Extension

Several studies have investigated the determinants of income and income inequality in rural areas in Brazil but without explicitly considering the role of rural extension. Araújo *et al.* (2008) identify the determinants of income inequality in rural areas of the Northeast using data from the PNAD. They calculate poverty indices in addition to an income decomposition methodology proposed by Fei *et al.* (1978). Their findings suggest a reduction in poverty in the period 1995-2001 and that the individual educational level is the most relevant factor explaining income inequality. Mariano and Neder (2006) also examined income inequality in the rural Northeast area of Brazil using data from the PNAD for the period 1999-2001. They have calculated poverty indexes and their findings suggest that agricultural income have contributed to

reductions on income inequality and non-agricultural income was associated with greater inequality.

Ney and Hoffman (2009) identify the determinants of rural income focusing on the role of human and physical capital of rural properties in Brazil using the Demographic Census of 2000. They have estimated income models using the weighted least squares method and find that although physical capital has been the main determinant of rural income, individual educational levels accounts for the largest share of income inequality. They also find that human capital has a larger effect on the formation of non-agricultural income compared to agricultural income.

As for literature focusing on rural areas in other countries, some studies have analyzed the role of rural extension in income inequality. Deribew (2016) investigates the effect of rural extension on household income and income inequality using information on 734 rural households in the northern Ethiopia, a decomposition of the Gini index and regressions of yield function. He identifies a positive effect of rural extension on rural households income and that the rural extension policy increases agricultural income inequality and decrease non-agricultural income inequality. Akpan *et al.* (2016) identify the determinants of poverty and income inequality among 300 young rural producers selected from the state of Akwa Ibom in southern Nigeria using descriptive statistics analyzes and *Logit* regressions. They find that producers with higher levels of schooling and with access to rural extension were less likely to be below the poverty line. It implies that these factors are relevant to reduce income inequality. Akobundu *et al.* (2004) estimate income gains from participating in a rural extension program in the state of Virginia to identify the effect of rural extension on rural income. They have used a two-step procedure to identify the determinants of participation and the effect of the program on income. Results suggest that a single

extension agent visit was not enough to generate significant results but income gains increases with the participation intensity.

These studies highlight the relevance of rural extension in enabling rural families development. There are several other studies that have investigated rural extension under a different perspective. A few papers have identified the impact of rural extension on farm technical efficiency (HELFAND; LEVINE, 2004, MAGALHÃES *et al.*, 2011), farm production and productivity (BALOCH; THAPA, 2016; JIN; HUFFMAN, 2016) and farm profit (HUFFMAN; EVENSON, 1989). Overall, they find that rural extension increases farm technical efficiency, productivity, production and profitability.

On the other hand, most of these studies have not focused on the effect of rural extension on these variables and have not estimated its effect on rural household income. It lacks in the literature a study that focus in this topic and uses a suitable methodology that allows to identify the effect of rural extension on different points of the income distribution, as well as to analyze the main factors that explain the difference of income between households that receive and do not receive the extension service. We seek to identify these effects using the household dataset (PNAD) made available by IBGE and the income decomposition methodology proposed by Firpo *et al.* (2007).

3. Theoretical model

The theoretical model used to analyze the effect of rural extension on the income of Brazilian rural households is based on models related to investments in human capital, such as those described by Mincer (1974), Becker (1962) and others.

Anderson and Feder (2004) argue that rural extension services fits within the human capital theory due to its ability affect farmer managerial skills and their agricultural production and income throughout the provision of information and

knowledge. These rural extension services also focus on providing an educational service to farm welfare enhancements throughout improvements on farm production (RODRIGUES, 1997; PLATA; FERNANDES, 2011).

Mincer (1974) and Becker (1962) have extensively discussed about income effect of investments in human capital. Mincer (1974) framework has been used to identify the factors that explain the household income level and inequality. It allows to determine the factors that explain income distribution across regions, countries or groups of individuals. Mincer (1974) described the relation between income and education throughout a wage function that depends on education and experience. It can be represented by

$$Y_i = a + b_1s_i + b_2j_i + b_3j_i^2 + v_i \quad (1)$$

where Y_i refers to the labor income, or wage of the individual; s_i refers to the individual's schooling, measured in years of study; j_i represents the age as a *proxy* to experience; a and b are the parameters to be estimated; and v refers to the random error term. Higher levels of schooling and experience would lead to higher wages (MINCER, 1974).

Mincer (1974) argues that individual human capital improvements also result in an increase in their marginal productivity and thus in an increase on their market value, which would increase the economic agent expectations on higher income. Therefore, the human capital theory provides a link between the individual income and the professional characteristics such as schooling, years of training and/or other factors. Therefore, as in Mincer (1974) wage function we expect a positive effect of rural extension on individual income given the correlation between rural extension and Mincer's explanatory variables such as education and experience.

Singh *et al.* (1986) also develop a theoretical model on the role of human capital in income. They adapt Becker's seminal work (1965) to investigate the effect of public policies on the well-being of rural households. Their model assumes that rural families allocate their time between work and leisure to maximize their utility function. It shows that increases in technology and human capital allows producers to allocate less time to labor and still maintain the same consumption, keeping the other factors and the budget constraint constant. Therefore, an efficient rural extension provision could increase rural income and profitability in two ways: incorporating better technologies to the production; and increasing farmer knowledge and skills, which represents an increase on farmer human capital.

Non-agricultural income also contribute to improvements on rural households welfare (SCHEIDER, 2001; URGESSA, 2015). Reardon *et al.* (2001) suggest that the farmer decision to work in non-agricultural activities depends mainly on two factors: economic incentives in the non-agricultural activity such as profitability; and individual abilities such as education, knowledge and skills, access to credit and access to rural extension. PNATER also seeks to generate new agricultural and non-agricultural jobs (MDA, 2007). It implies that the extension agent also can suggest complementary activities (agricultural and non-agricultural) to the farmer seeking to complement their income.

These studies show that rural extension services effect affect rural income. In this paper, we proposed rural income functions based on Dercon (2006) and Urgessa (2015) in which we incorporate the effect of access to rural extension along with the other farm/farmer economic characteristics (access to credit, farm size, etc.) and non-economic (gender, race, age, etc.) on income. It is represented as

$$Y_i = \alpha_i + \beta X_i + \phi RE_i + \varepsilon_i \quad (2)$$

where the dependent variable Y_i represents the household i income of rural properties (from agricultural and non-agricultural sources), X_i is the vector of covariates that explains rural income such as schooling, gender, race and farm size, and RE_i represents rural extension services. Thus, from (2) is expect a positive effect of Rural Extension on rural income.

4. The application

We first use the unconditional quantile regression method to identify the effect of the rural extension on different income quantiles in the Brazilian rural area based on Firpo *et al.* (2007, 2009). We then identify the farmer characteristics that create generate the income difference between the groups of farms by access to rural extension. In this section we present the dataset used to identify the effect of rural extension on income and the empirical methodology used to achieve this goal.

4.1. Data

We use the National Household Sample Survey (PNAD) for 2014, being made available by the IBGE³². In the 2014 PNAD a supplementary questionnaire was provided to the households in which questions related to access to rural extension were included. In this article, we define rural extension as what the PNATER delineates as technical assistance and rural extension. Individuals self-declared employers or self-employed as the main activity were questioned whether they have received any technical assistance during the last year. Technical assistance was split in four categories: Technical Assistance and Rural Extension Company (Empresa de

³² According to Araújo *et al.* (2008), the National Household Survey is a unique survey, conducted annually and nationwide, raising a variety of information about the population's well-being and setting thus a major source of data on the Brazilian social environment.

Assistência Técnica e Extensão Rural – EMATER); other government agency (federal, state or municipal); private company; or another source. We constructed dummy variables to represent access to rural extension based on these categories.

In this paper we have considered rural producers those that are: 1) economically active people; 2) employers or self-employed workers (these being the individuals interviewed in the questionnaire on productive inclusion); 3) and whose main activity of the enterprise was agricultural activity. Our sample also included a small portion of rural property managers residing in urban areas, which also appears in the microdata of the Agricultural Census of 2006 (IBGE, 2017). After dropping missing values and outliers, the final sample consists of 15,406 individuals. A descriptive statistical analysis of the data is presented in the results section.

We use monthly household income in R\$ as a proxy to farmer income. In addition to a variable capturing access to rural extension, we have included the following variables:

- i) Gender: a dummy variable equals to 1 if the individual (responsible for the domicile) is male;
- ii) Race: a dummy variable equals to 1 if the individual is black;
- iii) Schooling: several dummy variable split in the categories “do not read and write”, “incomplete elementary school”, “complete elementary school”, “incomplete high school”, “complete high school”, “incomplete higher education” and “complete higher education”;
- iv) Rural: a dummy variable equals to 1 if the individual resides in the rural area;
- v) Credit: a dummy variable equals to 1 if the individual have received credit from any credit program;

- vi) Land ownership: several dummy variables seeking to identify the condition of the producer in relation to the land such as whether the producer is a partner, tenant, occupant, owner or other condition;
- vii) Farm area: four dummy variables that represent the farm size split in very small (up to 10 hectares (ha)), small (10 to 100ha), medium (100 to 1000ha) and large (greater than 1000ha).

The group characteristics are presented in Table 3.1. Our sample is composed by 15,406 rural producers³³, in which only 14.1% have had access to rural extension in 2014 split in public extension (56% of those) and private extension (44%).

³³ Farmers were considered individuals whose main activity was agricultural, as an employer and/or self-employed.

Table 3. 1 - Mean and standard deviation of the variables used, for total sample and by rural extension group considered.

Variables	Brazil		No Rural Extension		Rural Extension		Public Rural Extension		Private Rural Extension	
	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD
<i>Income</i>	2505	3473	2252	3132	4051	4797	3200	3700	5143	5734
<i>Gender</i>	0.855	0.352	0.854	0.354	0.864	0.343	0.881	0.324	0.842	0.365
<i>Race</i>	0.0733	0.261	0.0778	0.268	0.0461	0.210	0.0739	0.262	0.0105	0.102
<i>Studyyears</i>	5.588	3.988	5.314	3.909	7.262	4.059	6.433	3.914	8.326	3.995
<i>do not read and write</i>	0.00402	0.0633	0.00400	0.0631	0.00415	0.0643	0.00739	0.0857	0	0
<i>incomplete elementary</i>	0.223	0.416	0.244	0.429	0.0978	0.297	0.140	0.348	0.0432	0.203
<i>complete elementary</i>	0.518	0.500	0.519	0.500	0.507	0.500	0.524	0.500	0.486	0.500
<i>incomplete high school</i>	0.0843	0.278	0.0775	0.267	0.126	0.331	0.123	0.329	0.129	0.335
<i>complete high school</i>	0.0329	0.178	0.0322	0.176	0.0374	0.190	0.0320	0.176	0.0443	0.206
<i>incomp. higher education</i>	0.107	0.309	0.0977	0.297	0.160	0.367	0.137	0.344	0.190	0.392
<i>comp. higher education</i>	0.0317	0.175	0.0258	0.158	0.0678	0.252	0.0361	0.187	0.109	0.311
<i>age25</i>	0.0537	0.226	0.0571	0.232	0.0332	0.179	0.0255	0.158	0.0432	0.203
<i>age26to35</i>	0.150	0.357	0.149	0.357	0.151	0.358	0.119	0.324	0.193	0.395
<i>age36to45</i>	0.218	0.413	0.216	0.411	0.234	0.424	0.226	0.418	0.246	0.431
<i>age46to55</i>	0.261	0.439	0.256	0.436	0.295	0.456	0.291	0.455	0.300	0.459
<i>age56to65</i>	0.206	0.405	0.207	0.405	0.205	0.404	0.240	0.427	0.160	0.367
<i>age65more</i>	0.110	0.313	0.115	0.319	0.0808	0.273	0.0985	0.298	0.0580	0.234
<i>Rural</i>	0.733	0.443	0.722	0.448	0.797	0.402	0.825	0.380	0.761	0.427
<i>Credit</i>	0.127	0.333	0.0766	0.266	0.434	0.496	0.408	0.492	0.467	0.499
<i>Partner</i>	0.0573	0.232	0.0581	0.234	0.0526	0.223	0.0460	0.210	0.0611	0.240
<i>Tenant</i>	0.0531	0.224	0.0516	0.221	0.0623	0.242	0.0378	0.191	0.0938	0.292
<i>Occupant</i>	0.0469	0.211	0.0486	0.215	0.0369	0.189	0.0427	0.202	0.0295	0.169
<i>Owner</i>	0.754	0.430	0.746	0.435	0.805	0.396	0.824	0.381	0.780	0.415
<i>Others</i>	0.0883	0.284	0.0956	0.294	0.0434	0.204	0.0493	0.217	0.0358	0.186
<i>very small</i>	0.600	0.490	0.622	0.485	0.468	0.499	0.539	0.499	0.377	0.485
<i>Small</i>	0.262	0.440	0.242	0.428	0.386	0.487	0.346	0.476	0.437	0.496
<i>Medium</i>	0.0704	0.256	0.0700	0.255	0.0729	0.260	0.0517	0.222	0.100	0.300
<i>Large</i>	0.0467	0.211	0.0450	0.207	0.0572	0.232	0.0542	0.226	0.0611	0.240
#Obs	15406		13239		2167		1218		949	

Source: Research results based on PNAD data from 2014. Note: SD - Standard deviation

We observe that farmers that have had access to rural extension services (group A) had a monthly income of, on average, R\$ 4,051.00, while the average income of those that have not accessed rural extension (group B), on average, was R\$ 2,252.00. The large standard deviation on this variable indicates great heterogeneity or a wide income distribution. Farmers in group A have a higher education level, on average, 7.3 years compared to farmers on Group B that have, on average, 5.3 years. Farmers in Group A also have a greater access to credit, on average, 43.4% of them had access to credit while only 7.7% of the farmer in Groups B have accessed to credit.

We do not observe a substantial difference between groups on farmer's age. 85% of the sample is male, 73% of sample lives in rural areas and 75% of them own the farm. On average, the monthly household income reported by farmers that have accessed private rural extension (R\$ 5,143) is 60% higher than the average income of farms that have had access to public service (R\$ 3,200). Farmers that have accessed private rural extension services have a higher level of education and have had greater access to credit. Among farmers in group A, 54% of them have had access to public rural extension services.

4.2. The unconditional quantile regression approach

To identify the effects of rural extension on rural income and income inequality we use the unconditional quantile regression approach proposed by Firpo *et al.* (2009) and the concept of Recentered Influence Function (RIF). The influence function³⁴ allows to identify the relative effect (the influence) of an individual observation on a statistic of interest (SILVA; FRANÇA, 2016). That is, for a distribution statistic $v(F_y)$, the

³⁴ The influence function method basically provides a linear approximation for a nonlinear function of a statistical distribution of interest, such as quantiles, variance or others, allowing to estimate the effect of one or more covariates on the distribution of the statistics of interest (CHI; LEE, 2008). For more details, see Chi and Lee (2008) and Firpo *et al.* (2009).

influence of each observation on $\nu(F_y)$ is given by the influence function $IF(y; \nu, F_y)$. The incorporation of the statistic $\nu(F_y)$ in the influence function results in the so-called Recentered Influence Function, $RIF(y; \nu) = \nu(y) + IF(y; \nu)$. It allows to analyze the effects of individual covariates on the statistical distribution of interest. We are interested on the distribution of the quantiles but it can also be applied to different statistical distributions such as Gini coefficient, variance, or another that can represent income inequality³⁵.

We define the τ -th quantile (q_τ) of the income distribution Y as $q_\tau = \nu_\tau(F_y) = \inf_q \{q : F_y(q) \geq \tau\}$, and its influence function $IF(y; q_\tau, F_y)$ as:

$$IF(y; q_\tau, F_y) = \frac{\tau - 1\{y \leq q_\tau(F_y)\}}{f_y(q_\tau(F_y))} \quad (7)$$

where $1\{y \leq q_\tau(F_y)\}$ is an indicator function, which shows whether the variable Y (monthly household income) is less than or equal to the quantile q_τ , and $f_y(q_\tau(F_y))$ represents the marginal density function of the distribution of Y evaluated in q_τ .

The recentered influence function, which will replace the dependent variable Y in the unconditional quantile analysis, is defined by the sum of the distribution statistics and their respective influence function, $RIF(y; \nu, F_y) = \nu(F_y) + IF(y; \nu, F_y)$. Thus, adapting the expression to the τ -th quantile (q_τ), the RIF for each income quantile is given by:

$$RIF(y; q_\tau, F_y) = q_\tau + \frac{\tau - 1\{y \leq q_\tau(F_y)\}}{f_y(q_\tau(F_y))} = c_{1\tau} \cdot 1\{y \leq q_\tau(F_y)\} + c_{2\tau} \quad (8)$$

³⁵ For an average, e.g. $\mu(F_y)$, the influence function - IF, would be given by $IF(y; \mu(F_y)) = y - \mu(F_y)$, with the RIF specified as: $RIF(y; \mu) = IF(y; \mu) + \mu$. Firpo *et al.* (2007) present the RIF regressions for the case of the variance and Gini coefficient.

where $c_{1\tau} = \frac{1}{f_y(q_\tau)}$ and $c_{2\tau} = q_\tau - c_{1\tau} \cdot (1 - \tau)$ and the conditional expectation is $\nu(F_y)$

(FIRPO *et al.*, 2009; SILVA; FRANÇA, 2016)

$$E[RIF(y; \nu, F_y)] = \nu(F_y) \quad (9)$$

We first obtain the sample quantile \hat{q}_τ (FIRPO *et al.*, 2009; KOENKER; BASSET, 1978) and then the marginal density function $\hat{f}_y(\hat{q}_\tau)$ through Kernel functions³⁶. After obtaining these estimates, they are incorporated in (8).

Assume a covariate vector X and the conditional expectation of the RIF as a function of X ; i.e. $E[RIF(y; \nu, F_y) | X = x]$. Then, it can be represented as a linear regression in function of X , $RIF(y; \nu, F_y) = X\beta + \varepsilon$. Assuming $E[\varepsilon | X] = 0$ and applying the Law of Iterated Expectations, we have the unconditional quantile regression

$$\nu(F_y) = E_x[E[RIF(y; \nu, F_y)]] = E[X]\beta \quad (10)$$

where y represents the monthly rural household income; $RIF(y; \nu, F_y)$ is the recentered influence function, which replaces the observed y in each observation; X is the vector of explanatory variables, described in the previous section; and β are the coefficients of interest, which capture the effect of changing the distribution of a variable on the

³⁶ As presented in Koenker and Basset (1978), the τ -th quantile estimator of the marginal distribution of Y (\hat{q}_τ), can be defined as: $\hat{q}_\tau = \arg \min_q \sum_{i=1}^N (\tau - 1\{Y_i - q \leq 0\}) \cdot (Y_i - q)$. The density function of Y

is obtained by estimating the kernel density: $\hat{f}_y(\hat{q}_\tau) = \frac{1}{Nb} \cdot \sum_{i=1}^N K_y\left(\frac{Y_i - \hat{q}_\tau}{b}\right)$, where $K_y(z)$ is a

kernel function and b is a positive scalar bandwidth. For more details see Firpo, Fortin and Lemieux (2009).

unconditional quantile of y or the unconditional quantile partial effect (FIRPO *et al.*, 2009). These coefficients can be estimated by OLS or another linear estimator³⁷.

As a limitation, it is important to note that in the estimation of nonconditional quantile regression we do not directly address the possible endogeneity in the adoption of rural extension. There is a possibility of such a bias since access to rural extension is a producer's choice, which can be affected by both observable and unobservable factors. However, we did not find adequate instrumental variables in the PNAD supplemental questionnaire to deal with this problem. In addition, the simultaneity between income and private rural extension can be a source of endogeneity, since higher income farms tend to have greater access to private service. Therefore, the coefficients estimated in this first step may be subject to the endogeneity bias. As a result of this limitation, the contribution of rural extension in the different income quantiles should not be interpreted as a causal relation.

The conditional quantile regression approach proposed by Koenker and Basset (1978) is different from the unconditional quantile regression proposed by Firpo *et al.* (2007, 2009), which is used in this paper. The former approach only allows to estimate the "within-group"³⁸ effect (FIRPO *et al.*, 2009). The unconditional quantile regression allows to estimate both "within-group" effect and the "between-group" effect. The latter effect represents the impact of a given variable throughout the entire distribution.

³⁷Firpo *et al.* (2009) present three possibilities of estimators, which are: ordinary least squares, logistic estimator, and a non-parametric estimator. However, the results presented by the three methods were very close, and inferences cannot be made about the advantage of one estimator over another.

³⁸The result for each quantile depends on the X characteristics of the individuals in that group and cannot be extrapolated to the other quantiles. It does not allow to analyze the effect of a given variable on the entire Y distribution (e.g., a positive rural extension effect, but lower for the .90 quantile compared to the .10 quantile, does not necessarily indicate that the policy contributes to the reduction of income inequality).

4.3. Decomposition of income differentials

We use an income decomposition procedure proposed by Firpo *et al.* (2007)³⁹ to estimate the income differentials between groups: farms that have accessed rural extension and farmers that have not. It consists of estimating the RIF regression along with a re-weighting scheme proposed by DiNardo *et al.* (1996). It is an adaptation of the Oaxaca-Blinder⁴⁰ decomposition approach which allows to expand the decomposition to other statistics of interest such as quantiles, variance and Gini coefficient.

Let's assume two groups of households: *A* (farmers that have accessed rural extension) and *B* (that have not accessed); a result variable *Y* (logarithm of household incomes); and a group of covariates that represents individuals characteristics. The decomposition seeks to identify the difference in the income distributions of the two groups based on some statistics of these distributions opposed to only analyzing the mean. It is represented as

$$\Delta^v = v(F_{yA}) - v(F_{yB}) \quad (11)$$

where $v(F_{yt})$ represents a statistic of the income distribution (income quantiles on this paper), for two groups $t = A, B$.

The term Δ^v is then divided in two components: difference in the observable individuals characteristics (Composition Effect); and difference in coefficients between the two groups (Return Effect). To implement this decomposition, first a counterfactual distribution (F_{yc}) has to be obtained in addition to its statistics of interest $v(F_{yc})$ such as in (10). It allows to simulate an income distribution with characteristics of group *A*

³⁹This method has been used in other studies such as in Machado and Mata (2005).

⁴⁰ The traditional Oaxaca-Blinder decomposition approach (Blinder, 1973; Oaxaca, 1973) consists of decomposing the mean income differences (or other outcome variable) of two groups of individuals into two components: one associated with the observed characteristics and the other related to the return of such characteristics, allowing also to identify the contribution of each explanatory variable over the total estimated difference. For more details, see Jann (2008).

and the returns (coefficients) to the characteristics of group B . We can insert F_{yc} in (11)

to obtain

$$\begin{aligned}\Delta^v &= [\nu(F_{yB}) - \nu(F_{yc})] + [\nu(F_{yc}) - \nu(F_{yA})] \\ \Delta^v &= \Delta_R^v + \Delta_X^v\end{aligned}\tag{12}$$

where the total income differential is decomposed into two terms: Δ_R^v , which represents the portion of the differential resulting from the differences in the returns (coefficients) of the characteristics (return effect); and Δ_X^v , which represents the portion of the differential associated with the differences in the distributions of the characteristics (composition effect).

To obtain (12) we re-estimate the RIF regressions for each of the groups and obtain the conditional expectation of the recentered functions of influence. This allows to obtain the expected value of the RIF for the observed distributions $\nu(F_{yt})$ and the counterfactual distribution $\nu(F_{yc})$ in a linear specification

$$\nu(F_{yt}) = E[RIF(y_t; \nu_t) | X, T = t] = X_t \beta_t\tag{13}$$

$$\nu(F_{yc}) = E[RIF(y_A; \nu_C) | X, T = B] = X_C \beta_C\tag{14}$$

for $t = A, B$. To obtain the parameters of interest β , Firpo *et al.* (2007) uses a reweighting technique based on the study of DiNardo *et al.* (1996). The reweighting factors for each group are

$$\begin{aligned}\hat{\omega}_A(T) &= \frac{T}{\hat{\rho}}, \\ \hat{\omega}_B(T) &= \frac{1-T}{1-\hat{\rho}}, \text{ and}\end{aligned}\tag{15}$$

$$\hat{\omega}_C(T; X) = \left[\frac{\hat{\rho}(X)}{1-\hat{\rho}(X)} \right] \left[\frac{1-T}{\hat{\rho}} \right]$$

where T is either 1 or 0 and indicates whether the individual participates in group A (value 1) or B (value 0); and $\hat{\rho}$ is an estimator of the probability that a farmer have accessed rural extension (group A , or $T = 1$) given the characteristics vector X and may be estimated using a probability model such as *Logit* or *Probit* (CHI; LI, 2008).

After obtaining the reweighting factors the RIF regressions for each group can be estimated by OLS

$$\hat{\beta}_t = \left(\sum_{i \in t} \hat{\omega}_i \cdot X_i \cdot X_i' \right)^{-1} \cdot \sum_{i \in t} \hat{\omega}_i \cdot \hat{RIF}(y_{it}; \nu_t) X_i \quad (16)$$

for $t = A, B$ and for the counterfactual the RIF is estimated as

$$\hat{\beta}_C = \left(\sum_{i \in A} \hat{\omega}_C(X_i) \cdot X_i \cdot X_i' \right)^{-1} \cdot \sum_{i \in A} \hat{\omega}_C(X_i) \cdot \hat{RIF}(y_{Ai}; \nu_C) X_i \quad (17)$$

where the decomposition presented in (11) can be obtained as

$$\begin{aligned} \hat{\Delta}^v &= \left[\bar{X}_B \cdot \hat{\beta}_B - \bar{X}_C \cdot \hat{\beta}_C \right] + \left[\bar{X}_C \cdot \hat{\beta}_C - \bar{X}_A \cdot \hat{\beta}_A \right] \\ \hat{\Delta}^v &= \hat{\Delta}_R^v + \hat{\Delta}_X^v \end{aligned} \quad (18)$$

We can also identify the contribution of each covariate X_k , where $k = 1, \dots, K$, on each of the effects obtained in (18) as in

$$\hat{\Delta}_X^v = \sum_{k=1}^K (\bar{X}_{ck} - \bar{X}_{Ak}) \hat{\beta}_A \quad (19)$$

$$\hat{\Delta}_R^v = \left(\hat{\beta}_{B1} - \hat{\beta}_{C1} \right) + \sum_{k=2}^K \bar{X}_{Bk} \left(\hat{\beta}_{Bk} - \hat{\beta}_{Ck} \right) \quad (20)$$

where in (20) the first term (difference in the returns of the covariate $k = 1$) represents the difference in the intercepts of the regressions of groups A and B , and the second term represents the contribution of the return of each covariate in the total return effect. Thus, a positive result for a given covariate, for example schooling, in (19) would indicate that the higher schooling of the producers served by the rural extension

contributed to raise the income differential between the adopters and non-adopters of the extension service. A positive result in (20) would indicate that the increase in the income differential is explained by the higher return (coefficient) of schooling by farmers with rural extension.

Fortin *et al.* (2011) argue that one of the main shortcomings of this method is that the feedback effect is sensitive to the choice of the base group. However, they indicate that there is no other method that corrects this limitation. On the other hand, this method presents is path independent which means that the order in which the different elements of the detailed decomposition are calculated does not affect the results of the decomposition (OLIVEIRA; SILVEIRA NETO, 2015).

5. Results and discussion

We first present the results of the unconditional quantile regression and then the results of the income decomposition to our sample of 15,406 rural producers. In short, we find that although rural extension increases rural income, it also increases income inequality. In addition, the results of the income differential decomposition show that higher level of schooling and access to rural credit augment the effect of rural extension on rural income but also contribute to the aggravation of the income inequality.

5.1. Effect of rural extension in rural income

In this section we present the results of the RIF regressions for the unconditional income distribution quantiles of the logarithm of monthly household income and of the ordinary least squares (OLS). The estimated coefficients have shown some variations along the income distribution quantiles with respect to the estimated coefficients

obtained for the mean. This result re-enforces the need to use the unconditional quantile regression approach. Results are displayed in Table 3.2.

Table 3. 2 - Estimates of unconditional quantile regression – Brazil (2014).

Ln(Yi)	MQO	q10	q20	q30	q40	q50	q60	q70	q80	q90
<i>Rural Extension</i>	0.426*** (0.0208)	0.285*** (0.0301)	0.339*** (0.0264)	0.394*** (0.0273)	0.469*** (0.0292)	0.361*** (0.0240)	0.411*** (0.0249)	0.523*** (0.0318)	0.581*** (0.0411)	0.601*** (0.0583)
<i>Gender</i>	-0.0339* (0.0189)	-0.0492 ^{NS} (0.0434)	-0.132*** (0.0314)	-0.156*** (0.0298)	-0.0605** (0.0301)	-0.00654 ^{NS} (0.0233)	-0.0286 ^{NS} (0.0221)	-0.0115 ^{NS} (0.0249)	0.0312 ^{NS} (0.0279)	0.0481 ^{NS} (0.0359)
<i>Race</i>	-0.168*** (0.0270)	-0.0135 ^{NS} (0.0629)	-0.0808* (0.0464)	-0.171*** (0.0438)	-0.212*** (0.0415)	-0.232*** (0.0307)	-0.192*** (0.0283)	-0.247*** (0.0298)	-0.253*** (0.0292)	-0.192*** (0.0361)
<i>Incomplete Elementary</i>	0.0311 ^{NS} (0.120)	0.482 ^{NS} (0.343)	0.585** (0.228)	0.115 ^{NS} (0.195)	-0.288 ^{NS} (0.183)	-0.223 ^{NS} (0.143)	-0.310** (0.132)	-0.191 ^{NS} (0.141)	-0.385** (0.159)	0.0378 ^{NS} (0.0650)
<i>Complete Elementary</i>	0.287** (0.119)	0.674** (0.342)	0.791*** (0.228)	0.318 ^{NS} (0.194)	-0.0140 ^{NS} (0.182)	0.00729 ^{NS} (0.143)	-0.0501 ^{NS} (0.131)	0.114 ^{NS} (0.140)	-0.0539 ^{NS} (0.159)	0.356*** (0.0643)
<i>Incomplete High School</i>	0.480*** (0.121)	0.893*** (0.344)	0.971*** (0.230)	0.470** (0.197)	0.187 ^{NS} (0.185)	0.183 ^{NS} (0.145)	0.0833 ^{NS} (0.134)	0.344** (0.144)	0.188 ^{NS} (0.164)	0.600*** (0.0828)
<i>Comp. High School</i>	0.504*** (0.125)	0.850** (0.352)	0.959*** (0.236)	0.599*** (0.203)	0.156 ^{NS} (0.191)	0.172 ^{NS} (0.149)	0.0951 ^{NS} (0.138)	0.323** (0.149)	0.323* (0.171)	0.777*** (0.112)
<i>Incomp. Higher education</i>	0.691*** (0.121)	0.890*** (0.344)	1.154*** (0.229)	0.718*** (0.196)	0.448** (0.184)	0.388*** (0.144)	0.350*** (0.133)	0.578*** (0.144)	0.416** (0.163)	0.894*** (0.0834)
<i>Comp. Higher education</i>	1.289*** (0.126)	1.035*** (0.343)	1.223*** (0.229)	0.826*** (0.198)	0.631*** (0.186)	0.629*** (0.146)	0.633*** (0.136)	1.077*** (0.149)	1.384*** (0.174)	2.306*** (0.145)
<i>Age26_35</i>	-0.0312 ^{NS} (0.0340)	-0.0106 (0.0922)	-0.0970 ^{NS} (0.0664)	-0.180*** (0.0599)	-0.156*** (0.0568)	-0.114*** (0.0420)	-0.0471 ^{NS} (0.0363)	-0.0748* (0.0413)	-0.0989** (0.0479)	0.0409 ^{NS} (0.0616)
<i>Age36_45</i>	0.138*** (0.0329)	0.252*** (0.0867)	0.197*** (0.0629)	0.0910 ^{NS} (0.0576)	0.0782 ^{NS} (0.0552)	0.0160 ^{NS} (0.0410)	0.102*** (0.0357)	0.0530 ^{NS} (0.0408)	-0.00802 ^{NS} (0.0473)	0.133** (0.0609)
<i>Age46_55</i>	0.197*** (0.0328)	0.153* (0.0874)	0.245*** (0.0624)	0.186*** (0.0574)	0.157*** (0.0552)	0.105** (0.0411)	0.208*** (0.0360)	0.165*** (0.0413)	0.0838* (0.0480)	0.193*** (0.0625)
<i>Age56_65</i>	0.476*** (0.0341)	0.513*** (0.0871)	0.677*** (0.0627)	0.638*** (0.0586)	0.590*** (0.0572)	0.405*** (0.0430)	0.411*** (0.0381)	0.329*** (0.0433)	0.234*** (0.0500)	0.337*** (0.0649)
<i>Age65m</i>	0.786*** (0.0372)	0.845*** (0.0862)	1.053*** (0.0616)	1.062*** (0.0585)	1.165*** (0.0578)	0.844*** (0.0455)	0.644*** (0.0424)	0.509*** (0.0489)	0.364*** (0.0563)	0.466*** (0.0724)
<i>Rural</i>	-0.246*** (0.0158)	-0.178*** (0.0317)	-0.209*** (0.0244)	-0.210*** (0.0242)	-0.232*** (0.0245)	-0.201*** (0.0190)	-0.225*** (0.0186)	-0.304*** (0.0221)	-0.283*** (0.0256)	-0.312*** (0.0344)

<i>Rural Credit</i>	0.257*** (0.0215)	0.204*** (0.0316)	0.166*** (0.0285)	0.251*** (0.0286)	0.241*** (0.0309)	0.235*** (0.0249)	0.259*** (0.0258)	0.318*** (0.0326)	0.407*** (0.0421)	0.303*** (0.0579)
<i>Partner</i>	-0.0374 ^{NS} (0.0290)	0.0368 ^{NS} (0.0666)	0.0414 ^{NS} (0.0519)	-0.0171 ^{NS} (0.0485)	-0.0765 ^{NS} (0.0466)	-0.128*** (0.0347)	-0.0644** (0.0327)	-0.0898** (0.0365)	-0.120*** (0.0414)	-0.0880* (0.0525)
<i>Tenant</i>	0.000632 ^{NS} (0.0287)	-0.0608 ^{NS} (0.0673)	-0.0159 ^{NS} (0.0501)	0.0151 ^{NS} (0.0467)	0.0567 ^{NS} (0.0462)	0.0331 ^{NS} (0.0355)	0.0368 ^{NS} (0.0356)	0.0177 ^{NS} (0.0411)	-0.0741 ^{NS} (0.0458)	0.00342 ^{NS} (0.0627)
<i>Ocupant</i>	-0.0989*** (0.0356)	0.0409 ^{NS} (0.0820)	-0.0637 ^{NS} (0.0650)	-0.130** (0.0609)	-0.211*** (0.0572)	-0.129*** (0.0411)	-0.100*** (0.0368)	-0.157*** (0.0355)	-0.125*** (0.0357)	-0.143*** (0.0346)
<i>Other_condition</i>	-0.261*** (0.0242)	-0.450*** (0.0694)	-0.235*** (0.0468)	-0.258*** (0.0422)	-0.260*** (0.0399)	-0.225*** (0.0292)	-0.268*** (0.0252)	-0.296*** (0.0265)	-0.265*** (0.0272)	-0.138*** (0.0362)
<i>Small</i>	0.257*** (0.0164)	0.268*** (0.0302)	0.266*** (0.0239)	0.219*** (0.0243)	0.240*** (0.0249)	0.202*** (0.0197)	0.224*** (0.0195)	0.276*** (0.0231)	0.346*** (0.0279)	0.296*** (0.0360)
<i>Medium</i>	0.370*** (0.0291)	0.183*** (0.0479)	0.186*** (0.0387)	0.158*** (0.0389)	0.167*** (0.0401)	0.196*** (0.0315)	0.305*** (0.0317)	0.445*** (0.0386)	0.541*** (0.0492)	0.881*** (0.0771)
<i>Large</i>	0.334*** (0.0335)	0.339*** (0.0529)	0.320*** (0.0452)	0.329*** (0.0468)	0.375*** (0.0485)	0.247*** (0.0406)	0.252*** (0.0396)	0.266*** (0.0474)	0.331*** (0.0576)	0.427*** (0.0824)
<i>Intercept</i>	6.811*** (0.124)	5.218*** (0.353)	5.525*** (0.235)	6.392*** (0.202)	6.928*** (0.190)	7.207*** (0.149)	7.449*** (0.137)	7.556*** (0.148)	7.964*** (0.169)	7.832*** (0.0916)
Observations	15,406	15,406	15,406	15,406	15,406	15,406	15,406	15,406	15,406	15,406
F	233.93	42.84	107.09	129.21	169	189.47	205.42	198.2	147.52	64.51
R-squared	0.259	0.058	0.118	0.143	0.168	0.183	0.190	0.204	0.201	0.157

Source: Research results.

Note: RE – Rural Extension; *** significant at 1%, **significant at 5%, * significant at 10%, NS - non significant; Standard errors in parentheses.

Our results suggest a positive effect of rural extension services on rural income and it increases as we evaluate higher quantiles of the income distribution. For instance, the coefficients for the first two income quantiles, q10 and q20, suggest that farmers in group A are associated with an income 28.5% and 33.9% higher than those in group B. The distance between the two immediate quantiles decreases as we evaluate higher quantiles; i.e. for q80 and q90, they were 58.1% and 60.1%, respectively. These results show two effects of rural extension: these services raise monthly household income; and, on the other hand, it increases income inequality in rural Brazil by having a stronger effect in higher income quantiles.

Alves *et al.* (2013) state that one of the main objectives of rural extension services is to increase rural income throughout the dissemination of new technologies and reduction of the negative effects caused by market imperfections. However, a higher access to these services by large and more profitable farms contributes to the maintenance of the income inequality. Deribew (2016) find a similar result for farmers in Ethiopia in which results suggest a positive effect of rural extension on the rural income and an increase on income inequality in the agricultural activity⁴¹.

Gender and *race* variables do not show a great discriminatory effect in the income quantiles analyzed. Women show a higher income compared to men only at the bottom of the income distribution. We also find that black individuals face lower wages compared to non-black individuals but there is no clear pattern along the income distribution. Overall, a higher level of education such as “complete elementary school”, “high school” and “higher education” is related to greater income compared to the base variable, “people who cannot read or write”. Duarte *et al.* (2003), Oliveira and Silveira Neto (2015), and Reis *et al.* (2017) have also identified positive effects of investments

⁴¹However, when considering different sources of income from livestock and other non-agricultural sources, Deribew (2016) finds a negative effect of rural extension on income inequality.

in human capital on income. Our results show that education can decrease income inequality; i.e. great income returns to “high school” level in the first quantiles of income distribution. On the other hand, focusing on “higher education” increases the inequality even though only 3.2% of the sample has a high education level. These results show the relevant role of human capital on explaining rural income inequalities (NEY; HOFFMAN, 2009).

Experience (the age variable) has a stronger effect at the bottom of income distribution; i.e. older individuals are related to higher income level compared to those younger than 25 years old (base category). It implies a significant contribution of experience on reducing rural income inequality. Overall, access to rural credit is also associated with higher income in all quantiles of the distribution. It allows improvements on farm productive capacity through acquisition of inputs and new technologies. Along the top quantiles of the income distribution, q70, q80 and q90, farmers that had access to rural credit obtained an income 31.8%, 40.7% and 30.3% higher than the others, respectively.

Farmers that are partners, occupant and other classifications face lower income compared to farm owners (base category) in all quantiles of the income distribution. Farm owners have a greater incentive to invest in innovations and in other long-term technology, which contribute to increase rural income. These properties also have greater access to credit and other services given that the land can be used as a tangible guarantee for the fulfillment of the financial obligations (BESLEY, 1995). Farmers that reside in rural areas are associated with lower income in all quantiles of the income distribution. Living in an urban area might lead to a greater access to information about market, banking institutions and other services.

The farm size dummies suggest that all categories (“small”, “medium” and “large”) are associated with greater income compared to “very small” farms. In fact, as argued by Helfand et al. (2015), insufficient land, coupled with strong financial constraints and low access to policies such as rural extension, rural credit, more advanced technologies and others contribute to a reduction in the productivity of such farms, resulting in lower incomes and high poverty rates, when compared to medium and large farms.

We are also interested in identifying whether the source of the rural extension provision have a different effect on income distribution. To obtain these effects we estimate RIF equations for each income quantile and different source of rural extension service provision. These results are displayed in Table 3.3 and Figure 3.1 shows the effect of rural extension, both aggregate and disaggregate by source, on income.

Table 3.3 - Estimates of unconditional quantile regression– Public and Private Rural Extension, Brazil (2014).

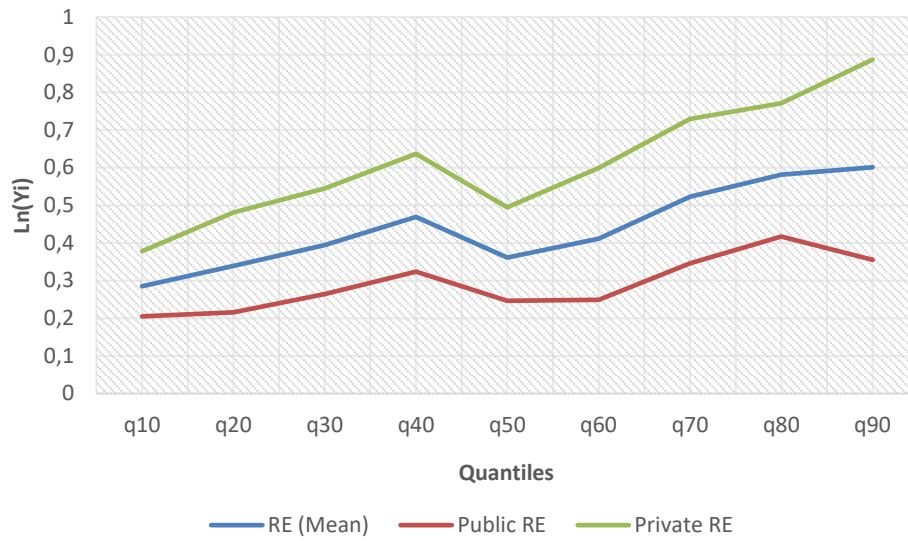
Ln(Yi)	MQO	q10	q20	q30	q40	q50	q60	q70	q80	q90
<i>Public RE</i>	0.268*** (0.0263)	0.205*** (0.0421)	0.216*** (0.0362)	0.264*** (0.0364)	0.324*** (0.0377)	0.246*** (0.0306)	0.249*** (0.0319)	0.346*** (0.0403)	0.417*** (0.0512)	0.355*** (0.0696)
<i>Private RE</i>	0.610*** (0.0280)	0.378*** (0.0311)	0.481*** (0.0279)	0.545*** (0.0316)	0.637*** (0.0358)	0.495*** (0.0308)	0.599*** (0.0315)	0.729*** (0.0422)	0.771*** (0.0577)	0.887*** (0.0879)
<i>Gender</i>	-0.0297 ^{NS} (0.0188)	-0.0470 ^{NS} (0.0435)	-0.129*** (0.0314)	-0.153*** (0.0298)	-0.0566* (0.0300)	-0.00344 ^{NS} (0.0233)	-0.0243 ^{NS} (0.0221)	-0.00676 ^{NS} (0.0249)	0.0356 ^{NS} (0.0280)	0.0548 ^{NS} (0.0357)
<i>Race</i>	-0.160*** (0.0270)	-0.00918 ^{NS} (0.0630)	-0.0741 ^{NS} (0.0464)	-0.164*** (0.0438)	-0.204*** (0.0414)	-0.226*** (0.0306)	-0.183*** (0.0283)	-0.237*** (0.0298)	-0.244*** (0.0292)	-0.179*** (0.0362)
<i>Incomplete Elementary</i>	0.00789 ^{NS} (0.120)	0.470 ^{NS} (0.341)	0.567** (0.226)	0.0962 ^{NS} (0.193)	-0.309* (0.180)	-0.240* (0.142)	-0.334** (0.130)	-0.217 ^{NS} (0.140)	-0.409*** (0.158)	0.00173 ^{NS} (0.0614)
<i>Complete Elementary</i>	0.263** (0.119)	0.662* (0.340)	0.773*** (0.226)	0.298 ^{NS} (0.192)	-0.0361 ^{NS} (0.179)	-0.0104 ^{NS} (0.142)	-0.0749 ^{NS} (0.130)	0.0865 ^{NS} (0.139)	-0.0790 ^{NS} (0.158)	0.318*** (0.0608)
<i>Incomp. High School</i>	0.456*** (0.121)	0.881*** (0.341)	0.952*** (0.228)	0.451** (0.195)	0.165 ^{NS} (0.182)	0.166 ^{NS} (0.144)	0.0592 ^{NS} (0.133)	0.318** (0.143)	0.164 ^{NS} (0.163)	0.564*** (0.0798)
<i>Comp. High School</i>	0.475*** (0.125)	0.836** (0.349)	0.937*** (0.234)	0.575*** (0.201)	0.129 ^{NS} (0.188)	0.150 ^{NS} (0.149)	0.0651 ^{NS} (0.137)	0.290* (0.149)	0.293* (0.171)	0.732*** (0.110)
<i>Incomp. Higher education</i>	0.662*** (0.121)	0.876** (0.341)	1.131*** (0.227)	0.694*** (0.194)	0.421** (0.181)	0.367** (0.144)	0.321** (0.132)	0.545*** (0.143)	0.386** (0.163)	0.849*** (0.0808)
<i>Comp. Higher education</i>	1.243*** (0.125)	1.012*** (0.340)	1.187*** (0.227)	0.788*** (0.196)	0.589*** (0.183)	0.596*** (0.146)	0.585*** (0.135)	1.025*** (0.148)	1.336*** (0.174)	2.234*** (0.144)
<i>Age26_35</i>	-0.0293 ^{NS} (0.0339)	-0.00960 ^{NS} (0.0921)	-0.0955 ^{NS} (0.0663)	-0.179*** (0.0598)	-0.154*** (0.0568)	-0.112*** (0.0420)	-0.0451 ^{NS} (0.0362)	-0.0727* (0.0413)	-0.0969** (0.0481)	0.0440 ^{NS} (0.0617)
<i>Age36_45</i>	0.143*** (0.0328)	0.255*** (0.0867)	0.201*** (0.0629)	0.0953* (0.0575)	0.0830 ^{NS} (0.0551)	0.0198 ^{NS} (0.0410)	0.108*** (0.0357)	0.0589 ^{NS} (0.0409)	-0.00262 (0.0475)	0.141** (0.0612)
<i>Age46_55</i>	0.201*** (0.0327)	0.155* (0.0874)	0.249*** (0.0624)	0.189*** (0.0573)	0.161*** (0.0551)	0.109*** (0.0411)	0.213*** (0.0360)	0.170*** (0.0413)	0.0885* (0.0482)	0.200*** (0.0628)
<i>Age56_65</i>	0.486*** (0.0340)	0.518*** (0.0871)	0.685*** (0.0627)	0.646*** (0.0586)	0.599*** (0.0571)	0.412*** (0.0430)	0.422*** (0.0380)	0.340*** (0.0433)	0.245*** (0.0502)	0.353*** (0.0651)
<i>Age65m</i>	0.796*** (0.0371)	0.851*** (0.0863)	1.061*** (0.0616)	1.070*** (0.0585)	1.175*** (0.0579)	0.852*** (0.0455)	0.655*** (0.0424)	0.520*** (0.0489)	0.375*** (0.0564)	0.482*** (0.0727)
<i>Rural</i>	-0.245***	-0.178***	-0.208***	-0.209***	-0.230***	-0.200***	-0.224***	-0.302***	-0.282***	-0.310***

	(0.0157)	(0.0317)	(0.0244)	(0.0242)	(0.0245)	(0.0191)	(0.0186)	(0.0221)	(0.0256)	(0.0344)
<i>Rural Credit</i>	0.255***	0.204***	0.165***	0.250***	0.240***	0.234***	0.257***	0.317***	0.406***	0.301***
	(0.0215)	(0.0315)	(0.0285)	(0.0285)	(0.0308)	(0.0249)	(0.0257)	(0.0324)	(0.0420)	(0.0578)
<i>Partner</i>	-0.0409 ^{NS}	0.0350 ^{NS}	0.0386 ^{NS}	-0.0200 ^{NS}	-0.0797*	-0.131***	-0.0680**	-0.0937**	-0.123***	-0.0935*
	(0.0289)	(0.0666)	(0.0519)	(0.0484)	(0.0465)	(0.0347)	(0.0328)	(0.0367)	(0.0416)	(0.0526)
<i>Tenant</i>	-0.00811 ^{NS}	-0.0653 ^{NS}	-0.0227 ^{NS}	0.00787 ^{NS}	0.0487 ^{NS}	0.0268 ^{NS}	0.0279 ^{NS}	0.00788 ^{NS}	-0.0832*	-0.0102 ^{NS}
	(0.0286)	(0.0673)	(0.0501)	(0.0468)	(0.0463)	(0.0356)	(0.0355)	(0.0410)	(0.0457)	(0.0625)
<i>Ocupant</i>	-0.0970***	0.0419 ^{NS}	-0.0622 ^{NS}	-0.129**	-0.209***	-0.127***	-0.0982***	-0.155***	-0.123***	-0.140***
	(0.0354)	(0.0819)	(0.0649)	(0.0608)	(0.0570)	(0.0410)	(0.0368)	(0.0356)	(0.0357)	(0.0344)
<i>Other_condition</i>	-0.261***	-0.450***	-0.235***	-0.258***	-0.260***	-0.225***	-0.268***	-0.295***	-0.265***	-0.137***
	(0.0241)	(0.0694)	(0.0467)	(0.0422)	(0.0398)	(0.0292)	(0.0251)	(0.0266)	(0.0273)	(0.0365)
<i>Small</i>	0.248***	0.263***	0.259***	0.211***	0.232***	0.195***	0.215***	0.266***	0.336***	0.281***
	(0.0164)	(0.0303)	(0.0239)	(0.0243)	(0.0249)	(0.0197)	(0.0195)	(0.0231)	(0.0278)	(0.0357)
<i>Medium</i>	0.361***	0.178***	0.179***	0.150***	0.159***	0.189***	0.296***	0.434***	0.531***	0.866***
	(0.0290)	(0.0480)	(0.0388)	(0.0389)	(0.0402)	(0.0316)	(0.0318)	(0.0386)	(0.0491)	(0.0770)
<i>Large</i>	0.327***	0.336***	0.315***	0.324***	0.369***	0.242***	0.245***	0.258***	0.324***	0.416***
	(0.0334)	(0.0530)	(0.0454)	(0.0469)	(0.0486)	(0.0407)	(0.0395)	(0.0473)	(0.0577)	(0.0819)
<i>Intercept</i>	6.828***	5.227***	5.539***	6.407***	6.944***	7.220***	7.467***	7.575***	7.982***	7.860***
	(0.124)	(0.350)	(0.233)	(0.200)	(0.187)	(0.148)	(0.136)	(0.148)	(0.169)	(0.0890)
Observations	15,406	15,406	15,406	15,406	15,406	15,406	15,406	15,406	15,406	15,406
F	229.54	41.86	103.7	125.8	163.17	183.73	207.31	197.13	143.85	62.81
R-squared	0.264	0.058	0.119	0.144	0.170	0.185	0.195	0.208	0.204	0.160

Source: Research results.

Note: RE – Rural Extension; *** significant at 1%, **significant at 5%, * significant at 10%, NS - non significant; Standard errors in parentheses.

Figure 3. 1 - Effects of rural extension on the distribution of income in the Brazil rural



Source: Research results. Note: RE: Rural Extension.

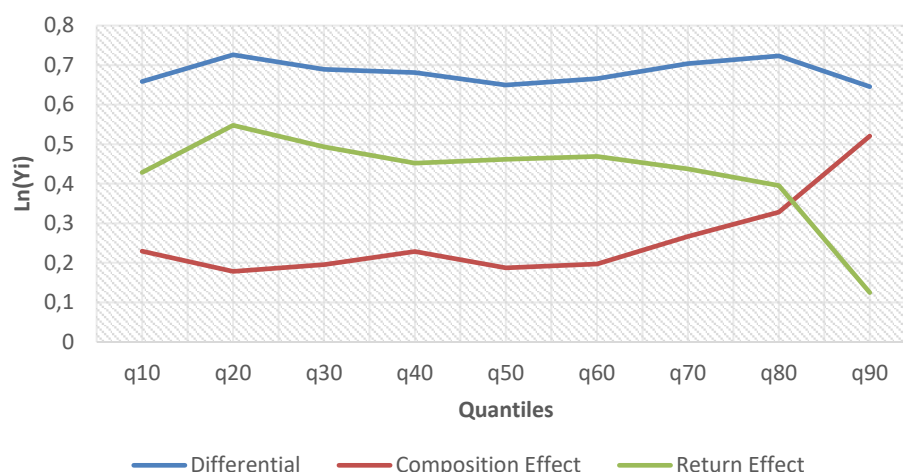
Our results show that the private rural extension service have a greater effect on rural income. For instance, these private services have a twice larger effect on income on the top part of the income distribution (q90) compared to the public services. For instance, private services increase rural income in 88.7% compared to non-adopters while the public services increase in 35.5%. A higher effect of private services compared to public service might be explained by the restriction on resources that small and poor farmers face, which limits the effect of public policy on rural extension. On the other hand, large farmers have easier access to a more specialized private extension service, which explains the increasing income gap between the source of extension as higher income quantiles are considered.

5.2. Decomposition of income differentials

The analysis of the data indicate differences in the characteristics of farms in group A and B. The results presented in the previous subsection also indicate differences in the return to rural extension on income. Although it increases rural income it also increases income inequality. In this section we identify which factors explain this difference in income between these farm groups. The income decomposition method is used along the RIF regressions to evaluate how much of the income differences between the farm groups is attributed to the *composition effect* and to the *return effect*. The former effect represents the differences in the distribution of the individuals characteristics and the latter effect represents the differences in the returns of the characteristics. It allows to identify the contribution of each explanatory variable on each of the estimated effects. The outcome of this methodology is presented in Tables A3 and A4 and are summarized in Figures 3.2, 3.3, 3.4 and 3.5.

The decomposition of the income differential between groups A and B in the *composition effect* and *return effect* is displayed in Figure 3.2. Farmers that have access to rural extension obtain a higher level of income in all the quantiles considered compared to farmers that have not accessed these services. Overall, the *return effect* predominates which means that the majority of the income differential between groups is explained by the higher returns of the explanatory variables. On the other hand, the *composition effect* impact on income increases along the quantiles; i.e. the differences in the individual characteristics such as schooling and access to rural credit explain almost the entire income gap between such groups in the top part of the income distribution, q90.

Figure 3. 2 - Decomposition of the income differential between groups A and B.

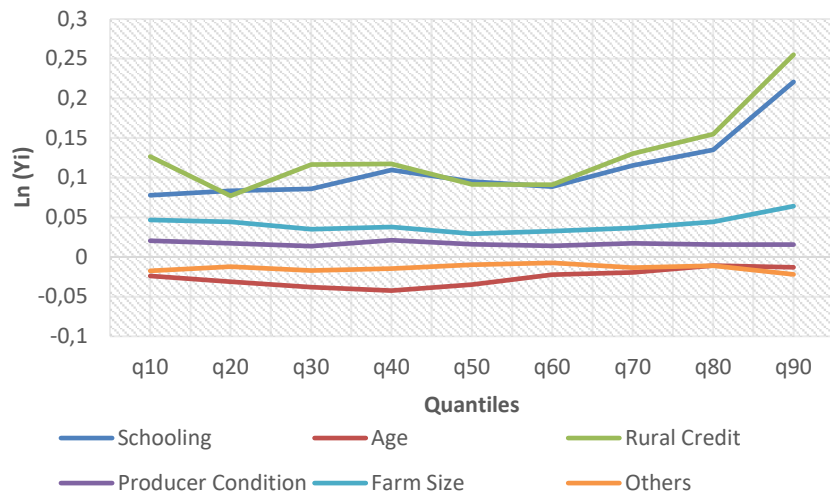


Source: Research results.

The detailing decomposition of the *composition effect* for each individual characteristic is displayed in Figure 3.3. Schooling and access to rural credit are the main factors explaining higher level of income for farmers that have accessed to rural extension (group A) compared to farmers in group B. This result indicates that might be occurring a selection bias on the provision of rural extension services, as also suggested by Plata and Fernandes (2011).

The negative effect of age indicates that the contribution of greater experience to increase income is greater among producers without rural extension. This result is not surprising, since part of the actions taken by farms with rural extension come from the extensionists' decisions, reducing the portion of the income increase derived from the farmer's own knowledge and experience. For the other characteristics such as gender and race (*Others*), the results also indicate that these variables contribute to the reduction of the income differential between the two groups (Figure 3.3).

Figure 3. 3 - Detailed decomposition of the composition effect of the income differential.

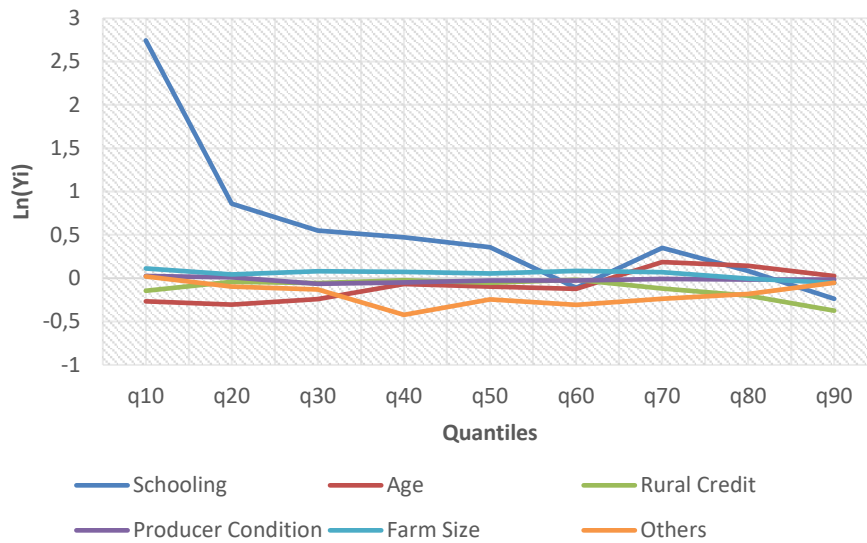


Source: Research results.

Our findings suggest that the outcome of an extension agent might be limited among the poorest farmers due to their lack of education and access to credit. Higher education levels facilitates their interaction with the extension agents allowing them to absorb information and implement the technical recommendations more precisely. Alves *et al.* (2013) also indicate that these farmers have greater access to rural credit and allow them to invest in modern inputs and adopt more productive technologies. Therefore, the current structure of the national rural extension policy is reinforcing social inequalities.

The *return effect* for each group of farmer is displayed in Figure 3.4. Although we observe a decreasing effect of schooling on rural income this variable contributes considerably to income in the first two income quantiles (q10 and q20). This result might be associated to the lower presence of farmers with high schooling levels in these quantiles, which leads to a higher return of this variable (marginal effect). Most of the variables have a similar effect on income differentials.

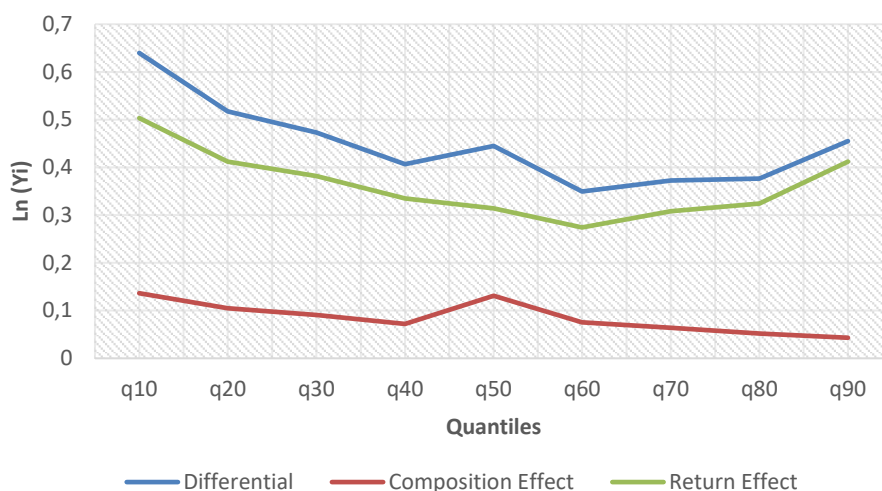
Figure 3. 4 - Detailed decomposition of the return effect of the income differential.



Source: Research results.

Our findings of the unconditional quantile regression presented in previous subsection also show a different effect of rural extension by source of provision. Then, we decompose these income differential by source of provision in the two *effect*. This results are displayed in Figure 3.5. The total income differential between the groups of farmers that have access to private and public rural extension services has a U-shape format. Although both effects are positive, the *return effect* explains the majority of the income differential. It implies that the observed higher income obtained by farmers that had access to private rural extension is mainly due to the greater returns to the individuals characteristics such as schooling and access to rural credit.

Figure 3. 5 - Decomposition of the income differential between producers assisted by private rural extension and assisted by the public rural extension.



Source: Research results.

6. Conclusions

In this paper we identify the effect of rural extension on income levels and income inequality in the Brazilian rural area using unconditional quantile regression along with an income differential decomposition approach. To obtain these effects, we use the household survey made available by the IBGE for 2014. Our results allows to identify the efficacy of the current rural extension policy and the main individual and farm characteristics that increase the effects of rural extension on income and income inequality.

Our results indicates that although rural extension increases rural household income in the all income distribution quantiles, it also increases income inequality. We also find that the private rural extension service has a greater effect on rural income compared to public service provision. The results of the income differential decomposition show that the difference in individual characteristics explains the majority of the income differential in upper end of income distribution. We find that

higher level of schooling and access to rural credit augment the effect of rural extension on rural income but also contribute to the aggravation of the income inequality. Thus, access to rural extension alone it is not enough to raise social welfare of the poorest farmers. These farmers are constrained by limited access to credit and schooling. The design of a joint public policy toward rural extension, rural credit and promotion of the human capital is needed to achieve the goal of reducing income inequality.

Our results are based on monthly total household income opposed to the household income of the agricultural activity exclusively. Although an analysis of the effect of rural extension on agricultural income would bring very interesting insights, the directions of the rural extension policy (PNATER) also seek to generates non-agricultural jobs (MDA, 2017). We are interested in the household welfare gain with this policy, which includes an analysis of the non-agricultural income that might be generated by the access to these services.

FINAL REMARKS

Rural extension services have received greater governmental attention as an instrument to support rural areas in Brazil given its role in promoting economic and social development of agricultural farms. Two factors contribute to a not accurate and under-evaluation of the effects of rural extension on the Brazilian agricultural performance: a small access to these services by smaller farms; and limited allocation and poor distribution of the resources. In this thesis we seek to identify the effect of rural extension on the Brazilian agricultural sector. We focus in identifying the effect of rural extension on the supply of commodities, on technical efficiency, and on income level and income inequality in the Brazil.

Our results suggest that rural extension services increase the supply of commodities in Brazil. Although private extension services have had a stronger effect on the supplies, public rural extension have led to an increase in the supply of soy and milk. Access to private services greatly increased the supply of soy, coffee, sugarcane and milk. Results suggested a greater effect of rural extension in medium and large-sized farms. Access to private services had also a stronger effect among small farms. We aggregated the effect of rural extension on output supplies by analyzing the change on revenue due to access to rural extension. Outputs revenue increased 4.1% in 2016, where 0.6% was generated by access to public extension and 3.5% by access to private extension.

We also found that rural extension increases farm technical efficiency in Brazil. Public rural extension increases technical efficiency more compared to private services. It suggests that public rural extension lead to an increase in production by contributing

to a more efficient use of scarce resources by small producers. Our results also indicate a greater effect of public rural extension on technical efficiency of medium and large rural producers compared to private services. Although rural extension increases the income of producers, it also leads to income concentration among the richest producers. These high-income producers have a greater access to rural credit and a higher schooling levels. These two factors explained a large part of why they obtain a greater return to rural extension. We also observed a greater effect of private rural extension compared to public rural extension.

Our results show the importance of rural extension services as a policy instrument to improve the socio-economic welfare of rural areas in Brazil. However, these services are available to a small portion of rural producers, mainly medium and large farms. We also found a greater effect of rural extension in larger farms, even though the public rural extension public should focus on small producers given the policy directions.

Rural extension services will be more effective on reducing inequality and improving farm income jointly applied to other actions such as credit availability. Most of the small farmers have shown a low schooling level and a constrained access to financial resources. It restricts the effect of rural extension services compared to producers with higher schooling and greater presence of skilled labor in the property. An integrated action with other government instruments is necessary to promote the development of human capital. Rural credit and instruments that facilitate the access to market can increase farm income and decrease income inequality.

Our results have shown that Pnater is not fully achieving its main goal of providing access to small farms. The Pnater targets small producers, which is around 4 million farms in Brazil (farms with an area of up to 4 fiscal modules). Although

resources directed to Pnater have increased over the last few years, it is not enough to provide access to a large share of this farm group. An alternative would be focusing on producers with lower productive and economic performance, and often in a poverty condition. The most developed and market-driven small producers would be able to access a more specialized service from private rural extension. Pnater could also be restructured as a "pluriactive institution" and allow a even greater participation of non-governmental institutions in the provision of extension services. An increase on private services would lead to a greater access to rural services, including small farms. Alves and Souza (2014) suggest that the assistance provided by private companies, agroindustries, and other institutions could be subsidized by the government. It would be an complement to the public rural extension. The government could also incentivize farm participation in cooperatives given its effect on the effectiveness of the rural extension.

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APPENDIX

Table A 1- Output Supply and Input Demand Equations for Brazilian Agriculture

<i>Variables</i>	Output Supply							Input
	<i>Corn</i>	<i>Milk</i>	<i>Soybean</i>	<i>Sugarcane</i>	<i>Coffee</i>	<i>Rice</i>	<i>Cassava</i>	<i>Labor</i>
<i>p6</i>	160.21*** (-48.79)	-83.92 ^{NS} (-5.83)	968.75*** (-46.69)	-235.87** (-114.63)	3.46** (-1.76)	-35.03*** (-13.04)	-6.53* (-3.97)	-0.0010 ^{NS} (-0.0010)
<i>p3</i>	-83.92*** (-5.83)	135.43*** (-6.21)	-1618.48*** (-38.67)	-13.59 ^{NS} (-11.78)	-29.79*** (-1.19)	-25.63*** (-7.17)	-2.91*** (-0.39)	0.0020*** (0.0002)
<i>p1</i>	968.75*** (-46.69)	-1618.48*** (-38.67)	40389.16*** (-483.07)	17.76 ^{NS} (-100.54)	-15.10 ^{NS} (-10.25)	-832.08*** (-61.49)	-17.90*** (-3.37)	0.0250*** (-0.0020)
<i>p4</i>	-235.87** (-114.63)	-13.59 ^{NS} (-11.78)	17.76 ^{NS} (-100.54)	346.39 ^{NS} (-932.83)	-20.61*** (-3.97)	-9.79 ^{NS} (-29.63)	27.10 ^{NS} (-25.63)	0.0330*** (-0.0030)
<i>p5</i>	-0.001 ^{NS} (-0.001)	0.002*** (0.0002)	0.025*** (-0.002)	0.033*** (-0.003)	0.001*** (0.0001)	0.004*** (-0.001)	-0.0002*** (0.0001)	5.55e-07*** (4.92e-08)
<i>p7</i>	3.46** (-1.76)	-29.79*** (-1.19)	-15.10 ^{NS} (-10.25)	-20.61*** (-3.97)	22.41*** (-0.48)	-0.73 ^{NS} (-2.18)	-0.22* (-0.13)	0.0010*** (0.0001)
<i>p8</i>	-35.03*** (-13.04)	-25.63*** (-7.17)	-832.08*** (-61.49)	-9.79 ^{NS} (-29.63)	-0.73 ^{NS} (-2.18)	249.90*** (-20.43)	-0.06 ^{NS} (-0.99)	0.0040*** (-0.0010)
<i>p9</i>	-6.53 ^{NS} (-3.97)	-2.91*** (-0.39)	-17.90*** (-3.37)	27.10 ^{NS} (-25.63)	-0.22* (-0.13)	-0.06 ^{NS} (-0.99)	14.33*** (-1.61)	-0.0002*** (0.0001)
<i>Fixed Factors</i>								
<i>z1</i>	1213.56 ^{NS} (-1399.10)	3785.66*** (-135.72)	2149.35* (-1164.68)	-5442.28 ^{NS} (-10948.74)	-175.57*** (-45.98)	1382.51*** (-343.77)	-563.64 ^{NS} (-605.23)	-0.1940*** (-0.0300)
<i>z2</i>	3544.29*** (-1178.84)	2286.90*** (-114.54)	-583.09 ^{NS} (-984.78)	-74277.12*** (-9224.87)	-768.05*** (-38.78)	4188.03*** (-289.84)	-1057.80** (-509.94)	-0.0070 ^{NS} (-0.0250)
<i>z3</i>	363.28*** (-9.53)	-15.87*** (-0.92)	804.64*** (-7.93)	10020.54*** (-74.57)	9.41*** (-0.31)	1819.23*** (-2.34)	-4.46 ^{NS} (-4.12)	-0.0130*** (0.0000)
<i>a2</i>	2968.65***	8227.21***	1234.09*	16597.78***	231.92***	97.89 ^{NS}	809.44**	-0.3920***

	(-805.95)	(-78.19)	(-670.93)	(-6306.92)	(-26.49)	(-198.03)	(-348.64)	(-0.0170)
<i>a3</i>	6713.44***	19174.64***	15298.98***	87602.95***	609.09***	1612.35***	6239.85***	-1.0290***
	(-1515.28)	(-147.00)	(-1261.46)	(-11857.84)	(-49.80)	(-372.33)	(-655.49)	(-0.0330)
<i>a4</i>	38859.60***	22685.75***	124185.80***	1056487.00***	1305.19***	7902.87***	4939.15***	-2.3960***
	(-3120.01)	(-302.66)	(-2597.35)	(-24415.66)	(-102.55)	(-766.62)	(-1349.67)	(-0.0670)
<i>N(r1)</i>	-7063.96***	1350.84***	3302.50***	-8867.56 ^{NS}	-150.58***	-1601.16***	9263.89 ^{NS}	-0.8310***
	(-1193.59)	(-116.09)	(-998.84)	(-9335.36)	(-39.29)	(-293.63)	(-516.34)	(-0.0260)
<i>NE(r2)</i>	-5413.87***	-1691.12***	3392.35***	12743.35**	-96.45***	-2197.56***	-272.79 ^{NS}	-0.4010***
	(-820.11)	(-79.96)	(-689.64)	(-6412.12)	(-27.04)	(-201.99)	(-354.44)	(-0.0180)
<i>SE (r3)</i>	-4904.03***	4601.80***	3041.13***	45343.70***	1039.86***	-3055.77***	-1216.89 ^{NS}	-0.1270***
	(-966.01)	(-94.16)	(-811.07)	(-7558.07)	(-31.85)	(-237.80)	(-417.78)	(-0.0210)
<i>CW(r5)</i>	-2924.38**	9666.83***	15971.15***	-44371.64***	-304.83***	-2027.84***	-2364.33***	0.1060***
	(-1447.25)	(-140.57)	(-1207.53)	(-11325.35)	(-47.60)	(-355.76)	(-626.05)	(-0.0310)
<i>r1z1</i>	-2688.51 ^{NS}	448.38*	-3229.78 ^{NS}	7548.56 ^{NS}	80.14 ^{NS}	-1795.98***	-7642.10***	0.2200***
	(-2806.74)	(-272.26)	(-2336.40)	(-21963.81)	(-92.25)	(-689.63)	(-1214.16)	(-0.0600)
<i>r2z1</i>	-2128.79 ^{NS}	-2696.26***	-4613.02***	2509.21 ^{NS}	76.83 ^{NS}	-2789.01***	-518.33 ^{NS}	-0.1160***
	(-2038.01)	(-197.70)	(-1696.54)	(-15948.31)	(-66.98)	(-500.77)	(-881.61)	(-0.0440)
<i>r3z1</i>	-2114.22 ^{NS}	830.40***	-3921.94 ^{NS}	14155.49 ^{NS}	1423.78***	-2912.39***	3173.78***	-0.0270 ^{NS}
	(-1975.90)	(-191.70)	(-1645.01)	(-15462.41)	(-64.95)	(-485.52)	(-854.74)	(-0.0430)
<i>r5z1</i>	4473.61 ^{NS}	-5298.00***	5541.30*	31188.35 ^{NS}	-227.27**	-5184.10***	1918.89 ^{NS}	0.1670**
	(-3548.25)	(-344.18)	(-2953.58)	(-27766.99)	(-116.62)	(-871.82)	(-1534.93)	(-0.0760)
<i>r1z2</i>	-36303.49***	1620.19***	-44719.13 ^{NS}	-106370.40***	-467.25***	-3108.55***	-8160.46***	0.2330***
	(-4333.53)	(-420.42)	(-3608.37)	(-33911.31)	(-142.44)	(-1064.83)	(-1874.63)	(-0.0930)
<i>r2z2</i>	-18875.04***	2830.35***	4387.49**	158681.90***	720.46***	-13257.20***	198.04 ^{NS}	-0.9210***
	(-2268.83)	(-220.23)	(-1890.93)	(-17754.17)	(-74.60)	(-557.61)	(-981.43)	(-0.0490)
<i>r3z2</i>	-16553.26***	13557.69***	-45361.75***	382795.80***	6340.37***	-13862.89***	1340.06*	-0.9680***
	(-1712.40)	(-166.24)	(-1427.73)	(-13400.06)	(-56.31)	(-420.88)	(-740.74)	(-0.0370)
<i>r5z2</i>	78111.19***	415.05*	217759.20***	-135837.60***	-1662.82***	-21771.18***	1927.94*	0.3540***

	(-2620.90)	(-254.24)	(-2181.82)	(-20509.96)	(-86.14)	(-643.98)	(-1133.77)	(-0.0560)
<i>a2z1</i>	821.71 ^{NS}	2011.75 ^{***}	2325.26 ^{NS}	-3308.91 ^{NS}	191.26 ^{***}	1111.46 ^{***}	-1107.52 ^{NS}	-0.1500 ^{***}
	(-1763.13)	(-171.03)	(-1467.65)	(-13797.44)	(-57.95)	(-433.21)	(-762.71)	(-0.0380)
<i>a3z1</i>	11824.09 ^{***}	5564.08 ^{***}	6669.25 ^{**}	-21540.22 ^{NS}	1143.57 ^{***}	4571.32 ^{***}	1779.49 ^{NS}	-0.8820 ^{***}
	(-3318.91)	(-321.94)	(-2762.71)	(-25972.29)	(-109.08)	(-815.47)	(-1435.72)	(-0.0710)
<i>a4z1</i>	47506.56 ^{***}	7780.67 ^{***}	38562.25 ^{***}	-643398.30 ^{***}	2074.61 ^{***}	11783.32 ^{***}	1930.54 ^{NS}	-2.2910 ^{***}
	(-6485.56)	(-629.10)	(-5398.62)	(-50753.11)	(-213.16)	(-1593.53)	(-2805.57)	(-0.1400)
<i>a2z2</i>	7315.27 ^{***}	3054.76 ^{***}	9538.36 ^{***}	27664.75 ^{**}	577.36 ^{***}	1582.99 ^{***}	-608.17 ^{NS}	-0.1750 ^{***}
	(-1507.90)	(-146.28)	(-1255.37)	(-11800.15)	(-49.56)	(-370.51)	(-652.30)	(-0.0320)
<i>a3z2</i>	63700.50 ^{***}	6670.77 ^{***}	87822.52 ^{***}	147740.40 ^{***}	3268.26 ^{***}	9420.98 ^{***}	-5241.24 ^{***}	-0.9870 ^{***}
	(-2354.21)	(-228.41)	(-1960.53)	(-18422.92)	(-77.38)	(-578.49)	(-1018.40)	(-0.0510)
<i>a4z2</i>	316566.70 ^{***}	9730.59 ^{***}	578986.20 ^{***}	436936.00 ^{***}	4792.41 ^{***}	36804.37 ^{***}	-1472.54 ^{NS}	-4.2000 ^{***}
	(-4065.01)	(-394.35)	(-3384.38)	(-31810.70)	(-133.61)	(-998.86)	(-1758.46)	(-0.0880)
<i>Intercept</i>	7096.68 ^{***}	2985.78 ^{***}	-3767.62 ^{***}	-9837.15 [*]	139.36 ^{***}	2136.25 ^{***}	2287.47 ^{***}	-2.3610 ^{***}
	(-730.41)	(-71.37)	(-616.95)	(-5713.83)	(-24.11)	(-179.95)	(-315.86)	(-0.0160)

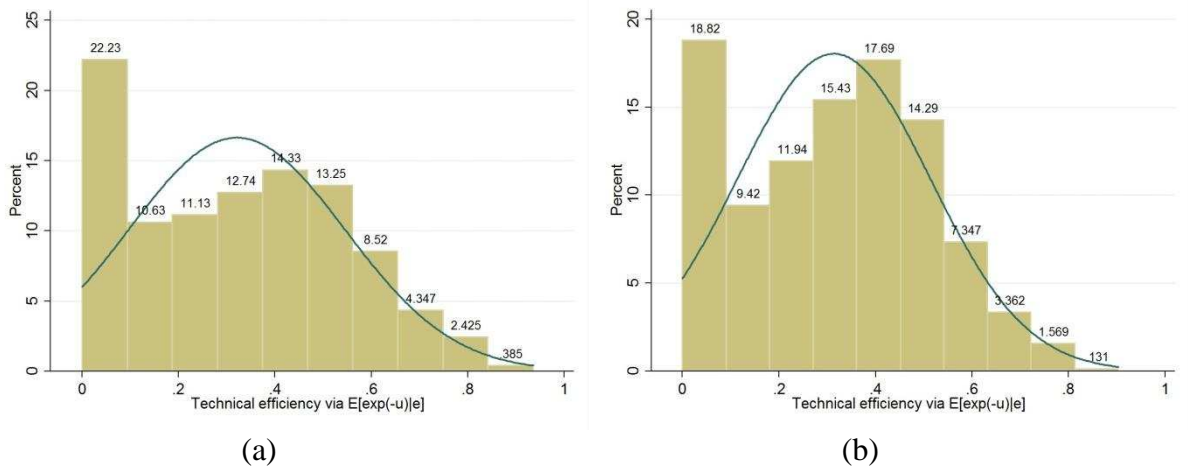
Note: Following the theory Labor input was estimated with a negative labor quantity as dependent variable. NS: non-significant; *** significant at 1% level; ** significant at 5% level, * significant at 10% level. Standard errors in parentheses.

Table A 2 - Information used to calculate market effect of rural extension on agricultural revenue

Output	Production (1 million kg)	AveragePrice (R\$/Kg)	Farms with PublicRural Extension	Farms with Private Rural Extension
Corn	23500	0.3	66294	108482
Milk	18200	0.5	180500	240695
Soybean	33700	0.5	30100	112000
Sugarcane	97100	0.2	5600	10838
Coffee	1410	3.2	21700	28935
Rice	5420	0.6	8793	8793
Cassava	5730	0.6	17200	9862

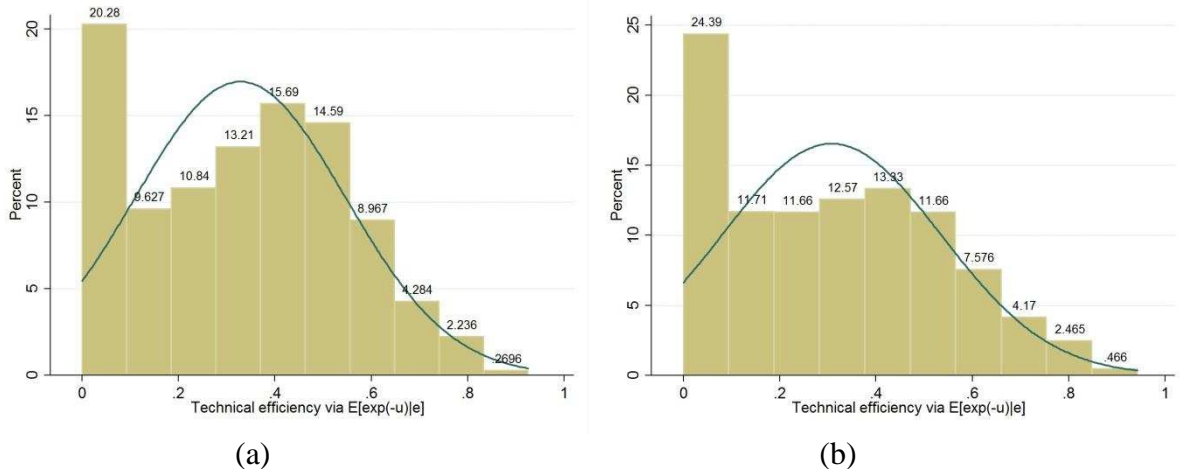
Source: Research results. Note: Parameters that were not statistically significant were considered zero.

Figure A1 – Distribution of the estimated technical efficiency: (a) Farms with Rural Extension; (b) Farms without Rural Extension



Source: Results.

Figure A2 – Distribution of the estimated technical efficiency: (a) Farms with Public Rural Extension; (b) Farms with Private Rural Extension



Source: Results.

Table A 3 - Decomposition of the income differentials: With Rural Extension – Without Rural Extension (2014).

	q10	q20	q30	q40	q50	q60	q70	q80	q90
Differential (LnYi)	0.65838	0.72606	0.68896	0.68119	0.64949	0.66605	0.70397	0.7232	0.64546
<i>Composition Effect</i>	0.22971	0.17838	0.19562	0.22875	0.18752	0.19684	0.26651	0.32788	0.52055
<i>Return Effect</i>	0.42867	0.54768	0.49333	0.45244	0.46197	0.46922	0.43746	0.39532	0.12491
Composition Effect Detailed									
<i>Schooling</i>	0.07781	0.08334	0.0859	0.10951	0.09517	0.0888	0.11548	0.13494	0.22071
<i>Age</i>	-0.0241	-0.0312	-0.0382	-0.0424	-0.035	-0.0223	-0.0193	-0.0108	-0.013
<i>Rural Credit</i>	0.12649	0.07709	0.11634	0.11724	0.09168	0.09108	0.13014	0.15469	0.25497
<i>Producer Condition</i>	0.02033	0.01712	0.01365	0.02111	0.01599	0.01415	0.01735	0.01556	0.01576
<i>Farm Size</i>	0.04675	0.04433	0.03494	0.03802	0.02927	0.0325	0.03644	0.04444	0.06406
<i>Others</i>	-0.0176	-0.0123	-0.017	-0.0147	-0.0096	-0.0074	-0.0136	-0.0109	-0.022
Return Effect Detailed									
<i>Schooling</i>	2.74381	0.85986	0.54795	0.47161	0.35943	-0.1123	0.35136	0.0825	-0.2374
<i>Age</i>	-0.2661	-0.3043	-0.2422	-0.0683	-0.0983	-0.1226	0.18654	0.14499	0.02634
<i>Rural Credit</i>	-0.1449	-0.0422	-0.0564	-0.0212	-0.0523	-0.018	-0.1203	-0.2001	-0.3743
<i>Producer Condition</i>	0.02589	0.0086	-0.0648	-0.0501	-0.0283	-0.026	-0.009	-0.0145	-0.0172
<i>Farm Size</i>	0.11253	0.04192	0.08047	0.07246	0.05576	0.08304	0.07112	-0.0041	-0.0532
<i>Others</i>	0.02019	-0.0966	-0.1317	-0.4223	-0.2448	-0.3058	-0.2381	-0.1825	-0.0506

Source: Research results.

Table A 4 - Decomposition of the income differential: Private Rural Extension – Public Rural Extension (2014).

	q10	q20	q30	q40	q50	q60	q70	q80	q90
Differential (LnYi)	0.63968	0.51764	0.47284	0.40674	0.44489	0.34952	0.37236	0.37637	0.45494
<i>Composition Effect</i>	0.13639	0.10524	0.09107	0.07197	0.13094	0.0753	0.06423	0.05223	0.04312
<i>Return Effect</i>	0.50329	0.4124	0.38177	0.33477	0.31394	0.27423	0.30813	0.32414	0.41182

Source: Research results.