Technical assistance support effect on Brazilian agricultural performance

Carlos Otávio de Freitas[1]
Felipe de Figueiredo Silva[2]
Mateus de Carvalho Reis Neves[3]
Marcelo Jose Braga[4]

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RESUMO

A assistência técnica tem sido utilizada como instrumento para difundir novas tecnologias entre os estabelecimentos agropecuários por meio de políticas governamentais como a Política Nacional de Assistência Técnica e Extensão Rural (PNATER). Isto contribuído para incrementos de produtividade na agricultura nas últimas décadas. No entanto, o efeito da assistência técnica sobre a oferta de produtos e demanda de insumos não tem sido estudado de forma mais profunda. Nós abordamos esta questão estimando um sistema de equações baseado em uma função de lucro quadrática normalizada para obter o impacto da assistência técnica nas produções de milho, soja, café, cana de açúcar, leite, trigo e arroz, e nas demandas de combustíveis e trabalho contratado. Nós estimamos oito equações de oferta e de demanda utilizando a abordagem dos Mínimos Quadrados em Três Estágios para dois conjuntos de dados – um em nível municipal e outro para fazendas representativas – com base no Censo Agropecuário de 2006. Nossos resultados sugerem um efeito positivo da assistência técnica governamental na produção de soja, milho e na demanda por combustíveis, enquanto que a assistência privada afetou positivamente as ofertas de soja e trigo, e reduziu a utilização de combustíveis e trabalho contratado. Além disso, observou-se um salto maior na oferta de soja com um aumento da assistência técnica governamental do que com a assistência privada. Nós também identificamos que o efeito da assistência técnica privada aumenta a oferta das commodities de acordo com o tamanho do estabelecimento, o que não foi identificado para a assistência governamental.

PALAVRAS-CHAVES: Agricultura, Assistência Técnica, Função de lucro restrita

ABSTRACT

Technical assistance support has been used as an instrument to spread new technologies across farms in Brazil via governmental policies such as the National Policy on Technical Assistance and Rural Extension (PNATER). It has contributed to productivity enhancement on agriculture in the last decades. However, the effect of technical assistance support on agricultural output supply and input demands has not been thoroughly studied. We address this issue by estimating a system of equations based on a quadratic normalized restricted profit function to obtain the impact of technical assistance support on corn, soybean, coffee, sugarcane, milk, wheat and rice supplies, and fuel and hired labor demands. We estimated eight equations of supply and demand using an Iterated Three Stage Least Square for two sets of representative scale data – a municipal scale and a farm representative– from the Brazilian Agricultural Census of 2006. Our results suggest a positive effect of governmental technical support on soybean and corn supply and fuel demand while the private support increases soybean and wheat supply and it saves on fuel and hired labor. In addition, a larger shift on soybean supply was observed --doubling the share of farms that receive governmental support over private support. We also found that private technical support effect on commodities supply increases with farm size while the governmental support does not.

Key-words: Agriculture, Technical Assistance, Restricted Profit Function.
JEL: Q1, Q11, and Q13.

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[1]Doutorando em Economia Aplicada do Departamento de Economia Rural da Universidade Federal de Viçosa – UFV. Email: carlos.freitas@ufv.br
[2]Doutorando em Economia Aplicada do Departamento de Economia Rural da UFV. Email: fsilva.f@hotmail.com
[3]Professor adjunto do Departamento de Economia Rural da Universidade Federal de Viçosa– UFV.Email: mateus.neves@ufv.br
[4]Professor titular do Departamento de Economia Rural da Universidade Federal de Viçosa–UFV. Email: mjbraga@ufv.br

1. Introduction

Brazilian agriculture has been experiencing a strong productivity enhancement in the last decades related to technological change (Mendes *et al.* 2009, Bragagnolo *et al.* 2010, Helfand *et al.* 2015). Buainin *et al.* (2013) asserts that the Brazilian agricultural performance is based on research, rural credit and rural extension. Several studies have studied the role of research and rural credit on agriculture (Gasques *et al.* 2004, Melo *et al.* 2015 and Cardoso *et al.* 2012), but a few studies have investigated the relevance of technical assistance and rural extension. Rodrigues (1997) and Peixoto (2014) highlight the relevance of the effects of such policy on agricultural performance and other socio-economic aspects.

On technical assistance support, the National Policy on Technical Assistance and Rural Extension (PNATER)[5] has been used to spread technical assistance support across the country in the last decades. Christoplos (2010) describes the former as a policy that seeks to make it possible for farms to obtain new technologies. Additionally, it aims to teach new agricultural techniques, advise on price analysis and consult on farm management. PNATER, first implemented in 2003, added new goals to the former strategy (ATER[6]) including managerial tools on more sustainable agricultural techniques – a more sustainable use of natural resources (Ministry of Agrarian Development – MDA, 2016).

Pettan (2010) and Peixoto (2009) highlight the increase on non-governmental institutions after the introduction of PNATER. In 2006, more than 40% of the technical assistance was provided by non-governmental institutions (private) (Brazilian Institute of Geography and Statistics – IBGE, 2016). Both research papers assert that private technical assistance support increased due to the restructuring of the governmental ATER service, which it was scarce among small farms. It is worth to notice that although private support lead to productivity and farm income enhancement it is still not affordable by all farms. Thus, the aim of the PNATER is to meet the needs of these farms which cannot afford private support. A larger participation of other than governmental institutions have been observed and also increased monetary resources with the introduction of PNATER, from R$ 3 million in 2001/2002 to R$ 109 million in 2006/2007. However, only 22% of farms had access to any technical assistance on 2006, which were mainly medium/large farms (IBGE, 2016).

Several papers have analyzed Brazilian agriculture but without focusing on the relevance of technical assistance support on its performance[7]. Overall, a positive effect of technical assistance on productivity and/or production has been found (Moura *et al.* 2000, Freitas *et al.* 2014, and Helfand and Levine 2004).[8] In this paper, we address this issue directly seeking to evaluate the effect of technical assistance support on agricultural output supplies and input demands. In addition, we seek to investigate the impact of both private and governmental technical assistance support. We are not aware of any other paper that analyzed specifically the effect of technical assistance on Brazilian Agriculture performance using this approach.

Our research focuses on the major agricultural commodities and inputs to estimate a system of equation based on the derivative properties of a quadratic normalized restricted profit function. We use data ata municipal scale and at farm level (a representative farm of differing sizes) from the Brazilian Agricultural Census of 2006. Specifically, we estimate a system of equations using Iterated Three Stage Least Square, which includes seven commodity supplies and two input demands to evaluate the impact of governmental and private technical assistance support as supply and demand shift. Our results have shown that technical assistance support positively impacts soybean, corn and wheat supplies and fuel and hired labor demands. For instance, on average, an increase of 10% on the share of farms that received governmental technical assistance support results in an increase of 16% of soybean supply while an increase on private support results in only 5.4%.

The remainder of this study is divided in five sections, section 2 presents a brief description of the background on technical assistance support in the Brazilian agricultural sector. Section 3 illustrates the

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[5]National policy on Technical Assistance and Rural Extension (in Portuguese, Política Nacional de Assistência técnica e Extensão rural).

[6] Technical Assistance and Rural Extension (in Portuguese, Assistência técnica e Extensão rural).

[7] On an international perspective, several papers have analyzed technical assistance for different countries using of production and cost functions (Birkhauser *et al.* 1991, Oehmke *et al.* 1997, Van Rijn *et al.* 2015).

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

theoretical framework adopted. It is followed by data description and the empirical specification in Section 4. Section 5 discusses the results and section 6 is the conclusion.

2. Background

Bergamasco (1983) indicates that technical assistance support has been occurring a long time in the Brazilian agriculture, since century XIX, but Pettan (2010) argues that most of it was realized by non-governmental institutions (private) and aimed to broadcast new techniques (in-farm training). Bergamasco (1983) also asserts that this type of technical assistance support took place until the late 1940's when ATER started to being formed, known as Technical Assistance and Rural Extension. She also highlights its positive effect on socio-economic (and income) aspects, which it was based on U.S. system.

However, Alves (2013) suggests a bias on ATER support toward larger farms and more developed agricultural regions. Figure 1 illustrates regional disparities o technical assistance support across the country. Municipalities on the south and southeast region have higher share of farms which have received any technical assistance support. Kageyama (1990) also states that family own-farms have been suppressed of ATER services.

The National Policy on Technical Assistance and Rural Extension (PNATER) was created in 2003 by the Ministry of Agrarian Development (MDA). Peixoto (2009) argues that the National Policy on Family Own-Farm (PRONAF), established in 1996, represented a seed to the PNATER establishment. PNATER was structured as decentralized ATER service system, where non-governmental institutions would participate actively (Peixoto 2009). Its implementation introduced raised more resources to ATER services, from R$ 3 million on 2001/2002 crop season to R$ 626 million on 2009/2010 crop season. Soares (2007) indicates that family own-farms gained more attention under this new system, where this category experienced an increase of 35% on ATER services received during the period 2002-2007.

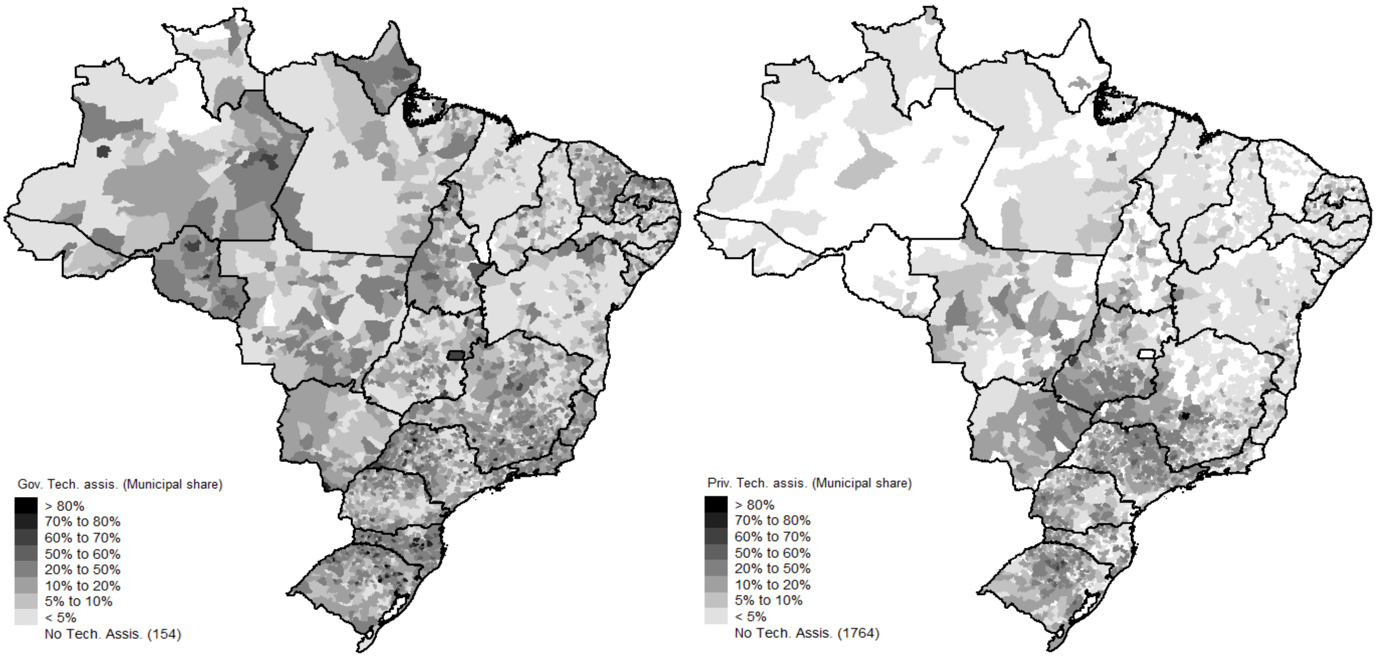

Figure 1: Share of farms that have received any technical assistance support in 2006
Source: IBGE (2016).

There is a vast international literature that investigates the outcome of ATER policies. The major assertion of these studies is the positive effect of this support on new technology propagation. Christoplos (2010) also suggested the broadcast information an important effect of these policies. Anderson and Feder (2004) identified its high impact on farm productivity and income enhancement mainly in developing countries while Landini (2016) highlights its influence on organization of farmers.

Shakya and Flinn (1985) found that rice farms in Nepal that received technical assistance support had shown a higher likelihood of adopting a new technology. They measured technical assistance support as yearly number of attending visits to the farm and new technology adoption as use of fertilizer and new varieties in rice. On the other hand, Gautam (2000) found a non-significant effect of rural extension on productivity[9] enhancement in farms on Kenia. The major conclusion is that the ATER policy has limited range given it has positive effect only on less productivity farms. Jim and Huffman (2016) have found a positive and strong impact of rural extension on total factor productivity (TFP) for the 48 U.S. states during the period 1970-2004. A smaller effect but still positive was found for public investment on agricultural research.

There are a few recent studies that have investigated directly technical assistance support for Brazilian agriculture. Several of them examine technical assistance effect only on farm efficiency such as inGonçalves *et al*. (2008), Helfand and Levine (2004) and Freitas *et al*. (2014). Overall, they have found a positive effect. The former found a stronger effect on larger farms and non-significant effect on small farms. Pereira *et al.* (2010) address this issue differently. They sought to investigate the determinants of post-harvest technologies on coffee production in a Southern Brazilian state, Minas Gerais. They have found a positive impact of technical assistant support (measured as employee training) on adoption of new technology, although monetary return, farmer characteristics and being in a cooperative had played a more relevant role.

3. Theoretical framework

There is a widespread literature on output supply and input demand shift influenced by quasi-fixed factors from a restricted profit function (Diewert, 1974; Lau, 1976; Diewert, 1971). The latter function represents the profit in the short run where some of the inputs have little or zero mobility during a short period, which implies time and cost to adjust (Huffman and Evenson, 1989), named quasi-fixed inputs. In this paper, we modeled technical assistance as a quasi-fixed input in a restricted profit function since it affects commodity production as an input but it is not flexible (i.e. labor). Several papers have used this approach to evaluate public policies and research and development impacts such as Shumway (1983), Huffman and Evenson (1989) and Fulginiti; Perrin, 1990. As mentioned before, this approach will permit to evaluate the impact for being assisted on commodities supply and input demands.

According with Lau (1976), 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. A numeraire output is represented by y_0, outputs by $y_i > 0$, $i = 0, 1, \dots, n$, where n represents outputs, and for m inputs $y_i < 0$, $i = n+1, \dots, n+m$. The quasi-fixed factors such technical assistance are represented by z_k, where $z_k \geq 0$, $k = 1, \dots, K$.

The transformation curve associated to the multi-output and multi-input described is a function of all these variables $F(y_0, y_1, \dots, y_n, y_{n+1}, \dots, y_{n+m};\ z_1, \dots, z_K) = 0$. Under perfect competition on output and input markets and a technology that satisfy monotonicity and convexity, a normalized restricted profit function is $\pi = F(p_1, \dots, p_n, p_{n+1}, \dots, p_{n+m};\ z_1, \dots, z_K)$ where $p_i = P_i/P_0$, P_0 represents the price of the numeraire output y_0, and P_i is the nominal price of each other input and output y_i, $i = 1, \dots, n+m$.

$$\pi = F(p, z) \qquad (1)$$

where π is the normalized restricted profit ($\pi = \pi'/P_0$), where π' is the nominal profit), p is a vector of $n+m$ normalized prices, and z is a vector of K quasi-fixed inputs. The normalized restricted profit function is homogeneous of degree one with respect to prices (which is imposed by dividing by one of the prices), non-decreasing in output prices and non-increasing in input prices (monotonicity in inputs and outputs), symmetric (which is also imposed in the estimation), and is convexity in prices (second order derivatives matrix is positive semidefinite).

[9]Two components were considering within the productivity effect estimation – efficiency and technical – using two different non-parametric methodologies (Data Envelopment Analysis and Malmquist Index)

We assume that all farms are profit maximizers on a perfect competition structure, so the supply curve and input demand can be recover by envelope theorem using the first derivative (which by the monotonicity property will have the following sign)

$$y_i^*(p,z) = \frac{\partial \pi}{\partial p_m} > 0, \qquad m = 1, \dots, M \tag{2a}$$

$$x_i^*(p,z) = \frac{\partial \pi}{\partial w_n} < 0, \qquad n = 1, \dots, N \tag{2b}$$

Once we normalized the restricted profit function by one of the output/input prices, the numeraire supply/demand can be obtained by

$$\frac{\partial \pi}{\partial p_0} = y_0^* = \pi^* - \sum_{j=1}^{n+m} p_i\, y_i^* \tag{3}$$

We obtain the effect of a quasi-fixed input on commodity supply and input demands (shift on supply or demand).

$$\mu_{z_k}^{y_i} = \frac{\partial y_i^*}{\partial z_k} \tag{4}$$

where $\mu_{z_k}^{y_i}$ represents the commodity supply of input demand individual shift and, according to Huffman e Evenson (1989). Theoretically, a sign is not excepted for equation (4), but since we expect a positive effect of being supported by technical assistance on commodity supply we expect these equations to show a positive value when $y_i^*$is representing an output.

4. Empirical application

4.1.Data

We use the Agricultural Census of 2006 made available by IBGE. At first, we use municipal data scale to achieve our objective. Our data set initially is formed by 5.548 observations but as noted in previous studies, such as Helfand *et al.* (2015), outliers affect heavily the estimation. Thus, we dropped all observations with normalized prices higher than its mean added by one and a half standard deviation, leading to a total of 4.678 observations that will be used. Table 1 displays descriptive statistics of the variables considered in our model for this set of observations. For example, the mean coffee price changes from R$ 890 to R$ 758 after controlling to outliers. In the extension part we use representative farm scale[10] to estimate the effect ATER on agricultural commodity supplies and input demands. In a later section we describe this procedure.

We chose the outputs based on its monetary relevance on total agricultural production in each region, such as in Huffman e Evenson (1989) and Figueiredo e Teixeira (2002). Output quantities of soybean, corn, sugarcane, coffee, rice, wheat and milk are in tons, while the output prices were obtained by the ratio of production value and production output, such as in Pereda (2012) and Figueiredo (2002). Figure 2, in Appendix C, shows the distribution of some of this outputs across the country. Some products are produced regionally such as soybean, wheat and sugarcane while other are spread across the country such as corn. Some states are well known as agricultural producers such as Sao Paulo and Minas Gerais, and have shown high level of production in different outputs.

[10]This is a special tabulation of Census constructed from IBGE microdata. We are grateful to Eustáquio José Reis from IPEA for providing us this dataset.

In the input side we chose two factors as variable inputs, hired labor and fuel. For the former, input price was calculated as the ratio of labor expenses by its quantity while for the latter was by the ratio of fuel expenses by its quantity. We decided for using fuel as variable input to capture a measure of farm capital use, as argued by Burniaux and Truong (2002) and Pereda (2012).

Table 1 – Descriptive statistics of the variables used in the estimation

Quantities[1]	***Mean***	***SD***	***Minimum***	***Maximum***
Soybean	8882.36	45851.94	0	1401719
Milk	104.02	122.52	0	1143.6
Sugarcane	56452.6	333996.1	0	7329985
Corn	7449.57	27219.78	0	597135
Coffee	446.92	2009.89	0	42487
Rice	1819.12	15389.16	0	465246
Wheat	391.17	2094.97	0	44938
Hired Labor	297.36	485.32	0	12364
Fuel	523.73	1066.56	0	25433.3
Prices[2]				
Soybean	97.43	182.77	0	1436.09
Milk	427.82	291.09	0	1926.53
Sugarcane	123.47	229.47	0	3000
Corn	334.02	199.67	0	3816.57
Coffee	758.84	1347.64	0	17328.87
Rice	236.19	305.16	0	2000
Wheat	45.98	129.97	0	1090.32
Hired Labor	10282.92	72412.48	0	3830958
Fuel	2064.13	830.004	0	17270
Fixed Factors				
Gov. Tech. Assistance (%)	0.14	0.15	0	0.91
Private Tech. Assistance (%)	0.04	0.13	0	0.77
Irrigated Area (ha.)	538.28	2608.96	0	59457.3
Nº Observations				**4678**

Note: [1] Quantities of soybean, sugarcane, corn, coffee, rice and wheat area defined in tons; milk and fuel are defined in liters; and hired labor is defined in number of workers, which are weighted by age and gender. [2] prices are defined in Brazilian R$ of 2006; ha - hectares
Source: Own elaboration.

Technical assistance support is a quasi-fixed input represented in two variables, governmental and private technical assistance support. Around 14% of farms in each municipality received governmental technical assistance support, while only 4% received any private support. As shown in Figure 1, the latter support is mainly concentrated on the south and southeast regions. Also in Figure 1, it is worth to notice how spread is the governmental technical assistance support is, although with lower attainment in each municipality. We also add irrigated area as a quasi-fixed.

4.2.Empirical estimation

Several papers have used the restricted profit function when facing a multi-input and multi-output technology such as Shumway (1983), Shumway *et al.* (1988), Huffman and Evenson (1989) and Schuring *et al.* (2011). For more details about this approach see Lau (1976) and Nadiri (1982). Three functional forms are usually used for restricted profit functions: transcendental logarithm (translog), quadratic normalized and generalized Leontief[11]. Chambers *et al.* (2013) indicated that the quadratic normalized is superior than the other using a Monte Carlo simulation. Therefore, we use a quadratic normalized restricted profit function to represent the Brazilian farms, represented in its matrix form, as described in Fulginiti (2010)

$$\pi^* = \alpha_0 + \alpha' d^* + \frac{1}{2} d^{*\prime} \beta d^* \tag{5}$$

where $\pi^* = \pi/p_0$ and

$$d^* = \begin{bmatrix} p_i/p_0 \\ z_k \end{bmatrix} \tag{6}$$

where input price (p_0 – hired labor) was used as the normalizing price for variable profit and inputs; p_i represents prices of *n* outputs and *m* inputs, *i* = *n*+*m* outputs and inputs (*netputs*) and z_k represents the quasi-fixed inputs. The restricted profit function was modeled using soybean, milk, sugarcane, corn, coffee, rice and wheat as outputs, labor and fuel as variable inputs, and public and private technical assistance, irrigated area and a dummy identifying farms in Brazilian South and Southeast regions as quasi-fixed inputs. Parameter α_0 is an estimated constant, α' is a row vector (1x8) of estimated parameters for the linear variables and β is a matrix (8x8) of estimated parameters for the interactions between normalized input and quasi-fixed inputs quantities

The normalized restricted profit represented in equation (6) is homogenous of degree one in prices and was used to obtain the commodity supply and input demand, represented by equations (2a) and (2b) on the theoretical framework, which can now be represented as

$$\frac{\partial \pi}{\partial p_i} = y_i^* = \alpha_i + \sum_{j=1}^{n+m} \beta_{ij} p_j + \phi_{ik} z_k + \varepsilon_{y_i} \tag{7a}$$

$$-\frac{\partial \pi}{\partial p_j} = y_j^* = \alpha_j + \sum_{i=1}^{n+m} \beta_{ji} p_i + \phi_{ik} z_k + \varepsilon_{y_j} \tag{7b}$$

where the first equation represents supply and the second input demand (which by Hotteling lemma has a negative sign on the left side), and ε_{y_i} and ε_{y_j} represent random errors for these equations.

A system of eight equations, considering seven outputs – soybean, milk, sugarcane, corn, coffee, rice and wheat – and fuel as variable input, represented in equations (7a) and (7b), respectively, were estimated using an Iterated Three Stage Least Square (3SLS). The hired labor was used as a normalizer price on the estimation and its demand can be recover using the homogeneity property represented by equation (3) on the theoretical framework

$$y_0^* = \alpha_0 + \sum_{k=1}^{K} \gamma_k z_k - \frac{1}{2} \sum_{i=1}^{n+m} \sum_{j=1}^{n+m} \beta_{ij} p_i p_j + \frac{1}{2} \gamma_{kl} z_k z_l \tag{8}$$

In addition, we also estimate the elasticity of supply and input demand with respect to governmental and private technical assistance support (a quasi-fixed input). This elasticity can be found as

$$\epsilon_{yizk} = \frac{\partial ln y_i^*}{\partial ln z_k} = \frac{\partial y_i^*}{\partial z_k} \cdot \frac{z_k}{y_i^*} = \phi_{ik} \cdot \frac{z_k}{y_i^*} \tag{9}$$

[11] For more details about these functional forms, see Diewert (1974), Lau (1976) and Diewert (1971).

where this equation can take any sign[12].

Symmetry and homogeneity were imposed on the estimation but monotonicity (sign of the equations (7a) and (7b) that represent supply and demand) was not and it was checked in the results. Monotonicity, in special, has an important effect on the elasticity calculation. The elasticities standard errors were obtained using Delta method[13]. All procedures were done using Stata 14, with the code *reg3*.

5. Results and discussion

A system of equation was estimated using Iterated 3SLS considering seven supplies (corn, soy, milk, coffee, sugar, rice and wheat) and one input demand (fuel). Hired labor price was used as normalizer price and was estimated after using of the symmetry property. Overall[14], the estimation presented a good fit. Most of the coefficients were statistically significant (around 67% of the coefficients were significant at 10%), monotonicity[15] was satisfied in at least 90% of the observations within outputs/inputs directly estimated in the system of equation. Table 2 displays the results in the Appendix B.

Most of the elasticities have presented a correct theoretical sign. The own-price elasticities and cross-price elasticities are displayed in Table 3. All own price elasticities are correctly signed, where output supply shows a positive elasticity and input demand a negative sign, except the own elasticity for sugarcane[16]. Own price elasticity for all outputs and input demand of fuel and hired labor are statistical significant. Rice, corn and coffee was the output with larger price-effect compare to the other outputs – an increase of 10% on its price would lead to an increase on supply of these products by 34%, 6.7% and 4.3%, respectively. Castro (2008) when estimating a profit function for Brazil (not per municipality, which is more aggregated) found a significant own-price elasticity for rice and corn of 0.43 and 0.21. On the other hand, soybean and corn have shown to be inelastic.

Both inputs have shown to be elastic. However previous studies such as Figueiredo (2002) haven't found a consistent result for input elasticities either. It is worth to notice that an increase in fuel prices would lead to a decrease in supply of agricultural commodities. Wheat and rice are the outputs more sensitive to changes in input prices. We have found that wages (hired labor prices) have an expected sign on soybean and milk, but not in the other outputs such as in Figueiredo (2002) and Castro (2008). Fuel and labor are substitutes, given the positive sign on their cross-elasticity. Additionally, soybean and corn supply are substitute given that both outputs are used on animal feed. In addition, as expected, milk and corn are complements given that corn is used as cattle feed.

Irrigated area was statistically significant for all commodities supply and input demands. A positive effect of the latter was found in the output supplies, with a larger effect on corn, rice and soybean. Our dummy variable identifying municipalities in the South and Southeast regions of Brazil (more agricultural developed regions) was statistically positive on sugarcane, coffee and wheat supply but negative for soybean supply. This outcome is related to the geographical distribution of their production, as you can see in Figure C1, in appendix C. Soybean production is also largely produced in the Midwest region.

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[12] For all other elasticities equations, including the numeraire own and cross equations, see the Appendix A of this paper.

[13] More details about this method *cf.*Seber (1973).

[14]Breusch-Pagan test indicated 3SLS estimation over separately Ordinary Least Square (OLS) equations estimation.

[15] Monotonicity property was satisfied in most of observation for the outputs and inputs: corn (98%), soy (80%), milk (98%), coffee (64%), sugar (88%), rice (33%), wheat (72%) and fuel (97%).

[16] However, we did not find a negative elasticity for sugarcane when we estimate the system of equations using the data set at farm scale.

Table3 – Average Brazilian agricultural output supply and input demand elasticities

Output/Input	Elasticity with Respect to the Price of								
	Soybean	***Milk***	***Sugarcane***	***Corn***	***Coffee***	***Rice***	***Wheat***	***Fuel***	***Hired Labor***
Soybean	**0.246**	**0.018**	-0.055[NS]	**1.247**	**-0.184**	-0.028[NS]	-0.0006[NS]	**-0.721**	**-0.521**
	(0.027)	**(0.002)**	(0.144)	**(0.195)**	**(0.070)**	(0.044)	(0.001)	**(0.0652)**	**(0.304)**
Milk	**0.075**	**0.669**	**0.060**	**-0.457**	0.003[NS]	0.051[NS]	**0.022**	**-0.159**	**-0.259**
	(0.002)	**(0.019)**	**(0.009)**	**(0.059)**	(0.011)	(0.166)	**(0.004)**	**(0.066)**	**(0.086)**
Sugarcane	0.088[NS]	0.591[NS]	**-0.996**	0.0002[NS]	-0.002[NS]	0.001[NS]	0.00005[NS]	0.002[NS]	**1.006**
	(0.085)	(1.057)	**(0.250)**	(0.095)	(0.014)	(0.016)	(0.0001)	(0.016)	**(0.271)**
Corn	**0.079**	**-0.005**	-0.002[NS]	**0.237**	**-0.082**	-0.017[NS]	**0.001**	**-0.196**	-0.111[NS]
	(0.012)	**(0.001)**	(0.047)	**(0.078)**	**(0.029)**	(0.029)	**(0.0003)**	**(0.030)**	(0.143)
Coffee	**-0.528**	0.001[NS]	0.085[NS]	**-0.538**	**0.443**	**-0.224**	-0.019[NS]	**-0.376**	**1.158**
	(0.202)	(0.004)	(0.150)	**(0.191)**	**(0.017)**	**(0.099)**	(0.015)	**(0.171)**	**(0.476)**
Rice	0.067[NS]	**0.042**	-0.188[NS]	-0.753[NS]	**-0.927**	**3.400**	0.00003[NS]	**-2.142**	0.616[NS]
	(0.077)	**(0.014)**	(0.604)	(1.336)	**(0.412)**	**(1.118)**	(0.002)	**(0.435)**	(1.825)
Wheat	-0.555[NS]	**1.245**	0.261[NS]	**2.023**	-0.353[NS]	0.010[NS]	**0.134**	**-4.984**	2.219[NS]
	(0.770)	**(0.221)**	(0.268)	**(1.146)**	(0.272)	(0.635)	**(0.006)**	**(1.440)**	(2.097)
Fuel	**0.0118**	**0.011**	0.032[NS]	**0.718**	**0.112**	**0.171**	**0.004**	**-2.094**	**0.928**
	(0.010)	**(0.005)**	(0.037)	**(0.111)**	**(0.051)**	**(0.035)**	**(0.001)**	**(0.196)**	**(0.209)**
Hired Labor	1.025	0.143	-15.843	0.245	16.315	0.111	0.170	0.249	-1.410

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: Own elaboration.

5.1.Policy implication

We estimated the supply and input elasticities with respect to the quasi-fixed inputs to evaluate the impact of technical assistance support on agriculture. Table 4 reports them. An increase of 10% on the governmental support leads to a statistical increase of around 16% on soybean supply and an increase of 3% and 4.6% on corn supply and fuel demand, respectively. Interestingly, we found a significant and negative effect of this type of support on milk supply, although Campos (2011) has also found a negative effect of governmental technical assistance support on dairy farm efficiency.

Table 4 – Effects of technical assistance (TA) on output supply and input demand

Variable	*Soybean*	*Milk*	*Sugar Cane*	*Corn*	*Coffee*	*Rice*	*Wheat*	*Fuel*	*Hired Labor*
Gov.TA	**1.601** **(0.296)**	**-0.249** **(0.054)**	0.101^{NS} (0.516)	**0.307** **(0.155)**	0.138^{NS} (0.550)	1.027^{NS} (1.912)	-0.571^{NS} (0.849)	**0.460** **(0.131)**	-0.396^{NS} (1.048)
Priv.TA	**0.537** **(0.107)**	0.222^{NS} (0.167)	**-0.234** **(0.139)**	-0.134^{NS} (0.225)	0.233^{NS} (0.197)	0.267^{NS} (0.706)	**0.836** **(0.409)**	**-0.379** **(0.071)**	**-1.138** **(0.498)**

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

Private technical assistance support has impacted positively and significantly soybean and wheat supplies, while negatively sugarcane supply and fuel demand. On average, an increase of 10% on the number of farms that received private technical assistance support would lead to an increase of 5.4% and 8.4% on soybean and wheat supply, respectively. Private technical assistance support is fuel and labor saver. We conclude based on these results that private technical assistance support is more effective than the governmental support given that is cost reducer.

We have found a much higher impact of technical assistance support than Evenson, Cruz and Avila (1988), which found that an increase of 10% on this support would lead to an increase of 0.2% on corn supply and 0.7% on livestock products supply. However, they haven't disaggregated technical assistance support in governmental and private, used similar framework and neither considered more agricultural commodities.

Figure 2 illustrates how the supply of soybean shifts right (increases) with a higher technical assistance support, independently whether governmental or private, as Table 4 shows. We considered the median technical assistance support to build these curves, for the gov. support it is 0.086 while for private is 0.0172. In both graphs the curve S0 represent the same level (holding all the other variables at their median) while S1 represents the same level but doubling technical assistance (i.e. 0.086 x 2 = 0.172 for governmental technical assistance support). It clearly shows a large effect of technical assistance and it highlights the relevance of governmental policies toward technical assistance support enhancement.

Alves (2013) and Kageyama (1990) highlights a higher access of larger farms to technical assistance support, which might be correlated to farmers' access to rural credit. Plata and Fernandes (2011) pointed out that the average farm size that received any technical assistance support was of 228 hectares while the farmers' that did not received had an average farm of 42 hectares. It clearly shows a bias on the distribution of technical assistance support.

As mentioned in previous section technical assistant support has been bias toward larger farms, under attending to small farms. Thus, we also estimated the system of equations considering four different farm sizes: zero to ten hectares, ten to 100 hectares, hundred to thousand hectares and larger than thousand hectares. We constructed representative farms per size by dividing the output by the number of farms in each of the categories in addition to including farm size dummies. This procedure is well used in the literature such as in Helfand *et al.* (2015). Here, we present only the results of technical assistance support by farm size (table 5).

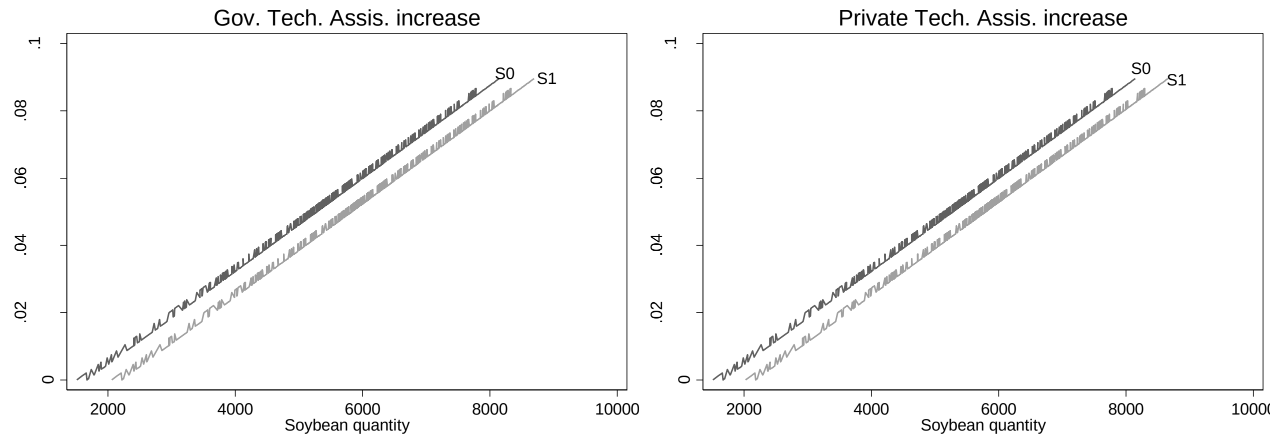

Figure 2: Impact of an increase on governmental and private technical assistance support on soybean supply
Note: Soybean supply is the predicted estimated soybean supply equation. Normalized soybean price is the price of soybean divided by the wage (labor price). S0 is the soybean supply considering the median of all other prices and quasi-fixed inputs (see Table 2 in Appendix B). S1 is the soybean supply holding all other prices and quasi-fixed inputs equal to S0 but the technical assistance support where the median is multiplied by two.
Source: Own elaboration.

Table 5 shows that governmental technical assistance support has a higher impact within small suppliers of soybean, milk and corn while for other outputs its effect does not differ across farm sizes. However, private technical assistance support has a higher effect on most of output supply on larger farm sizes but milk supply. This outcome was expected given that small farms cannot afford this expenses, relying more on governmental technical assistance support. Interestingly, technical assistance support is less fuel demand saver as farm size increases, which might be related to modernization of farm production since larger farms have higher access to credit and, thus, they are more capital intensive.

Table 5 - Effects of technical assistance (TA) on output supply and input demand per farm size

	Soybean	***Milk***	***Sugar Cane***	***Corn***	***Coffee***	***Rice***	***Wheat***	***Fuel***
Governmental TA								
0 to 10 ha (base)	-	-	-	-	-	-	-	-
10 to 100 ha	NS	NS	NS	NS	NS	NS	NS	Negative
100 to 1000 ha	NS	Negative	NS	NS	NS	NS	NS	NS
> 1000 ha	Negative	Negative*	NS	Negative	NS	NS	NS	NS
Private TA								
0 to 10 ha(base)	-	-	-	-	-	-	-	-
10 to 100 ha	NS	NS	Positive	NS	Positive*	NS	NS	Negative
100 to 1000 ha	Positive	Negative*	Positive*	Positive	Positive	Positive	Positive	Negative*
> 1000 ha	NS	Negative	Positive	NS	NS	NS	NS	Negative

Note: NS – not significant; Negative: indicates that the effect was smaller if compared to the base group; Positive: indicates that the effect was higher if compared to the base group; *: indicates the major effect (coefficient). The complete estimates of output supply and input demand considering the four area classes are not reported due the page limit, but available upon request.
Source: Own elaboration.

In short, our preliminary results suggest that a system of Technical Assistance and Rural Extension (ATER) that includes both governmental and private support, as proposed by the PNATER, is more effective given its complementarity impact on agriculture. It corroborates what was suggested by Peixoto (2014). Governmental policy on ATER has supported small farms while farms that can afford private support has been seeing gains in supply outcome due to its use.

6. Conclusions

In this paper, we seek to evaluate the impact of the National Policy on Technical Assistance and Rural Extension (PNATER) as well as the overall technical assistance support, which also includes private support. We estimated a system of agricultural supplies and input demands based on a restricted normalized quadratic profit function at municipal and farm (representative) scale. Overall, our preliminary results are robust with theoretical properties and could be used as guidance on policy design.

We have found that governmental technical assistance support affects positively soybean and corn supply while private support drives the supply of soybean and wheat up. As expected, private support has a higher effect on commodities supply on larger farms while governmental support has on smaller farms, with some exceptions. A higher investment on ATER accompanied by decentralization of it and association with different institutions, including private, would lead to an increase of farm income via higher output supply and input saver.

This is on-going research where valuable and reliable results have been found in a first step. In the nearby future we will be estimating this framework on a farm level scale available on the Agricultural Census of 2006, at IBGE. A more rigorous and robust analysis will be achieved and better policy resolutions could be drawn from it.

References

ALVES, E. Excluídos da modernização da agricultura. Responsabilidade da Extensão Rural? **Revista de Política Agrícola**, n.3, p. 3-5, 2013.

ANDERSON, J. R.; FEDER, G. Agricultural Extension: Good Intentions and Hard Realities. **The World Bank Research Observer**, v. 19, n. 1, p. 41-60, 2004.

BIRKHAUSER, D.; EVENSON, R. E.; FEDER, G. The economic impact of agricultural extension: A review. **Economic Development and Cultural Change**, v. 39, n.3, p.607-650, 1991.

BUAINAIN, A. M.; ALVES, E.; SILVEIRA, J. M.; NAVARRO, Z. Sete teses sobre o mundo rural brasileiro. **Revista de Política Agrícola**, Brasília, DF, v.23, n.2, p. 105-121, 2013.

BURNIAUX, J.M.; TRUONG, T.P. GTAP-E: **An Energy-Environmental Version of the GTAP Model.** GTAP Technical Paper N. 16, 2002.

CAMPOS, S. A. C. **Eficiência econômica e ambiental da produção leiteira em minas gerais**. Dissertação (Mestrado em Economia Aplicada). Universidade Federal de Viçosa - UFV, Viçosa – MG, 2011.

CARDOSO, D. F. ; TEIXEIRA, E. C. ; GURGEL, A. C. ; CASTRO, E. R. Effects of Government Intervention Via Rural Credit Subsidy on Economic Growth and Welfare of Brazilian Regions. **Indian Journal of Agricultural Marketing**, v. 25, p. 41-50, 2011.

CASTRO, E. R.; TEIXEIRA, E. C. Rural credit and agricultural supply in Brazil. **Agricultural Economics**, v. 43, n.3, p. 293-302, 2012.

CHAMBERS, R.G.; FÄRE, R.; GROSSKOPF, S.; VARDANYAN, M. Generalized quadratic revenue functions. **Journal of Econometrics**, v. 173, n. 1, p. 11-21, 2013.

CHRISTOPLOS, I. **Mobilizing the potential of rural and agricultural extension.** In: The Global Forum for Rural Advisory Services. Food and Agriculture Organization of the United Nations, 2010.

DIEWERT, W.E. Applications of duality theory. In: INTRILIGATOR, M.D; KENDRICK, D.A. (ed.), **Frontiers of Quantitative Economics**. Amsterdam, v. 2, p. 106-171, 1974.

DIEWERT, W. E.. An application of the Shephard duality theorem: A generalized Leontief production function. **Journal of Political Economy**,v.79, p. 481-507, 1971.

EVENSON, R. E.; CRUZ, E. R.; AVILA, A. F. D. **Brazilian Agricultural Research**: New Results from Census Data. Economic Growth Center. Yale University, 1988.

FIGUEIREDO, A.M.R. **Resposta da produção agrícola aos preços no Centro- Oeste brasileiro:** uma análise de econometria espacial para o período 1975-1995/1996. **Tese** (Doutorado em Economia Aplicada), Universidade Federal de Viçosa, 184 p., 2002.

FIGUEIREDO, A. M. R. ; TEIXEIRA, E. C. Resposta da produção agrícola aos preços no Centro-Oeste brasileiro: Uma análise de econometria espacial para o período 1975-1995/1996. **Revista de Estudos Sociais**, n.8, p. 72-104, 2002.

FREITAS, C. O. de; TEIXEIRA, E. C.; BRAGA, M. J. **Tamanho do estabelecimento e eficiência técnica na agropecuária brasileira.** In: 42º Encontro Nacional de Economia - ANPEC, Natal – RN, 2014.

FULGINITI, L.E.; PERRIN, R.K. Argentine agricultural policy in a multiple-input, multiple-output framework. **American Journal of Agricultural Economics**, v. 72, n. 2, p. 279-288, 1990.

FULGINITI, L. E. Estimating Griliches' K-Shifts. **American Journal of Agricultural Economics**, v.92, n.1, p. 86-101, 2010.

GASQUES, J.G.; BASTOS, E. T.; BACCHI, M. P. R.; CONCEIÇÃO, J. C. P. R. **Condicionantes da produtividade da agropecuária brasileira.** IPEA, texto para Discussão 1.017, Brasília, 2004.

GAUTAM, M.. **Agricultural Extension: The Kenya Experience: An Impact Evaluation.** Washington,D.C.: World Bank, Operations Evaluation Department, 2000.

GONÇALVES, R. M. L., VIEIRA, W. C.; LIMA, J. E.; GOMES, S. T. Analysis of technical efficiency of milk-production farms in Minas Gerais. **Economia Aplicada**, v.12, n.2, p.321-335, 2008.

HELFAND, S.M., LEVINE, E.S. Farm Size and the Determinants of Productive Efficiency in the Brazilian Center-West. **Agricultural Economics**, v. 31, p. 241-49, 2004.

HELFAND, S. M.; MAGALHÃES, M. M.; RADA, N. E. **Brazil's agricultural total fator productivity growth by farm size.** Inter-American Development Bank, IDB Working paper series n. 609, 2015.

HUFFMAN, W. E.; EVENSON, R.E. Supply and Demand Functions for Multiproduct U.S. Cash Grain Farms: Biases Caused by Research and Other Policies. **American Journal of Agricultural Economics**, v. 71, n.3, 1989.

IBGE – Instituto Brasileiro de Geografia e Estatística. Disponível em: <www.ibge.gov.br> .Acesso em abril de 2016.

JIN, Y.; HUFFMAN, E. Measuring public agricultural research and extension and estimating their impacts on agricultural productivity: new insights from U. S. evidence. **AgriculturalEconomics**, v. 47, n.1, p. 15-31, 2016.

KAGEWAMA, A. **O novo padrão agrícola brasileiro:** do complexo rural aos complexos agroindustriais. Cap. II, IN: DELGADO, G. C.; GASQUES, J. C.; VILLA VERDE, C. M. (org.) Agricultura e Políticas Públicas. Brasília: IPEA, 564p.,1990.

LANDINI, F. How to be a good rural extensionist. Reflections and contributions of Argentine practitioners. **Journalof Rural Studies**, v.43, p.193-202, 2016.

MELO, M. M.; MARINHO, E. L.; SILVA, A. B. O impulso do crédito rural no produto do setor primário brasileiro. **Revista Nexos Econômicos**, *v.*7, n.1, p. 9-36, 2015.

MENDES, S. M.; TEIXEIRA, E. C.; SALVATO, M. A. **Investimentos em Infraestrutura e Produtividade Total dos Fatores na Agricultura Brasileira**: 1985-2004. Revista Brasileira de Economia, Rio de Janeiro, v. 63, n.2, p. 91-102, Abr-Jun 2009.

MOURA, A. C. F.; KHAN, A. S.; SILVA, L. M. R. Extensão rural, produção agrícola e benefícios sociais no Estado do Ceará. **Revista Econômica do Nordeste**, v. 31, n. 2, p. 212-234, 2000.

MDA – Ministério do Desenvolvimento Agrário. Disponível em :<www.mda.gov.br>. Acesso em janeiro de 2016.

NADIRI, M.I. Producers Theory. In. ARROW, K.J., INTRILIGATOR, M.D. (ed).**Handbook of Mathematical Economics**. New York, NY: North-Holland Publishing Co., v. 2, 1982

OEHMKE, J. F.; ANANDAJAYASEKERAM P.; MASTERS, W. A. **Agricultural Technology Development and Transfer in Africa:** Impacts Achieved and Lessons Learned. USAID Technical Paper 77. Office of Sustainable Development, Bureau for Africa, Washington, D.C, 1997.

PEIXOTO, M. **A extensão privada e a privatização da extensão: uma análise da indústria de defensivos agrícolas.** Tese (Doutorado em Ciências Sociais) – Programa de Pós-graduação de Ciências Sociais em Desenvolvimento, Agricultura, Sociedade. Universidade Federal do Rio de Janeiro. 331 p., 2009.

PEIXOTO, M. **Mudanças e desafios da extensão rural no Brasil**. In: O mundo rural no Brasil do século 21. Brasília, 2014.

PEREDA, P. C. **Long-and short-run climate impacts on Brazil: theory nadevidence for agriculture and health.** Tese (Doutorado em Teoria Econômica) - Faculdade de Economia, Administração e Contabilidade, Universidade de São Paulo, São Paulo, 2012.

PEREIRA, M. W.; TEIXEIRA, E. C.; LIMA, J. E. Adoção Sequencial de Tecnologia Pós-colheita Aplicada à Cafeicultura em Viçosa (MG). **Revista de Economia e Sociologia Rural** (Impresso), v. 48, p. 381-404, 2010.

PETTAN, K. B. **A Política Nacional de Assistência Técnica e Extensão Rural PNATER)**: percepções e tendências. Tese (Doutorado em Engenharia Agrícola) – Universidade Estadual de Campinas - Campinas, 393 p., 2010.

PLATA, L. E. A.; FERNANDES, R. L. **A nova assistência técnica e extensão rural brasileira.** In: VI Workshop de Pós-Graduação e Pesquisa do Centro Paula Souza. Unidade de Ensino de Pós-Graduação, Extensão e Pesquisa, 2011

RODRIGUES, C. M. Conceito de seletividade de políticas públicas e sua aplicação no contexto da política de extensão rural no Brasil. **Cadernos de Ciência & Tecnologia**, Brasília, n.1, v. 14, p. 113-154, 1997.

SHAKYA, P. B.; FLINN, J. C. Adoption of modern varieties and fertilizer use on rice in the eastern of Nepal. **Journal of Agricultural Economics**, v. 36, n.3, p. 409-419, 1985.

SCHURING, J., HUFFMAN, W.E., FAN, X. **The Impact of Public and Private R&D on Farmers' Production Decisions:** 1960-2004. In: 2011 Annual Meeting, July 24-26, 2011, Pittsburgh, Pennsylvania. Agricultural and Applied Economics Association, 2011.

SHUMWAY, C. R. Supply, demand, and technology in a multiproduct industry: Texas field crops. **American Journal of Agricultural Economics**, v.65, n.4, p.748-760, 1983.

SHUMWAY, C.R.; SAEZ, R. R.; GOTTRET, P. E. Multiproduct Supply and Input Demand in U.S. Agriculture. **American Journal of Agricultural Economics,** v.70, 1988.

SOARES, J. S. **Extensão rural**: audiência pública. Brasília, DF, 2007. Disponível em: <http://www2.camara.leg.br/atividade-legislativa/comissoes/comissoes-permanentes/capadr/audiencias-publicas/audiencias-2007/rap251007josesilva.pdf>. Acesso em abril de 2016.

TEIXEIRA, E. C. ; MIRANDA, M. H. ; FREITAS, C. O. . **Políticas governamentais aplicadas ao agronegócio.**1. ed. Viçosa, MG: Editora UFV, v. 1., 199p, 2014.

VAN RIJN, F.; NKONYA, E.; ADEKUNLE, A. The impact of agricultural extension services on social capital: an application to the Sub-Saharan African Challenge Program in Lake Kivu region. **Agriculture and Human Values**, v.32, n. 4, p. 597-615, 2015.

Appendix A

The own-price elasticity can be estimated as

$$\epsilon_{pi} = \frac{\partial lny_i}{\partial lnp_i} = \frac{\partial y_i}{\partial p_i} \cdot \frac{p_i}{y_i} = \frac{\partial\,(\partial\pi/\partial p_i)}{\partial p_i} \cdot \frac{p_i}{(\partial\pi/\partial p_i)} = \\ = \frac{\partial y_i^*}{\partial p_i}\frac{p_i}{y_i^*} = \beta_{ii} \cdot \frac{p_i}{y_i^*} \tag{A.1}$$

where for outputs have to be positive reflecting the positive slope of a supply curve, and for an input it has to be negative reflecting the negative slope of a demand. The sign of these elasticities are based on the second order derivatives matrix (Hessian) or convexity of the restricted profit function. The cross-price elasticity (or the effect of a change in input price on output supply or vice-versa) can be found by

$$\epsilon_{yipj} = \frac{\partial lny_i}{\partial lnp_j} = \frac{\partial y_i^*}{\partial p_j} \cdot \frac{p_j}{y_i^*} = \beta_{ij} \cdot \frac{p_j}{y_i^*} \tag{A.2}$$

where no sign is expected theoretically. These elasticities can also be calculated for the normalized input demand, respectively as

$$\epsilon_{00} = \frac{\partial lny_0^*}{\partial lnp_0} = \frac{\partial y_0^*}{\partial p_0} \cdot \frac{p_0}{y_0^*} = \left[\sum_{i=1}^{n+m}\sum_{j=1}^{n+m}\beta_{ij}\frac{p_i p_j}{p_0^2}\right] \cdot \frac{p_0}{y_0^*} = \left[\sum_{i=1}^{n+m}\sum_{j=1}^{n+m}\beta_{ij}p_i p_j\right] \cdot \frac{1}{y_0^*} \tag{A.3a}$$

$$\epsilon_{i0} = \frac{\partial lny_i^*}{\partial lnp_0} = \frac{\partial y_i^*}{\partial p_0} \cdot \frac{p_0}{y_i^*} = \left[-\sum_{i=1}^{n+m}\beta_{ij}\frac{p_j}{p_0^2}\right] \cdot \frac{p_0}{y_i^*} = -\frac{1}{y_i^*}\sum_{i=1}^{n+m}\beta_{ij}\,p_j \tag{A.3b}$$

$$\epsilon_{0j} = \frac{\partial lny_0^*}{\partial lnp_j} = \frac{\partial y_0^*}{\partial p_j} \cdot \frac{p_j}{y_0^*} = \left[-\sum_{j=1}^{n+m}\beta_{ij}p_i\right] \cdot \frac{p_j}{y_0^*} \tag{A.3c}$$

where equation (A.3a) represents own-price elasticity, equation (A.3b) and (A.3c) the cross-price elasticity between non-normalized output and normalized output. As previously assigned, we expect a negative sign of the own-price elasticity since it is an input demand.

Appendix B

Table2 –Output Supply and Input Demand Equations for Brazilian Agriculture

	Output Supply							Input
Variables	***Soybean***	***Milk***	***Sugar Cane***	***Corn***	***Coffee***	***Rice***	***Wheat***	***Fuel (-)***
Soybean_price (p1)	214559.1***	787.54***	-6283.72^{NS}	72342.22***	-2.646.91***	-2938.72^{NS}	-1060.98^{NS}	-6601.93***
	(24126.55)	(78.81)	(16532.02)	(11308.4)	(1012.11)	(4622.57)	(1471.33)	(564.06)
Milk_price (p3)	787.54***	845.66***	267.09***	-285.77***	1.49^{NS}	70.65***	592.68***	-19.59**
	(78.81)	(24.164)	(39.03)	(37.25)	(6.04)	(23.15)	(105.36)	(8.16)
Sugar Cane_price (p4)	-6283.72^{NS}	267.09***	-491098***	-513.80^{NS}	385.14^{NS}	-1056.13^{NS}	699.63^{NS}	-308.24^{NS}
	(16532.02)	(39.03)	(123332.6)	(10018.2)	(701.96)	(3391.93)	(721.35)	(362.18)
Corn_price (p6)	72342.22***	-285.7***	-513.80^{NS}	23343.83***	-1505.39**	-1.415.79^{NS}	1185.13*	-2028.84***
	(11308.4)	(37.25)	(10018.2)	(7719.31)	(534.35)	(2512.77)	(671.33)	(313.82)
Coffee_price (p7)	-2646.91***	1.49^{NS}	385.14^{NS}	-1505.39***	2870.73***	-737.00**	-143.26^{NS}	-103.13**
	(1012.12)	(6.04)	(701.96)	(534.35)	(107.97)	(327.32)	(110.37)	(46.84)
Rice_price(p8)	-2938.72^{NS}	70.66***	-1056.13^{NS}	-1415.79^{NS}	-737.00**	6002.82***	6.72^{NS}	-896.14***
	(4622.57)	(23.15)	(3391.93)	(2512.77)	(327.32)	(1973.68)	(417.66)	(182.03)
Wheat_price (p9)	-1060.98^{NS}	592.68***	699.63^{NS}	1185.13*	-143.26^{NS}	6.72^{NS}	47906.74***	-490.63***
	(1471.33)	(105.36)	(721.35)	(671.33)	(110.37)	(417.66)	(2022.31)	(141.76)
Fuel_price (p5)	-6601.93***	-19.59**	-308.24^{NS}	-2028.84***	-103.1.3**	-896.14***	-4906.31***	672.62***
	(564.06)	(8.16)	(362.18)	(31.382)	(46.85)	(182.03)	(1417.61)	(63.09)
Fixed Factors								
Public Tech. Assistance (z1)	28801.67***	-87.35***	23357.33^{NS}	6382.53**	56.64***	586.622^{NS}	-155.46^{NS}	-407.98***
	(5335.53)	(12.50)	(39787.99)	(3.230.181)	(225.96)	(1091.89)	(231.10)	(116.44)
Private Tech. Assistance (z3)	62909.78***	-28.16*	387069.9***	28706.92***	971.88***	-1914.82^{NS}	1049.13***	-1550.68***
	(6168.56)	(14.60)	(45673.67)	(3.714.761)	(262.28)	(1266.34)	(269.83)	(135.48)
Irrigated Area (z2)	3.41***	0.008***	11.37***	1391.19***	0.083***	4.82***	0.052***	-0.14***
	(0.25)	(.0006)	(1.84)	(.1485133)	(0.010)	(0.049)	(0.01)	(0.01)
Dummy: South-Southeast (ss)	-11357.5***	-2.02^{NS}	23047.94**	156.044^{NS}	207.93***	53.43^{NS}	202.91***	165.07***
	(1467.71)	(3.61)	(10898.31)	(8.873.426)	(63.99)	(302.36)	(66.73)	(32.75)
Intercept	2230.59^{NS}	51.42***	28113.82***	3158.03***	30.37^{NS}	-497.61^{NS}	31.82^{NS}	-384.53***
	(1446.34)	(3.95)	(8654.11)	(9164.19)	(64.28)	(304.53)	(72.45)	(34.89)

Note: NS: non-significant; *** significant at 1% level; ** significant at 5% level, * significant at 10% level. Standard errors in parentheses.
Source: Own elaboration.

Appendix C

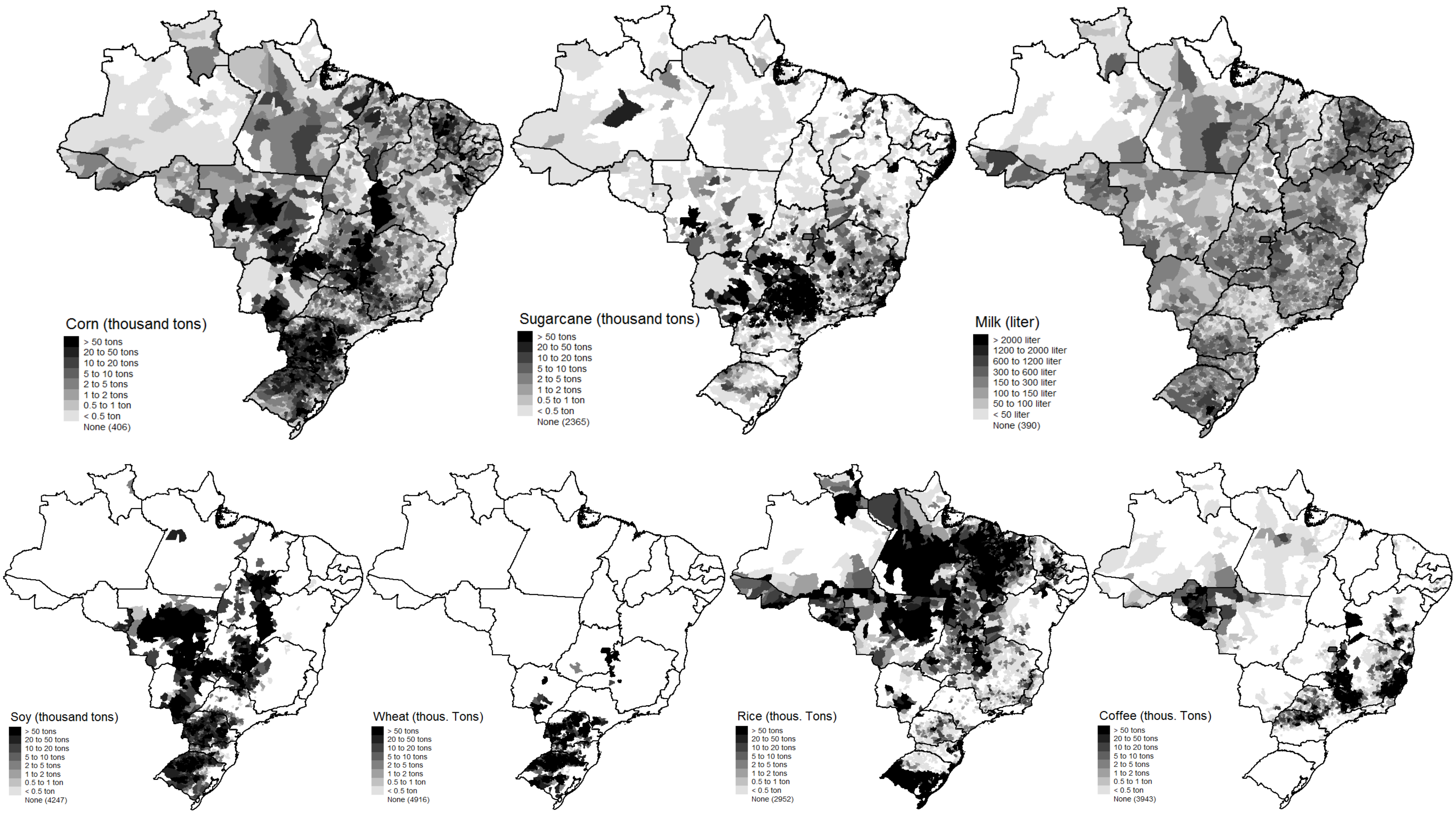

Figure C1 – Output distributiuon across the country.
Source: Ag. Census of 2006 (IBGE, 2016).